## 1 The World of Safety Valves

In the "World of Safety Valves" and their applications we are developing LESER into a global leader who is a competent, reliable and responsive partner for its customers. Due to its worldwide activities LESER is experiencing steady growth. Commitment, Integrity and Tradition are the foundations of the company.

## 2 This Handbook

This handbook is an engineering handbook, short ENGINEERING. The purpose of ENGINEERING is to help understand the "World of Safety Valves". Specifically, it explains:

- what is a safety valve
- the applications in which safety valves are used
- how a safety valve is installed
- how to size and select a safety valve
- the global standards and requirements which apply to safety valves

- ENGINEERING is intended to be a knowledge resource for the occasional user as well as the advanced user of safety valves. For this reason each chapter has the same structure: First, a general outline is given for the occasional user, this is followed by the presentation of more detailed knowledge for the advanced user.
- ENGINEERING is a reference book that can be consulted to clarify individual questions.
- ENGINEERING can be used to provide answers for trouble shooting.
- ENGINEERING can be used as the basis for technical trainings.
- ENGINEERING is the LESER statement to technical questions applicable to the complete LESER organization.

## 3 Use of Terminology

There is no single, agreed terminology in the field of safety valves. The terminology used to describe safety valves and their function is defined in a variety of codes and standards like ISO 4126-1, ASME Sec. VIII Div. 1, ASME Sec. XIII, ASME PTC 25, API 520 and others.
Some examples are shown below:

| Term as Per ISO 4126-1 | Equivalent terms as Per ASME and API |
|---|---|
| Safety valve | Pressure relief valve, safety relief valve |
| Flow area | Orifice area, discharge area, nozzle (throat) area, bore area, net flow area |
| Flow diameter | Orifice diameter |
| Maximum Allowable Pressure Ps | Maximum Allowable Working Pressure (MAWP) |
| Reseating pressure | Closing pressure |

Sometimes, different codes use only slightly different definitions for the same term, in other cases, definitions vary broadly across codes and also the terms are distinct.

Within ENGINEERING the terminology of ISO 4126-1 is used whenever different terms are in use for which similar definitions exist.
The only exception to this general rule is made when the text of a code needs to be quoted literally for the purpose of conceptual distinction, e. g. to explain the difference between a Safety Valve and a Safety Relief Valve by the relevant definitions of the ASME PTC 25 code.

The definitions and distinctions of terms according to various codes and standards are found in chapter 3 "Terminology".

## 4 Disclaimer

The information provided in ENGINEERING is intended for informational purposes only. It is meant to help the reader obtain an overview and gain a general understanding.
The information represents the current state of knowledge documented by the date at the bottom of each page. However, LESER does not represent or warrant that the information is accurate, complete or up to date.

Decisive for the user are the applicable codes and standards in the country or location where the safety valve is used. It is the user's responsibility to use the technical equipment described herein in accordance with the regulatory requirements of the country or location where the equipment is used. In particular, the user is responsible for using the latest editions of the codes and standards referenced herein.

The worldwide activities of LESER and LESER's customers require the supply of products and documentation that meet all national and international regulatory requirements. Although LESER's products generally meet the requirements of different codes and standards simultaneously, the relevant regulatory requirements are listed separately in each individual chapter as far as possible so that the user can identify the requirements they need to refer to in their specific case and region.

## 5 Edition

ENGINEERING is published on the internet as ENGINEERING Online. There is no single edition for the complete ENGINEERING. Newer editions of individual chapters or topics can be identified by the date at the bottom of each page.

ENGINEERING Online version can be downloaded from www.leser.com/engineering. Chapters or sections will be updated individually and will be ready for download as soon as they have passed LESER's internal approval procedure.
Please check regularly for latest updates, revisions and additions.

In a later stage a printed edition of ENGINEERING will be made available in form of complete chapters.

## 6 Contact

It is our goal to improve ENGINEERING in a continuous process. All suggestions for improvements or new topics are welcome.
Please send your suggestions to:
pm@leser.com

## Contents

## 1.1 History of Safety Valves

In 1679 Denis Papin developed a pressure cooker using pressurized steam. During the first demonstration in front of the Royal Society this pressure cooker exploded. Only after Papin invented the first safety valve his pressure cooker operated safely and in 1681 he achieved a patent on this design.

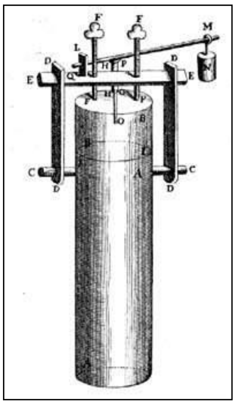


*Figure 1.1-1: Early Safety Valve by Denis Papin*

*Figure 1.1-2: Former LESER Weight loaded Safety Valve Type 421*

*Figure 1.1-3: LESER Spring loaded Safety Valve Type 526*

The invention of the steam engine and the growing use of steam boilers for steam supply during industrialization lead to the necessity to protect life and property from explosions.
The early and simple safety valves used a weight to hold the pressure of the steam, however, they were easily tampered with or accidentally released. In 1856 John Ramsbottom invented a tamper-proof spring loaded safety valve which became universal on railways and later on stationary installations.

Only 30 years later in 1885 LESER presented its first safety valve and since then remains the safety valve manufacturer with the longest history.

Spring loaded safety valves are still the most commonly used type of safety valve. Pilot operated safety valves and controlled safety valves were developed in the second half of the last century mainly to increase the operating pressure and improve the efficiency of the protected equipment. Then followed designs for specific applications, like aggressive chemicals or pharmaceuticals.

*Figure 1.1-4: Pilot Operated Safety Valve*

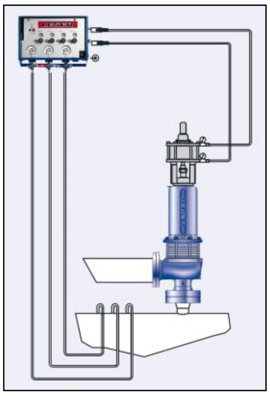


*Figure 1.1-5: Controlled Safety Valve*

*Figure 1.1-6: Critical Service Safety Valve Type 447*

*Figure 1.1-7: Clean Service Safety Valve Type 483*

### 1.1.1 History of Codes and Standards

In 1880 the ***A**merican **S**ociety of **M**echanical **E**ngineers* (ASME) was founded in response to numerous failures of steam boiler pressure vessels. Today the *ASME **B**oiler and **P**ressure **V**essel **C**ode (BPVC)* regulates the certification of pressure relief devices and is probably the most frequently applied code for safety valves worldwide.
In 1919, *The **N**ational **B**oard of Boiler and Pressure Vessel Inspectors (NB)* was founded and since 1921 the NB provides assurance that a pressure-retaining item is constructed in accordance with an acceptable standard and that it was inspected by a qualified National Board commissioned inspector.

In Germany, the *Dampfkessel-Revisions-Verein* (Steam Boiler Inspection Society), later to become the TÜV, was founded in 1866 with the same purpose, to avoid accidents by setting up rules for the design and inspection of pressure vessels. Other European Countries followed with their own regulations and authorities and, finally, in 1997 the Pressure Equipment Directive PED 97/23 was published in order to harmonize the different European standards for pressure vessels.

## 1.2 LESER's History and First Safety Valve

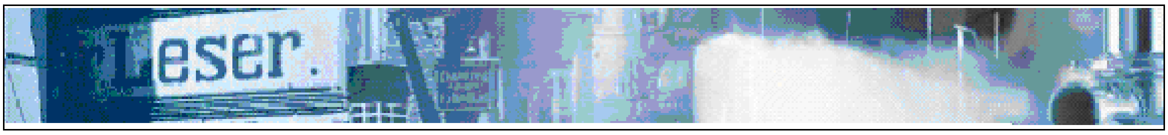
LESER was founded in 1818 as a brass foundry in Hamburg, Germany. In 1885 LESER designed and produced its first safety valve. Since the 1970s LESER has specialized in this product. LESER is now a fifth generation family-owned business and the market leader for industrial safety valves throughout Germany and Europe.

**1885**
Complete range of steam fittings, incl. safety valves

**1957**
First test lab for safety valves

**1980s**
Leading supplier for safety valves in Europe

**1994**
Test lab receives ASME certification (first and only outside of the USA)




**1818**
Founded as a brass foundry in Hamburg

**1943**
Destruction of the plant, relocation and founding of new factory in Hohenwestedt, Germany

**1970s**
Specialization in safety valves

**1990**
First ASME approval

**2010**
7 subsidiaries partners in over 78 countries worldwide

*Figure 1.2-1: LESER's history*

### 1.2.1 Continuous Product Development and Innovation

Product Quality is key to LESER's success. By continuously improving and re-designing its product lines, LESER constantly delivers state of the art technology to the customer and is well-placed to meet the challenges of the future. This is shown below.

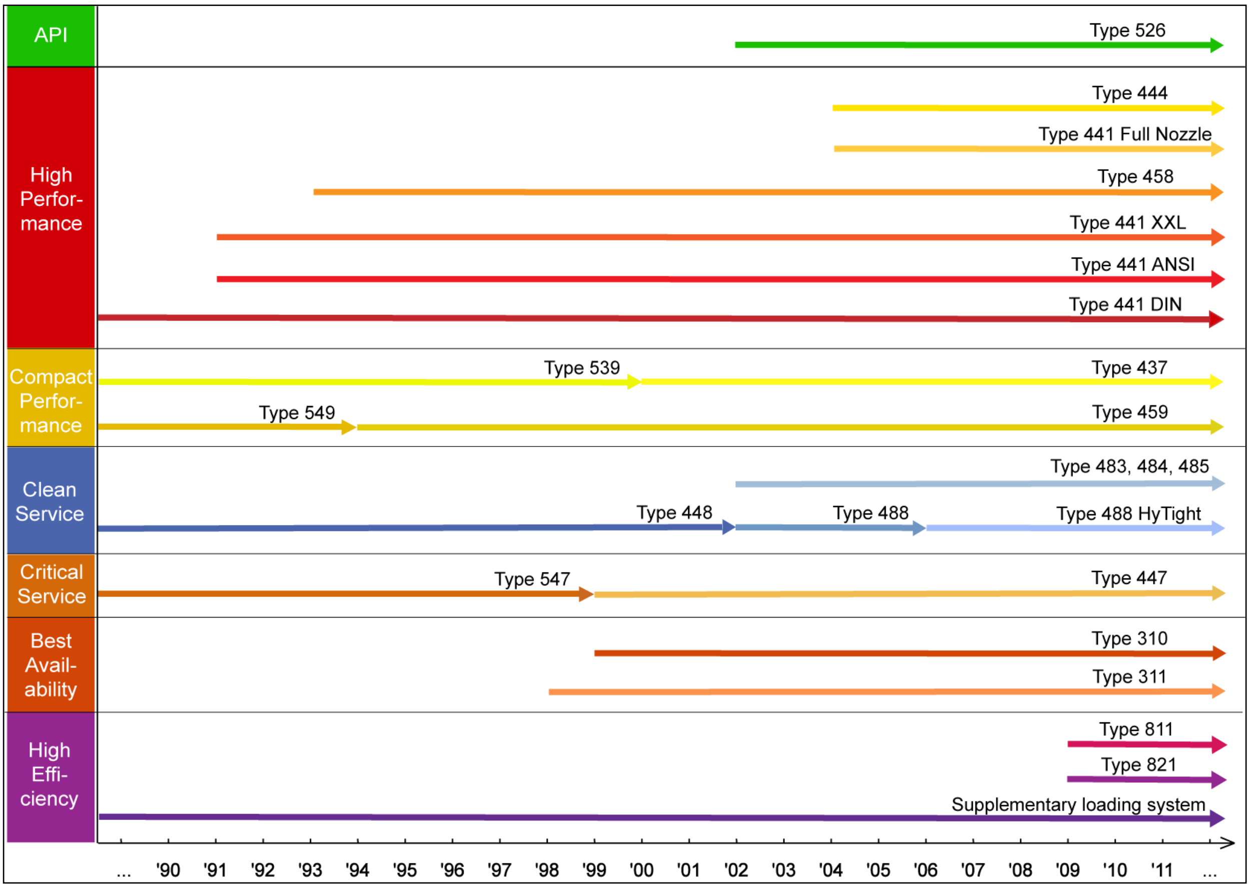



*Figure 1.2.1-1: Product development and innovation at LESER*

## 1.3 Purpose of a Safety Valve

The primary purpose of a safety valve is the protection of life, property and environment. A safety valve is designed to open and relieve excess pressure from vessels or equipment and to reclose and prevent the further release of fluid after normal conditions have been restored.

A safety valve is a safety device and in many cases the last line of defense. It is important to ensure that the safety valve is capable to operate at all times and under all circumstances.
A safety valve is not a process valve or pressure regulator and should not be misused as such.
It should have to operate for one purpose only: overpressure protection.

*Figure 1.3-1: Relieving safety valve*

## 1.4 Reasons for Excess Pressure in a Vessel

There are a number of reasons why the pressure in a vessel or system can exceeds a predetermined limit. API Standard 521/ISO 23251 Sect. 4, provides a detailed guideline about causes of overpressure. The most common are:

- Blocked discharge
- Exposure to external fire, often referred to as “Fire Case”
- Thermal expansion
- Chemical reaction
- Heat exchanger tube rupture
- Cooling system failure

Each of the above listed events may occur individually and separately from the other. They may also take place simultaneously. Each cause of overpressure also will create a different mass- or volume flow to be discharged, e.g. small mass flow for thermal expansion and large mass flow in case of a chemical reaction. It is the user’s responsibility to determine a worst case scenario for the sizing and selection of a suitable pressure relief device.

## 1.5 Basic Function of a Spring Loaded Safety Valve

In this section the opening and closing of a safety valve is explained using the basic terminology for the opening characteristic of a safety valve.

### 1.5.1 Valve Closed

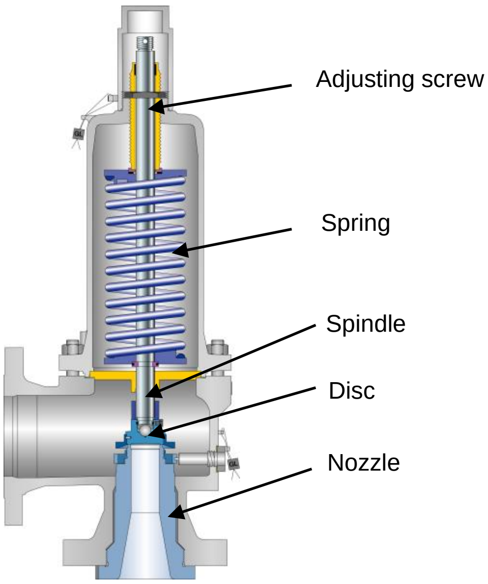



*Figure 1.5.1-1: Safety valve*

In a direct spring loaded safety valve the closing force or spring force is applied by a helical spring which is compressed by an adjusting screw.
The spring force is transferred via the spindle onto the disc.
The disc seals against the nozzle as long as the spring force is larger than the force created by the pressure at the inlet of the valve.
Figure 1-5.1-2 shows the enlarged nozzle and disc area of a safety valve with the forces acting on the disc.

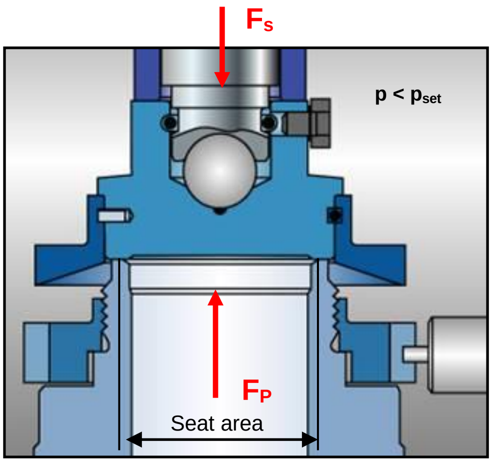



*Figure 1.5.1-2: Valve closed*

**Valve Closed ($p < p_{set}$)**

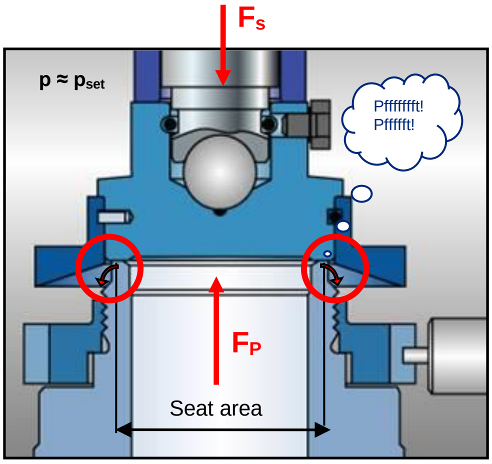
$F_p < F_s$

$F_s$ = Spring force
$F_p = p*A_s$ = Force by pressure

where
$A_s$ = Seat area affected by pressure p

### 1.5.2 Valve Opening

In an upset situation a safety valve will open at a predetermined *set pressure*. The spring force $F_s$ is acting in closing direction and $F_p$, the force created by the pressure at the inlet of the safety valve, is acting in opening direction. At set pressure the forces $F_s$ and $F_p$ are balanced. There is no resulting force to keep the disc down on the seat or to provide seat tightness. The safety valve will visibly or hearably start to leak (initial audible discharge).
Note: There are several definitions for the set pressure, which may differ from the above. LESER uses the definition of "initial audible discharge" as a standard. See chapter 3 "Terminology" and 5 "Function, Setting and Tightness" for details.




**Valve at Set Pressure ($p \approx p_{set}$)**

$F_p = F_s$

$F_s =$ Spring Force
$F_p = p*A_s =$ Force by pressure

where
$A_s$ = seat area affected by pressure p

*Figure 1.5.2-1: Valve at set pressure*

The pressure below the valve must increase above the set pressure before the safety valve reaches a noticeable lift. As a result of the restriction of flow between the disc and the adjusting ring, pressure builds up in the so called huddling chamber. The pressure now acts on an enlarged disc area. This increases the force $F_p$ so that the additional spring force required to further compress the spring is overcome. The valve will open rapidly with a "pop", in most cases to its full lift.

*Overpressure* is the pressure increase above the set pressure necessary for the safety valve to achieve full lift and capacity. The overpressure is usually expressed as a percentage of the set pressure. Codes and standards provide limits for the maximum overpressure. A typical value is 10%, ranging between 3% and 21% depending on the code and application.

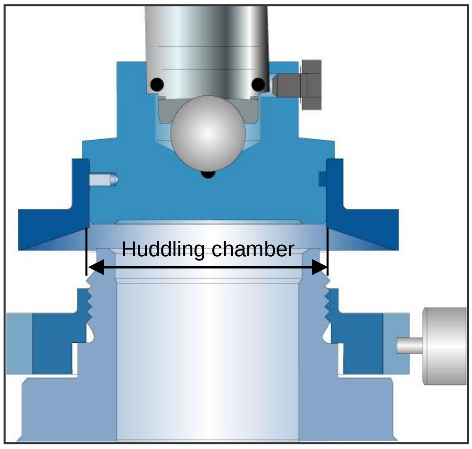



*Figure 1.5.2-2: Huddling chamber*

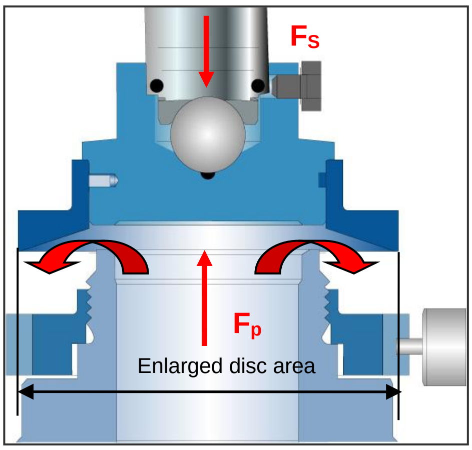



*Figure 1.5.2-3: Valve flowing*

**Valve Flowing ($p > p_{set}$)**

$F_p > F_s$
due to enlarged disc area

### 1.5.3 Valve Reclosing

In most applications a properly sized safety valve will decrease the pressure in the vessel when discharging. The pressure in the vessel will decrease at any subsequent point, but not later than the end of the upset situation.
A decreasing pressure in the vessel will lower the force $F_p$. At set pressure however the flow is still acting on the enlarged disc area, which will keep the valve open. A further reduction in pressure is required until the spring force $F_s$ is again greater than $F_p$ and the safety valve begins to reclose. At the so called *reseating pressure* the disc will touch the nozzle again and the safety valve recloses.

*Blowdown* is the difference between set pressure and reseating pressure of a safety valve expressed as a percentage of set pressure. Typical blowdown values as defined in codes and standards are -7% and -10%, ranging from -4% to -20% depending on the code and service (steam, gas or liquid).

### 1.5.4 Functional Diagram

The following diagram shows a typical functional diagram of a spring loaded safety valve.

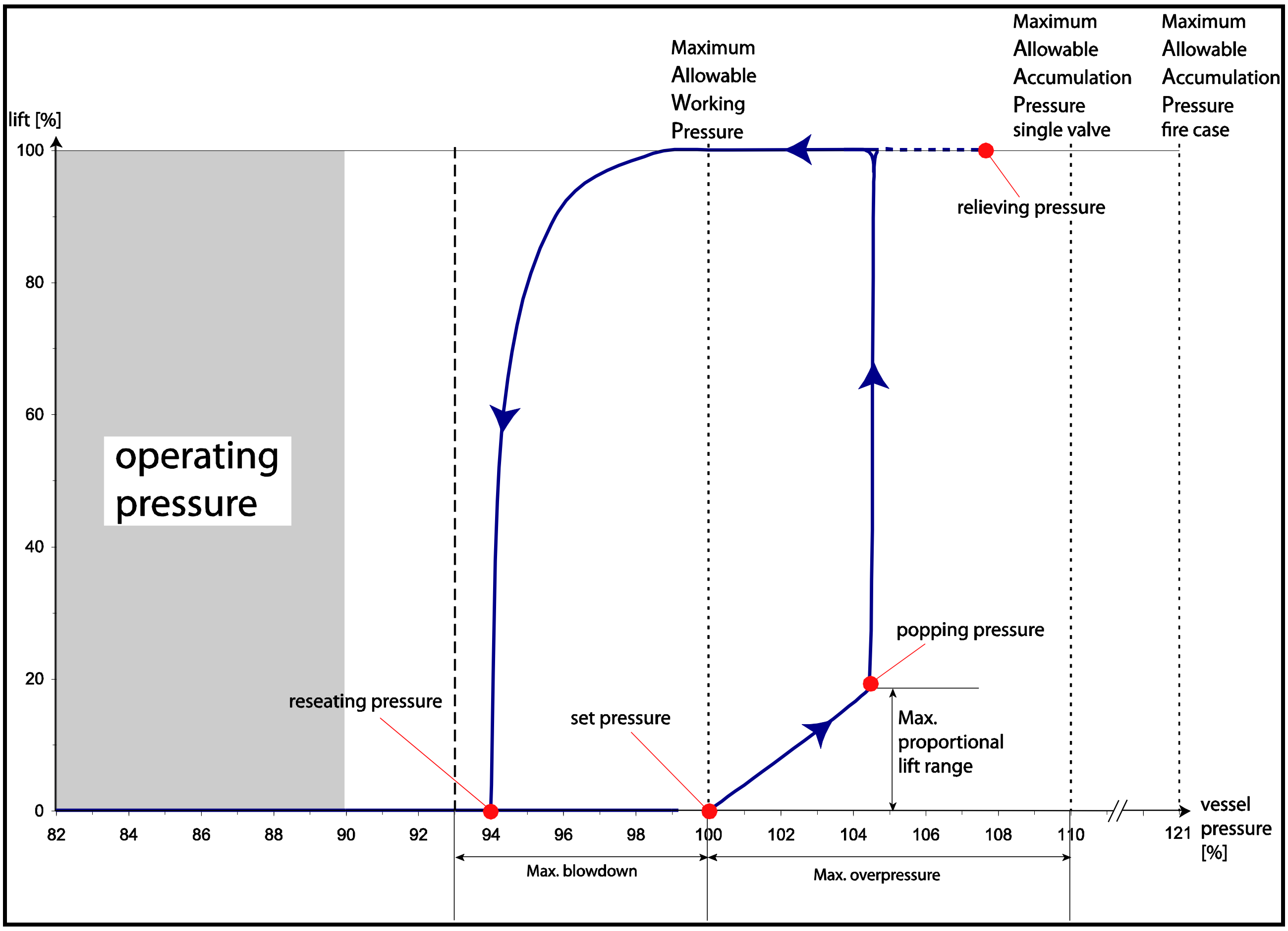



*Figure 1.5.4-1: Operation of a Series 526 API safety valve with adjusting ring and initial audible discharge set pressure definition*

It is important to understand that the *operating pressure* of the protected equipment should remain below the reseating pressure of the valve. Most manufacturers and codes and standards recommend a difference of 3 – 5% between reseating pressure and operating pressure to allow proper reseating of the valve and achieve good seat tightness again.

## Contents

## 2.1 Introduction

The purpose of this chapter is to provide an overview about the general design of safety valves. The parts commonly used in a safety valve are explained with reference to their function. Design variations are shown as well as the most common optional features.
The most common design is the direct spring loaded safety valve. Therefore, the focus of ENGINEERING is on direct spring loaded safety valves.
Other safety devices, like bursting discs or pressure vacuum valves, are not covered in this handbook.

## 2.2 Loading Principle

The loading principle significantly influences the design and components of a safety valve and is often used for the classification of safety valves.
Loading in this context refers to the application of a closing force to the safety valve. Thus, in the following diagram safety valves are classified according to the principle by which the closing force is applied:

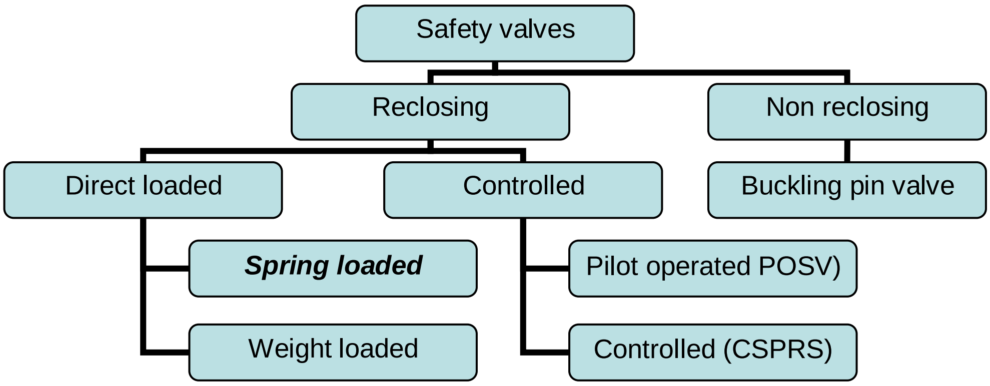



*Figure 2.2-1: Loading principles of safety valves*

- Direct spring loaded safety valve: a safety valve in which the disc is held closed by a spring
- Direct weight loaded safety valve: a safety valve in which the disc is held closed by a weight, or by a lever and a weight

- Pilot operated safety valve (POSV): a safety valve in which the disc is held closed by system pressure and the holding pressure is controlled by a pilot valve actuated by system pressure pressure. The pilot valve itself is a spring loaded safety valve.

- Controlled safety pressure relief system (CSPRS): a system consisting of a main valve in combination with control units. The closing force is applied by a control device which will typically control an actuator on a direct acting safety valve

- Rupture / Buckling pin safety valve: a safety valve in which the disc is held closed by a buckling pin. According to Euler's law of 1776 the pin will buckle at a particular load and release the disc.

There are further classifications of safety valves according to the operating characteristic, e.g. in the ASME Code XIII and the German AD 2000 – A2 standard. These classifications can be found in chapter 5 of this handbook.

### 2.3 Primary and Secondary Pressure Zone

A safety valve can be divided into two separate pressure zones. The primary pressure is the pressure at the inlet of a safety valve. The secondary pressure is the pressure existing in the zone situated after the valve nozzle in the course of the medium's passage through the valve, e.g. in the body and bonnet (for component definitions see section 6).
The pressure zones determine the pressure rating of valve components. In most cases the secondary pressure is significantly lower than the primary pressure. Therefore the pressure rating of components in the primary pressure zone (= valve inlet) is in most cases higher than the pressure rating of components in the secondary pressure zone (= components behind the valve nozzle).

- primary pressure zone (inlet): all parts of the safety valve affected by the primary pressure, these will typically be: nozzle, disc, inlet part of the body
- secondary pressure zone (outlet): all parts affected by the secondary pressure, these are among others: outlet part of the body, bonnet, cap.

This applies to conventional safety valves. A different design and distribution of primary and secondary pressure zones is found in balanced bellows safety valves (figure on right). In those valves the bonnet is not pressurized by the secondary pressure, because the bonnet must be vented to atmospheric pressure to prevent a pressure build up.

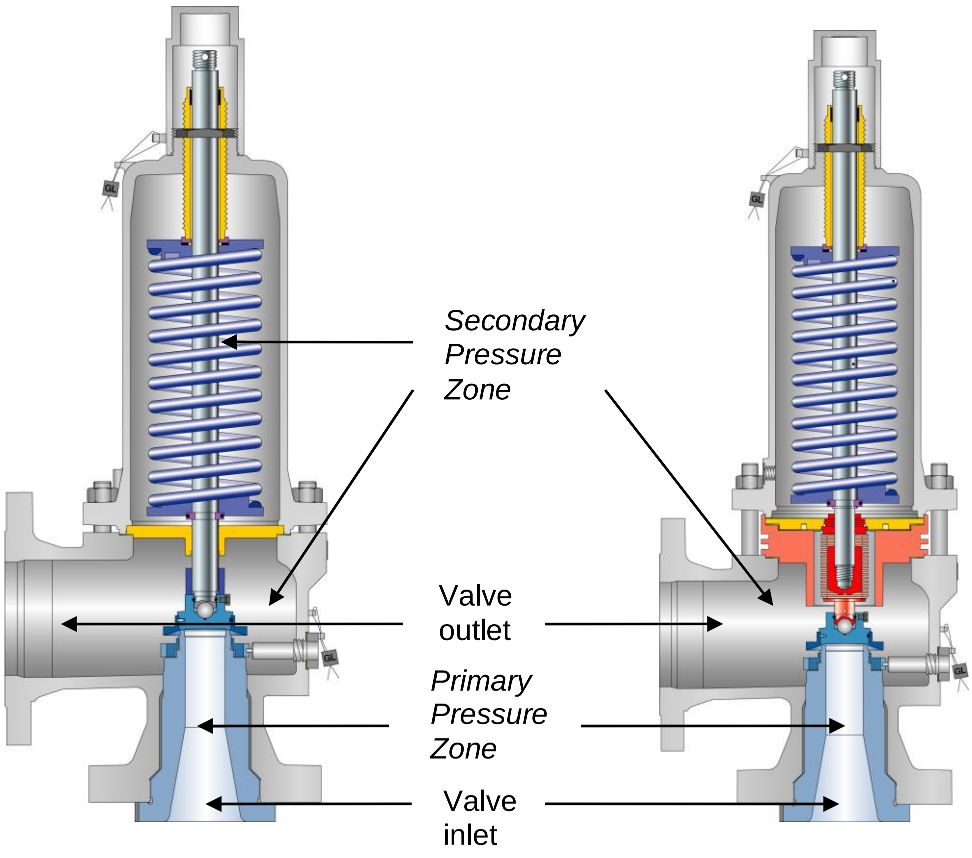



*Figure 2.3-1 :Pressure zones in a conventional safety valve*

*Figure 2.3-2: Pressure zones in a balanced bellows safety valve*

### 2.3.1 Nominal Sizes Inlet and Outlet

During discharge, compressible fluids like steam or gases will expand when passing the nozzle. In order to not restrict the flow of the expanded fluid, the nominal outlet size is typically larger than the inlet size of the valve, e.g. 1”x2”, 2”x3”, ….

The following table shows typical combinations of inlet and outlet sizes for flanged safety valves.
NPS = **N**ominal **P**ipe **S**ize; DN = **N**ominal **D**iameter

| API / ASME - NPS | | EN - DN | |
|---|---|---|---|
| **Inlet** | **Outlet** | **Inlet** | **Outlet** |
| | | 25 | 40 |
| 1 | 2 | 25 | 50 |
| | | 32 | 50 |
| 1 ½ | 2 | 40 | 50 |
| 1 ½ | 2 ½ | 40 | 65 |
| 1 ½ | 3 | 40 | 80 |
| 2 | 3 | 50 | 80 |
| 2 ½ | 4 | 65 | 100 |
| 3 | 4 | 80 | 100 |
| | | 80 | 125 |
| 4 | 6 | 100 | 150 |
| | | 125 | 200 |
| 6 | 8 | | |
| 6 | 10 | 150 | 250 |
| 8 | 10 | | |
| | | 200 | 300 |

Note:
Safety valves with relatively small capacity related to the inlet size or safety valves which are primarily used for liquid applications like the LESER Modulate Action Series may have the same inlet and outlet size.

*Table 2.3.1-1: Typical inlet and outlet sizes for flanged safety valves*

Inlet and outlet sizes for safety valves with threaded connections are typically expressed in inches.

| Threaded Connections | |
|---|---|
| **Inlet** | **Outlet** |
| ½” | ½” |
| ½” | 1” |
| ¾” | 1” |
| 1” | 1” |
| 1” | 1 ½” |

*Table 2.3.1-2: Typical inlet and outlet sizes for safety valves with threaded connections*

### 2.3.2 Angle Type Body

Unlike many other industrial valves, most safety valves have an angle type body and only very few inline designs are available. The main reason is that this facilitates the connection of the valve to pressure nozzles, which are mounted vertically on the pressure vessel.
Always avoid vertical upward orientation of the safety valve outlet  to allow the valve outlet to be drained and remain free of condensate or other liquids.

## 2.4 Vessel Connections

Safety valves are offered in a variety of connections to fit the user's application and requirements across different industries. The most common are flanged and threaded connections according the standards listed in section 4.1 and 4.2. Please refer to chapter 10 of ENGINEERING for more detailed information about connections.

### 2.4.1 Flanged Connections

| Standard | Originates from |
| --- | --- |
| ASME B16.5 (former ANSI B16.5) | America |
| EN 1092-1 | Europe |
| JIS B 2220 (JIS = Japanese Industry Standard) | Japan, equivalent to KS (Korean Standard) |

*Table 2.4.1-1: Standards for flanged connections*

### 2.4.2 Threaded Connections

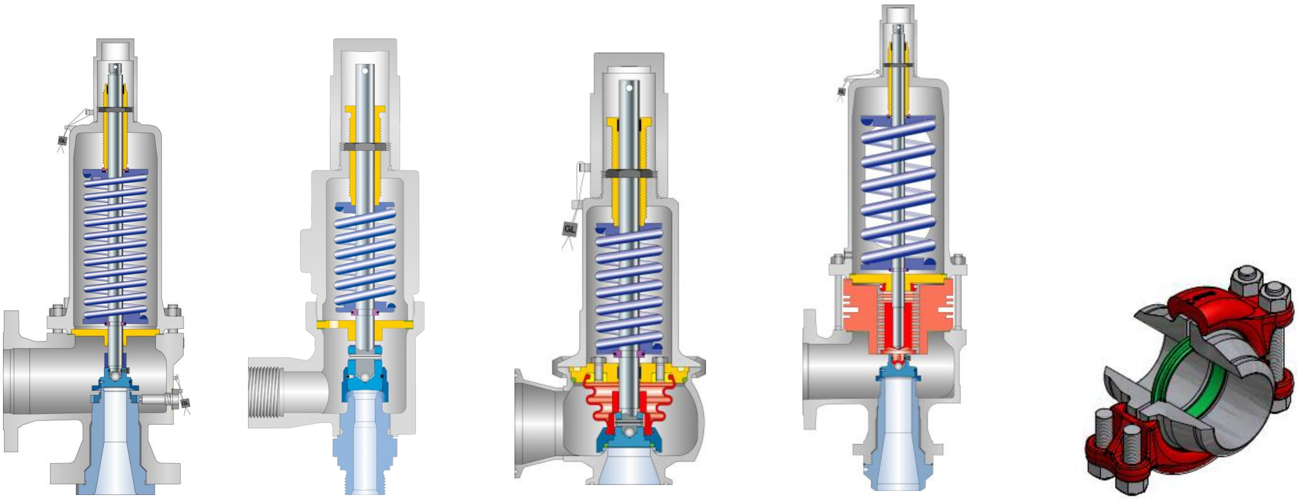
| Standard | Other common designation | Originates from |
| --- | --- | --- |
| ASME B 1.20.1 - NPT | | America |
| ASME B1.20.3 – NPTF | | America |
| ISO 7-1 – R | BS 21, BSP-T | Europe |
| ISO 7-1 – Rp | BS 21, BSP-P | Europe |
| ISO 228-1 - G | BS 2779 | Europe |

*Table 2.4.2-1: Standards for threaded connections*

### 2.4.3 Other Connections

In some industries connections other than flanged or threaded are common due to specific requirements like cleanability in the food and beverage industry. Examples are:

- Connections for sanitary applications, e.g. according to ASME BPE or DIN 11864: clamps, threaded, flanged
- Butt weld ends for high temperature / high pressure applications
- Grayloc®, Techlok® clamp connections for high pressure pipeline applications



Flanged    Threaded    Clamp    Butt Weld    Grayloc®, Techlok®

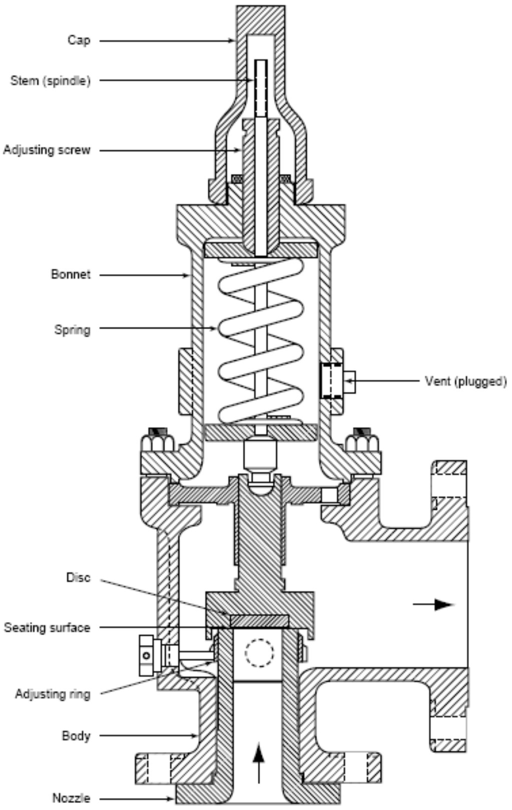
Figure 2.4.3-1: Typical connections for safety valves

## 2.5 Conventional and Balanced Safety Valves

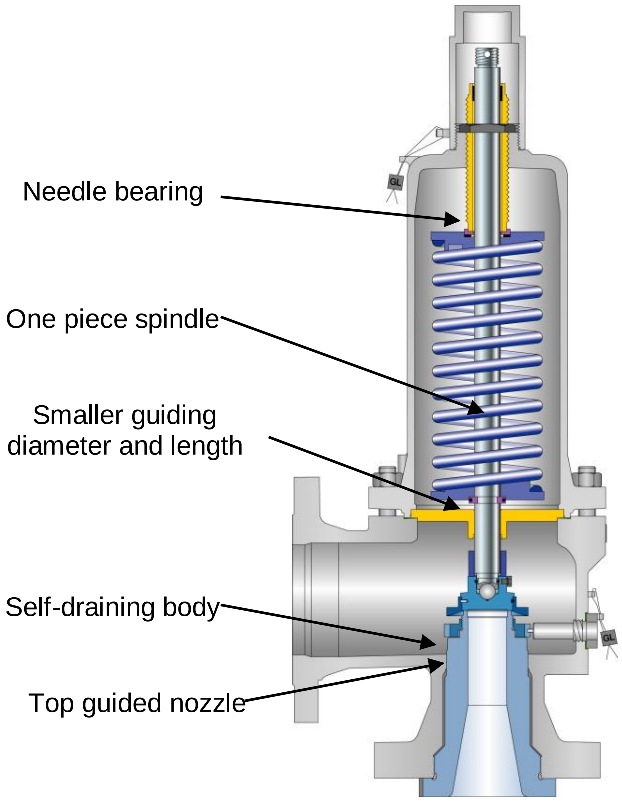
### 2.5.1 Conventional Safety Valves

A conventional direct spring loaded safety valve is a spring loaded safety valve whose operational characteristics are directly affected by changes in the back pressure (API 520-1, 1.2.1.2). Back pressure is the pressure present in the secondary pressure zone (outlet) of the valve (see also chapter 6 of ENGINEERING).

**Conventional Safety Valves - Flanged**




API 520 – 1 figure 2:
Conventional pressure relief valve with a single adjusting ring for blowdown control



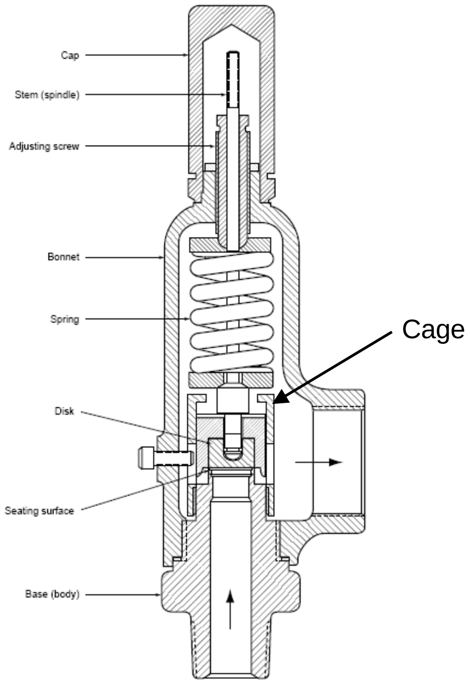

LESER API Series 526:
Improvements in the design

*Figure 2.5.1-1: Conventional flanged safety valves*

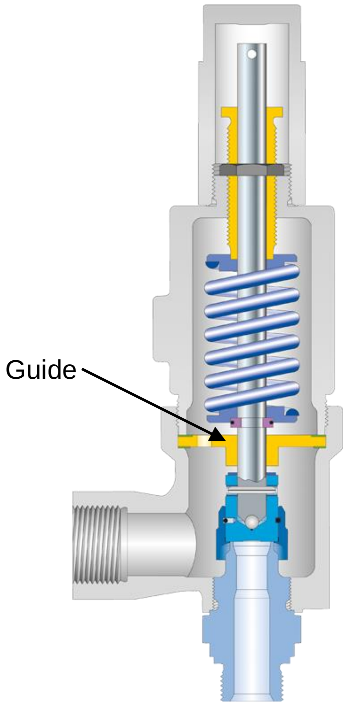
The API 520-1 figure 2 shows a typical design for a conventional flanged safety valve.
The LESER API Series 526 complies with all requirements of API 520-1 and API 526. Compared with the typical design there are some major improvements in the LESER design:

- one piece spindle spindle with widely spaced top and bottom guide for better alignment of moving parts
- smaller guiding diameter and length for less friction in the guide and less galling
- needle bearing between adjusting screw and upper spring plate for more precise and easier setting
- top guided nozzle for better alignment
- self-draining body for less corrosion
- horizontal installation possible at pressures > 3 barg / 45 psig and horizontal transport and storage due to one piece spindle design

### Conventional Safety Valves - Threaded




API 520 – 1 figure 5:
Conventional pressure relief valve with threaded connections




LESER design:
Compact Performance Series 459

*Figure 2.5.1-2: Conventional safety valves - threaded*

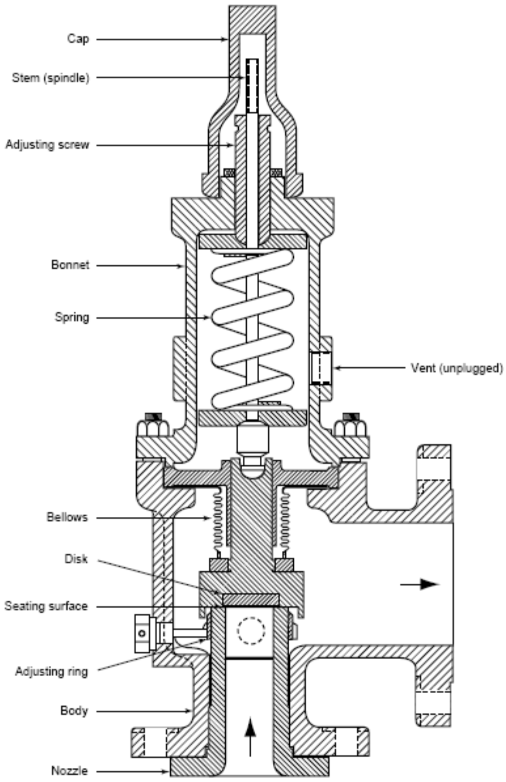
The API 520-1 figure 5 shows a typical design for a conventional threaded safety valve.
Compared with the typical design there are some major improvements in the LESER design:

- the two point guiding of the spindle instead of a disc guided in a “cage” for less corrosion and less friction in the guide
- less galling
- self-draining body for less corrosion
- free and unrestricted flow with larger discharge coefficient
- horizontal installation possible at pressures > 3 barg / 45 psig

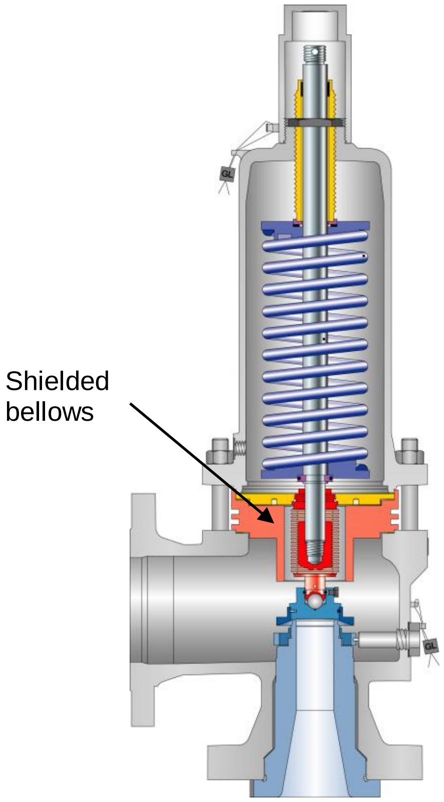
### 2.5.2 Balanced Safety Valves

A balanced direct spring loaded safety valve is a spring loaded safety valve that incorporates a bellows or other means for minimizing the effect of back pressure on the operational characteristics of the valve. Back pressure is the pressure present in the secondary pressure zone (outlet) of the valve (see also chapter 6 of ENGINEERING).

**Balanced Safety Valves - Flanged**




API 520 – 1 figure 3:
Balanced-bellows pressure relief valve



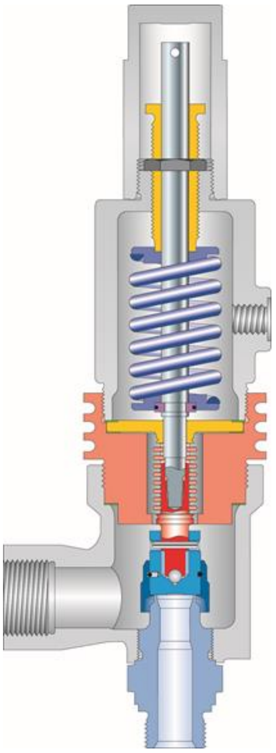

LESER API Series 526:
Improvements in the design

*Figure 2.5.2-1: Balanced safety valves - flanged*

The API 520 figure 3 shows a typical design for a balanced flanged safety valve.
The LESER API Series 526 complies with all requirements of API 520-1 and API 526. Compared with the typical design there are some major improvements in the LESER design:

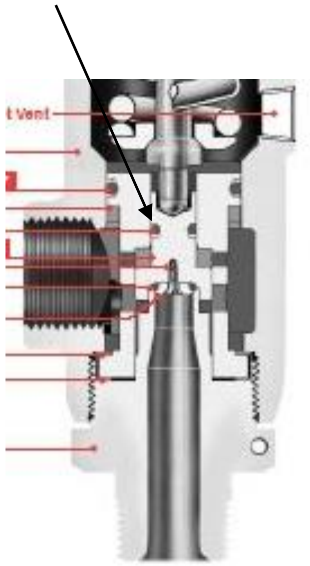
- all advantages as listed under "Conventional Safety Valves – Flanged"
- additionally: the protection of the bellows by a bonnet spacer for a shielded bellows with longer lifetime

### Balanced Safety Valves - threaded



LESER Compact Performance
Series 459 with balanced bellows

*Balanced piston with O-ring seal*



Typical competitor's design with
balanced piston

*Figure 2.5.2-2: Balanced safety valves - threaded*

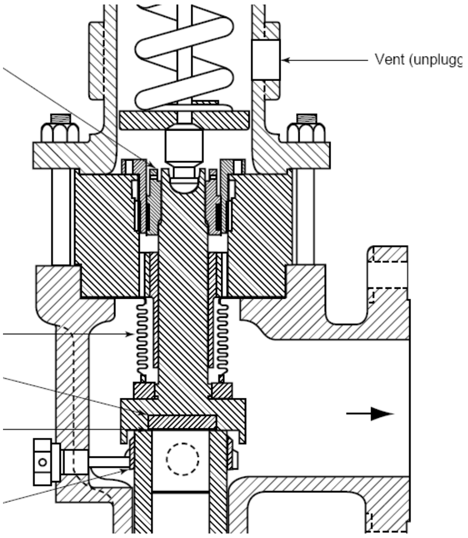
The API 520-1 does not show a design for a balanced threaded safety valve.
The design of the LESER Compact Performance Series 459 with a separated bonnet and outlet body allows to insert a balanced bellows the same way as in a flanged safety valve resulting in:

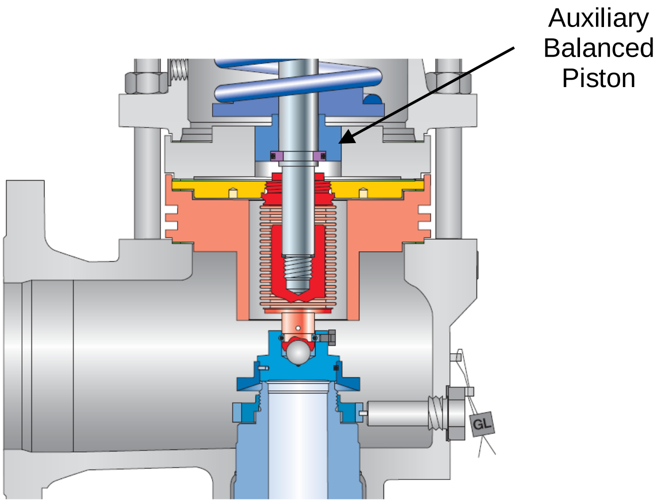
- full back pressure compensation
- protection of moving parts from dirt and corrosion

Many competitor's designs provide back pressure compensation by a balanced piston design requiring a spindle sealing by O-rings or similar sealing elements. A bellows design is superior because:

- no risk of locking the spindle due to O-ring failure, e.g. by swelling
- wider temperature range
- better chemical resistance

### 2.5.3 Balanced-Bellows Safety Valves with Auxiliary Balanced Piston




*API 520-1, Figure 4* *LESER Type 526*

*Figure 2.5.3-1: Balanced-bellows pressure relief valve with an auxiliary balanced piston*

### 2.5.4 Balanced-Bellows Safety Valve with Auxiliary Balanced Piston

The API 520-1 figure 4 shows a typical design for a balanced flanged safety valve with Auxiliary Balanced Piston.
The balanced piston shall provide back pressure compensation in case of a bellows failure. The effective area of the piston is equal to the seat area to provide the back pressure compensation.
Other than the bellows does not seal off the bonnet area from the valve outlet.

## 2.6 Parts of a Spring Loaded Safety Valve

### 2.6.1 Parts of a Conventional Spring Loaded Safety Valve – Flanged

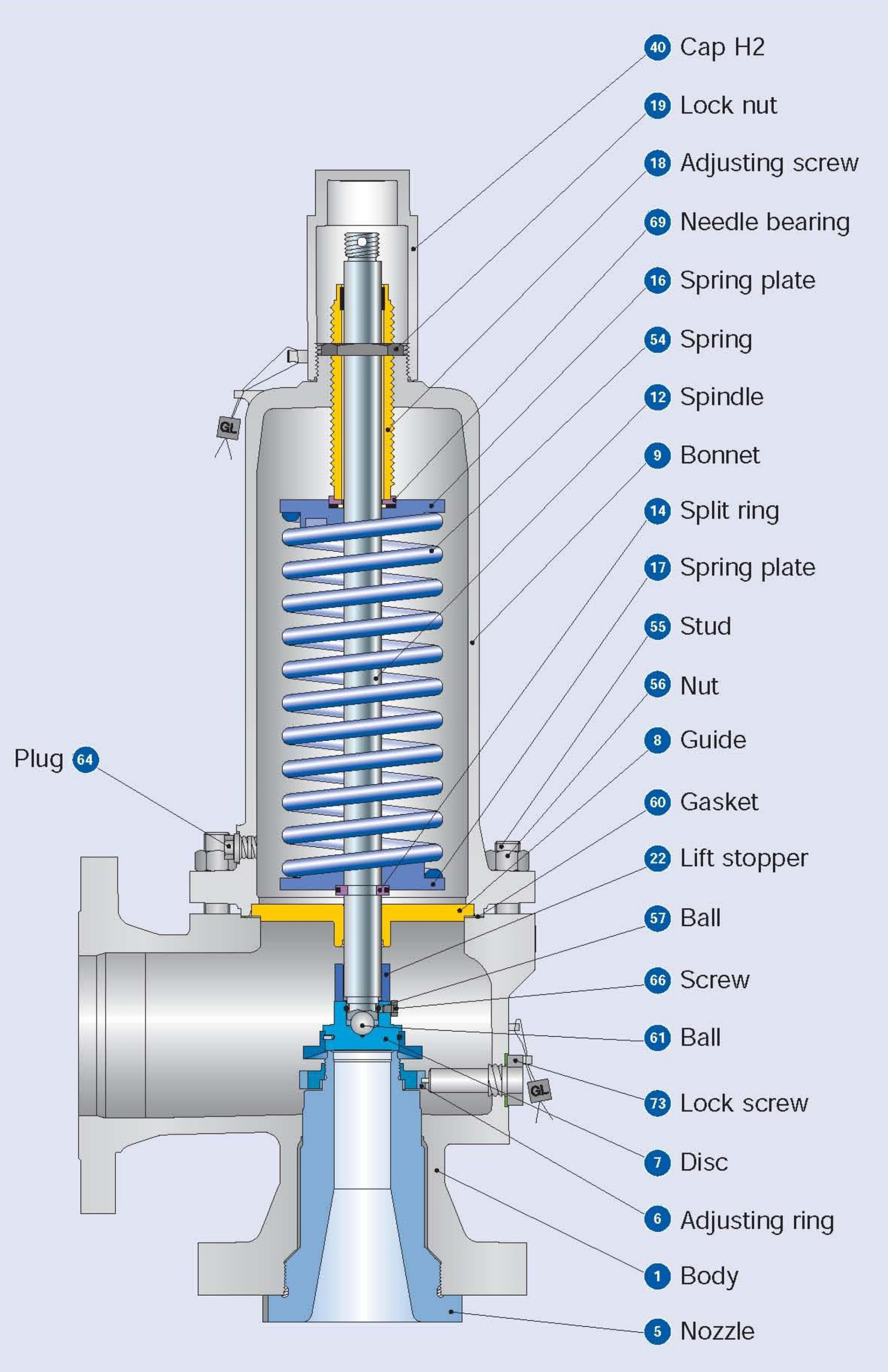



*Figure 2.6.1-1: Parts of a Conventional Spring Loaded Safety Valve – Flanged*

### 2.6.2 Parts of a Balanced Bellows Spring Loaded Safety Valve – Flanged

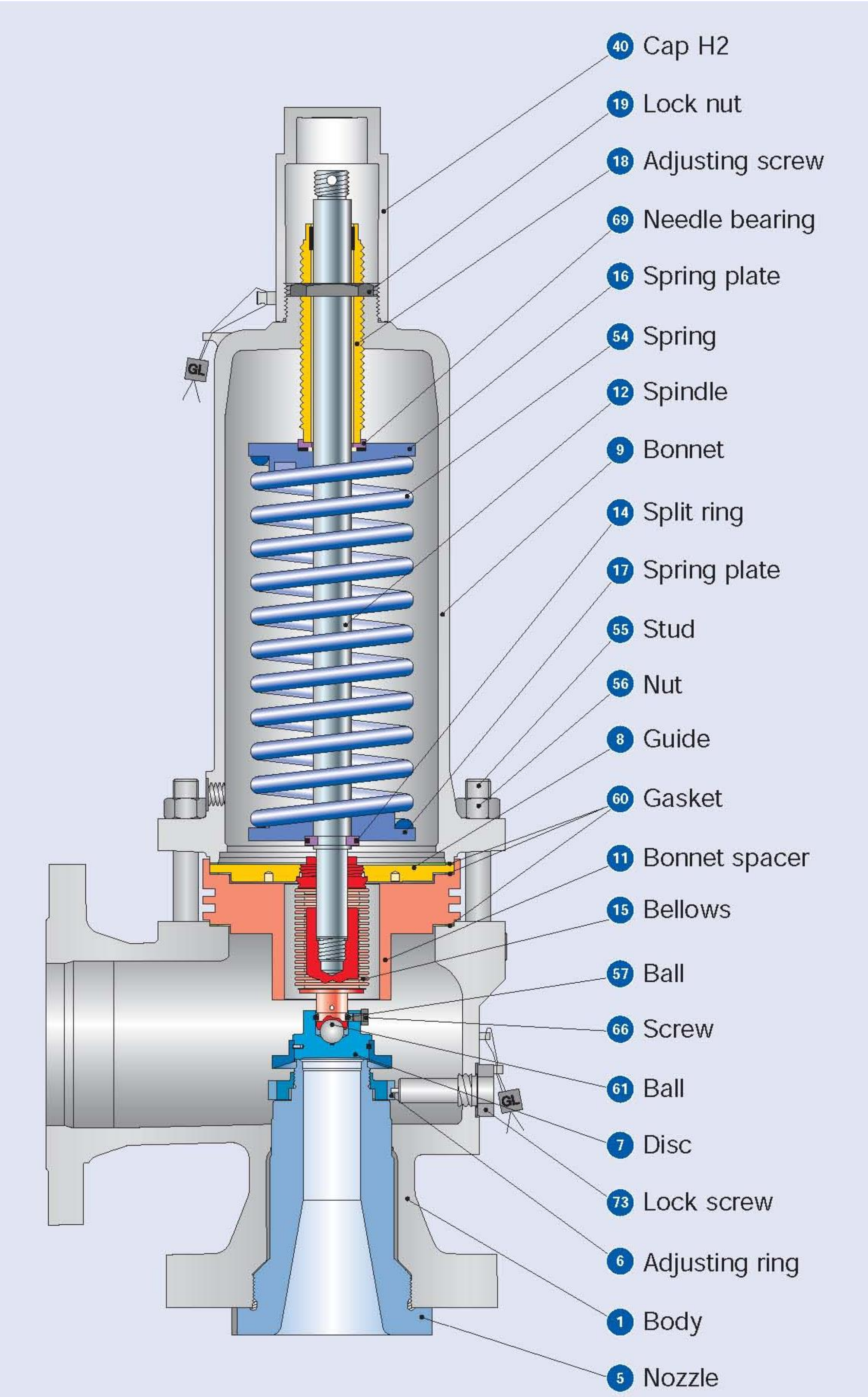



*Figure 2.6.2-1: Parts of a Balanced Bellows Spring Loaded Safety Valve - Flanged*

### 2.6.3 Parts of a Conventional Spring Loaded Safety Valve – Threaded

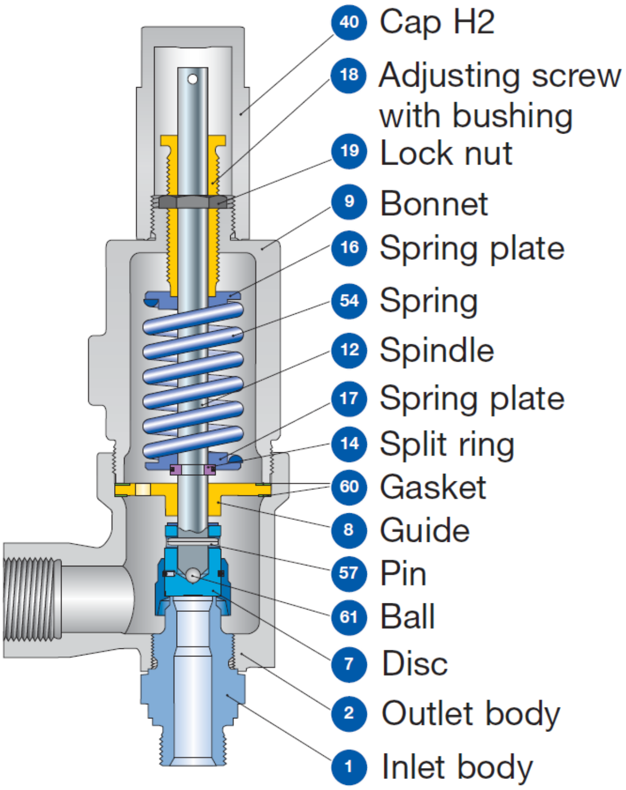



*Figure 2.6.3-1: Parts of a conventional spring loaded safety valve - threaded*

### 2.6.4 Parts of a Balanced Bellows Spring Loaded Safety Valve – Threaded

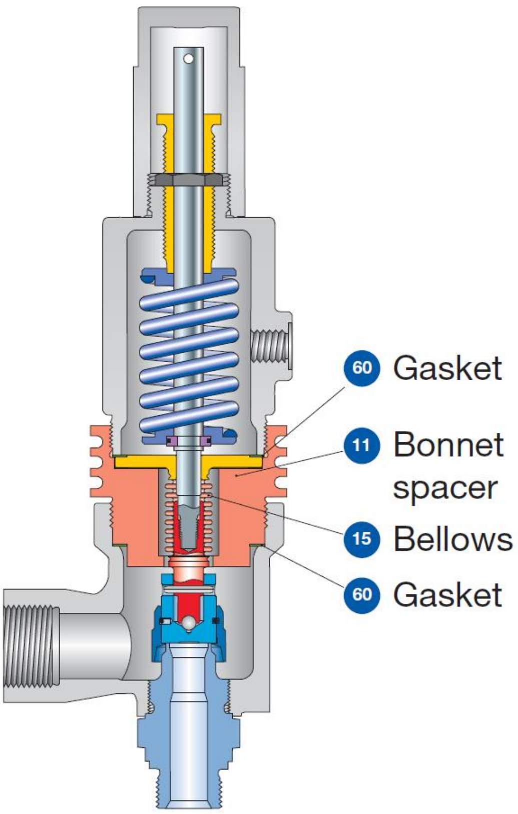



*Figure 2.6.4-1: Parts of a balanced bellows spring loaded safety valve - threaded*

### 2.6.5 Parts Description acc. to ASME PTC 25

| Item | Component | Description per ASME PTC 25 – Parts used by LESER |
|---|---|---|
| 1 | **Body** | a pressure-retaining or containing component of a pressure relief device that supports the parts of the valve assembly and has provision(s) for connecting to the primary and/or secondary pressure source(s). |
| 5 | **Nozzle** | a primary pressure- containing component in a safety valve that forms a part or all of the inlet flow passage. |
| 5 | **Seat** | the pressure-sealing surfaces of the fixed and moving pressure-containing components. |
| 6 | **Adjusting ring (blowdown ring)** | a ring assembled to the nozzle or guide of a direct spring valve, used to control the opening characteristics and/or the reseat pressure. |
| 7 | **Disc** | a moveable component of a pressure relief device that contains the primary pressure when it rests against the nozzle. |
| 9 | **Bonnet** | a component of a direct spring valve or of a pilot in a pilot-operated valve that supports the spring. It may or may not be pressure containing. |
| 8 | **Guide** | a component in a direct spring or pilot-operated pressure relief device used to control the lateral movement of the disc or disc holder. |
| 12 | **Spindle (stem)** | a part whose axial orientation is parallel to the travel of the disc. It may be used in one or more of the following functions: (a) assist in alignment, (b) guide disc travel, and (c) transfer of internal or external forces to the seats. |
| 15 | **Bellows** | a flexible pressure-containing component of a balanced direct spring valve used to prevent changes in set pressure when the valve is subject to superimposed back pressure, or to prevent corrosion between the disc holder and guide. |
| 16/17 | **Spring plate (spring step, -button, -washer)** | or spring step: a load-transferring component in a safety valve that supports the spring. |
| 18 | **Adjustment screw** | a screw used to adjust the set pressure or the reseat pressure of a reclosing pressure relief device. |
| 40 | **Cap** | a component used to restrict access and/or protect the adjustment screw in a reclosing pressure-relief device. It may or may not be a pressure-containing part. |
| 40 | **Lift Lever** | A device to apply an external force to the stem of a pressure relief valve to manually operate the valve at some pressure below the set pressure |
| 54 | **Spring** | the element in a safety valve that provides the force to keep the disc on the nozzle. |

*Table 2.6.5-1: Parts description acc. to ASME PTC 25*

The following parts are described in ASME PTC 25, but are not used in LESER safety valves.

| Component | Description per ASME PTC 25 | Not used in LESER safety valves, because |
|---|---|---|
| **Disc Holder** | a moveable component in a pressure relief device that contains the disc | One piece spindle with different disc design, does not require a disc holder |
| **Yoke** | a pressure-retaining component in a pressure relief device that supports the spring in a pressure relief valve or pin in a nonreclosing device but does not enclose them from the surrounding ambient environment | Open bonnets are used for the same purpose. |

*Table 2.6.5-2: Parts description acc. to ASME PTC 25 – not contained in LESER safety valves*

ASME PTC 25 contains descriptions of other components. These include components of pilot operated safety valves, rupture discs and non-reclosing safety devices that are not listed here.

### 2.6.6 Pressure Retaining or Containing Parts acc. to the ASME Code

The ASME code provides a precise description of pressure retaining or containing components of a safety valve. The classification pressure retaining or containing has consequences regarding the material selection and testing as described below.

**Definition of the Terms “Pressure Retaining” and “Pressure Containing”**

ASME PTC 25-2001, Section 2 Definitions and Description of Terms:
- Pressure-containing member: a component which is exposed to and contains pressure
- Pressure-retaining member: a component which holds one or more pressure-containing members together but is not exposed to the pressure

| Component | Classification per ASME PTC 25, 2.4 |
|---|---|
| **Body** | pressure-retaining or containing |
| **Bonnet** | may (closed design) or may not (open design) be pressure containing |
| **Cap** | may (closed design) or may not (open design) be pressure containing |
| **Nozzle** | pressure-containing |
| **Disc** | pressure-containing |

*Table 2.6.6-1: Parts classification acc. to ASME PTC 25, 2.4*

**Material Selection**

The materials for specific pressure retaining components of a safety valve must comply with the following requirements:
ASME Code XIII, 3.3.1(a) gives the following definition:
“(a) Materials used in bodies, bonnet or yokes, and body-to-bonnet or body-to-yoke bolting shall be as permittedin Section II, Part D by the referencing Code, ... .
In addition, the following requirements apply:
(1) For Section VIII, Division 1 (UV Designator) pressure relief valves, the bodies, bonnets, yokes, and body-to-bonnet or body-to-yoke bolting shall meet all applicable requirements of Section VIII, Division 1, Subsection C."
The reason why the ASME XIII code restricts the choice of materials that may be used for the above mentioned components is that these components are the most critical components in a safety valve. The failure of one of these components will result in an uncontrolled hazardous release of the inlet pressure. Failure of other safety valve components like nozzle, disc, spindle or spring may result in the release of pressure, but the release will be a controlled discharge through the valve outlet.

**Hydrostatic Pressure Test**

ASME Code XIII, 3.6.1 gives the following definition:
“(a) The pressure-containing parts of the shell of each valve are subject to pressure testing. The valve shell is defined by parts such as the body, bonnet, and cap that isolate primary or secondary pressure from atmosphere.
(b) A valve shell part is exempt from pressure testing if both of the following conditions apply:
    (1) The stress that would be applied under hydrostatic test conditions does not exceed 50% of the allowable stress.
    (2) The part is not cast or welded.
(c) When the valve is designed for discharging directly to atmosphere, the valve components downstream of the valve disk are exempt from pressure testing.
(d) Valve components are exempt from pressure testing if they are fully contained within pressurecontaining parts that have been either pressure tested or exempted from pressure testing by (b).
e) A valve shell part requiring pressure testing shall be tested either
    (1) hydrostatically at a minimum 1.5 times the design pressure of the part, or
    (2) pneumatically at a minimum 1.25 times the design pressure of the part"

As a consequence of this definition, normally the following components require a hydrostatic pressure test, unless they fulfill requirements for exemption:
- body, inlet body
- bonnet-closed
- nozzle-casted
- cap or gastight lifting device

The disc would fall into the same category, but testing of the disc is not practical and stresses within the disc become lower when pressurized.
The stainless steel bellows and the guide do not have to be tested, because they are downstream of the disc and fully contained within the body.

**Material Certificates**
The ASME Code does not define exact requirements for material certificates and does not distinguish between different types of material certificates that are defined in EN 10204.

## 2.6.7 Pressure Retaining or Containing Parts acc. to PED 2014/68/EU

### Definition of the Terms “Pressure Retaining” and “Pressure Containing”

The PED does not distinguish between “pressure retaining” and “pressure containing”. Instead, the term “main pressure-bearing parts” is used.
However, neither the PED 2014/68/EUnor the ISO 4126 determine those components of a safety valve that are main pressure-bearing.

The general definition of a main pressure-bearing component is given in a guideline from the Commission’s Working Group "Pressure" as follows:

Guideline 7/6 related to: Annex I Section 4.3:

> “The main pressure-bearing parts are the parts, which constitute the envelope under pressure, and the parts which are essential for the integrity of the equipment.
> Examples of main pressure-bearing parts are shells, ends, main body flanges, tube sheet of exchangers, tube bundles.
> The materials for these main pressure-bearing parts of equipment of categories II to IV shall have a certificate of specific product control (see Guideline 7/5).
> See also guideline 7/8 for bolting parts (fasteners).”

### Material Selection

The requirements for the main pressure-bearing parts are defined in:

PED 2014/68/EU, Annex 1, 4. Materials, section 4.2. (b):

> “The manufacturer must provide in his technical documentation elements relating to compliance with the materials specifications of the Directive in one of the following forms:
> - by using materials which comply with harmonized standards,
> - by using materials covered by a European approval of pressure equipment materials in accordance with Article 11,
> - by a particular material appraisal”

### Hydrostatic Pressure Test

See ISO 4126-1, Section 6.3.1 Application:

> “The portion of the valve from the inlet to the seat shall be tested to a pressure 1.5 times the manufacturer’s stated maximum pressure for which the safety valve is designed.
> The shell on the discharge side of the seat shall be tested to 1.5 times the manufacturer’s stated maximum back pressure for which the valve is designed.”

As a consequence of this definition, normally the following components require a hydrostatic pressure test, unless they fulfill requirements for exemption as stated in section 6.2 of ISO 4126-1:
- body, inlet body
- bonnet
- nozzle
- cap or gastight lifting device

### Material Certificates

See PED 2014/68/EU, Annex 1, 4. Materials, section See 4.3:

> "… For the **main pressure-bearing parts** of equipment in categories II, III and IV, this must take the form of a certificate of specific product control. Where a material manufacturer has an appropriate quality-assurance system, certified by a competent body established within the Community and having undergone a specific assessment for materials, certificates issued by the manufacturer are presumed to certify conformity with the relevant requirements of this section."

Note: It is common practice in Europe to request material certificates only for the pressure bearing safety valve body and not for other pressure bearing components. This results from the previously applied AD 2000 – A4 standard, which requires a material certificate only for the safety valve body.

### 2.6.8 Critical Parts Influencing the Operating Characteristic of the Safety Valve

**Nozzle and disc**

The geometry of nozzle and disc is critical to the valve operation. Small changes to the dimensions of these parts can change overpressure, blowdown and general valve operation significantly. Maintenance instructions of the manufacturer typically include critical dimensions of these parts. Critical dimensions must be maintained when performing repair and maintenance work. Maintenance work should only carried out by authorized and trained personnel!
Nozzle and disc also form the seat of the valve. The surface finish of the contact surfaces is critical for the tightness of the safety valve. For a metal to metal seat the contact surfaces are lapped for a specified tightness acc. to API 527.

**Spring**

The closing force on the disc is applied by the compression of the spring. When the valve opens, a further compression of the spring must be achieved by the opening forces underneath the disc. The correct spring rate of the spring is critical to overpressure and blowdown of the valve. Each spring has a defined set pressure range. The spring charts of the manufacturer must be followed when readjusting or changing the set pressure of the safety valve.
The following table lists the potential consequences of using a spring for a set pressure outside of its range.

| Condition | Consequences |
|---|---|
| Set pressure above spring range | - increased blowdown<br>- risk of excessive spring compression with coils approaching each other, resulting in restricted lift<br>- pressure accumulation in the vessel above acceptable levels due to restricted lift |
| Set pressure below spring range | - increased overpressure<br>- potential pressure accumulation in the vessel above acceptable levels |

*Table 2.6.8-1: Influence of incorrect set pressure on overpressure and blowdown*

### 2.6.9 Parts Providing Alignment

Correct alignment of nozzle and disc are critical for proper valve operation and tightness. Disc and spindle of the valve will move up and down during valve operation.

Proper guiding of the spindle is essential for trouble free valve performance. The spindle is guided by the guide and the adjusting screw.

Tolerances and materials must be selected such that no corrosion or galling will prevent the valve from operating.

When installed, the user must ensure that no dust, particles in the fluid or sticky media may enter the guiding surfaces and negatively influence the valve performance. In some cases the use of a bellows is advisable to protect the guiding parts.

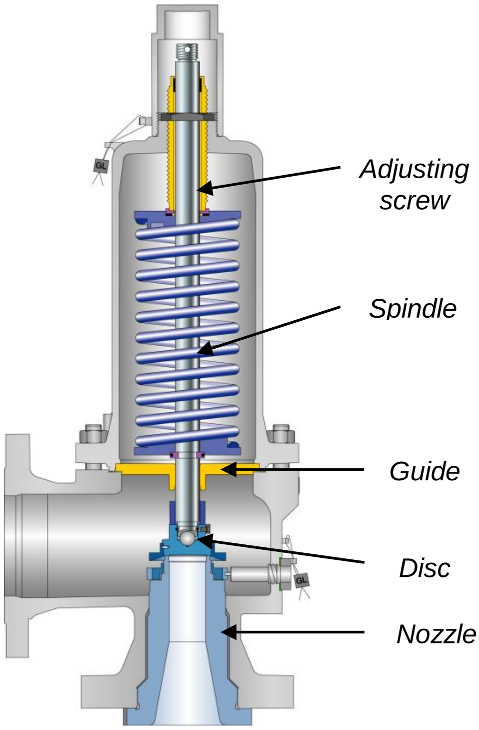


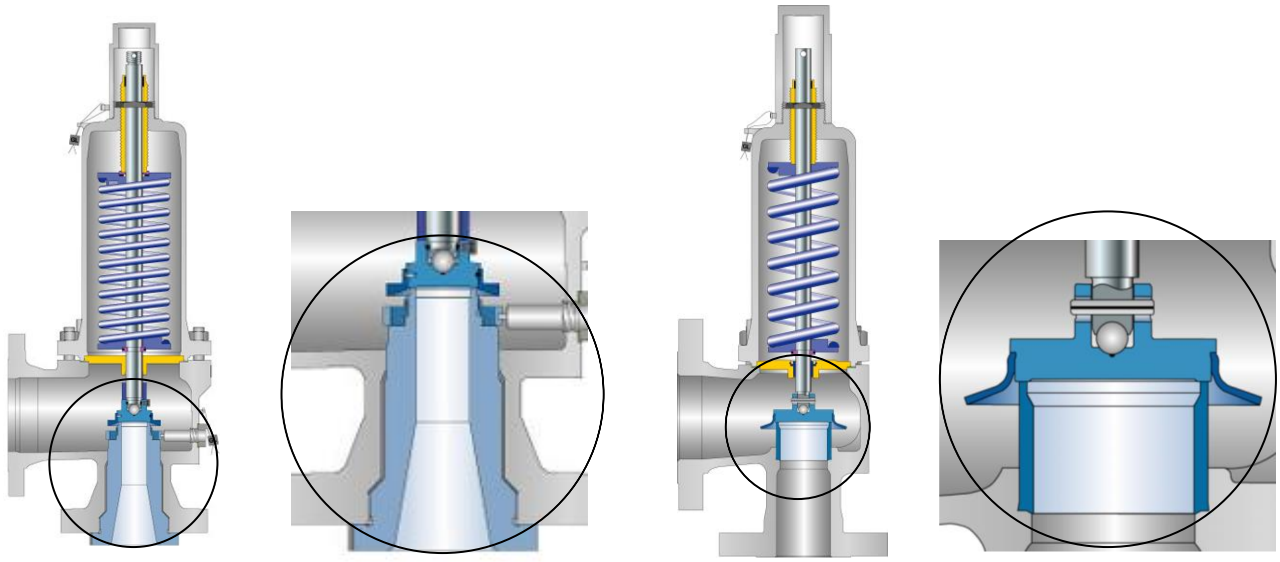

*Figure 2.6.9-1 Parts providing alignment*

## 2.7 Full Nozzle and Semi Nozzle Design

The nozzle is a primary pressure- containing component in a safety valve that forms a part or all of the inlet flow passage.

- Full nozzle: the nozzle forms all of the inlet flow passage and is typically threaded into the valve body
- Semi nozzle: the nozzle forms only a part of the inlet flow passage and is typically not removeable from the valve body

Most nozzles and discs are made from stainless steel to avoid corrosion and to ensure trouble free valve performance. Selection of other corrosion resistant materials may be advisable depending on the application.



Full nozzle design - LESER Type 526 Semi nozzle design - LESER Type 441

*Figure 2.7-1: Full nozzle and semi nozzle design*

### 2.7.1 Criteria for Selecting a Full Nozzle or Semi Nozzle Design

| Criteria | Full Nozzle | Semi Nozzle |
|---|---|---|
| Regional Preference | USA and regions where the API standard is the dominating standard | Europe<br>USA for ASME I applications |
| Design Standard | Design per API 526 / API 520 required | No design standard required |
| Application (corrosion) | Together with a disc in stainless steel, all permanently wetted parts have excellent corrosion resistance. In corrosive process applications selection of a carbon steel body material is possible. | The valve body will be permanently in contact with the medium.<br>A carbon steel body material can be selected for non corrosive applications, e.g. utility, air, steam, water.<br>A stainless steel body material should be selected for corrosive process applications. |
| Pressure | All pressure ranges | Max set pressure approx. 100 bar / 1450 psig |
| Capacity | In most cases according to API orifice designations. | In most cases full bore designs with maximum capacity relative to the valve size. |
| Repair | A full nozzle is typically removable and can either be replaced or repaired outside of the valve body | A semi nozzle can typically not be removed. Repair is possible inside of the valve body with lapping tools. To repair major damages of the seat, the complet body must be taken on a lathe. |
| Cost | Full nozzle designs require more machining and material and are less cost effective than semi nozzle designs. | A semi nozzle design requires less machining and less material than a full nozzle design thus being more cost effective. |

*Table 2.7.1-1: Criteria for selecting a full nozzle or semi nozzle design.*

## 2.8 Adjusting Ring and Ringless Designs

Codes and standards specify limits for the overpressure and blowdown of safety valves. In some designs adjusting rings are used to adjust the overpressure and blowdown of the safety valve in order to meet the requirements of codes and standards. In many of them a 10% accumulation pressure is used as a basis for the design strength calculation of a pressure vessel. Therefore the overpressure for safety valves is limited to 10% of the set pressure for the majority of the applications.

Overpressure:
For steam and gas applications the max. overpressure varies between 3% and 10% depending on applicable code and application. For liquids most codes specify a maximum overpressure of 10%.

Blowdown:
Typical values for the blowdown are 4% to 15% for steam and gas and 20% to unlimited for liquids. See tables 2.8.4-1 and 2.8.4-2

### 2.8.1 Ringless Designs

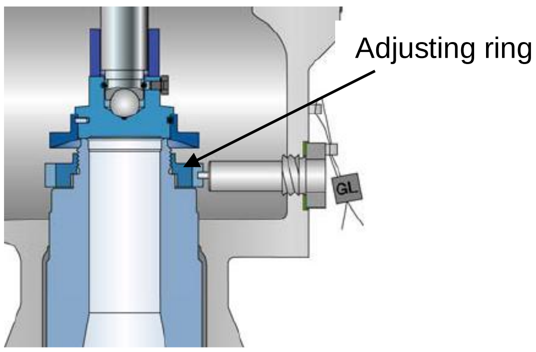
Precise machining within narrow tolerances of all flow relevant components allow to meet code requirements without any blowdown adjustments on the valve. Safety valves without adjustment options are called fixed blowdown valves. Safety valves of this type are very common in Europe.

### 2.8.2 Designs with One Adjusting Ring

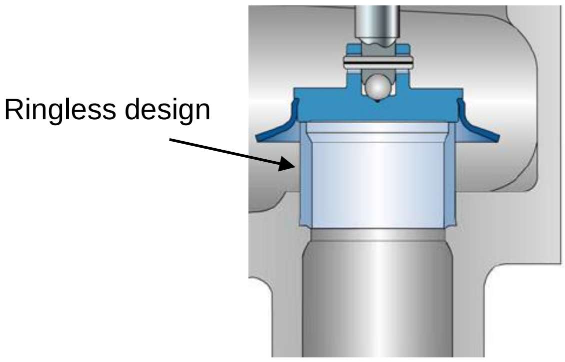
In the USA the majority of flanged valves are equipped with one or two adjusting rings, positioned around the nozzle and/or the disc. The position of these rings is usually factory set to meet overpressure and blowdown requirements of the applicable codes. The position of the rings can be adjusted to fine tune overpressure and blowdown of the valve.
Designs with one ring are typically used for ASME VIII pressure vessel applications in the process industry. These designs are in most cases safety valves built according to the API 526 Standard, which shows a design containing a lower adjusting ring (API 520-1 figure 2).
It is however not required to have an adjusting ring to meet ASME XIII requirements (see also section 2.8.4).
For the most common design with one lower adjusting ring, changing the ring position has the following effects:

| | |
|---|---|
| Lowering ring: | overpressure increases, blowdown decreases |
| Rising ring: | overpressure decreases, blowdown increases |

According to LESER's experience a significant change in the operating characteristic can only be achieved when the adjusting ring position is close to the disc and the ring almost touches the disc.
Manufacturer's instructions however do not provide information on how to adjust to specific values based on charts or tables. The effect of changed ring positions must be tested on suitable test benches that allow to measure overpressure and blowdown.
Ring adjustment should only be performed by authorized personnel and according to manufacturer's instructions. Otherwise the operation of the safety valve in accordance with code limitations may not be guaranteed anymore.




LESER Series 526




LESER High Performance Series

*Figure 2.8.2-1: Blowdown ring and ringless design*

### 2.8.3 Designs with Two Adjusting Rings

Designs with two rings are typically used for ASME I steam boiler applications in order to fulfill the stringent requirements for overpressure and blowdown.

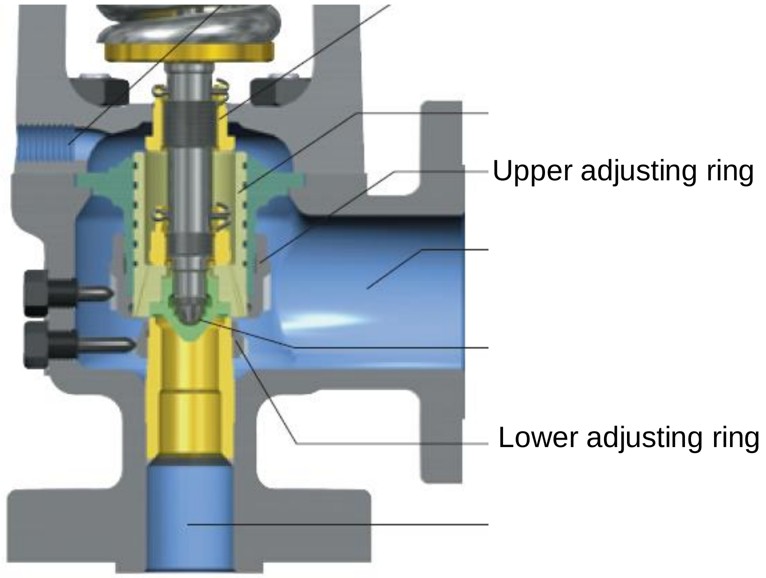



*Figure 2.8.3-1: Typical ASME I safety valve design with two adjusting rings*

### 2.8.4 Adjusting Ring at LESER

The LESER API Series 526 is the only safety valve in LESER's product range that is equipped with an adjusting ring, following the requirements of the API 520 and API 526 standard.

The adjusting ring in Series 526 should be turned to the lowest possible position on the nozzle to ensure all code requirements are met. No further ring adjustment depending on set pressure or medium is required.

The benefit for the user is the easier maintenance, because no complicated ring adjustment is required.

The same applies to all other LESER designs which are ringless designs. These designs still meet all requirements of the ASME XIII, PED 2014/68/EU and other worldwide codes and standards without any change of components. This means that even if there is no requirement for the blowdown acc. to ASME XIII for ringless designs, the ringless valve types like 441 or 459 still have certified values for the blowdown. Thus, exactly the same valve types meet the most stringent requirements of ISO 4126-1 and AD 2000 A2.
The tables below show the overpressure and blowdown requirements of ASME XIII, ISO 4126-1 and AD 2000 A2 and the actual values for selected LESER safety valve types. These actual values are met independently from the code applicable to an individual order. In other words, e.g a LESER type 441 with UV stamp acc. to ASME XIII will be fully open at 5% on a steam/gas application with a blowdown of 10%.

For the LESER API Series 526 it is possible to completely leave out the adjusting ring including the lock screw. Series 526 still meets the below certified values for overpressure and blowdown. This ringless design is certified according to ASME XIII within a separate certification and is part of the CE certification as an optional version.

| Overpressure Requirements (max. values) | | | | | | |
|---|---|---|---|---|---|---|
| | Code Requirements | | | Certified Values for LESER Types | | |
| Medium | ASME XIII | ISO 4126-1 | AD 2000 A2[1)] | 441 | 459 | 526 |
| Steam/Gas | +10% | +10% | +5% full lift<br>+10% other | +5% | +5% | +10% |
| Liquid | +10% | +10% | +5% full lift<br>+10% other | +10% | +10% | +10% |

*Table 2.8.4-1: Overpressure requirements and actual values of selected LESER types*

Notes: 1) +5% for "full lift" safety valves acc. to the AD 2000 A2 definition, +10% for all other safety valves

| Blowdown Requirements (max. values) | | | | | | |
|---|---|---|---|---|---|---|
| | Code Requirements | | | Certified Values for LESER Types | | |
| Medium | ASME XIII | ISO 4126-1 | AD 2000 A2 | 441 | 459 | 526 |
| Steam/Gas<br>- ringless design | No requirement | -15% | -10% | -10% | -10% | -7% |
| Steam/Gas<br>- with adj. ring | -7% | | | | | |
| Liquid | No requirement | -20% | -20% | -20% | -20% | -20% |

*Table 2.8.4-2: Blowdown requirements and actual values of selected LESER types*

## 2.9 Steam/Gas Trim and Liquid Trim versus Single Trim

### 2.9.1 Trim Definition

The trim is formed by the nozzle and the disc of the safety valve. The trim is often referred to as the “permanently wetted” parts of the safety valve.

### 2.9.2 Steam/Gas Trim and Liquid Trim

Different types of fluids have different properties which may influence the valve operation (overpressure and blowdown). The most significant difference can be found between a gas and a liquid. A liquid typically has a larger density than a gas and can be considered to be incompressible.

In order to account for different fluid properties many manufacturers select to use a “standard trim” for steam/gas applications and a separate “liquid trim” for liquid applications. A different trim in this sense may include some or all of the following components:

- nozzle, disc, spring, bonnet

In addition, a different setting of the adjusting ring depending on the service may be required.

### 2.9.3 Single Trim

So called “single trim” designs have been optimized to use the exact same components for steam/gas and liquid applications. The development of a single trim design requires extensive testing on flow test labs to find a geometry of the components that works for both types of fluids. Single trim designs meet the overpressure and blowdown requirements of codes and standards for steam/gas and liquids without any change of components.

The advantages of a single trim design are:

- less spare parts, because nozzle and disc are the same for all services
- easier repair and maintenance
- less potential mistakes during valve repair, because there is no risk to confound parts for different services/trims
- ensured operation under two phase flow conditions

All LESER designs are single trim designs.

## 2.10 Common Optional Features

### 2.10.1 Closed or Open Bonnet

The standard bonnet design for ASME VIII applications is the closed bonnet with a plain cap. A closed bonnet protects the spring and the guiding surfaces from intrusion of foreign matters like dust. A closed bonnet also will avoid any tampering with the valve spring from the outside.

If combined with a plain (gastight) cap or packed lever the closed bonnet further prevents any medium from escaping from the inside of the safety valve. This is important for the protection of humans and equipment from aggressive or toxic media.

An open bonnet is preferred mainly in high temperature steam applications to protect the spring from too high temperatures and to avoid the collection of condensate in the bonnet area.


Closed bonnet    Open bonnet

*Figure 2.10.1-1: Closed and open bonnet*

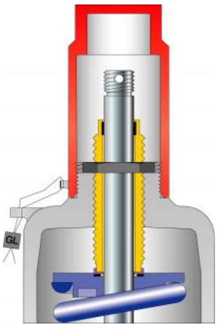
### 2.10.2 Lifting Devices

Standard design for the valve top is a plain cap, covering and sealing the adjustment of the safety valve.
Lifting levers allow users to check if the safety valve is still operational by lifting the disc off the seat. The valve remains in place while testing is performed.
Lifting levers must allow users to lift the disc off the seat when a certain percentage of the set pressure is present at the valve inlet. LESER safety valves fulfill the most stringent requirements of ASME XIII with a minimum of 75% of the set pressure (see table 10.2-1).
Caps and levers are sealed to prevent any unauthorized modification of the set pressure.

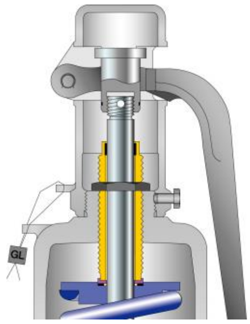
Certain codes require the installation of lifting levers for specific applications. The following chart provides an overview about the code requirements.

| Code | Section | Requirement to use lifting devices | Omission of lifting device |
|---|---|---|---|
| ASME XIII | 3.2.7(a) | (a) Section VIII (UV Designator) pressure relief valves intended for use on air or steam service, or on water service where the valve inlet temperature exceeds 60°C (140°F) excluding overpressure or relief events, shall have a substantial lifting device that, when activated, will release the seating force on the disk when the pressure relief valve is subjected to a pressure of at least 75% of the set pressure of the valve. | Code Case 2203:<br>- the user has a documented procedure … for the periodic removal of pressure relief valve for inspection and repair as necessary<br>- the omission is specified by the user<br>- the user shall obtain permission to omit the lifting device from the authority having jurisdiction over the installation of pressure vessels. |
| ISO 4126-9 | 9 | Not required.<br>Information in ISO 4126-9, section 9:<br>Safety valves for steam and compressed air duties may be provided with lifting (easing) gear, with the gear so arranged that the valves can be lifted positively off their seats when under operating pressure. | Not applicable |
| AD-2000 A2 | 4.3 | It shall be possible for safety valves to be made to open without external aids in the range ≥ 85% of the set pressure. | If it is necessary for operational reasons (inflammable / toxic gases or refrigerating plants) or if the serviceability of the safety valve can be checked in some other way. |
| TRD 421 | 4.3 | | |
| TRD 721 | 4.4 | | |

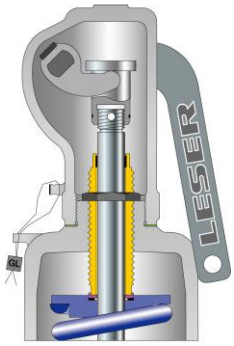
*Table 2.10.2-1: Lever requirements in codes and standards*



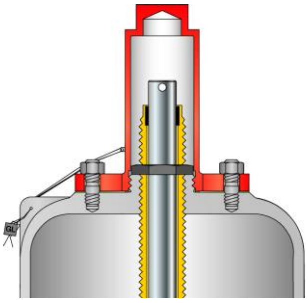
Plain Cap H2
- gastight -



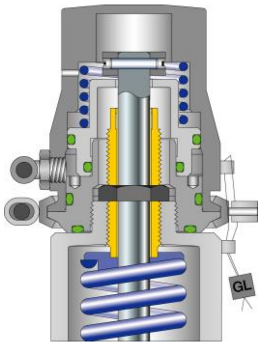
Plain lever H3-
- not gastight -




Packed lever H4
- gastight -



Bolted Cap H1
- gastight -



Pneumatic lever H8
- clean service -

*Figure 2.10.2-1: Cap and lever designs*

| Valve Top | LESER Designation | Select when |
|---|---|---|
| Plain cap | H2 | Standard valve top |
| Plain lever | H3 | Lifting lever is requested or required by codes and standards and application and medium is non-hazardous, e.g. steam, air |
| Packed lever | H4 | Lifting lever is requested or required by codes and standards and application or medium is hazardous |
| Bolted cap | H1 | For large valve sizes, allows easy removal of cap with small sized wrenches |
| Pneumatic lever | H8 | For Clean Service Series 48X, when valve lifting for CIP or SIP is requested |

*Table 2.10.2-2: Cap and lever selection*

### 2.10.3 Soft Seat

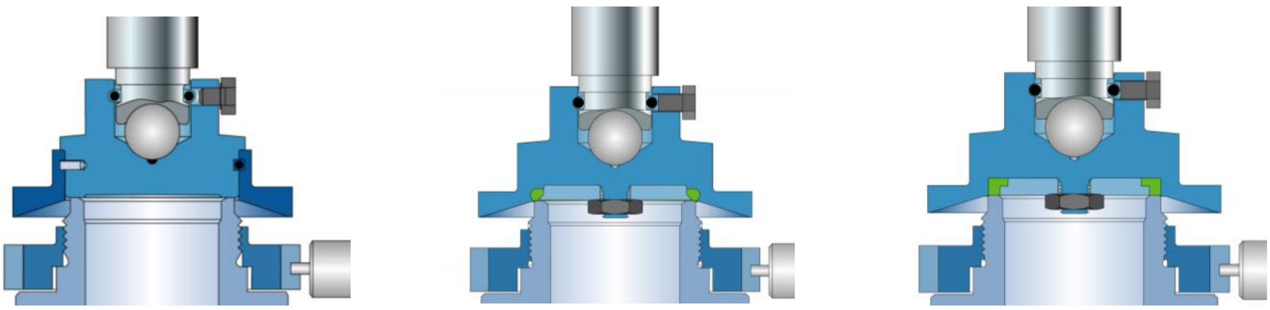
The standard design for safety valves is to be equipped with a metal to metal seat, which covers the largest variety of applications with regard to pressure/temperature combinations.

Selection of a soft seat design can provide the following advantages:

- Superior tightness especially at operating pressures above 90% of set pressure
- Maintained tightness
    - for media containing small particles, which would damage the metal to metal seat
    - for light, hard to hold fluids (e.g. helium)
    - where vibrations occur
    - under nozzle icing conditions (e.g. ethylene)

Specific temperature limits and medium resistance must be considered by the user when selecting soft seat materials.

Details can be found in the individual product catalogs.



Metal to Metal Seat | Soft Seat – O-ring | Soft Seat – Sealing Plate

*Figure 2.10.3-1: Soft seat discs*

## Contents

## 3.1 Introduction

This chapter provides an overview of terms and definitions for safety valves and other pressure relief devices according to the most important codes and standards.
Technical terms are not defined identically in different codes and standards. In some cases the same term is used for different meanings. The terms and definitions in this document are listed in alphabetical order and allow to see the differences between the standards.

## 3.2 List of Referenced Codes and Standards

The terms listed are based on the following codes and standards with edition.

| Name | Edition | Title |
|---|---|---|
| ASME PTC 25 | 2001 | Pressure Relief Devices Performance Test Codes |
| API 520 Part I | 2008 | Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries |
| API 526[1)] | 2009 | Flanged Steel Pressure Relief Valves |
| AD 2000 – A2 Merkblatt (English Edition) | 2001 | Safety devices against excess pressure - Safety valves - |
| ISO 4126 - Part 1 | 2004 | Safety devices for protection against excessive pressure, Part 1: Safety Valves |
| ISO 4126 - Part 4 | 2004 | Safety devices for protection against excessive pressure, Part 4: Pilot operated safety valves |
| ISO 4126 - Part 9 | 2008 | Safety devices for protection against excessive pressure, Part 9: Application and installation of safety devices excluding stand-alone bursting disc safety devices |

*Table 3.2-1: List of referenced codes and standards*

1): API 526 refers to API 520 Part I.

The following standards containing safety valve terminology have been withdrawn or will be withdrawn and are not considered:

| Name | Edition | Title |
|---|---|---|
| ANSI B95.1 | 1977 | Terminology for Pressure Relief Devices |
| DIN 3320-1 | 1984 | Safety Valves; Safety Shut-Off Valves; Definitions, Sizing, Marking |

*Table 3.2-2: List of not referenced codes and standards*

## 3.3 Overview Terms and Definitions

For the actual definition of the term see the page specified in the right hand column of the table below.

| Term | Specified in | | | | | | See page |
|---|---|---|---|---|---|---|---|
| | ASME PTC 25 | API 520 | ISO 4126 Part 1 | ISO 4126 Part 4 | ISO 4126 Part 9 | AD 2000-A2 | |
| Accumulated pressure | | | | | x | | 3.4-1 |
| Accumulation | | x | | | | | 3.4-1 |
| Actual discharge area | x | x | | | | | 3.4-1 |
| Adjusting ring | x | | | | | | 3.4-1 |
| Adjustment screw | x | | | | | | 3.4-1 |
| Assisted safety valve | | | x | | | | 3.4-1 |
| Back pressure | x | x | | | | | 3.4-1 |
| Backflow preventer | x | | | | | | 3.4-1 |
| Balanced bellows | | | x | | | | 3.4-2 |
| Balanced direct spring loaded PRV | x | | | | | | 3.4-2 |
| Balanced pressure relief valve | | x | | | | | 3.4-2 |
| Bellows | x | | | | | | 3.4-2 |
| Bench testing | x | | | | | | 3.4-2 |
| Blowdown | x | x | x | | | | 3.4-2 |
| Blowdown (of a pilot operated safety valve) | | | | x | | | 3.4-2 |
| Blowdown pressure | x | | | | | | 3.4-2 |
| Blowdown ring | x | | | | | | 3.4-3 |
| Body | x | | | | | | 3.4-3 |
| Bonnet | x | | | | | | 3.4-3 |
| Bore area | x | x | | | | | 3.4-3 |
| Bore diameter | x | | | | | | 3.4-3 |
| Breaking pin | x | | | | | | 3.4-3 |
| Breaking pin device | x | x | | | | | 3.4-3 |
| Breaking pin housing | x | | | | | | 3.4-3 |
| Breaking pressure | x | | | | | | 3.4-4 |
| Buckling pin | x | | | | | | 3.4-4 |
| Buckling pin device | x | x | | | | | 3.4-4 |
| Built-up backpressure | x | x | x | x | | | 3.4-4 |
| Burst pressure | x | x | | | | | 3.4-4 |
| Bursting disk device | x | | | | | | 3.4-4 |
| Burst-pressure tolerance | | x | | | | | 3.4-4 |
| Cap | x | | | | | | 3.4-5 |
| Certified (discharge) capacity | | | x | x | | | 3.4-5 |
| Chatter | x | | | | | | 3.4-5 |
| Closing pressure | x | x | | | | | 3.4-5 |
| Coefficient of discharge | x | x | x | x | | | 3.4-5 |
| Cold differential test pressure | x | x | x | x | | | 3.4-6 |
| Constant back pressure | x | | | | | | 3.4-6 |
| Controlled safety valves | | | | | | x | 3.4-6 |
| Conventional direct spring loaded PRV | x | | | | | | 3.4-6 |
| Conventional Pressure Relief Valve | | x | | | | | 3.4-6 |
| Cracking pressure | x | | | | | | 3.4-6 |
| Curtain area | x | x | | | | | 3.4-6 |
| Design features | x | | | | | | 3.4-7 |
| Design pressure | | x | | | | | 3.4-7 |
| Developed lift | x | | | | | | 3.4-7 |
| Diaphragm | x | | | | | | 3.4-7 |
| Direct loaded safety valve | | | x | | | | 3.4-7 |
| Direct spring-loaded device | x | | | | | | 3.4-7 |
| Direct spring-loaded PRV | x | | | | | | 3.4-7 |

| Term | Specified in | | | | | | |
|---|---|---|---|---|---|---|---|
| | ASME PTC 25 | API 520 | ISO 4126 Part 1 | ISO 4126 Part 4 | ISO 4126 Part 9 | AD 2000-A2 | See page |
| Direct-acting safety valves | | | | | | x | 3.4-7 |
| Discharge area | x | | | | | | 3.4-7 |
| Disk | x | | | | | | 3.4-7 |
| Disk holder | x | | | | | | 3.4-8 |
| Dome | x | | | | | | 3.4-8 |
| Dynamic blowdown | x | | | | | | 3.4-8 |
| Effective coefficient of discharge | | x | | | | | 3.4-8 |
| Effective discharge area | x | x | | | | | 3.4-8 |
| Fail-safe | | | | | x | | 3.4-8 |
| Field test | x | | | | | | 3.4-8 |
| Flow area | | | x | x | | | 3.4-8 |
| Flow capacity | x | | | | | | 3.4-9 |
| Flow capacity testing | x | | | | | | 3.4-9 |
| Flow diameter | | | x | x | | | 3.4-9 |
| Flowing pilot | | | | x | | | 3.4-9 |
| Flow-rating pressure | x | | | | | | 3.4-9 |
| Flow resistance | x | | | | | | 3.4-9 |
| Flutter | x | | | | | | 3.4-9 |
| Frangible disk device | x | | | | | | 3.4-9 |
| Full bore device | x | | | | | | 3.4-9 |
| Full bore PRV | x | | | | | | 3.4-9 |
| Full lift device | x | | | | | | 3.4-10 |
| Full lift PRV | x | | | | | | 3.4-10 |
| Full Lift Safety Valve | | | | | | x | 3.4-10 |
| Fusible plug | x | | | | | | 3.4-10 |
| Gag | x | | | | | | 3.4-10 |
| Guide | x | | | | | | 3.4-10 |
| Huddling chamber | x | x | | | | | 3.4-10 |
| Inlet area | x | | | | | | 3.4-10 |
| Inlet size | x | x | | | | | 3.4-10 |
| In-plate testing | x | | | | | | 3.4-11 |
| In-service testing | x | | | | | | 3.4-11 |
| Internal spring PRV | x | | | | | | 3.4-11 |
| Knife blade | x | | | | | | 3.4-11 |
| Leak pressure | x | | | | | | 3.4-11 |
| Leak test pressure | x | x | | | | | 3.4-11 |
| Lift | x | x | x | x | | | 3.4-11 |
| Lift lever | x | | | | | | 3.4-11 |
| Lot of rupture disks | x | x | | | | | 3.4-12 |
| Low lift device | x | | | | | | 3.4-12 |
| Low lift PRV | x | | | | | | 3.4-12 |
| Main relieving valve | x | | | | | | 3.4-12 |
| Manufacturing design range | | x | | | | | 3.4-12 |
| Marked breaking pressure | x | | | | | | 3.4-12 |
| Marked burst pressure | x | x | | | | | 3.4-12 |
| Marked relieving capacity | x | | | | | | 3.4-12 |
| Marked set pressure | x | | | | | | 3.4-12 |
| Maximum allowable pressure, PS | | | x | x | x | | 3.4-13 |
| Maximum allowable accumulated pressure, PSaccum | | | | | x | | 3.4-13 |
| Maximum allowable working pressure (MAWP) | | x | | | | | 3.4-13 |
| Maximum/minimum allowable temperature, TS | | | | | x | | 3.4-13 |
| Maximum operating pressure | | x | | | | | 3.4-13 |
| Measured relieving capacity | x | | | | | | 3.4-13 |
| Modulating | | | | x | | | 3.4-13 |

| Term | Specified in | | | | | | |
|---|---|---|---|---|---|---|---|
| | ASME PTC 25 | API 520 | ISO 4126 Part 1 | ISO 4126 Part 4 | ISO 4126 Part 9 | AD 2000-A2 | See page |
| Net flow area | x | x | | | | | 3.4-13 |
| Non-flowing pilot | | | | x | | | 3.4-14 |
| Non-fragmenting rupture disk | | x | | | | | 3.4-14 |
| Non-reclosing pressure relief device | x | x | | | | | 3.4-14 |
| Nozzle | x | | | | | | 3.4-14 |
| Nozzle area, nozzle throat area | x | | | | | | 3.4-14 |
| Nozzle diameter | x | | | | | | 3.4-14 |
| ON/OFF | | | | x | | | 3.4-14 |
| Opening pressure | x | x | | | | | 3.4-14 |
| Opening sensing pressure | | | | x | | | 3.4-14 |
| Operating ratio of a pressure relief valve | | x | | | | | 3.4-14 |
| Operating ratio of a rupture disk | | x | | | | | 3.4-15 |
| Orifice area | x | | | | | | 3.4-15 |
| Outlet size | x | x | | | | | 3.4-15 |
| Overpressure | x | x | x | | | | 3.4-15 |
| Overpressure (of a pilot operated safety valve) | | | | x | | | 3.4-15 |
| Pilot | x | | | | | | 3.4-15 |
| Pilot operated device | x | | | | | | 3.4-15 |
| Pilot-operated pressure relief valve | x | x | | | | | 3.4-16 |
| Pilot operated safety valve | | | x | x | | | 3.4-16 |
| Pin-actuated device | | x | | | | | 3.4-16 |
| Piston | x | | | | | | 3.4-16 |
| Popping pressure | x | | | | | | 3.4-16 |
| Power-actuated PRV | x | | | | | | 3.4-16 |
| Pressure-containing member | x | | | | | | 3.4-16 |
| Pressure relief device | x | x | | | | | 3.4-17 |
| Pressure relief valve (PRV) | x | x | | | | | 3.4-17 |
| Pressure-retaining member | x | | | | | | 3.4-17 |
| Primary pressure | x | | | | | | 3.4-17 |
| Proportional safety valves | | | | | | x | 3.4-17 |
| Rated coefficient of discharge | | x | | | | | 3.4-17 |
| Rated lift | x | | | | | | 3.4-17 |
| Rated relieving capacity | x | x | | | | | 3.4-18 |
| Reduced bore device | x | | | | | | 3.4-18 |
| Reduced bore PRV | x | | | | | | 3.4-18 |
| Redundancy | | | | | x | | 3.4-18 |
| Reference conditions | x | | | | | | 3.4-18 |
| Relief valve | x | x | | | | | 3.4-18 |
| Relieving conditions | x | x | | | | | 3.4-18 |
| Relieving pressure | x | | x | x | | | 3.4-19 |
| Resealing pressure | x | | | | | | 3.4-19 |
| Reseating pressure | x | | x | | | | 3.4-19 |
| Reseating pressure (of a pilot operated safety valve) | | | | x | | | 3.4-19 |
| Rupture disk | x | x | | | | | 3.4-19 |
| Rupture disk device | x | x | | | | | 3.4-19 |
| Rupture disk holder | x | x | | | | | 3.4-20 |
| Safety | | | | | x | | 3.4-20 |
| Safety device | | | | | x | | 3.4-20 |
| Safety relief valve | x | x | | | | | 3.4-20 |
| Safety system | | | | | x | | 3.4-20 |
| Safety valve | x | x | x | | | | 3.4-20 |
| Seal-off pressure | x | | | | | | 3.4-20 |
| Seat | x | | | | | | 3.4-21 |
| Seat angle | x | | | | | | 3.4-21 |

| Term | Specified in | | | | | | See page |
|---|---|---|---|---|---|---|---|
| | ASME PTC 25 | API 520 | ISO 4126 Part | | | AD 2000-A2 | |
| | | | 1 | 4 | 9 | | |
| Seat area | x | | | | | | 3.4-21 |
| Seat diameter | x | | | | | | 3.4-21 |
| Seat flow area | x | | | | | | 3.4-21 |
| Secondary pressure | x | | | | | | 3.4-21 |
| Set pressure | x | x | x | x | | | 3.4-21 |
| Shear pin | x | | | | | | 3.4-22 |
| Shear pin device | x | | | | | | 3.4-22 |
| Simmer | x | x | | | | | 3.4-22 |
| Specified burst pressure (of a rupture disk device) | x | x | | | | | 3.4-22 |
| Specified disk temperature | | x | | | | | 3.4-22 |
| Spindle | x | | | | | | 3.4-22 |
| Spring | x | | | | | | 3.4-22 |
| Spring button | x | | | | | | 3.4-22 |
| Spring step | x | | | | | | 3.4-23 |
| Spring washer | x | | | | | | 3.4-23 |
| Standard Safety Valve | | | | | | x | 3.4-23 |
| Start-to-discharge pressure | x | | | | | | 3.4-23 |
| Start-to-leak pressure | x | | | | | | 3.4-23 |
| Static blowdown | x | | | | | | 3.4-23 |
| Stem | x | | | | | | 3.4-23 |
| Superimposed backpressure | x | x | x | x | | | 3.4-23 |
| Supplementary loaded safety valve | | | x | | | | 3.4-24 |
| Temperature and PRV | x | | | | | | 3.4-24 |
| Test pressure | x | | | | | | 3.4-24 |
| Theoretical discharge capacity | | | x | x | | | 3.4-24 |
| Throat area | x | | | | | | 3.4-24 |
| Throat diameter | x | | | | | | 3.4-24 |
| Vacuum support | x | | | | | | 3.4-24 |
| Vapor-tight pressure | x | | | | | | 3.4-24 |
| Variable back pressure | x | | | | | | 3.4-24 |
| Warn | x | | | | | | 3.4-24 |
| Yield (melt) temperature | x | | | | | | 3.4-25 |
| Yoke | x | | | | | | 3.4-25 |

*Table 3.3-1: List of terms*

## 3.4 Description Terms and Definitions

### Accumulated pressure

*ISO 4126-9, 2008, 3.17*
Pressure in the equipment to be protected which can exceed maximum allowable pressure for a short duration during the operation of safety devices.

### Accumulation

*API 520, 2008, Part I, 3.1*
The pressure increase over the maximum allowable working pressure of the vessel, expressed in pressure units or as a percentage of maximum allowable working pressure (MAWP) or design pressure. Maximum allowable accumulations are established by applicable codes for emergency operating and fire contingencies.

### Actual discharge area

*ASME PTC 25, 2001, 2.5 PRV*
The measured minimum net area which determines the flow through a valve. The symbol is $a_d$.

*API 520, 2008, Part I, 3.2*
Actual orifice area
The area of a pressure relief valve (PRV) is the minimum net area that determines the flow through a valve.

### Adjusting ring

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A ring assembled to the nozzle or 'guide of a direct spring valve, used to control the opening characteristics and/or the reseat pressure.

### Adjustment screw

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A screw used to adjust the set pressure or the reseat pressure of a reclosing pressure relief device.

### Assisted safety valve

*ISO 4126-1, 2004, 3.1.1.2*
Safety valve which, by means of a powered assistance mechanism, may additionally be lifted at a pressure lower than the set pressure and will, even in the event of failure of the assistance mechanism, comply with all the requirements for safety valves given in this standard.

### Back pressure

*ASME PTC 25, 2001, 2.7 OC of PRD*
The static pressure existing at the outlet of a pressure relief device due to pressure in the discharge system.

*API 520, 2008, Part I, 3.3*
The pressure that exists at the outlet of a pressure relief device as a result of the pressure in the discharge system. Backpressure is the sum of the superimposed and built-up backpressures. The symbol is $P_2$ or $P_b$.

### Backflow preventer

*ASME PTC 25, 2001, 2.4, Parts of PRD*
A part or feature of a pilot operated pressure relief valve used to prevent the valve from opening and flowing backwards when the pressure at the valve outlet is greater than the pressure at the valve inlet.

**Balanced bellows**

*ISO 4126-1, 2004, 3.2.9*
Bellows device which minimizes the effect of superimposed back pressure on the set pressure of a safety valve.

**Balanced direct spring loaded PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A direct spring-loaded pressure relief valve which incorporates means of minimizing the effect of back pressure on the operational characteristics (opening pressure, closing pressure, and relieving pressure).

**Balanced pressure relief valve**

*API 520, 2008, Part I, 3.4*
A spring loaded pressure relief valve that incorporates a bellows or other means for minimizing the effect of backpressure on the operational characteristics of the valve.

**Bellows**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A flexible pressure-containing component of a balance direct spring valve used to prevent changes in set pressure when the valve is subjected to a superimposed back pressure, or to prevent corrosion between the disk holder and guide.

**Bench testing**

*ASME PTC 25, 2001, 2.2. General*
Testing of a pressure relief device on a test stand sing an external pressure source with or without an auxiliary lift device to determine some or all of its operation characteristics.

**Blowdown**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The difference between actual popping pressure of a pressure relief valve and actual reseating pressure expressed as a percentage of set pressure or in pressure units.

*API 520, 2008, Part I, 3.5*
The difference between the set pressure and the closing pressure of a pressure relief valve, expressed as a percentage of the set pressure or in pressure units.

*ISO 4126-1, 2004, 3.2.10*
Difference between set and reseating pressures, normally stated as a percentage of set pressure except for pressures of less than 3 bar when the blowdown is expressed in bar.

**Blowdown (of a pilot operated safety valve)**

*ISO 4126-4, 2004, 3.4.10*
Difference between set and reseating pressures, normally stated as a percentage of set pressure except for pressures of less than 3 bar when the blowdown is expressed in bar.

**Blowdown pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of decreasing inlet static pressure at which no further discharge is detected at the outlet of a pressure relief valve after the valve has been subjected to a pressure equal to or above the popping pressure.

### Blowdown ring

*ASME PTC 25, 2001, 2.4 Parts of PRD*
See adjusting ring.

### Body

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A pressure-retaining or containing member of a pressure relief device that supports the parts of the valve assembly and has provision(s) for connecting to the primary and/or secondary pressure source(s).

### Bonnet

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component of a direct spring valve or of a pilot in a pilot-operated valve that supports the spring. It may or may not be pressure containing.

### Bore area

*ASME PTC 25, 2001, 2.5 PRV*
The minimum cross- sectional flow area of a nozzle. See Fig. 1.

*API 520, 2008, Part I, 3.6*
Nozzle area
Nozzle throat area
Throat area
The minimum cross-sectional flow area of a nozzle in a pressure relief valve.

### Bore diameter

*ASME PTC 25, 2001, 2.5 PRV*
The minimum diameter of a nozzle. The symbol is $d_b$.

### Breaking pin

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The load-carrying element of a breaking pin non-reclosing pressure relief device.

### Breaking pin device

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device actuated by static differential or static inlet pressure and designed to function by the breakage of a load-carrying section of a pin which supports a pressure-containing member.

*API 520, 2008, Part I, 4.4.3.1*
A breaking pin device is a non-reclosing pressure relief device with a movable disc held in the closed position by a pin loaded in tension. When pressure reaches the set pressure of the device, the pin breaks and the disc opens. Breaking pin devices are generally used in combination with a PRV where valve tightness is of concern, for example, in corrosive or vibrating environments such as on fluid transport vessels.

### Breaking pin housing

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A pressure-retaining component that supports the breaking pin in a non-reclosing pressure relief device.

**Breaking pressure**
*ASME PTC 25, 2001, 2.4 Parts of PRD*
The value of inlet static pressure at which a breaking pin or shear pin device functions.

**Buckling pin**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The load-carrying element of a buckling device.

**Buckling pin device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device actuated by static differential or static inlet pressure and designed to function by the breakage of a load-carrying section of a pin which supports a pressure-containing member.

*API 520, 2008, Part I, 4.4.2.1*
Buckling pin devices, as shown in Figure 29, are compression-loaded, pin-actuated devices and are the most extensively used type of pin-actuated device. Compression-loaded buckling pin devices are very stable and well suited to applications that have both cyclic operating conditions, and an operating pressure to set pressure ratio greater than or equal to 90%.[...]

**Built-up backpressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
Pressure existing at the outlet of a pressure relief device caused by the flow through that particular device into a discharge system.

*API 520, 2008, Part I, 3.7*
The increase in pressure at the outlet of a pressure relief device that develops as a result of flow after the pressure relief device opens.

*ISO 4126-1, 2004, 3.2.7*
Pressure existing at the outlet of a safety valve caused by flow through the valve and the discharge system. The symbol is $p_b$.

*ISO 4126-4, 2004, 3.4.8*
Pressure existing at the outlet of the main valve caused by flow through the main valve and the discharge system. The symbol is $p_b$.

**Burst pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of inlet static pressure at which a rupture disk device functions.

*API 520, 2008, Part I, 3.8*
The value of the upstream static pressure minus the value of the downstream static pressure just prior to when the disk bursts. When the downstream pressure is atmospheric, the burst pressure is the upstream static gauge pressure.

**Bursting disk device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
See rupture disk device.

**Burst-pressure tolerance**

*API 520, 2008, Part I, 3.9*
The variation around the marked burst pressure at the specified disk temperature in which a rupture disk shall burst.

**Cap**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component used to restrict access and/or protect the adjustment screw in a reclosing pressure relief device. It may or may not be a pressure-containing part.

**Certified (discharge) capacity**

*ISO 4126-1, 2004, 3.6.3*
That portion of the measured capacity permitted to be used as a basis for the application of a safety valve. NOTE: It may, for example, equal the:
a) measured capacity times the derating factor; or
b) theoretical capacity times the coefficient of discharge times the derating factor; or
c) theoretical capacity times the certified derated coefficient of discharge.

*ISO 4126-4, 2004, 3.7.3*
That portion of the measured capacity permitted to be used as a basis for the application of a pilot operated safety valve. NOTE: It may, for example, equal the :
a) measured flow rate times the derating factor; or
b) theoretical flow rate times the coefficient of discharge times the derating factor ; or
c) theoretical flow rate times the certified derated coefficient of discharge.

**Chatter**

*ASME PTC 25, 2001, 2.7 OC of PRD*
Abnormal rapid reciprocating motion of the movable parts of a pressure relief valve in which the disk contacts the seat.

**Closing pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of decreasing inlet static pressure at which the valve disk reestablishes contact with the seat or at which lift becomes zero.

*API 520, 2008, Part I, 3.11*
The value of decreasing inlet static pressure at which the valve disc reestablishes contact with the seat or at which lift becomes zero as determined by seeing, feeling or hearing.

**Coefficient of discharge**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The ratio of the measured relieving capacity to the theoretical relieving capacity.

*API 520, 2008, Part I, 3.12*
The ratio of the mass flow rate in a valve to that of an ideal nozzle. The coefficient of discharge is used for calculating flow through a pressure relief device.

*ISO 4126-1, 2004, 3.6.2*
Value of actual flowing capacity (from tests) divided by the theoretical flowing capacity (from calculation). The symbol is $K_{d.}$

*ISO 4126-4, 2004, 3.7.2*
Value of actual flowing capacity (from tests) divided by the theoretical flowing capacity (from calculation). The symbol is $K_{d.}$

**Cold differential test pressure**
*ASME PTC 25, 2001, 2.7 OC of PRD*
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.

*API 520, 2008, Part I, 3.13*
The pressure at which a pressure relief valve is adjusted to open on the test stand. The cold differential test pressure includes corrections for the service conditions of backpressure or temperature or both.

*ISO 4126-1, 2004, 3.2.5*
The inlet static pressure at which a safety valve is set to commence to open on the test bench. NOTE: This test pressure includes corrections for service conditions, e.g. back pressure and/or temperature.

*ISO 4126-4, 2004, 3.4.6*
Inlet static pressure at which a pilot operated safety valve is set to commence to open on the test bench. NOTE: This test pressure includes corrections for service conditions, e.g. back pressure and/or temperature.

**Constant back pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
A superimposed back pressure which is constant with time.

**Controlled safety valves**

*AD 2000-A2, 2001, 3.2.2*
Controlled safety valves consist of the main valve and a control device. They also include direct-acting safety valves with supplementary loading in which, until the response pressure is reached, an additional force increases the closing force. […]

**Conventional direct spring loaded PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A direct spring-loaded pressure relief valve whose operational characteristics are directly affected by changes in the back pressure.

**Conventional Pressure Relief Valve**

*API 520, 2008, Part I, 3.14*
A spring-loaded pressure relief valve whose operational characteristics are directly affected by changes in the backpressure.

**Cracking pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See opening pressure.

**Curtain area**

*ASME PTC 25, 2001, 2.5 PRV*
The area of the cylindrical or conical discharge opening between the seating surfaces created by the lift of the disk above the seat. See Fig.1.

*API 520, 2008, Part I, 3.15*
The area of the cylindrical or conical discharge opening between the seating surfaces above the nozzle seat created by the lift of the disc.

**Design features**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
Non-reclosing pressure relief devices may include one or more of the following design features.

**Design pressure**

*API 520, 2008, Part I, 3.16*
Pressure, together with the design temperature, used to determine the minimum permissible thickness or physical characteristic of each vessel component as determined by the vessel design rules. The design pressure is selected by the user to provide a suitable margin above the most severe pressure expected during normal operation at a coincident temperature. It is the pressure specified on the purchase order. This pressure may be used in place of the maximum allowable working pressure (MAWP) in all cases where the MAWP has not been established. The design pressure is equal to or less than the MAWP.

**Developed lift**

*ASME PTC 25, 2001, 2.5 PRV*
The actual travel of the disk from closed position reached when the valve is at flow- rating pressure.

**Diaphragm**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A flexible metallic, plastic, or elastomer pressure-containing member of a reclosing pressure relief device used to sense pressure or to provide opening or closing force.

**Direct loaded safety valve**

*ISO 4126-1, 2004, 3.1.1.1*
Safety valve in which the loading due to the fluid pressure underneath the valve disc is opposed only by a direct mechanical loading device such as a weight, lever and weight, or a spring.

**Direct spring-loaded device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device actuated by static differential pressure or static inlet pressure n which the disk is held closed by a spring. Upon actuation, the disk is held open by a latching mechanism.

**Direct spring-loaded PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve in which the disk is held closed by a spring.

**Direct-acting safety valves**

*AD 2000-A2, 2001, 3.2.1*
Direct-acting safety valves are safety valves in which a direct mechanical loading (a weight, a weight and lever or a spring) acts as a closing force against the opening force acting an the underside of the valve disc.

**Discharge area**

*ASME PTC 25, 2001, 2.5 PRV*
See actual discharge area.

**Disk**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A moveable component of a pressure relief device that contains the primary pressure when it rests against the nozzle.

**Disk holder**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A moveable component in a pressure relief device that contains the disk.

**Dome**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The volume on the side of the unbalanced moving member opposite the nozzle in the main relieving valve of a pilot- operated pressure relief device.

**Dynamic blowdown**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The difference between the set pressure and closing pressure of a pressure relief valve when it is overpressured to the flow- rating pressure.

**Effective coefficient of discharge**

*API 520, 2008, Part I, 3.17*
A nominal value used with an effective discharge area to calculate the relieving capacity of a pressure relief valve per the preliminary sizing equations. The symbol is $K_d$.

**Effective discharge area**

*ASME PTC 25, 2001, 2.5 PRV*
A nominal or computed area of flow through a pressure relief valve, differing from the actual discharge area, for use in recognized flow formulas to determine the capacity of a pressure relief valve.

*API 520, 2008, Part I, 3.18*
A nominal area used with an effective discharge coefficient to calculate the relieving capacity of a pressure relief valve per the preliminary sizing equations. API 526 provides effective discharge areas for a range of sizes in terms of letter designations, “D” through “T”. The symbol is *A*.

**Fail-safe**

*ISO 4126-9, 2008, 3.4*
Status such that the pressure equipment remains in a safe condition in case of failure of any safety system component or energy source.

**Field test**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A device for in-service or bench testing of a pilot-operated pressure relief device to measure the set pressure.

**Flow area**

*ISO 4126-1, 2004, 3.4*
Minimum cross-sectional flow area (but not the curtain area) between inlet and seat which is used to calculate the theoretical flow capacity, with no deduction for any obstruction. NOTE: The symbol is *A*.

*ISO 4126-4, 2004, 3.5*
Minimum cross-sectional flow area (but not the curtain area) between inlet and seat which is used to calculate the theoretical flowing capacity of the main valve, with no deduction for any obstruction. NOTE: The symbol is *A*.

**Flow capacity**
*ASME PTC 25, 2001, 2.7 OC of PRD*
See measured relieving capacity.

**Flow capacity testing**

*ASME PTC 25, 2001, 2.2., General*
Testing of a pressure relief device to determine its operations characteristics including measured relieving capacity.

**Flow diameter**

*ISO 4126-1, 2004, 3.5*
Diameter corresponding to the flow area.

*ISO 4126-4, 2004, 3.6*
Diameter corresponding to the flow area.

**Flowing pilot**

*ISO 4126-4, 2004, 3.1.1.1*
Pilot which discharges the fluid throughout the relieving cycle of the pilot operated safety valve.

**Flow-rating pressure**

*ASME PTC 25, 2001, 2.7, OC of PRD*
The inlet stagnation pressure at which the relieving capacity of a pressure relief device is measured.

**Flow resistance**

*ASME PTC 25, 2001, 2.7, OC of PRD*
A dimensionless term (such as used in para.5.5.7) which expresses the number of velocity heads lost due to flow through a rupture disk device (where velocity head is one-half the velocity squared divided by the acceleration of gravity.

**Flutter**

*ASME PTC 25, 2001, 2.7, OC of PRD*
Abnormal, rapid reciprocating motion of the movable parts of a pressure relief valve in which the disk does not contact the seat.

**Frangible disk device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
See rupture disk device.

**Full bore device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device in which the flow path area below the seat is equal to the flow path area of the inlet to the device.

**Full bore PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve in which the bore area is equal to the flow area at the inlet to the valve and there are no protrusion in the bore.

**Full lift device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device in which the actual discharge area is independent of the lift of the disk.

**Full lift PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve in which the actual discharge area is the bore area.

**Full Lift Safety Valve**

*AD 2000-A2, 2001, 3.1.2*
Full lift safety valves, following response within the 5% pressure rise, open suddenly up to the full lift as limited by the design. The amount of lift up to the sudden opening (proportional range) shall not be more than 20% of the total lift.

**Fusible plug**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device designed to function by the yielding or melting of a plug, at a predetermined temperature, which supports a pressure-containing member or contains pressure by itself.

**Gag**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A device used on reclosing pressure relief devices to prevent the device from opening.

**Guide**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component in a direct spring or pilot-operated pressure relief device used to control the lateral movement of the disk or disk holder.

**Huddling chamber**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The annular pressure chamber between the nozzle exit and the disk or disk holder that produces the lifting force to obtain a pop action.

*API 520, 2008, Part I, 3.19*
An annular chamber located downstream of the seat of a pressure relief valve for the purpose of assisting the valve to achieve lift.

**Inlet area**

*ASME PTC 25, 2001, 2.6 DC- NPRD*
The cross-sectional flow area at the inlet opening of a pressure relief device.

**Inlet size**

*ASME PTC 25, 2001, 2.5 PRV*
The nominal pipe size of the inlet of a pressure relief valve, unless otherwise designated.

*API 520, 2008, Part I, 3.20*
The nominal pipe size (NPS) of the device at the inlet connection, unless otherwise designated.

*ASME PTC 25, 2001, 2.6 DC- NPRD*
The nominal pipe size of the inlet of a pressure relief device, unless otherwise designated.

### In-plate testing

*ASME PTC 25, 2001, 2.2., General*
Testing of a pressure relief device installed on and protecting a system, using an external pressure source, with or without an auxiliary lift device to determine some or all of its operating characteristics.

### In-service testing

*ASME PTC 25, 2001, 2.2., General*
Testing of a pressure relief device installed on and protecting a system, using system pressure or an external pressure source, with or without an auxiliary lift device to determine some or all of its operating characteristics.

### Internal spring PRV

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A direct spring-loaded pressure relief valve whose spring and all or part of the operating mechanism is exposed to the system pressure when the valve is in the closed position.

### Knife blade

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component with multiple blades used with reverse-acting rupture disks to cut the disk when it reverses.

### Leak pressure

*ASME PTC 25, 2001, 2.7, OC of PRD*
See start-to-leak pressure.

### Leak test pressure

*ASME PTC 25, 2001, 2.7, OC of PRD*
The specified inlet static pressure at which a quantitative seat leakage test is performed in accordance with a standard procedure.

*API 520, 2008, Part I, 3.21*
The specified inlet static pressure at which a seat leak test is performed.

### Lift

*ASME PTC 25, 2001, 2.5 PRV*
The actual travel of the disk away from closed position when a valve is relieving.

*API 520, 2008, Part I, 3.22*
The actual travel of the disc from the closed position when a valve is relieving.

*ISO 4126-1, 2004, 3.4*
Actual travel of the valve disc away from the closed position.

*ISO 4126-4, 2004, 3.4*
Actual travel of the main valve disc away from the closed position.

### Lift lever

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A device to apply an external force to the steam of a pressure relief valve to manually operate the valve at some pressure below the set pressure.

**Lot of rupture disks**

*ASME PTC 25, 2001, 2.7, OC of PRD*
Those disks manufactured of a material at the same time, and of the same size, thickness, type, heat, and manufacturing process, including heat treatment.

*API 520, 2008, Part I, 3.23*
Disks manufactured at the same time and of the same size, material, thickness, type, heat and manufacturing process, including heat treatment.

**Low lift device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device in which the actual discharge area is dependent on the lift of the disk.

**Low lift PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve in which the actual discharge area is the curtain area.

**Main relieving valve**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
That part of a pilot-operated pressure relief device through which the rated flow occurs during relief.

**Manufacturing design range**

*API 520, 2008, Part I, 3.24*
The pressure range in which the rupture disk shall be marked. Manufacturing design ranges are usually catalogued by the manufacturer as a percentage of the specified burst pressure. Catalogued manufacturing design ranges may be modified by agreement between the user and the manufacturer.

**Marked breaking pressure**

*ASME PTC 25, 2001, 2.7, OC of PRD*
The value of pressure marked on a breaking pin or a shear pin device or its nameplate.

**Marked burst pressure**

*ASME PTC 25, 2001, 2.7, OC of PRD*
The value of pressure marked on the rupture disk device or it's nameplate or on the tag of the rupture disk, indicating the burst pressure at the coincident disk temperature.

*API 520, 2008, Part I, 3.25*
Rated burst pressure
The burst pressure established by tests for the specified temperature and marked on the disk tag by the manufacturer. The marked burst pressure may be any pressure within the manufacturing design range unless otherwise specified by the customer. The marked burst pressure is applied to all of the rupture disks of the same lot.

**Marked relieving capacity**

*ASME PTC 25, 2001, 2.7, OC of PRD*
See rated relieving capacity.

**Marked set pressure**

*ASME PTC 25, 2001, 2.7, OC of PRD*
The value or values of pressure marked on a pressure relief device.

**Maximum allowable pressure, PS**

*ISO 4126-1, 2004, 3.2.2*
The maximum pressure for which the equipment is designed as specified by the manufacturer.

*ISO 4126-4, 2004, 3.4.2*
Maximum pressure for which the equipment is designed as specified by the manufacturer.

*ISO 4126-9, 2008, 3.15*
Maximum pressure for which the equipment is designed as specified by the manufacturer.

**Maximum allowable accumulated pressure, PSaccum**

*ISO 4126-9, 2008, 3.18*
Maximum allowable value of the accumulated pressure in the equipment being protected which is fixed by national codes, regulations or directives.

**Maximum allowable working pressure (MAWP)**

*API 520, 2008, Part I, 3.26*
The maximum gauge pressure permissible at the top of a completed vessel in its normal operating position at the designated coincident temperature specified for that pressure.[…]

**Maximum/minimum allowable temperature, TS**

*ISO 4126-9, 2008, 3.16*
Maximum/minimum temperatures for which the equipment is designed, as specified by the manufacturer.

**Maximum operating pressure**

*API 520, 2008, Part I, 3.27*
The maximum pressure expected during normal system operation.

**Measured relieving capacity**

*ASME PTC 25, 2001, 2.7, OC of PRD*
The relieving capacity of a pressure relief device measured at the flow-rating pressure, expressed in gravimetric or volumetric units.

**Modulating**

*ISO 4126-4, 2004, 3.1.2.2*
Action characterised by a gradual opening and closing of the disc of the main valve which is a function of the pressure, proportional but not necessarily linear.

**Net flow area**

*ASME PTC 25, 2001, 2.6 DC- NPRD*
The area which determines the flow after a non-reclosing pressure relief device has operated. The (minimum) net flow area of a rupture disk is the calculated net area after a complete burst of the disk, with appropriate allowance for any structural members which may reduce the net flow area through the rupture disk device.

*API 520, 2008, Part I, 3.28*
Minimum net flow area: The calculated net area after a complete burst of a rupture disc with appropriate allowance for any structural members which may reduce the net flow area through the rupture disk device.

**Non-flowing pilot**

*ISO 4126-4, 2004, 3.1.1.2*
Pilot in which the fluid flows only during the opening and/or closing of the pilot operated safety valve.

**Non-fragmenting rupture disk**

*API 520, 2008, Part I, 3.29*
A rupture disk designed and manufactured to be installed upstream of other piping components. Non-fragmenting rupture disks do not impair the function of pressure relief valves when the disk ruptures.

**Non-reclosing pressure relief device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A pressure relief device designed to actuate and remain open after operation. A manual resetting may be provided. Design types:

*API 520, 2008, Part I, 3.30*
A pressure relief device which remains open after operation. A manual resetting means may be provided.

**Nozzle**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A primary pressure-containing component in a pressure relief valve that forms a part or all of the inlet flow passage.

**Nozzle area, nozzle throat area**

*ASME PTC 25, 2001, 2.5 PRV*
See bore area.

**Nozzle diameter**

*ASME PTC 25, 2001, 2.5 PRV*
See bore diameter.

**ON/OFF**

*ISO 4126-4, 2004, 3.1.2.1*
Action characterized by stable operation resulting in fully open or fully closed main valve position.

**Opening pressure**

*ASME PTC 25, 2001, 2.7, OC of PRD*
The value of increasing inlet static pressure of a pressure relief valve at which there is a measurable lift, or at which the discharge becomes continuous as determined by seeing, feeling, or hearing.

*API 520, 2008, Part I, 3.31*
The value of increasing inlet static pressure at which there is a measurable lift of the disc or at which discharge of the fluid becomes continuous, as determined by seeing, feeling or hearing.

**Opening sensing pressure**

*ISO 4126-4, 2004, 3.4.3*
Pressure at which the pilot commences to open in order to achieve the set pressure.

**Operating ratio of a pressure relief valve**

*API 520, 2008, Part I, 3.32*
The ratio of maximum system operating pressure to the set pressure.

### Operating ratio of a rupture disk

*API 520, 2008, Part I, 3.33*
The ratio of the maximum system operating pressure to a pressure associated with a rupture disk (see Figure 26 and 28). For marked burst pressures above 40 psi, the operating ratio is the ratio of maximum system operating pressure to the disk marked burst pressure. For marked burst pressures between 15 psi and 40 psi, the operating ratio is the ratio of maximum system operating pressure to the marked burst pressure minus 2 psi. For marked burst pressures less than 15 psi, the operating ratio should be determined by consulting the manufacturer.

### Orifice area

*ASME PTC 25, 2001, 2.5 PRV*
See effective discharge area.

### Outlet size

*ASME PTC 25, 2001, 2.5 PRV*
The nominal pipe size of the outlet of a pressure relief valve, unless otherwise designated.

*ASME PTC 25, 2001, 2.6 DC- NPRD*
The nominal pipe size of the outlet passage from a pressure relief device, unless otherwise designated.

*API 520, 2008, Part I, 3.34*
The nominal pipe size (NPS) of the device at the discharge connection, unless otherwise designated.

### Overpressure

*ASME PTC 25, 2001, 2.7 OC of PRD*
A pressure increase over the set pressure of a pressure relief valve, usually expressed as a percentage of set pressure.

*API 520, 2008, Part I, 3.35*
The pressure increase over the set pressure of the relieving device. Overpressure is expressed in pressure units or as a percentage of set pressure. Overpressure is the same as accumulation only when the relieving device is set to open at the maximum allowable working pressure of the vessel.

*ISO 4126-1, 2004, 3.2.3*
Pressure increase over the set pressure, at which the safety valve attains the lift specified by the manufacturer, usually expressed as a percentage of the set pressure. NOTE: This is the overpressure used to certify the safety valve.

### Overpressure (of a pilot operated safety valve)

*ISO 4126-4, 2004, 3.4.4*
Pressure increase over the set pressure, at which the main valve attains the lift specified by the manufacturer, usually expressed as a percentage of the set pressure. NOTE: This is the overpressure used to certify the pilot operated safety valve.

### Pilot
*ASME PTC 25, 2001, 2.4 Parts of PRD*
The pressure- or vacuum-sensing component of a pilot-operated pressure relief valve that controls the opening and closing of the main relieving valve.

### Pilot operated device

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device in which the disk is held closed by system pressure and the holding pressure is controlled by a pilot actuated by system pressure. The pilot may consist of one of the devices listed above.

### Pilot-operated pressure relief valve

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve in which the disk is held closed by system pressure and the holding pressure is controlled by a pilot valve actuated by system pressure.

*API 520, 2008, Part I, 3.36*
A pressure relief valve in which the major relieving device or main valve is combined with and controlled by a self actuated auxiliary pressure relief valve (pilot).

### Pilot operated safety valve

*ISO 4126-1, 2004, 3.1.1.4*
Safety valve, the operation of which is initiated and controlled by the fluid discharged from a pilot valve which is itself a direct loaded safety valve subject to the requirement of this standard. NOTE: Other types of pilot operated safety valves with flowing, non-flowing and modulating pilots are in Part 4 of this standard.

*ISO 4126-4, 2004, 3.1*
Self actuated device comprising a valve and an attached pilot. Note: The pilot responds to the pressure of the fluid without any other energy than the fluid itself and controls the operation of the valve. The valve opens when the fluid pressure that keeps it closed is removed or reduced. The valve re-closes when the pressure is re-applied.

### Pin-actuated device

*API 520, 2008, Part I, 3.37*
A non-reclosing pressure relief device actuated by static pressure and designed to function by buckling or breaking a pin which holds a piston or a plug in place. Upon buckling or breaking of the pin, the piston or plug instantly moves to the full open position.

### Piston

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The moving element in the main relieving valve of a pilot-operated piston-type pressure relief valve which contains the seat that forms the primary pressure containment zone when in contact with the nozzle.

### Popping pressure

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of increasing inlet static pressure at which the disk moves in the opening direction at a faster rate as compared with corresponding movement at higher or lower pressures.

### Power-actuated PRV

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve actuated by an externally powered control device.

### Pressure-containing member

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component which is exposed to and contains pressure.

**Pressure relief device**

*ASME PTC 25, 2001, 2.2. General*
A device designed to prevent pressure or vacuum from exceeding a predetermined value in a pressure vessel by the transfer of fluid during emergency or abnormal conditions.

*API 520, 2008, Part I, 3.38*
PRD
A device actuated by inlet static pressure and designed to open during emergency or abnormal conditions to prevent a rise of internal fluid pressure in excess of a specified design value. The device also may be designed to prevent excessive internal vacuum. The device may be a pressure relief valve, a non-reclosing pressure relief device or a vacuum relief valve.

**Pressure relief valve (PRV)**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief device designed to actuate on inlet static pressure and to reclose after normal conditions have been restored.

*API 520, 2008, Part I, 3.39*
A pressure relief device designed to open and relieve excess pressure and to reclose and prevent the further flow of fluid after normal conditions have been restored.

**Pressure-retaining member**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component which holds one or more pressure-containing members together but is not exposed to the pressure.

**Primary pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The pressure at the inlet in a pressure relief device.

**Proportional safety valves**

*AD 2000-A2, 2001, 3.1.3*
Proportional safety valves open more or less steadily in relation to the increase in pressure . No sudden opening occurs unless the pressure increases beyond the range of more than 10% of the lift . Following response within a pressure increase of up to 10%, these safety valves achieve the lift necessary for the mass flow to be diverted (see 2.3 for exception).

**Rated coefficient of discharge**

*API 520, 2008, Part I, 3.40*
A value used with the actual discharge area to calculate the rated flow capacity of a pressure relief valve. The rated coefficient of discharge of a pressure relief valve is determined in accordance with the applicable code or regulation.

**Rated lift**

*ASME PTC 25, 2001, 2.5 PRV*
The design lift at which a valve attains it's rated relieving capacity.

**Rated relieving capacity**
*ASME PTC 25, 2001, 2.7 OC of PRD*
That portion of the measured relieving capacity permitted by the applicable code or regulation to be used as a basis for the application of a pressure relief device.

*API 520, 2008, Part I, 3.41*
The basis for the application of a pressure relief device. This capacity is determined in accordance with the applicable code or regulation and is provided by the manufacturer.

**Reduced bore device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device in which the flow path area below the seat is less than the flow path area of the inlet to the device.

**Reduced bore PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve in which the flow path area below the seat is less than the flow area at the inlet to the valve.

**Redundancy**

*ISO 4126-9, 2008, 3.5*
Provision of more than one device or system such that the necessary function will still be provided in case of failure of one or more of these devices.

**Reference conditions**

*ASME PTC 25, 2001, 2.7 OC of PRD*
Those conditions of test medium which are specified by either an applicable standard or an agreement between the parties to the test, which may be used for uniform reporting of measured flow test results.

**Relief valve**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve characterized by gradual opening or closing, generally proportional to the increase or decrease in pressure. It is normally used for incompressible fluids.

*API 520, 2008, Part I, 3.42*
A spring-loaded pressure relief valve actuated by the static pressure upstream of the valve. The valve opens normally in proportion to the pressure increase over the opening pressure. A relief valve is used primarily with incompressible fluids.

**Relieving conditions**
*ASME PTC 25, 2001, 2.7 OC of PRD*
The inlet pressure and temperature on a pressure relief device during an overpressure condition. The relieving pressure is equal to the valve set pressure or burst (or the rupture disk burst pressure) plus the overpressure (The temperature of the flowing fluid at relieving conditions may be higher or lower than the operating temperature).

*API 520, 2008, Part I, 3.43*
The inlet pressure and temperature on a pressure relief device during an overpressure condition. The relieving pressure is equal to the valve set pressure (or rupture disk burst pressure) plus the overpressure. The temperature of the flowing fluid at relieving conditions may be higher or lower than the operating temperature.

**Relieving pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
Set pressure plus overpressure.

*ISO 4126-1, 2004, 3.2.6*
Pressure used for the sizing of a safety valve which is greater than or equal to the set pressure plus overpressure. The symbol is $p_o$.

*ISO 4126-4, 2004, 3.4.7*
Pressure used for the sizing of a pilot operated safety valve which is greater than or equal to the set pressure plus overpressure. The symbol is $p_o$.

**Resealing pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of decreasing inlet static pressure at which no further leakage is detected after closing. The method of detection may be a specified water seal on the outlet or other means appropriate for this application.

**Reseating pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See closing pressure.

*ISO 4126-1, 2004, 3.2.4*
Value of the inlet static pressure at which the disc re-establishes contact with the seat or at which the lift becomes zero.

**Reseating pressure (of a pilot operated safety valve)**

*ISO 4126-4, 2004, 3.4.5*
Value of the inlet static pressure at which the disc re-establishes contact with the seat or at which the lift becomes zero.

**Rupture disk**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The pressure-containing element in a rupture disk device that is designed to burst at its rated pressure at a specified temperature.

*API 520, 2008, Part I, 3.44*
A pressure containing, pressure and temperature sensitive element of a rupture disk device.

**Rupture disk device**
*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device that contains a disk which ruptures when the static differential pressure between the upstream and downstream side of the disk reaches a predetermined value. A rupture disk device includes a rupture disk and may include rupture disk holder.

*API 520, 2008, Part I, 3.45*
A non-reclosing pressure relief device actuated by static differential pressure between the inlet and outlet of the device and designed to function by the bursting of a rupture disk. A rupture disk device includes a rupture disk and a rupture disk holder.

**Rupture disk holder**
*ASME PTC 25, 2001, 2.4 Parts of PRD*
The structure which clamps a rupture disk in position.

*API 520, 2008, Part I, 3.46*
The structure which encloses and clamps the rupture disk in position. Some disks are designed to be installed between standard flanges without holders.

**Safety**

*ISO 4126-9, 2008, 3.14*
Freedom from unacceptable risk. NOTE: See ISO/IEC Guide 51.

**Safety device**

*ISO 4126-9, 2008, 3.1*
Device that serves as the ultimate protection to ensure that the maximum allowable accumulated pressure is not exceeded. EXAMPLE: Safety valves, bursting disc safety devices, etc.

**Safety relief valve**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve characterized by rapid opening or closing or by gradual opening or closing, generally proportional to the increase or decrease in pressure. It can be used for compressible or incompressible fluids.

*API 520, 2008, Part I, 3.47*
A spring-loaded pressure relief valve that may be used as either a safety or relief valve depending on the application.

**Safety system**

*ISO 4126-9, 2008, 3.2*
System including the safety devices and the interconnections between the equipment to be protected and any discharge connection to the nearest location of a safe disposal place. NOTE: This location can either be an atmospheric outlet or the connection into a safe collecting system or flare.

**Safety valve**
*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve characterized by rapid opening or closing and normally used to relieve compressible fluids.

*API 520, 2008, Part I, 3.48*
A spring-loaded pressure relief valve actuated by the static pressure upstream of the valve and characterized by rapid opening or pop action. A safety valve is normally used with compressible fluids.

*ISO 4126-1, 2004, 3.1*
Valve which automatically, without the assistance of any energy other than that of the fluid concerned, discharges a quantity of the fluid so as to prevent a predetermined safe pressure being exceeded, and which is designed to re-close and prevent further flow of fluid after normal pressure conditions of service have been restored. NOTE: The valve can be characterized either by pop action (rapid opening) or by opening in proportion (not necessarily linear) to the increase in pressure over the set pressure.

**Seal-off pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See resealing pressure.

### Seat

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The pressure-sealing surfaces of the fixed and moving pressure-containing components.

### Seat angle

*ASME PTC 25, 2001, 2.5 PRV*
The angle between the axis of a valve and the seating surface. A flat-seated valve has a seat angle of 90 deg.

### Seat area

*ASME PTC 25, 2001, 2.5 PRV*
The area determined by the seat diameter.

### Seat diameter

*ASME PTC 25, 2001, 2.5 PRV*
The smallest diameter of contact between the fixed and moving portions of the pressure-containing elements of a valve. The symbol is $d_s$.

### Seat flow area

*ASME PTC 25, 2001, 2.5 PRV*
See curtain area.

### Secondary pressure

*ASME PTC 25, 2001, 2.7 OC of PRD*
The pressure existing in the passage between the actual discharge area and the valve outlet in a safety, safety relief, or relief valve.

### Set pressure

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of increasing inlet static pressure at which a pressure relief device displays one of the operational characteristics as defined under opening pressure, popping pressure, start-to-leak pressure, burst pressure, or breaking pressure (The applicable operating characteristic for a specific device design is specified by the device manufacturer).

*API 520, 2008, Part I, 3.49*
The inlet gauge pressure at which the pressure relief device is set to open under service conditions. The symbol is $P$.

*ISO 4126-1, 2004, 3.2.1*
Predetermined pressure at which a safety valve under operating conditions commences to open.
Note: It is the gauge pressure measured at the valve inlet at which the pressure forces tending to open the valve for the specific service conditions are in equilibrium with the forces retaining the valve disc on its seat.

*ISO 4126-4, 2004, 3.4.1*
Predetermined pressure at which the valve of a pilot operated safety valve under operating conditions commences to open. Note: It is the gauge pressure measured at the valve inlet at which the pressure forces tending to open the valve for the specific service conditions are in equilibrium with the forces retaining the valve disc on its seat.

**Shear pin**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The load-carrying element of a shear pin device.

**Shear pin device**

*ASME PTC 25, 2001, 2.3.2 Non-reclosing PRD*
A device actuated by static differential or static inlet pressure and designed to function by the shearing of a load-carrying member which supports a pressure containing-member.

**Simmer**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The audible or visible escape of fluid between the seat and disk at an inlet static pressure below the popping pressure and at no measurable capacity. It applies to safety or safety relief valves on compressible-fluid service.

*API 520, 2008, Part I, 3.50*
The audible or visible escape of compressible fluid between the seat and disc of a pressure relief valve which may occur at an inlet static pressure below the set pressure prior to opening.

**Specified burst pressure (of a rupture disk device)**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of increasing inlet static pressure, at a specified temperature, at which a rupture disk is designed to function.

*API 520, 2008, Part I, 3.51*
The burst pressure specified by the user. The marked burst pressure may be greater than or less than the specified burst pressure but shall be within the manufacturing design range. The user is cautioned to consider manufacturing range, superimposed back pressure and specified temperature when determining a specified burst pressure.

**Specified disk temperature**

*API 520, 2008, Part I, 3.52*
The temperature of the disk when the disk is expected to burst. The specified disk temperature is the temperature the manufacturer uses to establish the marked burst pressure. The specified disk temperature is rarely ever the design temperature of the vessel and may not even be the operating temperature or relief temperature, depending on the relief system configuration.

**Spindle**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A part whose axial orientation is parallel to the travel of the disk. It may be used in one or more of the following functions: assist in alignment, guide disk travel, and transfer of internal or external forces to the seats.

**Spring**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
The element in a pressure relief valve that provides the force to keep the disk on the nozzle.

**Spring button**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
See spring step.

**Spring step**
*ASME PTC 25, 2001, 2.4 Parts of PRD*
A load-transferring component in a pressure relief valve that supports the spring.

**Spring washer**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
See spring step.

**Standard Safety Valve**

*AD 2000-A2, 2001, 3.1.1*
These safety valves reach the degree of lift necessary for the mass flow to be diverted following response within a pressure rise of not more than 10% (see 2.3 for exception). No further requirements are made of the opening characteristics.

**Start-to-discharge pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See opening pressure.

**Start-to-leak pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The value of increasing inlet static pressure at which the first bubble occurs when a pressure relief valve is tested by means of air under a specified water seal on the outlet.

**Static blowdown**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The difference between the set pressure and the closing pressure of a pressure relief valve when it is not overpressured to the flow-rating pressure.

**Stem**
*ASME PTC 25, 2001, 2.4 Parts of PRD*
See spindle.

**Superimposed backpressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The static pressure existing at the outlet of a pressure relief device at the time the device is required to operate. It is the result of pressure in the discharge system from other sources.

*API 520, 2008, Part I, 3.53*
The static pressure that exists at the outlet of a pressure relief device at the time the device is required to operate. Superimposed backpressure is the result of pressure in the discharge system coming from other sources and may be constant or variable.

*ISO 4126-1, 2004, 3.2.8*
Pressure existing at the outlet of a safety valve at the time when the device is required to operate. NOTE: It is the result of pressure in the discharge system from other sources.

*ISO 4126-4, 2004, 3.4.9*
Pressure existing at the outlet of the main valve at the time when the device is required to operate. NOTE: It is the result of pressure in the discharge system from other sources.

**Supplementary loaded safety valve**
*ISO 4126-1, 2004, 3.1.1.3*
Safety valve which has, until the pressure at the inlet to the safety valve reaches the set pressure, an additional force which increases the sealing force. NOTE 1: This additional force (supplementary load), which may be provided by means of an extraneous power source, is reliably released when the pressure at the inlet of the safety valve reaches the set pressure. The amount of supplementary loading is so arranged that if such supplementary loading is not released, the safety valve will attain its certified discharge capacity at a pressure not greater than 1,1 times the maximum allowable pressure of the equipment to be protected. NOTE 2: Other types of supplementary loaded safety devices are dealt with in Part 5 of this standard.

**Temperature and PRV**

*ASME PTC 25, 2001, 2.3.1 Reclosing PRD*
A pressure relief valve that may be actuated by pressure at the valve inlet or by temperature at the valve inlet.

**Test pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See relieving pressure.

**Theoretical discharge capacity**

*ISO 4126-1, 2004, 3.6.1*
Calculated capacity expressed in mass or volumetric units of a theoretically perfect nozzle having a cross-sectional flow area equal to the flow area of a safety valve.

*ISO 4126-4, 2004, 3.7.1*
Calculated capacity expressed in mass or volumetric units of a theoretically perfect nozzle having a cross-sectional flow area equal to the flow area of a main valve.

**Throat area**
*ASME PTC 25, 2001, 2.5 PRV*
See bore area.

**Throat diameter**

*ASME PTC 25, 2001, 2.5 PRV*
See bore diameter.

**Vacuum support**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A component of a rupture disk to prevent flexing due to upstream vacuum or downstream back pressure.

**Vapor-tight pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See resealing pressure.

**Variable back pressure**

*ASME PTC 25, 2001, 2.7 OC of PRD*
A superimposed back pressure that will vary with time.

**Warn**

*ASME PTC 25, 2001, 2.7 OC of PRD*
See simmer.

**Yield (melt) temperature**

*ASME PTC 25, 2001, 2.7 OC of PRD*
The temperature at which the fusible material of a fusible plug device becomes sufficiently soft to extrude from its holder and relieve pressure.

**Yoke**

*ASME PTC 25, 2001, 2.4 Parts of PRD*
A pressure-retaining component in a pressure relief device that supports the spring in a pressure relief valve or pin in a non-reclosing device but does not enclose them from the surrounding ambient environment.

## Contents


## 6.1 Introduction

In complex facilities safety valves are an integral part of the plant safety in regard to overpressure protection. To ensure the safe and reliable function of safety valves, the installation in form of the inlet and outlet line must be considered.
The critical points regarding the installation of safety valves are 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

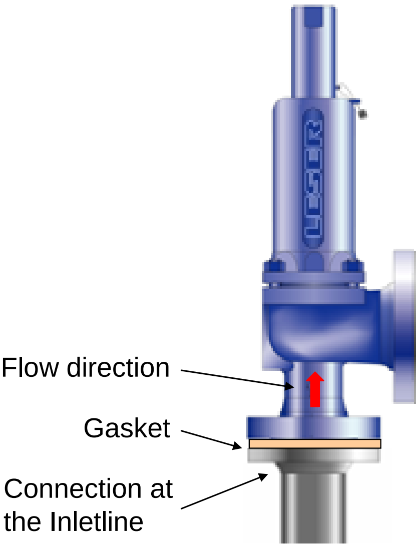



*Figure 6.2.3-1: Flow direction*

### 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)]

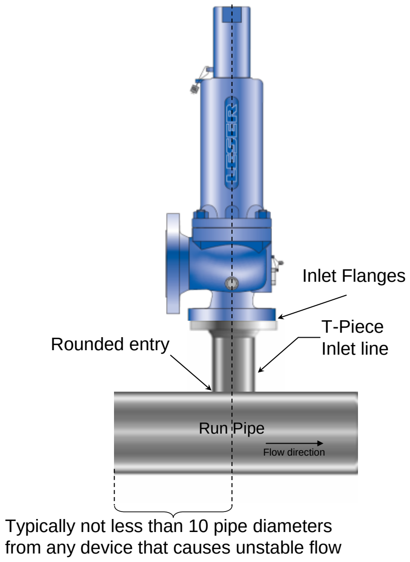



*Figure 6.2.4.2-1: Distance to other valve equipment acc. to API 520 part II*

#### 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]

---

[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)]

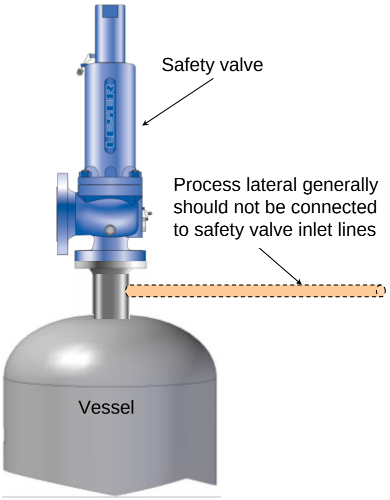



*Figure 6.2.4.4-1: Process lateral acc. to API 520 part II*

### 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.

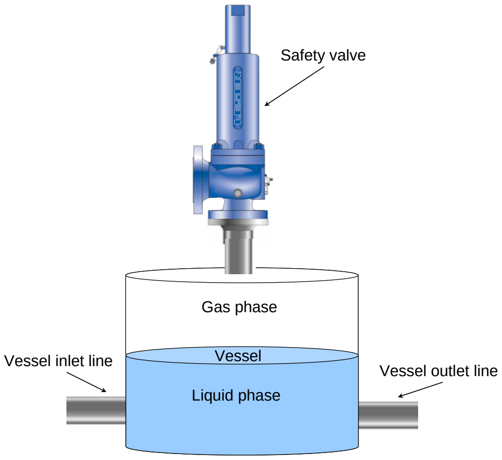



*Figure 6.2.4.5-1: Partly filled vessel*

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.

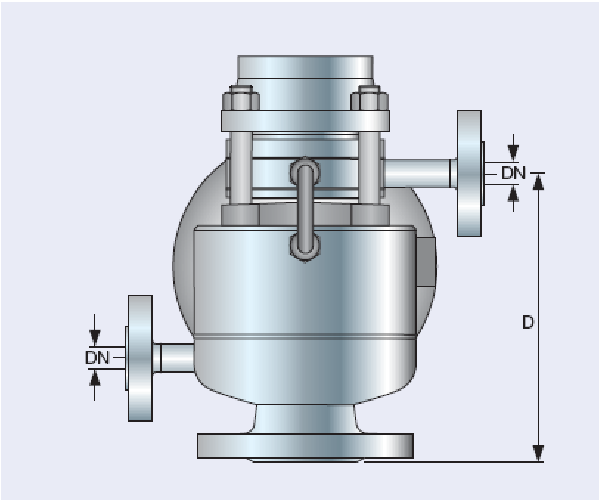



*Figure 6.2.10-1: LESER Safety Valves with heating jacket - balanced bellows design*

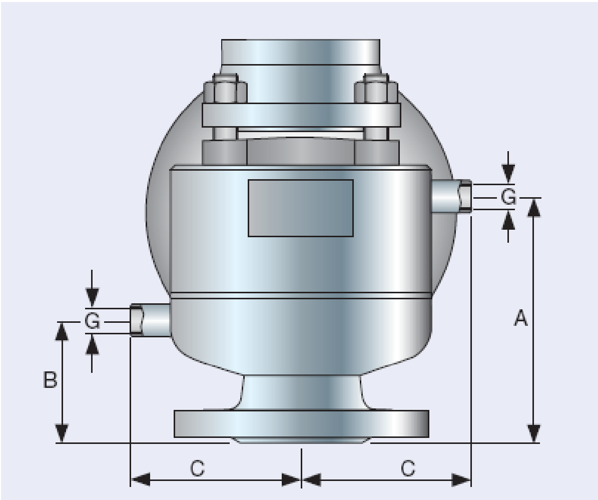



*Figure 6.2.10-2: Leser Safety Valves with heating jacket – conventional design*

### 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, 5$^{th}$ 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:

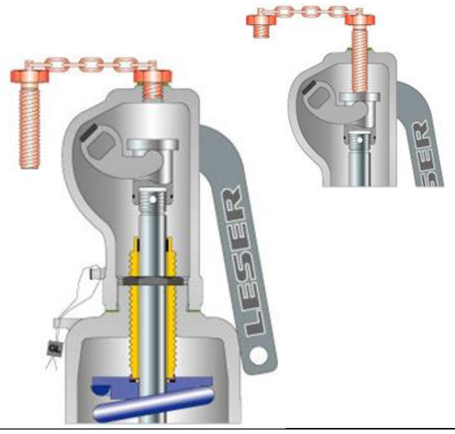
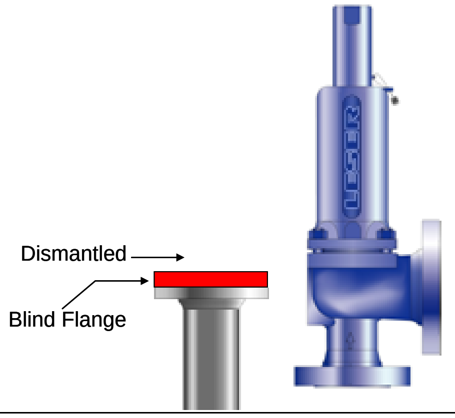
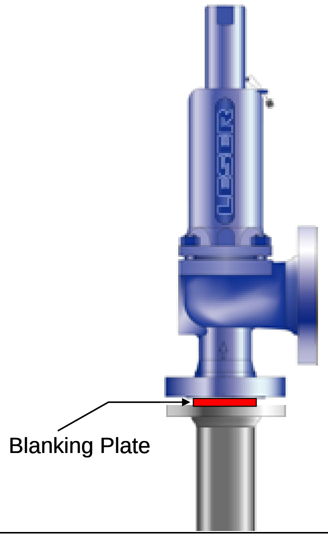
| Possibility | Figure | Description |
|---|---|---|
| Test gag |  | The test gag blocks the spindle and keeps the safety valve tight while the system pressure exceeds the set pressure.<br>Advantage: It is possible to perform pressure tests in a system without dismantling the safety valve.<br>After testing, 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/ 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 LGS 0201)
- ► 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 LDeS 4607.00), 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

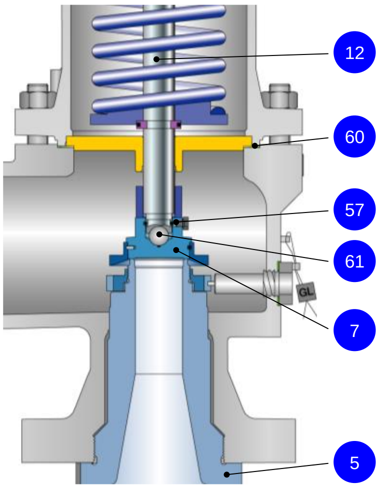



*Figure 6.2.14-1: Spare parts API series 526 - Conventional Design*

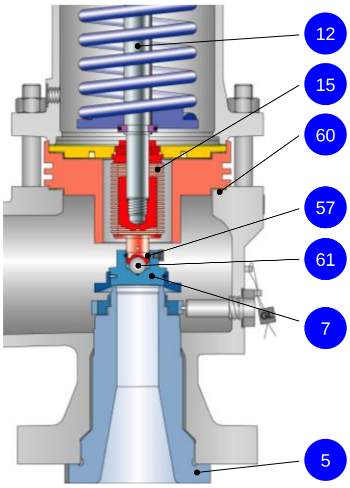



*Figure 6.2.14-2: - Balanced Bellows Design*

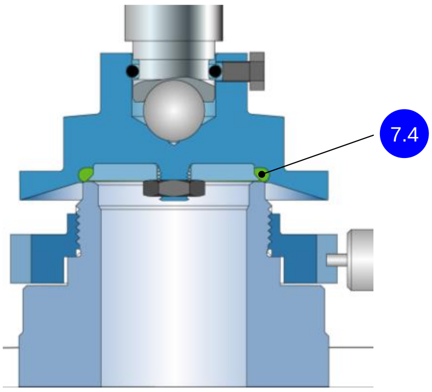



*Figure 6.2.14-3: - O-Ring Disc Design*

### 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

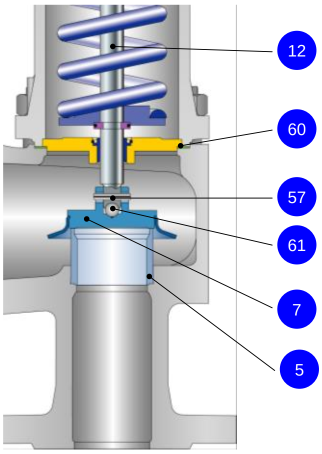



*Figure 6.2.14-4: Spare parts High Performance/ Modulate Action -Conventional Design*

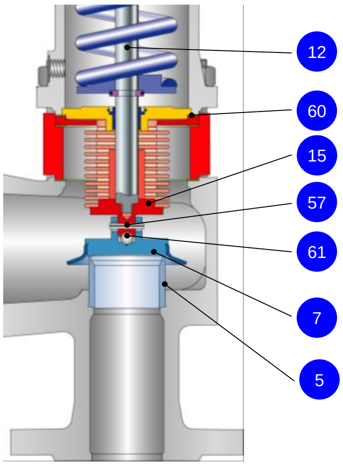



*Figure 6.2.14-5: - Balanced Bellows Design*

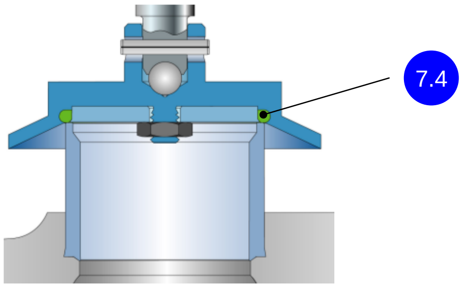



*Figure 6.2.14-6: - O-Ring Disc Design*

### 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

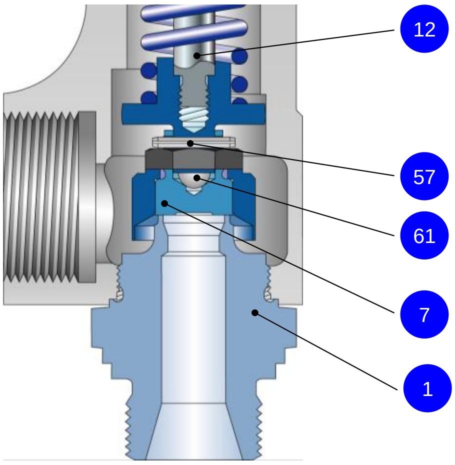



*Figure 6.2.14-7: Spare parts Compact Performance -Conventional Design*

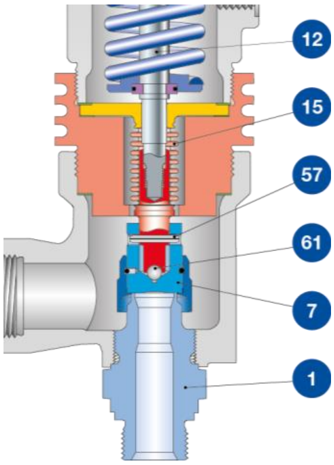



*Figure 6.2.14-8: - Balanced Bellows Design*

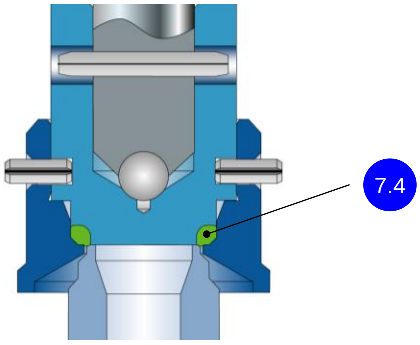



*Figure 6.2.14-9: - O-Ring Disc Design*

### 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

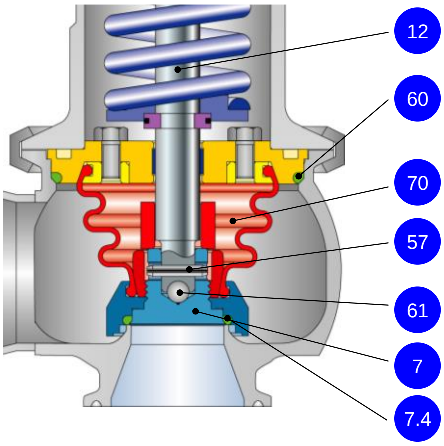



*Figure 6.2.14-10: Spare parts for Clean Service design*

| 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

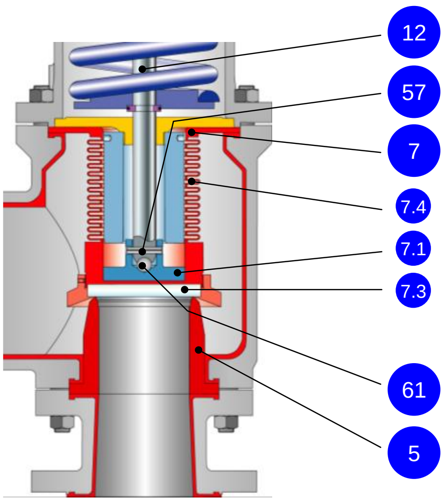



*Figure 6.2.14-11: Spare parts Critical Service*

| 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

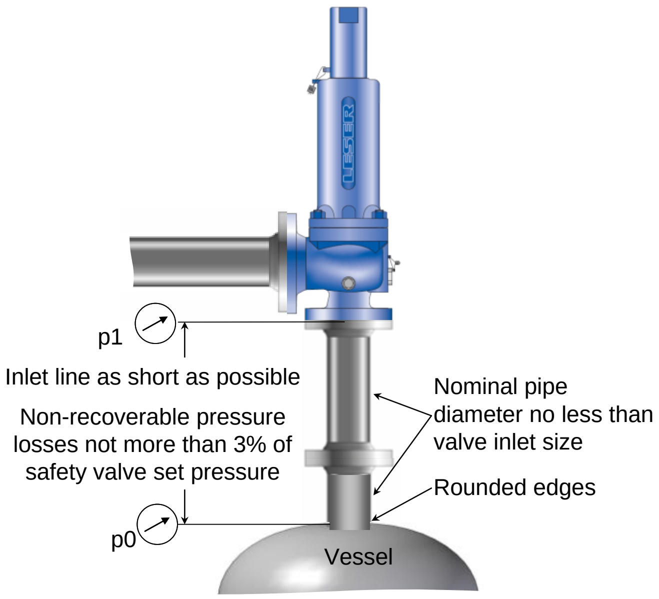



*Figure 6.3.1-1: General guidelines for inlet lines*

### 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

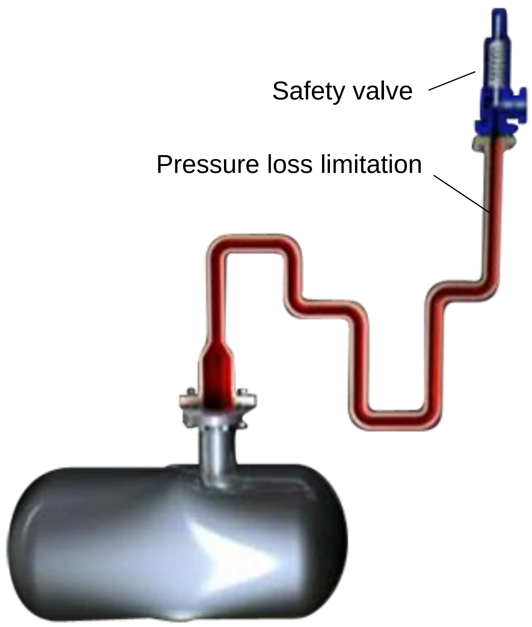



*Figure 6.3.2.1-1: Incorrect sizing of inlet line*

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.

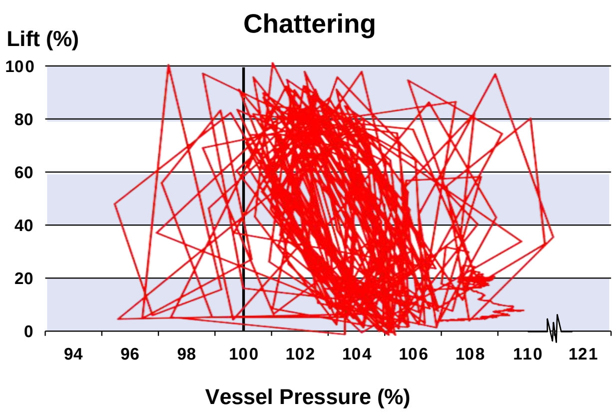



*Figure 6.3.2.3-1: Chattering*

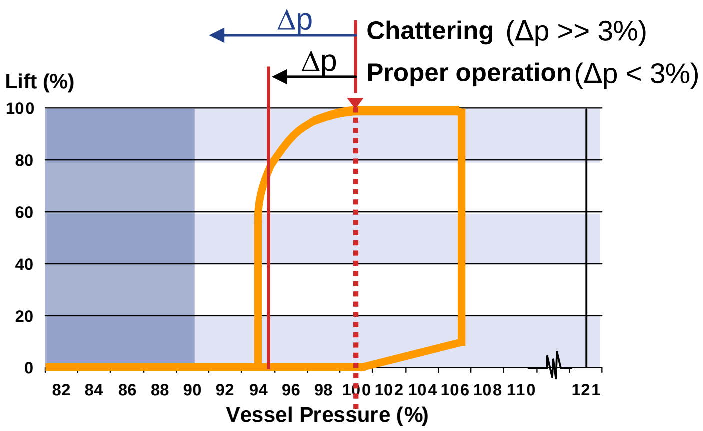



*Figure 6.3.2.3-2: Effect of pressure loss*

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.

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

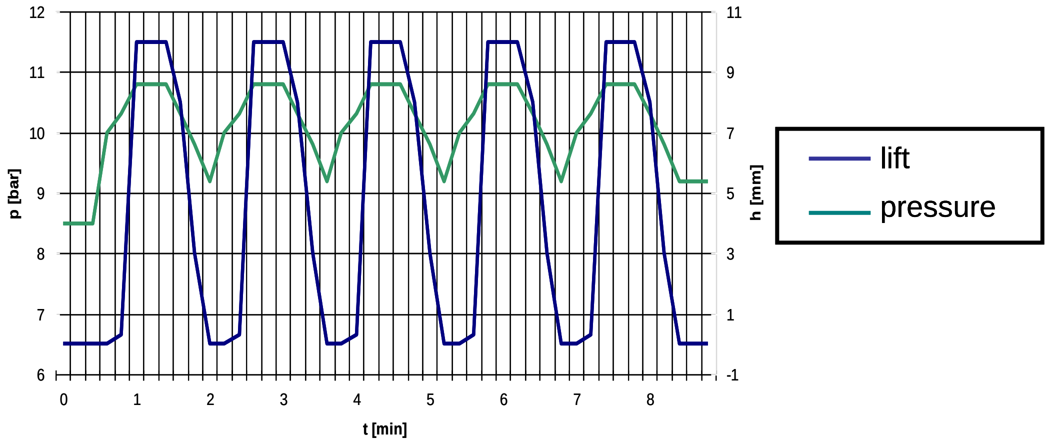



*Figure 6.3.2.3-3: Frequent opening*

### 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, April 2020, 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 6.6.2.

*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.

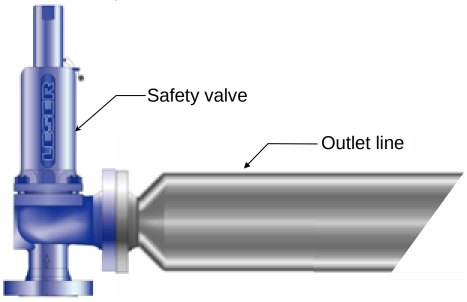



*Figure 6.4.1-1: Sizing of the outlet line*

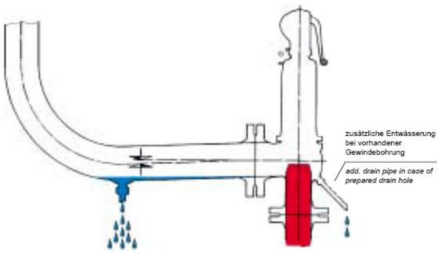



*Figure 6.4.1-2: Correct drainage*

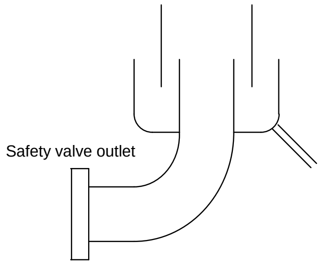



*Figure 6.4.1-3: Drip Pan Elbow*

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

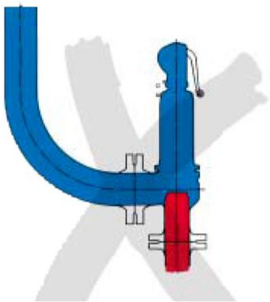


*Figure 6.4.2-1: wrong drainage*

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.

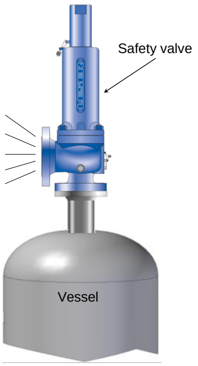



*Figure 6.4.4.1-1:*
*Without Back Pressure*

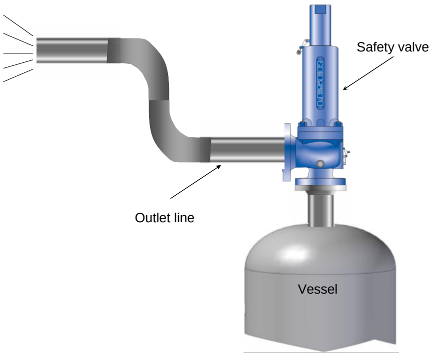



*Figure 6.4.4.1-2:*
*Built-up Back Pressure*

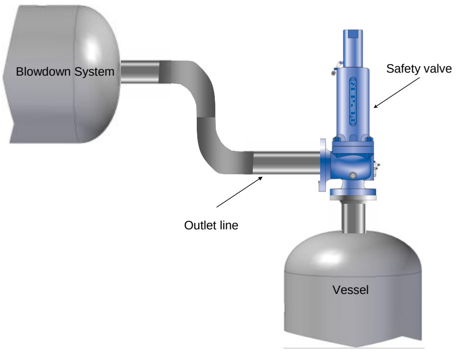



*Figure 6.4.4.1-3:*
*Superimposed Back pressure*

**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

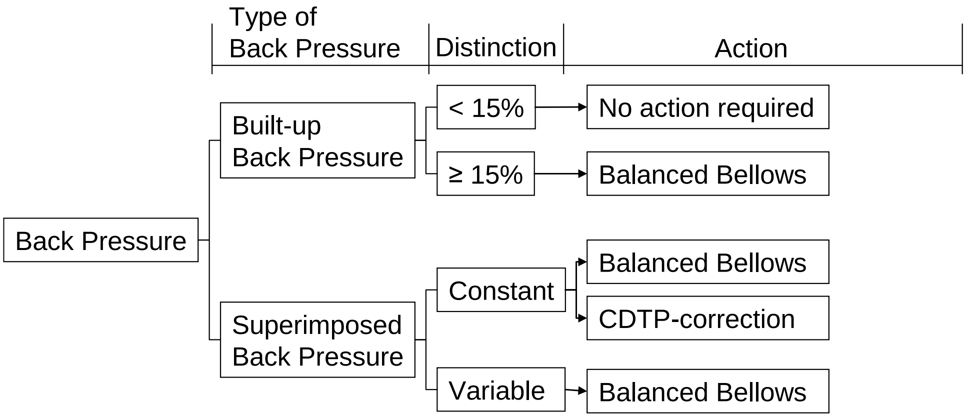



*Figure 6.4.4.2-1: Differences of back pressure types and required actions*

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

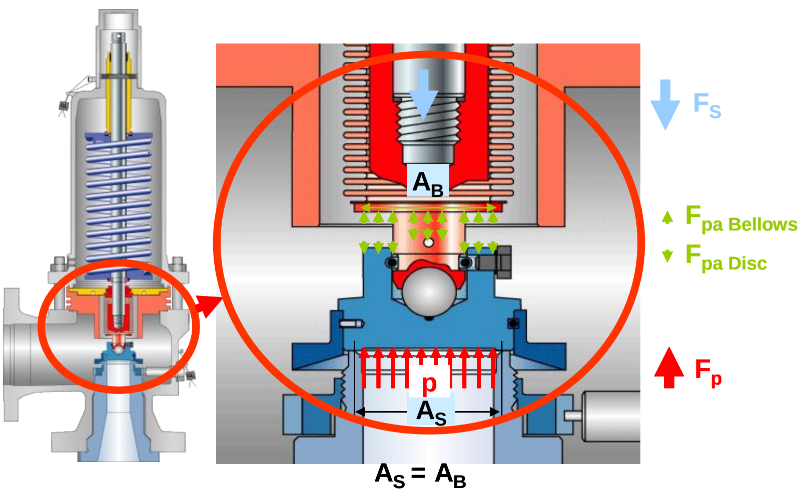
Note: API 520 defines the built- up back pressure limit for conventional safety valves to 10%.

**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 |
| Constant 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 it is recommended to install a balanced bellows. 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.

Alternatively also a variable superimposed back pressure can be compensated by a CDTP-correction of a conventional safety valve. Example:

| Pressure form | Pressure |
|---|---|
| Set pressure | 10 bar |
| Variable superimposed back pressure | 1 - 3 bar |
| Differential pressure (CDTP)<br>→ Setting of safety valve | 7 bar |

For the calculation of the CDTP always the max. value of the superimposed back pressure should be used. As a consequence the actual pressure at which the safety will start to open in the installation is not always 10 bar. The pressure will change between 8 bar and 10 bar depending on the actual value of the superimposed back pressure in this moment. This must be acceptable for the application. As a general recommendation, the CDTP should always be above the normal operating pressure, to avoid an unintended opening of the safety valve.

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

### 6.4.5 Vent Hole in the Bonnet of Balanced Bellows Safety Valves

Safety valves with balanced bellows for back pressure compensation and / or protection of the spring against temperature and medium generally have a vent hole into the bonnet. This chapter contains recommendations concerning the handling of the vent hole during installation of the safety valve.

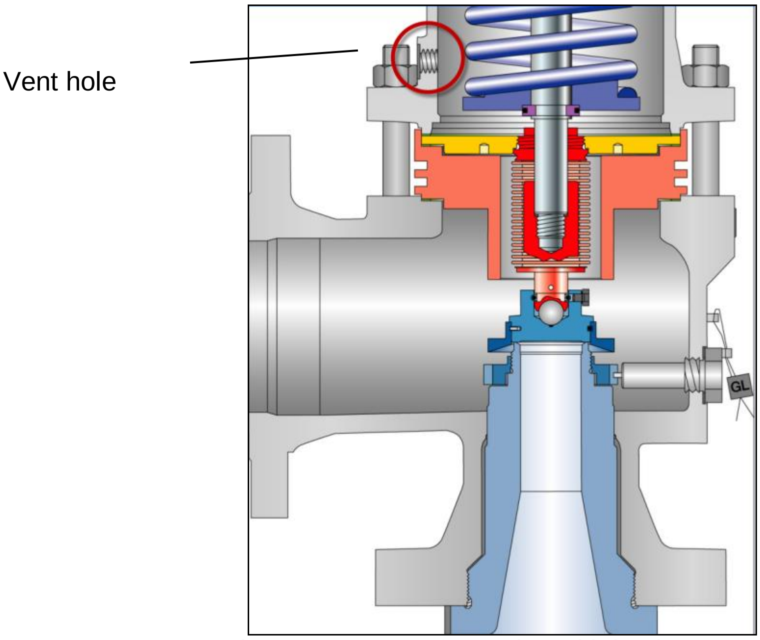



*Figure 6.4.5-1: Safety valve with back pressure compensating bellows*

#### 6.4.5.1 General

The function of a safety valve corresponding to the applicable codes and standards includes the opening and closing within the defined tolerances even under back pressure influence. The back pressure compensation is generated by the bellows. For the proper function of a safety valve it must be guaranteed that the bonnet space above the bellows is only exposed to atmospheric pressure, respectively is never exposed to inadmissible overpressure.

It is recommended that the vent hole should generally remain open. In this way a constant pressure balance is guaranteed between bonnet space and environment. At the same time the vent hole serves to detect leakages due to a potentially defect bellows. This recommendation follows API 520-2, the only standard providing a statement concerning the vent hole.

**“BALANCED BELLOWS VALVES**

Balanced bellows pressure-relief valves are utilized in applications where it is necessary to minimize the effect of back pressure on the set pressure and relieving capacity of the valve. This is done by balancing the effect of the backpressure on the top and bottom surfaces of the seat. This requires the bonnet to operate at atmospheric pressure.

The bonnets of balanced bellows pressure-relief valves must always be vented to ensure proper functioning of the valve. The bonnet vent may also provide a visual indication in the event of a bellows failure. The vent must be designed to avoid plugging caused by ice, insects, or other obstructions. When the fluid is flammable, toxic, or corrosive, the bonnet vent may need to be piped to a safe location.” [19)]

[19)] API 520-2 (2003), chapter 7.3

### 6.4.5.2 Open Vent hole

**Risks due to open vent hole**
Under certain circumstances the open vent hole constitutes a risk e. g. by penetration of moisture and freezing, leakage of critical media or nesting of insects.

**Preventive measures**

**Piping to a safe location**
Acc. to API 520-2 it is recommended for flammable, toxic or corrosive media to provide for a piping to a safe location, so that in case of a defect bellows the medium can be safely discharged. The discharge can directly be connected to the vent hole in the bonnet and should be constructed in a way that a penetration of moisture is not possible.

**Installation of a bug screen**
The installation of a bug screen at the vent hole serves to avoid the nesting of insects.

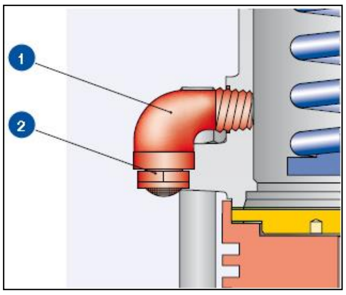



*Figure 6.4.5-2: bug screen*

**Space monitoring**
Another solution for monitoring the pressure in the bonnet space can be a space monitoring device. The space control serves to display a pressure increase in the bonnet as well as to guarantee a constant ventilation of the bonnet space. The space control can be constructed e. g. as water pocket pipe. The pressure balance is guaranteed by a balance valve (also called expansion valve). In case of defect bellows and low superimposed back pressure it can occur that a little amount of medium constantly leaks from the balance valve. Only with a higher pressure increase the ball in the balance valve is pushed outwards and in this way the effusion of medium is prevented.
By means of a pressure gauge which can be a standard gauge, Trailing pointer gauge or a contact gauge it must be ensured by the operator that a constant pressure monitoring is guaranteed.

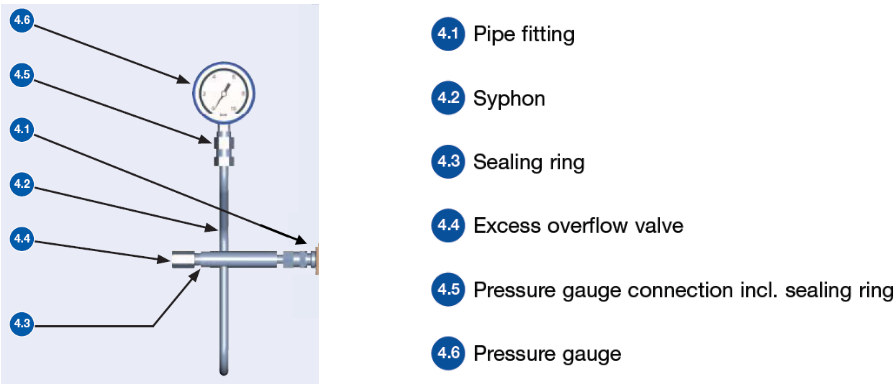



*Figure 6.4.5-3: Space monitoring device*

### 6.4.5.3 Closed Vent hole

**Risks of a closed vent hole**
When a vent hole is closed, the pressure in the bonnet can increase inadmissibly, which can cause a late opening of the safety valve and other unwanted impacts.

| Reason for pressure increase in the bonnet | Caused by | Risks |
| --- | --- | --- |
| Defect bellows | Superimposed back pressure | Set pressure increase of the safety valve by the amount of the superimposed back pressure |
| Defect bellows | Built-up back pressure | Function of the safety valve after actuating corresponds roughly to a safety valve without bellows. Consequently, there is the risk of chattering in case of inadmissibly high back pressure. |
| Thermal expansion of the air in the bonnet | e. g. solar radiation | Little increase of the set pressure |

*Table 6.4.5-1: Risks of pressure increase in the bonnet*

**Preventive measures**

**Contact pressure gauge**
When a pipe for discharge of medium is not possible on part of the customer, a pressure gauge (e. g. contact gauge) to control the bonnet space can be connected to the bonnet as alternative to the previously described solutions. In this way a possible pressure increase can be identified which can refer to a defect bellows. It must be considered that with this solution a constant monitoring of the pressure should be given as the closing of the vent hole can lead to the risks described in Table 6.4.5-2. E. g. a contact pressure gauge can be used for this purpose.

**Closing of the vent hole with a plug**
In exceptional cases the vent hole can be closed with a plug or with a screw. This can be the case when e. g. due to operational experience in connection with regular maintenance (no defect bellows) respectively regular control of the bonnet space an inadmissible pressure increase can be excluded without fail and when at the same time the risk of freezing of the bellows is considered as the higher risk. In this case the operator – if required after clearance with the responsible regulatory organization – can determine that the vent hole at the bonnet is closed.
In case of closing of the vent hole by means of a plug there is the risk of a pressure increase in the bonnet due to thermal expansion of the air encased in the bonnet and consequently the risk of an inadmissible increase of the set pressure. The thermal expansion can be caused by e. g. solar radiation or heating of the valve during operation.
Based on the ideal gas law and an initial temperature of 25° C the pressure increase in the bonnet due to thermal expansion can be defined as follows:

| $T_{FH}$ [°C] | $\Delta p_{FH}$ [bar] |
|---|---|
| 25 | 0,000 |
| 50 | 0,085 |
| 70 | 0,153 |
| 90 | 0,221 |
| 100 | 0,255 |
| 120 | 0,323 |
| 150 | 0,425 |

$T_{FH}$ = Temperature in the bonnet

$\Delta p_{FH}$ = Pressure increase in the bonnet due to thermal expansion

*Table 6.4.5-2: Pressure increase in the bonnet due to thermal expansion*

$T_{FH}$ is the temperature in the bonnet and not the operating temperature in the plant respectively of the medium to be protected. $T_{FH}$ is also always lower than the operating temperature in the plant due to the temperature isolating effect of the bellows. So it can be assumed that for valves with stainless steel bellows the temperature in the bonnet does not exceed the value of 120° C when the valve is closed even with the highest operational temperature of 550° C unless the valve is isolated or elsewise exposed to increased ambient temperatures.
Normally the increase of the set pressure is identical to the pressure increase in the bonnet when the effective cross-section of the bellows corresponds to the effective cross-section of the seat. The increase of the set pressure is an absolute effect; i. e. the set pressure increases by an absolute value depending on the bonnet temperature. The effect is independent from the set pressure level and the nominal size of the safety valve (refer to Table 6.4.5-2).
The operator must evaluate if a possible increase of the set pressure due to thermal expansion in the bonnet is a risk. This is especially depending on the following basic conditions of the application:
set pressure level
distance of the set pressure to the maximum pressure of the protected equipment
expected temperature in the bonnet

If an inadmissible pressure increase prevails in the bonnet and consequently an inadmissible increase of the set pressure by thermal expansion in the bonnet can be expected, the built-up pressure in the bonnet can possibly be discharged by temporarily venting and reclosing of the vent hole after reaching the operational temperature.

**Summary**

- Acc. to API 520-2 it is generally recommended that the vent hole should remain open.
- If API 520-2 is not applicable the vent hole can be closed as described in section 3.
- Independent from this, the possible risks and dangers of a closed but as well of an open vent hole must be evaluated by the operator and the regulatory organization and corresponding measures to prevent these risks must be taken (piping to a safe location, bug screen, control of the bonnet pressure, regular maintenance etc.).

### 6.4.6 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 6.6.2.

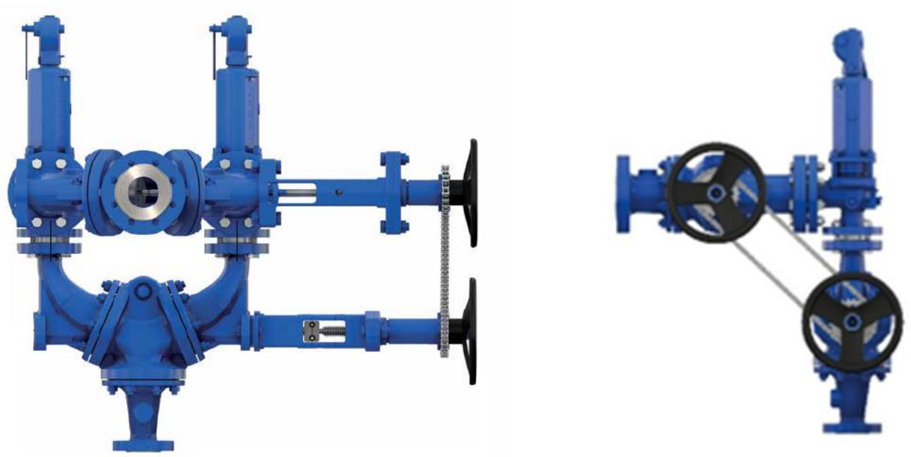


*Figure 6.4.6-1: Lockable combination*

## 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 | - |
| $\zeta_I$ | Pressure loss coefficient for pipe and assembly parts | - |
| $\zeta_Z$ | Allowable pressure loss coefficient | - |

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

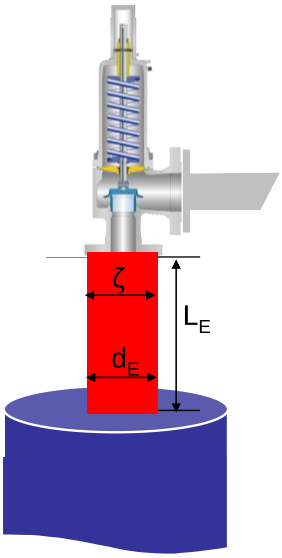



*Figure 6.5.1.1-1: Safety valve with inlet line*

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:

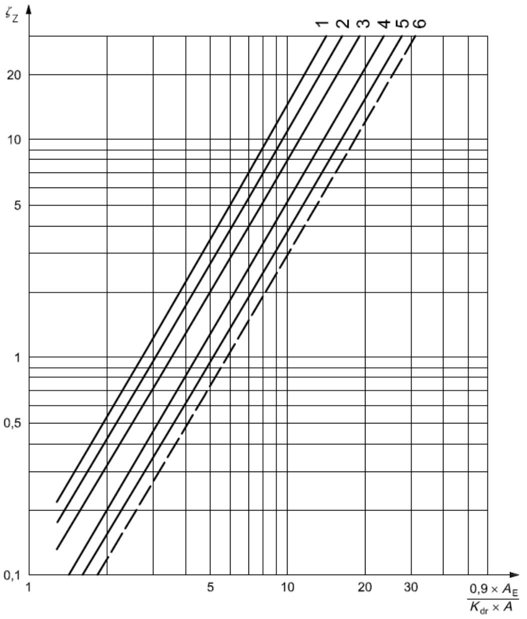
$$L_E = (\zeta_Z - \sum \zeta_I) \times \frac{d_E}{\lambda} \qquad (6.5.1.1\text{-}1)$$

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:

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

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

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

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:

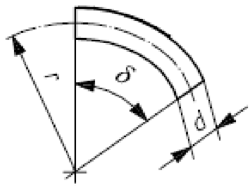
$$\zeta_Z = \frac{0{,}03}{0{,}97} \times \left( \frac{0{,}9 A_E}{K_{dr} \times A} \right)^2 \qquad (6.5.1.1\text{-}7)$$

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

| $\frac{r}{d}$ | 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 |

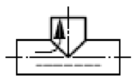
**Inlet pipe nozzle**

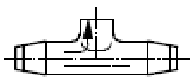
| Description | Resistance coefficient, $\zeta_l$ |
|---|---|
| well rounded | 0,1 |
| edge normally cut | 0,25 |
| sharp edge or set-through pipe | 0,50 |

**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

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

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

► 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*

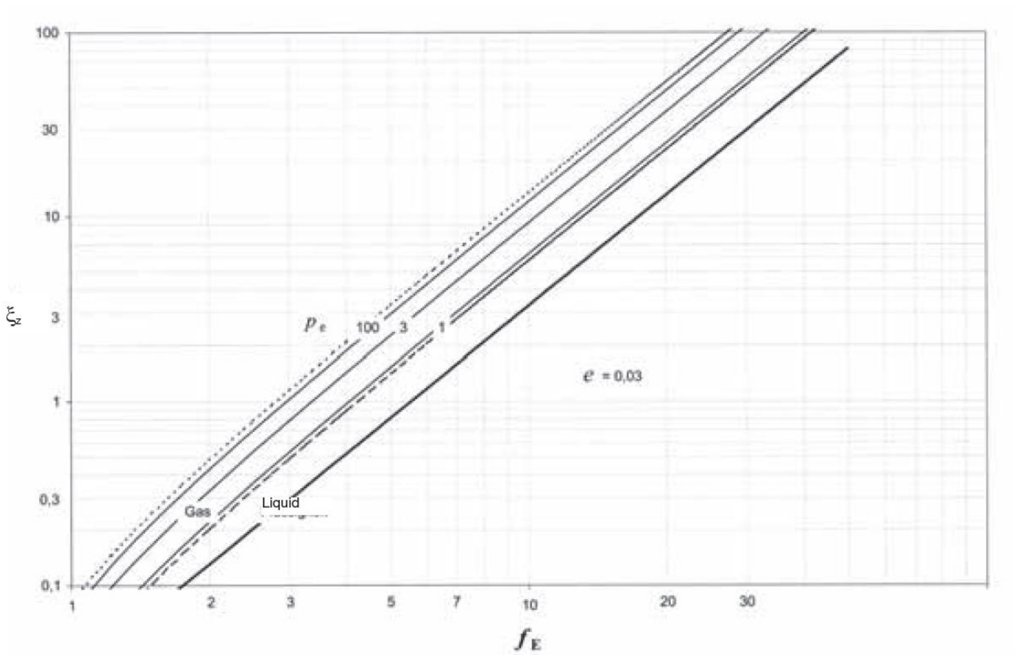
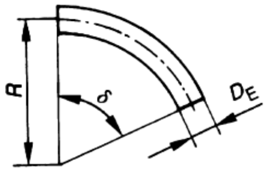
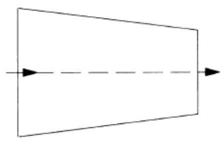
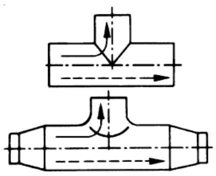



*Figure 6.5.1.2-1: Allowable pressure loss coefficient $\zeta_Z$ of the inlet line to a safety valve over the surface ratio $f_E$ for various response pressures $p_e$ at a permissible supply pressure loss of 3% (e = 0.03) relative to the static pressure $p_{a0} = p_u$ = 1 bar abs. for various isentropic 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 |
| for $\delta \neq$ 90° | 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 |

| | | | $\zeta_i$ |
|---|---|---|---|
| Supply line nozzle | 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 or Chapter 6.6.2.2.

### 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 |

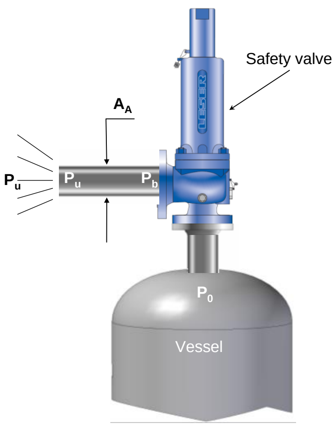
*Table 6.5.2.1-1: Symbols ISO 4126-9*

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.

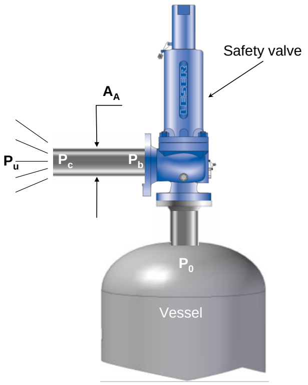



*Figure 6.5.2.1-2: Case of steam gases or vapour*

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.

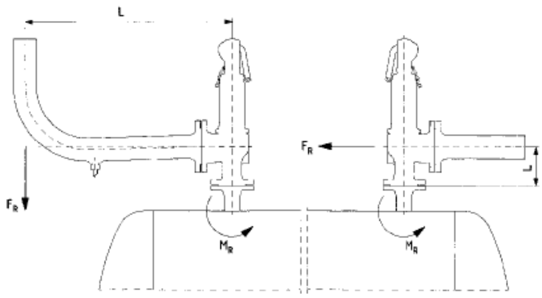



*Figure 6.5.3-1: Reaction Force*

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 | $mm^2$ |
| $M_n$ | 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 | $kg/m^3$ |

*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:

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

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.

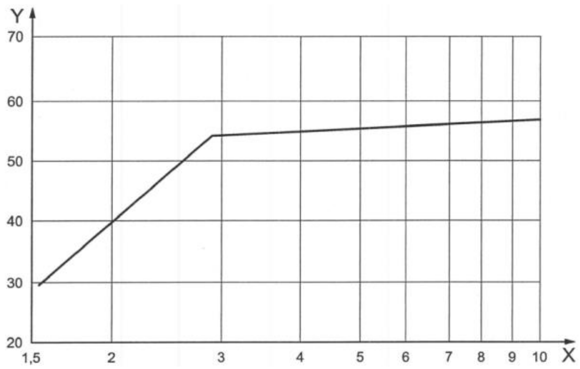



*Figure 6.5.4.2-1: Sound pressure level at 30m (100ft) from the stack tip (Y = $L_{30\ (100)}$)*

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:

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

In USC units

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

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:

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

In USC units:

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

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:

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

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

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

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 XIII; Sec. 8.2
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

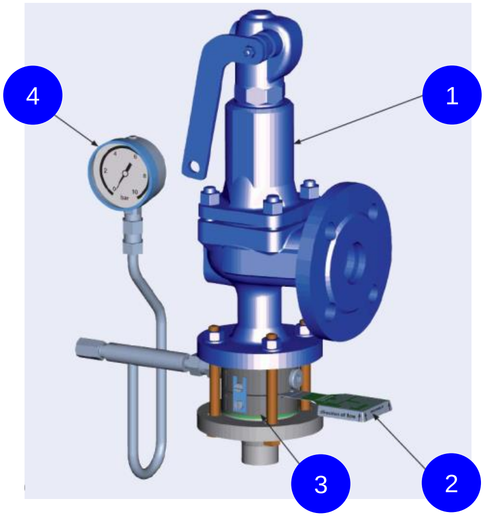



*Figure 6.6.1.1-1: Safety valve and bursting disc in combination*

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**

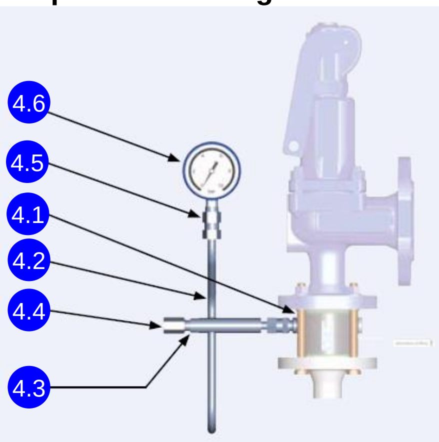



*Figure 6.6.1.1-2: Space monitoring device*

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. XIII, 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.

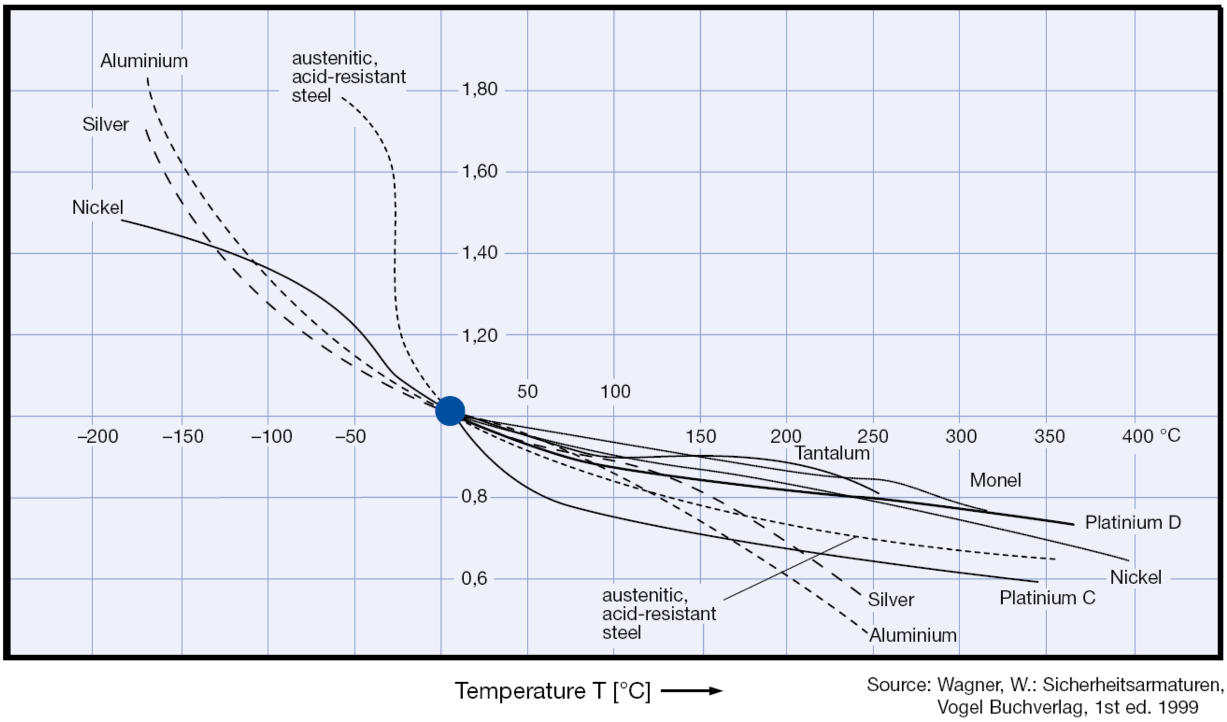



*Figure 6.6.1.2-1: Bursting pressure alterations in connection with the temperature*

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

Change-over valves are used to connect two safety valves with a pipe connection to a pressure system, in order to increase operational availability. One safety valve is in operation and one safety valve is on standby.
The standby safety valve can be disassembled and serviced, during running operation. The pressure system continues to be protected against impermissible pressure. This way, shutdown periods of the plant can be planned independently of the maintenance cycles of the safety valves.

*Figure 6.6.2-1: Inlet sided combination*

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

- have a flow optimized design for minimal inlet pressure loss.
- facilitate a productivity increase of the plant due to uninterrupted operation, which means
  - reduction of service time and costs
  - reduction of production downtime
- are specifically designed for combination with LESER safety valves.
- have a variable inlet body on the piping side to adjust to existing piping nominal sizes and to reduce the inlet pressure loss
- are available as
  - individual valve
  - inlet-sided combination with safety valves
  - lockable combination with safety valves
- are robust and maintenance free design.
- ensure a simple and failsafe switch-over.
- guarantee the full flow area when changing over and therefore meet all regulatory requirements

### 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-156 or AD 2000-Merkblatt A2 Par. 6 require that, even when changing-over, the required discharge 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 of the safety valve in accordance with 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 requirement of the 3% pressure loss criterion (explained in 6.3.2). 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 at high mass flows. This is reached by:

- An enhanced flow path with a widened seat area (Figure 6.6.2.2-1)
- A smaller then usual angle of inclination (67,5°) (Figure 6.6.2.2-2)

*Figure 6.6.2.2-1: Enhanced flow path*

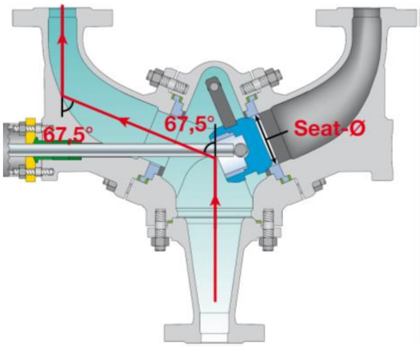



*Figure 6.6.2.2-2: Angle of inclination*

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
– switch to a larger inlet for the change over valve and increase the inlet line cross-section
If in spite of these measures, the 3% criterion is still exceeded, refer to the manufacturers declaration of inlet pressure loss by LESER. LESER has tested certain combinations to still work fine, even though the pressure drop is above 3%. If the chosen Safety Valve is within the tested scope, LESER has proven correct function.

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 a flow test lab. LESER change-over valves have the following pressure loss coefficients (ζ:)

| 320 PN40/ CL300 | | Piping Side | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Art. Nr. | SV-Side | DN40/ 1 ½“ | DN50/ 2“ | DN65/ 2 ½“ | DN80/ 3“ | DN100/ 4“ | DN125/ 5“ | DN150/ 6“ | DN200/ 8“ | DN250/ 10“ | DN300/ 12“ | DN400/ 16“ |
| 3200.0050 | DN40/ 1 ½“ | 0,59 | 0,32 | 0,23 | 0,22 | | | | | | | |
| 3200.0070 | DN50/ 2“ | | 0,53 | 0,35 | 0,28 | | | | | | | |
| 3200.0090 | DN65/ 2 ½“ | | | | 0,37 | 0,27 | | | | | | |
| 3200.0100 | DN80/ 3“ | | | | 0,51 | 0,35 | 0,25 | | | | | |
| 3200.0120 | DN100/ 4“ | | | | | 0,49 | 0,37 | 0,30 | | | | |
| 3200.0140 | DN125/ 5“ | | | | | | | 0,32 | 0,16 | | | |
| 3200.0150 | DN150/ 6“ | | | | | | | 0,52 | 0,21 | 0,15 | | |
| 3200.0170 | DN200/ 8“ | | | | | | | | 0,50 | 0,21 | 0,16 | |
| 3200.0190 | DN250/ 10“ | | | | | | | | | 0,44 | 0,25 | 0,20 |
| 3200.0200 | DN300/ 12“ | | | | | | | | | | | 0,22 |

*Table 6.6.2.2-3: Pressure loss coefficients ζ – Type 320 PN40*

| 320 PN250/ CL1500 | | Piping Side | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Art. Nr. | SV-Side | DN25/ 1“ | DN40/ 1 ½“ | DN50/ 2“ | DN80/ 3“ | DN100/ 4“ | DN150/ 6“ | DN200/ 8“ | DN250/ 10“ |
| 3200.0020 | DN25/ 1“ | 0,60 | 0,19 | 0,15 | | | | | |
| 3200.0060 | DN40/ 1 ½“ | | 0,60 | 0,30 | | | | | |
| 3200.0080 | DN50/ 2“ | | | 0,52 | | | | | |
| 3200.0110 | DN80/ 3“ | | | | 0,60 | 0,39 | 0,24 | | |
| 3200.0130 | DN100/ 4“ | | | | | 0,53 | 0,30 | | |
| 3200.0160 | DN150/ 6“ | | | | | | 0,74 | 0,23 | 0,15 |
| 3200.0180 | DN200/ 8“ | | | | | | | 0,63 | 0,29 |

*Table 6.6.2.2-4: Pressure loss coefficients ζ – Type 320 PN250*

*Table 6.6.2.2-5: Pressure loss coefficients ζ – Type 330*

| **330 PN40/ CL300** | | Piping Side | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Art. Nr. | SV-Side | DN25/ 1“ | DN40/ 1 ½“ | DN50/ 2“ | DN65/ 2 ½“ | DN80/ 3“ | DN100 / 4“ | DN125 / 5“ | DN150 / 6“ | DN200 / 8“ | DN250 / 10“ | DN300 / 12“ | DN350 / 14“ | DN400 / 16“ | DN450 / 18“ |
| 3300.0010 | DN25/ 1“ | 0,58 | 0,25 | 0,21 | | | | | | | | | | | |
| 3300.0050 | DN40/ 1 ½“ | | 0,40 | 0,51 | | | | | | | | | | | |
| 3300.0070 | DN50/ 2“ | | | 0,88 | | | | | | | | | | | |
| 3300.0090 | DN65/ 2 ½“ | | | | 0,70 | 0,56 | | | | | | | | | |
| 3300.0100 | DN80/ 3“ | | | | | 0,89 | | | | | | | | | |
| 3300.0120 | DN100 / 4“ | | | | | | 0,52 | 0,40 | | | | | | | |
| 3300.0140 | DN125 / 5“ | | | | | | | 0,80 | | | | | | | |
| 3300.0150 | DN150 / 6“ | | | | | | | | 0,91 | | | | | | |
| 3300.0170 | DN200 / 8“ | | | | | | | | | 1,32-0,67 | | | | | |
| 3300.0190 | DN250 / 10“ | | | | | | | | | | 0,74 | | | | |
| 3300.0200 | DN300 / 12“ | | | | | | | | | | | 1,07-0,62 | | | |
| 3300.0220 | DN350 / 14“ | | | | | | | | | | | | 1,11 | | |
| 3300.0230 | DN400 / 16“ | | | | | | | | | | | | | 0,62 | 0,50 |

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

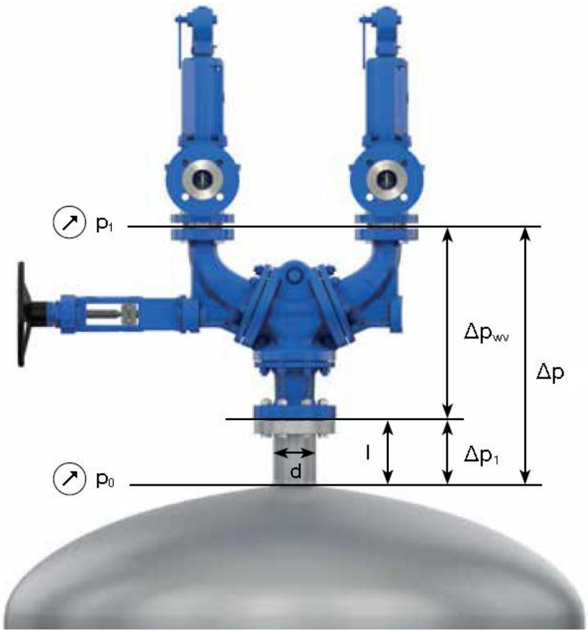



*Figure 6.6.2.3-1: Pressure loss*

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 a given installation, it is recommended to calculate the pressure loss in the inlet line. Mayor standards give a limit of 3% of the set pressure as limit for the inlet pressure loss.

The general pressure loss is calculated by this formula:

$$\underbrace{\Delta p = \left(\lambda \cdot \frac{l}{d} + \sum \zeta\right) \cdot \frac{\rho}{2} \cdot w^2}_{\text{General Formula (6.6.2.3-1)}} \quad \text{from this follows} \quad \Delta p = \underbrace{\lambda \cdot \frac{l}{d} \cdot \frac{\rho}{2} \cdot w^2}_{\text{Part 1 (6.6.2.3-2)}} + \underbrace{\sum \zeta \cdot \frac{\rho}{2} \cdot w^2}_{\text{Part 2}}$$

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 6.6.2.3-1: 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:

$$\Delta p_{COV} = \frac{\rho \cdot w^2}{2} \cdot \zeta \qquad (6.6.2.3\text{-}3)$$

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®. Within the calculation, the COV van be added as a part of the inlet line. VALVESTAR® is available online at www.valvestar.com.

### 6.6.2.4 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 discharges to 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 6.6.2.4-1: 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. With LESER change-over-valves, the inlet side valve can be adopted to any outlet side change-over-valve that may be needed with any LESER safety valve.

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.

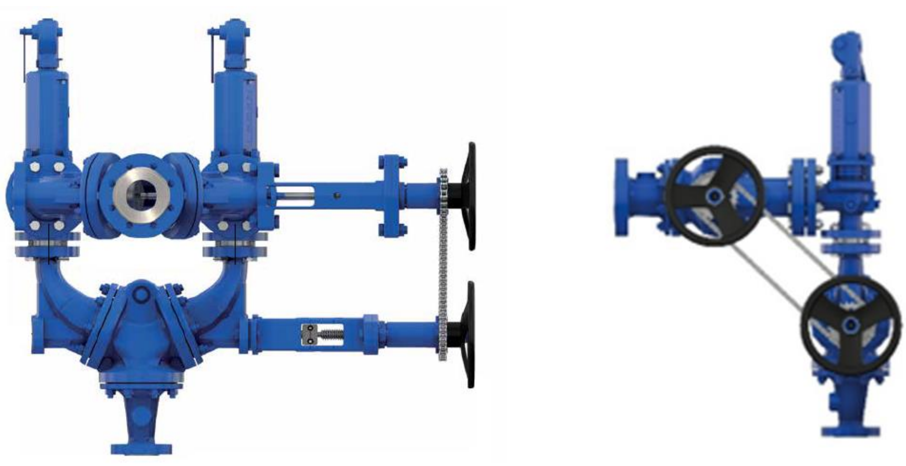


*Figure 6.6.2.4-2: Lockable combination*

### 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 |

## Contents

## 7.1 Introduction

Nowadays sizing of safety valves is generally performed with the help of sizing software like VALVESTAR®, which make the sizing and selection process fast and relatively easy.

The purpose of this chapter of ENGINEERING is to:

- provide an overview about the most important sizing standards and the formulas which are used within sizing software
- based on LESER's long experience provide helpful advice how to deal with specific applications or sizing problems
- explain some of the physical background, which is helpful to understand specific problems.

This chapter is limited to the sizing of safety valves. The calculation of

- pressure loss in the inlet line
- back pressure
- reaction force
- noise emission

can be found in chapter 6 Installation and Plant Design

### 7.1.1 General Sizing Procedure

A safety valve must be sized to vent the required amount of fluid so that the pressure within the protected equipment does not exceed the maximum allowable accumulated pressure (MAAP). The fluid can be steam, a gas or vapor, a liquid or a two-phase mixture, e. g. oil and gas or an evaporating liquid.

The general sizing procedure foresees:

- The determination of the required mass flow
- The calculation of the minimum orifice area using the selected sizing standard
- The selection of a larger orifice area from the LESER catalog

Safety valves must be sized and selected by those who have a complete knowledge of the safety requirements of the pressurized unit to be protected. These requirements comprehend at least but not exclusively the

- Knowledge of the fluid state during venting (gaseous, liquid, frozen or flashing two-phase)
- Relieving pressure and temperature
- Mass or volume flow rate
- Back pressure
- Fluid properties at the relieving temperature
  For *liquids*: density, viscosity
  For *gases, vapors*: isentropic coefficient[1], compressibility factor, molar mass, density
  For *two-phase flows*: those of the liquid and gas phase. Furthermore, for flashing flows, saturation enthalpies and specific volumes.

If some data are missing, it is general rule to consider those occurring in the worst possible case scenario, which considers the simultaneous occurrence of all possible causes of overpressure.

Once the required data are collected, there are three alternative ways to determine the correct size of the safety valve:

- Using VALVESTAR® ( www.valvestar.com )

  VALVESTAR® is LESER's sizing software and it delivers directly both the orifice size and the complete documentation for the safety valve according to the chosen sizing standard.

- Sizing formulas

  They permit the user to size the valve by himself. This presumes that the user is familiar with the sizing procedures and the formulas. It is one aim of this chapter of ENGINEERING to guide the users and to familiarize with the sizing procedures.

- Capacity charts

  They are tabulated capacities for steam, air and water in function of the relieving pressure, which are available in our catalogues for each valve type and orifice area. The user can immediately select the orifice area which meets or exceeds the required mass flow rate. Capacity charts were a common sizing tool, when no sizing software like VALVESTAR® was available

[1] In US technical literature, this quantity is often referred to as *ratio of specific heats*

### 7.1.2 Selection of the Sizing Standard

The information contained in chapter 7 Sizing is based on following edition of codes and standards:

| Code / Standard | Edition |
|---|---|
| ASME Section XIII | 2021 |
| ASME Section VIII | 2021 |
| ASME Section I | 2021 |
| API RP 520 | 2020 |
| API 521 | 2020 |
| ISO 4126-1 | 2016 |
| ISO 4126-7 | 2016 |
| TRD 421 | 1998 |
| TRD 721 | 1997 |
| AD Merkblatt 2000-A2 | 2020 |

*Table 7.1.1-1: Sizing standard edition*

This chapter of ENGINEERING covers the sizing procedures and their application with several examples according to the most common standards.

The standards which are described here for the sizing of gas and vapor, steam and liquid flows are

- ASME Section I & XIII (VIII) and API RP 520, incl. two-phase flow sizing from Appendix C, fire case and thermal expansion of entrapped liquids from API 521
- ISO 4126-1 and -7
- AD Merkblatt 2000-A2 as well as older TRD 421 and TRD 721

The ASME Boiler and Pressure Vessel Code has been extended by the additional Section XIII with the title "Section XIII RULES FOR OVERPRESSURE PROTECTION".
Various of the previous 12 Sections such as Section IV or VIII defined the requirements for overpressure protection devices, their design, testing, materials and approvals.
In the ASME BPVC Sec. XIII, a large part of these requirements is now combined into one section and deleted in the respective other sections. This means that from now on, these requirements are no longer spread over several sections, but are combined in Section XIII.

If the customer does not give any indication, according to which standard the sizing should be done, LESER adopts:

| Sizing standard selected by LESER | Customer based in | Section in this chapter |
|---|---|---|
| ISO 4126 | Europe, incl. Russia and former CIS States | Section 5 |
| AD 2000-A2 | | Section 6 |
| ASME Section XIII (ASME Section VIII) | US or in an other country/region which usually adopts American standards, like North America, Middle East or Far East Asian countries. | Section 4 |
| API RP 520 | only if explicitly requested by customer | Section 4 |

*Table 7.1.1-2: Selection of sizing standard*

## 7.2 Engineering Support

In this section the norms are based on following edition:
ASME Section XIII (2021), ASME Section VIII (2021) and API RP 520 (2020), ISO 4126-1 (2016), ISO 4126-7 (2016)

The section Engineering Support is a quick and concise guide to the physics involved in the sizing of safety valves. It explains the most important physical properties used in sizing formulas.

### 7.2.1 List of Symbols

| Symbol | Description | Units [SI] |
|---|---|---|
| $c_p$ | Specific heat at constant pressure | [J/(kg K)] |
| $c_v$ | Specific heat at constant volume | [J/(kg K)] |
| $G$ | Specific gravity | [--] |
| $h$ | Specific enthalpy | [J/kg] |
| $h_G$ | Specific enthalpy (gas) | [J/kg] |
| $h_L$ | Specific enthalpy (liquid) | [J/kg] |
| $h_{mix}$ | Specific enthalpy (two-phase mixture) | [J/kg] |
| $\Delta h_{GL}$ | Latent heat of evaporation | [J/kg] |
| $M$ | Molecular weight | [kg/kmol] |
| $k$ | Isentropic coefficient | [--] |
| $p$ | Pressure | [bar] |
| $p_b$ | Back pressure | [bar] |
| $p_c$ | Critical Pressure | [bar] |
| $p_r$ | Reduced Pressure | [--] |
| $p_0$ | Relieving Pressure | [bar] |
| $R$ | Gas constant divided by the molecular weight | [J/(kg K)] |
| $T$ | Temperature | [K] |
| $T_c$ | Critical temperature | [K] |
| $T_r$ | Reduced temperature | [--] |
| $v$ | Specific volume | [m³/kg] |
| $Z$ | Compressibility factor | [--] |
| $x$ | Gas mass portion in two-phase stream (quality) | [--] |
| $\rho$ | Density | [kg/m³] |
| $\mu$ | Dynamic viscosity | [Pa s] |

*Table 7.2.1-1: List of symbols*

### 7.2.2 Properties of Gases

Vapors and gases are gaseous media: a vapor is in a state of equilibrium with the liquid phase, like steam and water, while a gas is in a thermodynamic state, where no liquid or solid can form at that temperature, such as oxygen at typical ambient temperatures. It means that a vapor can condense or evaporate respectively by increasing or decreasing the pressure, while a gas can not.

The gas formulas in the sizing standards are based on the equation of state in equation *7.2.2-1*.

$$p\ v = Z\ R\ T \quad \textit{(Eq. 7.2.2-1)}$$

The density $\rho$ is the inverse of the specific volume and identifies the mass of a medium contained in a volume.
The specific gravity $G$ of a gas is the ratio of the density of the gas to that of air at the standard reference condition, see Eq. *7.2.2-2*.

$$G = \frac{\rho_G}{\rho_{air}} \ldots \textit{(Eq. 7.2.2-2)}$$

If the gas is pure (= no mixture of different gases), is at the same temperature and pressure of air and can be treated like an ideal gas (*Z=1*), the specific gravity G is the ratio of the molecular weights, see Eq. *7.2.2-3*. The molecular weight is the mass of one mole of a compound. A mole of any substance consists of an Avogadro's number ($6.02214\times10^{23}$) of atoms or molecules.

$$G = \frac{M_G}{M_{air}} \quad (T_G = T_{air}\ ;\ p_G = p_{air}\ ;\ Z_G = Z_{air} = 1) \ldots \textit{(Eq. 7.2.2-3)}$$

The compressibility factor Z is determined from Fig. *7.2.2-1* in function of the reduced temperature and the reduced pressure, which are defined in Eq. *7.2.2-4* and *7.2.2-5* as the ratio between the actual (absolute) pressure or temperature and the ones at the critical point.

$$T_r = T/T_c \quad \textit{(Eq. 7.2.2-4)} \quad \text{and} \quad p_r = p/p_c \quad \textit{(Eq. 7.2.2-5)}$$

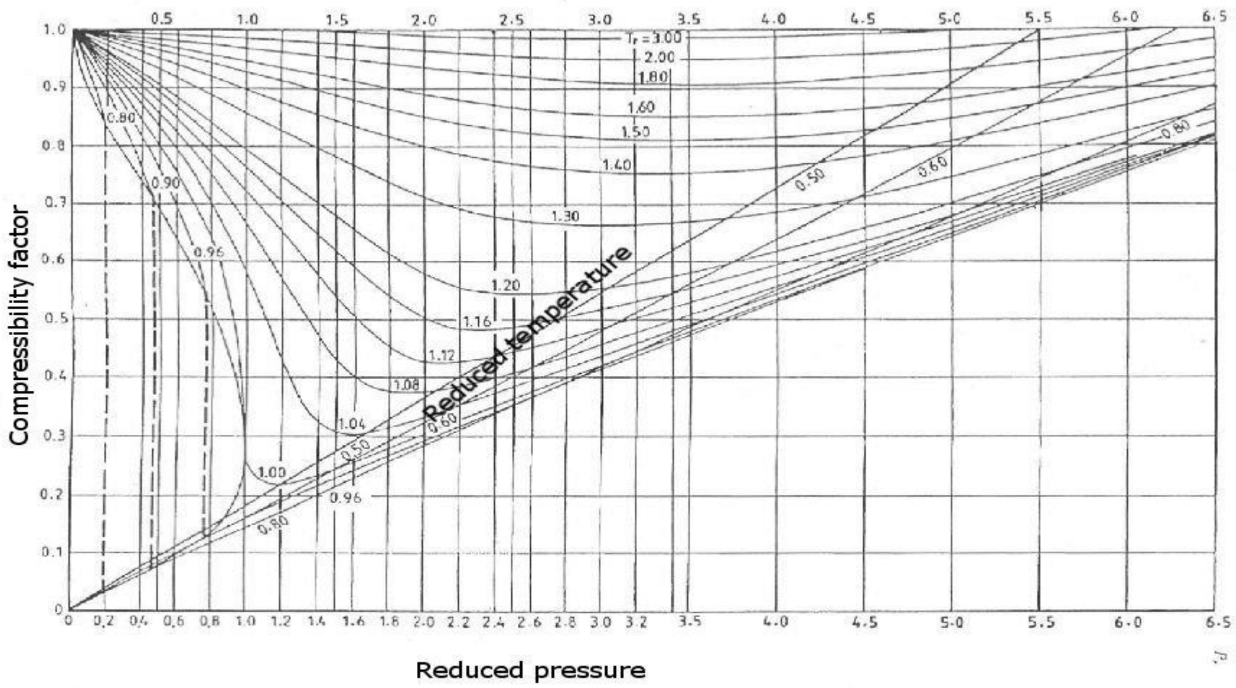



*Figure 7.2.2-1: Compressibility factor Z in DIN EN ISO 4126-7, Page 26*

The isentropic exponent or ratio of specific heats $k$ is the ratio between the specific heat at constant pressure Cp and the one at constant volume Cv, Eq. *7.2.2-6*

$$k = c_p / c_v \geq 1 \quad \textit{(Eq. 7.2.2-6)}$$

The sizing procedures require the knowledge of the isentropic exponent at the relieving condition. Since both specific heats are function of temperature and pressure, the isentropic coefficient at the relieving condition may differ significantly from the tabulated values at 1 atm and 15°C in ISO 4126-7 or 14.5 psi and 60°F in API RP 520. For instance, air at 100 bar and 20°C has an isentropic coefficient of 1.6 compared to 1.4 at atmospheric pressure. In general, at atmospheric pressure the isentropic coefficient is expected to decrease with the temperature.

The value of the compressibility and that of the isentropic coefficient may not be predicted a priori by a simple rule of thumb method. Dedicated commercial software for pure gases and gas mixtures, like NIST Standard Reference Database[2] or GERG-2004 and AGA8 for natural gas components may contain a detailed database for a specific application.

[2] NIST Chemistry WebBook

### 7.2.3 Critical and Subcritical Gas Flow

The distinction between critical and subcritical gas flows is present in all sizing standards and it generates two distinguished sizing formulas. In both cases the mass flow of gas in a safety valve is equal to that of an ideal nozzle multiplied by the discharge coefficient. On an engineering perspective, the gas flow in a nozzle is assumed to be adiabatic, that is without heat exchange with the ambience, and energy losses are usually neglected. Under these assumptions the relationship between the pressure and the specific volume follows Eq. *7.2.3-1*

$$p\, v^k = const \quad \text{(Eq. 7.2.3-1)}$$

If the back pressure $p_b$ is below the critical value $p_c$, the mass flow in the nozzle is called critical and it depends only on the relieving condition, otherwise it is called subcritical and it is a function of the ratio of the back pressure $p_b$ and the relieving pressure.

| | |
|---|---|
| Critical gas flow | $p_b \leq p_c$ |
| Subcritical gas flow | $p_b > p_c$ |

The critical pressure ratio in the nozzle depends only from the isentropic coefficient following Eq. *7.2.3-2.* In the calculation of the critical pressure ratio both the relieving and the back pressure are absolute pressures.

$$\frac{p_c}{p_0} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} \quad \text{(Eq. 7.2.3-2)}$$

Table 7.2.3-1 lists the critical pressure ratios for some gases at 20°C and atmospheric pressure (source: ISO 4126-7, 2016).

| Gas | k | $p_c/p_0$ |
|---|---|---|
| Air | 1.40 | 0.528 |
| Ethylene | 1.25 | 0.555 |
| Methane | 1.31 | 0.544 |
| Nitrogen | 1.40 | 0.528 |
| Ammonia | 1.31 | 0.544 |

*Table7.2.3-1: Critical pressure ratios for selected gases at 20°C and atmospheric pressure*

### 7.2.4 Liquid Properties and Viscous Flow

The density $\rho$ of liquids changes with temperature but it is almost unchanged with pressure, unless the pressure is in the order of hundreds of bar.

The specific gravity $G$ replaces liquid density in the sizing procedure of API RP 520. It is defined as the ratio of the density of the liquid to that of water at the same temperature. Therefore, substances with a specific gravity greater than 1 are denser than water and those with a specific gravity of less than 1 are less dense than water.

The dynamic viscosity $\mu$ is a measure of the resistance of a fluid to flow when it is deformed under stress. Viscous liquids need larger pressure differences to move the same mass flow than inviscid liquids. When sizing a safety valve, larger valves are necessary the more viscous the liquid is. The effect of the liquid viscosity in sizing a safety valve is accounted in the viscosity correction factor Kv, which is expressed in function of the Reynolds number *Re* at the orifice area.

The Reynolds number *Re*, see Eq. *7.2.4-1*, is the ratio of the inertial to the viscous force at the orifice area.

$$Re = \left(\frac{Q_m}{3{,}6\,\mu_o}\right)\sqrt{\frac{4}{\pi A}}$$

*(Eq. 7.2.4-1)*

The sizing standards consider the required mass flow rate in the definition of the Reynolds number, even if it is less than the actual discharged mass flow. VALVESTAR® optimizes the sizing procedure so that it determines the safety valve for the actual discharged mass flow at the relieving conditions. In Fig. *7.2.4-1* and *7.2.4-2* the viscosity correction factor in function of the Reynolds number is shown as it is respectively in ISO 4126-7 and in API RP 520.

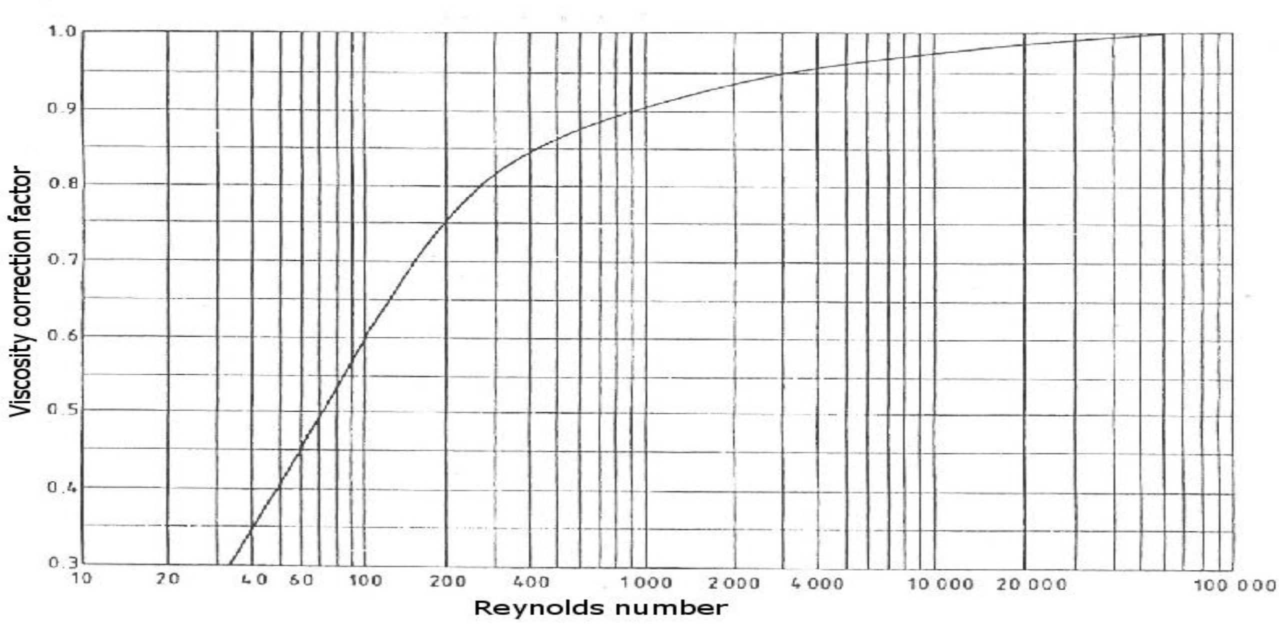



*Figure 7.2.4-1: Viscosity correction factor in DIN EN ISO 4126-7, Page 28*

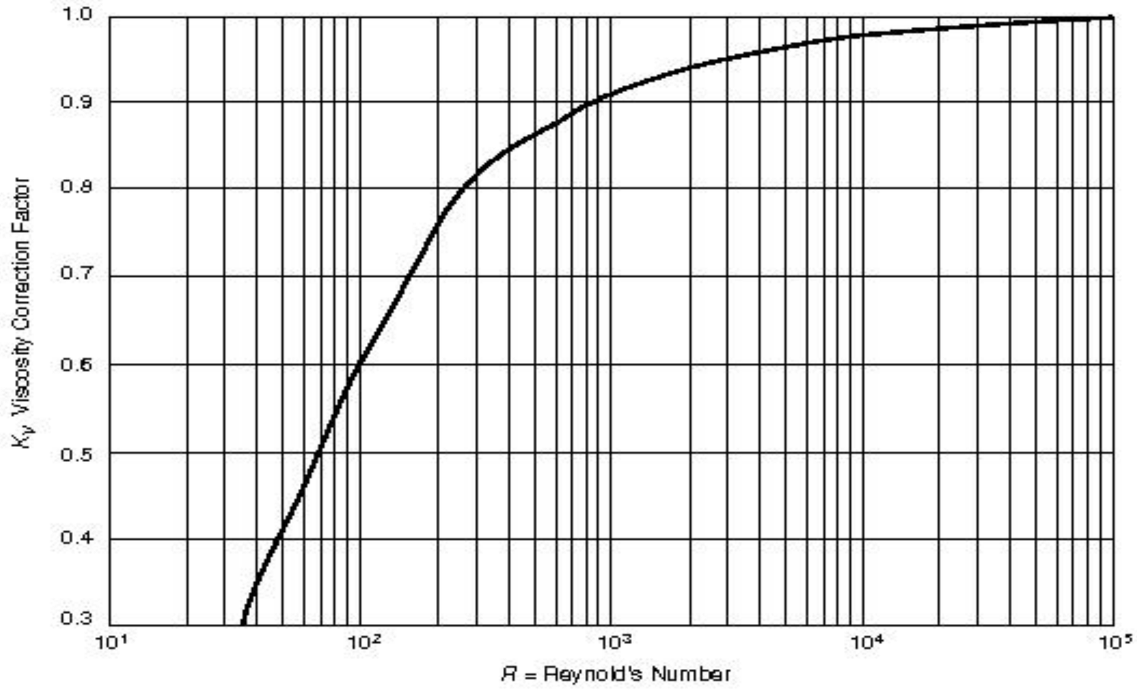



*Figure 7.2.4-2: Viscosity correction factor in API RP 520, Page 93*

**Question**: Is there a threshold in viscosity so that the proper safety valve can be selected without the calculation of the viscosity correction factor?

*Answer:* There is no general rule to define a threshold, since the Reynolds number depends not only on the viscosity of the liquid but also on the mass flow and on the orifice area.

**Question**: What should be done if the Reynolds number is below 34?

*Answer:* This occurrence is not yet regulated within the normative standards and there are some few publications in the scientific literature on the topic. In some cases it may be sufficient to heat up the liquid in order to reduce the viscosity and increase the Reynolds number.
In other cases performing flow tests with the viscous medium and a preliminary selected safety valve maybe the only option.

### 7.2.5 Phase Change and Two-Phase Flows

Depressurization of vessels partially filled with liquids may result in two-phase flows at the inlet of the safety valve. This paragraph presents a short introduction on the topic of phase change and two-phase flows and is helpful to understand the sizing algorithms presented e.g. by API RP 520 (see section 7.4.7).

For any combination of temperature and pressure a substance is present in one, two or even three states of agglomeration in equilibrium. Usually this information is reported in a phase diagram, where temperature and pressure are the coordinates and the result is the existing phase(s), see Fig. *7.2.5-1* for water. The triple point is individuated by that combination of temperature and pressure, where all three phases (solid, liquid, vapor) coexist in equilibrium. The critical point individuates the highest pressure and temperature where the gas and the liquid phase coexist. At any pressure between the triple point and the critical point there is a unique saturation temperature, when the liquid evaporates or the vapor condenses. A liquid at a temperature below that of saturation is said to be subcooled or *sub*-saturated , while a vapor, whose temperature is above that of saturation is superheated*.*

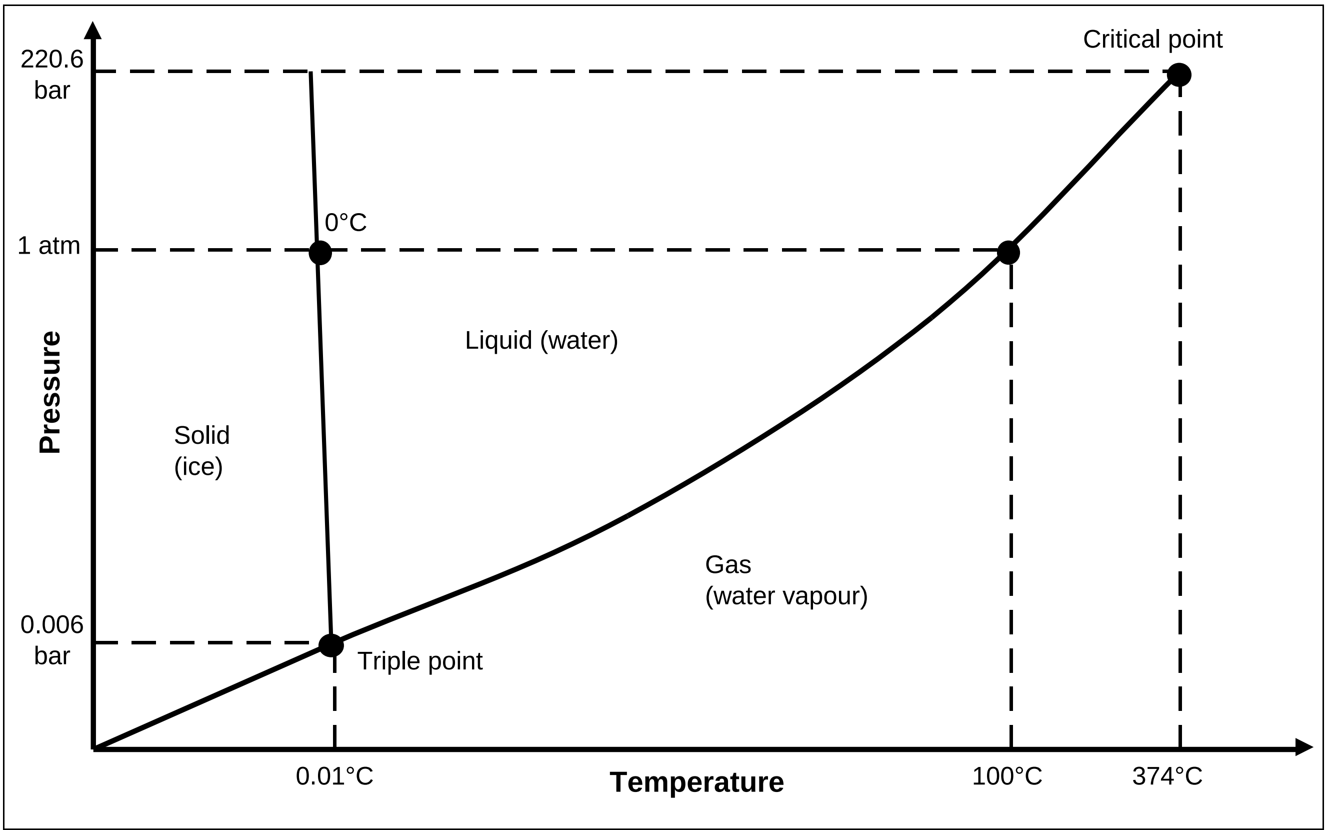



*Figure 7.2.5-1: Phase diagram for water*

Along the saturation curve the fluid is a two-phase mixture of liquid and vapor. From *7.2.5-1* it is however unclear how much of each phase is effectively present in the mixture. Therefore a second diagram, called *saturation diagram,* is necessary reporting the specific enthalpy of the vapor and the liquid at any saturation temperature or pressure, see Fig. *7.2.5-2* for water and steam.

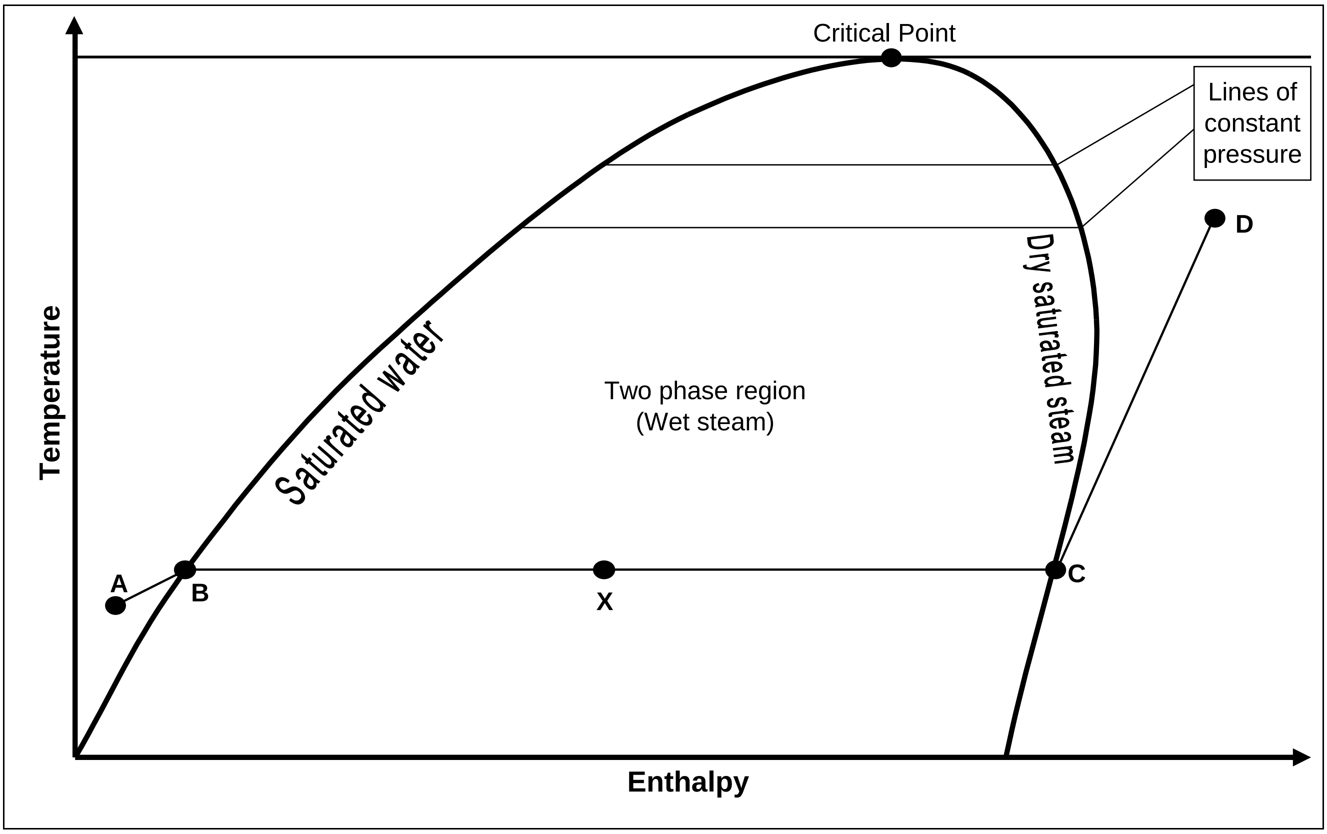



*Figure 7.2.5-2: Saturation diagram for water and steam.*

The diagram is made up of three sectors: the sub-cooled liquid region is on the left side, the region of superheated steam on the right and the two-phase region lies in the middle below the belt given by the saturation curves of vapor and liquid.

It shall be assumed that steam in a pressurized vessel at constant pressure is cooled from the initial state of superheated steam (Point D) to that of sub-cooled water (Point A). The first cooling reduces the temperature of steam until it reaches saturation. Any further cooling does not lead to a decrease in temperature but to condensation of some vapor: in any Point X the medium is present as a two-phase mixtures. The condensation goes on until the condition of saturated steam (Point C) is reached. Any further cooling of the now fully condensed water leads to a temperature reduction.

The difference between the enthalpy of the saturated liquid and that of the vapor is called latent heat of evaporation, Eq. *7.2.5-1*

$$\Delta h_{GL} = h_G - h_L \quad \textit{(Eq. 7.2.5-1)}$$

Fig. *7.2.5-2* shows that the latent heat of evaporation diminishes with the increase in the saturation pressure until it disappears at the critical point. From the knowledge of the enthalpy of the mixture and those of vapor and liquid the percental weight of steam in the mixture or quality can be calculated on the base of Eq. *7.2.5-2*

$$x = \frac{h_{mix} - h_L}{h_G - h_L} \quad \text{(Eq. 7.2.5-2)}$$

Graphically, the quality $x$ is the ratio of the segment between Point B und Point X to that of the segment between Point B und Point C of Fig. *7.2.5-1*

The saturation diagram is not representative to estimate the quality of a two-phase mixture, which is vented in a safety valve in a very short time. The fast depressurization in the safety valve can cause some evaporation of the liquid, which is usually referred to as flashing. If the liquid is very subcooled or the medium is a two-phase mixture of a liquid with a non-condensable gas, it is more possible that no phase change occurs at all and that the quality of the mixture, here meaning the percental weight of the gas in the mixture, remains constant during the flow. This type of two-phase flows is called frozen.

### 7.2.6 Examples

#### 7.2.6.1 Calculation of the Compressibility Factor of a Gas

**Example 7.2.6.1**. What is the compressibility factor of ethylene ($C_2H_4$) at the relieving condition of 55°C (328.15 K) and 62 bar a?

*Solution*. The first step is to find the critical temperature and pressure of ethylene. From Table *7.6.1-1* they are respectively 282.85 K and 51.57 bar. The reduced temperature and pressure at the relieving condition are then

$$T_r = \frac{T}{T_c} = \frac{328.15\ K}{282.85\ K} = 1.16 \qquad p_r = \frac{p}{p_c} = \frac{62\ bar\,a}{51.57\ bar\,a} = 1.20$$

implying a compressibility factor of around 0.712 according to Fig. 7.2.2-1.

#### 7.2.6.2 Critical and Subcritical Gas Flow

**Example 7.2.6.2**. A buffer reservoir filled with air at 6 bar ($k = 1.4$) vents to the ambience. Determine if the flow is critical or not.

*Solution*. The critical pressure ratio Eq. 7.2.3-2 is equal to

$$\frac{p_c}{p_0} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = \left(\frac{2}{1.4+1}\right)^{\frac{1.4}{1.4-1}} = 0.528$$

The back pressure to relief pressure ratio for this valve is equal to

$$\frac{p_b}{p_0} = \frac{1.01325\ bar}{6\ bar} = 0.169$$

which is below the critical pressure ratio and therefore the flow is critical.

## 7.3 Sizing Formulas - Summary

The following overview is a short summary of the main sizing formulas covered in the following sections.
The information contained in this section is based on following editions of codes and standards: ASME Section XIII (2021), ASME Section VIII (2021) and API RP 520 (2020), ISO 4126-7 (2016), AD Merkblatt 2000-A2 (2020).

| Medium | Unit | ASME XIII (ASME VIII) / API RP 520 | ISO 4126-7 | AD 2000 Merkblatt A2 |
|---|---|---|---|---|
| **Gases and Vapors- critical flow** | **US** | $A=\frac{W}{C\ K_b K_c K_d P_1}\sqrt{\frac{T\ Z}{M}}$ | $A=\frac{Q_m}{p_0 C\ K_{dr}}\sqrt{\frac{T_0 Z}{M}}$ | $A_0=0.1791\frac{q_m}{\psi\ \alpha_w p_0}\sqrt{\frac{T\ Z}{M}}$ |
| | **SI** | | | |
| **Gases and Vapors- subcritical flow -** | **US** | $A=\frac{1}{735}\frac{W}{F_2 K_c K_d}\sqrt{\frac{T\ Z}{M\ P_1}\frac{1}{P_1-P_2}}$ | | |
| | **SI** | $A=\frac{17.9\times W}{F_2 K_d K_c}\sqrt{\frac{ZT}{M\times P_1(P_1-P_2)}}$ | $A=\frac{Q_m}{p_0 C\ K_b K_{dr}}\sqrt{\frac{T_0 Z}{M}}$ | |
| **Steam** | **US** | $A=\frac{1}{51.5}\cdot\frac{W}{P_1 K_b K_c K_d K_N K_{SH}}$ | | |
| | **SI** | $A=\frac{190.5\times W}{P_1 K_d K_b K_c K_N K_{SH}}$ | $A=\frac{1}{0.2883}\ \frac{Q_m}{C\ K_{dr}}\sqrt{\frac{v}{p_0}}$ | $A_0=\frac{x\ q_m}{\alpha_w p_0}$ |
| **Liquids** | **US** | $A_{corr}=\frac{1}{38}\cdot\frac{Q}{K_c K_d K_v K_w}\sqrt{\frac{G}{P_1-P_2}}$ | | |
| | **SI** | $A=\frac{11.78\times Q}{K_d K_w K_c K_v}\sqrt{\frac{G1}{P_1-P_2}}$ | $A=\frac{1}{1.61}\frac{Q_m}{K_{dr} K_v}\sqrt{\frac{v}{p_0-p_b}}$ | $A_0=0.6211\frac{q_m}{\alpha_w\sqrt{\rho(p_0-p_a)}}$ |
| **Reference** | | **Section 7.4** | **Section 7.5** | **Section 7.6** |

*Table 7.3-1: Summary sizing formulas*

### General symbols:

A : Flow area, orifice area
G : Specific gravity (*process*)
Q : Volume flow (*process*)
$W/Q_m$ : Mass flow (*process*)
$Z/T_0$ : Relieving temperature (*process*)
v : Specific volume (*process*)
Z : Compressibility factor (*process*)

### Symbols in ASME XIII (ASME VIII) / API RP 520:

$F_2$ : Coefficient of subcritical flow see Eq. 7.4.4-1
$K_b$ : Capacity correction factor due to back pressure (gas, vapors, steam) see Fig. 7.4.3-1
$K_c$ = 1 (safety valve without rupture disk) and 0.9 (safety valve with rupture disk)
$K_d$ : Discharge coefficient (*LESER catalog*)
$K_N$ : Correction factor for Napier equation see Eq. 7.4.5-2 and Eq. 7.4.5-3
$K_{SH}$ : Superheat steam correction factor see Table 7.4.5-1
$K_v$ : Correction factor due to viscosity see Eq. 7.4.6-2
$K_w$ : Correction factor due to the back pressure (liquids) see Fig. 7.4.3-2
$P_1$ : Relieving pressure (*process*)
$P_2$ : Back pressure (*process*)
C : Coefficient

The coefficient C is determined as follows.

In USC units:

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{(k+1)}{(k-1)}}}$$

In SI units:

$$C = 0.03948\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{(k+1)}{(k-1)}}}$$

### Symbols in ISO 4126-7:

C : Function of the isentropic coefficient see Eq. 7.5.3-2

$$C = 3.948\sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}$$

$K_b$ : Theoretical capacity correction factor for subcritical flow see Eq. 7.5.5.2-2
$K_{dr}$ : Certified derated coefficient of discharge (*LESER catalog*)
$K_v$ : Viscosity correction factor see Fig. 7.9.3-1
$p_0$ : Relieving pressure (*process*)
$p_b$ : Back pressure (*process*)

### Symbols in AD Merkblatt A2:

$p_0$ : Relieving pressure (*process*)
$p_b$ : Back pressure (*process*)
$\alpha_w$ : Certified coefficient of discharge (*LESER catalog*)
$\psi$ : Outflow function (gas flows) see Table 7.6.2-1
x : Pressure medium coefficient (gas flows) or vapour void fraction (two-phase flows), see Eq. 7.6.3-2

## 7.4 Sizing according to ASME Sect. XIII (ASME Sect. VIII), API RP 520 and API 521

The information contained in this section is based on following editions of codes and standards: ASME Section XIII (2021), ASME Section VIII (2021), API RP 520 (2020), API 521 (2020), API 526 (2017), API Standard 2000 (2014), API Standard 2510 (2001), ISO 23251(2020), prEN 14015-1 (2000)

### 7.4.1 Premise on ASME Section XIII and API RP 520

The ASME Code is a pressure vessel code that covers the certification of safety valves for the flows of saturated steam, water, air and natural gas (Section XIII chapter 7.8).

API RP 520 is a recommended practice to standardize the pre-selection of safety valves for gases, vapors, liquids and two-phase flow service already in the design phase of the plant. API RP 520 uses the same basic formulas as the ASME Code but extends them with correction factors, e.g. for back pressure and viscosity, to make them applicable to many practical applications.

Both the ASME Code and API RP 520 apply for relieving pressures above 15 psig.

In API RP 520 the pre-selection of a safety valve requires the determination of an *effective relief area* and an *effective coefficient of discharge*, which are nominal values and therefore independent from the selection of either the design or the manufacturer. The effective relief areas are those listed in API 526 in increasing order from letter D to T.

Once the safety valve orifice is selected it must be proven that the certified capacity meets or exceeds that of the preliminary sizing. For this calculation the engineer must use the *actual discharge coefficient* and the *actual discharge area* from the manufacturer's catalog. In many practical cases it is enough to verify that the product of the actual area and the actual discharge coefficient exceeds that of the effective area and the effective discharge coefficient, as shown in Eq. *7.4.1-1* Actual orifice areas and discharge coefficient of LESER safety valves are documented in the *ASME NB-18* (*Red Book)*[3].

$$K_{actual} \cdot A_{actual} \geq K_{d-effective} \cdot A_{effective} \quad \text{(Eq. 7.4.1-1)}$$

LESER facilitates the selection of the safety valves by introducing LEO (LESER Effective Orifice). By using LEO the engineer can select the final size of the safety valve after the preliminary sizing by choosing a valve with a LEO larger than the effective orifice.

$$LEO = A_{actual} \cdot K_{actual} / K_{d-effective} \quad \text{(Eq. 7.4.1-2)}$$

[3] ASME National Board Pressure Relief Device Certifications NB-18, Edition: 2021
NB-18, Pressure Relief Device Certification (nationalboard.org)

The actual discharge coefficients must be certified by ASME. The application of API RP 520 formulas with the ASME certified actual discharge coefficient and the actual relief areas from the manufacturers' catalog is commonly called "*Sizing acc. to ASME Section XIII (ASME Section VIII)*".

ASME Section XIII (ASME VIII) and API RP 520 are interconnected with each other and it is therefore common practice to present them together as a unique sizing procedure. All formulas are cited here in US units.

In VALVESTAR® a similar structure is present:

- The option "Sizing acc. to ASME XIII (ASME VIII)" is a one-step sizing procedure considering the sizing formulas in API RP 520 with their correction factors and using the actual discharge areas and actual discharge coefficients.
- The option "Sizing acc. to API RP 520" considers the two-step sizing procedure discussed before.

In both cases the same safety valve will be selected.

Table *7.4.1-1* lists the effective and the actual discharge coefficients as well as the effective and actual discharge areas for LESER API Series Type 526.

| Medium | API RP 520 | ASME Code Sect. XIII (ASME Code Sect. VIII) LESER API Series 526 |
|---|---|---|
| | $K_{d-effective}$ [-] | $K_{actual}$ [-] |
| Gas, vapors, steam | 0.975 | 0.455 (Orifice D)<br>0.801 (Orifice E-T) |
| Liquid | 0.65 | 0.343 (Orifice D)<br>0.579 (Orifice E-T) |
| Two-phase flows | 0.85 | No certification procedure |

| Orifice letter | API RP 520 Effective discharge area | | ASME XIII (ASME VIII) Actual discharge area LESER API Series 526 | |
|---|---|---|---|---|
| | [in²] | [mm²] | [in²] | [mm²] |
| D | 0.110 | 71 | 0.239 | 154 |
| E | 0.196 | 126 | 0.239 | 154 |
| F | 0.307 | 198 | 0.394 | 254 |
| G | 0.503 | 325 | 0.616 | 398 |
| H | 0.785 | 506 | 0.975 | 625 |
| J | 1.287 | 830 | 1.58 | 1018 |
| K | 1.838 | 1186 | 2.25 | 1452 |
| L | 2.853 | 1841 | 3.48 | 2248 |
| M | 3.600 | 2322 | 4.43 | 2846 |
| N | 4.340 | 2800 | 5.30 | 3421 |
| P | 6.380 | 4116 | 7.79 | 5026 |
| Q | 11.050 | 7129 | 13.55 | 8742 |
| R | 16.000 | 10322 | 19.48 | 12668 |
| T | 26.000 | 16774 | 31.75 | 20485 |

*Table 7.4.1-1: Effective and actual discharge coefficients and discharge areas for LESER API Series Type 526*

### 7.4.2 List of Symbols/Nomenclature According to API RP 520

| Symbol | Description | Units [US] |
|---|---|---|
| $A$ | Required discharge area of the safety valve | in$^2$ |
| $C$ | Coefficient determined from an expression of the ratio of specific heats of the gas or vapor at relieving conditions | $\frac{\sqrt{lb \cdot lb_{mol} \cdot °R}}{lb_f \cdot hr}$ |
| $F_2$ | Coefficient of subcritical flow | -- |
| $G$ | Specific gravity of the gas at standard conditions referred to air at standard conditions or<br>Specific gravity of the liquid at flowing temperature referred to water at standard conditions | -- |
| $k$ | Ratio of the specific heats | -- |
| $K_b$ | Capacity correction factor due to back pressure (gas, vapors, steam).<br>Applies to balanced bellows valves only | -- |
| $K_c$ | Combination correction factor for safety valves installed with a rupture disk upstream of the valve | -- |
| $K_d$ | Discharge coefficient | -- |
| $K_N$ | Correction factor for Napier equation | -- |
| $K_{SH}$ | Superheat steam correction factor | -- |
| $K_v$ | Correction factor due to viscosity | -- |
| $K_w$ | Correction factor due to the back pressure (liquids).<br>Applies to balanced bellows valves only | -- |
| $M$ | Molecular weight of the gas or vapor at inlet relieving conditions | $lb/lb_{mol}$ |
| $P_1$ | Relieving pressure | psi |
| $P_2$ | Back pressure | psi |
| $Q$ | Flow rate | gpm |
| $T$ | Relieving temperature | °R |
| $U$ | Viscosity of the liquid at the flowing temperature | SSU |
| $V$ | Required flow through the device | scfm at 14.7 psia and 60°F |
| $W$ | Required flow | lb/hr |
| $Z$ | Compressibility factor for the deviation of the actual gas from a perfect gas, evaluated at relieving conditions | -- |
| $\mu$ | Absolute viscosity of the liquid at the flowing temperature | cP |

*Table 7.4.2-1: List of symbols*

The relieving pressure $P_1$ is defined in Eq. 7.4.2-1 as the sum of the set pressure, the overpressure and the atmospheric value.

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} \quad \text{(Eq. 7.4.2-1)}$$

The correction factor for the back pressure, $K_b$, is obtainable from LESER's catalog. Pilot and conventional valves in critical flows do not necessitate such a correction. The combination correction factor $K_c$ in the preliminary sizing must be taken equal to 0.9 if a rupture disk is inserted upstream of the valve. Otherwise $K_c = 1.0$.

### 7.4.3 Gases and Vapors - Critical Flow

$$A = \frac{W}{C\ K_b K_c K_d P_1}\sqrt{\frac{T\,Z}{M}} \quad \text{(Eq. 7.4.3-1)}$$

$$A = \frac{1}{6.32}\frac{V\sqrt{TZM}}{CK_b K_c K_d P_1} \quad \text{(Eq. 7.4.3-2)}$$

$$A = \frac{1}{1.175}\frac{V\sqrt{TZG}}{CK_b K_c K_d P_1} \quad \text{(Eq. 7.4.3-3)}$$

The correction factor due to the back pressure $K_b$ for the preliminary sizing is given in Fig. 7.4.3-1

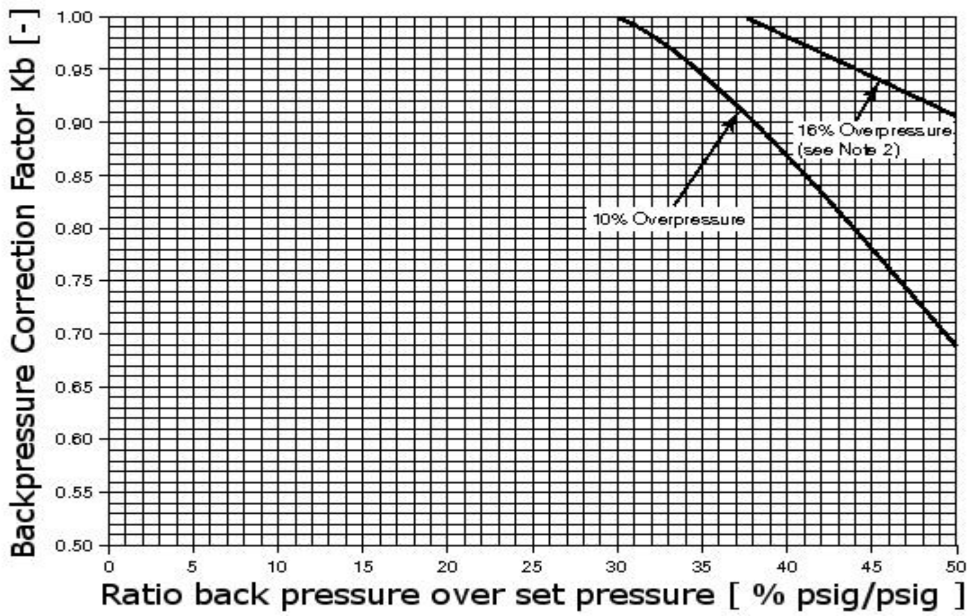



*Figure 7.4.3-1: Back pressure correction factor for gases and vapors $K_b$ from API RP 520, Page 59*

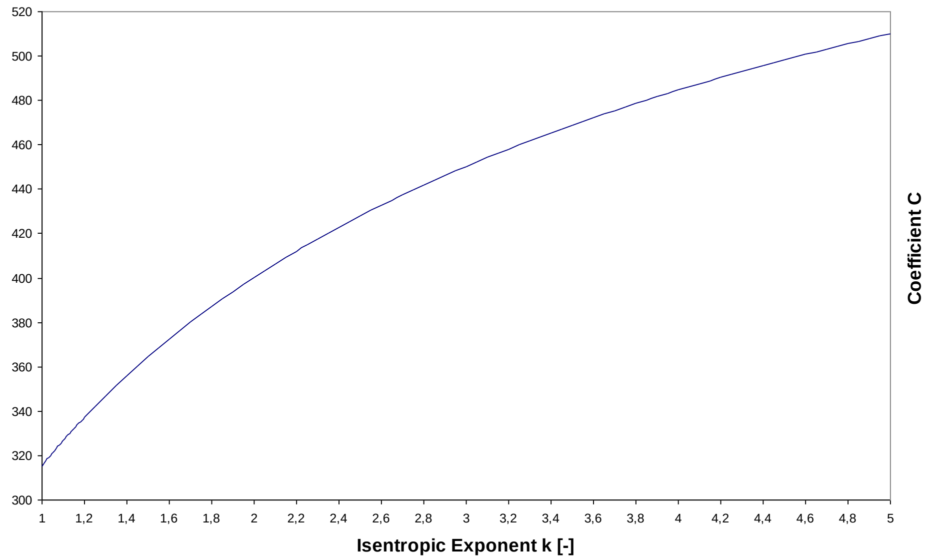



*Figure 7.4.3-2: Coefficient $C$ in function of the specific heat ratio from API RP 520, Page 74.*

In alternative to Fig. *7.4.3-1* the coefficient C can be calculated from Eq. 7.4.3-4

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad \text{Unit: } \frac{\sqrt{lb_m lb_{mol} \,^\circ R}}{lb_f hr} \qquad \textit{(Eq. 7.4.3-4)}$$

### 7.4.4 Gases and Vapors - Subcritical Flow

$$A = \frac{1}{735}\frac{W}{F_2 K_c K_d}\sqrt{\frac{T\,Z}{M\;P_1}\frac{1}{P_1 - P_2}} \quad \textit{(Eq. 7.4.4-1)}$$

$$A = \frac{1}{4645}\frac{V}{F_2 K_c K_d}\sqrt{\frac{ZTM}{P_1(P_1 - P_2)}} \quad \textit{(Eq. 7.4.4-2)}$$

$$A = \frac{1}{864}\frac{V}{F_2 K_c K_d}\sqrt{\frac{ZTG}{P_1(P_1 - P_2)}} \quad \textit{(Eq. 7.4.4-3)}$$

or equivalently

$$A = \frac{1}{735}\frac{W}{F_2 K_c K_d P_1}\sqrt{\frac{T\,Z}{M}\frac{1}{1-r}} \quad \text{with} \quad r = \frac{P_1}{P_2} \quad \textit{(Eq. 7.4.4-4)}$$

where $F_2$ is calculated from Eq. *7.4.4-5* or obtained from Fig. *7.4.4-1*

$$F_2 = \sqrt{\frac{k}{k-1}\cdot r^{\frac{2}{k}}\cdot\frac{1-r^{\frac{k-1}{k}}}{1-r}} \quad \textit{(Eq. 7.4.4-5)}$$

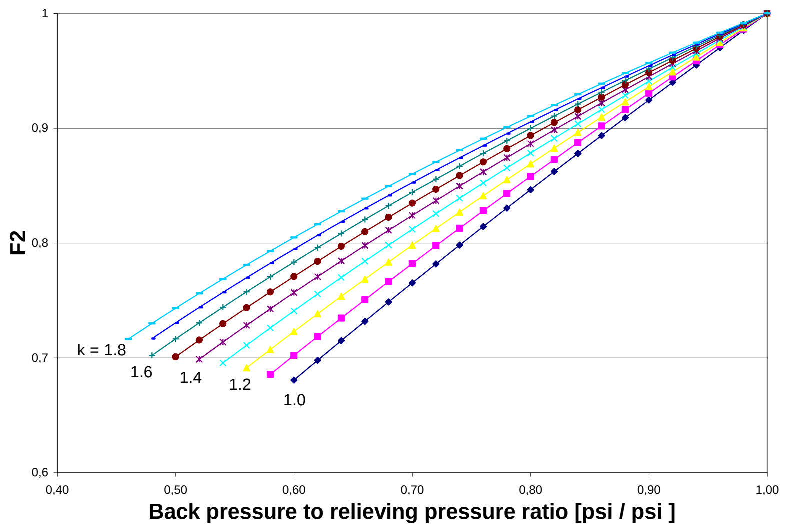



*Figure 7.4.4-1: Coefficient $F_2$ in function of the ratio of absolute back pressure on absolute relieving pressure for various specific heat ratios.*

### 7.4.5 Steam

$$A = \frac{1}{51.5} \cdot \frac{W}{P_1 K_b K_c K_d K_N K_{SH}} \quad \text{(Eq. 7.4.5-1)}$$

The correction factor for Napier equation $K_N$ is expressed by Eq. *7.4.5-2* and *7.4.5-3*

$$K_N = \frac{0.1906 \cdot P_1 - 1000}{0.2292 \cdot P_1 - 1061} \quad \text{if} \quad P_1 > 1500 \quad psia \quad \text{(Eq. 7.4.5-2)}$$

$$K_N = 1 \quad \text{if} \quad P_1 \leq 1500 \quad psia \quad \text{(Eq. 7.4.5-3)}$$

The Superheat steam correction factor $K_{SH}$ can be taken from Table 7.4.5-1, which is extracted from Table 9 on Page 51 of API RP 520.

| Set pressure [psig] | Temperature [°F] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 |
| 15 | 1.00 | 0.98 | 0.93 | 0.88 | 0.84 | 0.80 | 0.77 | 0.74 | 0.72 | 0.70 |
| 20 | 1.00 | 0.98 | 0.93 | 0.88 | 0.84 | 0.80 | 0.77 | 0.74 | 0.72 | 0.70 |
| 40 | 1.00 | 0.99 | 0.93 | 0.88 | 0.84 | 0.81 | 0.77 | 0.74 | 0.72 | 0.70 |
| 60 | 1.00 | 0.99 | 0.93 | 0.88 | 0.84 | 0.81 | 0.77 | 0.75 | 0.72 | 0.70 |
| 80 | 1.00 | 0.99 | 0.93 | 0.88 | 0.84 | 0.81 | 0.77 | 0.75 | 0.72 | 0.70 |
| 100 | 1.00 | 0.99 | 0.94 | 0.89 | 0.84 | 0.81 | 0.77 | 0.75 | 0.72 | 0.70 |
| 120 | 1.00 | 0.99 | 0.94 | 0.89 | 0.84 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 140 | 1.00 | 0.99 | 0.94 | 0.89 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 160 | 1.00 | 0.99 | 0.94 | 0.89 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 180 | 1.00 | 0.99 | 0.94 | 0.89 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 200 | 1.00 | 0.99 | 0.95 | 0.89 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 220 | 1.00 | 0.99 | 0.95 | 0.89 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 240 | 1.00 | 1.00 | 0.95 | 0.90 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 260 | 1.00 | 1.00 | 0.95 | 0.90 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 280 | 1.00 | 1.00 | 0.96 | 0.90 | 0.85 | 0.81 | 0.78 | 0.75 | 0.72 | 0.70 |
| 300 | 1.00 | 1.00 | 0.96 | 0.90 | 0.85 | 0.82 | 0.78 | 0.75 | 0.72 | 0.70 |
| 350 | | 1.00 | 0.96 | 0.90 | 0.86 | 0.82 | 0.78 | 0.75 | 0.72 | 0.70 |
| 400 | | 1.00 | 0.96 | 0.91 | 0.86 | 0.82 | 0.78 | 0.75 | 0.72 | 0.70 |
| 500 | | 1.00 | 0.96 | 0.92 | 0.86 | 0.82 | 0.78 | 0.75 | 0.73 | 0.70 |
| 600 | | 1.00 | 0.97 | 0.92 | 0.87 | 0.82 | 0.79 | 0.75 | 0.73 | 0.70 |
| 800 | | | 1.00 | 0.95 | 0.88 | 0.83 | 0.79 | 0.76 | 0.73 | 0.70 |
| 1000 | | | 1.00 | 0.96 | 0.89 | 0.84 | 0.78 | 0.76 | 0.73 | 0.71 |
| 1250 | | | 1.00 | 0.97 | 0.91 | 0.85 | 0.80 | 0.77 | 0.74 | 0.71 |
| 1500 | | | | 1.00 | 0.93 | 0.86 | 0.81 | 0.77 | 0.74 | 0.71 |
| 1750 | | | | 1.00 | 0.94 | 0.86 | 0.81 | 0.77 | 0.73 | 0.70 |
| 2000 | | | | 1.00 | 0.95 | 0.86 | 0.80 | 0.76 | 0.72 | 0.69 |
| 2500 | | | | 1.00 | 0.95 | 0.85 | 0.78 | 0.73 | 0.69 | 0.66 |
| 3000 | | | | | 1.00 | 0.82 | 0.74 | 0.69 | 0.65 | 0.62 |

*Table 7.4.5-1: Correction factors $K_{SH}$ for superheat steam acc. to API RP 520 Page 86*

## 7.4.6 Liquids

$$A = \frac{1}{38} \cdot \frac{Q}{K_c K_d K_v K_w} \sqrt{\frac{G}{P_1 - P_2}} \quad \textit{(Eq. 7.4.6-1)}$$

The correction factor due to the back pressure $K_w$ for the preliminary sizing can be read from Fig. *7.4.6-1*. The correction factor due to viscosity $K_v$ can be either calculated from Eq. *7.4.6-2.*

$$K_v = \left(\frac{170}{Re_L} + 1\right)^{-0.5}$$

…*(Eq. 7.4.6-2)*

by using the definition of the Reynolds number in Eq. *7.4.6-3*

$$\mathrm{Re} = 2800 \frac{Q\,G}{\mu\,\sqrt{A}} \quad \text{or} \quad \mathrm{Re} = 12700 \frac{Q}{U\,\sqrt{A}} \quad \textit{(Eq. 7.4.6-3)}$$

or graphically estimated from Fig. 7.2.4-2. When a safety valve is to be sized for viscous liquids, it should first be sized as the fluid were in viscid ($K_v = 1$) to obtain a preliminary minimum discharge area using Eq. *7.4.6-1*. The next larger effective orifice area is then selected from Table 7.4.1-1 to calculate the Reynolds number in Eq. 7.4.6-3, which is used to determine the viscosity correction factor in Eq. 7.4.6-2. This correction factor $K_v$ is introduced back into Eq. *7.4.6-1* to correct the preliminary discharge area. If the corrected area exceeds the chosen standard orifice, this procedure should be repeated using the next larger standard orifice area from Table 7.4.1-1.

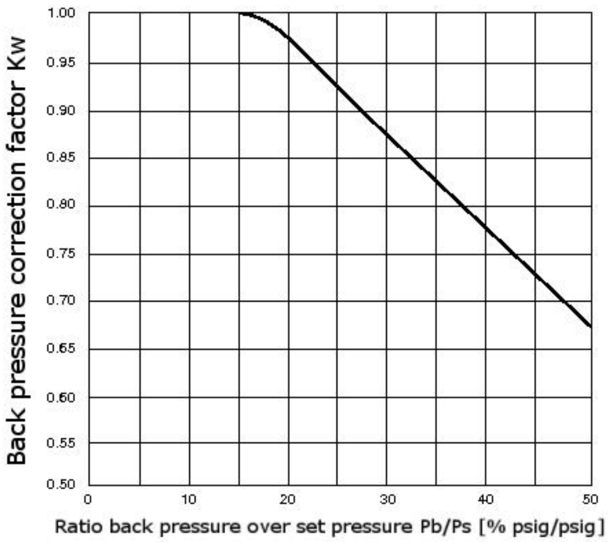



*Figure 7.4.6-1: Back pressure correction factor for liquids $K_w$ from API RP 520, Page 60*

### 7.4.7 Two-Phase Flows according to API RP 520

This first subchapter incl. 7.4.7.3 represent an older edition of the API 520 , 7th Edition, 2000, Appendix D. It shall remain in order to continue to provide the calculation logic of superseded case definitions as a calculation archive. The subchapter 7.4.7.4 and 7.4.7.5 of API 520, 10$^{th}$ Edition 2020 contain current sizing methods.

In API RP 520 on page 69 there is a short preface intended for people approaching two-phase flow calculation routines. The reader is invited to read it carefully before using this sizing procedure.

The most relevant points are that

1. This sizing procedure is just one of the several techniques currently in use.
2. This sizing procedure has not been yet validated by tests.
3. There is no recognized procedure for the certification of safety valves in two-phase flows.

Two-phase flows occur in a variety of scenarios, where either

- a liquid vaporizes within the safety valve, or
- a two-phase mixture enters the safety valve or
- a vapor condenses in the safety valve
- a supercritical fluid enters the safety valve and condenses

In all cases a two-phase mixture is likely to be discharged from the safety valve.

The complete list of the two-phase flow scenarios for safety valves is presented in Table 7.4.7-1.

| | |
|---|---|
| Saturated liquid and saturated vapor enter the valve and the liquid flashes. No non-condensable gas is present (*flashing flow*). | See section 7.4.7.1 |
| Supercritical fluid condensing in the safety valve. | |
| Highly subcooled liquid and either non-condensable gas, condensable vapors or both enter the valve but the liquid does not flash (*frozen flow*). | See section 7.4.7.2 |
| Subcooled liquid enters the valve and flashes. No vapor or gas is present at the inlet. | See section 7.4.7.3 |
| Generic two-phase flow with a subcooled or saturated liquid and non-condensable gas with or without condensable vapor. | (not present in this chapter) |

*Table 7.4.7-1: Two-phase flow scenarios*

The sizing procedure of API RP 520 Appendix D is based on the Omega method of Leung[4]. This sizing method uses the so-called Omega-parameter, which is a measure of the compressibility of the two-phase mixture.

The required steps of this method are:

- Calculation of the Omega-Parameter
- Determination if the flow is critical or subcritical
- Calculation of the mass flux, which is the mass flow per unit area
- Calculation of the required orifice area of the safety valve among those in API RP 526

[4] Leung, J.C. *On the application of the method of Landau and Lifshitz to sonic velocities in homogeneous two-phase mixtures*, **J. Fluids Engineering**, 1996, 118, 1,186–188.

Some additional nomenclature, which is necessary for two-phase flows, is given in Table 7.4.7-2.

| Symbol | Description | Units [US] |
|---|---|---|
| $C_p$ | Specific heat at constant pressure of the liquid at the safety valve inlet | Btu/(lb °R) |
| $G$ | Mass flux | lb/(s ft²) |
| $h_{vl0}$ | Latent heat of vaporization at the safety valve inlet. For multicomponent systems, it represents the difference between the vapor and the liquid specific enthalpies at the safety valve inlet | Btu/lb |
| $h_{vls}$ | Latent heat of vaporization at $P_s$. For multi-component systems it is the difference between the vapor and liquid specific enthalpies at $P_s$ | Btu/lb |
| $P_1$ | Pressure at safety valve inlet | psi |
| $P_a$ | Downstream back pressure | psi |
| $P_c$ | Critical pressure | psi |
| $P_r$ | Relative pressure | [--] |
| $P_s$ | Saturation pressure (single-component flows) or bubble point pressure (multi-component flows) at the relieving temperature $T_0$ | psi |
| $Q$ | Volumetric flow rate | gal/min |
| $T_0$ | Temperature at safety valve inlet | °R |
| $T_r$ | Relative temperature | [--] |
| $v_{v0}$ | Specific volume of the vapor at safety valve inlet | ft³/lb |
| $v_0$ | Specific volume of the two-phase mixture at safety valve inlet | ft³/lb |
| $v_{vg0}$ | Specific volume of the vapor, gas or combined vapor and gas at the safety valve inlet | ft³/lb |
| $v_{vl0}$ | Difference between the vapor and the liquid specific volumes at the safety valve inlet | ft³/lb |
| $v_{vls}$ | Difference between the vapor and the liquid specific volumes at $P_s$ | ft³/lb |
| $v_9$ | Specific volume evaluated at 90% of the safety valve inlet pressure (= relieving pressure), assuming isentropic flashing | ft³/lb |
| $x_0$ | Vapor (or gas or combined vapor and gas) mass fraction (quality) at safety valve inlet | [--] |
| $\eta_a$ | Ratio between ambient pressure and relieving pressure | [--] |
| $\eta_c$ | Ratio between critical pressure and relieving pressure | [--] |
| $\eta_s$ | Ratio between saturation pressure at relieving temperature and relieving pressure | [--] |
| $\rho_{l0}$ | Density of the liquid at the inlet of the safety valve | lb/ft³ |
| $\rho_9$ | Density evaluated at 90% of the saturation pressure (single-component flows) or bubble point pressure (multi-component flows) $P_s$ at $T_0$. The flash calculation should be carried out isentropically. | lb/ft³ |
| $\omega$ | Omega Parameter | [--] |
| $\omega_s$ | Omega Parameter for subcooled liquid flows at safety valve inlet | [--] |

*Table 7.4.7-2: List of symbols for two-phase flows*

### 7.4.7.1 Saturated Liquid and Saturated Vapor, Liquid Flashes

The definitions of the Omega-Parameter in Eq. *7.4.7.1-1*, *7.4.7.1-2* and *7.4.7.1-3* can be employed for multi-component systems, whose nominal boiling range, that is the difference in the atmospheric boiling points of the heaviest and the lightest components, is less than 150°F. For single-component systems with relative temperature $T_r \leq 0.9$ (see Eq. 7.2.2-4) and pressure (see Eq. 7.2.2-5) $p_r \leq 0.5$, either Eq. 7.4.7.1-1 or Eq. 7.4.7.1-2 can be used.

$$\omega = \frac{x_0 v_{v0}}{v_0} \cdot \left(1 - 0.37 \frac{P_1 \cdot v_{vl0}}{h_{vl0}}\right) + 0.185 \frac{C_p T_0 P_1}{v_0} \left(\frac{v_{vl0}}{h_{vl0}}\right)^2 \quad \text{(Eq. 7.4.7.1-1)}$$

$$\omega = \frac{x_0 v_{v0}}{v_0 k} + 0.185 \frac{C_p T_0 P_1}{v_0} \left(\frac{v_{vl0}}{h_{vl0}}\right)^2 \quad \text{(Eq. 7.4.7.1-2)}$$

For multi-component systems, whose nominal boiling range is greater than 150°F or for single-component systems close to the thermodynamic critical point or supercritical fluids in condensing two-phase flows Eq. 7.4.7.1-3 must be used.

$$\omega = 9\left(\frac{v_9}{v_0} - 1\right) \quad \text{(Eq. 7.4.7.1-3)}$$

The two-phase flow is critical if the critical pressure is larger than the back pressure

$P_c > P_b \Rightarrow$ the two-phase flow is *critical*

$P_c < P_b \Rightarrow$ the two-phase flow is *subcritical*

The critical pressure ratio, $\eta_c = P_c / P_1$, is the iterative solution of Eq. 7.4.7.1-4

$$\eta_c^2 + \left(\omega^2 - 2\omega\right)\left(1 - \eta_c\right)^2 + 2\omega^2 \ln\left(\eta_c\right) + 2\omega^2\left(1 - \eta_c\right) = 0 \quad \text{(Eq. 7.4.7.1-4)}$$

The mass flux is defined in Eq. 7.4.7.1-5 for critical flow and in Eq. 7.4.7.1-6 for subcritical flow

| | | |
|---|---|---|
| $G = 68.09 \cdot \eta_c \cdot \sqrt{\frac{1}{\omega}\frac{P_1}{v_0}}$ | critical flow | *(Eq. 7.4.7.1-5)* |
| $G = 68.09\sqrt{\frac{P_1}{v_0}}\frac{\sqrt{-2 \cdot \left[\omega \ln\left(P_a/P_1\right) + \left(\omega - 1\right)\left(1 - P_a/P_1\right)\right]}}{\omega\left(P_1/P_a - 1\right) + 1}$ | subcritical flow | *(Eq. 7.4.7.1-6)* |

Finally, the required area of the safety valve can be computed from Eq. 7.4.7.1-7

$$A = 0.04 \cdot \frac{1}{K_b K_c K_d} \cdot \frac{W}{G} \quad \text{(Eq.7.4.7.1-7)}$$

For a preliminary sizing to calculate the effective orifice area the discharge coefficient $K_d$ can be assumed equal to 0.85 and the correction factor for back pressure is that in Fig 7.4.3-1.

7.4.7.2 Highly Subcooled Liquid, Non-Condensable Gas/Condensable Vapors, Non-Flashing Liquid (Frozen Flow).

Same sizing procedure as in Section 7.4.7.1 but with the Omega Parameter in Eq. 7.4.7.2-1

$$\omega = \frac{x_0 v_{vg0}}{v_0 k} \quad \textit{(Eq. 7.4.7.2.-1)}$$

7.4.7.3 Subcooled Liquid enters the Valve and Flashes, No Vapor or Gas at the Inlet

For subcooled liquid flows the Omega-Parameter is generally referred with $\omega_s$. For multi-component systems with nominal boiling range less than 150°F $\omega_s$ can be calculated either from Eq. 7.4.7.3-1 or from Eq. 7.4.7.3-2. For single component systems with a relative temperature and pressure within the limits $T_r \le 0.9$ and $p_r \le 0.5$ $\omega_s$ is given by Eq. 7.4.7.3-1.

$$\omega_s = 0.185 \rho_{l0} C_p T_0 P_s \left( \frac{v_{vls}}{h_{vls}} \right)^2 \quad \textit{(Eq. 7.4.7.3-1)}$$

For multi-component systems, whose nominal boiling range is greater than 150°F or for single-component systems close to the thermodynamic critical point $\omega_s$ is given by Eq. 7.4.7.3-2.

$$\omega_s = 9 \left( \frac{\rho_{l0}}{\rho_9} - 1 \right) \quad \textit{(Eq. 7.4.7.3-2)}$$

When a liquid enters the safety valve in a subcooled state, it is necessary to determine where indicatively it saturates and the extension of the subcooling region on the base of the following table:

| | |
|---|---|
| $P_s > P_0 \frac{2 \cdot \omega_s}{1 + 2 \cdot \omega_s}$ | *low subcooling region*<br>(flashing occurs before the valve throat) |
| $P_s < P_0 \frac{2 \cdot \omega_s}{1 + 2 \cdot \omega_s}$ | *high subcooling region*<br>(flashing occurs at the valve throat) |

The condition for the existence of critical and subcritical flow are:

| | Critical flow | Subcritical flow |
|---|---|---|
| in the low subcooling region | $P_c > P_a$ | $P_c < P_a$ |
| in the high subcooling region | $P_s > P_a$ | $P_s < P_a$ |

The mass flux in case of low and high subcooling is:

| | | | | |
|---|---|---|---|---|
| *Low subcooling region* | $G = 68.09 \frac{\left\{ 2(1-\eta_s) + 2\left[\omega_s \eta_s \ln\left(\eta_s/\eta\right) - (\omega_s - 1)(\eta_s - \eta)\right] \right\}^{0.5}}{\omega_s\left(\eta_s/\eta - 1\right) + 1} \sqrt{P_1 \rho_{l0}}$ | *with* | $\eta = \eta_c$ | Crit. flow |
| | | | $\eta = \eta_a$ | Subcrit. flow |
| *High subcooling region* | $G = 96.3 \left[\rho_{l0} \cdot (P_1 - P)\right]^{0.5}$ | *with* | $P = P_s$ | Crit. Flow |
| | | | $P = P_a$ | Subcrit. flow |

The required area of the pressure relief valve is calculated from Eq. 7.4.7.3-3

$$A = 0.3208 \frac{1}{K_b K_c K_d} \frac{Q \cdot \rho_{l0}}{G} \quad \textit{(Eq.7.4.7.3-3)}$$

The correction factor for back pressure for balanced bellow valves is $K_w$ in Fig. 7.4.6-1. The discharge coefficient $K_d$ for a preliminary sizing is equal to 0.65 for subcooled liquids at the safety valve inlet or 0.85 for saturated liquids.

### 7.4.7.4 Omega Method API 520-1 (2020) Chapter C2.2 Sizing for Two-phase Flashing or Nonflashing Flow Through a pressure-relief valve using the Omega Method

$$\omega = 9\left(\frac{v_9}{v_0} - 1\right)$$ *(Eq. 7.4.7.4-1)*

Note that here for determining $v_9$, it should be evaluated using isentropic flash calculation; but an isenthalpic (adiabatic) flash is sufficient for low quality mixtures far from the thermodynamic critical point.

The two-phase flow is critical if the critical pressure is larger than the back pressure

$P_c > P_b \Rightarrow$ the two-phase flow is *critical*

$P_c < P_b \Rightarrow$ the two-phase flow is *subcritical*

The critical pressure ratio, $\eta_c = P_c / P_1$, is the iterative solution of Eq. 7.4.7.4-2

$$\eta_c^2 + (\omega^2 - 2\omega)(1-\eta_c)^2 + 2\omega^2 \ln(\eta_c) + 2\omega^2 (1-\eta_c) = 0$$ *(Eq. 7.4.7.4-2)*

The mass flux is defined in Eq. 7.4.7.4-3 for critical flow and in Eq. 7.4.7.4-4 for subcritical flow

| | | |
|---|---|---|
| $G = 68.09 \cdot \eta_c \cdot \sqrt{\frac{1}{\omega} \frac{P_1}{v_0}}$ | critical flow | *(Eq. 7.4.7.4-3)* |
| $G = 68.09 \sqrt{\frac{P_1}{v_0}} \frac{\sqrt{-2 \cdot [\omega \ln(P_a/P_1) + (\omega - 1)(1 - P_a/P_1)]}}{\omega (P_1/P_a - 1) + 1}$ | subcritical flow | *(Eq. 7.4.7.4-4)* |

Finally, the required area of the safety valve can be computed from Eq. 7.4.7.4-5

$$A = \frac{0{,}04\ W}{K_b K_d K_c K_v G}$$

$$A = \frac{277.8\ W}{K_b K_d K_c K_v G}$$ *(Eq.7.4.7.4-5)*

For a preliminary sizing to calculate the effective orifice area the discharge coefficient $K_d$ can be assumed equal to 0.85 and the correction factor for back pressure is that in Fig 7.4.3-1.

#### 7.4.7.5 Omega Method API 520-1 (2020) Chapter C2.3 Sizing for Subcooled Liquid at the Pressure-relief Valve Inlet Using the Omega Method considering SI-Units

Calculation for saturated omega parameter can be performed using two pressure specific volume data points ($\rho_{10}$ & $\rho_9$), using following equation

| | |
|---|---|
| $\omega_s = 9\left(\frac{\rho_{10}}{\rho_9} - 1\right)$ | *(Eq. 7.4.7.5-1)* |

Note that for Multicomponent system, the bubble point pressure corresponding to To for Ps should be used.

For determining Density ($\rho_9$) evaluated at 90% of PRV inlet pressure, it should be evaluated using isentropic flash calculation; but an isenthalpic (adiabatic) flash is sufficient for low quality mixtures far from the thermodynamic critical point.

1. Determine the subcooling region:
   a. Calculation of Transition saturation pressure ratio ($\eta_{st}$):

| | |
|---|---|
| $\eta_{st} = \frac{2\omega_s}{1 + 2\omega_s}$ | *(Eq. 7.4.7.5-2)* |

   b. Determine the type (high or low) of subcooling region with following comparison:

   If saturation pressure (Ps) is less than product of transition saturation pressure ratio ($\eta_{st}$) and relieving pressure ($P_0$) then the region will be high subcooling region.

$$If \quad P_s < \eta_{st} P_0 \text{ then high subcooling region (flashing occurs at throat)}$$

   If saturation pressure (Ps) is greater than or equal to the product of transition saturation pressure ratio ($\eta_{st}$) and relieving pressure ($P_0$) then the region will be low subcooling region.

$$If \quad P_s \geq \eta_{st} P_0 \text{ then low subcooling region (flashing occurs upstream of throat)}$$

2. Check for critical or subcritical flow depending on subcooling region (high or low):
   1. Determination of critical or subcritical flow for high subcooling region:

   If saturation pressure (Ps) is greater than or equal to total back pressure (Pa) then flow will be critical flow.

$$If \quad P_s \geq P_a \text{ then flow is critical flow}$$

If saturation Pressure (Ps) is less than the total back pressure (Pa) then flow will be subcritical flow.

$$If \quad P_s < P_a \text{ then flow is subcritical flow (all liquid flow)}$$

2. Determination of critical or subcritical flow for low subcooling region:

A. Calculation of Critical Flow Pressure:

| | |
|---|---|
| $P_c = \eta_c P_0$ | *(Eq. 7.4.7.5-3)* |

i. Considerations for calculation of critical pressure ratio ($\eta_c$):

The critical pressure ratio ($\eta_c$) is dependent on saturation pressure ratio ($\eta_s$) and transition saturation pressure ratio ($\eta_{st}$). The critical pressure is evaluated using following given steps.

a. Calculation for Saturation pressure ratio ($\eta_s$):

| | |
|---|---|
| $\eta_s = \frac{P_s}{P_0}$ | *(Eq. 7.4.7.5-4)* |

b. Calculation of critical pressure ratio where saturation pressure ratio is less than or equal to transition saturation pressure ratio, i.e. if ($\eta_s \leq \eta_{st}$), use following equation:

| | |
|---|---|
| $\eta_c = \eta_s$ | *(Eq. 7.4.7.5-5)* |

c. Calculation of critical pressure ratio where saturation pressure ratio is greater than transition saturation pressure ratio, i.e. if ($\eta_s > \eta_{st}$), use following equation:

The critical pressure ratio ($\eta_c$) is calculated using following approximated equation

| | |
|---|---|
| $\eta_c = \eta_s \times \left(\frac{2 \times \omega_s}{2 \times \omega_s - 1}\right) \times \left[1 - \sqrt{1 - \frac{1}{\eta_s} \times \left(\frac{2 \times \omega_s - 1}{2 \times \omega_s}\right)}\right]$ | *(Eq. 7.4.7.5-6)* |

User can also calculate critical pressure ratio ($\eta_c$) using following equation

| | |
|---|---|
| $\frac{\left(\omega_s + \frac{1}{\omega_s} - 2\right)}{2 \times \eta_s} \times \eta_c^2 - 2 \times (\omega_s - 1) \times \eta_c + \omega_s \times \eta_s \times \ln\left(\frac{\eta_c}{\eta_s}\right) + \frac{3}{2} \times \omega_s \times \eta_s - 1 = 0$ | *(Eq. 7.4.7.5-7)* |

Note that the critical pressure ratio ($\eta_c$) can also be calculated using figure C.2 given on page 123 in API 520-1 Ninth Edition 2014 Annex C.2.3.1. Refer screenshot given

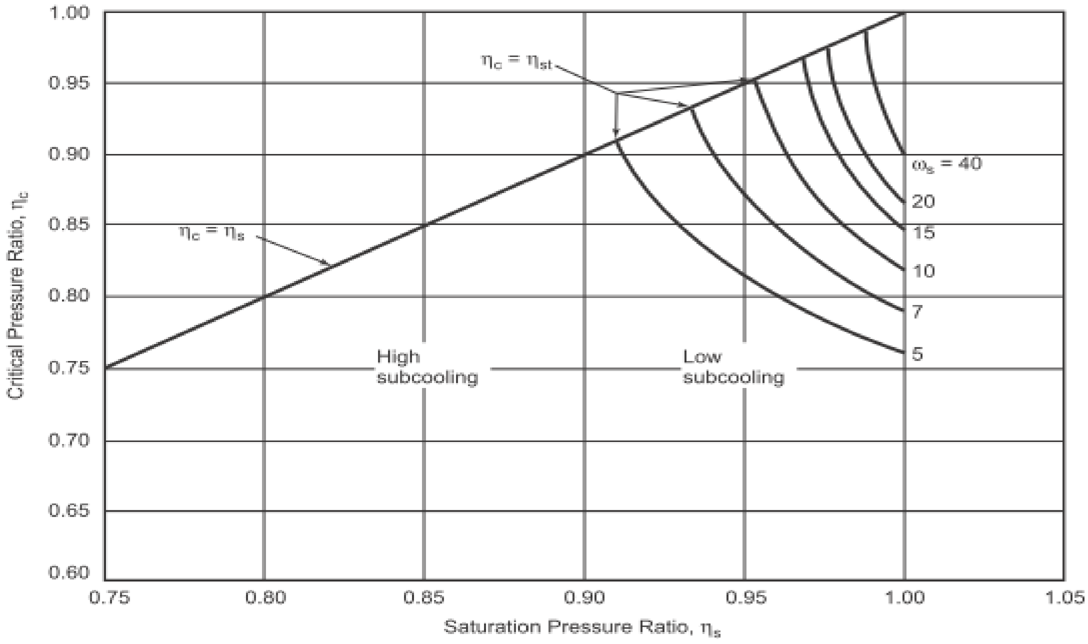



**Figure C.2—Correlation for Nozzle Critical Flow of Inlet Subcooled Liquid**

B. Determination of critical or subcritical flow for low subcooling region:

If Critical Pressure (Pc) is greater than or equal to downstream back pressure (Pa) then flow will be critical flow.

$If \quad P_c \geq P_a$ then flow is critical flow

If Critical Pressure (Pc) is less than downstream back pressure (Pa) then flow will be subcritical flow.

$If \quad P_c < P_a$ then flow is subcritical flow

3. Calculation of the mass flux (G) depending on subcooling region:
   1. Calculation of the mass flux (G) depending on type of flow (critical or subcritical) in low subcooling region:
      Standardized equation for mass flux (G):

| | |
|---|---|
| $G = \frac{\left\{2(1-\eta_s) + 2\left[\omega_s \eta_s \ln\frac{\eta_s}{\eta} - (\omega_s - 1)(\eta_s - \eta)\right]\right\}^{1/2}}{\omega_s\left(\frac{\eta_s}{\eta} - 1\right) + 1}\sqrt{P_0\,\rho_{10}}$ | *(Eq. 7.4.7.5-8)* |

a. For critical flow use following equation to calculate mass flux (G) for critical flow in low subcooling region (This equation is obtained by substituting $\eta_c$ for $\eta$ in above standardized equation).

| | |
|---|---|
| $G = \frac{\left\{2(1-\eta_s)+2\left[\omega_s \eta_s \ln\frac{\eta_s}{\eta_c}-(\omega_s-1)(\eta_s-\eta_c)\right]\right\}^{1/2}}{\omega_s\left(\frac{\eta_s}{\eta_c}-1\right)+1}\sqrt{P_0\,\rho_{10}}$ | *(Eq. 7.4.7.5-9)* |

b. For subcritical flow (all liquid flow) using following equation to calculate mass flux (G) for subcritical flow in low subcooling region (This equation is obtained by substituting $\eta_a$ for $\eta$ in above standardized equation).

| | |
|---|---|
| $G = \frac{\left\{2(1-\eta_s)+2\left[\omega_s \eta_s \ln\frac{\eta_s}{\eta_a}-(\omega_s-1)(\eta_s-\eta_a)\right]\right\}^{1/2}}{\omega_s\left(\frac{\eta_s}{\eta_a}-1\right)+1}\sqrt{P_0\,\rho_{10}}$ | *(Eq. 7.4.7.5-10)* |

i. Considerations for calculation of subcritical pressure ratio in above equation:

The subcritical pressure ratio ($\eta_a$) can be calculated using following equation

| | |
|---|---|
| $\eta_a = \frac{P_a}{P_0}$ | *(Eq. 7.4.7.5-11)* |

2. Calculation of the mass flux (G) depending on type of flow (critical or subcritical) in high subcooling region:

Standardized equation for mass flux (G):

| | |
|---|---|
| $G = 1.414\,[\rho_{10}(P_0 - P)]^{\frac{1}{2}}$ | *(Eq. 7.4.7.5-12)* |

a. For critical flow use following equation to calculate mass flux (G) for critical flow in high subcooling region (This equation is obtained by substituting $P_s$ for $P$ in above standardized equation).

| | |
|---|---|
| $G = 1.414\,[\rho_{10}(P_0 - P_s)]^{\frac{1}{2}}$ | *(Eq. 7.4.7.5-13)* |

b. For subcritical flow (all liquid flow) using following equation to calculate mass flux (G) for subcritical flow in high subcooling region (This equation is obtained by substituting $P_a$ for $P$ in above standardized equation).

| | |
|---|---|
| $G = 1.414\,[\rho_{10}(P_0 - P_a)]^{\frac{1}{2}}$ | *(Eq. 7.4.7.5-14)* |

4. Calculation of required effective discharge area (A):

a. Calculation for required flow area can be performed based on various combinations of user inputs. Considering required volumetric flow rate (Q) is known and Mass Flux (G) calculated above, use following equation

| | |
|---|---|
| $A = 16.67\frac{Q \times \rho_{10}}{K_b K_d K_c K_v G}$ | *(Eq. 7.4.7.5-15)* |

### 7.4.8 Fire Case and Hydraulic (Thermal) Expansion acc. to API 521 and ISO 23251

This standard deals with the planning of safety requirements for pressure-relieving and depressurizing systems. It analyses the major causes for overpressure and gives some indicative values for the determination of the individual relieving rates in a variety of practical cases. It was fully introduced in the new standard[5] ISO 23251. This ISO 23251 document supplements API Std 521, the requirements of which are applicable with the exceptions specified in this document. Formulas in both standards are identical, except for the units. For the application of API 521 formulas the user must use the US units, which are reported on the third column of Table 7.4.8.1-1, while for the formulas in ISO 23251 the SI units, defined of the fourth column of the same table.

This section of ENGINEERING shows the equations for the sizing in case of

- ✓ Hydraulic Expansion (API 521, ISO 23251)
- ✓ External Fire Case (API 521, ISO 23251)

Hydraulic expansion or Thermal expansion is the increase in the liquid volume due to an increment in temperature. Typically it occurs for liquids, which are trapped in vessels, pipes, heat exchangers and exposed to heat, for instance from electrical coils, ambient heat, fire, etc.

In the external fire case sizing API 521 distinguishes between *wetted* and *unwetted vessels* according to the following definitions and presents for each of them a sizing procedure.

A wetted vessel contains a liquid in equilibrium with its vapor or a gas. Wetted vessels contain temperated systems. In consequence of the heat transfer from the external fire a partial evaporation of the liquid occurs. In the calculation of the portion of vessel exposed to fire only that portion in contact with the liquid within a distance of 25 feet (7.6 m) above the fire source must be considered for sizing, see Table 7.4.8.3-1. If the exposure to fire leads to vapor generation from thermal cracking, alternate sizing methods may be appropriate.

An unwetted vessel is a vessel, which is either thermally insulated on the internal walls or filled with gases, vapors or a supercritical fluid. Unwetted vessels contain gassy systems. Vessels with separated liquid and vapor under normal conditions which become single-phase at relieving conditions belong here as well. However, vessels, whose walls become thermally insulated due to the deposition of coke or material from the contained fluids, are still considered wetted for fire sizing case however additional protection is required. In comparison to wetted vessels the thermal flow from the walls to the interior is low in unwetted vessels due to the large thermal resistance. In case of prolonged exposure of the outside surface to the fire source the temperature within the walls may be so high to cause thermal rupture of the vessel.

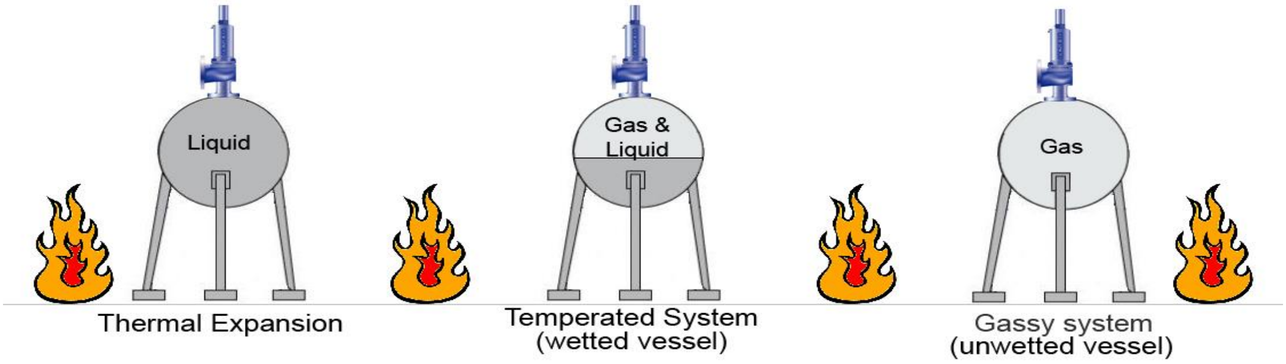



*Figure: 7.4.8-1: Hydraulic (thermal) expansion and fire case*

[5] ISO 23251 Petroleum and natural gas industries – Pressure relieving and depressuring systems, 2020

7.4.8.1 List of Symbols/Nomenclature

| Symbol | Description | Units [US] | Units [SI] |
|---|---|---|---|
| $A$ | Effective discharge area of the valve | [in²] | * |
| $A'$ | Exposed surface area of the vessel | [ft²] | * |
| $A_{ws}$ | Total wetted surface | [ft²] | [m²] |
| $\alpha_v$ | Cubical expansion coefficient of the liquid at the expected temperature | [1/°F] | [1/°C] |
| $c$ | Specific heat capacity of the trapped liquid | [Btu/(lb °F)] | [J/(kg K)] |
| $F$ | Environment factor | -- | -- |
| $d$ | Relative density referred to water at 60°F (15.6°C) | -- | -- |
| $h_{vl0}$ | Latent heat of vaporization | [Btu/lb] | [J/kg] |
| $K_D$ | Coefficient of discharge | -- | -- |
| $\phi$ | Total heat transfer rate | [Btu/hr] | [W] |
| $M$ | Molecular mass of the gas | [lb/$lb_{mol}$] | [kg/$k_{mol}$] |
| $P_1$ | Upstream relieving absolute pressure | [psi] | * |
| $Q$ | Total absorbed (input) heat to the wetted surface | [Btu/hr] | [W] |
| $q$ | Volume flow rate at the flowing temperature | [gpm] | [m³/s] |
| $q_m$ | Relief load / mass flow rate | [lb/hr] | * |
| $T_1$ | Gas temperature at upstream relieving pressure | [°R] | * |
| $T_w$ | Recommended max. vessel wall temperature | [°R] | * |

*Table 7.4.8.1-1 List of symbols for sizing acc. to API 521*

* For-application of the formula using US units is recommended.

### 7.4.8.2 Hydraulic Expansion (Thermal Expansion)

The mass flow rate for the sizing of the safety valve for a liquid vessel exposed to a heat source can be approximated by Eq. 7.4.8.2-1 (Eq. 7.4.8.2-2) for the case that the trapped liquid does not evaporate. However, the mass flow rates are usually so small that a safety valve sized NPS ¾ x NPS 1 (DN 20 x DN 25) should be sufficient acc. to API 521 Par. 4.14.12.2.

$$q = \frac{1}{500}\frac{\alpha_v \cdot \phi}{d \cdot c}$$ (USC Units) *(Eq. 7.4.8.2-1)*

$$q = \frac{1}{1000}\frac{\alpha_v \cdot \phi}{d \cdot c}$$ (SI Units) *(Eq. 7.4.8.2-2)*

The cubical expansion coefficient of the liquid should be obtained from the process data; however, for water and hydrocarbon liquids at 60°F (15.6°C) some reference values are given in Table 7.4.8.2-1. However, more precise values should be obtained from process design data.

| Gravity of liquid (°API) | $\alpha_v$ [1/°F] | $\alpha_v$ [1/°C] |
|---|---|---|
| 3 – 34.9 | 0.0004 | 0.00072 |
| 35 – 50.9 | 0.0005 | 0.0009 |
| 51 – 63.9 | 0.0006 | 0.00108 |
| 64 – 78.9 | 0.0007 | 0.00126 |
| 79 – 88.9 | 0.0008 | 0.00144 |
| 89 – 93.9 | 0.00085 | 0.00153 |
| 94 – 100 and lighter | 0.0009 | 0.00162 |
| Water | 0.0001 | 0.00018 |

*Table 7.4.8.2-1 Value of cubical expansion coefficient for hydrocarbon liquids at 60°F in API 521*

If the liquid is supposed to flash or form solids during the flow in the safety valve, the sizing procedure for two-phase flows in API RP 520 is recommended.

### 7.4.8.3 External Fire - Wetted Vessels

| Class of vessels | Portion of liquid inventory | Remarks |
|---|---|---|
| Liquid-full, e.g. treaters | All up to the height of 25 ft (7.6 m) | |
| Surge or knockout drums, process vessels | Normal operating level up to the height of 25 ft (7.6 m) | |
| Fractionating columns | Normal level in bottom plus liquid hold-up from all trays dumped to the normal level in the column bottom; total wetted surface up to the height of 25 ft (7.6 m) | Level in reboiler is to be included if the reboiler is an integral part of the column |
| Working storage | Max. inventory level up to 25 ft (7.6 m), normally excluding the portions of the wetted area in contact with the foundations or the ground | For storage and process tanks, see API Standard 2000[6] or prEN 14015[7] |
| Spheres and spheroids | Up to the height of 25 ft or up to the max. horizontal diameter, whichever is greater | |

*Table 7.4.8.3-1 Portions of wetted surfaces to be considered*

The amount of heat absorbed from a non-insulated vessel filled with a liquid depends at least on

- The type of fuel feeding the fire
- The degree of envelopment of the vessel with fire, which is a function of its size and shape
- The immediateness of firefighting measures and the possibility of drainage of flammable materials from the vessel

The total heat absorption Q for the wetted surface can be estimated by Eq. 7.4.8.3-1 in case of adequate drainage and prompt firefighting measures and by Eq. 7.4.8.3-2 in case of absent adequate drainage and/or firefighting measures.

| | US units | SI units | |
|---|---|---|---|
| Drainage and firefighting measures | $Q=21000\,FA_{ws}^{0.82}$ | $Q=43200\,FA_{ws}^{0.82}$ | (Eq. 7.4.8.3-1) |
| Absent drainage and/or firefighting measures | $Q=34500\,FA_{ws}^{0.82}$ | $Q=70900\,FA_{ws}^{0.82}$ | (Eq. 7.4.8.3-2) |

Adequate drainage of flammable fuels might be implemented with a strategic use of sewers and trenches as well as of the natural slope of the land. The values of the environment factor F for some types of installations are collected in Table 7.4.8.3-2. In case the conditions for Eq. 7.4.8.3-1 and 7.4.8.3-2 are not present, either higher values of the environment factor are assigned on the base of engineering judgment or some protection measures against fire exposure must be introduced to the plant. For water application facilities on bare vessels and depressurizing or emptying facilities insulation should withstand dislodgement by fire hose streams. Some example drainage criteria are given in API Standard 2510[8]

[6] API Standard 2000 Venting atmospheric and low pressure storage tanks : nonrefrigerated and refrigerated, 2014.

[7] prEN 14015: Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, metallic tanks for the storage of liquids at ambient temperature and above – Part 1: Steel tanks, 2017.

[8] API Standard 2510 Design and construction of liquefied petroleum gas installations (LPG), 2001

| Type of Equipment | | F |
|---|---|---|
| Bare vessel | | 1.0 |
| Insulated vessel , with insulation conductance values for fire exposure conditions | | |
| 4 [Btu/(hr ft² °F)] | 22.71 [W/ (m² K)] | 0.3 |
| 2 | 11.36 | 0.15 |
| 1 | 5.68 | 0.075 |
| 0.67 | 3.80 | 0.05 |
| 0.5 | 2.84 | 0.0376 |
| 0.4 | 2.27 | 0.03 |
| 0.33 | 1.87 | 0.026 |
| Water-application facilities, on bare vessel | | 1.0 |
| Depressurizing and emptying facilities | | 1.0 |
| Earth-covered storage | | 0.03 |
| Below-grade storage | | 0.00 |

*Table 7.4.8.3-2 Values of the environment factor F for various types of installations*

Heat absorption equations in Eq. 7.4.8.3-1 and 7.4.8.3-2 are for process vessels and pressurized storage of liquefied gases. For other storage, whether on pressure vessels or vessels and tanks with a design pressure of 15 psig or less the recommended heat absorption rates in case of external fire exposure can be extracted from API Standard 2000. The wetted areas for pressurized vessels of different forms in respect of Table 7.4.8.3-1 are collected in Table 7.4.8.3-3. Some examples are described also graphically in Fig. 7.4.3.3-1. The symbols are conform to those in VALVESTAR®.

| Class of vessels | Portion of liquid inventory and remarks |
|---|---|
| Sphere | $A_{wet} = \pi \cdot D \cdot F_{eff}$ |
| Horizontal cylindrical vessel with flat ends | $A_{wet} = \beta \cdot D \cdot \left[ L + \frac{D}{2} \right] - D \cdot \sin\beta \cdot \left[ \frac{D}{2} - F_{eff} \right]$ |
| Horizontal cylindrical vessel with spherical ends | $A_{wet} = \pi \cdot D \cdot \left[ (L - D)\frac{\beta}{\pi} + F_{eff} \right]$ |
| Vertical cylinder with flat ends<br>✓ Partially filled ( $F < L$ ) | $A_{wet} = \pi \cdot D \cdot \left[ \frac{D}{4} + F_{eff} \right]$ |
| ✓ Totally filled ( $F = L$ ) | $A_{wet} = \pi \cdot D \cdot \left[ \frac{D}{2} + F_{eff} \right]$ |
| Vertical cylinder with spherical ends | $A_{wet} = \pi \cdot D \cdot F_{eff}$ |

*Table 7.4.8.3-3 Calculation of the total wetted surface for some vessels.*

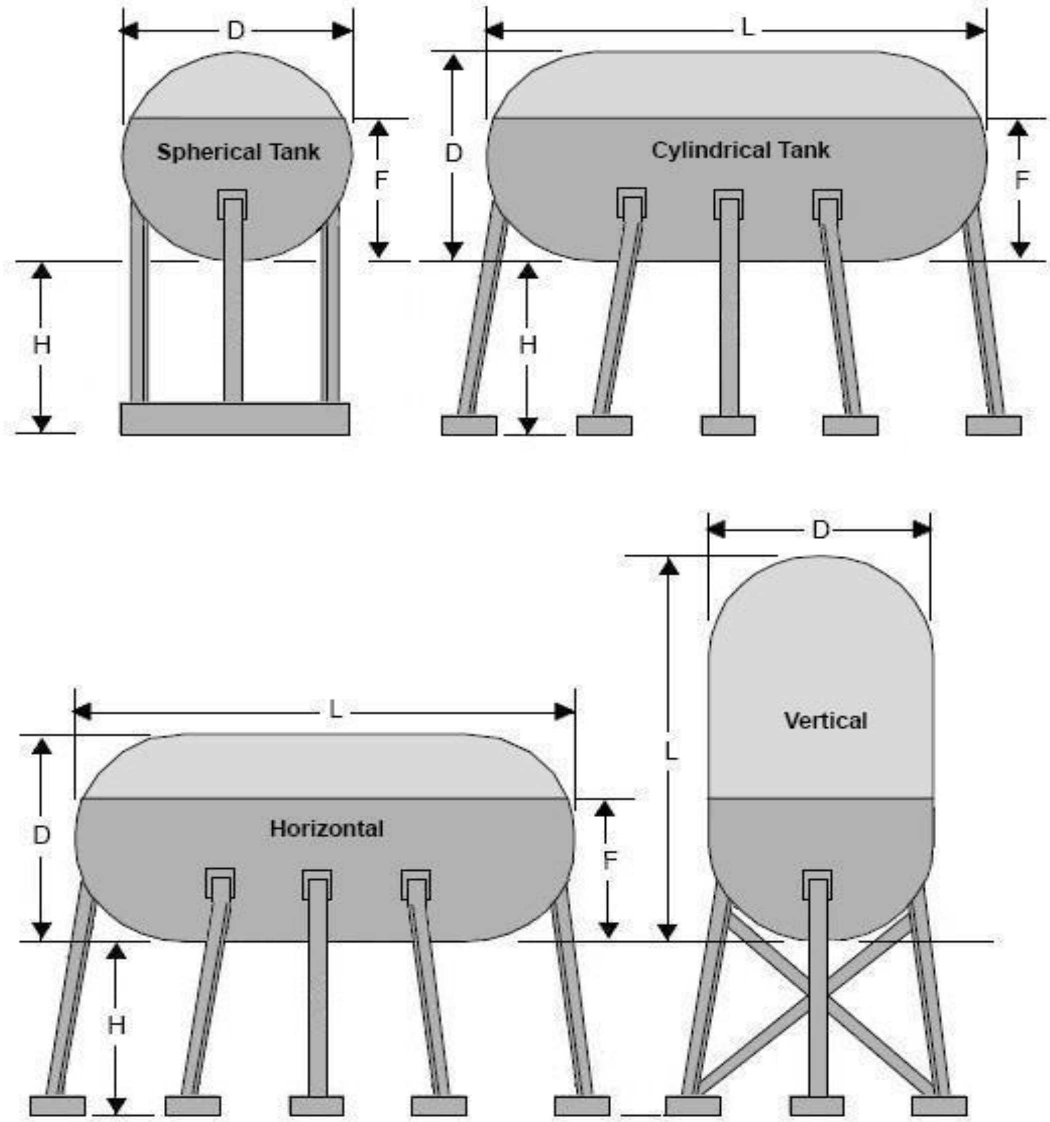



*Figure 7.4.8.3-1 : Possible positions of wetted vessels, partially filled with liquids*

The angle $\beta$ in Table 7.4.8.3-3 is defined in Eq. 7.4.8.3-3

$$\beta = \cos^{-1}(1 - 2F/D) \quad \textit{(Eq. 7.4.8.3-3)}$$

and the height $F_{eff}$ is the effective liquid level up to a max. distance of 25 feet away from the flame source, Eq. 7.4.8.3-4 (Eq. 7.4.8.3-5)

$$F_{eff} = \min(25 \;\; ft; F) - H \quad \text{(USC Units)} \quad \textit{(Eq. 7.4.8.3-4)}$$

$$F_{eff} = \min(7.6 \;\; m; F) - H \quad \text{(SI Units)} \quad \textit{(Eq. 7.4.8.3-5)}$$

The mass flow rate to the safety valve is determined by Eq. 7.4.8.3-6, considering that all absorbed heat vaporizes the liquid

$$W = Q / h_{vl0} \quad \textit{(Eq. 7.4.8.3-6)}$$

### 7.4.8.4 External Fire - unwetted vessels

If the vessel is filled with a gas, a vapor or a supercritical medium, Eq. 7.4.8.4-1 may be used to find the safety valve discharge area

$$A = \frac{F'A'}{\sqrt{P_1}} \quad \textit{(Eq. 7.4.8.4-1)}$$

F' may be determined from Eq. 7.4.8.4-2 if the calculated value is less than 0.01, then a recommended minimum value equal to 0.01 must be taken. When the available information is not enough to use Eq. 7.4.8.3-8, then the environment factor can be assumed equal to 0.045. The recommended maximum vessel wall temperature $T_w$ for the usual carbon steel plate materials is 1100°F (593°C). For plates made of alloys the wall temperature must be changed to a more adequate recommended max. value.

The constant C is given from Eq. 7.4.3-4.

$$F' = \frac{0.1406}{C \cdot K_d}\left[\frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}}\right] \quad \textit{(Eq. 7.4.8.4-2)}$$

The relieving temperature $T_1$ is determined from Eq. 7.4.8.4-3 in function of the normal operating temperature and pressure, respectively $T_n$ and $p_n$, and of the relieving pressure

$$T_1 = T_n \frac{P_1}{P_n} \quad \textit{(Eq. 7.4.8.4-3)}$$

For plates made of alloys the gas mass flow rate can be calculated from Eq. 7.4.8.4-4

$$W = 0.1406\sqrt{M\ P_1}\left(A'\frac{(T_w - T_1)^{1.25}}{T_1^{1.1506}}\right) \quad \textit{(Eq. 7.4.8.4-4)}$$

The derivation of the formulas for unwetted vessels is based on the physical properties of air and ideal gas laws. Furthermore, they assume that the vessel is non-insulated and without its own mass, that the vessel wall temperature will not reach rupture under stress and that the fluid temperature does not change. All these assumptions should be checked if they are appropriate for the particular situation.

### 7.4.8.5 Consideration of Accumulated Pressure in Fire and Non-Fire Contingencies

The requirements on the accumulated pressure in API RP 520, propose different treatments for the cases of fire and non-fire contingencies.

In non-fire contingencies the accumulated pressure shall be limited to 110% of the maximum allowable working pressure (MAWP) in vessels that are protected by only one safety valve. If the MAWP lies between 15 and 30 psig, the allowable accumulation is fixed to 3 psi.
In vessels which are protected by more valves in non-fire contingencies, the accumulated pressure shall be limited to 116% of the maximum allowable working pressure (MAWP) or to 4 psi, if the MAWP lies between 15 and 30 psig. Typically the first safety valve is set at 100% of the MAWP and it is smaller than all other ones so to minimize the product loss. The additional valve is larger and it is sized in order to ensure the protection against the maximum required mass flow.

In fire contingencies the accumulated pressure shall be below 121% (= 10% above 110%) of the maximum allowable working pressure (MAWP), independently if the vessels are protected by one or more safety valves. Safety valves sized for the fire case may be also used in non-fire situations, provided that they satisfy the constrain on the accumulated pressure of 110% (one valve) and 116% (= 10% above 105%) (more valves) respectively.

Following the strategy of Table 7.4.8.5-1, which is extracted from the table in API RP 520, a safe sizing with a minimum product loss is possible. The supplemental valves are installed in case of an additional hazard, like fire case or other sources of external heat. Supplemental valves are in addition to devices for non-fire contingency.

| | Single valve installation | | Multiple valve installation | |
|---|---|---|---|---|
| Contingency | Max. set pressure [%] | Max. accumulated pressure [%] | Max. set pressure [%] | Max. accumulated pressure [%] |
| **Non-fire contingency** | | | | |
| First valve | 100 | 110 | 100 | 116 |
| Additional valves | - | - | 105 | 116 |
| **Fire contingency** | | | | |
| First valve | 100 | 121 | 100 | 121 |
| Additional valves | - | - | 105 | 121 |
| Supplemental valve | - | - | 110 | 121 |

*Table 7.4.8.5-1 Set pressure and accumulated pressure limits for safety valves*

### 7.4.9 Lift Restriction according to ASME Section XIII

ASME Section XIII of the ASME Boiler and Pressure Vessel Code provides the guidelines for restricting the lift of a safety valve to achieve a reduced relieving capacity. Safety valves of NPS ¾" or larger can be lift restricted to not less than 30% of the full rated lift, nor less than 0.08 inch / 2.0 mm.

A lift restriction according ASME Section XIII requires a certification by an ASME designated organization, which LESER currently does not have.

As LESER safety valves have double certification by ASME XIII (ASME VIII) and PED / ISO 4126 , LESER can supply LESER products with a lift restriction according to PED / ISO 4126. In this case the safety valve will not carry an UV-stamp. For details please refer to section 7.5.8 and 7.6.5.

Examples

### 7.4.9.1 Gases and Vapors - Critical Flow (1)

**Example 7.4.9.1**. It is required to size a conventional valve without rupture disc for a vessel filled with ethylene ($C_2H_4$) at the relieving temperature of 55°C (590.7 °R) and a set pressure of 55 bar g (797.7 psig). The mass flow rate and the back pressure are respectively 4200 kg/h (9259 $lb_m$/hr) and 10 bar g (145 psig). The safety valve shall be from the LESER API Series 526.

*Solution*. The relieving pressure is calculated from Eq. 7.4.2-1 and it values

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 797.7 \ \ psig + 79.8 \ \ psig + 14.7 \ \ psi = 892.2 \ \ psi$$

From the Example 7.2.6.1 the calculated compressibility factor $Z$ is 0.712. The isentropic exponent $k$ and the molecular weight $M$ are given from the customer as 1.19 and 28.03 lb/$lb_{mol}$ respectively. The back pressure coefficient can be calculated from Fig. 7.4.3-1, by expressing the set pressure and the back pressure in psig

$$\frac{p_b}{p_s} = \frac{10 \ bar\ g}{55 \ bar\ g} = \frac{145 \ \ psig}{797.7 \ \ psig} = 0.182$$

and it results that no correction for the back pressure is necessary ($K_b = 1.0$).

The value of the coefficient C is obtained from Eq. 7.4.3-3

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 520\sqrt{1.19\left(\frac{2}{1.19+1}\right)^{\frac{1.19+1}{1.19-1}}} = 336.22\frac{\sqrt{lb \cdot lb_{mol} \cdot {}^{\circ}R}}{lb_f \cdot hr}$$

The critical pressure ratio can be calculated from Eq. 7.2.3-2

$$\left.\frac{p}{P_1}\right]_{critical-flow} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = \left(\frac{2}{1.19+1}\right)^{\frac{1.19}{1.19-1}} = 0.5664$$

The absolute pressure ratio for this sizing problem is

$$\frac{p_b}{P_1} = \frac{145 \ psig + 14.7 \ psi}{892.2 \ psi} = 0.178$$

which is much lower than the critical pressure ratio and therefore the flow is critical. The minimum required effective discharge area can be calculated from Eq. 7.4.4-1 with $K_d = 0.975$

$$A = \frac{W}{C \ K_b K_c K_d P_1}\sqrt{\frac{T\,Z}{M}} = \frac{9259}{336.22 \cdot 1 \cdot 1 \cdot \underline{0.975} \cdot 892.2}\sqrt{\frac{590.7 \cdot 0.712}{28.03}} in^2 = 0.122 \ \ in^2$$

From Table 7.2.1-2 the discharge area of the effective orifice E ($A = 0.196 \ \ in^2 > 0.122 \ \ in^2$) exceeds the minimum requirement. It must be now proven that the actual discharge area of the E orifice ($K_d = 0.801$ ; $A = 0.239 \ \ in^2$) meets or exceeds the minimum required actual relief area.

$$A = \frac{W}{C \ K_b K_c K_d P_1}\sqrt{\frac{T\,Z}{M}} = \frac{9259}{336.22 \cdot 1 \cdot 1 \cdot 0.801 \cdot 892.2}\sqrt{\frac{590.7 \cdot 0.712}{28.03}} in^2 = 0.149 \ \ in^2$$

The discharge area of the actual Orifice E is larger than that the required minimum relief area and therefore it suffices the sizing. From the Selection Chart on Page 01/20 of the Catalog LESER Series API the required flange ratings are 600 for the inlet and 150 for the outlet. The safety valve size would be then **LESER Type 526 1E2 (5262.0172)**.

7.4.9.2 Gases and Vapors - Critical Flow (2)

**Example 7.4.9.2**. A safety valve is required for a vessel containing natural gas (= methane, $M = 16.04\ lb/lb_{mol}$) venting to the ambience. The required mass flow is 22600 lb/hr. The relieving temperature is 650°R and the design pressure (= set pressure) of the vessel is 80 psig.

*Solution*. The relieving pressure for an overpressure of 10 % values

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 80\ psig + 8\ psig + 14.7\ psi = 102.7\ psi$$

The critical temperature and pressure of methane are extracted from Table 7 on Page 43 of API RP 520. They are 673 psi and -116°F ( = 343°R). The relative temperature and pressure are therefore

$$T_R = \frac{T}{T_c} = \frac{650\,°R}{343\,°R} = 1.895 \qquad p_R = \frac{P_1}{p_c} = \frac{102.7\ psi}{673\ psi} = 0.152$$

The compressibility factor $Z$ from Fig. 7.9.1-1 for the calculated relative temperature and pressure is about 0.98 (NIST WebBook : 0.993). The isentropic exponent $k$ from the NIST Chemistry WebBook is almost 1.286.
The back pressure coefficient can be extracted from Fig. 7.4.3-1 in terms of ratio between the set pressure and the back pressure, both in psig

$$\frac{p_b}{p_s} = \frac{14.7\ psig}{80\ psig} = 0.1837$$

and here as well no correction for the back pressure is necessary ($K_b = 1.0$).
The value of the coefficient C is obtained from Eq. 7.4.3-3

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 520\sqrt{1.286\left(\frac{2}{1.286+1}\right)^{\frac{1.286+1}{1.286-1}}} = 345.65\ \frac{\sqrt{lb \cdot lb_{mol} \cdot °R}}{lb_f \cdot hr}$$

The critical pressure ratio can be calculated from Eq. 7.3.2-2

$$\left.\frac{p}{P_1}\right]_{critical-flow} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = \left(\frac{2}{1.286+1}\right)^{\frac{1.286}{1.286-1}} = 0.548$$

The absolute pressure ratio is much lower than the critical pressure ratio and therefore the flow is critical. The minimum required <u>effective discharge area</u> from Eq. 7.4.4-1 is

$$A = \frac{W}{C\,K_b K_c K_d P_1}\sqrt{\frac{T\,Z}{M}} = \frac{22600}{345.65 \cdot 1 \cdot 1 \cdot \underline{0.975} \cdot 102.7}\sqrt{\frac{650 \cdot 0.993}{16.04}}in^2 = 4.14\ in^2$$

From Table 7.4.1-2 the effective discharge area of the orifice N exceeds the minimum requirement. It remains to prove that the <u>actual discharge area</u> of the N orifice ( $K_d = 0.801$ ; $A = 5.30\ in^2$ ) exceeds the minimum requirement.

$$A = \frac{W}{C\,K_b K_c K_d P_1}\sqrt{\frac{T\,Z}{M}} = \frac{22600}{345.65 \cdot 1 \cdot 1 \cdot \underline{0.801} \cdot 102.7}\sqrt{\frac{650 \cdot 0.993}{16.04}}in^2 = 5.06\ in^2 \rightarrow \text{OK}$$

and therefore the actual orifice N will be selected. From the Selection Chart on Page 01/20 of the LESER Catalog API Series the required flange levels are 150 for both the inlet and the outlet and therefore the safety valve **<u>LESER Type 526 4N6 (5262.5902)</u>** suits the requirements.

7.4.9.3 Gases and Vapors - Subcritical Flow

**Example 7.4.9.3**. Same case as Example 7.4.9.2. but with a set pressure of 20 psig (20+3+14.7 =37.7 psi), back pressure 10 psig (24.7 psi) and $Z=1$.

*Solution*. The critical pressure ratio is again that of the Example 7.4.9.2.

$$\left.\frac{p}{P_1}\right]_{critical-flow} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = \left(\frac{2}{1.286+1}\right)^{\frac{1.286}{1.286-1}} = 0.548$$

However, this time the ratio of the absolute back pressure on the relieving pressure, which is

$$r = \frac{P_2}{P_1} = \frac{24.7 \ \ psi}{37.7 \ \ psi} = 0.6552$$

is larger than the critical pressure ratio and therefore the flow is subcritical. The parameter $F_2$ from Eq. 7.4.4-3 is equal to

$$F_2 = \sqrt{\frac{k}{k-1} \cdot r^{2/k} \cdot \frac{1-r^{1-1/k}}{1-r}} = \sqrt{\frac{1.286}{1.286-1} \cdot 0.6552^{2/1.286} \cdot \frac{1-0.6552^{1-1/1.286}}{1-0.6552}} = 0.779$$

The minimum required <u>effective</u> discharge area from Eq. 7.4.4-2 is

$$A = \frac{1}{735} \frac{W}{F_2 K_c K_d P_1} \sqrt{\frac{T Z}{M} \frac{1}{1-r}} = \frac{1}{735} \frac{22600}{0.779 \cdot 1 \cdot 0.975 \cdot 37.7} \sqrt{\frac{650 \cdot 1}{16.04} \cdot \frac{1}{1-0.6552}} = 11.73 \ in^2$$

The effective discharge area is then an R orifice. It must now be verified that the <u>actual</u> discharge area of a R orifice of LESER Type 526 ( $K_d = 0.801$ ; $A = 19.48 \ \ in^2$ ) is large enough, which is when it exceeds the minimum actual required area of

$$A = \frac{1}{735} \frac{W}{F_2 K_c K_d P_1} \sqrt{\frac{T Z}{M} \frac{1}{1-r}} = \frac{1}{735} \frac{22600}{0.779 \cdot 1 \cdot 0.801 \cdot 37.7} \sqrt{\frac{650 \cdot 1}{16.04} \cdot \frac{1}{1-0.673}} = 14.28 \ in^2 \rightarrow \text{OK}$$

The final choice of the safety valve is therefore **<u>LESER Type 526 6R8 (5262.6652)</u>**.

7.4.9.4 Steam

**Example 7.4.9.4**. A safety valve must be sized for a large vessel containing saturated steam ($K_{SH}=1$) at a set pressure of 1600 psig (10% accumulation). The expected mass flow rate is of 154000 lb/hr.

*Solution*: A conventional safety valve ($K_b = 1$) without additional rupture disk ($K_c = 1$) is chosen.

The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 1600 \ \ psig + 160 \ \ psig + 14.7 \ \ psi = 1774.7 \ \ psi$$

The correction factor for Napier equation $K_N$ is calculated from Eq. 7.4.5-2

$$K_N = \frac{0.1906 \cdot P_1 - 1000}{0.2292 \cdot P_1 - 1061} = \frac{0.1906 \cdot 1774.7 - 1000}{0.2292 \cdot 1774.7 - 1061} = 1.0115$$

The minimum required <u>effective</u> discharge area is calculated from Eq. 7.4.5-1

$$A = \frac{1}{51.5} \cdot \frac{W}{P_1 K_b K_c K_d K_N K_{SH}} = \frac{1}{51.5} \cdot \frac{154000}{1774.4 \cdot 1 \cdot 1 \cdot 0.975 \cdot 1.0115 \cdot 1} = 1.709 \ \ in^2$$

which is exceeded by selecting an orifice K.

The orifice K of LESER Type 526 ( $K_d = 0.801$ ; $A = 2.25 \ \ in^2$ ) is selected for the actual discharge area since it exceeds the minimum requirement of

$$A = \frac{1}{51.5} \cdot \frac{W}{P_1 K_b K_c K_d K_N K_{SH}} = \frac{1}{51.5} \cdot \frac{154000}{1774.4 \cdot 1 \cdot 1 \cdot 0.801 \cdot 1.0115 \cdot 1} = 2.08 \ \ in^2$$

The required flanges are 900 (inlet) and 150 (outlet) according to Page 01/40 of LESER Catalog for the API Series and therefore the safety valve to be purchased is **<u>LESER Type 526 3K6 (5262.2053).</u>**

7.4.9.5 Liquids

**Example 7.4.9.5**. A safety valve must be sized for a flow rate of 5 l/s (79.25 gpm) of glycerin ($G = 1.26$; $\mu = 1410\ \ cP$). The set pressure is 10 bar-g (145 psig) with 10% accumulation and atmospheric backpressure.

*Solution* The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 145\ \ psig + 14.5\ \ psig + 14.7\ \ psi = 174.2\ \ psi$$

The procedure in API RP 520 foresees a preliminary relief area for inviscid service by using Eq. 7.4.6-1 assuming $K_v = 1$. The minimum preliminary effective discharge area is

$$A_{prel} = \frac{1}{38} \cdot \frac{Q}{K_c K_d K_w} \sqrt{\frac{G}{P_1 - P_2}} = \frac{1}{38} \cdot \frac{79.25}{1 \cdot 0.65 \cdot 1} \sqrt{\frac{1.26}{159.5}} = 0.285\ \ in^2$$

which would lead to an F orifice ($A = 0.307\ \ in^2$) as effective discharge area for the inviscid fluid.

Now the viscosity of the fluid has to be considered. The assumption of the API RP 520 is that the effective relief area for the inviscid flow may also suit the sizing of the viscous flow. Therefore the user must calculate the Reynolds number on the base of Eq. 7.4.6-3 on that orifice area.

$$\mathrm{Re} = 2800 \frac{Q\,G}{\mu\,\sqrt{A}} = 2800 \frac{79.25 \cdot 1.26}{1410\ \sqrt{0.307}} = 357.9$$

and on the base of this Reynolds number the viscosity correction factor from Eq. 7.4.6-2

$$Kv = \left(\frac{170}{ReL} + 1\right)^{-0,5} = \quad Kv = \left(\frac{170}{357,9} + 1\right)^{-0,5} = 0,8234$$

The corrected (effective minimum) discharge area for the viscous liquid is then

$$\mathrm{A} = \frac{\mathrm{Q}}{38 * \mathrm{K_w K_d K_c K_v}} \left(\frac{G}{\mathrm{P_1} - \mathrm{P_2}}\right)^{0,5} = \frac{79.25}{38 * 1 * 1 * 0.65 * 0.8234} \left(\frac{1.26}{159.5}\right)^{0,5} = 0.3465\ in^2$$

Since the effective minimum corrected discharge area exceeds the foreseen orifice, the above procedure for viscous flows must be repeated with the larger orifice G ($A = 0.503\ \ in^2$). For sake of brevity the Reynolds number, viscosity correction factor and corrected minimum discharge area are given here below.

Re = 279.6 $K_v$ = 0.789 $A_{corr}$ = 0.362 in²

Since the corrected minimum discharge area is smaller than the G orifice, the selected orifice size is sufficient. A quick verification that the actual G orifice of LESER Type 441 ($K_d = 0.579$; $A = 0.616\ \ in^2$) suffices is given as following.

$A_{prel}$ = 0.320 in² Re = 252.65 $K_v$ = 0.773 $A_{corr}$ = 0.414 in²

The required valve, incl. the flanges, is **LESER Type 526 1½G3 (5262.0452)**.

7.4.9.6 Two Phase Flow – Flashing C2.2 (API 520-1 Rev. 2020)

| Input | Value | Unit |
|---|---|---|
| Set pressure, $P_s$ | 413.7 | kPag |
| Total Back pressure, $P_2$ | 103.421<br>204746 | kPag<br>Pa |
| Allowable Overpressure (10%) for single valves | 41.37 | kPa |
| Viscosity correction factor, $K_v$ | 1 | - |
| Mass flow rate, W | 216560 | kg / h |
| Specific volume evaluated at 90% of PRV inlet pressure, $v_9$ | 0.02265 | $m^3$/kg |
| Specific volume of two phase system, $v_1$ | 0.01945 | $m^3$/kg |
| Relieving Temperature, T | 200<br>366.5 | °F<br>K |
| Combination capacity factor (if Safety valve is in combination of Rupture disk), $K_c$ | 0.9 | - |
| Combination capacity factor (if Safety valve with no Rupture disk), $K_c$ | 1.0 | - |
| Certified derated coefficient of discharge (Considered average of vapor (0.699) and liquid (0.521) coefficient discharge), $K_d$ | 0.61 | - |
| Type | 441 XXL | - |

Note: For this example Combination capacity factor ($K_c$) value of 1.0 is considered.

1. Calculation of Relief Pressure:

   Relief pressure (P1) = Ps + allowable overpressure + environmental pressure absolute

   P1 = 413.7 + (0.10 * 413.7) + 101.325

   = 556.395 kPa

   = 556395 Pa (conversion from kilopascal to pascal)

   Here, a single valve is considered to be in operation, hence an allowable overpressure of 0.1 times the PRV Set pressure is considered.

2. Calculation of Back pressure correction factor, Kb:

   Percentage gauge pressure = (Pa/Ps) × 100

   = (103.421/413.7)

= 24.99 %

Note this calculated % gauge backpressure needs to be checked in Figure 31 from API 520-1 Tenth Edition 2020 ( page 59) to get the value of Back pressure correction factor (Kb).

For the case under consideration, Kb = 1 (Taken from figure 31) considering valve is of Balanced Bellows type valve.

Note: For LESER products the generated p20/p0 curves shall be used for sizing if balanced bellows is used for gas/steam only. As for two-phase flow no values are available, the figure 31 data shall be used.

3. Calculation of omega parameter ($\omega$):

$$\omega = 9\left(\frac{v_9}{v_1} - 1\right)$$

$$\omega = 9\left(\frac{0.02265}{0.01945} - 1\right)$$

= 1.481

Where, $v_9$ = Specific volume evaluated at 90% of PRV inlet pressure

$v_1$ = Specific volume of two phase system

4. Calculation of critical pressure ratio ($\eta_c$) using above equations specified in step 5.1.2.a.i

$$\eta_c = [1 + (1.0446 - 0.0093431 \times \omega^{0.5}) \times \omega^{-0.56261}]^{(-0.70356+0.014685\times\ln\omega)}$$

$$\eta_c = [1 + (1.0446 - 0.0093431 \times 1.481^{0.5}) \times 1.481^{-0.56261}]^{(-0.70356+0.014685\times\ln 1.481)}$$

= 0.66

5. Calculation of Critical Pressure (Pcf):

$$P_{cf} = \eta_c P_0$$

$$P_{cf} = 0.66 * 556395$$

= 365170.78 Pa

Where, $\eta_c$ = Critical pressure ratio ($\eta_c$)

$P_1$ = Relieving Pressure ( $P_1$)

6. Check for critical and subcritical flow using above equations specified in step 5.1.2.b

$P_2\ (204746) < P_{cf}\ (365170.78)$, hence flow is considered as critical flow.

7. Calculation of mass flux (G) based on critical flow:

$$G = \eta_c \sqrt{\frac{P_1}{v_1 \omega}}$$

$$G = 0.66 \sqrt{\frac{556395}{0.01945 * 1.481}}$$

= 2884.7 kg/s·m2

8. Calculation of required orifice area, A

$$\mathrm{A} = \frac{277.8 * \mathrm{W}}{K_b * K_d * K_c * K_v * G}$$

$$\mathrm{A} = \frac{277.8 * 216560}{0.981 * 0.61 * 1 * 1 * 2884.7}$$

= 34850.1 mm2

9. Select valve (Type 441 XXL, do =235 mm, As = 43373.6 mm2)

Certified mass flow (qm, zu) is evaluated by substituting A=43373.6 mm2 in the above equation:

$$\mathrm{qm, zu} = \frac{A_s\ \mathrm{K_b\ K_d\ K_c\ K_v\ G}}{277.8}$$

$$qm, zu = \frac{43373.6 * \ 0.981 * 0.61 * 1 * 1 * 2884.7}{277.8}$$

= 269526 kg/h

The required valve, incl. the flanges, is **LESER Type 441 XXL DN300 (4412.4772)**.

### 7.4.9.7 Two Phase Flow – Subcooled C2.3 (API 520-1 Rev. 2020)

| Input | Value | Unit |
|---|---|---|
| Set pressure, P | 1792.6<br>1893925 | kPag<br>Pa |
| Total Back pressure, $P_a$ | 68.95<br>170272.57 | kPag<br>Pa |
| Allowable Overpressure (10%) | 179.2 | kPa |

| | | |
|---|---|---|
| Viscosity correction factor, $K_v$ | 1 | - |
| Mass flow rate, Q | 378.5 | L/min |
| Density evaluated at 90% of PRV inlet pressure, $\rho_9$ | 262.727 | kg/m³ |
| Liquid density at PRV inlet, $\rho_{10}$ | 511.3 | kg/m³ |
| Relieving Temperature, T | 60<br>288.7 | F<br>K |
| Saturation Pressure, $P_s$ | 741.875<br>741875 | KPa<br>Pa |
| Combination capacity factor (if Safety valve is in combination of Rupture disk), $K_c$ | 0.9 | - |
| Combination capacity factor (if Safety valve with no Rupture disk), $K_c$ | 1.0 | - |
| Certified derated coefficient of discharge (Considered average of vapor (0.801) and liquid (0.579) coefficient discharge), $K_d$ | 0.69 | - |
| Type | 526 | - |

Note: For this example Combination capacity factor ($K_c$) value of 1.0 is considered.

1. Calculation of Relief Pressure:

   Relief pressure (P0) = P + allowable overpressure + environmental pressure absolute

   P0 = 1792.6 + (0.10 * 1792.6) + 101.325

   = 2073.185 kPa

   = 2073185 Pa (conversion from kilopascal to pascal)

   Here, a single valve is considered to be in operation, hence an allowable overpressure of 0.1 times the PRV Set pressure is considered.

2. Calculation of Back pressure correction factor, Kb:

   Percentage gauge backpressure = (Pa/P) × 100 (in gauge)

   = (68947.57/1792600)

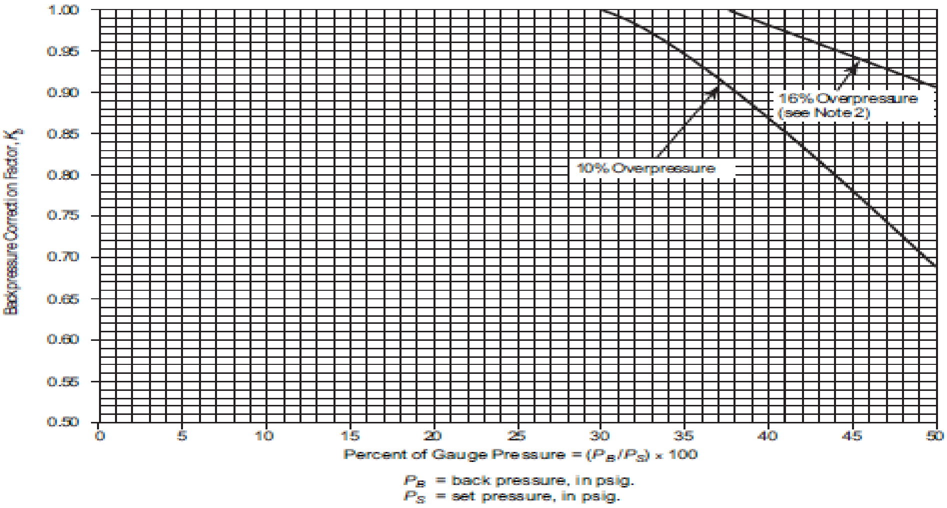
   = 3.84 %

   Note this calculated % gauge pressure needs to be checked in Figure 30 from API 520-1 Ninth Edition 2014 ( page 48) to get the value of Back pressure correction factor (Kb).

   For the case under consideration, Kb = 1 (Taken from figure 30) considering valve is of Balanced Bellows type valve.

Note: For LESER products the generated pa0/p0 curves shall be used for sizing if balanced bellows is used.

Refer Screenshot provided below for Figure 30:




NOTES

1. The curves above represent a compromise of the values recommended by a number of relief valve manufacturers and may be used when the make of the valve or the critical flow pressure point for the vapor or gas is unknown. When the make of the valve is known, the manufacturer should be consulted for the correction factor. These curves are for set pressures of 50 psig and above. They are limited to back pressure below critical flow pressure for a given set pressure. For set pressures below 50 psig or for subcritical flow, the manufacturer must be consulted for values of $K_b$.
2. See 5.3.3.
3. For 21 % overpressure, $K_b$ equals 1.0 up to $P_B/P_S$ = 50 %.

**Figure 30—Backpressure Correction Factor, $K_b$, for Balanced-bellows PRV (Vapors and Gases)**

3. Calculation of saturated omega parameter ($\omega_s$):

$$\omega_s = 9\left(\frac{\rho_{10}}{\rho_9} - 1\right)$$

$$\omega_s = 9\left(\frac{511.3}{262.727} - 1\right)$$

$\omega_s$ = 8.515

Where, $\rho_9$ = Specific volume evaluated at 90% of PRV inlet pressure from Table 6.1

$\rho_{10}$ = Specific volume of two phase system from Table 6.1

4. Calculation of Transition saturation pressure ratio ($\eta_{st}$):

$$\eta_{st} = \frac{2\omega_s}{1 + 2\omega_s}$$

$$\eta_{st} = \frac{2 * 8.515}{1 + 2 * 8.515}$$

$\eta_{st}$ = 0.9445

5. Determine the type (high or low) subcooling region with following comparison:

   Need to compare saturation pressure (Ps) with the product of transition saturation pressure ratio ($\eta_{st}$) and relieving pressure ($P_0$)

Here, $P_s(741875) < \eta_{st}P_0(1958201.5)$, Hence flow is considered in high subcooling region.

6. Determination of critical or subcritical flow for high subcooling region:
   Need to compare saturation pressure (Ps) with the total backpressure;

Here, $P_s(741875) \geq P_a(68947.57)$, hence flow is considered as critical flow.

7. Calculation of the mass flux (G) depending on type of flow (critical or subcritical) in high subcooling region:
   Here, flow type is observed as critical flow in high subcooling region. Therefore used formula mentioned in above step 5.1.4.2.a for calculating mass flux (G);

   $G = 1.414\,[\rho_{10}(P_0 - P_s)]^{\frac{1}{2}}$

   $G = 1.414\,[511.3 * (2073185 - 741875)]^{\frac{1}{2}}$

   G = 36891.6 kg/s.m²

8. Calculation of required orifice area, A:

   $A = 16.67 \frac{Q \times \rho_{10}}{K_b K_d K_c K_v G}$

   $A = 16.67 \frac{378.5 * 511.3}{0.65 * 1.0 * 0.69 * 1.0 * 36891.6}$

   A = 126.7 mm²

9. Select valve (Type 526, do = 14 mm, As = 153.938 mm²)
   Certified volume flow (qvb, zu) is evaluated by substituting A = 153.938 mm² in the above equation:

   $qvb, zu = \frac{A_s\, K_b\, K_d\, K_c\, K_v\, G}{16.67\, \rho_{10}}$

   $qvb, zu = \frac{153.938 * 1.0 * 0.69 * 1.0 * 1.0 * 36891.6}{16.67 * 511.3}$

   qvb, zu = 460 L/min

The required valve, incl. the flanges, is **LESER Type 526 1E2 (5262.0015)**.

### 7.4.9.8 Hydraulic (Thermal) Expansion acc. to API 521

**Example 7.4.9.8**. The vessel containing ~~the~~ heating oil ~~of the previous example~~ is exposed to sun light. Calculate the mass flow rate that would occur in case of thermal radiation and size the safety valve for the same relieving and back pressure, assuming a maximum heat transfer rate of 55.2 kJ/hr (58.24 BTU/hr).

*Solution:* The specific gravity of the heating oil at relieving conditions is $G = 687/999.1 = 0.6876$ .
The gravity of the liquid in API for oils is calculated on the base of the well known formula

$$°API = \frac{141.5}{G} - 131.5 = \frac{141.5}{0.6876} - 131.5 = 74.28$$

which corresponds to a value of the cubical expansion coefficient B of approx. 0.0007.
The mass flow rate to be released according to Eq. 7.4.8.2-1 is

$$Q_{gpm} = \frac{1}{500}\frac{B \cdot H}{G \cdot C} = \frac{1}{500} \cdot \frac{0.0007 \cdot 58.24}{0.6876 \cdot 0.633} = 0.000187 \ gpm \text{ (0.56 kg/hr)}$$

The minimum effective safety valve flow area can be calculated. However, for such a small flow rate the smallest safety valve, orifice **1D2 (5262.0012)**, is by far enough.

### 7.4.9.9 External Fire acc. to API 521 - Unwetted Walls

**Example 7.4.9.9**. A carbon steel vessel ($T_w = 1560\ °R$) is filled with air at a set pressure of 100 psig. The exposed surface area A' is 250 ft². The normal temperature and pressure are 125°F (584.7°R) and 80 psig (94.7 psi).

*Solution*:The relieving pressure according to Paragraph 7.4.8.4 is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 100 \ \ psig + 21 \ \ psig + 14.7 \ \ psi = 135.7 \ \ psi$$

On the base of Eq. 7.4.8.4-3 the relieving temperature is

$$T_1 = T_n \frac{P_1}{P_n} = 584.7°R \cdot \frac{135.7\,psi}{94.7\,psi} = 837.84°R$$

The specific heat ratio at relieving conditions according to the NIST WebBook Database is almost $k \cong 1.4$ ($k = 1.392$). With this isentropic coefficient the value of the parameter C is calculated with Eq. 7.4.3-3

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 520\sqrt{1.4\left(\frac{2}{1.4+1}\right)^{\frac{1.4+1}{1.4-1}}} = 356.06\frac{\sqrt{lb_m lb_{mol}°R}}{lb_f hr}$$

The parameter F' is determined from Eq. 7.4.8.4-2

$$F' = \frac{0.1406}{C \cdot K_d}\left[\frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}}\right] = \frac{0.1406}{356.06 \cdot 0.975}\left[\frac{(1560 - 837.84)^{1.25}}{837.84^{0.6506}}\right] = 0.019$$

Finally, the minimum effective relief area for the safety valve acc. to Eq. 7.2.8.4-1 is

$$A = \frac{F'A'}{\sqrt{P_1}} = \frac{0.019 \cdot 250}{\sqrt{135.7}} = 0.40 \ in^2$$

which is satisfied by an effective orifice **1½G3 (5262.0452)**.

7.4.9.10 External Fire acc. to API 521 - Wetted Walls

**Example 7.4.9.10.** A vertical vessel with spherical ends at a set pressure of 200 psig contains benzene at 100°F (559.7°R). The vessel has a diameter of 15 ft, a length of 40 ft and an elevation of 15 ft. The maximum fluid level is 12 ft. Assume that the fire-fighting measures intervene promptly in the eventuality of fire and that adequate drainage is present.

*Solution* The amplitude of the wetted walls, heated by the flames, must be estimated to calculate the input thermal flow to the liquid. The free surface of benzene is 32 ft over the ground. Assuming that the fire level is at the ground, the height of the wetted walls, heated by the flames, is acc. to Eq. 7.4.8.3-5 equal to

$F_{eff} = \min(32\ ;\ 25) - 15 = 10\ \ ft$ .

And the size of the wetted area from Table 7.4.8.3-3 is

$A_{wet} = \pi \cdot D \cdot F_{eff} = \pi \cdot 15 \cdot 10\ \ ft^2 = 471.23\ \ ft^2$

The thermal heat flow is calculated from Eq. 7.4.8.3-1, assuming the worst case of bare vessel (with *F=1* from Table 7.4.8.3-2)

$Q = 21000\ F\ A_{wet}^{0.82} = 21000 \cdot 1 \cdot 471.23^{0.82}$ Btu/hr = 3 267 911 Btu/hr

The relieving pressure $P_1$ in the vessel is equal to 256.7 psi (= 200*1.21+14.7 psi). From NIST WebBook Database the latent heat of vaporization of benzene at 256 psi ($T_{vap} = T_1 = 875.5°R$) is about 114.9 Btu/$lb_m$. The discharged mass flow of vapor is calculated from Eq. 7.4.8.3-6

$W = Q / h_{vl0} = 3\ 267\ 911 / 114.9 \cong 28441.4$ Btu/$lb_m$.

The parameter C at relieving conditions is calculated from Eq. 7.4.3-3 with the specific heat ratio at relieving conditions of $k \cong 1.23$ taken from the NIST WebBook Database.

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 520\sqrt{1.23\left(\frac{2}{1.23+1}\right)^{\frac{1.23+1}{1.23-1}}} = 340.23\frac{\sqrt{lb_m lb_{mol}\,°R}}{lb_f\,hr}$$

The required effective flow area is given by Eq. 7.4.3-1 for critical vapor flow assuming ideal gas behavior.

$$A = \frac{W}{C\ K_b K_c K_d P_1}\sqrt{\frac{T\ Z}{M}} = \frac{28\ 441.4}{340.23 \cdot 1 \cdot 1 \cdot 0.975 \cdot 256.7}\sqrt{\frac{875.5 \cdot 1}{78.11}} = 1.118\ in^2$$

For this requirement the orifice **3J4 (5262.1622)** would be large enough.

## 7.5 Sizing according to ISO 4126-7

The information contained in this section is based on following editions of codes and standards: ISO 4126-1 (2016), ISO 4126-7 (2016), ISO 23251 (2020).

### 7.5.1 Introduction

ISO 4126- is a Standard for the certification of safety valves, ISO 4126-7 for the sizing .The flow area, which is extracted from LESER's catalog, must be in excess of the minimum required flow area, which is calculated with the formulae in Paragraph 5.2 to 5.6 of this Chapter.
In comparison to API RP 520 there are no predefined effective orifices to select in a preliminary sizing procedure and the sizing for fire case and thermal expansion is described in the separate norm[9] ISO 23251, which is based on the API 521 (2020). ISO 4126-1 is applicable to safety valves with a flow diameter of at least 6 mm and at set pressures equal or above 0.1 bar gauge.
The sizing formulas in this section are solved explicitly in terms of the required flow area A, which permit the immediate selection of an actual flow area from LESER catalog. The sizing formulas in ISO 4126-7 are identical to those presented here except that they are written in terms of the mass flow rate $Q_m$.

### 7.5.2 List of Symbols/Nomenclature

| Symbol | Description | Units [SI] |
|---|---|---|
| $A$ | Flow area of the safety valve | [mm²] |
| $C$ | Function of the isentropic coefficient | -- |
| $K_b$ | Theoretical capacity correction factor for subcritical flow | -- |
| $K_{dr}$ | Certified derated coefficient of discharge | -- |
| $K_v$ | Viscosity correction factor | -- |
| $k$ | Isentropic coefficient (see Par. 3.1) | -- |
| $M$ | Molar mass | [kg/$k_{mol}$] |
| $p_0$ | Relieving pressure | [bar] |
| $p_b$ | Back pressure | [bar] |
| $Q_m$ | Mass flow rate | [kg/hr] |
| $T_0$ | Relieving temperature | [K] |
| $\mu$ | Dynamic viscosity | [Pa s] |
| $v$ | Specific volume at actual relieving pressure and temperature | [m³/kg] |
| $x$ | Dryness fraction of wet steam at the safety valve inlet at actual relieving pressure and temperature | -- |
| $Z$ | Compressibility factor at actual relieving pressure and temperature (see Par. 3.21) | -- |

*Table 7.5.2-1: List of symbols for sizing according to ISO 4126-7*

The relieving pressure $p_0$ is defined in Eq. 7.5.2-1 as the sum of the set pressure, the overpressure and the atmospheric pressure. In Eq. 7.5.2-1 the overpressure is generally 10% of the set pressure also for safety valves, which are fully open at set pressure plus an overpressure below 10%.

$$p_0 = p_{set} + \Delta\ p_{over} + p_{amb} \quad \text{(Eq. 7.5.2-1)}$$

[9] ISO 23251 Petroleum, petrochemical and natural gas industries – pressure-relieving and depressurising systems, 2020

### 7.5.3 Saturated or Superheated Steam - Critical Flow (ISO 426-1 2004)

$$A = \frac{1}{0.2883} \frac{Q_m}{C\ K_{dr}} \sqrt{\frac{v}{p_0}} \quad \textit{(Eq. 7.5.3-1)}$$

with

$$C = 3.948 \sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \quad \textit{(Eq. 7.5.3-2)}$$

Values for the isentropic coefficient *k* at ambient temperature and pressure of many common pure gases, which are cited in ISO 4126-7 [10].

### 7.5.4 Wet Steam (ISO 426-1 2004)

$$A = \frac{\sqrt{x}}{0.2883} \frac{Q_m}{C\ K_{dr}} \sqrt{\frac{v}{p_0}} \quad \textit{(Eq. 7.5.4-1)}$$

The formula applies only to homogeneous wet steam with a minimum dryness fraction of 90 %. The dryness fraction of 90% is an indicative value to distinguish between a wet steam flow and a more complex two phase flow.

### 7.5.5 Gaseous Media - Critical Flow occurring-lower dryness fraction (ISO 4126-1 2004)

$$A = \frac{Q_m}{p_0 C\ K_{dr}} \sqrt{\frac{Z T_0}{M}} \quad \textit{(Eq. 7.5.5-1)}$$

### 7.5.6 Gaseous Media - Subcritical Flow (ISO 4126-1 2004)

$$A = \frac{Q_m}{p_0 C\ K_b K_{dr}} \sqrt{\frac{Z T_0}{M}} \quad \text{(\textit{Eq.} 7.5.6-1)}$$

with

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_0}\right)^{2/k} - \left(\frac{p_b}{p_0}\right)^{(k+1)/k}\right]}{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}} \quad \text{(\textit{Eq.} 7.5.6-2)}$$

### 7.5.7 Liquids (ISO 4126-1 2004)

$$A = \frac{1}{1.61} \frac{Q_m}{K_{dr} K_v} \sqrt{\frac{v}{p_0 - p_b}} \quad \text{(\textit{Eq.} 7.5.7-1)}$$

The viscosity correction factor $K_v$ in function of the Reynolds number *Re* follows Fig. 7.9.3-1. The Reynolds number is defined as

$$\mathrm{Re} = \frac{1}{3.6} \frac{Q_m}{\mu} \sqrt{\frac{4}{\pi\ A}} \quad \text{(\textit{Eq.} 7.5.7-2)}$$

Two phase flow is covered by ISO 4126-10

[10] ISO 4126-7 Safety devices for protection against excessive pressure – Part 7: common data, 2016.

### 7.5.8 Discharge Coefficient of Valves with Restricted Lift

A restricted lift allows the user to limit the discharged flow capacity from the safety valve to a value equal or closer to the required capacity. The restriction of the valve lift makes sense, when:

Gas or Two-phase flows

- the safety valve is oversized AND
- the inlet pressure loss is larger than 3% (→ possibility of valve chattering) or the built-up back pressure is too large due to excessive flow.

Liquid flows

- the inlet pressure loss is larger than 3% (→ possibility of valve chattering) or the built-up back pressure is too large due to excessive flow. Thermal expansion alone is not a reason.

In any case, oversizing alone is not the reason to install a lift restriction and there is no rule of thumb determination of an indicative percentage of allowable oversizing. It rather depends on the installation conditions of the safety valve, for instance on the inlet and outlet line configuration.
A lift restriction should be installed to reduce problems with excessive inlet pressure loss or built-up back pressure caused by the excessive flow in an oversized safety valve. The lift restriction limits the flow of the safety valve to the required one and therefore reduces the pressure loss at the inlet and the built-up back pressure at the outlet.

ISO 4126-1 allows the manufacturer to restrict the lift to a value larger than either 30 % of the unrestricted lift or 1 mm, whichever is greater.
For safety valves with a restricted lift the manufacturers are required to generate a curve showing the change of the discharge coefficient with the lift, like that in Fig. 7.5.8-1 for LESER Type 441/442. VdTÜV[11] guidance requires that this curve must be obtained with a ratio of the absolute back pressure on the relieving pressure, $p_{a0}/p_{0}$, above the critical pressure ratio. An example how to calculate the restricted lift is proposed at the end of this chapter.

In VALVESTAR® the user can select the option of restricted lift with just a mouse click and the software sizes the safety valve with the minimum lift required to deliver the required mass flow.

[11] VdTÜV-Merkblatt Sicherheitsventil 100, *Richtlinie für die Baumusterprüfung von Sicherheitsventilen im Geltungsbereich der Richtlinie 2014/68/EU (Drückgeräte-Richtlinie)*

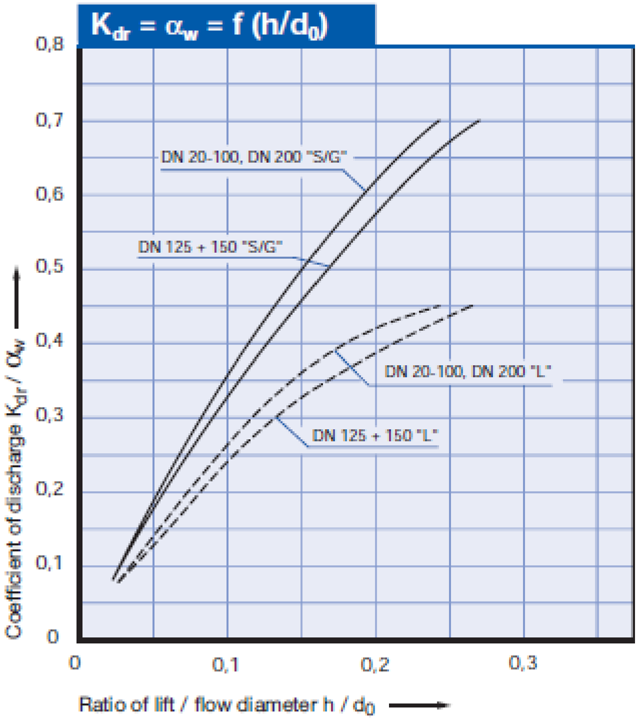



*Figure 7.5.8-1 Discharge coefficient $K_{dr}$ for gases in function of the lift h over flow diameter $d_o$ for LESER Type 441*

### 7.5.9 Discharge Coefficient of Valves at High Back Pressures

ISO 4126-7 also considers the possibility that the discharge coefficient for gases and vapors in subcritical flows is less than that in critical conditions. Concretely, if the ratio of the absolute back pressure $P_{a0}$ to the relieving pressure $P_0$ exceeds the value of 0.25, the coefficient of discharge can depend upon this ratio. The manufacturer is required to certify the flow capacity of the valve for ratios of the absolute back pressure on the relieving pressure between 0.25 and the maximum pressure ratio. This curve may be extended to cover the tests with pressure ratios less than 0.25, if necessary. VdTÜV states explicitly that this curve must be obtained with a constant lift ratio, $h/d_0$. Fig. 7.5.9-1 represents such an example of a back pressure dependence for the safety valve LESER Type 441.

From its internal databases VALVESTAR® selects the discharge coefficients of the safety valve which occur for the given ratio of absolute back pressure to relieving pressure.

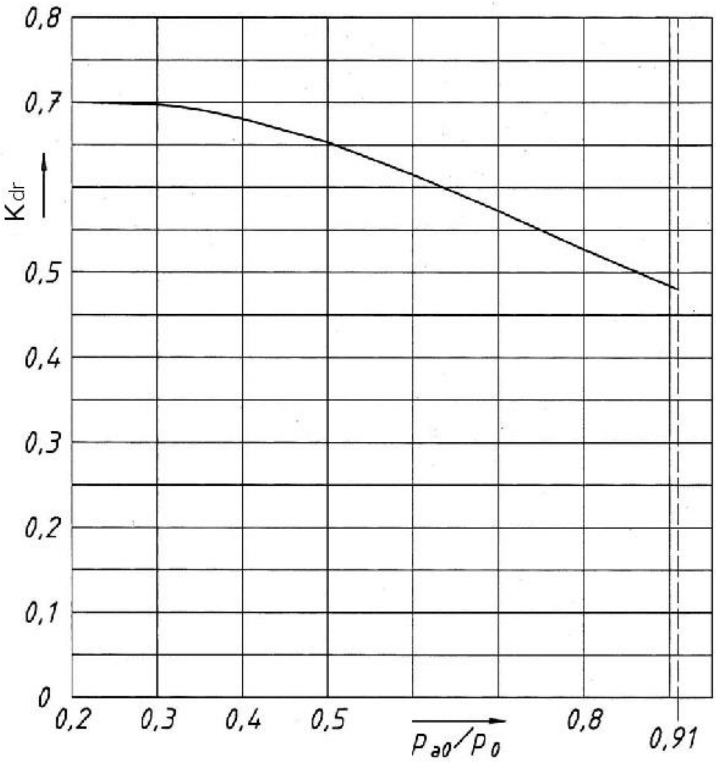



*Figure 7.5.9-1 Discharge coefficient $K_{dr}$ for gases in function of the ratio of the absolute back pressure $P_{a0}$ on the relieving $P_0$ pressure for LESER Type 441*

## 7.5.10 Examples

### 7.5.10.1 Gases - Critical Flow

**Example 7.5.10.1**. A safety valve for ethylene ($C_2H_4$) at the relieving temperature of 55°C (328.15 K) and a set pressure of 55 bar g for a relieving mass flow rate of 4200 kg/h and back pressure of 10 bar g is required. For the type assume LESER Type 459 with a $K_{dr}$ equal to 0.81.

*Solution*. The relieving pressure values

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 55 \ bar + 5.5 \ bar + 1 \ atm = 61.51 \ bar$$

From the Example 7.2.6.1 the compressibility factor $Z$ is 0.712, the isentropic exponent $k$ and the molecular weight $M$ are respectively 1.19 and 28.03 kg/$k_{mol}$.
The flow function C is calculated from Eq. 7.5.3-2

$$C = 3.948\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 3.948\sqrt{1.19\left(\frac{2}{1.19+1}\right)^{\frac{1.19+1}{1.19-1}}} = 2.553$$

The critical back pressure is calculated from Fig. 7.5.2-2 and it is equal to

$$p_c = p_0\left(\frac{2}{k+1}\right)^{k/(k-1)} = 61.51 \ bar \cdot \left(\frac{2}{1.19+1}\right)^{1.19/(1.19-1)} = 34.84 \ bar$$

and the flow is critical since the back pressure of 11.01 bar is lower than the critical pressure. Therefore the coefficient $K_b$ is in this case not necessary.
The required necessary relief area comes from Eq. 7.5.5.1-1

$$A = \frac{Q_m}{p_0 C \ K_{dr}}\sqrt{\frac{Z \ T_0}{M}} = \frac{4200}{61.51 \cdot 2.553 \cdot 0.81}\sqrt{\frac{0.712 \cdot 328.15}{28.03}} \ mm^2 = 95.4 \ mm^2$$

which is satisfied by the valve with a relief area of 133 mm² (diameter: 13 mm) **(4593.2512)**.

### 7.5.10.2 Gases - Subcritical Flow

**Example 7.5.10.2**. Same as Example 7.4.7.1 but with a back pressure of 35 bar g (36.01 bar).

*Solution*. The flow in the safety valve is in this case subcritical and therefore the correction factor must be calculated acc. to Eq. 7.5.5.2-2

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_0}\right)^{2/k} - \left(\frac{p_b}{p_0}\right)^{(k+1)/k}\right]}{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}} = \sqrt{\frac{\frac{2 \cdot 1.19}{1.19-1}\left[\left(\frac{36.01}{61.51}\right)^{2/1.19} - \left(\frac{36.01}{61.51}\right)^{(1.19+1)/1.19}\right]}{1.19\left(\frac{2}{1.19+1}\right)^{(1.19+1)/(1.19-1)}}} = 0.9991$$

The minimum required relief area, calculated from Eq. 7.5.4.2-1 is

$$A = \frac{Q_m}{p_0 C \ K_{dr} K_b}\sqrt{\frac{Z \ T_0}{M}} = \frac{4200}{61.51 \cdot 2.553 \cdot 0.721 \cdot 0.9991}\sqrt{\frac{0.712 \cdot 328.15}{28.03}} \ mm^2 = 107.2 \ mm^2$$

which is satisfied again by the LESER Type 459 with a relief area of 133 mm² (**4593.2512**).

**Note:** Observe that the derated discharge coefficient is less than that of the previous example due to the higher back pressure ratio. See Example 7.5.10.8 for a detailed example.

7.5.10.3 Dry Steam (ISO 4126-1 2004)

**Example 7.5.10.3**. A safety valve must be sized for (saturated) steam in a large vessel at a set pressure of 110.4 bar gauge for a mass flow rate of 69800 kg/hr , assuming 10% overpressure.

*Solution*. The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 110.4\ bar + 11.04\ bar + 1.01\ bar = 122.45\ bar$$

The specific volume and the isentropic exponent of saturated steam at relieving conditions acc. to IAPWS – IF 97 tables[12] is equal to 0.013885 m³/kg and 0.966, which is in good agreement with the value, obtained by interpolating the data from ISO 4126-7. With this isentropic coefficient the required parameter C from Eq. 7.5.3-2 is

$$C = 3.948\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 3.948\sqrt{0.966\left(\frac{2}{0.966+1}\right)^{\frac{0.966+1}{0.966-1}}} = 2.3636$$

In view of the high pressure and capacity requirements, a safety valve **LESER Type 458** is selected. At first we size using the derated discharge coefficient of 0.84 , which suits for most of the sizes of this safety valve type. With that value of the discharge coefficient the required flow area from Eq. 7.4.3-1 is

$$A = \frac{1}{0.2883}\frac{Q_m}{C\ K_{dr}}\sqrt{\frac{v}{p_0}} = \frac{1}{0.2883}\frac{69800}{2.3636\cdot 0.84}\sqrt{\frac{0.013885}{122.45}}\ mm^2 = 1298\ mm^2$$

Consequently, a relief area of 1964 mm² (**DN 80/100**) (**4582.6142**) would suffice. However, the derated discharge coefficient for that size is 0.83; nevertheless, introducing of the true value of the discharge coefficient the valve size is confirmed.

$$A = \frac{1}{0.2883}\frac{Q_m}{C\ K_{dr}}\sqrt{\frac{v}{p_0}} = \frac{1}{0.2883}\frac{69800}{2.3636\cdot 0.83}\sqrt{\frac{0.013885}{122.45}}\ mm^2 = 1314\ mm^2$$

**Note.** The isentropic coefficient of steam at the relieving conditions is different in ISO 4126-7 and IAPWS Database.

7.5.10.4 Wet Steam (ISO 4126-1 2004)

**Example 7.5.10.4.** Same problem as in Example 7.5.10.3. but assuming a wet fraction of 3 %

*Solution Wet Steam*. The fraction of dry steam on the wet steam is equal to 97 % or 0.97 . For wet steam a smaller minimum flow area is required than that if the steam were dry.
From Eq. 7.5.4-1 it is equal to

$$A = \frac{1}{0.2883}\frac{Q_m\sqrt{x}}{C\ K_{dr}}\sqrt{\frac{v}{p_0}} = \frac{1}{0.2883}\frac{69800\cdot\sqrt{0.97}}{2.3636\cdot 0.83}\sqrt{\frac{0.013885}{122.45}}\ mm^2 = 1294.3\ mm^2$$

The relief area of the safety valve is nevertheless again equal to 1964 mm² (**4582.6142**).

[12] W. Wagner , H. Kretzschmar Ed., *International steam tables: Properties of water and steam based on the industrial formulation IAPWS-IF97,* Springer, Berlin, 2008

7.5.10.5 Superheated Steam (ISO 4126-1 2004)

**Example 7.5.10.5.** Same problem as in Example 7.5.10.3 but assuming superheated steam at a set pressure of 110.4 bar and 420°C

*Solution Superheated Steam*. Also in case of superheated heat values of the isentropic coefficient and of the specific volume at relieving conditions are needed. From IAPWS tables they are respectively 1.279 for the isentropic coefficient and 0.0214 m³/kg for the specific volume and they are close to the values from the interpolation of data in ISO 4126-7. On their behalf the parameter C from Eq. 7.5.3-2 is equal to

$$C = 3.948\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 3.948\sqrt{1.279\left(\frac{2}{1.279+1}\right)^{\frac{1.279+1}{1.279-1}}} = 2.6192$$

Assuming the derated discharge coefficient of 0.84, the required area using Eq. 7.5.3-1 must exceed

$$A = \frac{1}{0.2883}\frac{Q_m}{C\ K_{dr}}\sqrt{\frac{v}{p_0}} = \frac{1}{0.2883}\frac{69800\cdot}{2.6192\cdot 0.84}\sqrt{\frac{0.0214}{122.45}}\ mm^2 = 1454.7\ mm^2$$

which suggests that again a relief area of 1964 mm² is enough (**4582.6142**). Indeed, considering the corresponding derated discharge coefficient for that valve size, which is 0.83, the minimum required area is equal to

$$A = \frac{1}{0.2883}\frac{Q_m}{C\ K_{dr}}\sqrt{\frac{v}{p_0}} = \frac{1}{0.2883}\frac{69800\cdot}{2.6192\cdot 0.83}\sqrt{\frac{0.0214}{122.45}}\ mm^2 = 1472.2\ mm^2$$

7.5.10.6 Liquid - Viscous Flow

**Example 7.5.10.6**. A safety valve must be sized for a flow rate of 5 l/s of glycerin (density :1260 kg/m³ and viscosity: 1410 mPa s) at a set pressure is 10 bar-g and atmospheric backpressure with 10 % accumulation.

*Solution* The (mass) flow capacity must be expressed with the units of ISO 4126-7.

$$Q_m = 5l/s\cdot 1260\ kg/m^3\cdot 3600\ s/hr = 22680\ kg/hr$$

For this high discharge application **LESER Type 441** can be selected. The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 10\ bar + 1\ bar + 1.01\ bar = 12.01\ bar$$

The required minimum flow area is calculated with a two-step procedure. At first the relief area is calculated as the liquid were inviscid. According to Eq. 7.5.6-1 this preliminary minimum flow area is

$$A = \frac{1}{1.61}\frac{Q_m}{K_{dr}}\sqrt{\frac{v}{p_0 - p_b}} = \frac{1}{0.2883}\frac{22680}{0.45}\sqrt{\frac{0.00079}{122.45}}\ mm^2 = 265.9\ mm^2$$

Then the next larger relief area $A'$ must be selected from the manufacturer's catalog, which equals in this case 416 mm² ( **DN 25/40** ) and is assumed as the preliminary flow area. The ratio of the calculated $A$ to $A'$ gives the minimum value of the viscosity correction factor that the real factor is required to exceed. In this case the minimum viscosity correction factor is

$$K_{v-\min} = A/A' = 265.9/416 = 0.639$$

Using the selected relief area the Reynolds number is calculated from Eq. 7.4.6-2

$$\mathrm{Re} = \frac{1}{3.6}\frac{Q_m}{\mu}\sqrt{\frac{4}{\pi\ A'}} = \frac{1}{3.6}\frac{22680}{1.41}\sqrt{\frac{4}{\pi\ 416}} = 247.2$$

On behalf of this Reynolds number the viscosity correction factor from Fig. 7.9.3-1 is about 0.79. Since this viscosity correction factor coefficient exceeds the minimum required value, the safety valve **LESER Type 441 DN 25/40 (4411.4382)** is the final flow area acc. to ISO 4126. In case it were not, the next larger $A'$ must be extracted from the manufacturer's catalog and the previously illustrated procedure routines until the minimum viscosity correction factor is exceed.

7.5.10.7 Determination of a Required Lift Restriction

**Example 7.5.10.7**. Which lift restriction would be necessary in Example 7.5.10.1 to minimize the flow from the safety valve in excess of the required one?

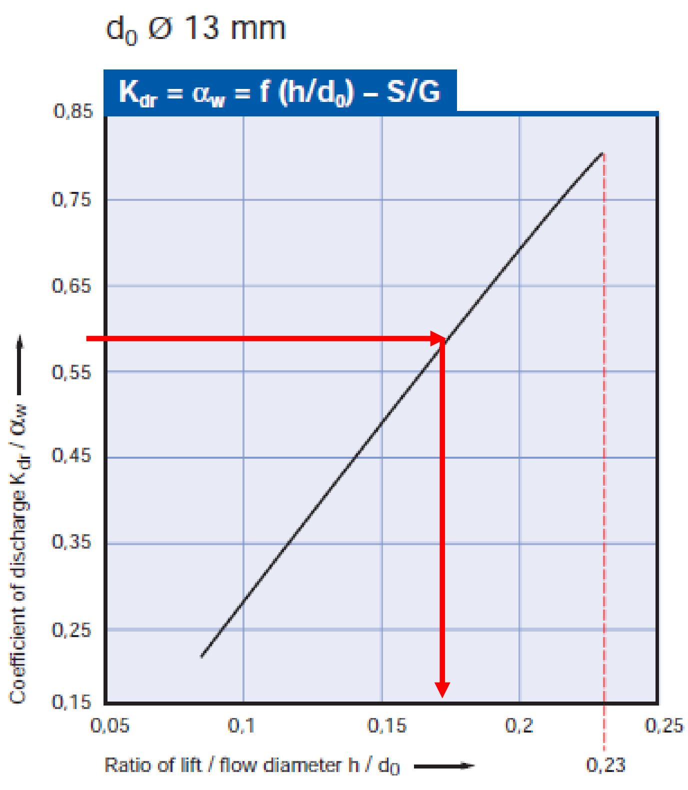
*Solution*. As a result from Example 7.5.10.1 a flow area of 133 mm² ($d_0$ = 13 mm) is chosen. However, from the process data the actual discharged mass flow acc. to Eq. 7.5.5.1-1 is much larger than the required one and exactly it is

$$Q_{m\ real} = p_0 C\ A\ K_{dr}\sqrt{\frac{M}{ZT_0}} = 61.51 \cdot 2.553 \cdot 133 \cdot 0.81\sqrt{\frac{28.03}{0.712 \cdot 328.15}} = 5859.6\ \frac{kg}{h}$$

In order to have a discharged mass flow closer to the required one, the disk lift must be reduced. The ratio between the reduced and the full lift derated discharge coefficient is given by the ratio of the required to the effectively discharged mass flow

$$\frac{K_{dr\ red}}{K_{dr\ full}} = \frac{Q_{m\ required}}{Q_{m\ effective}} \rightarrow K_{dr\ red} = K_{dr\ full} \cdot \frac{Q_{m\ required}}{Q_{m\ effective}} = 0.81 \cdot \frac{4200}{5859.6} = 0.58$$

which corresponds to the lift ratio $h/d_0$ of 0.1714 or 2.23 mm, acc. to the LESER Catalog Compact Performance, reported here below.



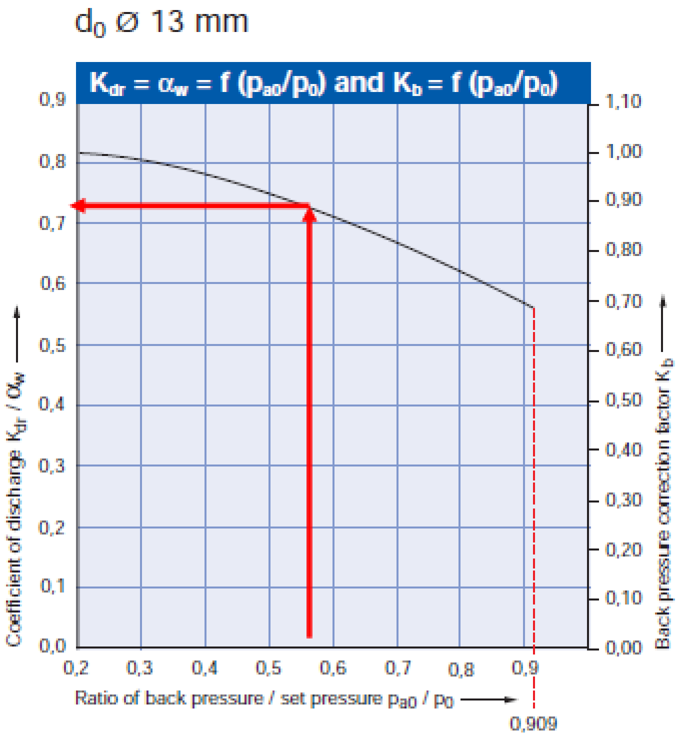
7.5.10.8 Determination of the Discharge Coefficient for Higher Back Pressures

**Example 7.5.10.8**. Find the discharge coefficient for the ratio of back pressure on the relieving pressure in Example 7.5.10.2

*Solution*. In Example 7.5.10.2 the back pressure is 35 bar gauge (36.01 bar) and the relieving pressure 61.51 bar, which corresponds to a $p_{a0}/p_0$ ratio

$$\frac{p_{a0}}{p_0} = \frac{36.01}{61.51} = 0.5854$$

Acc. to the LESER Catalog Compact Performance, reported here below, it corresponds to the derated discharge coefficient of 0.721.



## 7.6 Sizing according to AD 2000-Merkblatt A2

The information contained in this section is based on **AD 2000-Merkblatt A2 edition 2020.**

AD 2000 Merkblätter are guidelines satisfying the requirements for the construction of pressurized vessels contained in the PED directives. Among all other information, AD 2000 A2 contains indications for the installation and the sizing of safety valves and may be used alternatively to ISO 4126. Sizing acc. to AD 2000 A2 is applied by LESER upon explicit request from customers.

The minimal flow cross section of the safety valve must exceed the minimum one, which results from the following formulas. AD 2000 A2 prescribes a minimal flow diameter of at least 6 mm for the general case or 20 mm for pressure vessels with greasy or powdery media or for media, which are inclined to coalesce. The minimum values of the derated discharge coefficient that the safety valves are required to have are:

| | |
|---|---|
| 0.5 | for full-lift valves, except for those with a lift restriction |
| 0.08 (Gas/Vapor)<br>0.05 (Liquid) | respectively for normal and proportional safety valves |

### 7.6.1 List of Symbols / Nomenclature

| Symbol | Description | Units [SI] |
|---|---|---|
| $A_0$ | Minimal cross section of flow | [mm²] |
| $k$ | Isentropic exponent (see isentropic coefficient in ISO 4126) (see Par. 3.1) | -- |
| $M$ | Molar mass | [kg/k$_{mol}$] |
| $p_a$ | Dynamic back pressure behind the valve | [bar] |
| $p_s$ | Pressure of the medium at saturation temperature | [bar] |
| $p_0$ | Absolute pressure in the pressure chamber | [bar] |
| $q_m$ | Mass flow to be discharged | [kg/h] |
| $T$ | Temperature of the medium in the protected system | [K] |
| $v$ | Specific volume of the medium in the pressure chamber | [m³/kg] |
| $x$ | Pressure medium coefficient (gas flows)<br>Vapour void fraction (two-phase flows) | [h mm² bar/kg]<br>-- |
| $Z$ | Compressibility factor of the medium in the pressure chamber (see Par. 3.21) | -- |
| $\alpha_w$ | Certified discharge coefficient | -- |
| $\psi$ | Outflow function (gas flows) | -- |
| $\rho$ | Density | Kg/m³ |

*Table 7.6.1-1: List of symbols for sizing according to AD 2000 A2*

The relieving pressure $p_0$ is defined in Eq. *7.6.1-1* as the sum of the set pressure, the overpressure and the atmospheric value. For the overpressure in Eq. *7.6.1-1* generally 10% of the set pressure is used, also for safety valves that are fully open at set pressure plus an overpressure below 10%, e.g. for full lift safety valves with 5% overpressure..

$$p_0 = p_{set} + \Delta\ p_{over} + p_{amb} \quad \textit{(Eq. 7.6.1-1)}$$

## 7.6.2 Gases and Vapors

$$A_0 = 0.1791 \frac{q_m}{\psi \, \alpha_w \, p_0} \sqrt{\frac{T\,Z}{M}} \quad \text{(Eq. 7.6.2-1)}$$

with the outflow function defined in Table 7.6.2-1

| | | |
|---|---|---|
| Subritical flow | $\frac{p_a}{p_0} > \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$ | $\psi = \sqrt{\frac{k}{k-1}} \sqrt{\left(\frac{p_a}{p_0}\right)^{\frac{2}{k}} - \left(\frac{p_a}{p_0}\right)^{\frac{k+1}{k}}}$ |
| Critical flow | $\frac{p_a}{p_0} \le \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$ | $\psi = \sqrt{\frac{k}{k+1}} \left(\frac{2}{k+1}\right)^{\frac{1}{k-1}}$ |

*Tab. 7.6.2-1 Outflow function for critical and subcritical gas flows*

## 7.6.3 Steam

$$A_0 = \frac{x \, q_m}{\alpha_w \, p_0} \quad \textit{(Eq. 7.6.3-1)}$$

The pressure medium coefficient $x$ is defined in Eq. 7.6.3-2

$$x = 0.6211 \frac{\sqrt{p_0 v}}{\psi} \quad \textit{(Eq. 7.6.3-2)}$$

The values of the specific volume and the isentropic exponent for the calculation of $\psi$ are extracted from *State Variables of Water and Steam*, Springer, Berlin, 1969. AD 2000 A2 does not state, if more actual versions of this database, like the IAPWS tables, shall be consulted. In replacement of Eq. 7.6.3-2 the pressure medium coefficient for critical flows can be taken from Fig. 7.6.3-1. For subcritical flows as well as for set pressures below 2 bar this graph can not be used and the pressure medium coefficient must be calculated.

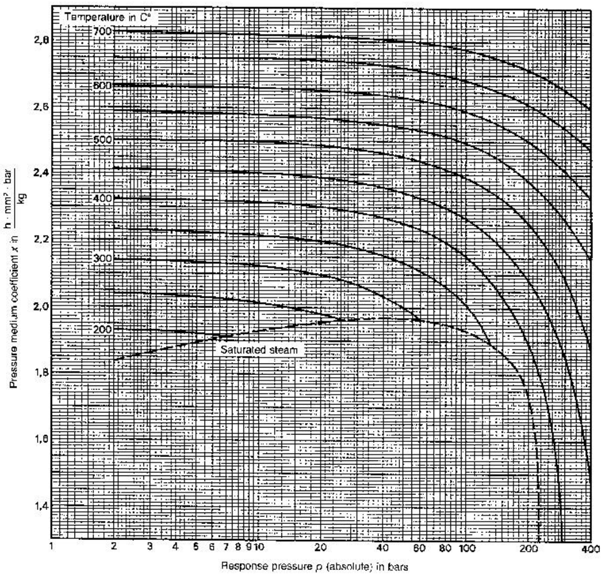



*Fig. 7.6.3-1 Pressure medium coefficient for steam in function of the response pressure (set pressure)*

### 7.6.4 Non-Boiling Liquids

$$A_0 = 0.6211 \frac{q_m}{\alpha_w \sqrt{\rho\left(p_0 - p_a\right)}}$$ (Eq. 7.6.4-1)

Non-boiling liquids do not change phase when flowing in the safety valve. AD 2000 A2 gives no reference to a viscosity correction factor for viscous liquids. Nevertheless, VALVESTAR® follows the sizing procedure in ISO 4126-7 for the determination of the viscosity correction factor.

### 7.6.5 Discharge Coefficient of Valves with Restricted Lift

The discharge coefficient for safety valves with a lift restriction or in case of high back pressures are certified acc. to VdTÜV Merkblatt 100 *Sicherheitsventile* (see section 7.5.8 and 7.5.9). The lift must be at least 1 mm or 30% of the maximum lift, whichever value is greater. For all other details see 7. 5.8.

### 7.6.6 Discharge Coefficient of Valves at High Back Pressures

Qualitatively identical to Section 7.5.9.

### 7.6.7 Summary AD 2000 - Merkblatt A2

The AD 2000 Code can be applied to satisfy the basic safety requirements of the Pressure Equipment Directive (PED). That means, sizing a safety valve acc. to AD 2000 A2 is in compliance with the PED requirements. The sizing formulas in the standard AD 2000 A2 are for gases, vapors, liquids not requiring viscosity correction factors are identical to those in ISO 4126-7.

## 7.6.8 Examples

### 7.6.8.1 Gas - Critical Flow

**Example 7.6.8.1**. A safety valve is sized for a mass flow rate of 4200 kg/h ethylene ($C_2H_4$) at the relieving temperature of 55°C and a set pressure of 55 bar g and back pressure of 10 bar g. The safety valve is the **LESER Type 459** with $\alpha_w$ equal to 0.81.

*Solution*. The relieving pressure values

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 55\ bar + 5.5\ bar + 1\ atm = 61.51\ bar$$

From Example 7.2.6.1 the compressibility factor $Z$ is 0.712. The isentropic coefficient *k* and the molecular weight $M$ are given from the customer as 1.19 and 28.03 kg/$k_{mol}$ and the flow is critical.

The flow function $\psi$ is calculated from the first line of Table 7.6.2-1

$$\psi = \sqrt{\frac{k}{k+1}\left(\frac{2}{k+1}\right)^{\frac{1}{k-1}}} = \sqrt{\frac{1.19}{1.19+1}\left(\frac{2}{1.19+1}\right)^{\frac{1}{1.19-1}}} = 0.4572$$

The required necessary flow area is calculated from Eq. 7.6.2-1

$$A_0 = 0.1791\frac{q_m}{\psi\ \alpha_w p_0}\sqrt{\frac{T\ Z}{M}} = 0.1791\frac{4200}{0.4572\cdot 0.81\cdot 61.51}\sqrt{\frac{328.15\cdot 0.712}{28.03}} = 95.4\ mm^2$$

The flow area of 133 mm² ($d_0$ = 13 mm) **(4593.2512)**, as already seen using ISO 4126-7, will be large enough to release the given mass flow rate.

### 7.6.8.2 Gas - Subcritical Flow

**Example 7.6.8.2**. Same as Example 7.6.8.1 but with a back pressure of 35 bar g (36.01 bar). The discharge coefficient comes from Example 7.5.10.8 and is equal to 0.721.

*Solution*. From Example 7.5.10.2 we know that the flow in the safety valve is in this case subcritical and therefore the outflow function must be taken from the first line of Table 7.6.2-1

$$\psi = \sqrt{\frac{k}{k-1}}\sqrt{\left(\frac{p_a}{p_0}\right)^{\frac{2}{k}} - \left(\frac{p_a}{p_0}\right)^{\frac{k+1}{k}}} = \sqrt{\frac{1.19}{1.19-1}}\sqrt{\left(\frac{36.01}{61.51}\right)^{\frac{2}{1.19}} - \left(\frac{36.01}{61.51}\right)^{\frac{1.19+1}{1.19}}} = 0.4568$$

The minimum required flow area according to Eq. 7.5.2-1 is

$$A_0 = 0.1791\frac{q_m}{\psi\ \alpha_w p_0}\sqrt{\frac{T\ Z}{M}} = 0.1791\frac{4200}{0.4568\cdot 0.721\cdot 61.51}\sqrt{\frac{328.15\cdot 0.712}{28.03}} = 107.2\ mm^2$$

which is satisfied again by the LESER Type 459 with a relief area of 133 mm² ($d_0$ = 13 mm) **(4593.2512).**

### 7.6.8.3 Saturated Steam

**Example 7.6.8.3**. A safety valve must be sized for saturated steam at a set pressure of 110.4 bar g with a mass flow of 69800 kg/hr , assuming 10% overpressure. In view of the high pressure and capacity requirements, a safety valve **LESER Type 458** with a discharge coefficient of 0.83 is selected.

*Solution*. The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 110.4\ bar + 11.04\ bar + 1.01\ bar = 122.45\ bar$$

The specific volume and the isentropic exponent of saturated steam at 122.45 bar are taken from IAPWS tables equal to 0.013885 m³/kg and 0.966. The outflow function $\psi$ from Table 7.6.2-1 equals

$$\psi = \sqrt{\frac{k}{k+1}}\left(\frac{2}{k+1}\right)^{\frac{1}{k-1}} = \sqrt{\frac{0.966}{0.966+1}}\left(\frac{2}{0.966+1}\right)^{\frac{1}{0.966-1}} = 0.4233$$

The pressure medium coefficient is calculated from Eq. 7.6.3-2 as

$$x = 0.6211\frac{\sqrt{p_0 v}}{\psi} = 0.6211\frac{\sqrt{122.45\cdot 0.013885}}{0.4233} = 1.9128\ \frac{h\cdot mm^2\cdot bar}{kg}$$

The required flow area is finally calculated from Eq. 7.6.3-1

$$A_0 = \frac{x\ q_m}{\alpha_w p_0} = \frac{1.9128\cdot 69800}{0.83\cdot 122.45} = 1313.7\ mm^2$$

The required relief area would be 1964 mm² ($d_0$ = 40 mm) **DN 80/100 (4582.6142.**

7.6.8.4 Non-Boiling Liquid

**Example 7.6.8.4**. A safety valve Type 441 must be sized for a flow rate of 5 l/s of water (density :998 kg/m³ ) and a set pressure is 10 bar g with atmospheric back pressure and 10% accumulation.

*Solution* The required mass capacity is

$$q_m = 5 \;\; l/s * 998 \; kg/m^3 * 3600 \;\; s/h * 0.001 \; m^3/l = 17964 \; kg/h$$

The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 10 \;\; bar + 1 \;\; bar + 1.01 \;\; bar = 12.01 \;\; bar$$

The required flow area according to Eq. 7.6.4-1 is equal to

$$A_0 = 0.6211 \frac{q_m}{\alpha_w \sqrt{\rho(p_0 - p_a)}} = 0.6211 \frac{17964}{0.45\sqrt{998(12.01)}} = 226.5 mm^2$$

The required relief area is 254 mm², which corresposnds to the size **DN 20/32 (4411.4372)**

## 7.7 Sizing Standards Applying to Cryogenic Applications

In this section the norms are based on following edition:
ASME Section XIII (2021), EN 13136 (2013), ISO 4126-7 (2016), ISO 21013-3 (2016), EN 12693 (2008)

ASME Section XIII, ISO 4126-7 and AD 2000 Merkblatt A2 apply to the general sizing occurrence of a gas, vapor or liquid in a pressurized unit. However, in the specific case of pressurized vessels for LNG, LPG or similar, where high pressures and very low temperatures occur, special standards have been developed to estimate the mass flow rate to the safety devices.
The standards presented in this section are useful to calculate the mass flow rate to the safety valve used in the protection of these vessels.

### 7.7.1 Sizing acc. to ISO 21013-3

This standard applies to vacuum-insulated and non-vacuum insulated cryogenic vessels under different conditions of intactness of the insulation system (outer jacket + insulating material). The outer jacket temperature is ambient temperature and the inner vessel is at the temperature of the contained medium. It applies also for vessels with a totally lost insulation system and fire engulfment.

#### 7.7.1.1 List of Symbols/Nomenclature

| Symbols | Description | Units [SI] |
|---|---|---|
| L | Latent heat of vaporization of the cryogenic liquid at relieving conditions | kJ/kg |
| L' | Specific heat input , defined as $v\left[\frac{\partial h}{\partial v}\right]_p$ at the relieving pressure $p_0$ and temperature which maximizes $\sqrt{v}\Big/v\left[\frac{\partial h}{\partial v}\right]_p$ | kJ/kg |
| $v_G$ | Specific volume of saturated vapor at relieving pressure | m³/kg |
| $v_L$ | Specific volume of saturated liquid at relieving pressure | m³/kg |
| W | Quantity of heat per unit time | W |

*Table 7.7.1.1-1: List of symbols for sizing according to ISO 21013-3*

For the determination of the minimum mass flow requirements follow Table 7.7.1.1-2 which relates it to the ratio $p_0/p_c$ of the relieving pressure $p_0$ to the (thermodynamical) critical pressure $p_c$ (see sect. 2.3)

| $p_0/p_c$ [-] | $Q_m$ [kg/h] |
|---|---|
| less than 0.4 | $3.6\ W/L$ |
| between 0.4 and 1 | $3.6\left(\frac{v_G - v_L}{v_G}\right)W/L$ |
| more than or equal to 1 | $3.6\ W/L'$ |

*Table 7.7.1.1-2 Criteria to select the mass flow rate into the safety valve. for standard*

The required heat input should be provided as input data, following the calculation scheme in the norm.

The minimum required flow area is determined acc. to ISO 4126-7. The sum of the relieving capacities of all the safety valves must be equal or exceed the minimum required mass flow $Q_m$. from Table 7.7.1.1-2.

7.7.1.2 Example

**Example 7.7.1.2**. Determine the mass flow rate to the safety valve for a vessel of liquid hydrogen at a relieving pressure of 2.8 bar. Consider an heat input of 15000 W.

*Solution*. The critical point of hydrogen is 13 bar and 33.2 K and the relieving pressure is les than 40 % of the thermodynamic critical pressure.

The latent heat L at that relieving pressure acc. to NIST is 417.274 kJ/kg.
The mass flow rate of hydrogen vapor to the safety valve is
$Q_m = 3.6 W / L = 3.6 \cdot 15000 / 417.274 = 129.4$ kg/h

### 7.7.2 Sizing acc. To DIN EN 13136

The standard DIN EN 13136[13] describes calculation procedures to estimate the required mass flow rates of refrigerants in the gaseous phase.

#### 7.7.2.1 List of Symbols /Nomenclature

| Symbol | Description | Units [SI] |
|---|---|---|
| $\varphi$ | Density of heat flow rate | [kW/m²] |
| $\eta_v$ | Volumetric efficiency estimated at suction pressure and discharge pressure equivalent to the safety valve setting | [--] |
| $\rho_{10}$ | Vapor density at refrigerant saturation pressure/dew point at 10°C | [kg/m³] |
| $A$ | Flow area of the safety valve | [mm²] |
| $A_c$ | Calculated flow area | [mm²] |
| $A_{surf}$ | External surface area of the vessel | [m²] |
| $h_{vap}$ | Heat of vaporization calculated at 1.1 times the set pressure of the safety valve | [kJ/kg] |
| $K_{dr}$ | Derated coefficient of discharge | [--] |
| $n$ | Rotational frequency | [min$^{-1}$] |
| $Q_h$ | Rate of heat production, internal heat source | [kW] |
| $Q_m$ | Calculated mass flow rate | [kg/h] |
| $Q_{md}$ | Minimum required capacity of refrigerant of the safety valve | [kg/h] |
| $V$ | Theoretical displacement | [m³] |

*Table 7.2-1: List of symbols for sizing according to EN 13136*

If heat, which is either internally generated or transmitted from an external source, warms up the tank, overpressure may arise from a partial evaporation of the liquid. The minimum required vapor discharge capacity of the safety valve is determined by either Eq. 7.7.2-1 if the heat source is external or Eq. 7.7.2-2 if internal.

$$Q_{md} = 3600 \frac{\varphi \cdot A_{surf}}{h_{vap}} \quad \text{(external heat sources) (7.7.2-1)}$$

If no better value is known, the density of heat flow rate φ can be assumed as 10 kW/m².

$$Q_{md} = 3600 \frac{Q_h}{h_{vap}} \quad \text{(internal heat sources) (7.7.2-2)}$$

The minimum discharge area of the safety valve in case of overpressure in the vessel caused by compressor inflow is determined using Eq. 7.7.2-3

$$Q_{md} = 60 \cdot V \cdot n \cdot \rho_{10} \cdot \eta_v \quad \text{(compressors) (7.7.2-3)}$$

The standard EN 12693[14] covers the case of compressors running against a closed discharge valve.

[13] EN 13136 Refrigerating systems and heat pumps – Pressure relief devices and their associated piping – Method for calculation, 2013.
[14] EN12693 Refrigerating systems and heat pumps – Safety and environmental requirements – Refrigerant compressors, 2008.

The minimum flow area of the safety valve is calculated from the minimum required mass flow rate determined from Eq. 7.7.2-1 to Eq. 7.7.2-3 using Eq. 7.7.2-4. To determine *C* and $K_b$, see Paragraph 7.5.3 and 7.5.6

$$A_c = 3.469 \frac{Q_{md}}{C \cdot K_{dr} \cdot K_b} \sqrt{\frac{v_0}{p_0}} \quad (7.7.2\text{-}4)$$

The minimum product of area coefficient of discharge $A \cdot K_{dr}$ in case of thermal expansion of trapped liquids shall be at least 0.02 mm² per liter of trapped volume.

## 7.8 Guidelines for Specific Applications

In this section the norms are based on following edition:
ASME Section XIII (2021), API RP 520 (2020), API 521 (2020), ISO 4126-1 (2016), ISO 4126-7 (2016), ISO 23251(2020)

In this chapter the user is given some quick but reliable guidance to determine the mass flow rate to the safety valve for some practical cases of overpressure, which are not expressively discussed in the above cited standards.

### 7.8.1 Shell Boilers and Tube Boilers

There are two types of boilers, namely tube boilers and shell boilers. In tube boilers water is carried in tubes exposed to combustion gases, while in shell boilers the hot gases flow in tubes immersed in a water bath. Both types of boilers can be either used for steam or hot water generators.

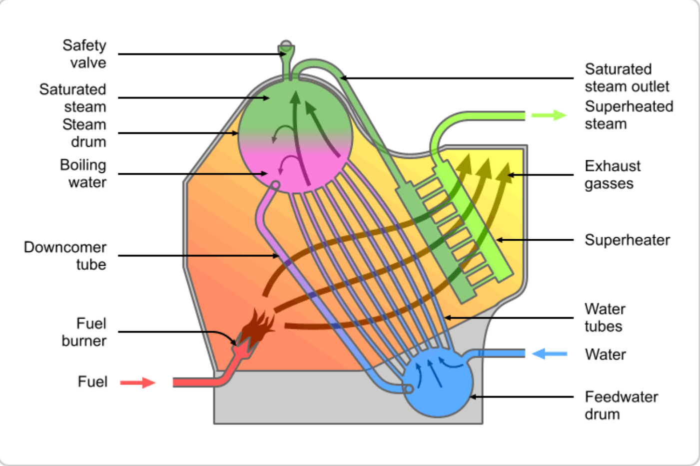



*Fig. 7.8.1-1 Marine type tube boiler for steam generation: steam generator (feedwater drum, steam drum, downcomer tube) and superheater (Source : Wikipedia Images)*

Acc. to EN 12952-10[15] (2020) every steam generator as well as all isolable heated vessels in a **tube boiler steam generator,** see Fig. 7.8.1-1, incl. reheaters and economizers, must be protected by at least one pressure relieving device. The minimum diameter of the flow area of the safety valves must be 15 mm. The position of the safety valve for the protection of the vessels in a tube boiler steam generator is given in Table 7.8.1-1.

[15] Water-tube boilers and auxiliary installations – Part 10: Requirements for safeguards against excessive pressure, 2020.

| Tube boiler steam generator | Position of safety valve in EN 12952-10 (2020) |
|---|---|
| Steam generator<br><br>(feedwater and steam drum) | For a generator with no superheater the safety valves or the main valve of CSPRS[16] valves must be placed on the steam side (EN 12952-10).<br>The cumulative certified capacity of the safety valves installed on the steam generator must be at least equal to the max. steam generation (EN 12952-10). |
| Non-isolable superheater<br><br>no control valve is present between superheater and steam generator | A safety valve at the superheater outlet must prevent the release capacity to exceed the allowable wall temperature. Direct-loaded and supplementary loaded safety valves on the steam generator must discharge at least 75 % of the required release capacity. CSPRS valves instead at least 25 %: however, the CSPRS on the superheater can discharge the whole capacity provided that it is monitoring the pressure of the steam drum as well (EN 12952-10). |
| Isolable superheater<br><br>a control valve is placed between superheater and steam generator | These superheaters must be protected with safety valves or the main valves of the CSPRS at the outlet of a superheater, which must be sized for at least 20 % of the required release capacity. The main valve of the CSPRS on the steam generator must discharge the whole allowable steam generation (EN 12952-10). |

*Table 7.8.1-1: Position of the safety valve for the protection of the vessels in a tube boiler steam generator*

Every reheater must be equipped with a safety valve as well. The release capacity of the safety valve or of the main valve of the CSPRS must correspond to the max. design steam mass flow through the reheater (EN 12952-10).

In EN 12952-10[17] (2020) every **tube boiler hot water generator** must be protected by at least one pressure relieving device. The cumulative certified mass flow of several safety valves must be at least equal to the generated mass flow rate of steam (EN 12952-10), which is calculated using Eq. 7.8.1-1 assuming that no heat is lost

$$q_m = 3600 \cdot Q / L_{vap} \quad (7.8.1\text{-}1) \quad \text{with}$$

| | | |
|---|---|---|
| $q_m$ | Steam mass flow rate | [kg/h] |
| $Q$ | Heat flow to the saturated water | [kW] |
| $L_{vap}$ | Latent heat of evaporation | [kJ/kg] |

The minimum diameter of the flow area of the safety valves must be 15 mm (EN 12952-10). The safety valves must be placed on or in proximity of the highest point of the feed line or on the feed line as close to the boiler as possible (EN 12952-10). The safety valves must be sized for saturated steam flows at relieving conditions even for boilers where the valve is under water pressure (EN 12952-10).

[16] CSPRS : Controlled Safety Pressure Relief Systems

[17] Water-tube boilers and auxiliary installations – Part 10: Requirements for safeguards against excessive pressure, 2020.

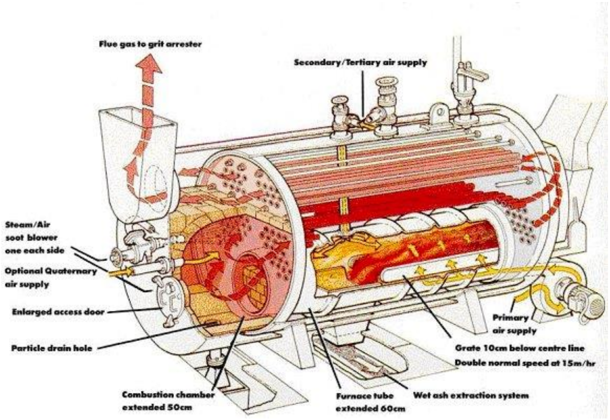



*Figure 7.8.1-2 Shell boiler ; Source: [RISE , Murdoch University, Perth (AUS)]*

In **shell boilers** the control of the liquid and steam filling levels in the boiler should guarantee that the pressure in the shell boiler does not exceed the set value. In EN 12953-8[18] (2002) every vessel in the shell boiler must be protected by a safety valve, which should be able to discharge the allowable steam mass flow. (EN 12953-8, Par 4.1.1) The minimum seat diameter of the safety valve must be 15 mm (EN 12953-8, Par. 4.1.5). The position of the safety valve for the protection of the vessels in a shell boiler is given in Table 7.8.1-2.

| General shell boiler | Position of safety valve in EN 12953-8 (2002) |
|---|---|
| Isolable economizer | The min. relieving capacity of the safety valve must be determined on the base of the heat inflow to the economizer using Eq. 7.8.1.1 (EN 12953-8, Par. 4.1.4). |
| Non-isolable superheater<br><br>no control valve is present between superheater and steam generator | The release capacity of the superheater may be added to that of the steam generator in order to determine the min. relieving flow rate of the safety valves (EN 12953-8, Par 4.1.2).<br><br>The superheater must have a safety valve at the outlet, whose release capacity must be at least 25 % of the whole capacity of the boiler (EN 12953-8, Par 4.1.1). This condition may fall, when the max. expected wall temperature does not exceed the sizing temperature (EN 12953-8, Par 4.1.1) |
| Isolable superheater<br><br>a control valve is placed between superheater and steam generator | The superheater must have an additional safety valve at the outlet, whose release capacity must be at least 25 % of the whole capacity of the boiler (EN 12953-8, Par 4.1.1). |

*Table 7.8.1-2: Position of the safety valve for the protection of the vessels in a shell boiler as well as the particular requirements for steam generators and hot water generators*

For **steam generator shell boilers** the certified steam capacity of the safety valves must exceed the allowable steam production. The calculation of the steam capacity of the safety valve for the steam conditions, for which no certified steam capacity is available, must comply with ISO 4126-7 and it must exceed the allowable steam production (EN 12953-8, Par 4.2.1).

In **hot water generator shell boilers,** the safety valve must be sized under the assumption of saturated steam flows at relieving conditions. In alternative (EN 12953-8, Par 4.2.2) the safety valves for oil- or gas-fired hot water generators may be sized for the maximum possible volumetric

[18] Shell boilers – Part 8: Requirements for safeguard against excessive pressure, 2002.

expansion of water and for the water feed coming from the feeder at the allowable operating pressure in case that respectively two pressure and two temperature limiters reduce or shut down the firing, when the respective thresholds are exceeded.

**Set pressure selection of multiple safety valves:** For the protection of boilers with more than one safety valve LESER's experience shows that the set pressures of the safety valves are not always the same but a slightly different, indicatively either 1 bar for set pressures above 30 bar-g or 3 % otherwise, is usually considered. By doing so, the safety valve with the lower set pressure protects the other safety valves by releasing a part of the mass flow rate and mitigate the pressure peaks in the unit. This solution avoids also conflicts among the safety valves like vibrations, pressure shocks etc., which would occur if they open simultaneously.
In the case of communicating steam drum and superheater, the safety valve on the superheater is the one which is set at a slightly lower pressure, so that it opens before the safety valve on the steam drum. The released mass flow rate by wetting the superheater walls prevents their overheating. Otherwise, if the safety valve on the steam drum opens first while the one on the superheater remains closed, no steam flow would pass through the superheater with the consequent overheating of its walls exposed to the hot exhaust gases. In the determination of the set pressures of steam drum and superheater, the frictional pressure losses between the units should be accounted for.

### 7.8.2 Pressure Side of a Pump

In case of pump blockage the mass flow to the safety valve must be at least the mass flow that would be flowing in the pump at relieving conditions (API 521 and ISO 23251). It is determined from the characteristic curves of the pump manufacturer. The safety valve must be placed on the pressure side of the pump. If the safety valve outlet is connected to the suction side of the pump, the suction pressure must be accounted as back pressure during sizing.

### 7.8.3 Control Valve Failure

A control valve regulates the flow to a unit or user and it takes normally a partially open position in accordance to the required mass flow rate. The flow rate to the safety valve postulates worst-case malfunction of the control valve, considering it as fully opened when placed before the safety valve or fully closed when located after the safety valve in the output line to the users. The safety valve must be sized for the case of maximum malfunction. For complex lines with more inlets and outlets the determination of the relieving capacity can be determined respectively using either ISO 23251 for input control valves or for output control valves.

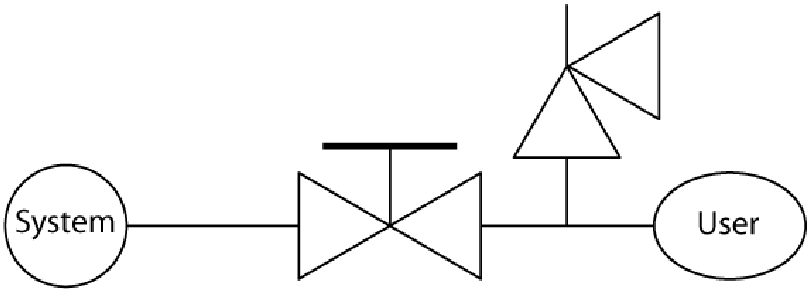



*Fig. 7.8.3-1: Example of protection against malfunction of control valve*

### 7.8.4 Pressure Reducing Valve

In pressure reducing stations the safety valve has to be placed downstream the pressure reducing valve. The discharge capacity of the safety valve must exceed that through the pressure reducing device.

### 7.8.5 Heat Exchanger

From API 521 and ISO 23251 in consequence of rupture steam from the hot pressure tubes may overpressurize equipment. on the low-pressure side.

LESER recommends the installation of the pressure relieving valve on the cold side of a shell-and-tube heat exchanger. The reason is to prevent thermal expansion or even vaporizing of the cold liquid, in the case that it is trapped by a blocked line.

### 7.8.6 Pressurized Hot Water (T > 100°C)

Beside the ISO 4126-10, our experience proved that the formula in Eq. 7.8.6-1 for pressurized (liquid) water at temperatures above 100°C leads to a reliable estimation of the flow area of the safety valve.

$$A_0 = \left( \frac{0.6211 \frac{\sqrt{p_0 v}}{\psi} \frac{h-h'}{r}}{K_{dD} p_0} + \frac{0.6211\sqrt{v}\left(1-\frac{h-h'}{r}\right)}{K_{dL}\sqrt{p_0-p_a}} \right) \qquad (7.8.6\text{-}1)$$

with the following meaning of the symbols

| | | |
|---|---|---|
| h | Enthalpy of water at operating condition | kj/kg |
| h’ | Enthalpy of water at 99.6°C and 1 bar | 417.51 kj/kg |
| $K_{dD}$ | Derated discharge coefficient Vapor | -- |
| $K_{dL}$ | Derated discharge coefficient Water | -- |
| $p_a$ | Absolurte back pressure | bar |
| $p_0$ | Absolute relieving pressure | bar |
| r | Latent heat of evaporation at $p_0$ | kj/kg |
| v | Specific volume | $m^3$/kg |
| ψ | See Table 7.6.2-1 on Page 7.6-2 | -- |

The basic assumption is that a partial evaporation of the liquid will take place in the safety valve.

### 7.8.7 Indicative Values for Physical Quantities (k, Z, μ, v)

In case physical properties of gases or liquids are missing, the following values can be used.

| Physical property | Value | Comments |
|---|---|---|
| Isentropic coefficient Gas – k | 1.0 | See API RP 520 (2020) Section 5.6.3.1.1* and Fig. 33 |
| Compressibility factor Gas - Z | 1.0 | Conservative and adequate, when the relieving pressure is equal or less than – indicatively - 10 times the thermodynamic critical pressure $p_{crit}$ . Values of $p_{crit}$ for most common gases can be found in API RP 520 (2020) Table 10 or in ISO 4126-7 (2020) Table 5. Further references are written in Chapter 10. |
| Viscosity Liquid – μ, v | 0 mPa s<br>0 $m^2$/s<br>0 $mm^2$/s | Optimal case, it would lead to the smallest orifice area, LESER suggests to use this value for liquids with a viscosity assumed to be close to that of water |

### 7.8.8 Undersizing (not less than – 3%)

Since the selected orifice area is typically larger than the required orifice, a larger mass flow than the required one will be released. In this sense the sizing procedures are precautionary in regard of the safety of the protected item. However, an excessive release of product may be unwanted or an oversized valve may cause excessive pressure losses in the inlet or outlet line.
LESER's experience shows that a modest undersizing with a certified mass flow, which does not deviate for more than about 3 % from the required mass flow, can be eventually taken into consideration, given that the actual mass flow rate is around 10 % larger than the certified one and therefore the actual flow rate is still larger than the required one .Nevertheless, if a safety valve is undersized, an approval from the supervising certifying authority, like TÜV in Germany, is required for the individual application.
Alternatively the assumptions for the determination of the required mass flow may be reviewed critically. A more detailed engineering analysis can lead to more precise eventually lower values.

### 7.8.9 Pressure Loss Considerations

Pressure losses in the inlet and outlet piping of the safety valve depend from the actual mass flow discharged by the selected safety valve and not from the required one, which is based on process requirements. VALVESTAR® calculates the effective pressure loss with the actual discharge from the valve. For calculation of pressure losses see chapter 6, Installation and Plant Design.

## 7.9 Conversion Between US and Metric Units

In this section the norms are based on following edition:
ASME Section XIII (2021) and API RP 520 (2020)

This section presents some tables to convert from US to metric units and vice versa the physical quantities required by the sizing standards. Source: http://www.onlineconversion.com
In addition to these tables, VALVESTAR® provides the possibility to convert a broad range of units

*How to read the tables*: the target dimension is written in a vertical column; each cell in a horizontal line contains how much of that quantity equals the target. For example, in Table 7.8.1-1 you need 304.8 mm, 0.3048 m or 12 in to make one foot.

### 7.9.1 Length

| To / From | mm | m | ft | in |
|---|---|---|---|---|
| **mm** | 1 | 1000 | 304.8 | 25.4 |
| **m** | 0.001 | 1 | 0.3048 | 0.0254 |
| **ft** | 0.00328 | 3.28 | 1 | 0.0833 |
| **in** | 0.03937 | 39.370 | 12 | 1 |

*Table 7.9.1-1: Conversion of lengths*

### 7.9.2 Area

| To / From | mm² | in² | m² | ft² |
|---|---|---|---|---|
| **mm²** | 1 | 645.16 | $10^6$ | 92903 |
| **in²** | 0.00155 | 1 | 1550.00 | 144 |
| **m²** | $10^{-6}$ | $6.4516*10^{-4}$ | 1 | 0.092903 |
| **ft²** | $1.0764*10^{-5}$ | 0.00694 | 10.764 | 1 |

*Table 7.9.2-1: Conversion of surfaces*

### 7.9.3 Mass

| To / From | g | kg | lb | oz |
|---|---|---|---|---|
| **g** | 1 | 1000 | 453.592 | 28.350 |
| **kg** | 0.001 | 1 | 0.453592 | 0.02835 |
| **lb** | $2.205*10^{-3}$ | 2.205 | 1 | 0.0625 |
| **oz** | 0.035274 | 35.274 | 16 | 1 |

*Table 7.9.3-1: Conversion of masses*

### 7.9.4 Temperature

| To / From | °C | °F | °R | K |
|---|---|---|---|---|
| **°C** | - | [°F] = [°C] × 9/5 + 32 | [°R] = ([°C] + 273.15) × 9/5 | [K] = [°C] + 273.15 |
| **°F** | [°C] = ([°F] − 32) x 5/9 | - | [°R] = [°F] + 459.67 | [K] = ([°F] + 459.67) × 5/9 |
| **°R** | [°C] = ([°R] − 491.67) × 5/9 | [°F] = [°R] − 459.67 | - | [K] = [°R] × 5/9 |
| **K** | [°C] = [K] − 273.15 | [°F] = [K] × 9/5 − 459.67 | [°R] = [K] × 9/5 | - |

*Table 7.9.4-1: Conversion of temperatures*

| Temperature examples | | | | |
|---|---|---|---|---|
| To / From | °C | °F | °R | K |
| Absolute zero | -273.15 | −459.67 | 0 | 0 |
| Freezing point (water) (1.013 bar) | 0 | 32 | 491.67 | 273.15 |
| Boiling point (water) (1.013 bar) | 99.984 | 211.971 | 671.641 | 373.134 |

*Table 7.9.4-2: Examples for conversion of temperatures*

### 7.9.5 Density

| To / From | kg/m³ | g/cm³ | lb/ft³ | oz/in³ | lb/in³ |
|---|---|---|---|---|---|
| kg/m³ | 1 | 1000 | 16.018 | 1729.99 | 27680 |
| g/cm³ | 0.001 | 1 | 0.016018 | 1.72999 | 27.680 |
| lb/ft³ | 0.06243 | 62.43 | 1 | 108 | 1728 |
| oz/in³ | $5.780*10^{-4}$ | 0.5780 | 0.00926 | 1 | 16 |
| lb/in³ | $3.613*10^{-5}$ | 0.03613 | $5.787*10^{-4}$ | 0.0625 | 1 |

*Table 7.9.5-1: Conversion of densities*

### 7.9.6 Mass flow

| To / From | kg/s | kg/h | lb/s | lb/h |
|---|---|---|---|---|
| kg/s | 1 | $2.778*10^{-4}$ | 0.454 | $1.260*10^{-4}$ |
| kg/h | 3600 | 1 | 1632.931 | 0.454 |
| lb/s | 2.205 | $6.124*10^{-4}$ | 1 | $2.778*10^{-4}$ |
| lb/h | 7936.648 | 2.205 | 3600 | 1 |

*Table 7.9.6-1: Conversion of mass flow*

### 7.9.7 Volume Flow – Operating Conditions

| Volume flow (operating conditions) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| To / From | m³/s | m³/h | l/h | ft³/s | ft³/h | gal US/ min | gal UK/ min | cfm (ft³/min) |
| m³/s | 1 | $2.778*10^{-4}$ | $2.778*10^{-7}$ | 0.0283 | $7.866*10^{-6}$ | $6.309*10^{-5}$ | $7.577*10^{-5}$ | $4.719*10^{-4}$ |
| m³/h | 3600 | 1 | 0.001 | 101.941 | 0.028317 | 0.22712 | 0.27277 | 1.69901 |
| l/h | $3.6*10^{6}$ | 1000 | 1 | 101941 | 28.317 | 227.12 | 272.77 | 1699.01 |
| ft³/s | 35.315 | 0.00981 | $9.810*10^{-6}$ | 1 | $2.778*10^{-4}$ | 0.00223 | 0.00268 | 0.0167 |
| ft³/h | 127132.798 | 35.315 | 0.035315 | 3600 | 1 | 8.0208 | 9.633 | 60 |
| gal US/ min | 15850.323 | 4.403 | 0.004403 | 448.831 | 0.125 | 1 | 1.201 | 7.481 |
| gal UK/ min | 13198.155 | 3.666 | 0.003666 | 373.730 | 0.104 | 0.833 | 1 | 6.229 |
| cfm | 2118.880 | 0.5886 | $5.886*10^{-4}$ | 60 | 0.0167 | 0.134 | 0.161 | 1 |

*Table 7.9.7-1: Conversion of volume flow*

### 7.9.8 Volume Flow – Standard Conditions

| Operating conditions | | Standard conditions | |
|---|---|---|---|
| m³/h | cubic meters per hour | Nm³/h | *Normal* cubic meters per hour = m³/h at standard conditions of temperature and pressure (STP) |
| cfm | cubic feet per minute | scfm | *Standard* cubic feet per minute = cfm at standard conditions of temperature and pressure (STP). |

*Table 7.9.8-1: Operating and standard conditions*

The standard temperature and pressure (STP) establish a reference to enable cross comparisons between sets of experimental data, for instance gas mass flow rates at different relieving pressures.

When stating that a gas volume or flow is in **Normal Cubic Meters (Nm³)** or **Standard Cubic Feet (scf)** or any other notation (nm, Scf, STP, etc.), the user should state the value of the reference temperature and pressure to which he refers. Not to do so can lead to confusion since there is no universally accepted set of reference conditions.

- In VALVESTAR® the reference conditions are 60°F and 14.7 psi for API RP 520 and ASME Section XIII 15°C and 1 atm for ISO 4126 and AD 2000 A2

However, sizing standards normally refer to mass flow rates in the operating conditions.

### 7.9.9 Pressure

| To / From | atm | bar | Pa | kPa | MPa | psi (=lb/in²) | torr (=mmHg 0°C) | $kg_f/cm^2$ (= kgsi) | $mmH_2O$ 4°C |
|---|---|---|---|---|---|---|---|---|---|
| **atm** | 1 | 0.9869 | $9.869 \cdot 10^{-6}$ | $9.869 \cdot 10^{-3}$ | 9.869 | 0.0680 | 0.00132 | 0.9678 | $9.678 \cdot 10^{-5}$ |
| **bar** | 1.01325 | 1 | $10^{-5}$ | 0.01 | 10 | 0.068948 | $1.3332 \cdot 10^{-3}$ | 0.980665 | $9.80665 \cdot 10^{-5}$ |
| **Pa** | 101325 | $10^5$ | 1 | 1000 | $10^6$ | 6894.8 | 133.32 | 98066.5 | 9.80665 |
| **kPa** | 101.325 | 100 | 0.001 | 1 | 1000 | 6.8948 | 0.1332 | 98.0665 | $9.80665 \cdot 10^{-3}$ |
| **MPa** | 0.101325 | 0.1 | $10^{-6}$ | 0.001 | 1 | $6.8948 \cdot 10^{-3}$ | $1.3332 \cdot 10^{-4}$ | 0.0980665 | $9.80665 \cdot 10^{-6}$ |
| **psi** | 14.696 | 14.50 | $1.450 \cdot 10^{-4}$ | 0.145 | 145.0 | 1 | 0.0193 | 14.22 | 0.001422 |
| **torr (mmHg (0°C))** | 760.000 | 750.06 | $7.5006 \cdot 10^{-3}$ | 7.5006 | 7500.6 | 51.715 | 1 | 735.56 | 0.073556 |
| **$kg_f/cm^2$ (= kgsi)** | 1.0332276 | 1.0197 | $1.01972 \cdot 10^{-5}$ | 0.0101972 | 10.1972 | 0.070307 | 0.00136 | 1 | $10^{-4}$ |
| **$mmH_2O$ (4°C)** | 10332.276 | 10197 | 0.101972 | 101.972 | 101972 | 703.07 | 13.6 | $10^4$ | 1 |

*Table 7.9.9-1: Conversion of pressure*

*Gauge and absolute pressure*
It is common practice in the design of plants to indicate the set pressure in units as *gauge* (unit: bar-g or psig), meaning its deviation from the atmospheric pressure. However, common sizing procedures require the knowledge of the relieving pressure in absolute terms (unit: bar or psi). The relationship between the two of them: is

Absolute pressure = Gauge pressure + Atmospheric pressure (14.7 psi ; 1.013 bar)

## 7.9.10 Dynamic and Kinematic Viscosity

| Dynamic viscosity (Symbol: μ) | | | | Kinematic viscosity (Symbol: ν) | | | |
|---|---|---|---|---|---|---|---|
| To / From | Pa s | cP = mPa s | P (Poise) | | m²/s | cSt = mm²/s | St |
| Pa s | 1 | 0.001 | 0.1 | m²/s | 1 | $10^{-6}$ | $10^{-4}$ |
| cP= mPa s | 1000 | 1 | 100 | cSt = mm²/s | $10^{6}$ | 1 | 100 |
| P (Poise) | 10 | 0.01 | 1 | St | 10000 | 0.01 | 1 |
| | | | | St | 10000 | 0.01 | 1 |

*Table 7.9.10-1: Conversion of dynamic and kinematic viscosity*

In science there are two types of viscosity: the so-called *dynamic viscosity*, which is what usually people refer to, and *kinematic viscosity,* that is the ratio of dynamic viscosity and density. Indeed, the user, may be confronted with some commonly used technical units for the kinematic viscosity, referenced here as engineering units. The most well known engineering units are the Saybolt Universal Second, Engler Degree and Redwood seconds. Among them the Saybolt Universal Second finds the widest application in petroleum technology and related industries.

Viscosity in Engler Degree (°E, E, E°) is the ratio of the time required by 200 cm³ of the liquid, whose viscosity is being measured, to flow in an capillary viscometer to the time of flow of the same amount of water at the same temperature.

The Saybolt Universal Second (Often SUS or SSU) is the time it takes for 60 cm³ of the liquid under consideration to flow through a calibrated tube at a controlled temperature.

The Redwood Second (R.I.) has an identical definition to that of the SSU, differing only in the quantity of test liquid, which is 50 cm³.
The following table permits a quick conversion between the kinematic viscosity, expressed either in mm²/s or using one of the three engineering units.

| Engler Degree [°E] | Saybolt Universal Second [SSU] | Redwood Second [R.I.] | mm²/s |
|---|---|---|---|
| 1.119 | 32.6 | 30.2 | 2.0 |
| 1.307 | 39.1 | 35.3 | 4.0 |
| 1.479 | 45.5 | 40.5 | 6.0 |
| 1.651 | 52.0 | 46.0 | 8.0 |
| 1.831 | 58.8 | 51.7 | 10.0 |
| 2.020 | 65.9 | 57.9 | 12.0 |
| 2.220 | 73.4 | 64.4 | 14.0 |
| 2.430 | 81.1 | 71.1 | 16.0 |
| 2.640 | 89.2 | 78.1 | 18.0 |
| 2.870 | 97.5 | 85.4 | 20.0 |

*Table 7.9.10-2:: Comparison of kinematic viscosity and common engineering units for viscosity*

As an alternative to the table the following conversion formulas can be employed

| | |
|---|---|
| [mm²/s] = [SSU] x ¼.55 |
| [mm²/s] = [°E] x 7.45 |
| [mm²/s] = [R.I.] x 0.2469 |

*Table 7.9.10-3:: Conversion of different viscosity units*

### 7.9.11 Energy

| To / From | kJ | $BTU_{IT}$ | $BTU_{th}$ | kWh | $kcal_{IT}$ | $kcal_{th}$ |
|---|---|---|---|---|---|---|
| kJ | 1 | 1.0551 | 1.0544 | 3600 | 4.187 | 4.184 |
| $BTU_{IT}$ | 0.948 | 1 | 0.999 | 3412.141 | 3.968 | 3.966 |
| $BTU_{th}$ | 0.948 | 1.00067 | 1 | 3414.425 | 3.971 | 3.968 |
| kWh | $2.778*10^{-4}$ | $2.931*10^{-4}$ | $2.929*10^{-4}$ | 1 | 0.00116 | 0.00116 |
| $kcal_{IT}$ | 0.239 | 0.252 | 0.252 | 859.845 | 1 | 0.999 |
| $kcal_{th}$ | 0.239 | 0.252 | 0.252 | 860.421 | 1.001 | 1 |

*Table 7.9.11-1: Conversion of energy units*

The British Thermal Unit or BTU (calorie) is the amount of heat required to raise the temperature of one pound (one kg) of water by 1°F (1°C) at one atmosphere. Several definitions of the BTU and of the calorie exist due to the different boiling water temperatures of reference. In the table the $BTU_{IT}$ ($kcal_{IT}$) adopts the definition in the International [Steam] Table[19] (IT), while the $BTU_{th}$ ($kcal_{th}$) represents the common "thermo chemical value".

### 7.9.12 Specific Energy

| To / From | kJ/kg | $BTU_{IT}$/lb | $BTU_{th}$/lb |
|---|---|---|---|
| kJ/kg | 1 | 2.330 | 2.324 |
| $BTU_{IT}$/lb | 0.430 | 1 | 0.999 |
| $BTU_{th}$/lb | 0.430 | 1.00067 | 1 |

*Table 7.9.12-1: Conversion of specific energy*

### 7.9.13 Specific Heat

| To / From | kJ/(kg K) | $BTU_{IT}$/(lb °R) | $BTU_{th}$/(lb °R) |
|---|---|---|---|
| kJ/(kg K) | 1 | 1.292 | 1.291 |
| $BTU_{IT}$/(lb °R) | 0.774 | 1 | 0.999 |
| $BTU_{th}$/(lb °R) | 0.774 | 1.00067 | 1 |

*Table 7.9.13-1: Conversion of specific heat*

[19] W. Wagner , H. Kretzschmar Ed., *International steam tables: Properties of water and steam based on the industrial formulation IAPWS-IF97,* Springer, Berlin, 2008

## 7.10 Physical Property Databases

In this section the norms are based on following edition:
ASME Section XIII (2021) and API RP 520 (2020), EN 13136 (2013), ISO 4126-7 (2016)

In this chapter references are given for the data present in VALVESTAR for gases and liquids as well as additional sources, if some of the readers wish to collect more data about some specific media.

### 7.10.1 Physical Properties of Gases

The properties for the gases are extracted from ISO 4126-7, API RP 520, EN 13136, the NIST Chemistry WebBook (http://WebBook.nist.gov/chemistry) and for cryogenics also from Medard, L. *Gas Encyclopaedia*, Air Liquide/Elsevier Science Publishing, 1976 (encyclopedia.airliquide.com).

### 7.10.2 Physical Properties of Liquids

The density of the liquids are extracted from ISO 4126-7, API RP 520, EN 13136, the NIST Chemistry WebBook and the *CRC Handbook of Chemistry and Physics*, D.R. Lide Editor, 85th Edition, CRC Press, 2004.

### 7.10.3 Additional Literature Sources

[1] Wang, B.H.; Adcock, J.L.; Mathur, S.B.; Van Hook, W.A., *Vapor pressures, liquid molar volumes, vapor non-idealities, and critical properties of some fluorinated ethers: CF3OCF2OCF3, CF3OCF2CF2H, c-CF2CF2 CF2O, CF3OCF2H, and CF3OCH3; and of CCl3F and CF2CI*, J. Chem. Thermodyn., 1991, 23, 699-710.

[2] Altunin, V.V.; Geller, V.Z.; Kremenvskaya, E.A.; Perel'shtein, I.I.; Petrov, E.K., Thermophysical Properties of Freons, Methane Ser. Part 2, Vol. 9, NSRDS-USSR, Selover, T. B., Ed., Hemisphere, New York, 1987.

[3] Krauss, R.; Stephan, K., *Thermal Conductivity of Refrigerants in a Wide Range of Temperature and Pressure*, J. Phys. Chem. Ref. Data, 1989, 18, 43.

[4] Weber, L.A., Simple Apparatus for Vapor-Liquid Equilibrium Measurements with Data for the Binary Systems of Carbon Dioxide with n-Butane and Isobutane, J. Chem. Eng. Data, 1989, 34, 171.

[5] Higashi, Y.; Uematsu, M.; Watanabe, K., *Measurements of the Vapor-liquid Coexistence Curve and Determination of the Critical Parameters for Refrigerant 13B1*, Bull. JSME, 1985, 28, 2660-6.

[6] Ohgaki, K.; Umezono, S.; Katayama, T., *Pressure-density-temperature (p-ρ-T) relations of fluoroform, nitrous oxide, and propene in the critical region*, J. Supercrit. Fluids, 1990, 3, 78-84.

[7] Hori, K.; Okazaki, S.; Uematsu, M.; Watanabe, K., *An Experimental Study of Thermodynamic Properties of Trifluoromethane* in Proc. Symp. Thermophys. Prop., 8th, 1981, Gaithersburg, Vol. II, Sengers, J. V., Ed., ASME: New York, p. 370-6, 1982.

[8] Garcia-Sanchez, F.; Romero-Martinez, A.; Trejo Rodriguez, A., *Vapour Pressure, Critical Temperature, and Critical Pressure of Dichloro- methane*, J. Chem. Thermodyn., 1989, 21, 823-6.

[9] Shi, L.; Zhu, M.; Han, L.; Duan, Y.; Sun, L.; Fu, Y.-D., *Thermophysical Properties of Difluoromethane (HFC-32)*, Science in China, Ser. E, 1998, 41, 435-42.

[10] Mastroianni, M.J.; Stahl, R.F.; Sheldon, P.N., *Phys. and Thermo. Prop. of 1,1,2-Trrifluorotrichloromethane (R-113) 113)*, J. Chem. Eng. Data, 1978, 23, 113-118.

[11] Yada, N.; Uematsu, M.; Watanabe, K., *Measurements of the vapor pressure and PVT properties for refrigerant 115*, Nippon Kikai Gakkai Ronbunshu, B-hen, 1989, 55, 2426.

[12)] Mears, W.H.; Rosenthal.E.; Sinka, J.V., *Pressure-Volume-Temperature Behavior of Pentafluoromonochlorethane*, J. Chem. Eng. Data, 1966, 11, 338.

[13)] Fukushima, M.; Watanabe, N.; Kamimura, T., *Measurements of the PVT properties of HCFC123 and HFC134a*, Nippon Reito Kyokai Ronbunshu, 1990, 7, 243-56.

[14)] Yamashita, T.; Kubota, H.; Tanaka, Y.; Makita, T.; Kashiwagi, H., *Physical properties of new halogenated hydrocarbons*, Proc. Symp. Thermophys. Prop. 10th, 1989,, 1989, p 75-8.

[15)] Fukushima, M.; Watanabe, N., *Thermodynamic properties of HCFC-124*, Nippon Reito Kyokai Ronbunshu, 1993, 10, 75-86.

[16)] Higashi, Y., Critical parameters for HFC134a, HFC32 and HFC125, Int. J. Refrig., 1994, 17, 524-531.

[17)] Wilson, L.C.; Wilding, W.V.; Wilson, G.M.; Rowley, R.L.; Felix, V.M.; Chisolm-Carter, T., *Thermophysical properties of HFC-125*, Fluid Phase Equilib., 1992, 80, 167-77.

[18)] Duarte-Garza, H.A.; Hwang, C.-A.; Kellerman, S.A.; Miller, R.C.; Hall, K.R.; Holste, J.C.; Marsh, K.N.; Gammon, B.E., *Vapor pressure, vapor density, and liquid density for 1,1-dichloro-1- fluoroethane(R-141b)*, J. Chem. Eng. Data, 1997, 42, 497-501.

[19)] Sako, T.; Sato, M.; Nakazawa, N.; Oowa, M.; Yasumoto, M.; Ito, H.; Yamashita, S., *Critical Properties of Fluorinated Ethers*, J. Chem. Eng. Data, 1996, 41, 802-805.

[20)] Fukushima, M.; Watanabe, N., *Thermodynamic properties of HCFC-142b (1-chloro-1,1-difluoroethane)*, Nippon Reito Kyokai Ronbunshu, 1992, 9, 247-55.

[21)] Fujiwara, K.; Nakamura, S.; Noguchi, M., *Critical Parameters and Vapor Pressure Measurements for 1,1,1-Trifluoroethane (R-143a)*, J. Chem. Eng. Data, 1998, 43, 55-9.

[22)] Fukushima, M., Measurements of vapor pressure , vapor-liquid coexistence curve and critical parameters of HFC-143a, Nippon Reito Kyokai Ronbunshu, 1993, 10, 87-93.

[23)] Fransson, E.; Barreau, A.; Vidal, J., *Vapor-liquid equilibrium in binary systems of n-pentane + chlorodifluoromethane or + 1,1-difluoroethane*, J. Chem. Eng. Data, 1992, 37, 521-5.

[24)] Tamatsu, T.; Sato, T.; Sato, H.; Watanabe, K., *An experimental study of the thermodynamic properties of 1,1-difluoroethane*, Int. J. Thermophys., 1992, 13, 985-97.

[25)] Berthoud, A., Determination of Critical Temperatures and Pressures of Amines and Alkyl Chlorides, J. Chim. Phys. Phys.-Chim. Biol., 1917, 15, 3.

[26)] Leu, A.D.; Robinson, D.B., *High-pressure vapor-liquid equilibrium phase properties of the octafluoropropane (K-218)-chlorodifluoromethane (Freon-22) binary system*, J. Chem. Eng. Data, 1992, 37, 7-10.

[27)] Young, S., The Internal Heat of Vaporization constants of thirty pure substances, Sci. Proc. R. Dublin Soc., 1910, 12, 374.

[28)] Sato, H.; Watanabe, K.; Levelt Sengers, J.M.H.; Gallagher, J.S.; Hill, P.G.; Straub, J.; Wagner, W., *Sixteen Thousand Evaluated Experimental Thermodynamic Property Data for Water and Steam*, J. Phys. Chem. Ref. Data, 1991, 20, 1023.

[29)] Morita, T.; Sato, H.; Uematsu, M.; Watanabe, K., *PVT Properties and Vapor-Pressures of Ordinary Water Substance in the Critical Region*, Physica A: (Amsterdam), 1989, 156, 436.

[30)] Lide, D.R.: *CRC Handbook of Chemistry & Physics* 85$^{th}$ Edition, CRC Press, 2004

## Content

## 9.1 Introduction

This chapter shall be a general guideline for the selection of materials for safety valves. Criteria influencing the material selection are explained. These criteria are

- general function of the individual valve component (pressure retaining, guiding, etc.)
- material codes and standards for materials of pressure vessels
- pressure and temperature ratings
- corrosion, resistance to chemical wear
- wear, erosion

An overview about commonly used materials for safety valves is provided with information on their applications and limits as well as codes and standards regulating material requirements.

## 9.2 General Considerations for the Main Components of a Safety Valve

Safety valves are considered to be part of the pressure vessel or the pressurized system they protect. The selection of materials must be done carefully. Especially for pressure retaining or containing components the selection of materials is regulated by applicable codes and standards.

### 9.2.1 Pressure Retaining or Pressure Containing Parts

ASME PTC 25-2001, Section 2 Definitions and Description of Terms:
- Pressure-containing member: a component which is exposed to and contains pressure
- Pressure-retaining member: a component which holds one or more pressure-containing members together but is not exposed to the pressure

The main pressure retaining or containing part of a safety valve is the body. Also the bonnet and the bolting that connects body and bonnet are considered to be part of the pressure retaining shell of the valve and pressure vessel codes typically do have material requirements for bonnet and bolting.
Failure of these components may result in the hazardous exposure to pressure, temperature or chemicals. All materials for pressure retaining parts must fulfill the requirements of the applicable codes and standards.

Pressure vessel codes normally list allowable materials for pressure retaining parts.

For a detailed definition of pressure retaining or containing components acc. to ASME VIII and PED 97/23 refer to chapter 2 Design Fundamentals.

### 9.2.2 Not Pressure Retaining or Containing Parts

Parts which are not considered to be pressure retaining may be manufactured from materials that are not listed in pressure vessel codes. Failure of these components may result in premature opening and discharge of the safety valve, but does not have the same consequences like a failure of a pressure retaining component.

### 9.2.3 Application Criteria Influencing the Material Selection

The criteria that generally influence the material selection of safety valve components are:
- pressure
- temperature
- corrosive media or environment
- application specific codes and standards

### 9.2.4 Critical Parts for Material Selection

A safety valve has a number of parts that are critical for the safe operation and function of the valve. These parts can be classified in to:

- **pressure retaining parts** – retaining the inlet pressure (body) or outlet pressure (bonnet) including body-to-bonnet bolting
- **guiding parts** – providing alignment of the disc to the nozzle, spindle must be moveable at all times
- **permanently medium wetted parts** – parts permanently in contact with the medium, also providing tightness of the valve
- **spring** – providing the force to keep the valve closed
- **bellows** (balanced design only) – providing back pressure compensation and/or corrosion protection of the guiding part and spring

Figure 9.2.4-1 shows these parts in a conventional and a balanced bellows safety valve design.

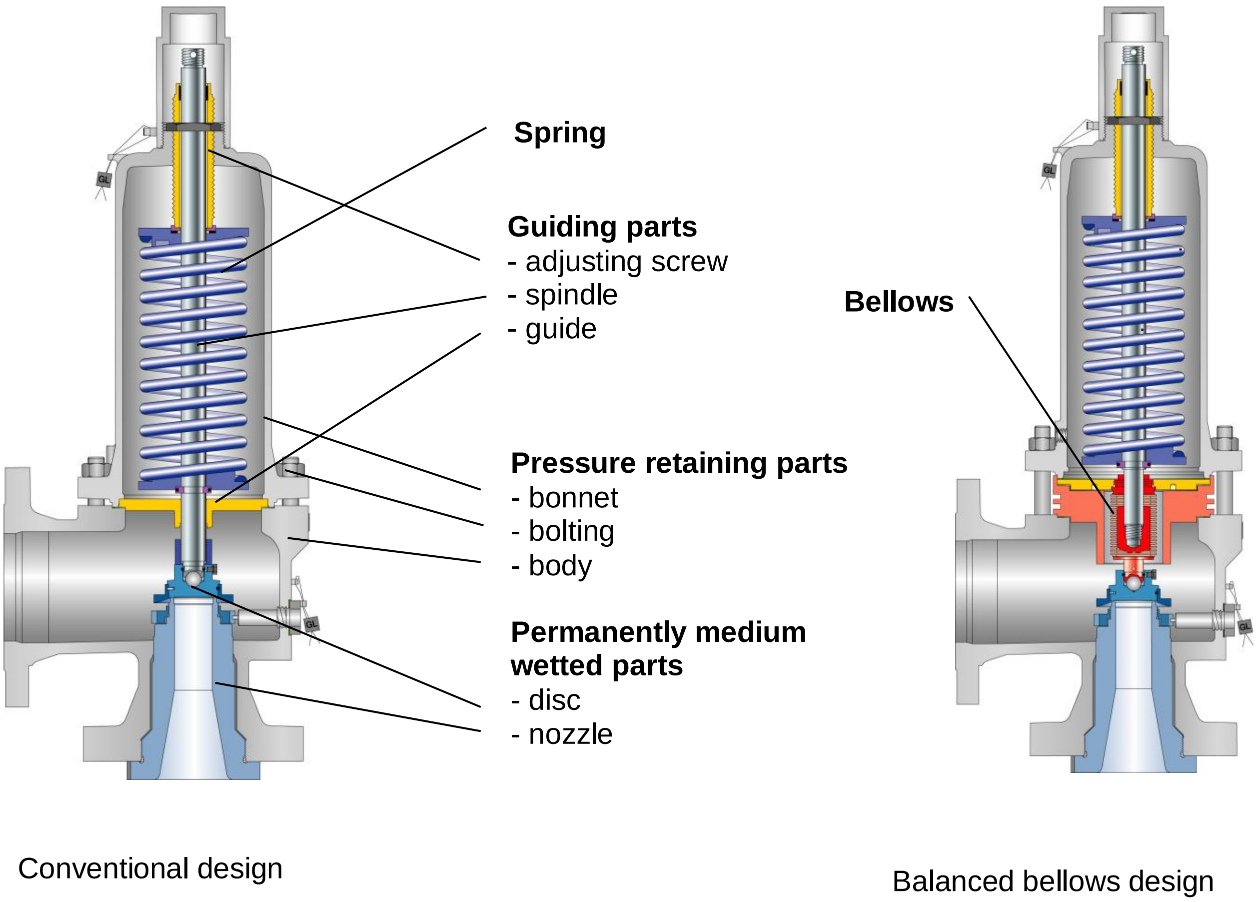



*Figure 9.2.4-1: Critical parts for material selection in conventional and balanced bellows designs*

Table 9.2.4-1 explains typical materials, product forms and the influence of corrosion on the different components.

| | |
|---|---|
| **Pressure retaining parts: Body / Bonnet** | |
| Effect of Corrosion | Corrosive attack from medium and/or environment.<br>Limited corrosion can be tolerated as long as valve operation and pressure-temperature ratings are not affected. |
| Typical Materials | Large variety from cast iron, ductile iron, carbon steel, stainless steel, high temperature carbon steels and high alloy materials. Material selection is restricted by applicable codes and standards. |
| Product form | Mostly castings, but also bar, forgings or welded designs |
| **Pressure retaining parts: Bolting** | |
| Effect of Corrosion | Corrosive attack from environment.<br>Corrosion can typically not be tolerated, because corrosion may result in failure of the pressure retaining shell of the valve. |
| Typical Materials | Specific bolting materials for pressure purposes must be selected. Material selection is restricted by applicable codes and standards. |
| Product form | Stud, nut. |
| **Permanently medium wetted parts: Nozzle / Disc** | |
| Effect of Corrosion | Corrosive attack from medium (permanently wetted components).<br>Corrosion can not be tolerated, because corrosion between nozzle and disc may prevent the valve from opening at set pressure. |
| Typical Materials | Stainless steels, frequently 316 ss is standard material.<br>Hardenable chrome steels or stellited stainless steel for extended product life (erosion). |
| Product form | Bar, investment castings, forgings |
| **Guiding parts: Guide / Spindle / Adjusting Screw** | |
| Effect of Corrosion | Corrosive attack from medium only when valve opens (not permanently wetted components).<br>Corrosion of guiding surfaces can not be tolerated, because corrosion may prevent the valve from opening at set pressure. |
| Typical Materials | Stainless steels or chrome steels.<br>In most cases different materials of spindle vs. guide/adjusting screw to avoid galling.<br>Often specific measures to avoid galling like bushing or surface treatment. General material requirements in ASME VIII UG 136 (b)(1),(2),(3),(4). |
| Product form | Bar, investment castings, forgings |
| **Spring** | |
| Effect of Corrosion | Corrosive attack from medium only when valve opens (not permanently wetted), condensate in the valve outlet or from environment with open bonnet designs.<br>Corrosion can typically not be tolerated, because corrosion may result in premature failure of spring. |
| Typical Materials | Typical materials: carbon steel, stainless steel, tungsten, Inconel X-750, Hastelloy.<br>Specific spring materials must be selected, because main property of a spring material is the coefficient of elasticity. |
| Product form | Bar |
| **Bellows** | |
| Effect of Corrosion | Corrosive attack from medium only when valve opens (not permanently wetted).<br>Corrosion can not be tolerated, because bellows are made from very thin sheet metal and corrosion may result in premature failure of bellows, eliminating the back pressure compensating effect. |
| Typical Materials | Stainless steels, frequently 316 ss or Inconel 625 are standard materials, Hastelloy. |
| Product form | Sheet metal, single or double walled, usually welded to machined end pieces which may be manufactured from a different material |

*Table 9.2.4-1: Critical parts, effect of corrosion, typical materials and product forms*

### 9.2.5 Full Nozzle Versus Semi Nozzle

Full nozzle designs have the advantage that all permanently wetted components are typically from corrosion resistant stainless steel as a standard. Only in case the valve opens the components at the outlet of the valve will be in contact with the medium.
In semi nozzle designs the body which is normally carbon steel is also permanently wetted.
If carbon steel does not provide sufficient corrosion resistance the full nozzle design with carbon steel body may still provide a good solution when valve opening is expected to be rare. For a semi nozzle design the selection of a body material with higher corrosion resistance would be required.

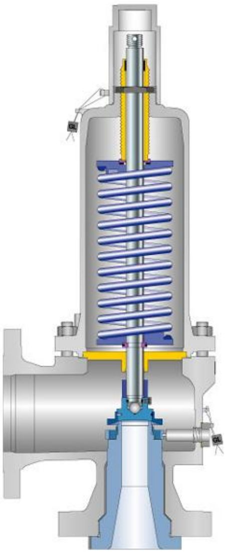


*Figure 9.2.5-1: Full nozzle design Type 526*

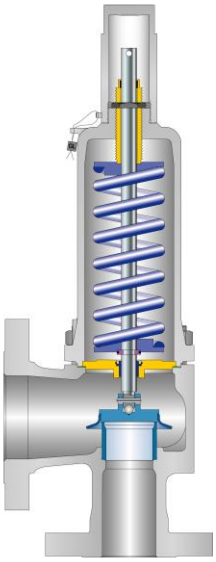


*Figure 9.2.5-2: Semi nozzle design Type 441*

### 9.2.6 Piping Material as a Guideline for the Selection of Safety Valve Materials

In some cases all details about the corrosive nature of the medium may not be easily available for a proper and detailed selection of safety valve materials. When the inlet piping material is available however, it can be taken as a rough guideline for the selection of the safety valve body material.
If the inlet piping material is from carbon steel, a safety valve with carbon steel body will be sufficient in most cases.
If the inlet piping material is stainless steel, the body material for semi nozzle designs should also be stainless steel. For full nozzle designs the carbon steel body may still be an option. If carbon steel is selected the user should consider preventive maintenance actions to ensure the outlet of the valve is not affected by corrosive attack after valve discharge or potential valve leakage.

## 9.3 Pressure Vessel Codes and Material Standards

As mentioned in the previous section, pressure retaining parts must fulfill requirements not only from material standards but also from pressure vessel codes. The general relationship between pressure vessel codes and material standards can be described as follows:
The material standards determine the general properties for the material like chemical composition and mechanical properties acc. to the product form (casting, bar, …). The determination of the scope of testing and documentation is normally left to the purchaser and supplier.
Pressure vessel codes define which materials may be used for the construction of pressure vessels and determine the scope of testing, documentation and limits of application for the individual material, using the material standards as a basis.

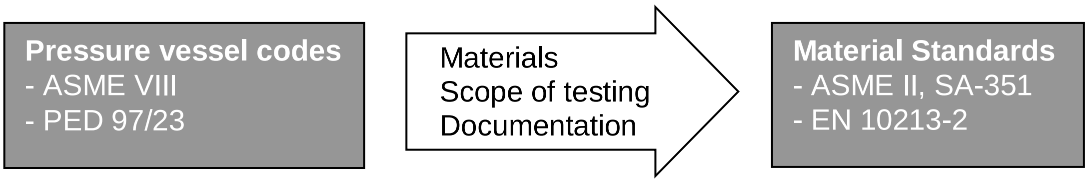



*Figure 9.3-1: Relationship between pressure vessel codes and material standards*

### 9.3.1 ASME VIII

The ASME code specifies in detail material requirements for the components of a safety valve.

Acc. to ASME VIII – Div. 1: UG 136(b)(3):
"Materials used in bodies, bonnet or yokes, and body-to-bonnet or body-to-yoke bolting, shall be listed in ASME II and this Division."

ASME VIII Subsection C determines the requirements for materials to be used in construction of pressure vessels and contains material tables with acceptable materials. Not every material contained in ASME II is allowable per these tables.

| Type of material | Subsection C | Material tables |
|---|---|---|
| Carbon and Low Alloy Steels | Part UCS | UCS-23 |
| Nonferrous Materials | Part UNF | UNF-23.1 – Aluminum and Aluminum Alloys<br>UNF-23.2 – Copper and Copper Alloys<br>UNF-23.3 – Nickel, Cobalt and High Nickel Alloys<br>UNF-23.4 – Titanium and Titanium Alloys<br>UNF-23.5 – Zirconium |
| High Alloy Steels | Part UHA | UHA-23 |
| Cast Iron | Part UCI | UCI-23 |
| Cast Ductile Iron | Part UCD | UCD-23 |

*Table 9.3.1-1: Material tables per ASME VIII – Div 1, Subsection C*

In addition to the above tables there are so called "Code Cases" which contain further materials acceptable for the construction of pressure vessels. For pressure relief valves especially code case 1750-20 lists a large variety of additional materials.

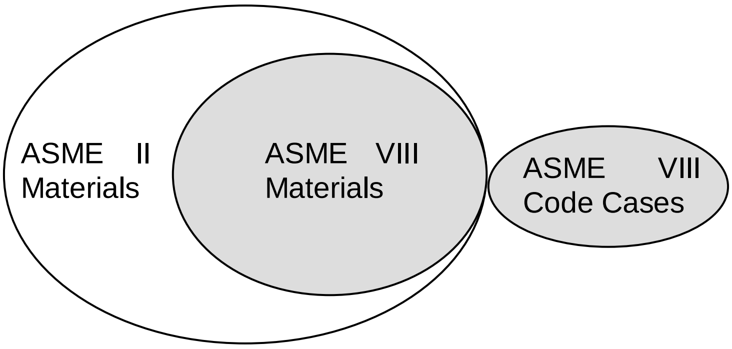



*Figure 9.3.1-1: Allowable materials ASME VIII*

The following parts of ASME Section II contain commonly used materials and product forms for materials used in safety valves:

- SA-105 - Specification for carbon steel forgings for piping applications -
- SA 182 - Specification for forged and rolled alloy and stainless steel pipe flanges, forged fittings, and valves and parts for high-temperature service -
- SA-193 - Specification for alloy-steel and stainless steel bolting materials for high-temperature service -
- SA-194 - Specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both -
- SA-216 - Specification for steel castings, carbon, suitable for fusion welding for high-temperature service -
- SA-217 - Specification for steel castings, martensitic stainless and alloy, for pressure-containing parts, suitable for high-temperature service -
- SA-351 - Specification for casting, austenitic, austenitic-ferritic (duplex), for pressure – containing parts -
- SA-352 - Specification for steel castings, ferritic and martensitic, for pressure containing parts, suitable for low temperature service -
- SA-479 - Specification for stainless steel bars and shapes for use in boilers and other pressure vessels. –

### 9.3.2 AISI and ASTM Material Specifications, UNS, ACI, SUS Number

**AISI = American Iron and Steel Institute**
**ASTM = American Society for Testing and Materials**

ASME has adopted many of the ASTM material standards and the number of the ASME material standard is only distinguished by the additional letter S.

As an example:

ASME SA-216 WCB is the ASME II equivalent to ASTM A-216 WCB.

Sometimes AISI or ASTM materials are requested for pressure retaining components of a safety valve.
As defined in ASME VIII – Div. 1: "UG 136(b)(3) for bodies, bonnet and body-to-bonnet bolting LESER always uses materials according to ASME VIII and ASME II SA specifications or materials defined in ASME code cases like code case 1750-20.

**UNS = Unified Numbering System**

Extract from www.wikipedia.com: The **Unified Numbering System** (UNS) is an alloy designation system widely accepted in North America. It consists of a prefix letter and five digits designating a material composition. A prefix of S indicates stainless steel alloys, C for copper, brass, or bronze alloys. The UNS is managed jointly by the American Society for Testing and Materials and SAE International. A UNS number alone does not constitute a full material specification because it establishes no requirements for material properties, heat treatment, form, or quality.

| UNS Series | Metal type(s) |
|---|---|
| A00001 to A99999 | Aluminum and aluminum alloys |
| C00001 to C99999 | Copper and copper alloys |
| F00001 to F99999 | Cast irons |
| G00001 to G99999 | AISI and SAE carbon and alloy steels (except tool steels) |
| J00001 to J99999 | Cast steels (except tool steels) |
| N00001 to N99999 | Nickel and nickel alloys |
| R00001 to R99999 | Reactive and refractory metals and alloys |
| S00001 to S99999 | Heat and corrosion resistant (stainless) steels |

Link to free UNS numbers:
http://www.e-pipe.co.kr/eng/uns_no/linkuns.html

**ACI = Alloy Casting Institute**

In North America, the common designations for cast stainless steel and nickel-base alloys are descriptive of their chemistry and purpose. This designation system was established by the Alloy Casting Institute (ACI) (Now the Steel Founder's Society of America) and has been adopted by ASTM.
A designation beginning with the letter "C" indicates that the alloy is used primarily for corrosive service; if the first letter is "H", the alloy is used primarily for high temperature service at or above 1200°F (649°C). The second letter indicates the approximate nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram (ASTM A 781, Appendix X1 and Figure X1.1). For C classifications, the single or double digit number following the first two letters indicates the maximum carbon content of the grade (% x 100). For H classifications, this number is the midpoint of the carbon content range in units of 0.01 % with a ±0.05% limit. Other alloying elements, if present, are represented by one or more letters following the number.

For example:
the designation “CF8M” indicates that the grade is corrosion resistant (C), contains between 17% and 21 % chromium and between 8% and 12% nickel (F), a maximum carbon content of 0.08% (8), and molybdenum (M);
the designation “HD” indicates that the grade is heat resistant (H), and contains between 26% and 30% chromium and between 4% and 7% nickel (D).

**SUS**

Material designation according Japanese JIS standards. In general the grade designation from the equivalent ASTM standard is taken and the three letters “SUS” are added.
Example:
ASTM grade = 316L
JIS grade = SUS 316L

### 9.3.3 PED 97/23/EC

The requirements for the main pressure-bearing parts are defined in PED 97/23/EC, Annex 1, 4. Materials, section 4.2. (b):

> "The manufacturer must provide in his technical documentation elements relating to compliance with the materials specifications of the Directive in one of the following forms:
> - by using materials which comply with harmonized standards,
> - by using materials covered by a European approval of pressure equipment materials in accordance with Article 11,
> - by a particular material appraisal"

**Materials which comply with harmonized standards**

The following listing is an overview of the most important harmonized material standards. This means that materials listed in these standards can be used for main pressure-bearing parts in accordance with PED 97/23/EC:

- EN 10272 Stainless Steel bars for pressure purposes
- EN 10273 Hot rolled weldable steel bars for pressure purposes with specified elevated temperature
- EN 10028 Flat products made of steels for pressure purposes
  - Part 1: General requirements
  - Part 2: Non-alloy and alloy steels with specified elevated temperature properties
  - Part 3: Weldable fine grain steels, normalized
  - Part 4: Nickel alloyed steels with specified low temperature properties
  - Part 5: Weldable fine grain steels, thermomechanically rolled
  - Part 6: Weldable fine grain steels, quenched and tempered
  - Part 7: Stainless steels
- EN 10213 Steel castings for pressure purposes
  - Part 1: General
  - Part 2: Steel grades for use at room temperature and elevated temperatures
  - Part 3: Steel grades for use at low temperatures
  - Part 4: Austenitic and austenitic-ferritic steel grades
- EN 10222 Steel forgings for pressure purposes
  - Part 1: General requirements for open die forgings
  - Part 2: Ferritic and martensitic steels with specified elevated temperature properties
  - Part 3: Nickel steels with specified low temperature properties
  - Part 4: Weldable fine grain steels with high proof strength
  - Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels

**Materials covered by a European approval of pressure equipment materials in accordance with Article 11 (EAM)**

The following link contains an overview of materials that have successfully passed an EAM:
http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/published/index_en.htm
Particular material appraisal

The following link contains an overview of materials that have been submitted for an EAM:
http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/submitted/index_en.htm

**Particular material appraisal (PMA)**

LESER has obtained the following PMA:

| | |
|---|---|
| Material: | 1.4104 acc. to EN 10088-3 |
| Application: | Inlet bodies and outlet bodies of Compact Performance safety valves |
| PMA-No.: | PMA 1326W126000, Rev.01 |
| Notified body: | TÜV NORD Systems GmbH & Co KG |

| | |
|---|---|
| Material: | B7M acc. to ASME SA-193, 2HM acc. to ASME SA-194 |
| Application: | Studs and nuts for body-to-bonnet and body to top plate bolting |
| PMA-No.: | PMA 1326W137310-1, Rev.01, PMA 1326W137310-2, Rev.01 |
| Notified body: | TÜV NORD Systems GmbH & Co KG |

### 9.3.3.1 Relevance of Further European Standards Dealing with Materials

The following standards contain requirements relative to materials. This section shall explain their relevance in combination with the PED 97/23/EC.

**EN 13445-2 Unfired Pressure Vessels - Part 2: Materials**

EN 13445 shall substantiate the basic safety requirements of the PED 97/23/EC Annex 1 and specifies the requirements for design, construction, inspection and testing of unfired pressure vessels.
EN 13445-2 specifies the requirements for materials for unfired pressure vessels and supports which are covered by EN 13445-1. Part 2 deals with

- the general philosophy on materials
- material grouping
- low temperature behavior in relation to room temperature performance.

It is limited to steel with sufficient ductility and excludes at present materials operating in the creep range.
Annex A adds a list of all those material grades based upon European base material standards which are accepted to be used for unfired pressure vessels made to this standard
EN 13445-2 is harmonized with PED 97/23/EC, Annex 1, 4. Materials, section 4.2. (b) and other sections.

**ISO 4126 Safety devices for protection against excessive pressure**

- Part 1: Safety Valves
    - Materials for pressure retaining bodies must be acc. to Part 7
- Part 7: Common data
    - Determines material groups for pressure-temperature ratings
    - Lists steel materials which are not specified in European material standards. These are specifically ASTM materials

While some parts of ISO 4126, e.g. part 1 are harmonized with PED 97/23/EC, part 7 is not harmonized with PED 97/23/EC. Therefore the use of ASTM materials can be assumed to be in compliance with the PED.

**EN 1503, Valves - Materials for bodies, bonnets and covers**
EN 1503 has replaced the old DIN 3339.

- part 1: Steels specified in European Standards
- part 2: Steels not specified in European Standards (ASTM standards)
- part 3: Cast irons specified in European Standards
- part 4: Copper alloys specified in European Standards

Part 1 lists all steel materials that can be used for body, bonnets and covers of valves and which are specified in European material standards. It includes material groups and applicable material standards for each product form.
Part 2 lists additional steel materials which are not specified in European material standards. These are specifically ASTM materials. It includes material groups and applicable material standards for each product form as well as temperature limits.
EN 1503 is not harmonized with PED 97/23/EC. Therefore the use of ASTM materials can not be assumed to be in compliance with the PED.

**EN 12516, Industrial valves –Shell design strength – Part 1: Tabulation method for steel valve shells**

- Refers to material standards for pressure vessel steel
  - European standards: Sheet and plate: EN 10028 -1 through -7, castings: EN 10213-2 through -4, forgings: EN 10222 – 2 through -5
  - ASTM standards: e.g. castings: ASTM A-216, ASTM A-351, sheet and plate: ASTM A-240, bar: ASTM A-479
- Determines material groups for pressure-temperature ratings
- Assigns European materials and ASTM materials to material groups
- Provides pressure/temperature ratings for the material groups (equivalent to ASME 16.34)

Parts of EN 12516-1 are harmonized with PED 97/23/EC, however it is not harmonized in regard of the Annex 1, 4. Materials, section 4.2. (b), which determines which materials can be used. This means that although EN 12516-1 is listing ASTM materials, the use of ASTM materials can not be assumed to be in compliance with the PED.

**EN 1092-1, Flanges and their Joints - Circular Flanges for Pipes, Valves, Fittings and Accessories, PN Designated - Part 1: Steel Flanges**

EN 1092-1 contains in Annex D additional materials outside of European material specifications. These are mainly ASTM materials. However it is clearly stated that if these materials are intended to be used in pressure equipment categorie I – IV a EAM or PMA is required,

### 9.3.3.2 Summary

Within the European system of pressure vessel codes it is not as clearly defined which materials can be used for pressure retaining components as it is in the ASME code. PED 97/23/EC determines the basic requirements without listing any materials.
It is essential that the EN material standard is harmonized with the PED 97/23/EC. To which extend a standard is harmonized is documented in the Annex ZA of each harmonized standard. This means that not necessarily the complete content of a standard is harmonized and a detailed review of the harmonized parts of the standard is required.

| Code or Standard | Covers materials acc. to | | Information contained | | | |
|---|---|---|---|---|---|---|
| | | | | Temperature limit | | |
| | EN | ASTM | Material group | Min. | Max. | P/T-rating |
| PED 97/23/EC | Only general requirements | | - | - | - | - |
| EN 13445-2 | √ | - | - | √3) | - | - |
| ISO 4126-7 | - 1) | √2) | √ | - | √ | - |
| EN 1503-1 | √ | - | √ | - | - | - |
| EN 1503-2 | - | √2) | √ | - | √ | - |
| EN 12516-1 | √ | √2) | √ | - | √ | √ |
| EN 1092-1 | √ | √ 2) | √ | - | √ | √ |

1): only reference to EN 12516-1 for pressure/temperature ratings is made
2): suitable only if an EAM – European approval of pressure equipment materials in accordance with Article 11 or a PMA – particular material appraisal" is available
3): Table B 2-2

*Table 9.3.3.2-1: EN and ISO Codes/ standards covering material requirements*

### 9.3.4 AD-2000 together with TRB

Before the PED 97/23 was introduced the AD-2000 code in combination with TRB rules were the applicable codes and standards for pressure equipment in Germany and were adopted in a number of further European markets. Today the AD-2000 code is still existing and has been modified so that the essential safety requirements of the PED are fulfilled, especially the conformity assessment. In other words: with the application of the AD-2000 code as a whole it is assumed that the requirements of the PED are fulfilled.
Within the AD-2000 code applicable parts referring to materials are:

| | |
|---|---|
| AD-W2 | Materials- Austenitic Steels |
| AD W3/1 | Cast iron with lamellar graphite (grey cast iron) non-alloy and low-alloy |
| AD W3/2 | Cast iron materials- Spheroidal-graphite cast iron non-alloy and low alloy |
| AD W4 | Tubes made from non-alloyed and alloy steels |
| AD W5 | Materials- Cast steels |
| AD W10 | Materials for low temperatures- Ferrous materials |

### 9.3.5 Low temperature applications acc. to AD-W10

Especially AD-W10 contains a useful concept regarding low temperature applications with three different load cases:
Case I: material strength parameters and safety factors may be used up to 100%
Case II: material strength parameters and safety factors may be used up to 75%
Case III: material strength parameters and safety factors may be used up to 25%

Depending on the load cases a further reduction of the lowest temperature without further testing of the material at low temperatures is allowed.

Example carbon steel 1.0619 with a pressure rating of PN40 (40 bar):

| Load case | Max. pressure [bar] | Min. temperature [°C] |
|---|---|---|
| Case I | 40 | -10 |
| Case II | 30 | -60 |
| Case III | 10 | -85 |

*Table 9.3.5-1: Load cases acc. to AD-W10 for 1.0619*

Instead of a minimum temperature of -10°C, 1.0619 may be used down to -85°C, if the pressure does not exceed 10 bar.

## 9.4 Material Groups and Applications

This section contains definitions of material groups and their general applications.

| CAST IRON | |
|---|---|
| **Cast Iron** | |
| General description | Low cost material. Not weldable.<br>Due to the lamellar graphite structure cast iron is relatively brittle.<br>Limited pressure rating up to PN 16 or Class 125. |
| Chemical composition | Carbon content: > 2% C < 4,5%<br>Other elements: silicon, normally 1-3 % |
| Typical materials | DIN 1691, 0.6025 (GG-25) |
| Temperature limits | DIN/EN: -10°C up to 300°C |
| Applications | Low pressure steam, water |
| **Ductile Iron** | |
| General description | Also called nodular cast iron. Not weldable.<br>Due to its nodular graphite inclusions ductile iron is much more ductile than cast iron and allows higher pressure ratings than cast iron.<br>Pressure rating up to PN 40 or Class 300. |
| Chemical composition | Carbon content: > 2% C < 4,5%<br>Other elements: silicon, normally 1-3 % |
| Typical materials | 0.7043 (GGG-40.3),<br>60-40-18 |
| Temperature limits | DIN/EN: -60°C (AD-W10) up to 350°C |
| Applications | Low pressure steam, water |

*Table 9.4-1: Properties of cast iron / ductile iron*

| CARBON STEEL | |
|---|---|
| **Carbon Steel** | |
| General description | Higher ductility than cast iron, weldable.<br>Most common material for pressure vessel design. |
| Chemical composition | Carbon content: < 0.2% C<br>Other elements: not significant |
| Typical materials | 1.0619 (GP240GH)<br>WCB |
| Temperature limits | DIN EN: -85°C/-121°F (AD-W10) up to 450°C/842°F<br>ASME: -29°C/-20°F up to 427°C/800°F |
| Applications | Wide range of applications, standard material as long as temperature or chemical resistance do not require different material. In the chemical and petrochemical industry carbon steel stands for approximately 70% - 80 % of the applications. |
| **High Temperature Carbon Steel / Chrome Molybdenum Steel** | |
| General description | Increased upper temperature limit compared to carbon steel. |
| Chemical composition | Carbon content: < 0.2% C<br>Other elements: Cr: 0.5 – 1%, Mo: 0.5 – 1,4%, Ni: 0,4 – 1.0%, some grades contain also Cu, Tu or V. |
| Typical materials | 1.7357 (G17CrMo5-5)<br>WC6 |
| Temperature limits | DIN EN: -85°C/-121°F (AD-W10) up to 550°C/1022°F<br>ASME: -29°C/-20°F up to 538°C/1000°F |
| Applications | Similar to standard carbon steel but temperature above carbon steel limits like in high pressure, high temperature steam applications. |
| **Low Temperature Carbon Steel** | |
| General description | There is no difference in the chemical composition to a standard carbon steel. Different heat treatment and charpy impact test at low temperature (-46°C/-50°F) allow for lower application temperatures. |
| Chemical composition | Carbon content: < 0.2% C<br>Other elements: not significant |
| Typical materials | LCB |
| Temperature limits | ASME: -46°C/-50°F up to 343°C/650°F |
| Applications | Similar to standard carbon steel, especially under low ambient temperature conditions, as they are found e.g. in Canada or Russia. |

*Table 9.4-2: Properties of carbon steel*

| STAINLESS STEEL | |
|---|---|
| **Ferritic Stainless Steel** | |
| General description | Passivation of the surface which provides corrosion resistance. Advantage of ferritic stainless steels vs. austenitic is their resistance against chloride induced intercrystalline corrosion. Ferritic stainless steels are typically magnetic. |
| Chemical composition | Carbon content: typically < 0,03% C<br>Other elements: Cr > 10.5%, better > 12-13%, up to Cr < 27% and very little Ni, if any to avoid austenitic structure. Most compositions include Mo. |
| Typical materials | Ferritic materials are typically not used in LESER safety valves |
| Temperature limits | n/a |
| Applications | n/a |
| **Austenitic Stainless Steel** | |
| General description | Compared to ferritic stainless steels, austenitic stainless steel can be work hardened and has a higher elongation. The almost temperature independent high toughness makes austenitic stainless steel a preferred material for pressure retaining components. Austenitic stainless steel is typically not magnetic. |
| Chemical composition | Carbon content: typically < 0,08% C<br>Other elements: > 16% Cr and sufficient Ni and/or Mn to retain an austenitic structure at all temperatures |
| Typical materials | 1.4408/CF8M, 1.4581/CF10M, 1.4404/316L |
| Temperature limits | DIN EN: -270°C/-454°F up to 550°C/1022°F<br>ASME: -268°C/-450°F up to 538°C/1000°F |
| Applications | Wide range of applications, standard material when carbon steel is not sufficient. In the chemical and petrochemical industry austenitic stainless steel stands for approximately 15 % of the applications. |
| **Martensitic Stainless Steel** | |
| General description | Martensitic steels have due to their relatively high carbon content high strength and hardness, but are typically brittle and have little toughness. They are magnetic and hardenable by quenching and tempering. Martensitic materials are typically not used for pressure retaining parts like bodies or bonnets. |
| Chemical composition | Carbon content: 0.1 – 1.2%<br>Other elements: Cr 12 – 18%, Ni < 2%, Mo 0.2 – 1-0, |
| Typical materials | 1.4021/AISI420, 1.4122/MT440 |
| Temperature limits | Not applicable |
| Applications | Safety valve discs or spindles. |
| **Super Austenitic Stainless Steel** | |
| General description | Super (austenitic) stainless steels contain over 50% non-ferrous elements. Compared to conventional austenitic stainless steels, superaustenitic materials have a superior resistance to pitting and crevice corrosion in environments containing halides. |
| Chemical composition | Carbon content: < 0.08%<br>Other elements: Cr 19 – 23 %, high Mo contents (>6% for AL-6XN and 254 SMO) and nitrogen additions 0.1 – 0.25% for resistance to chloride pitting and crevice corrosion, Ni 17.5 – 38% ensures better resistance to stress-corrosion cracking. |
| Typical materials | Alloy AL-6XN / UNS N08367, 254SMO / UNS S31254, Alloy 20 / UNS N08020, 1.4529, 1.4539 |
| Temperature limits | Depending on material |
| Applications | Originally developed for seawater applications, AL-6XN is used successfully in food, pharmaceutical, and biopharmaceutical processes. 254SMO is used for seawater applications. |

*Table 9.4-3: Properties of stainless steel*

| DUPLEX STAINLESS STEEL | |
|---|---|
| **22 Cr Duplex Stainless Steel** | |
| General description | Duplex stainless steels have a grain structure that is ideally 50% austenitic and 50% ferritic. In practise a 40% to 60% ration is still considered a duplex structure. The Ferritic-Austenitic grain structure of duplex stainless steel provides a higher yield and tensile strength and sufficient toughness. Duplex stainless steels show a better resistance against chloride induced intercrystalline corrosion compared to austenitic stainless steels. Duplex materials have a PREN of 30 to 40 while 300 series stainless steels have a PREN of 20 - 25 |
| Chemical composition | Carbon content: C < 0,03%<br>Other elements: Cr 21% - 23%, Ni 4,5% - 6,5%, Mo 2,5% - 3,5% |
| Typical materials | CD3MN / Gr 4A / UNS J92205, Alloy 2205 / F51 / S31803, 1.4470, 1.4462 |
| Temperature limits | DIN EN: up to / 280°C / 536°F<br>ASME: -46°C/-50°F up to 316°C / 600°F |
| Applications | Urea plants, Marine and Offshore |
| **25 Cr Super Duplex Stainless Steel** | |
| General description | The 25 Cr grades with 25% Chromium and approx. 7% Nickel are called "SuperDuplex" due to the higher Corrosion resistance. They have PREN > 40, which is considered to be resistant against sea water.<br>Disadvantage of Super Duplex versus Duplex is a more difficult welding, because of heat induced changes of the duplex grain structure. |
| Chemical composition | Carbon content: C < 0,04%<br>Other elements: Other elements: Cr 24% - 27%, Ni 5% - 8%, Mo 2,5% - 5% |
| Typical materials | CD3MWCuN / Gr 6A / J93380, UNS S32760 / F55 |
| Temperature limits | DIN EN: up to 250°C / 482°F<br>ASME: -46°C / -50°F up to 316°C / 600°F |
| Applications | Seawater |
| **Safurex** | |
| General description | SAFUREX is a Duplex material patented by STAMICARBON, the DSM Licensing Center and SANDVIK for the use in urea plants acc. to the process licensed by Stamicarbon. Stamicarbon requires the use of SAFUREX for certain parts of the plant and only certain valve manufacturer are licensed to use the material.<br>The material is recognized in the ASME system under UNS 32906 and applied as per ASME Code Case 2295. Available product forms are bar, forging, pipe, plate, but no casting. |
| Chemical composition | Carbon content: C < 0,03%<br>Other elements: Other elements: Cr 28% - 30%, Ni 5,8% - 7,5%, Mo 1,5% - 2,6% |
| Typical materials | SAFUREX UNS 32906 |
| Temperature limits | Not available, Urea processes of STAMICARBON typically run at approximately 200°C |
| Applications | Urea plants with processes licensend by STAMICARBON. |

*Table 9.4-4: Properties of duplex stainless steel*

| Nickel Base Materials | |
|---|---|
| General description | The primary constituent is nickel instead of iron. However Nickel might be less than 50% of the total composition. Nickel based alloys are used for a wide range of applications and have a large range of alloying elements. They are commonly recognized under the tradenames of the primary manufacturers like Hastelloy®, Inconel®, Incoloy®, Monel®. |
| Chemical composition | Carbon content: normally below 0.07%, Monel M 35-1 up to 0.35%<br>Other elements: normally Ni > 50%,<br>B-Alloys : Ni < 1,5%, Mo 25 – 33%,<br>C-Alloys: Ni 14 - 23%, Mo 12 – 18%, |
| Typical materials | CX2MW / UNS N26022, HASTELLOY C-22 / N06022, 2.4602<br>CW-12MW / UNS N30002, HASTELLOY C-276 / UNS N10276, 2.4686, 2.4819, M35-1 / UNS N24135, MONEL 400 / UNS N04400, 2.4360,<br>CW-6MC / UNS N26625, INCONEL 625 / UNS N06625, 2.4816, 2.4856 |
| Pressure rating | No limitation |
| Temperature limits | Varies with material |
| Applications | Hastelloy B-Alloys: for reducing acids<br>Hastelloy C-Alloys: for oxidizing acids |

*Table 9.4-5: Properties of nickel base materials*

| Pure Metals | |
|---|---|
| General description | Occasionally traditional stainless steels or nickel base alloys can not fulfill the corrosions resistance requirements of a specific application.<br>Except for pure Nickel also Titanium, Zirconium or Tantalum may be used for pressure retaining components acc. to ASME code. |
| Chemical composition | Typically pure metal with little other elements |
| Typical materials | Nickel, Titanium, Zirconium, Tantalum |
| Pressure rating | No limitation |
| Temperature limits | Varies with material |
| Applications | Titanium:<br>- titanium is advantageous in environments subject to attack by oxidizing media or by chlorides and other chlorine ions<br>- sometimes preferred over Duplex grades in offshore applications.<br>Zirconium:<br>- Acetic Acid Production - MONSANTO carbonylation process<br>- Urea Production (Stripper)<br>- Nitric Acid Applications<br>- Sulfuric Acid Applications<br>- Formic Acid Environments<br>Tantalum:<br>- Tantalum is resistant to all acids with the exception of hot, fuming sulphuric acid (oleum) and hydrofluoric acid. It is only attacked slowly by alkaline solutions. |

*Table 9.4-6: Properties of pure materials*

Materials for pressure retaining components like body, bonnet, bolts must be from materials that are listed in the applicable codes and standards (see…). Therefore not every available material may be used for these components.

## 9.5 Standard Parts and Materials for LESER Safety Valves

The following table shows the materials that are used in LESER safety valves as a standard. A standard material per LESER definition is available as a materials from stock.

| Part | Material Group | Product form | EN Material | ASME/ASTM Material 1) | Notes |
|---|---|---|---|---|---|
| **Body / Bonnet** | Cast Iron | Casting | 0.6025 | Cast Iron | max. PN 16 |
| | Ductile Iron | Casting | 0.7043 | SA 395 - 60-40-18 | max. PN 40, ANSI 300 |
| | Carbon Steel | Casting | 1.0619 | SA 216 – WCB/WCC | |
| | Carbon Steel | Plate | 1.0460 / 1.0425 | SA 105 | Type 441XXL only |
| | Low Temp C.S. | Casting | - | SA 352 – LCB/LCC | Type 526 |
| | High Temp C.S. | Casting | 1.7357 | SA 217 - WC6 | |
| | Chrome Steel | Bar | 1.4104 | N/A | Compact Performance within PED only |
| | Stainless Steel | Casting | 1.4408 | SA 351 - CF8M | |
| | Stainless Steel | Bar, Forging, Pipe | 1.4404 | SA 479 / SA 182 / SA 312 - 316L | bonnets, inlet body Compact Performance |
| | Stainless Steel | Bar | 1.4435 – BN2 | SA 479 - 316L | series 48X, low Delta Ferrite |
| | High Temp S.S. | Casting | 1.4581 | SA 351 - CF10M | Series 458 only |
| | High Temp S.S. | Bar, Forging, Pipe | 1.4571 | SA 479 / SA 182 / SA 312 - 316Ti | Type 441XXL only |
| **Bonnet Spacer** | Stainless Steel | Bar | 1.4404 | SA 479 - 316L | |
| | Carbon Steel | Bar | 1.0460 | SA 105 | |
| **Nozzle** | Stainless Steel | Investm. Casting | 1.4408 | SA 351 - CF8M | |
| | Stellite | Investm. Casting | 1.4408 / Stellite | SA 351 - CF8M Stellite | |
| | Stainless Steel | Bar | 1.4404 | SA 479 - 316L | |
| | Stellite | Bar | 1.4404 / Stellite | Sa 479 - 316L / Stellite | |
| **Disc** | Chrome Steel | Bar | 1.4122 | MT 440 | hardened stainless steel |
| | Stainless Steel | Bar | 1.4404 | SA 479 - 316L | |
| | Stellite | Bar | 1.4404 / Stellite | SA 479 - 316L / Stellite | optional |
| **Studs** | Carbon Steel | Stud | 1.1181 | | |
| | Carbon Steel | Stud | 1.7225 | SA 193 - B7 | |
| | High Temp Alloy | Stud | 1.7709 | SA 193 - B16 | |
| | Stainless Steel | Stud | 1.4401 | SA 193 – B8M | |
| **Nuts** | Carbon Steel | Nut | 1.0501 | | |
| | High Temp Alloy | Nut | 1.7258 | SA 194 – 7M | |
| | Stainless Steel | Nut | 1.4401 | SA 194 - 8M | |
| **Spindle** | Chrome Steel | Bar | 1.4021 | 420 | |
| | Stainless Steel | Bar | 1.4404 | 316L | |
| | Stainless Steel | Bar | 1.4404 tenifer | 316L tenifer | for higher pressure stainless steel valves |
| **Spring** | Carbon Steel | Bar | 1.1200 | Carbon Steel | |
| | High Temp Alloy | Bar | 1.8159 | High Temp Alloy | |
| | High Temp Alloy | Bar | 1.7102 | High Temp Alloy | |
| | Stainless Steel | Bar | 1.4310 | 302 | |
| | Inconel | Bar | 2.4669 | Inconel X-750 | |
| **Bellows** | Stainless Steel | Sheet | 1.4571/1.4404 | 316Ti/316L | bellows flange and tailpiece from 316L |
| | Inconel | Sheet | 2.4856/1.4404 | Inconel 625/316L | Type 526 only |
| | Elastomer | | EPDM FDA | EPDM FDA | Series 48X |
| **Gasket** | Graphite/S.S. | Gasket | Graphite/1.4401 | Graphite/316 | |
| | Reinforced PTFE | Gasket | Gylon | Gylon | optional |

1): Material for pressure retaining components are supplied with double material certificate, ASME materials for other components may be equivalent materials only

*Table 9.5-1: LESER standard materials*

## 9.5.1 Chemical Composition of Materials acc. to EN Standards

| Product form | Standard | Mat. Nr. | C | Si | Mn | P ≤ | S ≤ | Cr | Ni | Mo | Other | Material Group EN 12516-1 | Material Group AD-W10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LESER Standard Materials** | | | | | | | | | | | | | |
| Casting | DIN 1691 | 0.6025 | 2,9-3,1 | 1,8-2,0 | 1,0-1,3 | --- | --- | --- | --- | --- | Approx. analysis | --- | --- |
| Casting | DIN 1693 | 0.7043 | 3,5-3,7 | 2,0-2,2 | 0,25 | --- | --- | --- | --- | --- | Approx. analysis | --- | --- |
| Casting | EN 10213-2 | 1.0619 | 0.18-0.23 | 0.60 | 0.50-1.20 | 0.030 | 0.020 | --- | --- | --- | --- | 3 E 0 | --- |
| Forging | EN 10222-2 | 1.0460 | 0.18-0.23 | 0.40 | 0.40-0.90 | 0.025 | 0.015 | 0.30 | --- | --- | Al: 0.015-0.050 | --- | --- |
| Plate | EN 10028-2 | 1.0425 | 0.20 | 0.40 | 0.80-1.40 | 0.025 | 0.015 | 0.30 | 0.30 | exactly 0.08 | Al: min 0.020, N: 0.012 Cu: 0.30, Nb: 0.020, Ni: 0.30, Ti: 0.03, V: 0.02, Cr+Cu+Mo+Ni ≤ 0.70 | 3 E 0 | --- |
| Casting | EN 10213-2 | 1.7357 | 0.15-0.20 | 0.60 | 0.50-1.00 | 0.020 | 0.020 | 1.00-1.50 | --- | 0.45-0.65 | --- | 5 E 0 | --- |
| Bar | EN 10088-3 | 1.4104 | 0.10-0.17 | 1.00 | 1.50 | 0.040 | 0.15-0.35 | 15.50-17.50 | --- | 0.20-0.60 | --- | --- | --- |
| Casting | EN 10213-4 | 1.4408 | 0.07 | 1.50 | 1.50 | 0.040 | 0.030 | 18.00-20.00 | 9.00-12.00 | 2.00-2.50 | --- | 14 E 0 | 3 |
| Investm. Casting | EN 10213-4 | 1.4408 | 0.07 | 1.50 | 1.50 | 0.040 | 0.030 | 18.00-20.00 | 9.00-12.00 | 2.00-2.50 | --- | 14 E 0 | 3 |
| Bar, Pipe Forging, | EN 10272 | 1.4404 | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 16.50-18.50 | 10.00-13.00 | 2.00-2.50 | N: ≤ 0.11 | 13 E 0 | 3 |
| Bar | EN 10272 | 1.4435 | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 17.00-19.00 | 12.50-15.00 | 2.50-3.00 | N: ≤ 0.11 | --- | 3 |
| Casting | EN 10213-4 | 1.4581 | 0.07 | 1.50 | 1.50 | 0.040 | 0.030 | 18.00-20.00 | 9.00-12.00 | 2.00-2.50 | Nb: 8xC, max. 1.00 | 15 E 0 | --- |
| Bar, Pipe, Forging | EN 10272 | 1.4571 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.50-18.50 | 10.50-13.50 | 2.00-2.50 | Ti: 5xC to 0.70 | 15 E 0 | 3 |
| Bar | EN 10088-3 | 1.4122 | 0.33-0.45 | 1.00 | 1.50 | 0.040 | 0.030 | 15.50-17.50 | 1.00 | 0.80-1.30 | --- | --- | --- |
| Stud | EN 10269 | 1.1181 | 0.32-0.39 | 0.40 | 0.50-0.80 | 0.035 | 0.035 | 0.40 | 0.40 | 0.10 | Cr+Mo+Ni ≤ 0.63 | --- | --- |
| Stud | EN 10269 | 1.7225 | 0.38-0.45 | 0.40 | 0.60-0.90 | 0.035 | 0.035 | 0.90-1.20 | --- | 0.15-0.30 | --- | --- | --- |
| Stud | EN 10269 | 1.7709 | 0.17-0.25 | 0.40 | 0.40-0.80 | 0.030 | 0.030 | 1.20-1.50 | 0.60 | 0.55-0.80 | Al: 0.030, V: 0.20-0.35 | --- | --- |
| Stud | EN ISO 3506-1 | A4-70 (1.4401) | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.5 | 10.00-15.00 | 2.00-3.00 | C: 1.00 | 14 E 0 | 3 |
| Nut | DIN EN 10269 | C35 (1.0501) | 0.32-0.39 | 0.15-0.35 | 0.50-0.80 | 0.045 | 0.045 | --- | --- | --- | --- | --- | --- |
| Nut | DIN EN 10269 | 24 CrMo5 (1.7258) | 0.20-0.28 | 0.15-0.35 | 0.50-0.80 | 0.030 | 0.035 | 0.90-1.20 | --- | 0.20-0.35 | --- | --- | --- |
| Nut | EN ISO 3506-1 | A4-70 (1.4401) | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.5 | 10.00-15.00 | 2.00-3.00 | C: 1.00 | 14 E 0 | 3 |
| Bar | EN 10088-3 | 1.4021 | 0.16-0.25 | 1.00 | 1.50 | 0.040 | 0.030 | 12.00-14.00 | --- | --- | --- | --- | --- |
| Spring | EN 10270-1 | SH (1.1200) | 0.35-1.00 | 0.10-0.30 | 0.50-1.20 | 0.035 | 0.035 | --- | --- | --- | Cu: 0.20 | --- | --- |
| Spring | EN 10089 | 1.8159 | 0.47-0.55 | 0.40 | 0.70-1.10 | 0.025 | 0.025 | 0.90-1.20 | --- | --- | V: 0.10-0.25, Cu+10Sn±0.60 | --- | --- |
| Spring | EN 10089 | 1.7102 | 0.51-0.59 | 1.20-1.60 | 0.50-0.80 | 0.025 | 0.025 | 0.50-0.80 | --- | --- | Cu+10Sn±0.60 | --- | --- |
| Spring | EN 10270-3 | 1.4310 | 0.05-0.15 | 2.00 | 2.00 | 0.045 | 0.015 | 16.00-19.00 | 6.00-9.50 | 0.80 | N: ≤ 0.11 | --- | --- |

*Table 9.5.1-1: Chemical composition LESER standard materials acc. to EN standards*

| Product form | Standard | EN Mat. Nr. | C | Si | Mn | P ≤ | S ≤ | Cr | Ni | Mo | Other | Material Group | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | EN 12516-1 | AD-W10 |
| **Other Common Materials** | | | | | | | | | | | | | |
| Casting | EN 10213-3 | 1.1131 | 0.15-0.20 | 0.60 | 1.00-1.60 | 0.020 | 0.020 | --- | --- | --- | --- | 7 E 0 | --- |
| Casting | EN 10213-3: | 1.6220 | 0.17-0.23 | 0.60 | 1.00-1.60 | 0.020 | 0.020 | --- | --- | --- | Ni: max. 0.80 | 7 E 0 | --- |
| Casting | EN 10213-4 | 1.4308 | 0.07 | 1.50 | 1.50 | 0.040 | 0.030 | 18.00-20.00 | 8.00-11.00 | --- | --- | 11 E 0 | 3 |
| Casting | EN 10213-2 | 1.5419 | 0.15-0.23 | 0.60 | 0.50-1.00 | 0.025 | 0.020 | --- | --- | 0.40-0.60 | --- | 4 E 0 | --- |
| Casting | EN 10213-4 | 1.4409 | 0.030 | 1.50 | 2.00 | 0.035 | 0.025 | 18.00-20.00 | 9.00-12.00 | 2.00-2.50 | N: 0.20 | 13 E 0 | --- |
| Plate | EN 10028-7 | 1.4961 | 0.04-0.10 | 0.30-0.60 | 1.50 | 0.035 | 0.015 | 15.00-17.00 | 12.00-14.00 | --- | Nb: ≥ 10xC bis 1.20 | --- | --- |
| Bar | EN 10025 | 1.0570 | 0.20, > 40 mm 0.22 | 0.55 | 1.60 | 0.035 | 0.035 | --- | --- | --- | --- | --- | --- |
| Bar | EN 10273 | 1.7335 | 0.08-0.18 | 0.35 | 0.40-1.00 | 0.025 | 0.010 | 0.70-1.15 | --- | 0.40-0.60 | N: 0.012, Cu: 0.30 | 5 E 0 | --- |
| Forging | EN 10222-2 | 1.5415 | 0.12-0.20 | 0.35 | 0.40-0.90 | 0.025 | 0.015 | --- | --- | 0.25-0.35 | --- | 4 E 0 | --- |
| Pipe | EN 10216-5 | 1.4988* | 0.04-0.10 | 0.30-0.60 | 1.50 | 0.035 | 0.015 | 15.50-17.50 | 12.50-14.50 | 1.10-1.50 | N: 0.06-0.14, Nb: 10xC bis 1.20, V: 0.60-0.85 | --- | --- |
| Pipe | EN 10216-5 | 1.4981* | 0.04-0.10 | 0.30-0.60 | 1.50 | 0.035 | 0.015 | 15.50-17.50 | 15.50-17.50 | 1.60-2.00 | Nb: 10xC bis 1.20 | --- | --- |
| Plate | EN 10028-7 | 1.4910* | 0.04 | 0.75 | 2.00 | 0.035 | 0.015 | 16.00-18.00 | 12.00-14.00 | 2.00-3.00 | N: 0.10-0.18, B: 0.0015-0.0050 | --- | --- |
| Plate | EN 10028-7 | 1.4301 | 0.07 | 1.00 | 2.00 | 0.045 | 0.015 | 17.00-19.50 | 8.00-10.50 | --- | N: 0.11 | 11 E 0 | 3 |
| Plate | EN 10028-7 | 1.4401 | 0.07 | 1.00 | 2.00 | 0.045 | 0.015 | 16.50-18.50 | 10.00-13.00 | 2.00-2.50 | N: 0.11 | 14 E 0 | 3 |
| Plate | EN 10028-7 | 1.4541 | 0.08 | 1.00 | 2.00 | 0.045 | 0.015 | 17.00-19.00 | 9.00-12.00 | --- | Ti: 5xC bis 0.70 | 12 E 0 | 3 |

*** = not listed in EN 12516-1**

Notes:
- All values are maximum unless otherwise indicated.
- Additional notes about the chemical composition can be found in the respective standard.

*Table 9.5.1-2: Chemical composition of further common materials acc. to EN standards*

## 9.5.2 Chemical Composition of Materials acc. to ASME Specifications

| Product form | ASME/ ASTM Spec. | ASME Material | C | Si | Mn | P ≤ | S ≤ | Cr | Ni | Mo | Other | Listed in ASME Sec. VIII | Listed in ASME B 16.34 Group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Casting | SA 395 | 60-40-18 | min. 3.00 | 2.50 | --- | 0.08 | --- | --- | --- | --- | --- | UCD-23 | --- |
| Casting | SA 216 | WCB | 0.30 | 0.60 | 1.00 | 0.04 | 0.045 | 0.50 | 0.50 | 0.20 | Cu: 0.30 V: 0.03 | UCS-23 | 1.1 |
| Plate, Forging | SA 105 | SA 105 | 0.35 | 0.10-0.35 | 0.60-1.05 | 0.035 | 0.040 | 0.30 | 0.40 | 0.12 | Cu: 0.40 V: 0.08 | UCS-23 | 1.1 |
| Casting | SA 352 | LCB | 0.30 | 0.60 | 1.00 | 0.040 | 0.045 | 0.50 | 0.50 | 0.20 | Cu: 0.30 V: 0.03 | UCS-23 | 1.3 |
| Casting | SA 217 | WC6 | 0.05-0.20 | 0.60 | 0.50-0.80 | 0.04 | 0.045 | 1.00-1.50 | --- | 0.45-0.65 | --- | UCS-23 | 1.9 |
| Casting | SA 351 | CF8M | 0.08 | 1.50 | 1.50 | 0.040 | 0.040 | 18.0-21.0 | 9.0-12.0 | 2.0-3.0 | --- | UHA-23 | 2.2 |
| Casting | SA 351 | CF10M | 0.04-0.10 | 1.50 | 1.50 | 0.040 | 0.040 | 18.0-21.0 | 9.0-12.0 | 2.0-3.0 | --- | --- | --- |
| Bar | SA 479 | 316L | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | --- | UHA-23 | 2.3 |
| Bar | SA 479 | 316Ti | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | N: 0.10 Ti: 5*(C+N) - 0.70 | UHA-23 | --- |
| Bar | SA 276 | 440A | 0.60-.075 | 1.00 | 1.00 | 0.040 | 0.030 | 16.00-18.00 | --- | 0.75 | --- | --- | --- |
| Bar | SA 276 | 420 | min. 0.15 | 1.00 | 1.00 | 0.040 | 0.030 | 12.00-14.00 | --- | --- | --- | --- | --- |
| Stud | SA 193 | B7 | 0.37-0.49 | 0.15-0.35 | 0.65-1.10 | 0.035 | 0.040 | 0.75-1.20 | --- | 0.15-0.25 | --- | UCS-23 | --- |
| Stud | SA 193 | B16 | 0.36-0.47 | 0.15-0.35 | 0.45-0.70 | 0.035 | 0.040 | 0.80-1.15 | --- | 0.50-0.65 | V: 0.25-0.35 Al: 0.015 | UCS-23 | --- |
| Stud | SA 193 | B8M | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | --- | UHA-23 | --- |
| Nut | SA 194 | 2H | min. 0.40 | 0.40 | 1.00 | 0.040 | 0.050 | --- | --- | --- | --- | --- | --- |
| Nut | SA 194 | 7M | 0.37-0.49 | 0.15-0.35 | 0.65-1.10 | 0.035 | 0.040 | 0.75-1.20 | --- | 0.15-0.25 | --- | --- | --- |
| Nut | SA 194 | 8M | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | --- | --- | --- |
| Casting | SA 217 | WC5 | 0.05-0.20 | 0.60 | 0.40-0.70 | 0.04 | 0.045 | 0.50-0.90 | 0.60-1.00 | 0.90-1.20 | --- | UCS-23 | 1.7 |
| Casting | SA 217 | WC9 | 0.05-0.18 | 0.60 | 0.40-0.70 | 0.04 | 0.045 | 2.00-2.75 | --- | 0.90-1.20 | --- | UCS-23 | 1.10 |
| Casting | SA 217 | C5 | 0.20 | 0.75 | 0.40-0.70 | 0.04 | 0.045 | 4.00-6.50 | --- | 0.45-0.65 | --- | UCS-23 | 1.13 |
| Casting | SA 217 | C12 | 0.20 | 1.00 | 0.35-0.65 | 0.04 | 0.045 | 8.00-10.00 | --- | 0.90-1.20 | --- | UCS-23 | 1.14 |
| Casting | SA 351 | CF8 | 0.08 | 2.00 | 1.50 | 0.040 | 0.040 | 18.0-21.0 | 8.0-11.0 | 0.50 | --- | UHA-23 | 2.1 |
| Casting | SA 351 | CF3 | 0.03 | 2.00 | 1.50 | 0.040 | 0.040 | 17.0-21.0 | 8.0-12.0 | 0.50 | --- | UHA-23 | 2.1 |
| Casting | SA 351 | CF3M | 0.03 | 1.50 | 1.50 | 0.040 | 0.040 | 17.0-21.0 | 9.0-13.0 | 2.0-3.0 | --- | UHA-23 | 2.2 |
| Casting | SA 351 | CF3MN | 0.03 | 1.50 | 1.50 | 0.040 | 0.040 | 17.0-21.0 | 9.0-13.0 | 2.0-3.0 | N: 0.10-0.20 | --- | --- |
| Casting | SA 351 | CG8M | 0.08 | 1.50 | 1.50 | 0.040 | 0.040 | 18.0-21.0 | 9.0-13.0 | 3.0-4.0 | --- | UHA-23 | 2.2 |
| Casting | SA 351 | CG3M | 0.03 | 1.50 | 1.50 | 0.040 | 0.040 | 18.0-21.0 | 9.0-13.0 | 3.0-4.0 | --- | --- | --- |
| Casting | SA 351 | CF8C | 0.08 | 2.00 | 1.50 | 0.040 | 0.040 | 18.0-21.0 | 9.0-12.0 | 0.50 | Nb: see Note | UHA-23 | 2.11 |
| Bar | SA 479 | 304 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 18.0-20.0 | 8.0-10.5 | --- | --- | UHA-23 | 2.1 |
| Bar | SA 479 | 304L | 0.03 | 1.00 | 2.00 | 0.045 | 0.030 | 18.0-20.0 | 8.0-12.0 | --- | --- | UHA-23 | 2.3 |
| Bar | SA 479 | 316 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | --- | UHA-23 | 2.2 |
| Bar | SA 479 | 316Cb | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | N: 0.10 Nb: 10*C-1.10 | UHA-23 | --- |
| Bar | SA 479 | 316Ti | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | N: 0.10 Ti: 5*(C+N) -0.70 | UHA-23 | --- |
| Bar | SA 479 | 317 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 18.0-20.0 | 11.0-15.0 | 3.0-4.0 | --- | UHA-23 | --- |
| Forging | SA 182 | 317L | 0.03 | 1.00 | 2.00 | 0.045 | 0.030 | 18.0-20.0 | 11.0-15.0 | 3.0-4.0 | --- | UHA-23 | --- |
| Bar | SA 479 | 321 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 17.0-19.0 | 9.0-12.0 | --- | Ti: 5*(C+N) -0.70 | UHA-23 | 2.4 |
| Bar | SA 479 | 347 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 17.0-19.0 | 9.0-12.0 | --- | Nb: 10*C -1.10 | UHA-23 | 2.5 |

Notes:
- All values are maximum unless otherwise indicated.
- Additional notes about the chemical composition can be found in the respective standard.
- High Alloy and Nickel base materials: see section 9.4
- For equivalent SA specifications depending on product form see section 9.7.1

*Table 9.5.2-1: Chemical composition of selected materials acc. to ASME specifications*

### 9.5.3 LESER Standard Materials Versus other Common Materials

This section explains the selection of materials for the main components in LESER safety valves in comparison to other manufacturers.

The following chart compares standard materials for LESERs API series 526 and competitive models.

| Component | Type | LESER standard material | Farris | Crosby | Consolidated |
|---|---|---|---|---|---|
| Body/Bonnet | 5262 | 1.0619 / SA-216 GR. WCB | SA-216 GR. WCB | SA-216 GR. WCB | SA-216 GR. WCC |
| | 5263 | LCB | | | LCC |
| | 5264 | 1.4408 / CF8M | SA-351 Gr. CF8M | SA-351 Gr. CF8M | SA-351 Gr. CF8M |
| | 5267 | 1.7357 / SA-217 GR. WC6 | SA-217 GR. WC6 | SA-217 GR. WC6 | SA-217 GR. WC6 |
| Nozzle | 5262<br>5263<br>5624 | 1.4408 / CF8M<br>1.4408 / CF8M stellited | 316 St. St. | 316 St. St. | 316 St. St. |
| | 5267 | 1.4408 / CF8M stellited | 316 St. St. | 316 St. St. | 316 St. St. |
| | Optional | 1.4404 / 316L stellited | 316 St. St. | 316 St. St. | 316 St. St. |
| Disc | 5262<br>5263<br>5267 | 1.4122 / hardened stainless steel | 316 St. St. | 316 St. St. | 316 St. St. |
| | 5264 | 1.4404 / 316L stellited | | | |
| Guide with bushing | 5262<br>5263<br>5267 | 1.0501 / Carbon Steel<br>1.4104 tenifer / Chrome steel | 316 St.St. | ASTM A297 GR. HE SST | 316 St.St. |
| Guide | 5264 | 1.4404 / 316L | 316 St. St. | ASTM A297 GR. HE SST | 316 St. St. |
| Spindle | 5264 | 1.4404 / 316L | | | |
| | 5262<br>5263<br>5267 | 1.4021 / 420 | 316 St. St. | 416 St. St. | 400 Series SS |
| Spring | 5264 | 1.4310 | 316 St. St. | 316 St. St. | 316 St. St. |

*Table 9.5.3-1: Material comparison of LESER and other manufacturers*

#### 9.5.3.1 Body and Bonnet Materials

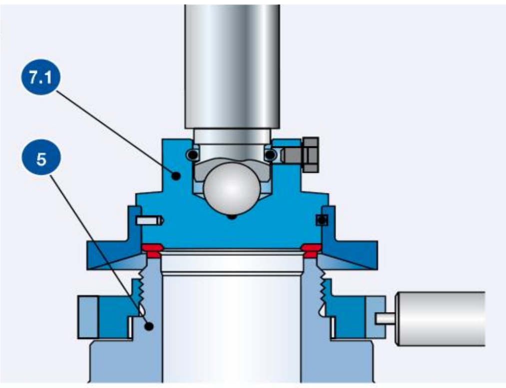
LCB vs. LCC:

LESER specifies casting with a so called five-fold-material-certificate. This means that chemical analysis and chemical properties of the material are limited in such a way that the material fulfils the material requirements of five different materials at the same time.
These materials are: 1.0619, WCB, WCC, LCB and LCC. Therefore the LCC specification of other manufacturers is automatically covered.
The material supplier certifies all five materials in one single material certificate at the same time. This certification of LCB and LCC requires the performance and certification of a charpy impact test at -46°C.
In other words: If LESER supplies the material LCB this material is at the same time a 1.0619 but with an extended application range for temperatures below -10°C down to – 46°C. For details please refer to LESER Work Standard LDeS 3290.03.

### 9.5.3.2 Nozzle Materials

LESER uses the casting material 1.4408/ CF8M as a standard material for nozzles of API Series safety valves. Material 1.4404/316L can be configured as an option.
International competitors describe the nozzle material as 316 st.st. in their catalogs. 316 st.st. is used as a synonym for bar or forged 316 and casting CF8M. A stellited sealing surface is always an option associated with additional cost.

Stellited sealing surfaces
LESER automatically supplies the nozzles with stellited sealing surface in the following cases:
- valve size 4M6 or larger
- WC6 body material
- WCB/LCB body material: inlet flange class #600 or higher
- CF8M body material: inlet flange class #900 or higher




Stellite is a cobalt-chromium based, non-ferrous alloy with increased hardness, corrosion resistance and wear resistance up to high temperatures.
Stellited sealing surfaces provide a significantly longer lifetime of the valve seat especially in the following cases:
– high pressure applications, due to the high stress of the sealing surfaces
– high temperature applications to avoid a permanent deformation of the sealing surfaces
– applications with abrasive fluids to increase the wear resistance of the sealing surfaces

*Figure 9.5.3.2-1: Stellited sealing surfaces*

### 9.5.3.3 Disc Materials

LESER uses the martensitic material 1.4122 as a standard material for safety valve discs. International competitors use the austenitic material 316 as standard material. To compare the materials this part describes the differences.

Chemical composition of 1.4122 and 316

| Standard | Mat. No. | C | Si | Mn | P ≤ | S ≤ | Cr | Ni | Mo | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| EN 10088-3 | 1.4122 | 0.33 - 0.45 | 1.00 | 1.50 | 0.040 | 0.030 | 15.50-17.50 | 1.00 | 0.80 - 1.30 | --- |
| SA 479 | 316 | 0.08 | 1.00 | 2.00 | 0.045 | 0.030 | 16.0-18.0 | 10.0-14.0 | 2.00 - 3.00 | --- |

*Table 9.5.3.3-1: Chemical composition of 1.4122 and 316*

1.4122 is a martensitic hardened stainless steel. Due to the relatively high carbon content a high strength and hardness is provided.
316 is an austenitic stainless steel. Due to the content of Cr and Ni content it provides a very good corrosion resistance. However 316 is a relatively soft material.
For uncritical media like steam, water or many gases a disc from 1.4122 provides a perfect solution. Due to its hardness it has a longer lifetime than 316. The combination of a hard disc with a relatively soft material for the nozzle/seat (CF8M or 316L) additionally leads to a better tightness, especially after the valves has opened.

| Material | Average Hardness |
|---|---|
| 1.4408/CF8M | 14 – 16 HRC |
| 1.4404/316L | 16 – 19 HRC |
| 1.4408/CF8M stellited<br>1.4404/316L stellited | 40 HRC |
| 1.4122 | 42 – 46 HRC |

*Table 9.5.3.3-2: Hardness of 1.4122 hardened versus austenitic stainless steel*

In case corrosive media like chemicals require the corrosion resistance of a 316 stainless steel, LESER supplies a disc of material 316L which is automatically equipped with a stellited sealing surface.

### 9.5.3.4 Guide Materials

Main task of the guide is to provide alignment for the spindle when the valve has to operate and assure that the spindle is always free to move. It is essential that no corrosion and no galling occurs between spindle and guide.
LESER uses the material combination guide in carbon steel 1.0501 and bushing in 1.4104 tenifer (chrome steel tenifer). The bushing serves as the contact/guiding surface for the spindle.

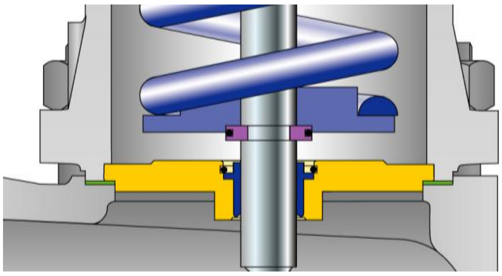


*Figure 9.5.3.4-1: Guide with bushing*

1.4104 tenifer is a corrosion resistant chrome steel with a tenifer surface hardening treatment. This nitrocarburisation procedure improves the hardness of the material and reduces the friction between a tenifer surface (guide) and a metallic surface (spindle). This leads to a longer lifetime and avoids galling between spindle and guide.

Chemical Composition

| Standard | Mat. No. | C | Mn | Si | Cr | Ni | Mo | P ≤ | S ≤ | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| EN 10088-3 | 1.4104 | 0.10-0.17 | 1.50 | 1.00 | 15.50-17.50 | --- | 0.20-0.60 | 0.040 | 0.15-0.35 | --- |
| SA 479 | 316 | 0.08 | 2.00 | 1.00 | 16.0-18.0 | 10.0-14.0 | 2.00-3.00 | 0.045 | 0.030 | --- |
| ASTM A-297 | GR HE | 0.20-0.50 | 2.00 | 2.00 | 26.0 -30.0 | 8.0 -11.0 | 0.50 | 0.04 | 0.04 | --- |

*Table 9.5.3.4-1: Chemical composition of 1.4104, 316 and ASTM A-297 GR HE*

### 9.5.3.5 Spindle Materials

LESER uses the martensitic material 1.4021 as a standard material for safety valve spindles. This section compares 1.4021 to the martensitic AISI grade 410 and 416 stainless steel.

LESER sources 1.4021 with a defined heat treatment and hardening procedure, resulting in defined mechanical properties.
AISI 410/416 can be sourced with a variety of heat treatment conditions resulting in completely different mechanical properties.
Only if AISI 410/416 are sourced with a heat treatment resulting in the highest possible tensile and yield strength this material reaches mechanical properties comparable but not superior to 1.4021.

Chemical Composition

| Material | Standard | C | Cr | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| 1.4021 | EN 10088-3 | 0,16 - 0,25 | 12 - 14 | 1,5 | 0,04 | 0,015 | 1 |
| AISI 410 | SA 276 | 0.15 | 11.5 - 13.5 | 1 | 0,04 | 0,03 | 1 |
| AISI 416 | ASTM A582 | 0.15 | 12 - 14 | 1.25 | 0.06 | 0.015 | 1 |

*Table 9.5.3.5-1: Chemical composition of 1.4021, AISI 410 and AISI 416*

The chemical composition of the three materials is almost identical, resulting in comparable chemical resistance.

9.5.3.6 Spring Materials

LESER standard stainless steel spring material is 1.4310. Competitors often use 316 springs as standard (DIN equivalent: 1.4401). This chapter shall compare both materials and give an overview about the range of application for both.

Chemical Composition
The following chemical composition and mechanical properties were taken from referenced material codes for spring wire:

| Material | | 1.4310 | 1.4401 | 316 |
|---|---|---|---|---|
| Short name | | X10CrNi18-8 | X5CrNiMo17-12-2 | S 31600 |
| Code | | DIN EN 10270-3: 2012-01 | DIN EN 10270-3: 2012-01 | A 313/A 313M – 03 |
| Chemical composition | C | 0,05 - 0,15 | max. 0,07 | max. 0,07 |
| | Si | max. 2,00 | max. 1,00 | max. 1,00 |
| | Mn | max. 2,00 | max. 2,00 | max. 2,00 |
| | P | max. 0,045 | max. 0,045 | max. 0,045 |
| | S | max. 0,015 | max. 0,015 | max. 0,03 |
| | Cr | 16,0 - 19,0 | 16,5 - 19,0 | 16,5 - 18,0 |
| | Mo | max. 0,80 | 2,00 - 2,50 | 2,00 - 2,50 |
| | Ni | 6,5 - 9,0 | 10,0 - 13,0 | 10,5 - 13,5 |
| | N | max. 0,11 | max. 0,11 | max. 0,10 |

*Table 9.5.3.6-1: Chemical composition of 1.4310, 1.4401 and 316*

The only differences lay in the Si, Mo, and Ni- content. The main difference can be found in Mo- and Ni-content which is lower for 1.4310. Molybdenum and nickel as alloying component lead to higher corrosion resistance, mainly when it comes to highly concentrated and hot acids.

Mechanical Properties:
The following tables summarize the mechanical properties from material standards:

| Material | | 1.4310 NS | 1.4310 HS | 1.4401 | 316 |
|---|---|---|---|---|---|
| Short name | | X10CrNi18-8 | X10CrNi18-8 | X5CrNiMo17-12-2 | S 31600 |
| Code | | DIN EN 10270-3: 2012-01 | DIN EN 10270-3: 2012-01 | DIN EN 10270-3: 2012-01 | A 313/ A 313M – 03 |
| Mechanical properties | Tensile str. Ø5mm [MPa] | 1450 - 1670 | 1550 - 1790 | 1200 - 1380 | 1105 - 1310 |
| | Tensile str. Ø10mm [MPa] | 1250 - 1440 | 1350 - 1560 | 1050 - 1210 | 895 - 1105 |

*Table 9.5.3.6-2: Mechanical properties of 1.4310, 1.4310HS, 1.4401 and 316 from material standards*

Additionally to above mentioned mechanical properties the following values from spring suppliers shall be taken into account, because they are relevant for the design of springs:

| | Material | 1.4310 NS | 1.4310 HS | 1.4401 | 316 |
|---|---|---|---|---|---|
| | Short name | X10CrNi18-8 | X10CrNi18-8 | X5CrNiMo17-12-2 | S 31600 |
| Mechanical properties | E-Module | 180000 | 185000 | 185000 | n.a. |
| | Rm | 1336,1 | 1440,8 | 1019 | n.a. |
| | G | 71500 | 73000 | 69500 | n.a. |

*Table 9.5.3.6-2: Additional mechanical properties of 1.4310, 1.4310HS, 1.4401 and 316*

The mechanical properties, especially Rm (tensile strength) and G-module (shear modulus) of LESER's standard material are higher than for 316. This is advantageous for the design of springs, because it allows to design springs with a larger force in a given space (bonnet). This means a higher possible set pressure for a given valve design.

LESER standard springs made of 1.4310 are suitable for a temperature range between -196°C up to +280°C (temperature at the spring, not medium temperature).
As 316 springs have the same temperature range, both materials can be considered to be equal.

Summary
1.4310 provides better mechanical properties with a wider set pressure range. For a large majority of applications 1.4310 provides also a very good corrosion resistance. The only point where 316 offers a benefit is in regards to corrosion resistance when it comes to highly concentrated and hot acids. In those cases a bellows should be selected to protect the spring area.

## 9.6 High Alloy Materials and Applications

Whenever a standard material like carbon steel or austenitic stainless steel is not sufficient for an application, high alloy materials must be considered for trim and body materials.
There can be various reasons requiring the choice of a non standard material, e.g.

- corrosive medium
- corrosive environment
- high or low temperature
- p/t rating

The list of potential materials is extensive and this section shall provide general guidelines as well as an overview of material options.

### 9.6.1 High Alloy Material Concept

High alloy materials are typically expensive materials and sourcing and machining of individual components vs. large lot sizes can add further costs. When selecting high alloy materials the user should evaluate the application properly and decide which components of the safety valve shall be made from these materials.
For this decision it is important to analyse if, when and how often the different components of a safety valve come into contact with a corrosive medium or environment and what the consequences of a corrosive attack of these components would be. Limited corrosion of the valve external may be acceptable, whereas corrosion of the spindle and guide can not be accepted.

The following figures and charts shall help to understand the critical areas and components in a safety valve.

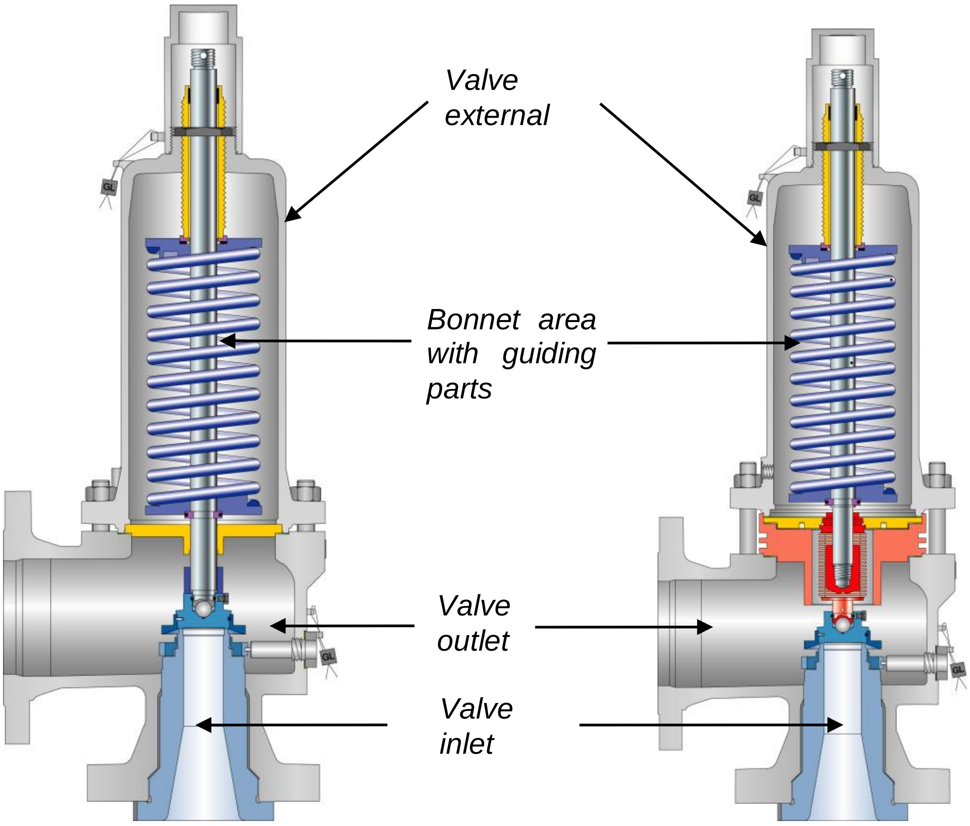



*Figure 9.6.1-1: Critical areas and components in a conventional safety valve*

*Figure 9.6.1-2: Critical areas and components in a balanced bellows safety valve*

The different areas of a safety valve can be distinguished regarding corrosion considerations as follows:

<table>
<tr><th>Area</th><th>Conventional Design</th><th>Balanced Bellows Design</th></tr>
<tr><td>Valve inlet</td><td colspan="2">- Permanently medium wetted area<br>- Corrosion at seat and disc must be avoided to ensure proper opening of the safety valve</td></tr>
<tr><td>Valve outlet</td><td colspan="2">- Not permanently medium wetted area<br>- Wetted only<br>• after discharge or<br>• if safety valve shows leakage (e.g. when operating close to set pressure) or<br>• if corrosive medium is present also in the discharge system</td></tr>
<tr><td>Bonnet area with guiding parts</td><td>- See “Valve Outlet”<br>- Corrosion of guide and spindle must be avoided to ensure proper opening of the safety valve</td><td>- The bellows seals and protects the bonnet area and the guiding parts from any medium in the valve outlet<br>- The only potential for corrosive attack of the guiding parts comes from a corrosive environment (e.g. marine) entering the bonnet through the bonnet vent.</td></tr>
<tr><td>Valve External</td><td colspan="2">Corrosive attack of the body and bonnet from a corrosive environment (e.g. marine, sea water).</td></tr>
</table>

*Table 9.6.1-1: Different areas of a conventional design and balanced bellows design*

At the end a decision between the cost of a corrosion resistant design and a more frequent maintenance cycle must be made by the user.
To assist making this decision LESER offers different levels for the extent of components in high alloy materials.

## 9.6.2 The LESER Level Concept

The pictures below visualize the different levels of corrosion protection for a LESER API Series safety valve. Components in red color indicate the high alloy material component within each level.

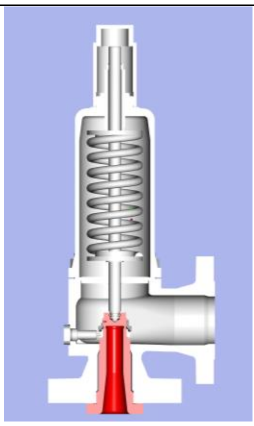
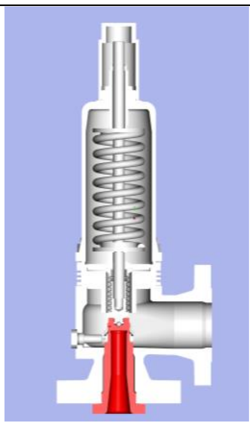
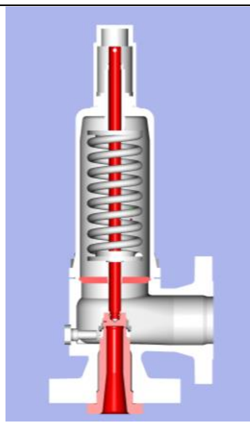
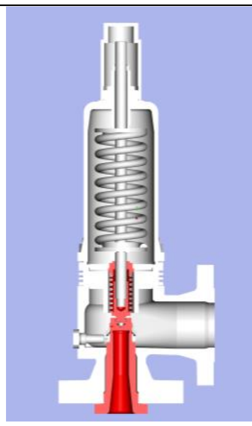
| **Level 1**<br>**Inlet Wetted parts** | | **Level 2**<br>**Inlet Wetted & Guiding parts** | |
|---|---|---|---|
| 1.0 Conventional | 1.1 Bellows | 2.0 Conventional | 2.1 Bellows |
|  |  |  |  |

*Figure 9.6.2-1: Level 1 and 2 of high alloy material components*

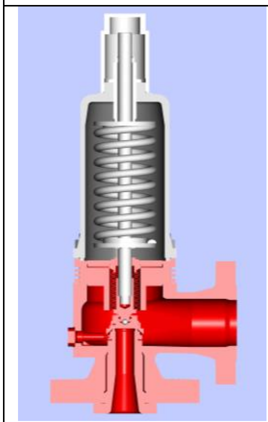
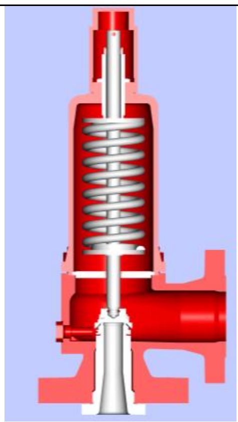
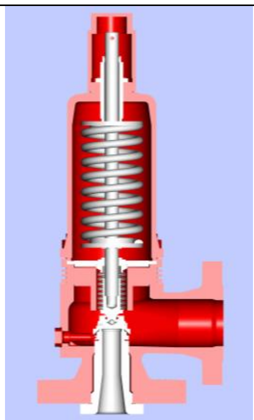
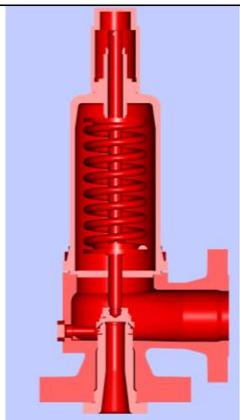
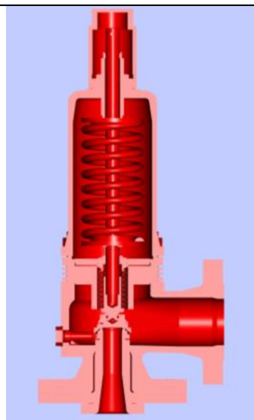
| **Level 3 - Inlet & Outlet Wetted** | **Level 4**<br>**Valve Externals** (body and bonnet) | | **Level 5**<br>**Complete Valve** | |
|---|---|---|---|---|
| 3.1 Bellows | 4.0 Conventional | 4.1 Bellows | 5.0 Conventional | 5.1 Bellows |
|  |  |  |  |  |

*Figure 9.6.2-2: Level 3, 4 and 5 of high alloy material components*

The following chart provides a guideline for the application of the different levels depending on the general operating conditions and maintenance aspects.

| Level | Components | Criteria for Selection | Explanation |
|---|---|---|---|
| 1 | Inlet Wetted parts | - corrosive medium<br>- set pressure much higher than operating pressure<br>- safety valve opening unlikely<br>- immediate maintenance after discharge | When it is very unlikely due to other measures controlling the process that a safety valve will ever open, it may be sufficient to change only the permanently wetted nozzle and disc. The outlet wetted parts can remain standard materials, because it is very unlikely that they ever come in contact with the medium. |
| 2 | Inlet Wetted & Guiding parts | - corrosive medium<br>- operating pressure closer to set pressure<br>- safety valve opening more likely<br>- delayed maintenance after discharge | Through a potential opening of the safety valve or small leakage also outlet components might come in to contact with the medium. The most critical parts in the valve outlet for the proper function of the safety are the spindle and the guide which should be changed to a high alloy material, or alternatively be protected by a balanced bellows in a corrosion resistant material. |
| 3 | Inlet & Outlet Wetted parts (bellows design only) | - corrosive medium<br>- operating pressure close to set pressure<br>- safety valve opening likely<br>- continuous operation without maintenance after discharge required | All medium wetted components are in a corrosion resistant material. The bellows protects all components above the guide, which can remain in standard materials. Cost effective solution compared to a full valve in high alloy materials. |
| 4 | Valve Externals (body & bonnet) | - corrosive environment<br>- high or low temperature | Marine or offshore application may lead to corrosion of the external components of a safety valve while the internal medium wetted components are not affected. |
| 5 | Complete Valve | - extremely corrosive medium and/or environment<br>- corrosive attack of any component in the valve is expected<br>- safety valve opening likely<br>- continuous operation without maintenance after discharge | Highest level of corrosion protection, but also expensive. |

*Table 9.6.2-1: LESER level concept for high alloy materials*

### 9.6.3 LESER High Alloy Material Options

The following table shows a selection of the high alloy materials that are available for the LESER safety valves Series 526 as an option. Further materials are available on request. Materials highlighted in grey are standardized at LESER and available within short delivery time.

| Part | Material Group | Product form | EN Material[1)] | ASME / ASTM Material[1)] | UNS | Notes [3)] |
|---|---|---|---|---|---|---|
| **Body / Bonnet [2)]** | Austenitic S.S. | Casting | | SA 351 - CF3M | J92800 | low carbon version of CF8M |
| | | Casting | | SA 351 - CG8M | J93000 | |
| | | Casting | 1.4552 | SA 351 - CF8C | J92710 | |
| | Duplex | Casting | 1.4470 | SA 995 – CD3MN | J92205 | Gr. 4A, Code Case 2402 |
| | Super Duplex | Casting | | SA 995 - CD3MWCuN | J93380 | Gr. 6A, Code Case 2244-2 |
| | | Casting | 1.4517 | SA 995 - CD4MCuN | J93372 | Gr. 1B, Code Case 1750-20 |
| | Super Austenitic | Casting | | SA 351 - CK3MCuN | J93254 | Code Case 1750-20, 254 SMO equivalent |
| | | Casting | | SA 351 - CN3MN | J94651 | AL6XN equivalent |
| | | Casting | | SA 351 - CN7M | J95150 | Alloy 20 equivalent |
| | Nickel base | Casting | | SA 494 – CX2MW | N26022 | Hastelloy C-22 equivalent |
| | | Casting | | SA 494 – CW-12MW | N30002 | Hastelloy C-276 equivalent |
| | | Casting | | SA 494 – M35-1 | N24135 | Monel 400 equivalent |
| | | Casting | | SA 494 – CW-6MC | N26625 | Inconel 625 equivalent |
| **Nozzle**<br><br>**Disc**<br><br>**Spindle**<br><br>**Guide** | Austenitic S.S. | Bar | 1.4404 | SA 479 – 316L<br>SA 182 – F316L | S31603 | |
| | | Bar | 1.4552 | SA 479 – 347<br>SA 182 – F347 | S34700 | |
| | Duplex | Bar<br>Forging | 1.4462 | SA 479 - S31803<br>SA 182 – F51 | S31803 | Alloy 2205 |
| | Super Duplex | Bar<br>Forging | 1.4501 | SA 479 - S32760<br>SA 182 – F55 | S32760 | Zeron 100 |
| | | Bar<br>Forging | 1.4507 | SA 479 - S32550<br>SA 182 – F61 | S32550 | Alloy 255 |
| | Super Austenitic | Bar<br>Forging | 1.4547 | SA 479 – S31254<br>SA 182 – S31254 | S31254 | 254 SMO |
| | | Bar | 1.4529 | SB 691 / SB 462 - N08367 | N08367 | AL6XN |
| | | Bar | 2.4660 | SB 473 / SB 462 - N08020 | N08020 | Alloy 20 |
| | Nickel base | Bar | 2.4610 | SB 574 - N06455 | N06455 | Hastelloy C-4 |
| | | Bar | 2.4602 | SB 574 / SB 564 - N06022 | N06022 | Hastelloy C-22 |
| | | Bar | 2.4856 | SB 446 – N06625 | N06625 | INCONEL 625 |
| | | Bar | 2.4360 | SB 164 – N04400 | N04400 | Monel-400 |
| **Studs** | Nickel base | Bar | 2.4819 | SB 574 - N10276 | N10276 | Hastelloy C-276 |
| | | Bar | 2.4360 | SB 164 – N04400 | N04400 | Monel 400 |
| | | Bar | 2.4375 | ASTM B 865 – N05500 | N05500 | Monel K-500 |
| | | Bar | 2.4856 | SB 446 – N06625 | N06625 | Inconel 625 |
| **Nuts** | Nickel base | Bar | 2.4819 | SB 574 - N10276 | N10276 | Hastelloy C-276 |
| | | Bar | 2.4360 | SB 164 – N04400 | N04400 | Monel 400 |
| | | Bar | 2.4375 | ASTM B 865 – N05500 | N05500 | Monel K-500 |
| | | Bar | 2.4856 | SB 446 – N06625 | N06625 | Inconel 625 |
| **Spring** | Nickel base | Bar | 2.4669 | ASTM B637 / AMS 5699 - N07750 | N07750 | Inconel X-750 |
| | | Bar | 2.4610 | N06455 | N06455 | Hastelloy C-4 |
| **Bellows** | Nickel base/ Stainless St. | Sheet | 2.4856/<br>1.4404 | SB 446 – N06625 /<br>SA 479 – 316L | N06625 | Bellows from Inconel 625, flange and tailpiece from 316L |
| | Nickel base | Sheet | 2.4856 | SB-443 - N06625 | N06625 | |
| | Nickel base | Sheet | 2.4819 | SB-619/SB-622 - N10276<br>SB 574 - N06455 | N10276 | Bellows from Hastelloy C 276, flange and tailpiece from Hast. C-4 |

1) EN materials listed in each line are equivalent materials to the ASME materials. They may or may not be supplied with material double certificate.
2) Some bonnet sizes may be offered in welded design or bar material versus the listed casting material
3) Hastelloy is a trademark of Haynes International, Inc., Inconel, Monel are trademarks of Special Metals Corporation

*Table 9.6.3-1: High alloy material options for LESER API Series 526*

## 9.6.4 Corrosion Resistance of Selected High Alloy Materials

**A Guide to Aqueous Corrosion-Resistance**
(All alloys listed are resistant to chloride cracking)

★ = Good to excellent
☆ = Acceptable
– = Not suitable

| | Sulfuric Acid | Hydrochloric Acid | Hydrofluoric Acid | Phosphoric Acid | Nitric Acid | Organic Acids | Alkalines & Salts | Seawater |
|---|---|---|---|---|---|---|---|---|
| Nickel 200 | ☆ | ☆ | ★ | ☆ | – | ★ | ★ | ☆ |
| Nickel 201 | ☆ | ☆ | ★ | ☆ | – | ★ | ★ | ☆ |
| DURANICKEL® alloy 301 | ☆ | ☆ | ★ | ☆ | – | ★ | ★ | ☆ |
| MONEL® alloy 400 | ★ | ☆ | ★ | ★ | – | ★ | ★ | ★ |
| MONEL® alloy R-405 | ★ | ☆ | ★ | ★ | – | ★ | ★ | ★ |
| MONEL® alloy K-500 | ★ | ☆ | ★ | ★ | – | ★ | ★ | ★ |
| INCONEL® alloy 600 | ☆ | – | ☆ | ☆ | – | ★ | ★ | ☆ |
| INCONEL® alloy 622 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCONEL® alloy 625 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCONEL® alloy 625LCF® | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCONEL® alloy 686 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCONEL® alloy 690 | ☆ | ☆ | ★ | ★ | ★ | ★ | ★ | ☆ |
| INCONEL® alloy 718 | ☆ | ☆ | ☆ | ☆ | ☆ | ★ | ★ | ★ |
| INCONEL® alloy 725™ | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCONEL® alloy C-276 | ★ | ★ | ★ | ★ | ☆ | ★ | ★ | ★ |
| INCONEL® alloy G-3 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCONEL® alloy 050 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCOLOY® alloy 800 | ☆ | ☆ | – | ☆ | ★ | ★ | ☆ | ☆ |
| INCOLOY® alloy 825 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCOLOY® alloy 864™ | ☆ | ☆ | ☆ | ☆ | ★ | ★ | ★ | ★ |
| INCOLOY® alloy 925™ | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCOLOY® alloy 020 | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ |
| INCOLOY® alloy 25-6MO | ★ | ★ | ☆ | ★ | ★ | ★ | ★ | ★ |
| INCOLOY® alloy 028 | ☆ | ★ | ☆ | ☆ | ★ | ★ | ★ | ★ |

*[“High-Performance Alloys for Resistance to Aqueous Corrosion”, Publication from Special Metals Corporation, Huntington, West Virginia, USA]*

*Table 9.6.4-1: Corrosion resistance of selected high alloy materials*

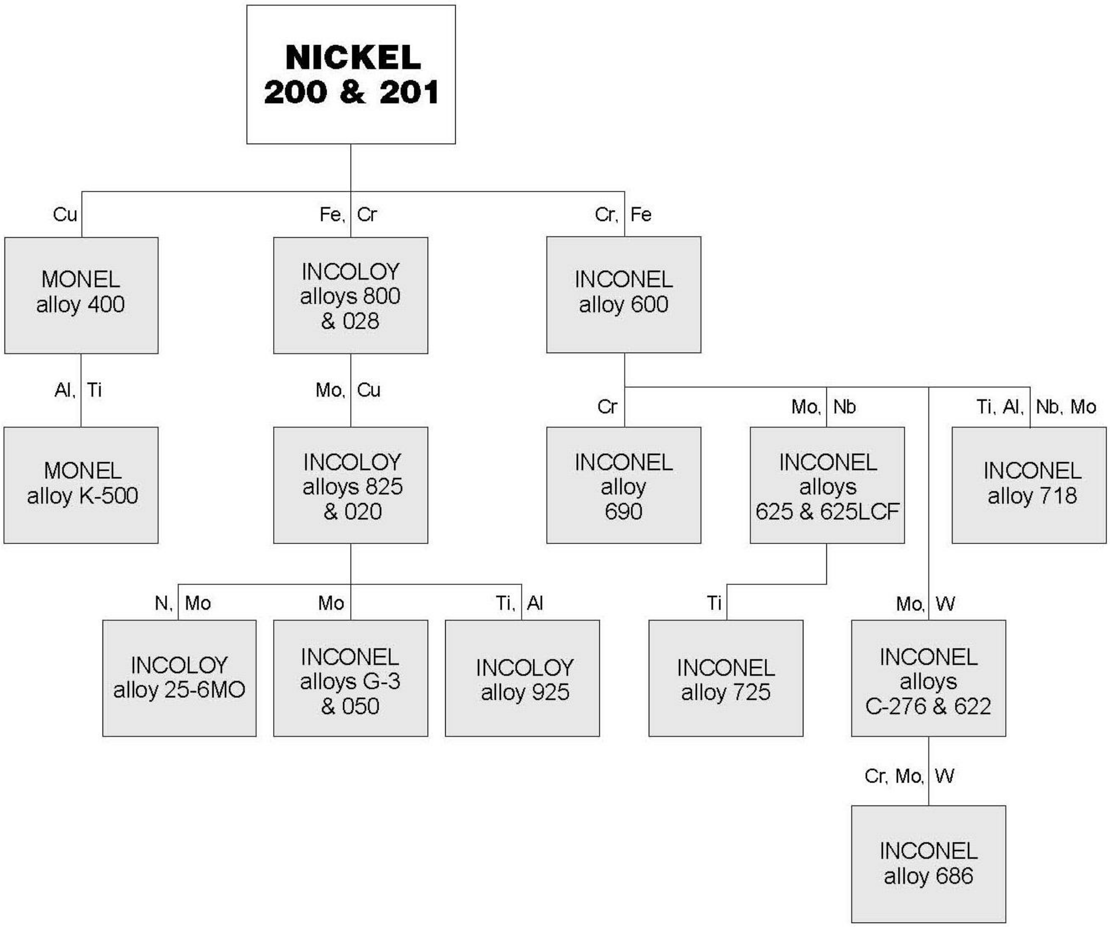
## 9.6.5 Chemical Compositions of High Alloy Materials

| Material | UNS Bar / Casting | Ni min-max | Cr min-max | Mo min-max | Fe min-max | Cu min-max | Other min-max |
|---|---|---|---|---|---|---|---|
| **NICKEL BASE MATERIALS** | | | | | | | |
| HASTELLOY C-4 | N06455 / --- | balance | 14.0-18.0 | 14.0-17.0 | | | |
| HASTELLOY C-22 | N06022 / N26022 | balance | 20.0-22.5 | 12.5-14.5 | | | 2.5-7.0 |
| HASTELLOY C-276 | N10276 / N30002 | balance | 14.5-16.5 | 15.0-17.0 | | | 3.0-8.5 |
| Hastelloy B-2 | N10665 / --- | balance | | 26.0-30.0 | | | |
| Hastelloy B-3 | N10675 / --- | ≥ 65.0 | | 27.0-32.0 | | | |
| Alloy B-4 | N10629 / --- | balance | | 26.0-30.0 | | | |
| Monel 400 | N04400 / N24135 | ≥ 63.0 | | | | 28.0-34.0 | |
| Monel K-500 | N05500 / --- | ≥ 63.0 | | | | 27.0-33.0 | 2.7-6.2 |
| Nickel 200 | N02200 / N02100 | ≥ 99.0 | | | | | |
| Inconel 600 | N06600 / N06040 | ≥ 72.0 | 14.0-17.0 | | 6.0-10.0 | | |
| Inconel 601 | N06601 / --- | 58.0-63.0 | 21.0-25.0 | | balance | | |
| Inconel 625 | N06625 / N26625 | ≥ 58.0 | 20.0-23.0 | 8.0-10.0 | 0-5.0 | | 3.2-7.1 |
| Inconel X-750 | N07750 / --- | ≥ 70.0 | 14.0-17.0 | | 5.0-9.0 | | 3.4-7.5 |
| Incoloy 800 | N08800 / --- | 30.0-35.0 | 19.0-23.0 | | ≥ 39.5 | | |
| Incoloy 825 | N08825 / N08826 | 38.0-46.0 | 19.5-23.5 | | ≥22.0 | | 2.1-6.0 |
| **22 Cr STANDARD DUPLEX MATERIALS** | | | | | | | |
| Alloy 2205 | S31803 / J92205 | | 21.0-23.0 | | balance | | |
| **25 Cr SUPER DUPLEX MATERIALS** | | | | | | | |
| Alloy 2507 | S32750 / --- | 6.0-8.0 | 24.0-26.0 | | balance | | |
| Zeron 100 | S32760 / J93380 | 6.0-8.0 | 24.0-26.0 | | balance | | |
| Alloy 255 | S32550 / J93372 | 4.5-6.5 | 24.0-27.0 | | balance | | |
| **SUPER AUSTENITIC MATERIALS** | | | | | | | |
| 254 SMO | S31254 / J93254 | 17.5-18.5 | 19.5-20.5 | 6.0-6.5 | balance | | |
| AL6XN | N08367 / J94651 | 23.5-25.5 | 20.0-22.0 | 6.0-7.0 | balance | | |
| Alloy 20 | N08020 / J95150 | 32.0-38.0 | 19.0-21.0 | | balance | | 3.6-8.2 |
| Alloy 904 | N08925 / --- | 24.0-26.0 | 19.0-21.0 | 6.0-7.0 | balance | | |
| Alloy 904L | N08904 / --- | 23.0-28.0 | 19.0-23.0 | | balance | | |
| Alloy 926 | N08926 / --- | 24.0-26.0 | 19.0-21.0 | 6.0-7.0 | balance | | |

Notes:
- UNS numbers are linked only if material is listed in ASME VIII.
- Cu is only listed separately if the content is higher than 4 %, else Cu is listed under “Other”.
- Composition is listed only for bar material, the equivalent casting may have a slightly different composition.
- Additional information about the composition can be found in the respective material standard.

*Table 9.6.5-1: Chemical composition of selected high alloy materials*

The following chart shows the development of nickel-based alloys with multiple alloying additions.




*["High-Performance Alloys for Resistance to Aqueous Corrosion", Publication from Special Metals Corporation, Huntington, West Virginia, USA]*

*Figure 9.6.5-1: Development of nickel-based alloys with multiple alloying additions*

### 9.6.6 Alloying Elements and their Function

**Nickel** – Provides metallurgical stability, improves thermal stability and weldability, improves resistance to reducing acids and caustics, and increases resistance to stress corrosion cracking particularly in chlorides and caustics.

**Chromium** – Improves resistance to oxidizing corrosives and to high-temperature oxidation and sulfidation, and enhances resistance to pitting and crevice corrosion.

**Molybdenum** – Improves resistance to reducing acids, and to pitting and crevice corrosion in aqueous chloride containing environments. It contributes to increased high-temperature strength.

**Iron –** Improves resistance to high-temperature carburizing environments, reduces alloy costs, and controls thermal expansion.

**Copper** – Improves resistance to reducing acids (particularly non-aerated sulfuric and hydrofluoric) and to salts. Copper additions to nickel-chromium-molybdenum iron alloys provide improved resistance to hydrochloric, phosphoric and sulfuric acids.

**Aluminum** – Improves resistance to oxidation at elevated temperatures and promotes age hardening.

**Titanium –** Combines with carbon to reduce susceptibility to intergranular corrosion due to chromium carbide precipitation resulting from heat treatments, and enhances age hardening.

**Niobium (Columbium)** – Combines with carbon to reduce susceptibility to intergranular corrosion due to chromium carbide precipitation resulting from heat treatments, improves resistance to pitting and crevice corrosion, and increases high temperature strength.

**Tungsten** – Improves resistance to reducing acids and to localized corrosion, and enhances both strength and weldability.

**Nitrogen** – Enhances metallurgical stability, improves pitting and crevice corrosion resistance, and increases strength.

**Cobalt** – Provides increased high-temperature strength, and resistance to carburization and sulfidation.

*[“High-Performance Alloys for Resistance to Aqueous Corrosion”, Publication from Special Metals Corporation, Huntington, West Virginia, USA]*

The following link provides additional information on alloying elements and their effect on steel:

http://www.stahlschluessel.de/en/info_element__lang.html

### 9.6.7 Corrosion Types

**Pitting Corrosion**

Pitting is a form of localised corrosion and is characterised by attacks at small discrete spots on the steel surface. Pitting occurs mainly in the presence of neutral or acidic solutions containing chlorides or other halides. Chloride ions facilitate a local breakdown of the passive layer, especially if there are imperfections in the metal surface.

**Crevice corrosion**

Crevice corrosion is a form of localised corrosion and occurs under the same conditions as pitting, i.e. in neutral or acidic chloride solutions. However, attack starts more easily in a narrow crevice than on an unshielded surface. Crevices, such as those found at flange joints or at threaded connections, are thus often the most critical sites for corrosion.

**Stress corrosion cracking**

A material failure may be accelerated by the combined effect of corrosion and mechanical stress. The most common type is transgranular stress-corrosion cracking, SCC, that may develop in concentrated chloride-containing environments. Previously, it was generally considered that an elevated temperature was necessary for SCC to occur. In recent years, however, SCC has been experienced at ambient temperature on standard grade steels like 304(L) or 316(L) that were exposed to high tensile stresses. In these cases the steel surface was contaminated with solid salt deposits and the humidity of the atmosphere was rather high. These two factors resulted in a thin liquid film saturated with chloride. Other contaminants, such as H2S, may increase the risk of SCC in chloride containing environments. Other environments that may give rise to SCC, particularly on low alloy steels, include very alkaline solutions at high temperatures. A typically SCC attack takes the form of thin, branched cracks.

**Intergranular corrosion**

This type of corrosion may occur if the area around the grain boundaries is less corrosion resistant than the matrix in the medium in question. The classical case is when chromium carbide is precipitated at the grain boundaries. The adjacent matrix will be depleted in chromium and a narrow region around the grain boundary may, therefore, be less corrosion resistant than the rest of the material.

**Corrosion fatigue**

It is well known that a material subjected to a cyclic load far below the ultimate tensile stress can fail, a process called fatigue. If the metal is simultaneously exposed to a corrosive environment, the failure can take place at even lower loads and after shorter time. Contrary to a pure mechanical fatigue, there is no fatigue limit load in corrosion-assisted fatigue.

*[http://www.stainless-steel-world.net]*

### 9.6.8 PREN

Pitting resistance equivalent numbers (PREN) are a theoretical way of comparing the pitting corrosion resistance of various types of stainless steels, based on their chemical compositions. A higher value of the PREN number represents a better resistance.

PREN = %Cr + 3,3*%Mo + 16*%N (+1,65*%W).

This number can be used to rank different materials but does not provide an absolute value for corrosion resistance and is not applicable in all environments.
Sometimes nitrogen is weighted more, with factors of 27 or 30, but as the actual nitrogen levels are quite modest in most stainless steels, this does not have a dramatic effect on ranking.

| **Typical ranges of PREN** | |
|---|---|
| Material | PREN |
| 300 Series stainless steel | 20 - 25 |
| Duplex stainless steel | 30 – 40 |
| Super Duplex<br>Super Austenitic | > 40 |

*Table 9.6.8-1: Typical ranges of PREN*

PREN > 40 is considered to be resistant against sea water.

## 9.7 Equivalent Materials

Metallic materials for use in pressure vessels can be furnished as casting, forging, bar or plate. Equivalent materials with similar chemical composition and similar mechanical properties are manufactured according to different specifications and may have different grade designations depending on the product form. This section shall help to identify equivalent materials in different product forms.

### 9.7.1 Equivalent Material Grades by Product Form – ASME Materials

The following table is based on table 1 of ASME B16.34-2004 and allows to find the equivalent materials depending on the product form. The material groups in this table identify materials with the same pressure temperature ratings per ASME B16.34.

| GROUP 1 MATERIALS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Forging | | Casting | | Plates | | Bars | | Tubular | |
| Mat. Group | Nominal Designation | Spec | Grade | Spec | Grade | Spec | Grade | Spec | Grade | Spec | Grade |
| 1.1 | C-Si | A 105 | | A 216 | WCB | A 515 | 70 | A 105 | | | |
| | C-Mn-Si | A 350 | LF2 | | | A 516 | 70 | A 350 | LF2 | A 672 | C 70 |
| | | | | | | A 537 | Cl.1 | A 696 | C | | B 70 |
| | 3 ½ Ni | A350 | LF3 | | | | | | | | |
| | C-Mn-Si-V | A350 | LF6 Cl.1 | | | | | | | | |
| 1.2 | C-Si | | | | | | | | | A 106 | C |
| | 2 ½ Ni | | | A 352 | LC2 | A 203 | B | | | | |
| | 3 ½ Ni | | | A 352 | LC3 | A 203 | E | | | | |
| | C-Mn-Si | | | A 216 | WCC | | | | | | |
| | | | | A 352 | LCC | | | | | | |
| | C-Mn-Si-V | A 350 | LF6 Cl.2 | | | | | | | | |
| 1.3 | C | | | | | | | A 675 | 70 | | |
| | C-Si | | | A 352 | LCB | A 515 | 65 | | | A 672 | B 65 |
| | 2 ½ Ni | | | | | A203 | A | | | | |
| | 3 ½ Ni | | | | | A203 | D | | | | |
| | C-Mn-Si | | | | | A516 | 65 | | | A 672 | C 65 |
| | C-½ Mo | | | A 217 | WC1 | | | | | | |
| | | | | A 352 | LC1 | | | | | | |
| 1.7 | C-½ Mo | | | | | | | | | A 691 | CM-75 |
| | ½ Cr-½ Mo | A 182 | F2 | | | | | A182 | F2 | | |
| | Ni-½Cr-½Mo | | | A 217 | WC4 | | | | | | |
| | ¾Ni-Mo-¾Cr | | | A 217 | WC5 | | | | | | |
| 1.9 | 1¼Cr-½Mo-Si | A182 | F11 Cl. 2 | | | A 387 | 11 Cl. 2 | A 182 | F11 Cl. 2 | | |
| | 1¼Cr-½Mo | | | A 217 | WC6 | | | A 739 | B11 | | |
| 1.10 | 2¼Cr-1Mo | A182 | F22 Cl. 3 | A 217 | WC9 | A 387 | 22 Cl. 2 | A182 | F22 Cl. 3 | | |
| | | | | | | | | A 739 | B22 | | |
| 1.13 | 5Cr-½Mo | A 182 | F5a | A 217 | C5 | | | A 182 | F5a | | |
| 1.14 | 9Cr-1Mo | A 182 | F9 | A 217 | C12 | | | A 182 | F9 | | |
| 1.15 | 9Cr-1Mo-V | A 182 | F91 | A 217 | C12A | A 387 | 91 Cl. 2 | A 182 | F91 | A 335 | P91 |

*Table 9.7.1-1: Group 1 materials*

| GROUP 2 MATERIALS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Forging | | Casting | | Plates | | Bars | | Tubular | |
| Mat. Group | Nominal Designation | Spec | Grade | Spec | Grade | Spec | Grade | Spec | Grade | Spec | Grade |
| 2.1 | 18Cr-8Ni | A 182 | F304 | A 351 | CF3 | A 240 | 304 | A 182 | F304 | A312 | TP304 |
| | | A 182 | F304H | A 351 | CF8 | A 240 | 304H | A 182 | F304H | A312 | TP304H |
| | | | | | | | | A 479 | 304 | A 358 | 304 |
| | | | | | | | | A 479 | 304H | A 376 | TP304 |
| | | | | | | | | | | A 376 | TP304H |
| | | | | | | | | | | A 430 | FP304 |
| | | | | | | | | | | A 430 | FP304H |
| 2.2 | 16Cr-12Ni-2Mo | A 182 | F316 | A 351 | CF3M | A 240 | 316 | A 182 | F316 | A 312 | TP316 |
| | | A 182 | F316H | A 351 | CF8M | A 240 | 316H | A 182 | F316H | A 312 | TP316H |
| | | | | | | | | A 479 | 316 | A 358 | 316 |
| | | | | | | | | A 479 | 316H | A 376 | TP316 |
| | | | | | | | | | | A 376 | TP316H |
| | | | | | | | | | | A 430 | FP316 |
| | | | | | | | | | | A 430 | FP316H |
| 2.2 | 18Cr-8Ni | | | A 351 | CF3A | | | | | | |
| | 18Cr-13Ni-3Mo | A 182 | F317 | | | A 240 | 317 | | | A 312 | TP317 |
| | | A 182 | F317H | A 351 | CF8A | A 240 | 317H | | | A 312 | TP317H |
| | 19Cr-10Ni-3Mo | | | A 351 | CG8M | | | | | | |
| 2.3 | 18Cr-8Ni | A 182 | F304L | | | A 240 | 304L | A 182 | F304L | A 312 | TP304L |
| | | | | | | | | A 479 | 304L | | |
| | 16Cr-12Ni-2Mo | A182 | F316L | | | A 240 | 316L | A 182 | F316L | A 312 | TP316L |
| | | | | | | | | A 479 | 316L | | |
| 2.4 | 18Cr-10Ni-Ti | A 182 | F321 | | | A 240 | 321 | A 182 | F321 | A 312 | TP321 |
| | | A 182 | F321H | | | A 240 | 321H | A 479 | 321 | A 312 | TP321H |
| | | | | | | | | A 182 | F321H | A 358 | 321 |
| | | | | | | | | A 479 | 321H | A 376 | TP321 |
| | | | | | | | | | | A 376 | TP321H |
| | | | | | | | | | | A 430 | FP321 |
| | | | | | | | | | | A 430 | FP321H |
| 2.5 | 18Cr-10Ni-Cb | A 182 | F347 | | | A 240 | 347 | A 182 | F347 | A 312 | TP347 |
| | | A 182 | F347H | | | A 240 | 347H | A 182 | F347H | A 312 | TP347H |
| | | A 182 | F348 | | | A 240 | 348 | A 182 | F348 | A 312 | TP348 |
| | | A 182 | F348H | | | A 240 | 348H | A 182 | F348H | A 312 | TP348H |
| | | | | | | | | A 479 | 347 | A 358 | TP347 |
| | | | | | | | | A 479 | 347H | A 376 | TP347 |
| | | | | | | | | A 479 | 348 | A 376 | TP347H |
| | | | | | | | | A 479 | 348H | A 376 | TP348 |
| | | | | | | | | | | A 376 | TP348H |
| | | | | | | | | | | A 430 | FP347 |
| | | | | | | | | | | A 430 | FP347H |
| 2.6 | 23Cr-12Ni | | | | | | | | | A 312 | TP309H |
| | | | | | | A 240 | 309H | | | A 358 | 309H |
| 2.7 | 25Cr-20Ni | A 182 | F310H | | | A 240 | 310H | A 182 | F310H | A 312 | TP310H |
| | | | | | | | | A 479 | 310H | A 358 | 310H |
| 2.8 | 20Cr-18Ni-6Mo | A 182 | F44 | A 351 | CK3MCuN | A 240 | S31254 | A 479 | S31254 | A 312 | S31254 |
| | | | | | | | | | | A 358 | S31254 |
| | 22Cr-5Ni-3Mo-N | A 182 | F51 | | | A 240 | S31803 | A479 | S31803 | A 789 | S31803 |
| | | | | | | | | | | A 790 | S31803 |
| | 25Cr-7Ni-4Mo-N | A 182 | F53 | | | A 240 | S32750 | A 479 | S32750 | A 789 | S32750 |
| | | | | | | | | | | A 790 | S32750 |
| | 24Cr-10Ni-4Mo-V | | | A 351 | CE8MN | | | | | | |
| | 25Cr-5Ni-2Mo-3Cu | | | A 351 | CD4MCuN | | | | | | |
| | 25Cr-7Ni-3.5Mo-W-Cb | | | A 351 | CD3MWCuN | | | | | A 789 | S32760 |
| | 25Cr-7Ni-3.5Mo-N-Cr-W | A 182 | F55 | | | A 240 | S32760 | | | A 790 | S32760 |
| 2.9 | 23Cr-12Ni | | | | | A 240 | 309S | | | | |
| | 25Cr-20Ni | | | | | A 240 | 310S | A 479 | 310S | | |
| 2.10 | 25Cr-12Ni | | | A 351 | CH8 | | | | | | |
| | | | | A 351 | CH20 | | | | | | |
| 2.11 | 18Cr-10Ni-Cb | | | A 351 | CF8C | | | | | | |
| 2.12 | 25Cr-20NI | | | A 351 | CK20 | | | | | | |

*Table 9.7.1-2: Group 2 materials*

| GROUP 3 MATERIALS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Forging | | Casting | | Plates | | Bars | | Tubular | |
| Mat. Group | Nominal Designation | Spec | Grade | Spec | Grade | Spec | Grade | Spec | Grade | Spec | Grade |
| 3.1 | 35Ni-35Fe-20Cr-Cb | B 462 | N08020 | | | B 463 | N08020 | B 473 | N08020 | B 464 | N08020 |
| | | | | | | | | | | B 468 | N08020 |
| 3.2 | 99Ni | B 160 | N02200 | | | B 162 | N02200 | B 160 | N02200 | B161 | N02200 |
| | | | | | | | | | | B 163 | N02200 |
| 3.3 | 99Ni-Low C | B 160 | N02201 | | | B 162 | N02201 | B160 | N02201 | | |
| 3.4 | 67Ni-30Cu | B164 | N04400 | | | B 127 | N04400 | B 164 | N04400 | B 165 | N04400 |
| | | | | | | | | | | B 163 | N04400 |
| | 60Ni-22Cr-9Mo-3.5Cb | B 564 | N04400 | | | | | | | | |
| | 67Ni-30Cu-S | B 164 | N04405 | | | | | B 164 | N04405 | | |
| 3.5 | 72Ni-15Cr-8Fe | B 564 | N06600 | | | B 168 | N06600 | B 166 | N06600 | B 167 | N06600 |
| | | | | | | | | | | B 163 | N06600 |
| 3.6 | 33Ni-42Fe-21Cr | B 564 | N08800 | | | B 409 | N08800 | B 408 | N08800 | B 163 | N08800 |
| 3.7 | 65Ni-28Mo-2Fe | B 462 | N10665 | | | B 333 | N10665 | B 335 | N10665 | B 622 | N10665 |
| | | B 564 | N10665 | | | | | | | | |
| | 64Ni-29.5Mo-2Cr-2Fe-Mn-W | B 462 | N10675 | | | B 333 | N10675 | B 335 | N10675 | B 622 | N10675 |
| | | B 564 | N10675 | | | | | | | | |
| 3.8 | 54Ni-16Mo-15Cr | B 462 | N10276 | | | B 575 | N10276 | B 574 | N10276 | B 622 | N10276 |
| | | B 564 | N10276 | | | | | | | | |
| | 60Ni-22Cr-9Mo-3.5Cb | B 564 | N06625 | | | B 443 | N06625 | B 446 | N06625 | | |
| | 62Ni-28Mo-5Fe | B 335 | N10001 | | | B 333 | N10001 | B 335 | N10001 | B 622 | N10001 |
| | 70Ni-16Mo-7Cr-5Fe | B 573 | N10003 | | | B 434 | N10003 | B 573 | N10003 | | |
| | 61Ni-16Mo-16Cr | B 574 | N06455 | | | B 575 | N06455 | B 574 | N06455 | B 622 | N06455 |
| | 42Ni-21.5Cr-3Mo-2.3Cu | B 425 | N08825 | | | B 424 | N08825 | B 425 | N08825 | B 423 | N08825 |
| | 55Ni-21Cr-13.5Mo | B 462 | N06022 | | | B 575 | N06022 | B 574 | N06022 | B 622 | N06022 |
| | | B 564 | N06022 | | | | | | | | |
| | 55Ni-23Cr-16Mo-1.6Cu | B 462 | N06200 | | | B 575 | N06200 | B 574 | N06200 | B 622 | N06200 |
| | | B 564 | N06200 | | | | | | | | |
| 3.9 | 47Ni-22Cr-9Mo-18Fe | B 572 | N06002 | | | B 435 | N06002 | B 572 | N06002 | B 622 | N06002 |
| 3.10 | 25Ni-47Fe-21Cr-5Mo | B 672 | N08700 | | | B 599 | N08700 | B 672 | N08700 | | |
| 3.11 | 44Fe-25Ni-21Cr-Mo | B 649 | N08904 | | | B 625 | N08904 | B 649 | N08904 | B 677 | N08904 |
| 3.12 | 26Ni-43Fe-22Cr-5Mo | B 621 | N08320 | | | B 620 | N08320 | B 621 | N08320 | B 622 | N08320 |
| | 47Ni-22Cr-20Fe-7Mo | B 581 | N06985 | | | B 582 | N06985 | B 581 | N06985 | B 622 | N06985 |
| | 46Fe-24Ni-21Cr-6Mo-Cu-N | B 462 | N08367 | A 351 | CN3MN | B 688 | N08367 | | | | |
| 3.13 | 49Ni-25Cr-18Fe-6Mo | B 581 | N06975 | | | B 582 | N06975 | B 581 | N06975 | B 622 | N06975 |
| | Ni-Fe-Cr-Mo-Cu-Low C | B 564 | N08031 | | | B 625 | N08031 | B 649 | N08031 | B 622 | N08031 |
| 3.14 | 47Ni-22Cr-19Fe-6Mo | B 581 | N06007 | | | B 582 | N06007 | B 581 | N06007 | B 622 | N06007 |
| | 40Ni-29Cr-15Fe-5Mo | B 462 | N06030 | | | B 582 | N06030 | B 581 | N06030 | B 622 | N06030 |
| 3.15 | 33Ni-2Fe-21Cr | B 564 | N08810 | | | B 409 | N08810 | B 408 | N08810 | B 407 | N08810 |
| | Ni-Mo | | | A 494 | N-12MV | | | | | | |
| | Ni-Mo-Cr | | | A 494 | CW-12MW | | | | | | |
| 3.16 | 35Ni-19Cr-1¼ Si | B 511 | N08330 | | | B 536 | N08330 | B 511 | N08330 | B 535 | N08330 |
| 3.17 | 29Ni-20½Cr-3½Cu-2½Mo | | | A 351 | CN7M | | | | | | |
| 3.18 | 72Ni-15Cr-8Fe | B 167 | N06600 | | | | | | | | |

*Table 9.7.1-3: Group 3 materials*

### 9.7.2 Equivalent Material Grades by Product Form – EN Materials

The following table is an extract of table 9 of EN 1092-1 and allows to find the equivalent materials depending on the product form. The material groups in this table identify materials with the same pressure temperature ratings per EN 1092-1.

| | Forging | | Plates | | Casting | | Bars | | Tubular | |
|---|---|---|---|---|---|---|---|---|---|---|
| Mat. Group | EN – Spec. | Grade | EN – Spec. | Grade | EN – Spec. | Grade | EN – Spec. | Grade | EN – Spec. | Grade |
| 3E0 | --- | --- | 10028-2 | 1.0345 | 10213-2 | 1.0619 | 10273 | 1.0345 | 10216-2<br>10217-2 | 1.0345 |
| 4E0 | 10222-2 | 1.5415 | 10028-2 | 1.5415 | 10213-2 | 1.5419 | 10273 | 1.5415 | 10216-2<br>10217-2 | 1.5415 |
| 5E0 | 10222-2 | 1.7335 | 10028-2 | 1.7335 | 10213-2 | 1.7357 | 10273 | 1.7335 | 10216-2 | 1.7335 |
| 11E0 | 10222-5 | 1.4301 | 10028-7 | 1.4301 | 10213-4 | 1.4308 | 10272 | 1.4301 | 10216-5<br>10217-7 | 1.4301 |
| 12E0 | 10222-5 | 1.4541 | 10028-7 | 1.4541 | --- | --- | 10272 | 1.4541 | 10216-5<br>10217-7 | 1.4541 |
| 13E0 | 10222-5 | 1.4404 | 10028-7 | 1.4404 | 10213-4 | 1.4409 | 10272 | 1.4404 | 10216-5<br>10217-7 | 1.4404 |
| 13E0 | 10222-5 | 1.4435 | 10028-7 | 1.4435 | --- | --- | 10272 | 1.4435 | 10216-5<br>10217-7 | 1.4435 |
| 13E0 | 10222-5 | 1.4539 | 10028-7 | 1.4539 | 10213-4 | 1.4458 | 10272 | 1.4539 | 10216-5<br>10217-7 | 1.4539 |
| 13E1 | --- | --- | 10028-7 | 1.4547 | --- | --- | 10272 | 1.4547 | 10216-5<br>10217-7 | 1.4547 |
| 14E0 | 10222-5 | 1.4401 | 10028-7 | 1.4401 | 10213-4 | 1.4408 | 10272 | 1.4401 | 10216-5<br>10217-7 | 1.4401 |
| 15E0 | 10222-5 | 1.4571 | 10028-7 | 1.4571 | --- | --- | 10272 | 1.4571 | 10216-5<br>10217-7 | 1.4571 |
| 15E0 | --- | --- | 10028-7 | 1.4580 | 10213-4 | 1.4581 | 10272 | 1.4580 | 10216-5 | 1.4580 |
| 16E0 | --- | --- | --- | --- | 10213-4 | 1.4517 | --- | --- | --- | --- |
| 16E0 | 10222-5 | 1.4462 | 10028-7 | 1.4462 | 10213-4 | 1.4470 | 10272 | 1.4462 | 10216-5<br>10217-7 | 1.4462 |
| 16E0 | 10222-5 | 1.4410 | 10028-7 | 1.4410 | --- | --- | 10272 | 1.4410 | 10216-5<br>10217-7 | 1.4410 |
| 16E0 | --- | --- | --- | --- | 10213-4 | 1.4469 | --- | --- | --- | --- |

*Table 9.7.2-1: Equivalent material grades by product form – EN materials*

### 9.7.3 Equivalent ASME / EN Materials

The following chart shows equivalent materials between ASME and EN specifications. Equivalent means that chemical composition and mechanical requirements do overlap, so that it is possible to fulfill both requirements with one material.
In case of LESER standard (stock) materials LESER will supply a material double certificate, certifying both ASME and EN material in one certificate. For materials procured to order the certificate may show only one material ASME or EN.

**CARBON STEEL**

| Product form | ASME Spec. | ASME Grade | UNS Number | EN Grade | EN Spec. | Notes |
|---|---|---|---|---|---|---|
| Forging | SA 105 | 105 | | | 10222-2 | |
| Plate | SA 515 | 70 | | 1.0460 | VdTÜV 350/1 | C22.8 |
| Bar | SA 105 | 105 | | | 10273 | |
| Tubular | | | | | | |
| Casting | SA 216 | WCB | J03002 | 1.0619 | 10213-2 | Supplied with three fold material certificate WCB/WCC/1.0619 |
| Forging | | | | | | |
| Plate | SA 515 | 65 | | | | |
| Bar | | | | | | |
| Tubular | SA 672 | B 65 | | | | |
| Casting | SA 352 | LCB | | | | Supplied with five fold material certificate LCB/LCC/WCB/WCC/ 1.0619 |

*Table 9.7.3-1: ASME / EN equivalent carbon steel*

**HIGH TEMPERATURE ALLOY CARBON STEEL**

| Product form | ASME Spec. | ASME Grade | UNS Number | EN Grade | EN Spec. | Notes |
|---|---|---|---|---|---|---|
| Forging | | | | | 10222-2 | |
| Plate | | | | 1.7335 | 10028-2 | |
| Bar | SA 739 | B11 | | | 10273 | |
| Tubular | | | | | 10216-2 | |
| Casting | SA 217 | WC6 | J12072 | 1.7357 | 10213-2 | Supplied with double material certificate WC6/1.7357 |

*Table 9.7.3-2: ASME / EN equivalent high temperature carbon steel*

**AUSTENITIC STAINLESS STEEL**

| Product form | ASME Spec. | ASME Grade | UNS Number | EN Grade | EN Spec. | Notes |
|---|---|---|---|---|---|---|
| Forging | SA 182 | F316 | | | 10222-5 | 1.4401/316 and 1.4404/316L are commercially frequently produce as one grade fulfilling all four material standards. |
| Plate | SA 240 | 316 | | | 10028-7 | |
| Bar | SA 479 | 316 | S31600 | 1.4401 | 10272 | |
| Tubular | SA 312 | TP316 | | | 10216-5<br>10217-7 | |
| Casting | SA 351 | CF8M | J92900 | 1.4408 | 10213-4 | Supplied with double material certificate CF8M/1.4408 |
| Forging | SA 182 | F316L | | | 10222-5 | 1.4401/316 and 1.4404/316L are commercially frequently produced as one grade fulfilling all four material standards. |
| Plate | SA 240 | 316L | | 1.4404<br>or<br>1.4435 | 10028-7 | |
| Bar | SA 479 | 316L | S31603 | | 10272 | |
| Tubular | SA 312 | TP316L | | | 10216-5<br>10217-7 | |
| Casting | SA 351 | CF3M | J92800 | 1.4409 | 10213-4 | |

*Table 9.7.3-3: ASME / EN equivalent stainless steel*

| SUPER AUSTENITIC STAINLESS STEEL | | | | | | |
|---|---|---|---|---|---|---|
| **Product form** | **ASME Spec.** | **ASME Grade** | **UNS Number** | **EN Grade** | **EN Spec.** | **Notes** |
| Forging | SA 182 | F44 | S31254 | 1.4547 | 10222-5 | Commercial designation:<br>254 SMO, 6Mo Material<br>CK3MCuN: Code Case 1750-20 |
| Plate | SA 240 | S31254 | | | 10028-7 | |
| Bar | SA 479 | | | | 10272 | |
| Tubular | SA 312 | | | | 10216-5 | |
| Casting | SA 995 | CK3MCuN | J93254 | | | |
| Forging | SB 462 | N08367 | N08367 | 1.4529 | 10222-5 | Commercial designation:<br>AL6XN, 6Mo Material<br>1.4529 is similar but not absolute identic to N08367. Both materials have an overlapping chemical composition for all elements, however N08926 is the full UNS equivalent for 1.4529. |
| Plate | SB 688 | | | | 10028-7 | |
| Bar | SB 691 | | | | 10272 | |
| Tubular | SB 690 | | | | 10216-5 | |
| Casting | SA 351 | CN3MN | J94651 | | | |
| Forging | SB 462 | N08020 | N08020 | 2.4660 | n/a | Commercial designation:<br>Alloy 20<br>Carpenter 20 CB 3™<br>AL 20™<br>Carlson Alloy C20™<br>Nickelvac 23™<br>Nicrofer 3620 Nb™ |
| Plate | SB 463 | | | | 17750 | |
| Bar | SB 473 | | | | 17752 | |
| Tubular | SB 464<br>SB 468 | | | | 17751<br>17751 | |
| Casting | SA 351 | CN7M | J95150 | | | |

*Table 9.7.3-4: ASME / EN equivalent super austenitic stainless steel*

| DUPLEX / SUPER DUPLEX | | | | | | |
|---|---|---|---|---|---|---|
| **Product form** | **ASME Spec.** | **ASME Grade** | **UNS Number** | **EN Grade** | **EN Spec.** | **Notes** |
| Forging | SA 182 | F51 | S31803 | 1.4462 | 10222-5 | Commercial designation: Alloy 2205 |
| Plate | SA 240 | S31803 | | | 10028-7 | |
| Bar | SA 479 | | | | 10272 | |
| Tubular | SA 789 | | | | 10216-5<br>10217-7 | |
| Casting | SA 351 | CD3MN | J92205 | 1.4470 | 10213-4 | |
| Forging | SA 182 | F55 | S32760 | 1.4501 | n/a | Commercial designation: Zeron 100 |
| Plate | SA 240 | S32760 | | | 10028-7 | |
| Bar | SA 479 | | | | 10272 | |
| Tubular | SA 790 | | | | 10216-5<br>10217-7 | |
| Casting | SA 995 | CD3NWCuN | J93380 | (1.4508) | | 1.4508 is obsolete |
| Forging | SA 182 | F61 | S32550 | 1.4507 | n/a | Commercial designation: Alloy 255 |
| Plate | | | | | 10028-7 | |
| Bar | SA 479 | S32550 | | | 10272 | |
| Tubular | | | | | 10216-5 | |
| Casting | | CD4MCuN | J93372 | 1.4517 | 10213-4 | |

*Table 9.7.3-5: ASME / EN equivalent duplex / super duplex steel*

| NICKEL BASE MATERIALS | | | | | | |
|---|---|---|---|---|---|---|
| Product form | ASME Spec. | ASME Grade | UNS Number | EN Grade | EN Spec. | Notes |
| Forging | SB 462 / 564 | N06022 | N06022 | 2.4602 | | Commercial designation: Hastelloy C-22 2.4602 chemical composition: DIN 17744 |
| Plate | SB 575 | | | | DIN 17750 | |
| Bar | SB 574 | | | | DIN 17752 | |
| Tubular | SB-619/622/ 626 | | | | DIN 17751 | |
| Casting | SA 494 | CX2MW | N26022 | | | |
| Forging | SB 462 / 564 | N10276 | N10276 | 2.4819 | | Commercial designation: Hastelloy C-276 2.4819 chemical composition: DIN 17744 |
| Plate | SB 575 | | | | DIN 17750 | |
| Bar | SB 574 | | | | DIN 17752 | |
| Tubular | SB 622 | | | | DIN 17751 | |
| Casting | SA 494 | CW-12MW | N30002 | 2.4686 | | |
| Forging | SB 574 | N06455 | N06455 | 2.4610 | | Commercial designation: Hastelloy C-4 CW2M is not listed in ASME VIII 2.4610 chemical composition: DIN 17744 |
| Plate | SB 575 | | | | DIN 17750 | |
| Bar | SB 574 | | | | DIN 17752 VDTÜV 424 | |
| Tubular | SB 622 | | | | DIN 17751 | |
| Casting | SA 494 | CW2M | | | | |
| Forging | SB 164 | N04400 | | 2.4360 | DIN 17754 | Commercial designation: Monel 400 2.4360 chemical composition: DIN 17744 |
| Plate | SB 127 | | | | DIN 17750 | |
| Bar | SB 164 | | | | DIN 17752 | |
| Tubular | SB 165 | | | | DIN 17751 | |
| Casting | SA 494 | M35-1 | N24135 | | | |
| Forging | SB 546 | N06625 | N06625 | 2.4856 | | Commercial designation: Inconel 625 2.4856 chemical composition: DIN 17744 |
| Plate | SB 443 | | | | DIN 17750 | |
| Bar | SB 446 | | | | DIN 17752 | |
| Tubular | SB 444 | | | | DIN 17751 | |
| Casting | SA 494 | CW-6MC | N26625 | | | |

*Table 9.7.3-6: ASME / EN equivalent nickel base materials*

## 9.8 Resistance Charts

The resistance of materials against the large number of chemicals under various conditions is a field that would exceed the scope of ENGINEERING. This section is limited to provide a number of references that contain helpful information on the corrosion resistance of different materials.

### 9.8.1 Metallic Materials

**Outokumpu:**
A free online guide for the corrosion resistance of selected stainless steel, superaustenitic stainless steel and duplex materials:
http://www.outokumpu.com/applications/corrosion/corrstart.asp

**Thyssenkrupp:**
A free downloadable guide for the corrosion resistance of selected stainless steel and duplex materials:
http://www.nirosta.org/fileadmin/media/PDF/chembest_en.pdf

**Special Metals Corporation:**
A detailed overview on nickel base materials, their general properties and specifics of their selection depending on different media:
http://www.specialmetals.com/documents/SM%20Aqueous%20Corrosion%20Book.pdf

**www.engineeringtoolbox.com:**
A free and simplified guide for a variety of different materials groups and chemicals:
http://www.engineeringtoolbox.com/metal-corrosion-resistance-d_491.html

**DIN 6601:**
Resistance of selected carbon steels and austenitic stainless steels against more than 3000 chemicals.

**DECHEMA:**

The DECHEMA Corrosion Handbook represents a comprehensive collection of knowledge that is unique both in its scope as well as content. It covers corrosion data and the chemical resistance of all technically important metallic, non-metallic, inorganic and organic materials in contact with more than 1000 aggressive media and 110.000 material-media combinations. The DECHEMA Corrosion Handbook is for purchase:

http://www.dechema.de/en/corrosion.html

### 9.8.2 Non-Metallic Materials

**DuPont:**
A free online guide for the chemical resistance of selected elastomers, plastics (registration required):
http://www.dupontelastomers.com/tech_info/chemical.asp

**Buerkert:**
A free downloadable guide for the chemical resistance of selected elastomers, plastics and steels:
http://www.buerkert.com/media/COM_Chemical_Resistance_Chart.pdf

## 9.9 Material Certificates and Traceability

### 9.9.1 Requirements for Material Certificates

PED 97/23/EC defines in Annex 1, 4. Materials, section 4.3:
"… For the **main pressure-bearing parts** of equipment in categories II, III and IV, this must take the form of a certificate of specific product control.
Where a material manufacturer has an appropriate quality-assurance system, certified by a competent body established within the Community and having undergone a specific assessment for materials, certificates issued by the manufacturer are presumed to certify conformity with the relevant requirements of this section."

### 9.9.2 Content of a Material Certificate

A material certificate contains always two sections:
- chemical analysis
- mechanical properties

The scope of testing and resulting from this the content of a material certificate is defined by the applicable material standards (EN or ASME), amended by requirements of the purchaser.
European material standards also define the type of material certificate acc. to EN 10204 (see section 9.3) depending on the material, while for ASME specifications typically a 3.1 certificate is expected.

### 9.9.3 Types of Material Certificates acc. to EN 10204

EN 10204 defines different types of test reports depending on specific or non-specific inspection and different authorities issuing the test report.

| Type of Test Report | Specific / Non-Specific Testing | Issued by |
|---|---|---|
| Test Report 2.2 | Non-Specific | Manufacturer |
| Inspection Certificate 3.1 | Specific | Manufacturer, validated by manufacturer's authorized inspection representative, independent of the manufacturing department |
| Inspection Certificate 3.2 | Specific | Manufacturer's authorized inspection representative, independent of the manufacturing department<br>and either<br>the purchaser's authorized inspection representative<br>or<br>the inspector designated by the official regulations. |

*Table 9.9.3-1: Material certificates*

- Specific testing: tests are performed on the batch which is supplied to the purchaser
- Non-specific testing: tests are performed regularly on the same material but not necessarily on the same batch which is supplied to the purchaser.

### 9.9.4 Double Material Certificates

Every pressure retaining or containing component like body, bonnet, nozzle, disc supplied by LESER is double material certified acc. to the applicable EN material standard and the corresponding ASME II material.
That means chemical composition and mechanical properties of the supplied material fulfills EN and ASME II requirements at the same time.
This applies to LESER standard materials available from stock. Materials sourced to order like Nickel base materials may supplied with either EN or ASME material certificate, depending on the requirements of the order.

### 9.9.5 Traceability of Materials

To ensure that the material and the material certificate of a pressure bearing component can always be traced a proper marking of the component is required.
The minimum requirement for the content of marking is
- heat or batch number
- material designation

For casting components the marking is typically provided by the casting supplier on every individual casting. For LESER safety valves this applies to:
- bodies
- bonnets
- lever caps
- nozzles

For components that are machined from bar stock, LESER uses a coding system which allows to trace back the material certificate for each individual part manufactured from a batch of bar material. For LESER safety valves this applies to:
- nozzles / seat
- inlet bodies / outlet bodies / bonnets (Compact Performance safety valves)
- discs
- caps
- bonnet spacers
- studs / nuts

For each safety valve manufactured by LESER the material certificates of the following components are always recorded with the order:
- body / inlet body
- nozzle / seat
- spring

That means, based only on the serial number of the valve LESER can always trace the material certificate for these components. If further material certificates were ordered also these can easily be traced by valve serial number only. Material certificates for other components can be traced based on the marking of the individual component.

As an example the coding system for a disc is shown below. For details on marking of components, please refer to chapter “Marking” of ENGINEERING.

| Part | 1 | 2 | 3 |
|---|---|---|---|
| Disc | GL1 | 1.4404.316L | CODE3924 |

| Explanation |
|---|
| Material code Number |
| Material designation DIN/ ANSI |
| Name of the factory authorized expert |

*Figure 9.9.5-1: Marking of a disc*

### 9.9.6 Download of Material Certificates

Material certificates for supplied valves can be downloaded from the LESER website:
http://www.leser.com/en/services/certificates.html

For further details, please refer to chapter “Quality and Environmental Management” of ENGINEERING.

## 9.10 Specific Material Requirements

### 9.10.1 Carbon Equivalent and Weldability

The Carbon Equivalent (CE) is used for rating of weld-ability of ferritic low alloy steels. It takes into account the equivalent additive effects of carbon and other alloying elements on a particular characteristic of steel.

A commonly used formula to calculate the Carbon Equivalent is based on a publication of the International Institute of Welding (IIW) [Technical Report 1967, IIW Doc. IX-535-67]:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15$$

For this equation the weldability based on a range of CE values can be defined as follows:

| Carbon equivalent (CE) | Weldability |
|---|---|
| Up to 0.35 | Excellent |
| 0.36–0.40 | Very good |
| 0.41–0.45 | Good |
| 0.46–0.50 | Fair |
| Over 0.50 | Poor |

*[Ginzburg, Vladimir B.; Ballas, Robert (2000), Flat rolling fundamentals]*
*[SA-6/SA-6M - Specification For General Requirements For Rolled Structural Steel Bars, Plates, Shapes, And Sheet Piling. ASME BPVC Section II]*

### 9.10.2 Killed or Fully Killed Carbon Steel

The definition of "killed steel" is given in ASTM A 941: "A steel deoxidized to such level that essentially no reaction occurred between carbon and oxygen during solidification." The purpose of the deoxidation is to avoid gas bubbles in the material in order to fulfill the quality requirements given in material standards like ASME SA 216.
Killed/ Fully Killed requirements in general are applicable to “Steel Ingot Casting“ which are then further processed to wrought products. However the main pressure containing components of a safety valve like body and bonnet are in most cases made from steel castings. Typical materials are WCB, WCC, LCB, LCC, 1.0619. The applicable material standards for these cast steel materials like ASME SA 216 , ASME SA 352 or ASME SA 703 actually do not explicitly mention the term killed steel/ fully killed steel.
Nevertheless in order to meet quality standards, today’s casting process in foundries is requiring materials to be always properly deoxidized using strong deoxidizers like Aluminium/ Calcium/ Zirconium/ Titanium to kill the steel melt. Therefore entire deoxidation can be seen as an industry standard in foundries. Furthermore, LESER defines material quality grades which can only be fulfilled with entirely deoxidized steel castings. All carbon steel castings supplied by LESER are consequently considered to be "killed" or, equivalently, "fully killed".

### 9.10.3 Corrosion Allowance

Other than for pressure vessels or pipelines (see e.g. ASME Code Sec. VIII Div. 1 UG-25) it is not common practice to increase the material thickness of safety valve bodies or nozzle and disc to allow for a certain corrosion. Material selection, especially of nozzle and disc should be such that corrosion does not occur, because it may lead to untightness or malfunction of the safety valve.

## 9.11 ASME Publications

SA 105, *Carbon Steel Forgings for Piping Components*

SA 106, *Seamless Carbon Steel Pipe for High Temperature Service*

SA 182, *Forged of Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service*

SA 193, *Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service*

SA 194, *Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature-Service or both*

SA 203, *Pressure Vessel Plates, Alloy Steel, Nickel*

SA 204, *Pressure Vessel Plates, Alloy Steel, Molybdenum*

SA 216, *Steel Castings, Carbon Suitable for Fusion Welding, for High-Temperature Service*

SA 217, *Steel Castings, Martensic Stainless and Alloy, for Pressure Containing Parts, Suitable for High-Temperature Service*

SA 240, *Chromium and Chromium-Nickel stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

SA 307, *Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*

SA 320, *Alloy/Steel Bolting Materials for Low Temperature Service*

SA 350, *Carbon and Low-Alloy Steel Forgings, Requiring Notch toughness Testing for Piping Components*

SA 351, *Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure Containing Parts*

SA 352, *Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*

SA 354, *Quenched and Tempered Alloy Steel Bolts, Studs and other Externally Threaded Fasteners*

SA 387, *Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

SA 449, *Quenched and Tempered Steel Bolts and Studs*

SA 453, *High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels*

SA 515, *Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

SA 516, Pressure *Vessel Plates, Carbon Steel, for Moderated- and Lower-Temperature Service*

SA 537, *Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon-Steel*

SA 540, *Alloy-Steel Bolting Materials for Special Applications*

SB 127, *Nickel-Copper Alloy (UNS N04400) Plate, Sheet and Strip*

SB 160, *Nickel Rod and Bar*

SB 162, *Nickel-Plate, Sheep and Strip*

SB 164, *Nickel-Copper Alloy Rod, Bar and Wire*

SB 166, *Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025 and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire*

SB 168, *Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025 and N06045)) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheep, and Strip*

SB 333, *Nickel-Molybdenum Alloy Plate, Sheet, and Strip*

SB 335, *Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*

SB 408, *Nickel-Iron-Chromium Alloy Rod and Bar*

SB 409, *Nickel-Iron-Chromium Alloy, Plate, Sheet, Strip*

SB 424, *Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08821) Plate, Sheet and Strip*

SB 425, *Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Rod and Bar*

SB 434, *Nickel-Molybdenum-Chromium-Iron Alloys (UNS N10003, UNS N10242) Plate, Sheet and Strip*

SB 435, *UNS N06002, UNS N06230, UNS N12160 and UNS R30556 Plate, Sheet, and Strip*

SB 443, *Nickel-Chromium-Molybdenum-Columbium Alloy (N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip*

SB 446, *Nickel-Chromium-Molybdenum-Columbium Alloy (N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Rod and Bar, and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar*

SB 462, *Forged or Rolled UNS N06030, UNS N06022, UNS N06200, UNS N08020, UNS N08024, UNS N08026, UNS N08367, UNS N10276, UNS N10665, UNS N10675 and UNS R20033 Alloy Pipe Flanges, Forged Fittings and Valves and Parts for Corrosive High-Temperature Service*

SB 463, *UNS N08020, UNS N08024 and UNS N08026 Alloy Plate, Sheet and Strip*

SB 473, *UNS N08020, UNS N08024 and UNS N08026 Nickel Alloy Bar and Wire*

SB 511, *Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes*

SB 536, *Nickel-Iron-Chromium-Silicon Alloy (UNS N08330 and N08332) Plate, Sheet, and Strip*

SB 564, *Nickel Alloy Forgings*

SB 572, *UNS N06002, UNS N06230, UNS N12160 and UNS R30556 Rod*

SB 573, *Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003, N10242)*

SB 574, *Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low Carbon Nickel Molybdenum-Chromium-Tantalum, Low-Carbon Nickel Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Rod*

D 575-1999a, *Low Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium Molybdenum-Copper, Low-Carbon Nickel-Chromium-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet and Strip*

SB 581-1997, *Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod*

SB 582-1997, *Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet and Strip*

SB 599-1992 (R1997), *Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Plate, Sheet, and Strip*

SB 620-1998a, *Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet and Strip*

SB 621-1995a, *Nickel Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod*

SB 625-1999, *UNS N08904, UNS N08925, UNS N08031, UNS N08932, UNS N08926 and UNS R20033 Plate, Sheet and Strip*

SB 649-1995, *Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe Cr-Mo-Cu-N Low Carbon Alloys (UNS N08925, UNS N08031 and UNS N08926) and Cr-Ni-Fe-N Low-Carbon Alloy (UNS R20033) Bar and Wire*

SB 672-1995, *Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Bar and Wire*

SB 6881-1996, *Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNS N08367) Plate, Sheet and Strip*

E 29-1993a (1999), *Using Significants Digits in Test Data to Determine Conformance with Specifications*

Publisher: The American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

## Content

## 10.1 Introduction

Safety valves are used in a large variety of applications and industries. Different operating conditions and industry specific requirements lead to a variety of requested end connections for the safety valve inlet and outlet.

Most commonly flanged or threaded connections are used, but also clamp connections, butt weld ends or three piece union connections.

This chapter shall provide an overview about standard and special connections with reference to applicable codes and standards. Dimensions and pressure/temperature ratings for flanged connections are provided and assistance for the selection of other connections is given.

Product specific information like availability of a connection for a given product can be found in the product catalogs.

## 10.2 Connections Overview

### 10.2.1 Pressure/Temperature Rating of Connection versus Safety Valve

The p/t ratings in this chapter refer always to the limits given by relevant codes or standards for the specific connection. This rating will in general be determined by the selected flange rating and material. Maximum set pressure and maximum temperature ratings of safety valves may be different from the p/t ratings of the inlet and outlet connection due to the following potentially limiting factors:

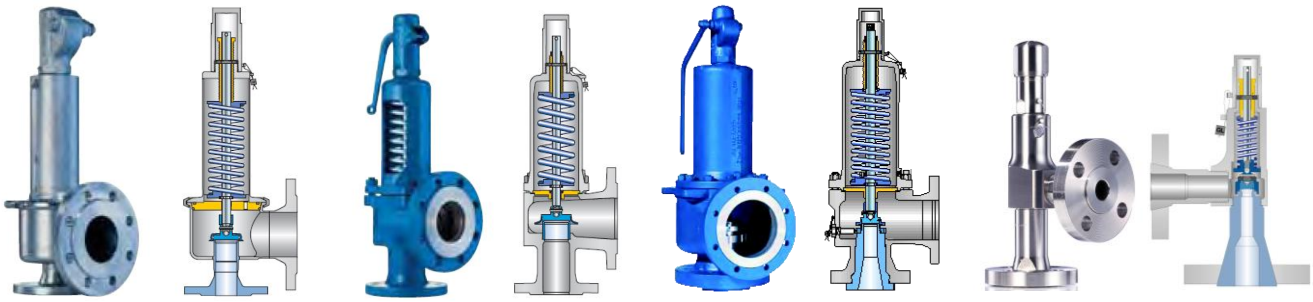
- selected soft good options
- spring chart and spring materials
- approvals
- design

The individual product catalogs will allow the proper selection of the safety valve configuration to meet the requirements.

### 10.2.2 Flanged Connections

There are four main types of flanged connections:

- welding neck flange
- integrally cast flange
- flange with full nozzle
- lap joint flange



**Welding neck flange LESER type 444** | **Integrally cast flange LESER type 441 DIN** | **Flange with full nozzle LESER type 526 full nozzle** | **Lap joint flange LESER type 437**

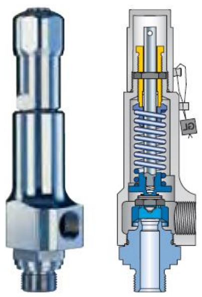
*Figure 10.2-1: Four main types of flange connection*

### 10.2.3 Threaded Connections

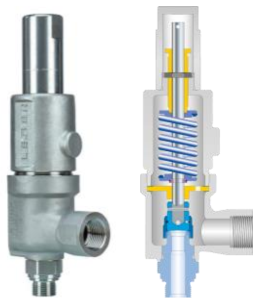
Threaded connections can be selected according to ASME B 1.20.1 (NPT), DIN ISO 228 (G) and other standards.

In addition male and female threads can be combined freely for inlet and outlet.
However male inlets and female outlets are used commonly. In some cases female inlets are preferred, but rarely male outlets.

Examples of threaded connections are shown below.



**Threaded connection (inlet male, outlet female)**
**LESER type 437**



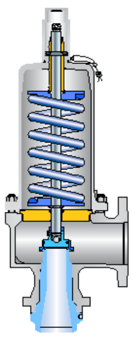
**Threaded connection (inlet male, outlet female)**
**LESER type 459**

*Figure 10.2.3-1: Examples of threaded valve connections*

### 10.2.4 Welding Ends

Welding ends are used for high pressure / high temperature applications, when it becomes difficult to obtain suitable gasket materials for a flanged connection. Valve repair becomes difficult, because the repair of the valve is in most cases performed in situ.

An example for a welded connection at the inlet is shown below.



**Welding end at the inlet**
**LESER type 457**

*Figure 10.2.4-1: Example for a welded connection at the inlet*

### 10.2.5 Clean Service Connections

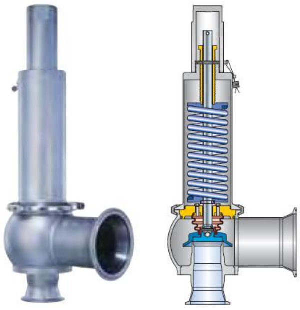
Clean Service safety valves can have different connections:

- threaded connections
- flanged connections
- clamp connections
- welded connections

In most cases these connections will be according to industry specific standards like ASME BPE, DIN 11864 or manufacturer standards.

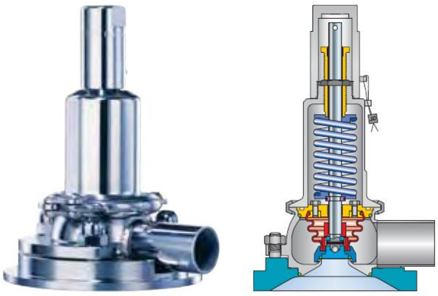
**Threaded connection**
**LESER type 481**

**Flanged connection**
**LESER type 483**

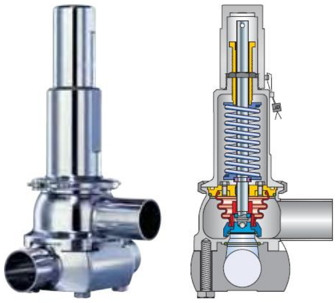


**Clamp connection**
**LESER type 488**

*Figure 10.2.5-1: Different connections cfor LESER's clean service*



**Welded connection**
**LESER type 484**



**Welded connection**
**LESER type 485**

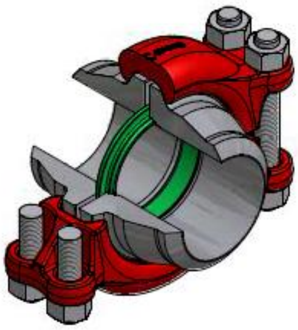
*Figure 10.2.5-2: Different connections for LESER's clean service*

### 10.2.6 Other Connections

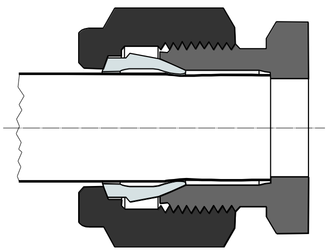
In specific applications further connection types are required.

For example:

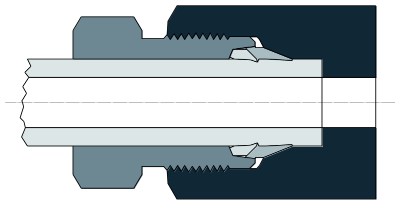
- High pressure clamp connections
- Compression fitting with locking ring
- Compression fitting with cutting ring



High pressure clamp connection



Compression fitting with locking ring



Compression fitting with cutting ring

*Figure 10.2.6-1: Connection types for special application*

## 10.3 Flanged Connections acc. to EN 1092

EN 1092 is split into two sections:

- EN 1092-1 edition 09-2008 for steel flanges
- EN 1092-2 edition 06-1997 for cast iron flanges

EN 1092 contains dimensions as well as pressure temperature ratings.

### 10.3.1 Pressure/Temperature Ratings acc. to EN 1092

The materials shown in the first column (material) are used generally by LESER. The p/t rating charts on the following pages are organized by material groups. All materials listed in the same group have the same p/t rating.

| LESER standard materials | | |
|---|---|---|
| **Material** | **Material group** | **Further materials of material group** |
| 0.6025 | Cast iron | ISO 1083 grade 200<br>ISO 1083 grade 250 |
| 0.7043 | Ductile iron | ISO 1083 grade 350-22<br>ISO 1083 grade 400-15<br>ISO 1083 grade 400-18<br>EN 545 grade 420-5<br>ISO 1083 grade 500-7<br>ISO 1083 grade 600-3 |
| 1.0425<br>1.0460<br>1.0619 | 3E0 | 1.0345<br>1.0348<br>1.0352<br>1.0625<br>ASME SA 105 |
| 1.7357 | 5E0 | 1.7335<br>ASME SA 217 WC 6<br>ASME SA 217 C 5<br>ASME SA 335 P 12<br>ASME SA 182 F11 Cl 1/Cl 2/Cl 3<br>ASME SA 182 F12 Cl 1/Cl 2<br>ASME SA 387 11<br>ASME SA 387 12 |
| 1.4404 | 13E0 | 1.4432<br>1.4435<br>1.4458<br>1.4539<br>1.4563<br>1.4918 |
| 1.4408 | 14E0 | 1.4401<br>1.4436<br>ASME SA 351 CF8M<br>ASME SA 312 TP316<br>ASME SA 312 TP 316 L/H<br>ASME SA 182 F 316<br>ASME SA 182 F 316 L/H<br>ASME SA 240 316<br>ASME SA 240 316 L/H |
| 1.4581 | 15E0 | 1.4571<br>1.4580<br>ASME SA 240 316 Ti |
| **Additional materials** | | |
| **Material** | **Material group** | **Further materials of material group** |
| 1.4462<br>1.4470 | 16E0 | 1.4362<br>1.4410<br>1.4469 |

*Table 10.3.1-1: LESER standard materials and material groups acc. to EN 1092*

## Overview of materials and material groups – further materials

The following materials are typically not used by LESER and pressure-temperature ratings are not listed here, but in EN 1092.
In the case that a material is not listed in EN1092, LESER can provide a proof if this material can be used by a strength calculation or a comparison of mechanical properties with a listed material.

| Further materials | | |
|---|---|---|
| **Material group** | **Materials of material group** | |
| Malleable iron | ISO 5922 B 30-06<br>ISO 5922 B 32-12 | ISO 5922 B 35-10 |
| 1E0 | 1.0432 | ASME SA 106 B |
| 1E1 | 1.0038 | |
| 3E1 | 1.0425<br>1.0426<br>1.0481<br>ASME SA 216 WCB<br>ASME SA 216 WCC | ASME SA 333 6<br>ASME SA 515 70<br>ASME SA 516 70<br>ASME SA 537 CL1 |
| 4E0 | 1.5415<br>1.5419 | ASME SA 217 WC 1<br>ASME SA 182 F1<br>ASME SA 204 A/B |
| 6E0 | 1.7375<br>1.7380<br>1.7383 | ASME SA 217 C 12<br>ASME SA 335 P5/P9/P22<br>ASME SA 182 F5/F9/F22 Cl 1/F22 Cl 3<br>ASME SA 387 5/9/22 |
| 6E1 | 1.7362+NT1<br>1.7365 | 1.7366 |
| 7E0 | 1.0488<br>1.1104 | 1.1131<br>1.6220 |
| 7E1 | 1.0566 | 1.1106 |
| 7E2 | 1.5637<br>1.5682<br>1.6212 | 1.6228<br>1.6217 |
| 7E3 | 1.5637<br>1.5638<br>1.5662<br>1.5680 | 1.6217<br>ASME SA 352 LC 2/LC 3/LC 8<br>ASME 350 LF 3<br>ASME SA 203 A/E |
| 8E0 | 1.0488 | 1.1104 |
| 8E2 | 1.0477<br>1.0478 | 1.0487<br>ASME SA 350 LF 2 Cl 1/Cl 2 |
| 8E3 | 1.0562<br>1.0565 | 1.0571<br>1.8867 |
| 9E0 | 1.4922 | 1.4931 |
| 9E1 | 1.4903 | |
| 10E0 | 1.4307<br>1.4306<br>1.4335 | ASME SA 351 CF 8<br>ASME SA 312 TP 304 L/TP 304/ TP 304 H<br>ASME SA 182 F 304/F 304 L/F 304 H<br>ASME SA 240 304/304 L/304 H |
| 10E1 | 1.4311 | |
| 11E0 | 1.4301 | 1.4948 |
| 12E0 | 1.4541<br>1.4550<br>1.4940<br>1.4941<br>1.4912 | 1.4961<br>ASME SA 312 TP 321/TP 321 H<br>ASME SA 182 F 321/321 H<br>ASME SA 240 |
| 13E1 | 1.4406<br>1.4429<br>1.4439 | 1.4529<br>1.4547 |

*Table 10.3-2: LESER's materials and material groups*

## Pressure/temperature ratings acc. to EN 1092

*General notes:*

(1) Pressure/temperature ratings are generally calculated without considering a creep resistance. The following p/t rating charts contain some values with a gray background. These values are calculated with a creep resistance of 100,000 hours. Please refer to EN 1092-1 G.1.3 or G.2.1 for details.
(2) The following p/t rating charts are simplified versus the EN 1092 charts and list p/t ratings only for limited $v_R$ values as they are used in LESER safety valves. $v_R$ is the reference value for the thickness of a flange. If a chart has such a limit it is noted under the chart. See EN 1092-1 annex G for p/t ratings of flanges with a larger value of $v_R$ and F.2.4 for further information on $v_R$.
(3) RT stands for reference temperature (-10°C to +50°C).

**Material Group: cast iron (0.6025)**

| | Maximum allowable temperature [°C] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | -10 | 120 | 150 | 180 | 200 | 230 | 250 | 300 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | |
| PN 10 | 10 | 10 | 9 | 8.4 | 8 | 7.4 | 7 | 6 |
| PN 16 | 16 | 16 | 14.4 | 13.4 | 12.8 | 11.8 | 11.2 | 9.6 |
| PN 25 | 25 | 25 | 22.5 | 21 | 20 | 18.5 | 17.5 | 15 |
| PN 40 | 40 | 40 | 36 | 33.6 | 32 | 29.6 | 28 | 24 |

*Table 10.3.1-3: pressure/temperature ratings acc. to EN 1092-2 – cast iron*

**Material Group: ductile iron (0.7043)**

| | Maximum allowable temperature [°C] | | | | | | |
|---|---|---|---|---|---|---|---|
| | -10 | 120 | 150 | 200 | 250 | 300 | 350 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | |
| PN 10 | 10 | 10 | 9.7 | 9.2 | 8.7 | 8 | 7 |
| PN 16 | 16 | 16 | 15.5 | 14.7 | 13.9 | 12.8 | 11.2 |
| PN 25 | 25 | 25 | 24.3 | 23 | 21.8 | 20 | 17.5 |
| PN 40 | 40 | 40 | 38.8 | 36.8 | 34.8 | 32 | 28 |
| PN 63 | 63 | 63 | 62 | 58.8 | 55.6 | 51.2 | 44.8 |

*Table 10.3.1-4: pressure/temperature ratings acc. to EN 1092-2 – ductile iron*

**Material Group: 3E0 (1.0425; 1.0460; 1.0619)**

| | Maximum allowable temperature [°C] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RT | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 (1) |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | |
| PN 10 | 10 | 9,2 | 8,8 | 8,3 | 7,6 | 6,9 | 6,4 | 5,9 | 3,2 |
| PN 16 | 16 | 14,8 | 14 | 13,3 | 12,1 | 11 | 10,2 | 9,5 | 5,2 |
| PN 25 | 25 | 23,2 | 22 | 20,8 | 19 | 17,2 | 16 | 14,8 | 8,2 |
| PN 40 | 40 | 37,1 | 35,2 | 33,3 | 30,4 | 27,6 | 25,7 | 23,8 | 13,1 |
| PN 63 | 63 | 58,5 | 55,5 | 52,5 | 48 | 43,5 | 40,5 | 37,5 | 20,7 |
| PN 100 | 100 | 92,8 | 88 | 83,3 | 76,1 | 69 | 64,2 | 59,5 | 32,8 |
| PN 160 | 160 | 148,5 | 140,9 | 133,3 | 121,9 | 110,4 | 102,8 | 95,2 | 52,5 |
| PN 250 | 250 | 232,1 | 220,2 | 208,3 | 190,4 | 172,6 | 160,7 | 148,8 | 82,1 |
| PN 320 | 320 | 297,1 | 281,9 | 266,6 | 243,8 | 220,9 | 205,7 | 190,4 | 105,1 |
| PN 400 | 400 | 371,4 | 352,3 | 333,3 | 304,7 | 276,1 | 257,1 | 238 | 131,4 |

*Table 10.3.1-5: Pressure/temperature ratings acc. to EN 1092-1 – 3E0*

*Notes:*

Please note that this table is only valid if $v_R$ is smaller or equal 50 millimeters
(1) see general note (1)

## Pressure/temperature ratings acc. to EN 1092

**Material Group: 5E0 (1.7357)**

| | Maximum allowable temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RT | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 460 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | |
| PN 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9,5 | 9 | 8,4 | 8 |
| PN 16 | 16 | 16 | 16 | 16 | 16 | 16 | 15,2 | 14,4 | 13,4 | 12,8 |
| PN 25 | 25 | 25 | 25 | 25 | 25 | 25 | 23,8 | 22,5 | 21 | 20 |
| PN 40 | 40 | 40 | 40 | 40 | 40 | 40 | 38 | 36 | 33,7 | 32 |
| PN 63 | 63 | 63 | 63 | 63 | 63 | 63 | 60 | 56,7 | 53,1 | 50,5 |
| PN 100 | 100 | 100 | 100 | 100 | 100 | 100 | 95,2 | 90 | 84,2 | 80,2 |
| PN 160 | 160 | 160 | 160 | 160 | 160 | 160 | 152,3 | 144 | 134,8 | 128,3 |
| PN 250 | 250 | 250 | 250 | 250 | 250 | 250 | 238 | 225 | 210,7 | 200,5 |
| PN 320 | 320 | 320 | 320 | 320 | 320 | 320 | 304,7 | 288 | 269,7 | 256,6 |
| PN 400 | 400 | 400 | 400 | 400 | 400 | 400 | 380,9 | 360 | 337,1 | 320,8 |

*Table 10.3.1-5: Pressure/temperature ratings acc. to EN 1092-1*

| | Maximum allowable temperature [°C] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 470 | 480 | 490 | 500 (1) | 510 (1) | 520 (1) | 530 (1) | 540 (1) | 550 (1) | 560 (1) | 570 (1) |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | |
| PN 10 | 7,6 | 7,2 | 6,8 | 6,5 | 5,5 | 4,4 | 3,7 | 2,9 | 2,3 | 1,9 | 1,5 |
| PN 16 | 12,1 | 11,5 | 10,8 | 10,4 | 8,8 | 7,1 | 5,9 | 4,6 | 3,7 | 3 | 2,5 |
| PN 25 | 19 | 18 | 17 | 16,3 | 13,8 | 11,1 | 9,2 | 7,2 | 5,8 | 4,7 | 3,9 |
| PN 40 | 30,4 | 28,8 | 27,2 | 26 | 22 | 17,9 | 14,8 | 11,6 | 9,3 | 7,6 | 6,2 |
| PN 63 | 47,9 | 45,4 | 42,8 | 41,1 | 34,8 | 28,2 | 23,4 | 18,3 | 14,7 | 12 | 9,9 |
| PN 100 | 76,1 | 72 | 68 | 65,2 | 55,2 | 44,7 | 37,1 | 29 | 23,3 | 19 | 15,7 |
| PN 160 | 121,8 | 115,3 | 108,8 | 104,3 | 88,3 | 71,6 | 59,4 | 46,4 | 37,3 | 30,4 | 25,1 |
| PN 250 | 190,3 | 180,1 | 170 | 163 | 138 | 111,9 | 92,8 | 72,6 | 58,3 | 47,6 | 39,2 |
| PN 320 | 243,6 | 230,6 | 217,6 | 208,7 | 176,7 | 143,2 | 118,8 | 92,9 | 74,6 | 60,9 | 50,2 |
| PN 400 | 304,5 | 288,2 | 272 | 260,9 | 220,9 | 179 | 148,5 | 116,1 | 93,3 | 76,1 | 62,8 |

*Table 10.3.1-6: Pressure/temperature ratings acc. to EN 1092-1 – 5E0*

*Notes:*

Please note that this table is only valid if $v_R$ is smaller or equal 60 millimeters

(1) see general note (1)

**Material Group: 13E0 (1.4404)**

| | Maximum allowable temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RT | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | |
| PN 10 | 10 | 9,4 | 8,6 | 7,9 | 7,4 | 6,9 | 6,6 | 6,4 | 6,2 | 6 |
| PN 16 | 16 | 15,1 | 13,7 | 12,7 | 11,9 | 11 | 10,5 | 10,2 | 10 | 9,7 |
| PN 25 | 25 | 23,6 | 21,5 | 19,8 | 18,6 | 17,2 | 16,5 | 16,0 | 15,6 | 15,2 |
| PN 40 | 40 | 37,9 | 34,4 | 31,8 | 29,9 | 27,6 | 26,4 | 25,7 | 25,0 | 24,3 |
| PN 63 | 63 | 59,7 | 54,3 | 50,1 | 47,1 | 43,5 | 41,7 | 40,5 | 39,4 | 38,4 |
| PN 100 | 100 | 94,7 | 86,1 | 79,5 | 74,7 | 69,0 | 66,1 | 64,2 | 62,6 | 60,9 |
| PN 160 | 160 | 151,6 | 137,9 | 127,2 | 119,6 | 110,4 | 105,9 | 102,8 | 100,1 | 97,5 |
| PN 250 | 250 | 236,9 | 215,4 | 198,8 | 186,9 | 172,6 | 165,4 | 160,7 | 156,5 | 152,3 |
| PN 320 | 320 | 303,2 | 275,8 | 254,4 | 239,2 | 220,9 | 211,8 | 205,7 | 200,3 | 195,0 |
| PN 400 | 400 | 379,0 | 344,7 | 318,0 | 299,0 | 276,1 | 264,7 | 257,1 | 250,4 | 243,8 |

*Table 10.3.1-7: Pressure/temperature ratings acc. to EN 1092-1 – 13E0*

## Pressure/temperature ratings acc. to EN 1092

**Material Group: 14E0 (1.4408)**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RT | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 560 | 570 | 580 | 590 | 600 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | | |
| PN 10 | 10 | 10 | 9 | 8,4 | 7,9 | 7,4 | 7,1 | 6,8 | 6,7 | 6,6 | 6,5 | 6,4 | 6,3 | 6,2 | 6,1 | 5,6 |
| PN 16 | 16 | 16 | 14,5 | 13,4 | 12,7 | 11,8 | 11,4 | 10,9 | 10,7 | 10,5 | 10,4 | 10,3 | 10,1 | 10 | 9,9 | 8,9 |
| PN 25 | 25 | 25 | 22,7 | 21 | 19,8 | 18,5 | 17,8 | 17,1 | 16,8 | 16,5 | 16,3 | 16 | 15,8 | 15,6 | 15,4 | 14 |
| PN 40 | 40 | 40 | 36,3 | 33,7 | 31,8 | 29,7 | 28,5 | 27,4 | 26,9 | 26,4 | 26 | 25,7 | 25,4 | 25 | 24,7 | 22,4 |
| PN 63 | 63 | 63 | 57,3 | 53,1 | 50,1 | 46,8 | 45 | 43,2 | 42,4 | 41,7 | 41,1 | 40,5 | 40 | 39,5 | 39 | 35,4 |
| PN 100 | 100 | 100 | 90,9 | 84,2 | 79,5 | 74,2 | 71,4 | 68,5 | 67,3 | 66,1 | 65,2 | 64,3 | 63,5 | 62,7 | 61,9 | 56,1 |
| PN 160 | 160 | 160 | 145,5 | 134,8 | 127,2 | 118,8 | 114,2 | 109,7 | 107,8 | 105,9 | 104,3 | 103 | 101,6 | 100,3 | 99 | 89,9 |
| PN 250 | 250 | 250 | 227,3 | 210,7 | 198,8 | 185,7 | 178,5 | 171,4 | 168,4 | 165,4 | 163 | 160,9 | 158,8 | 156,7 | 154,7 | 140,4 |
| PN 320 | 320 | 320 | 291 | 269,7 | 254,4 | 237,7 | 228,5 | 219,4 | 215,6 | 211,8 | 208,7 | 206 | 203,3 | 200,6 | 198 | 179,8 |
| PN 400 | 400 | 400 | 363,8 | 337,1 | 318 | 297,1 | 285,7 | 274,2 | 269,5 | 264,7 | 260,9 | 257,5 | 254,1 | 250,8 | 247,6 | 224,7 |

*Table 10.3.1-8: Pressure/temperature ratings acc. to EN 1092-1 – 14E0*

**Material Group: 15E0 (1.4581)**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RT | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 560 | 570 (1) | 580 (1) | 590 (1) | 600 (1) |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | | |
| PN 10 | 10 | 10 | 9,8 | 9,3 | 8,8 | 8,3 | 8 | 7,8 | 7,6 | 7,5 | 7,4 | 7,4 | 7,3 | 6,7 | 6 | 5,5 |
| PN 16 | 16 | 16 | 15,6 | 14,9 | 14,1 | 13,3 | 12,8 | 12,4 | 12,2 | 12 | 11,9 | 11,8 | 11,7 | 10,7 | 9,7 | 8,8 |
| PN 25 | 25 | 25 | 24,5 | 23,3 | 22,1 | 20,8 | 20,1 | 19,5 | 19,1 | 18,8 | 18,6 | 18,5 | 18,3 | 16,7 | 15,2 | 13,8 |
| PN 40 | 40 | 40 | 39,2 | 37,3 | 35,4 | 33,3 | 32,1 | 31,2 | 30,6 | 30 | 29,9 | 29,6 | 29,3 | 26,8 | 24,3 | 22 |
| PN 63 | 63 | 63 | 61,8 | 58,8 | 55,8 | 52,5 | 50,7 | 49,2 | 48,3 | 47,4 | 47,1 | 46,6 | 46,2 | 42,3 | 38,4 | 34,8 |
| PN 100 | 100 | 100 | 98 | 93,3 | 88,5 | 83,3 | 80,4 | 78 | 76,6 | 75,2 | 74,7 | 74 | 73,3 | 67,1 | 60,9 | 55,2 |
| PN 160 | 160 | 160 | 156,9 | 149,3 | 141,7 | 133,3 | 128,7 | 124,9 | 122,6 | 120,3 | 119,6 | 118,5 | 117,3 | 107,4 | 97,5 | 88,3 |
| PN 250 | 250 | 250 | 245,2 | 233,3 | 221,4 | 208,3 | 201,1 | 195,2 | 191,6 | 188 | 186,9 | 185,1 | 183,3 | 167,8 | 152,3 | 138 |
| PN 320 | 320 | 320 | 313,9 | 298,6 | 283,4 | 266,6 | 257,5 | 249,9 | 245,3 | 240,7 | 239,2 | 237 | 234,6 | 214,8 | 195 | 176,7 |
| PN 400 | 400 | 400 | 392,3 | 373,3 | 354,2 | 333,3 | 321,9 | 312,3 | 306,6 | 300,9 | 299 | 296,2 | 293,3 | 268,5 | 243,8 | 220,9 |

*Table 10.3.1-9: Pressure/temperature ratings acc. to EN 1092-1 – 15E0*

*Notes:*

(1) see general note (1)

**Material Group: 16E0 (1.4462, 1.4470)**

| | Maximum allowable temperature [°C] | | | | |
|---|---|---|---|---|---|
| | RT | 100 | 150 | 200 | 250 |
| **Class** | **Maximum allowable pressure [bar]** | | | | |
| PN 10 | 10,0 | 10,0 | 10,0 | 10,0 | 10,0 |
| PN 16 | 16,0 | 16,0 | 16,0 | 16,0 | 16,0 |
| PN 25 | 25,0 | 25,0 | 25,0 | 25,0 | 25,0 |
| PN 40 | 40,0 | 40,0 | 40,0 | 40,0 | 40,0 |
| PN 63 | 63,0 | 63,0 | 63,0 | 63,0 | 63,0 |
| PN 100 | 100,0 | 100,0 | 100,0 | 100,0 | 100,0 |
| PN 160 | 160,0 | 160,0 | 160,0 | 160,0 | 160,0 |
| PN 250 | 250,0 | 250,0 | 250,0 | 250,0 | 250,0 |
| PN 320 | 320,0 | 320,0 | 320,0 | 320,0 | 320,0 |
| PN 400 | 400,0 | 400,0 | 400,0 | 400,0 | 400,0 |

*Table 10.3.1-10: Pressure/temperature ratings acc. to EN 1092-1 – 16E0*

### Pressure/temperature ratings below reference temperature (RT)

Lower temperature limits are described in the standards EN 13445-2 as well as AD-2000 Merkblatt W10. The application of AD-2000 Merkblatt W10 is in compliance with the PED 2014/68/EU and is used to determine pressure/temperature ratings for temperatures below ambient temperature (RT). AD-2000 Merkblatt W10 differentiates between 3 load-cases.

### Load-cases

| | |
|---|---|
| Load case I | No restrictions |
| Load case II | The operating pressure may not be larger than 75% of the maximum allowable pressure |
| Load case III | The operating pressure may not be larger than 25% of the maximum allowable pressure |

*Table 10.3.1-11: Overview of load cases*

### Minimum temperatures

| Material | Load case | | |
|---|---|---|---|
| | I | II | III |
| | Minimum temperature °C | | |
| 1.0425<br>1.0460<br>1.0619 | -10 | -60 | -85 |
| 1.4404<br>1.4408 | -200 | -255 | -273 |
| 1.4462 | -40 | -60 | -60 |

*Table 10.3.1-12: Overview of minimum temperatures for different load cases*

10.3.2 Dimensions acc. to EN 1092

Flange dimensions are available from DN 15 to DN 500. The tables are sorted by classes in ascending order. The flange dimensions depend on different flange types.

This is only an extraction of standard EN 1092-1/-2.

Only type 11 and type 21 steel flanges and type 11 cast iron flanges are used by LESER and are listed below. Cast iron flanges in classes PN 2.5, PN 6 and PN63 aren't used at LESER.

**Types of flanges:**

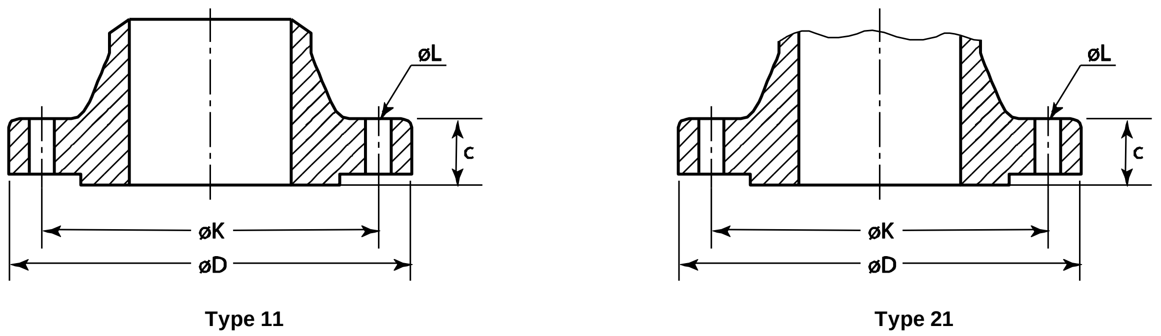



*Figure 10.3.2-1: EN1092-1 – types of flanges made of steel*

## Dimensions acc. to EN 1092

All connection dimensions up to DN 50 in pressure groups PN 10 (table 10.3.2-1) – PN 40 (10.3.2-4) are equal.

**Class PN 10**

| DN | Connection dimensions | | | | | | Thickness | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | | Bolting | | | | | |
| | D | K | L | | Number | Size | $C_2$ | $C_3$ | C | C |
| | | | Steel | Cast iron | | | Steel | | DG (ductile iron) (1), (3) | GG (cast iron) (1), (4) |
| | Type of flange | | | | | | | | | |
| | 11<br>21 | | | | | | 11 | 21 | 11 | 21 |
| 15 | use nominal pressure of PN40 for this size | | | | | | 16 | 16 | 14 | 14 |
| 20 | | | | | | | 18 | 18 | 16 | 16 |
| 25 | | | | | | | 18 | 18 | 16 | 16 |
| 32 | | | | | | | 18 | 18 | 18 | 18 |
| 40 | | | | | | | 18 | 18 | 19 | 18 |
| 50 | | | | | | | 18 | 18 | 19 | 20 |
| 65 | | | | | 4 or 8(5) | | 18 | 18 | 19 | 20 |
| 80 | | | | | | | 20 | 20 | 19 | 22 |
| 100 | 220 | 180 | 18 | 19 | 8 | M16 | 20 | 20 | 19 | 24 |
| 125 | 250 | 210 | 18 | 19 | 8 | M16 | 22 | 22 | 19 | 26 |
| 150 | 285 | 240 | 22 | 23 | 8 | M20 | 22 | 22 | 19 | 26 |
| 200 | 340 | 295 | 22 | 23 | 8 | M20 | 24 | 24 | 20 | 26 |
| 250 | 395 (2) | 350 | 22 | 23 | 12 | M20 | 26 | 26 | 22 | 28 |
| 300 | 445 (2) | 400 | 22 | 23 | 12 | M20 | 26 | 26 | 24,5 | 28 |
| 350 | 505 | 460 | 22 | 23 | 16 | M20 | 26 | 26 | 26.5 | 30 |
| 400 | 565 | 515 | 26 | 28 | 16 | M24 | 26 | 26 | 28 | 32 |
| 500 | 670 | 620 | 26 | 28 | 20 | M24 | 28 | 28 | 31.5 | 34 |

*Table 10.3.2-1: EN1092-1 – dimensions of flanges – class PN 10*

*Notes:*

(1) see table 10.3.2-1 for further information about the material shortcut

(2) for pipes and fittings of ductile iron, the outside diameter have to correspond the dimensions below:
- DN 250: D = 400 mm / - DN 300: D = 455 mm

(3) flanges class PN 10 of ductile iron can be used at sleeve pipes up to a pressure of 15 bar

(4) these flangethicknisses are also valid for flanges of ductile iron type 21-2

(5) flanges of steel acc. to EN 1092-1 shall be delivered with 8 holes,
flanges of cast iron acc. to EN 1092-2 shall be delivered with 4 holes.
Both, EN 1092-1 and EN 1092-2 allow to deviate and supply steel flanges with 4 holes and cast iron flanges with 8 holes, if agreed between purchaser and manufacturer.
Please note that LESER delivers steel and cast iron flanges with 4 holes until further notice. This is to ensure compatibility of flanges made of steel and flanges made of cast iron. LESER will of course supply steel flanges with 8 holes if requested.

## Dimensions acc. to EN 1092

### Class PN 16

| DN | Connection dimensions | | | | | | Thickness | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | | Bolting | | | | | |
| | D | K | L | | Number | Size | $C_2$ | $C_3$ | C | C |
| | | | Steel | Cast iron | | | Steel | | DG (ductile iron) (1), (2) | GG (cast iron) (1), (3) |
| | Type of flange | | | | | | | | | |
| | 11<br>21 | | | | | | 11 | 21 | 11 | 21 |
| 15 | | | | | | | 16 | 16 | 14 | 14 |
| 20 | | | | | | | 18 | 18 | 16 | 16 |
| 25 | | | | | | | 18 | 18 | 16 | 16 |
| 32 | use nominal pressure of PN40 for this size | | | | | | 18 | 18 | 18 | 18 |
| 40 | | | | | | | 18 | 18 | 19 | 18 |
| 50 | | | | | | | 18 | 18 | 19 | 20 |
| 65 | | | | | 4 or 8 (4) | | 18 | 18 | 19 | 20 |
| 80 | | | | | | | 20 | 20 | 19 | 22 |
| 100 | 220 | 180 | 18 | 19 | 8 | M16 | 20 | 20 | 19 | 24 |
| 125 | 250 | 210 | 18 | 19 | 8 | M16 | 22 | 22 | 19 | 26 |
| 150 | 285 | 240 | 22 | 23 | 8 | M20 | 22 | 22 | 19 | 26 |
| 200 | 340 | 295 | 22 | 23 | 12 | M20 | 24 | 24 | 20 | 30 |
| 250 | 405 (2) | 355 | 26 | 28 | 12 | M24 | 26 | 26 | 22 | 32 |
| 300 | 460 (2) | 410 | 26 | 28 | 12 | M24 | 28 | 28 | 24.5 | 32 |
| 350 | 520 | 470 | 26 | 28 | 16 | M24 | 30 | 30 | 26.5 | 36 |
| 400 | 580 | 525 | 30 | 31 | 16 | M27 | 32 | 32 | 28 | 38 |
| 500 | 715 | 650 | 33 | 34 | 20 | M30 | 36 | 44 | 31.5 | 42 |

*Table 10.3.2-2: EN1092-1 – dimensions of flanges – class PN 16*

*Notes:*

(1) see table 10.3.2-1 for further information about the material shortcut
(2) for pipes and fittings of ductile iron, the outside diameter have to correspond the dimensions below:
- DN 250: D = 400 mm / - DN 300: D = 455 mm
(3) these flangethicknisses are also valid for flanges of ductile iron type 21-2
(4) flanges of steel acc. to EN 1092-1 shall be delivered with 8 holes,
flanges of cast iron acc. to EN 1092-2 shall be delivered with 4 holes.
Both, EN 1092-1 and EN 1092-2 allow to deviate and supply steel flanges with 4 holes and cast iron flanges with 8 holes, if agreed between purchaser and manufacturer.
Please note that LESER delivers steel and cast iron flanges with 4 holes until further notice. This is to ensure compatibility of flanges made of steel and flanges made of cast iron. LESER will of course supply steel flanges with 8 holes if requested.

## Dimensions acc. to EN 1092

### Class PN 25

| DN | Connection dimensions | | | | | | Thickness | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | | Bolting | | | | | |
| | D | K | L | | Number | Size | $C_2$ | $C_3$ | C | C |
| | | | Steel | Cast iron | | | Steel | | DG (ductile iron) (1) | GG (cast iron) (1), (2) |
| | Type of flange | | | | | | | | | |
| | 11<br>21 | | | | | | 11 | 21 | 11 | 21 |
| 15 | | | | | | | | | 14 | |
| 20 | | | | | | | | | 16 | |
| 25 | | | | | | | | | 16 | |
| 32 | | | | | | | | | 18 | |
| 40 | | | | | | | | | | |
| 50 | use nominal pressure of PN40 for this size | | | | | | | | | |
| 65 | | | | | | | | | | |
| 80 | | | | | | | | | | |
| 100 | 235 | 190 | 22 | 23 | 8 | M20 | 24 | 24 | 19 | 28 |
| 125 | 270 | 220 | 26 | 28 | 8 | M24 | 26 | 26 | 19 | 30 |
| 150 | 300 | 250 | 26 | 28 | 8 | M24 | 28 | 28 | 20 | 34 |
| 200 | 360 | 310 | 26 | 28 | 12 | M24 | 30 | 30 | 22 | 34 |
| 250 | 425 | 370 | 30 | 31 | 12 | M27 | 32 | 32 | 24.5 | 36 |
| 300 | 485 | 430 | 30 | 31 | 16 | M27 | 34 | 34 | 27.5 | 40 |
| 400 | 620 | 550 | 36 | 37 | 16 | M33 | 40 | 40 | 32 | 48 |

*Table 10.3.2-3: EN1092-1 – dimensions of flanges – class PN 25*

*Notes:*

(1) see table 10.3.2-1 for further information about the material shortcut
(2) these flangethicknisses are also valid for flanges of ductile iron type 21-2

### Class PN 40

| DN | Connection dimensions | | | | | | Thickness | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | | Bolting | | | | | |
| | D | K | L | | Number | Size | $C_2$ | $C_3$ | C | C |
| | | | Steel | Cast iron | | | Steel | | DG (ductile iron) (1) | GG (cast iron) (1), (2) |
| | Type of flange | | | | | | | | | |
| | 11<br>21 | | | | | | 11 | 21 | 11 | 21 |
| 15 | 95 | 65 | 14 | 14 | 4 | M12 | 16 | 16 | - | 16 |
| 20 | 105 | 75 | 14 | 14 | 4 | M12 | 18 | 18 | - | 18 |
| 25 | 115 | 85 | 14 | 14 | 4 | M12 | 18 | 18 | - | 18 |
| 32 | 140 | 100 | 18 | 19 | 4 | M16 | 18 | 18 | - | 20 |
| 40 | 150 | 110 | 18 | 19 | 4 | M16 | 18 | 18 | 19 | 20 |
| 50 | 165 | 125 | 18 | 19 | 4 | M16 | 20 | 20 | 19 | 22 |
| 65 | 185 | 145 | 18 | 19 | 8 | M16 | 22 | 22 | 19 | 24 |
| 80 | 200 | 160 | 18 | 19 | 8 | M16 | 24 | 24 | 19 | 26 |
| 100 | 235 | 190 | 22 | 23 | 8 | M20 | 24 | 24 | 19 | 28 |
| 125 | 270 | 220 | 26 | 28 | 8 | M24 | 26 | 26 | 23.5 | 30 |
| 150 | 300 | 250 | 26 | 28 | 8 | M24 | 28 | 28 | 26 | 34 |
| 200 | 375 | 320 | 30 | 31 | 12 | M27 | 34 | 34 | 30 | 40 |
| 250 | 450 | 385 | 33 | 34 | 12 | M30 | 38 | 38 | 34.5 | 46 |
| 300 | 515 | 450 | 33 | 34 | 16 | M30 | 42 | 42 | 39.5 | 50 |

*Table 10.3.2-4: EN1092-1 – dimensions of flanges – class PN 40*

*Notes:*

(3) see table 10.3.2-1 for further information about the material shortcut
(4) these flangethicknesses are also valid for flanges of ductile iron type 21-2

## Dimensions acc. to EN 1092

### Class PN 63 (steel flanges)

| DN | Connection dimensions | | | | | Thickness | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | K | L | Number | Size | $C_2$ | $C_3$ |
| | Type of flange | | | | | | |
| | 11<br>21 | | | | | 11 | 21 |
| 15 | 105 | 75 | 14 | 4 | M12 | 20 | 20 |
| 20 | 130 | 90 | 18 | 4 | M16 | 22 | 22 |
| 25 | 140 | 100 | 18 | 4 | M16 | 24 | 24 |
| 32 | 155 | 110 | 22 | 4 | M20 | 24 | 26 |
| 40 | 170 | 125 | 22 | 4 | M20 | 26 | 28 |
| 50 | 180 | 135 | 22 | 4 | M20 | 26 | 26 |
| 65 | 205 | 160 | 22 | 8 | M20 | 26 | 26 |
| 80 | 215 | 170 | 22 | 8 | M20 | 28 | 28 |
| 100 | 250 | 200 | 26 | 8 | M24 | 30 | 30 |
| 125 | 295 | 240 | 30 | 8 | M27 | 34 | 34 |
| 150 | 345 | 280 | 33 | 8 | M30 | 36 | 36 |

*Table 10.3.2-5: EN1092-1 – dimensions of flanges made of steel – class PN 63*

### Class PN 100 (steel flanges)

| DN | Connection dimensions | | | | | Thickness | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | K | L | Number | Size | $C_2$ | $C_3$ |
| | Type of flange | | | | | | |
| | 11<br>21 | | | | | 11 | 21 |
| 15 | 105 | 75 | 14 | 4 | M12 | 20 | 20 |
| 20 | 130 | 90 | 18 | 4 | M16 | 22 | 22 |
| 25 | 140 | 100 | 18 | 4 | M16 | 24 | 24 |
| 32 | 155 | 110 | 22 | 4 | M20 | 24 | 26 |
| 40 | 170 | 125 | 22 | 4 | M20 | 26 | 28 |
| 50 | 195 | 145 | 26 | 4 | M24 | 28 | 30 |
| 65 | 220 | 170 | 26 | 8 | M24 | 30 | 34 |
| 80 | 230 | 180 | 26 | 8 | M24 | 32 | 36 |
| 100 | 265 | 210 | 30 | 8 | M27 | 36 | 40 |
| 125 | 315 | 250 | 33 | 8 | M30 | 40 | 40 |
| 150 | 355 | 290 | 33 | 12 | M30 | 44 | 44 |

*Table 10.3.2-6: EN1092-1 – dimensions of flanges made of steel – class PN 100*

### Class PN 160 (steel flanges)

| DN | Connection dimensions | | | | | Thickness | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | K | L | Number | Size | $C_2$ | $C_3$ |
| | Type of flange | | | | | | |
| | 11<br>21 | | | | | 11 | 21 |
| 15 | 105 | 75 | 14 | 4 | M12 | 20 | 20 |
| 25 | 140 | 100 | 18 | 4 | M16 | 24 | 24 |
| 40 | 170 | 125 | 22 | 4 | M20 | 28 | 28 |
| 50 | 195 | 145 | 26 | 4 | M24 | 30 | 30 |
| 65 | 220 | 170 | 26 | 8 | M24 | 34 | 34 |
| 80 | 230 | 180 | 26 | 8 | M24 | 36 | 36 |
| 100 | 265 | 210 | 30 | 8 | M27 | 40 | 40 |
| 125 | 315 | 250 | 33 | 8 | M30 | 44 | 44 |
| 150 | 355 | 290 | 33 | 12 | M30 | 50 | 50 |

*Table 10.3.2-7 – EN1092-1 – dimensions of flanges made of steel – class PN 160*

## Dimensions acc. to EN 1092

### Class PN 250 (steel flanges)

| DN | Connection dimensions | | | | | Thickness | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | K | L | Number | Size | $C_2$ | $C_3$ |
| | Type of flange | | | | | | |
| | 11 21 | | | | | 11 | 21 |
| 15 | 130 | 90 | 18 | 4 | M16 | 26 | 26 |
| 25 | 150 | 105 | 22 | 4 | M20 | 28 | 28 |
| 40 | 185 | 135 | 26 | 4 | M24 | 34 | 34 |
| 50 | 200 | 150 | 26 | 8 | M24 | 38 | 38 |
| 65 | 230 | 180 | 26 | 8 | M24 | 42 | 42 |
| 80 | 255 | 200 | 30 | 8 | M27 | 46 | 46 |
| 100 | 300 | 235 | 33 | 8 | M30 | 54 | 54 |
| 125 | 340 | 275 | 33 | 12 | M30 | 60 | 60 |
| 150 | 390 | 320 | 36 | 12 | M33 | 68 | 68 |

*Table 10.3.2-8: EN1092-1 – dimensions of flanges made of steel – class PN 250*

### Class PN 320 (steel flanges)

| DN | Connection dimensions | | | | | Thickness | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | K | L | Number | Size | $C_2$ | $C_3$ |
| | Type of flange | | | | | | |
| | 11 21 | | | | | 11 | 21 |
| 15 | 130 | 90 | 18 | 4 | M16 | 26 | 26 |
| 25 | 160 | 115 | 22 | 4 | M20 | 34 | 34 |
| 40 | 195 | 145 | 26 | 4 | M24 | 38 | 38 |
| 50 | 210 | 160 | 26 | 8 | M24 | 42 | 42 |
| 65 | 255 | 200 | 30 | 8 | M27 | 51 | 51 |
| 80 | 275 | 220 | 30 | 8 | M27 | 55 | 55 |
| 100 | 335 | 265 | 36 | 8 | M33 | 65 | 65 |
| 125 | 380 | 310 | 36 | 12 | M33 | 75 | 75 |
| 150 | 425 | 350 | 39 | 12 | M36 | 84 | 84 |

*Table 10.3.2-9: EN1092-1 – dimensions of flanges made of steel – class PN 320*

### Class PN 400 (steel flanges)

| DN | Connection dimensions | | | | | Thickness | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | K | L | Number | Size | $C_2$ | $C_3$ |
| | Type of flange | | | | | | |
| | 11 21 | | | | | 11 | 21 |
| 15 | 145 | 100 | 22 | 4 | M20 | 30 | 30 |
| 25 | 180 | 130 | 26 | 4 | M24 | 38 | 38 |
| 40 | 220 | 165 | 30 | 4 | M27 | 48 | 48 |
| 50 | 235 | 180 | 30 | 8 | M27 | 52 | 52 |
| 65 | 290 | 225 | 33 | 8 | M30 | 64 | 64 |
| 80 | 305 | 240 | 33 | 8 | M30 | 68 | 68 |
| 100 | 370 | 295 | 39 | 8 | M36 | 80 | 80 |

*Table 10.3.2-10: EN1092-1 – dimensions of flanges made of steel – class PN 400*

10.3.3 Flange Facings and Finish acc. to EN 1092

Forms of flange facings are shown in Fig. 10.3.3-1 and their dimensions in Tab. 10.3.3-1.

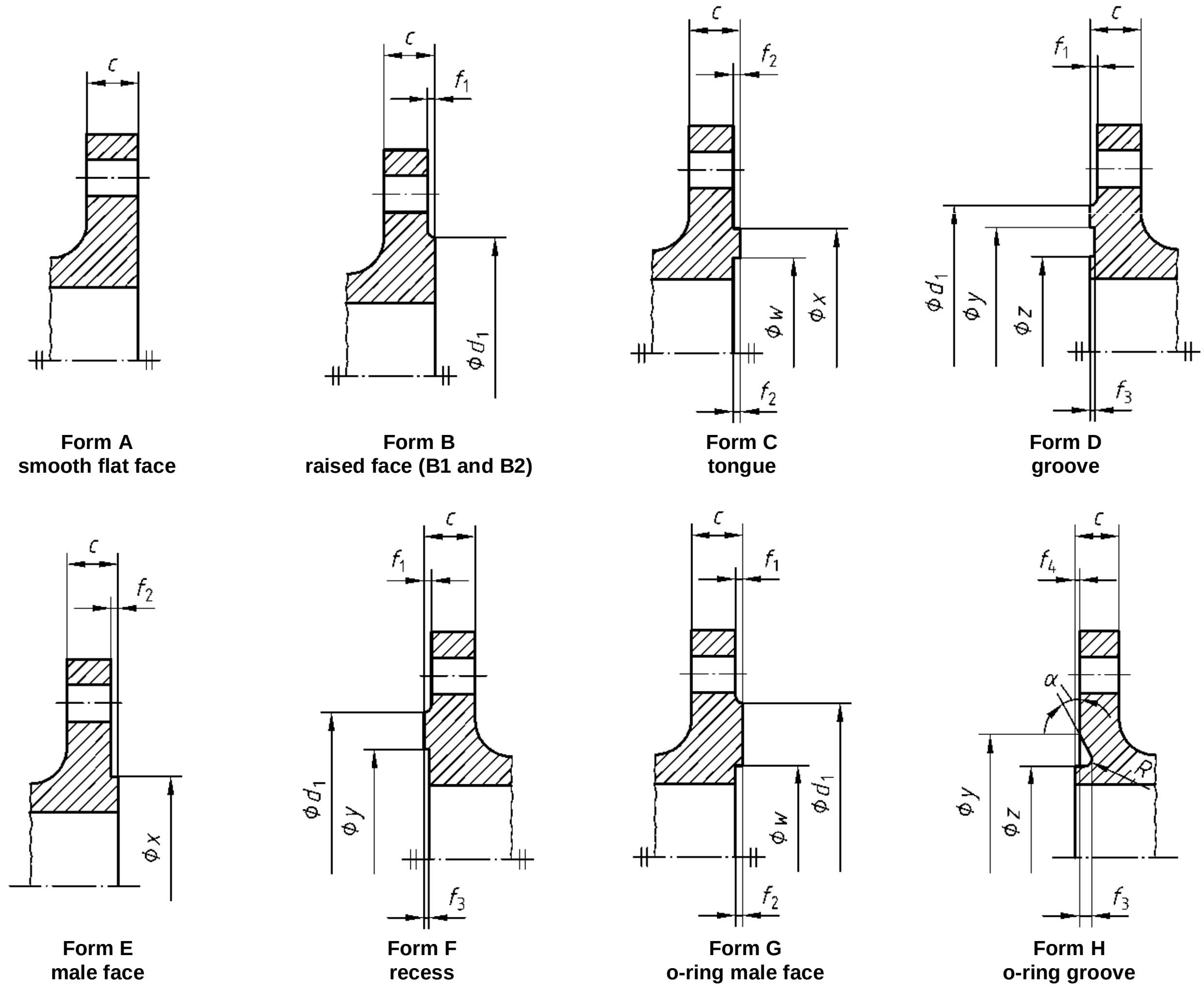



*Figure 10.3.3-1: EN 1092 – forms of flange facings*

### Dimensions of flange facings

This table gives an overview about flange facing dimensions and can be used to select a sealing or to identify an existing sealing surface acc. to EN 1092-1 and parent standards. See chapter 3.2 for flange thickness “C”.

| DN | $d_1$ | | | | | | | | | | $f_1$ | $f_2$ | $f_3$ | $f_4$ | w[b] | x | y | z[b] | α ≈ | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PN 10 | PN 16 | PN 25 | PN 40 | PN 63 | PN 100 | PN 160 | PN 250 | PN 320 | PN 400 | | | | | | | | | | |
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | | mm |
| 15 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 2 | 4,5 | 4 | 2 | 29 | 39 | 40 | 28 | - | 2,5 |
| 20 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | | | | | 36 | 50 | 51 | 35 | - | |
| 25 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | | | | | 43 | 57 | 58 | 42 | 41° | |
| 32 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | | | | | 51 | 65 | 66 | 50 | | |
| 40 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 3 | | | | 61 | 75 | 76 | 60 | | |
| 50 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | | | | | 73 | 87 | 88 | 72 | | |
| 65 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | | | | | 95 | 109 | 110 | 94 | | |
| 80 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | | | | | 106 | 120 | 121 | 105 | | |
| 100 | 158 | 158 | 162 | 162 | 162 | 162 | 162 | 162 | 162 | 162 | | 5 | 4,5 | 2,5 | 129 | 149 | 150 | 128 | 32° | 3 |
| 125 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | 188 | | | | | 155 | 175 | 176 | 154 | | |
| 150 | 212 | 212 | 218 | 218 | 218 | 218 | 218 | 218 | 218 | 218 | | | | | 183 | 203 | 204 | 182 | | |
| 200 | 268 | 268 | 278 | 285 | 285 | 285 | 285 | 285 | 285 | 285 | | | | | 239 | 259 | 260 | 238 | | |
| 250 | 320 | 320 | 335 | 345 | 345 | 345 | 345 | 345 | 345 | - | | | | | 292 | 312 | 313 | 291 | | |
| 300 | 370 | 378 | 395 | 410 | 410 | 410 | 410 | - | - | - | 4 | | | | 343 | 363 | 364 | 342 | | |
| 350 | 430 | 438 | 450 | 465 | 465 | 465 | - | - | - | - | | 5,5 | 5 | 3 | 395 | 421 | 422 | 394 | 27° | 3,5 |
| 400 | 482 | 490 | 505 | 535 | 535 | 535 | - | - | - | - | | | | | 447 | 473 | 474 | 446 | | |
| 450 | 532 | 550 | 555 | 560 | 560 | 560 | - | - | - | - | | | | | 497 | 523 | 524 | 496 | | |
| 500 | 585 | 610 | 615 | 615 | 615 | 615 | - | - | - | - | | | | | 549 | 575 | 576 | 548 | | |

*Table 10.3.3-1: EN 1092 – dimensions of flange facings*

*Notes:*

(a) Flange sealing surfaces form C, D, E, F, G and H are not used for PN 2,5 and PN 6.
(b) Flange sealing surfaces form G and H are used for PN 10 to PN 40 only.

### Surface finish for flange faces

It is not intended that instrument measurements are taken on the faces themselves; the $R_a$ and $R_z$ values as defined in EN ISO 4287 relate to reference specimens. That means an inspection is performed visually by comparing the surface finish of the flange face with the reference specimen.

| Flange facings form | Machining operation | Radius of cutting edge mm | $R_a$[a] µm | | $R_z$[a] µm | |
|---|---|---|---|---|---|---|
| | | min. | min. | max. | min. | max. |
| A, B1[b], E, F | turning[c] | 1,0 | 3,2 | 12,5 | 12,5 | 50 |
| B2[b], C, D, G, H | turning[c] | - | 0,8 | 3,2 | 3,2 | 12,5 |

*Table 10.3.3-2: EN 1092 – surface finish for flange faces*

*Notes:*

in some applications (e.g. low temperature casting) it is necessary to define a more detailed quality inspection
(a) Ra and Rz are defined to EN ISO 4287
(b) B1 and B2 are forms of sealing surfaces with raised face (form B) with different surface roughnesses
B1: standard sealing surface for all pressure ratings
B2: an agreement between customer and manufacturer is required
(c) “turning” covers every single machining operation, in which concentrical or spiral grooves are produced

EN 1092 does further contain surface roughness requirements for the outer diameter of the flange. The outer diameter of casted valve bodies is typically not machined (see also section 3.6), because the outer diameter is used to clamp the body during machining.

### 10.3.4 Comparison of Old DIN Flange Standards and EN 1092-1

Table 10.3.4-1 shows a comparison of old DIN standards for flanges, which were replaced by DIN EN 1092-1 and the application range of EN 1092-1.

See the table below (reference: EN 1092-1, Tab. NA.1)

| DIN (old) | Flange type according to EN | Application area | Size according to previous DIN | Size according to EN 1092-1 |
|---|---|---|---|---|
| 2512 | - | flanges – tongue and groove – sizes, insert rings PN 10 to PN 160 | ≤ PN 160<br>DN 4 to DN 1000 | ≤ PN 100<br>DN 10 to DN 2000 |
| 2513 | - | male face und recess | DN 10 to DN 1000 | ≤ PN 100<br>DN 10 to DN 2000 |
| 2514 | - | male face with groove and recess | DN 10 to DN 3000 | ≤ PN 100<br>DN 10 to DN 2000 |
| 2527 | 05 | blind flange, PN 2.5 | not specified | DN 10 to DN 2000 |
| | 05 | blind flange, PN 6 | DN 10 to DN 500 | DN 10 to DN 2000 |
| | 05 | blind flange, PN 10 | DN 10 to DN 500 | DN 10 to DN 1200 |
| | 05 | blind flange, PN 16 | DN 10 to DN 500 | DN 10 to DN 1200 |
| | 05 | blind flange, PN 25 | DN 10 to DN 500 | DN 10 to DN 600 |
| | 05 | blind flange, PN 40 | DN 10 to DN 500 | DN 10 to DN 600 |
| | 05 | blind flange, PN 64 (new PN 63) | DN 10 to DN 400 | DN 10 to DN 400 |
| | 05 | blind flange, PN 100 | DN 10 to DN 350 | DN 10 to DN 350 |
| 2528 | - | flanges | no sizes, only materials / application temperatures | - |
| 2543 | 21 | cast steel flange, PN 16 | DN 10 to DN 2200 | DN 10 to DN 2000 |
| 2544 | 21 | cast steel flange, PN 25 | DN 10 to DN 2000 | DN 10 to DN 2000 |
| 2545 | 21 | cast steel flange, PN 40 | DN 10 to DN 1600 | DN 10 to DN 600 |
| 2546 | 21 | cast steel flange, PN 64 (new PN 63) | DN 10 to DN 1200 | DN 10 to DN 1200 |
| 2547 | 21 | cast steel flange, PN 100 | DN 125 to DN 700 | DN 10 to DN 500 |
| 2548 | 21 | cast steel flange, PN 160 | DN 10 to DN 300 | DN 10 to DN 300 |
| 2549 | 21 | cast steel flange, PN 250 | DN 10 to DN 300 | DN 10 to DN 300 |
| 2550 | 21 | cast steel flange, PN 320 | DN 10 to DN 250 | DN 10 to DN 250 |
| 2551 | 21 | cast steel flange, PN 400 | DN 10 to DN 200 | DN 10 to DN 200 |
| 2566 | 13 | threaded flange with socket, PN 10 to PN 16 | DN 6 to DN 100 | DN 10 to DN 600 |
| 2573 | 1 | flanges, blank for brazing and welding, PN 6 | DN 10 to DN 500 | DN 10 to DN 600 |
| 2576 | 1 | flanges, blank for brazing and welding, PN 10 | DN 10 to DN 500 | DN 10 to DN 600 |
| 2627 | 11 | weld neck flanges, PN 400 | DN 10 to DN 200 | DN 10 to DN 200 |
| 2628 | 11 | weld neck flanges, PN 250 | DN 10 to DN 250 | DN 10 to DN 300 |
| 2629 | 11 | weld neck flanges, PN 320 | DN 10 to DN 250 | DN 10 to DN 250 |
| 2630 | 11 | weld neck flange, PN 1 and PN 2.5 | DN 10 to DN 4000 | DN 10 to DN 4000 |
| 2631 | 11 | weld neck flange, PN 6 | DN 10 to DN 3600 | DN 10 to DN 3600 |
| 2632 | 11 | weld neck flange, PN 10 | DN 10 to DN 3000 | DN 10 to DN 3000 |
| 2633 | 11 | weld neck flange, PN 16 | DN 10 to DN 2000 | DN 10 to DN 2000 |
| 2634 | 11 | weld neck flange, PN 25 | DN 10 to DN 1000 | DN 10 to DN 1000 |
| 2635 | 11 | weld neck flange, PN 40 | DN 10 to DN 500 | DN 10 to DN 600 |
| 2636 | 11 | weld neck flange, PN 64 (new PN 63) | DN 10 to DN 400 | DN 10 to DN 400 |
| 2637[a] | 11 | weld neck flange, PN 100 | DN 10 to DN 350 | DN 10 to DN 350 |
| 2638[a] | 11 | weld neck flanges, PN 160 | DN 10 to DN 300 | DN 10 to DN 300 |
| 2641[a] | 02, 33, 32 | lapped flange; unturned welding flange; plain flange, PN 6 | DN 10 to DN 1200 | DN 10 to DN 600 |
| 2642[a] | 02, 33, 32 | lapped flange; unturned welding flange; plain flange, PN 10 | DN 10 to DN 800 | DN 10 to DN 600 |
| 2655[a] | 02, 33, 32 | lapped flange; plain flange, PN 25 | DN 10 to DN 500 | DN 10 to DN 600 |
| 2656[a] | 02, 33, 32 | lapped flange; plain flange, PN 40 | DN 10 to DN 400 | DN 10 to DN 600 |
| 2673[a] | 04, 34 | lapped flange with welded flange, PN 10 | DN 10 to DN 1200 | DN 10 to DN 600 |

*Table 10.3.4-1: EN 1092 – comparison of old DIN standards and EN 1092*

*Notes*

(a) replaced by DIN EN 1092-1

### 10.3.5 Comparison of Flange Facings Old DIN Standards and EN 1092-1

See the table below (reference: EN 1092-1, Tab. NA.2)

| Old designation according to DIN (see table 10.3.4-1) | New designation according to EN 1092-1 |
|---|---|
| form A | form A |
| form B | |
| form C | form B1 |
| form D | |
| form E | form B2[a] |
| form F | form C |
| form N | form D |
| form V 13 | form E |
| form R 13 | form F |
| form V 14 | form H |
| form R 14 | form G |
| [a]) the sealing surface form B2 has to be arranged separately between customer and manufacturer. See EN 1092-1 table 2, note b | |

*Table 10.3.5-1: EN 1092-1 – comparison of flange facings old DIN standards and EN 1092-1*

### 10.3.6 Flanges according to EN 1759-1

The title of EN 1759-1 is Circular flanges for pipes, valves, fittings and accessories, Class designated.

It contains flanges with ANSI/ASME origin (ASME B16.5) with the dimensions taken from ASME B16.5, hard metricated.

That means that flanges acc. to ASME B16.5 and EN 1759-1 match. If flanges acc. to EN 1759-1 are requested, LESER will confirm and provide flanges acc. to ASME B 16.5.

In addition to ASME B 16.5, EN 1759-1 permits the use of European steels according to EN 1092-1 and contains also pressure temperature ratings for these materials.

### 10.3.7 Codes and Standards – EN 1092 Flanges

DIN EN 1092-1, *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories, PN designated – Part 1: Steel flanges*

DIN EN 1092-2, *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories, PN designated – Part 2: Cast iron flanges*

DIN EN 1092-3, *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories, PN designated – Part 1: Copper alloy flanges*

EN 1333*, Flanges and their joints - Pipework components - Definition and selection of PN*

EN 1591-1*, Flanges and their joints - Design rules for gasketed circular flange connections - Part 1: Calculation method*

EN ISO 6708*, Pipework components - Definition and selection of DN*

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 2768-1, *General tolerances — Part 1: tolerances for linear and angular dimensions without individual tolerance indications*

## 10.4 Flanged Connections acc. to ASME B16.5 / ASME B16.34

Within the ASME Code there are several standards covering pressure-temperature ratings:

| Standard | Title | Applies to: |
|---|---|---|
| ASME B16.5 | Pipe Flanges and Flanged Fittings: NPS 1/2 through 24 | Steel flanges |
| ASME B16.34 | Valves Flanged, Threaded and Welding End | Steel valve bodies |
| ASME B16.42 | Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300 | Ductile iron flanges |

*Table 10.4-1: ASME code standards covering pressure-temperature ratings*

ASME B16.5 and ASME B16.34 contain material groups and pressure/temperature ratings which are identical. ASME B16.34 however contains some more materials than ASME B16.5. ASME B16.34 does not list the flange class 400, however it contains a class 4500 which applies to butt weld ends only. Only ASME B16.5 contains flange dimensions. Therefore all tables and chapters in this Engineering Handbook are based on ASME B16.5 (edition 2009)

Flanges and pressure-temperature ratings for ductile iron flanges are listed in ASME B16.42 (edition 1998).

Pressure/Temperature Ratings acc. to ASME B16.5:

Pressure-temperature ratings are maximum allowable working gage pressures at the temperatures shown in the following tables for the applicable material and class designation. For intermediate temperatures, linear interpolation is permitted. Interpolation between class designations is not permitted.

## Overview of materials and material groups

| Material | Material group | Further materials of material group | Notes |
|---|---|---|---|
| **LESER standard materials** | | | |
| **Material** | **Material group** | **Further materials of material group** | **Notes** |
| SA 105 (1)<br>SA 216 Gr. WCB (1) | 1.1 | SA 350 Gr. LF2 (1)<br>SA 350 Gr. LF6 Cl. (4)<br>SA 350 Gr. LF3<br>SA 515 Gr. 70 (1)<br>SA 516 Gr. 70 (1), (2)<br>SA 537 Cl. 1 (3) | (1) Upon prolonged exposure to temperatures above 425°C, the carbide phase of steel may be converted to graphite. Permissible but not recommend for prolonged use above 425°C.<br>(2) Not to be used over 455°C (850°F)<br>(3) Not to be used over 370°C (700°F)<br>(4) Not to be used over 260°C (500°F) |
| SA 352 LCB (3) | 1.3 | SA 217 Gr. WC1 (4), (5)<br>SA 352 Gr. LC1 (3)<br>SA 515 Gr. 65 (1)<br>SA 515 Gr. 65 (1), (2)<br>SA 203 Gr. A (1)<br>SA 203 Gr. D (1) | (1) Upon prolonged exposure to temperatures above 425°C (800°F), the carbide phase of steel may be converted to graphite. Permissible but not recommend for prolonged use above 425°C (800°F).<br>(2) Not to be used over 455°C (850°F)<br>(3) Not to be used over 340°C (650°F)<br>(4) Upon prolonged exposure to temperatures above 465°C (875°F), the carbide phase of steel may be converted to graphite. Permissible but not recommend for prolonged use above 465°C (875°F).<br>(5) Use normalized and tempered material only |
| SA 217 Gr. WC6 (1), (3) | 1.9 | SA 182 Gr. F11 Cl. 2 (1), (2)<br>SA 387 Gr. 11 Cl. 2 (2) | (1) Use normalized and tempered material only<br>(2) Permissible, but not recommend for prolonged use above 590°C (1100°F)<br>(3) Not to be used over 590°C (1100°F) |
| SA 351 Gr. CF8M (1) | 2.2 | SA 182 Gr. F316 (1)<br>SA 182 Gr. F316H<br>SA 182 Gr. F317 (1)<br>SA 351 Gr. CF3M (2)<br>SA 351 Gr. CG8M (3)<br>SA 240 Gr. 316 (1)<br>SA 240 Gr. 316H<br>SA 240 Gr. 317 (1) | (1) At temperatures over 538°C (1000°F), use only when carbon content is 0.04% or higher<br>(2) Not to be used over 455°C (850°F)<br>(3) Not to be used over 538°C (1000°F) |
| SA 182 Gr. F316L<br>SA 240 Gr. 316L | 2.3 | SA 182 Gr. 304L (1)<br>SA 240 Gr. 304L (1) | (1) Not to be used over 425°C (800°F) |
| **Additional materials** | | | |
| **Material** | **Material group** | **Further materials of material group** | **Notes** |
| SA 216 Gr. WCC (1)<br>SA 352 Gr. LCC (2) | 1.2 | SA 350 Gr. LF6 Cl.2 (3)<br>SA 352 Gr. LC2<br>SA 352 Gr. LC3<br>SA 203 Gr. B (1)<br>SA 203 Gr. E (1) | (1) Upon prolonged exposure to temperatures above 425°C (800°F), the carbide phase of steel may be converted to graphite. Permissible but not recommend for prolonged use above 425°C (800°F).<br>(2) Not to be used over 340°C (650°F)<br>(3) Not to be used over 260°C (500°F) |
| SA 217 Gr. WC5 (1) | 1.7 | SA182 Gr. F2 (2)<br>SA 217 Gr. WC4 (1), (2) | (1) Use normalized and tempered material only.<br>(2) Not to be used over 538° C (1000°F) |
| SA 217 Gr. WC9 (1), (3) | 1.10 | SA 182 Gr. F22 Cl. 3 (2)<br>SA 387 Gr. 22 Cl. 2 (2) | (1) Use normalized and tempered material only<br>(2) Permissible, but not recommend for prolonged use above 590°C (1100°F)<br>(3) Not to be used over 590°C (1100°F) |
| SA 217 Gr C5 (1), (2) | 1.13 | SA 182 Gr 5Fa | (1) Use normalized and tempered material only<br>(2) The deliberate addition of any element not listed in ASTM A 217, Table 1 is prohibited, except that Ca and Mg may be added for deoxidation |
| SA 351 Gr. CK3MCuN<br>SA 351 Gr. CE8MN (1)<br>SA 351 Gr. CD4MCu (1)<br>SA 351 Gr. CD3MWCuN (1) | 2.8 | SA 182 Gr. F44<br>SA 182 Gr. F51 (1)<br>SA 182 Gr. F53 (1)<br>SA 240 Gr. S31254<br>SA 240 Gr. S31803 (1)<br>SA 240 Gr. S32750 (1) | (1) This steel may become brittle after service at moderately elevated temperatures. Not to be used over 315° C (600°F) |
| SA 351 Gr. CF8C (1) | 2.11 | - | (1) At temperatures over 538° C (1100°F), use only when the carbon content is 0.04% or higher |

*Table 10.4.-2: ASME B16.5 – materials and their groups*

## Overview of materials and material groups – further materials

The following materials are typically not used by LESER and pressure-temperature ratings are not listed here, but in ASME B16.5.
Materials for body and bonnet must be listed in ASME VIII and ASME II. In the case that a material is not listed in ASME B16.5, LESER can provide a proof if this material can be used by a strength calculation or a comparison of mechanical properties with a listed material.

| Further materials | | |
|---|---|---|
| **Material group** | **Materials of material group** | |
| 1.4 | SA 515 Gr 60 | SA 516 Gr 60 |
| 1.5 | SA 182 Gr F1 | SA 204 Gr A/B |
| 1.11 | SA 204 Gr C | |
| 1.14 | SA 182 Gr F9 | SA 217 Gr C12 |
| 1.15 | SA 182 Gr F91<br>SA 217 Gr C12 | SA 387 Gr 91 Cl 2 |
| 1.17 | SA 182 Gr F12 Cl 2 | SA 182 Gr F5 |
| 2.1 | SA 182 Gr F304<br>SA 182 Gr F304H<br>SA 351 Gr CF3 | SA 351 Gr CF8<br>SA 240 Gr 304<br>SA 240 Gr 304H |
| 2.4 | SA 182 Gr F321<br>SA 182 Gr F321H | SA 240 Gr 321<br>SA 240 Gr 241H |
| 2.5 | SA 182 Gr F347<br>SA 182 Gr F347H<br>SA 182 Gr F348<br>SA 182 Gr F348H | SA 240 Gr 347<br>SA 240 Gr 347H<br>SA 240 Gr 348<br>SA 240 Gr 348H |
| 2.6 | A 240 Gr 309H | |
| 2.7 | SA 182 Gr F310 | SA 240 Gr 310H |
| 2.9 | SA 240 Gr. 309S | SA 240 Gr. 310S |
| 2.10 | SA 351 Gr. CH8 | SA 351 Gr. CH20 |
| 2.12 | SA 351 Gr. CK20 | |
| 3.1 | SB 462 Gr. N08020 | SB 463 Gr. N08020 |
| 3.2 | SB 160 Gr. N02200 | SB 162 Gr. N02200 |
| 3.3 | SB 160 Gr. N02201 | SB 162 Gr. N02201 |
| 3.4 | SB 564 Gr. N04400<br>SB 164 Gr. N04405 | SB 127 Gr. N04400 |
| 3.5 | SB 564 Gr. N06600 | SB 168 Gr. N06600 |
| 3.6 | SB 564 Gr. N08800 | SB 409 Gr. N08800 |
| 3.7 | SB 462 Gr. N10665<br>SB 462 Gr. N10675 | SB 333 Gr. N10665<br>SB 333 Gr. N10675 |
| 3.8 | SB 462 Gr. N10276<br>SB 564 Gr. N06625<br>SB 335 Gr. N10001<br>SB 573 Gr. N10003<br>SB 574 Gr. N06455<br>SB 564 Gr. N08825<br>SB 462 Gr. N06022<br>SB 462 Gr. N06200 | SB 575 Gr. N10276<br>SB 443 Gr. N06625<br>SB 333 Gr. N10001<br>SB 434 Gr. N10003<br>SB 575 Gr. N06455<br>SB 424 Gr. N08825<br>SB 575 Gr. N06022<br>SB 575 Gr. N06200 |
| 3.9 | SB 572 Gr. N06002 | SB 435 Gr. N06002 |
| 3.10 | SB 672 Gr. N08700 | SB 599 Gr. N08700 |
| 3.11 | SB 649 Gr. N08904 | B 625 Gr. N08904 |
| 3.12 | SB 621 Gr. N08320<br>SB 581 Gr. N06985<br>SB 462 Gr. N08367<br>SA 351 Gr. CN3MM | SB 620 Gr. N08320<br>SB 582 Gr. N06985<br>SB 688 Gr. N08367 |
| 3.13 | SB 581 Gr. N06975<br>SB 564 Gr. N08031 | SB 582 Gr. N06975<br>SB 625 Gr. N08031 |
| 3.14 | SB 581 Gr. N06007<br>SB 462 Gr. N06030 | SB 582 Gr. N06007<br>SB 582 Gr. N06030 |
| 3.15 | SB 564 Gr. N08810 | SB 409 Gr. N08810 |
| 3.16 | SB 511 Gr. N08330 | SB 536 Gr. N08330 |
| 3.17 | SA 351 Gr. CN7M | |

*Table 10.4 -3: ASME B16.5 – materials and their groups*

## 10.4.1 Pressure/Temperature Ratings acc. to ASME B16.5

**Material Group: 1.1 (SA 216 Gr. WCB (1))**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 | 500 | 538 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | | | |
| 150 | 19.6 | 19.6 | 19.2 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 |
| 300 | 51.1 | 51.1 | 50.1 | 46.6 | 45.1 | 43.8 | 41.9 | 39.8 | 38.7 | 37.6 | 36.4 | 34.7 | 28.8 | 23.0 | 17.4 | 11.8 | 5.9 |
| 600 | 102.1 | 102.1 | 100.2 | 93.2 | 90.2 | 87.6 | 83.9 | 79.6 | 77.4 | 75.1 | 72.7 | 69.4 | 57.5 | 46.0 | 34.9 | 23.5 | 11.8 |
| 900 | 153.2 | 150.4 | 150.4 | 139.8 | 135.2 | 131.4 | 125.8 | 119.5 | 116.1 | 112.7 | 109.1 | 104.2 | 86.3 | 69.0 | 52.3 | 35.3 | 17.7 |
| 1500 | 255.3 | 255.3 | 250.6 | 233.0 | 225.4 | 219.0 | 209.7 | 199.1 | 193.6 | 187.8 | 181.8 | 173.6 | 143.8 | 115.0 | 87.2 | 58.8 | 29.5 |
| 2500 | 425.5 | 425.5 | 417.7 | 388.3 | 375.6 | 365.0 | 349.5 | 331.8 | 322.6 | 313.0 | 303.1 | 289.3 | 239.7 | 191.7 | 145.3 | 97.9 | 49.2 |

*Table 10.4.1-1: ASME B16.5 – metric units of material group 1.1 ( SA 216 Gr. WCB)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | | | | |
| 150 | 285 | 285 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 | 65 | 50 | 35 | 20 |
| 300 | 740 | 740 | 680 | 655 | 635 | 605 | 570 | 550 | 530 | 505 | 410 | 320 | 230 | 135 | 85 |
| 600 | 1480 | 1480 | 1360 | 1310 | 1265 | 1205 | 1135 | 1100 | 1060 | 1015 | 825 | 640 | 460 | 275 | 170 |
| 900 | 2220 | 2220 | 2035 | 1965 | 1900 | 1810 | 1705 | 1650 | 1590 | 1520 | 1235 | 955 | 690 | 410 | 255 |
| 1500 | 3705 | 3705 | 3395 | 3270 | 3170 | 3015 | 2840 | 2745 | 2655 | 2535 | 2055 | 1595 | 1150 | 685 | 430 |
| 2500 | 6170 | 6170 | 5655 | 5450 | 5280 | 5025 | 4730 | 4575 | 4425 | 4230 | 3430 | 2655 | 1915 | 1145 | 715 |

*Table 10.4.1-2: ASME B16.5 – US units of material group 1.1 ( SA 216 Gr. WCB)*

(1) WCB: Upon prolonged exposure to temperatures above 425°C (800°F), the carbide phase of steel may be converted to graphite. Permissible but not recommend for prolonged use above 425°C (800°F).

**Material Group: 1.2 (SA 216 Gr. WCC (1), SA 352 Gr. LCC (2))**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 | 500 | 538 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | | | |
| 150 | 19.8 | 19.8 | 19.5 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 |
| 300 | 51.7 | 51.7 | 51.7 | 51.5 | 50.2 | 48.6 | 46.3 | 42.9 | 41.4 | 40.0 | 37.8 | 34.7 | 28.8 | 23.0 | 17.1 | 11.6 | 5.9 |
| 600 | 103.4 | 103.4 | 103.4 | 103.0 | 100.3 | 97.2 | 92.7 | 85.7 | 82.6 | 80.0 | 75.7 | 69.4 | 57.5 | 46.0 | 34.2 | 23.2 | 11.8 |
| 900 | 155.1 | 155.1 | 155.1 | 154.6 | 150.5 | 145.8 | 139.0 | 128.6 | 124.0 | 120.1 | 113.5 | 104.2 | 86.3 | 69.0 | 51.3 | 34.7 | 17.7 |
| 1500 | 258.6 | 258.6 | 258.6 | 257.6 | 250.8 | 243.2 | 231.8 | 214.4 | 206.6 | 200.1 | 189.2 | 173.6 | 143.8 | 115.0 | 85.4 | 57.9 | 29.5 |
| 2500 | 430.9 | 430.9 | 430.9 | 429.4 | 418.1 | 405.4 | 386.2 | 357.1 | 344.3 | 333.5 | 315.3 | 289.3 | 239.7 | 191.7 | 142.4 | 96.5 | 49.2 |

*Table 10.4.1-3: ASME B16.5 – metric units of material group 1.2 (SA 216 Gr. WCC (1), SA 352 Gr. LCC (2))*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | | | | |
| 150 | 290 | 290 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 | 65 | 50 | 35 | 20 |
| 300 | 750 | 750 | 750 | 730 | 705 | 665 | 605 | 590 | 555 | 505 | 410 | 320 | 225 | 135 | 85 |
| 600 | 1500 | 1500 | 1500 | 1455 | 1405 | 1330 | 1210 | 1175 | 1110 | 1015 | 825 | 640 | 445 | 275 | 170 |
| 900 | 2250 | 2250 | 2250 | 2185 | 2110 | 1995 | 1815 | 1765 | 1665 | 1520 | 1235 | 955 | 670 | 410 | 255 |
| 1500 | 3750 | 3750 | 3750 | 3640 | 3520 | 3325 | 3025 | 2940 | 2775 | 2535 | 2055 | 1595 | 1115 | 685 | 430 |
| 2500 | 6250 | 6250 | 6250 | 6070 | 5865 | 5540 | 5040 | 4905 | 4630 | 4230 | 3430 | 2655 | 1855 | 1145 | 715 |

*Table 10.4.1-4: ASME B16.5 – US units of material group 1.2 (SA 216 Gr. WCC (1), SA 352 Gr. LCC (2))*

(1) WCC: Upon prolonged exposure to temperatures above 425°C (800°F), the carbide phase of steel may be converted to graphite. Permissible but not recommend for prolonged use above 425°C (800°F).
(2) LCC: Not to be used over 340°C (650°F).

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 1.3 (SA 352 LCB [(1)])**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 | 500 | 538 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | | | |
| 150 | 18.4 | 18.4 | 18.2 | 17.4 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 |
| 300 | 48.0 | 48.0 | 47.5 | 45.3 | 43.9 | 42.5 | 40.8 | 38.7 | 37.6 | 36.4 | 35.0 | 32.6 | 27.3 | 21.6 | 15.7 | 11.1 | 5.9 |
| 600 | 96.0 | 96.0 | 94.9 | 90.7 | 87.9 | 85.1 | 81.6 | 77.4 | 75.2 | 72.8 | 69.9 | 65.2 | 54.6 | 43.2 | 31.3 | 22.1 | 11.8 |
| 900 | 144.1 | 144.1 | 142.4 | 136.0 | 131.8 | 127.6 | 122.3 | 116.1 | 112.7 | 109.2 | 104.9 | 97.9 | 81.9 | 64.8 | 47.0 | 33.2 | 17.7 |
| 1500 | 240.1 | 240.1 | 237.3 | 226.7 | 219.7 | 212.7 | 203.9 | 193.4 | 187.9 | 182.0 | 174.9 | 163.1 | 136.5 | 107.9 | 78.3 | 55.4 | 29.5 |
| 2500 | 400.1 | 400.1 | 395.6 | 377.8 | 366.1 | 354.4 | 339.8 | 322.4 | 313.1 | 303.3 | 291.4 | 271.9 | 227.5 | 179.9 | 130.6 | 92.3 | 49.2 |

*Table 10.4.1-5: ASME B16.5 – metric units of material group 1.3 (SA 352 Gr. LCB)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | | | | |
| 150 | 265 | 265 | 255 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 | 65 | 50 | 35 | 20 |
| 300 | 695 | 695 | 660 | 640 | 615 | 585 | 550 | 535 | 510 | 475 | 390 | 300 | 200 | 135 | 85 |
| 600 | 1395 | 1395 | 1320 | 1275 | 1230 | 1175 | 1105 | 1065 | 1025 | 955 | 780 | 595 | 405 | 275 | 170 |
| 900 | 2090 | 2090 | 1980 | 1915 | 1845 | 1760 | 1655 | 1600 | 1535 | 1430 | 1175 | 895 | 605 | 410 | 255 |
| 1500 | 3480 | 3480 | 3300 | 3190 | 3075 | 2930 | 2755 | 2665 | 2560 | 2385 | 1955 | 1490 | 1010 | 685 | 430 |
| 2500 | 5805 | 5805 | 5505 | 5315 | 5125 | 4885 | 4595 | 4440 | 4270 | 3970 | 3255 | 2485 | 1685 | 1145 | 715 |

*Table 10.4.1-6: ASME B16.5 – US units of material group 1.3 (SA 352 Gr. LCB)*

(1) LCB: Acc. to ASME 16.5 LCB is not to be used over 340°C(650°F). LESER supplies LCB material with a fivefold material certificate that includes WCB. That means in a critical case where LCB must be used at temperature above 340°C (650°F) the pressure temperature rating of WCB can be applied.

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 1.7 (SA 217 Gr. WC5)**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | |
| 150 | 19.8 | 19.8 | 19.5 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 |
| 300 | 51.7 | 51.7 | 51.7 | 51.5 | 50.3 | 48.6 | 46.3 | 42.9 | 41.4 | 40.3 |
| 600 | 103.4 | 103.4 | 103.4 | 103.0 | 100.3 | 97.2 | 92.7 | 85.7 | 82.6 | 80.4 |
| 900 | 155.1 | 155.1 | 155.1 | 154.6 | 150.6 | 145.8 | 139.0 | 128.6 | 124.0 | 120.7 |
| 1500 | 258.6 | 258.6 | 258.6 | 257.6 | 250.8 | 243.4 | 231.8 | 214.4 | 206.6 | 201.1 |
| 2500 | 430.9 | 430.9 | 430.9 | 429.4 | 418.2 | 405.4 | 386.2 | 357.1 | 344.3 | 335.3 |

*Table 10.4.1-7: ASME B16.5 – metric units of material group 1.7 (SA 217 Gr. WC5)*

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 375 | 400 | 425 | 450 | 475 | 500 | 538 | 550 | 575 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | |
| 150 | 7.4 | 6.5 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 | - | - |
| 300 | 38.9 | 36.5 | 35.2 | 33.7 | 31.7 | 26.7 | 13.9 | 12.6 | 7.2 |
| 600 | 77.6 | 73.3 | 70.0 | 67.7 | 63.4 | 53.4 | 27.9 | 25.2 | 14.4 |
| 900 | 116.5 | 109.8 | 105.1 | 101.4 | 95.1 | 80.1 | 41.8 | 37.8 | 21.5 |
| 1500 | 194.1 | 183.1 | 175.1 | 169.0 | 158.2 | 133.4 | 69.7 | 63.0 | 35.9 |
| 2500 | 323.2 | 304.9 | 291.6 | 281.8 | 263.9 | 222.4 | 116.2 | 105.0 | 59.8 |

*Table 10.4.1-8: ASME B16.5 – metric units of material group 1.7 (SA 217 Gr. WC5)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | |
| 150 | 290 | 290 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 |
| 300 | 750 | 750 | 750 | 730 | 705 | 665 | 605 | 590 | 570 | 530 |
| 600 | 1500 | 1500 | 1500 | 1455 | 1410 | 1330 | 1210 | 1175 | 1135 | 1065 |
| 900 | 2250 | 2250 | 2250 | 2185 | 2115 | 1995 | 1815 | 1765 | 1705 | 1595 |
| 1500 | 3750 | 3750 | 3750 | 3640 | 3530 | 3325 | 3025 | 2940 | 2840 | 2660 |
| 2500 | 6250 | 6250 | 6250 | 6070 | 5880 | 5540 | 5040 | 4905 | 4730 | 4430 |

*Table 10.4.1-9 : ASME B16.5 – US units of material group 1.7 (SA 217 Gr. WC5)*

**US units**

| | Maximum allowable temperature [°F] | | | | | |
|---|---|---|---|---|---|---|
| | 800 | 850 | 900 | 950 | 1000 | 1050 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | |
| 150 | 80 | 65 | 50 | 35 | 20 | - |
| 300 | 510 | 485 | 450 | 315 | 200 | 160 |
| 600 | 1015 | 975 | 900 | 630 | 405 | 315 |
| 900 | 1525 | 1460 | 1350 | 945 | 605 | 475 |
| 1500 | 2540 | 2435 | 2245 | 1575 | 1010 | 790 |
| 2500 | 4230 | 4060 | 3745 | 2630 | 1685 | 1315 |

*Table 10.4.1-10: ASME B16.5 – US units of material group 1.7 (SA 217 Gr. WC5)*

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 1.9 (SA 217 Gr. WC6 (1))**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | |
| 150 | 19.8 | 19.8 | 19.5 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 |
| 300 | 51.7 | 51.7 | 51.7 | 51.5 | 49.7 | 48.0 | 46.3 | 42.9 | 41.4 | 40.3 | 38.9 | 36.5 |
| 600 | 103.4 | 103.4 | 103.4 | 103.0 | 99.5 | 95.9 | 92.7 | 85.7 | 82.6 | 80.4 | 77.6 | 73.3 |
| 900 | 155.1 | 155.1 | 155.1 | 154.4 | 149.2 | 143.9 | 139.0 | 128.6 | 124.0 | 120.7 | 116.5 | 109.8 |
| 1500 | 258.6 | 258.6 | 258.6 | 257.4 | 248.7 | 239.8 | 231.8 | 214.4 | 206.6 | 201.1 | 194.1 | 183.1 |
| 2500 | 430.9 | 430.9 | 430.9 | 429.0 | 414.5 | 399.6 | 386.2 | 357.1 | 344.3 | 335.3 | 323.2 | 304.9 |

*Table 10.4.1-11: ASME B16.5 – metric units of material group 1.9 (SA 217 Gr. WC6)*

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 425 | 450 | 475 | 500 | 538 | 550 | 575 | 600 | 625 | 650 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | |
| 150 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 | - | - | - | - | - |
| 300 | 35.2 | 33.7 | 31.7 | 25.7 | 14.9 | 12.7 | 8.8 | 6.1 | 4.3 | 2.8 |
| 600 | 70.0 | 67.7 | 63.4 | 51.5 | 29.8 | 25.4 | 17.6 | 12.2 | 8.5 | 5.7 |
| 900 | 105.1 | 101.4 | 95.1 | 77.2 | 44.7 | 38.1 | 26.4 | 18.3 | 12.8 | 8.5 |
| 1500 | 175.1 | 169.0 | 158.2 | 128.6 | 74.5 | 63.5 | 44.0 | 30.5 | 21.3 | 14.2 |
| 2500 | 291.6 | 281.8 | 263.9 | 214.4 | 124.1 | 105.9 | 73.4 | 50.9 | 35.5 | 23.6 |

*Table 10.4.1-12: ASME B16.5 – metric units of material group 1.9 (SA 217 Gr. WC6)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | |
| 150 | 290 | 290 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 | 65 |
| 300 | 750 | 750 | 750 | 720 | 695 | 665 | 605 | 590 | 570 | 530 | 510 | 485 |
| 600 | 1500 | 1500 | 1500 | 1445 | 1385 | 1330 | 1210 | 1175 | 1135 | 1065 | 1015 | 975 |
| 900 | 2250 | 2250 | 2250 | 2165 | 2080 | 1995 | 1815 | 1765 | 1705 | 1595 | 1525 | 1460 |
| 1500 | 3750 | 3750 | 3750 | 3610 | 3465 | 3325 | 3025 | 2940 | 2840 | 2660 | 2540 | 2435 |
| 2500 | 6250 | 6250 | 6250 | 6015 | 5775 | 5540 | 5040 | 4905 | 4730 | 4430 | 4230 | 4060 |

*Table 10.4.1-13: ASME B16.5 – US units of material group 1.9 (SA 217 Gr. WC6)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | |
|---|---|---|---|---|---|---|---|
| | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | |
| 150 | 50 | 35 | 20 | - | - | - | - |
| 300 | 450 | 320 | 215 | 145 | 95 | 65 | 40 |
| 600 | 900 | 640 | 430 | 290 | 190 | 130 | 80 |
| 900 | 1350 | 955 | 650 | 430 | 290 | 195 | 125 |
| 1500 | 2245 | 1595 | 1080 | 720 | 480 | 325 | 205 |
| 2500 | 3745 | 2655 | 1800 | 1200 | 800 | 545 | 345 |

*Table 10.4.1-14 : ASME B16.5 – US units of material group 1.9 (SA 217 Gr. WC6)*

(1) WC6: Not to be used over 590°C.

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 1.10 (SA 217 Gr. WC9 (1))**

Metric units

| | Maximum allowable temperature [°C] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | |
| 150 | 19.8 | 19.8 | 19.5 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 |
| 300 | 51.7 | 51.7 | 51.7 | 51.5 | 50.3 | 48.6 | 46.3 | 42.9 | 41.4 | 40.3 | 38.9 |
| 600 | 103.4 | 103.4 | 103.4 | 103.0 | 100.3 | 97.2 | 92.7 | 85.7 | 82.6 | 80.4 | 77.6 |
| 900 | 155.1 | 155.1 | 155.1 | 154.6 | 150.6 | 145.8 | 139.0 | 128.6 | 124.0 | 120.7 | 116.5 |
| 1500 | 258.6 | 258.6 | 258.6 | 257.6 | 250.8 | 243.4 | 231.8 | 214.4 | 206.6 | 201.1 | 194.1 |
| 2500 | 430.9 | 430.9 | 430.9 | 429.4 | 418.2 | 405.4 | 386.2 | 357.1 | 344.3 | 335.3 | 323.2 |

*Table 10.4.1-15: ASME B16.5 –metric units of material group 1.10 (SA 217 Gr. WC9)*

Metric units

| | Maximum allowable temperature [°C] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 400 | 425 | 450 | 475 | 500 | 538 | 550 | 575 | 600 | 625 | 650 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | |
| 150 | 6.5 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 | - | - | - | - | - |
| 300 | 36.5 | 35.2 | 33.7 | 31.7 | 28.2 | 18.4 | 15.6 | 10.5 | 6.9 | 4.5 | 2.8 |
| 600 | 73.3 | 70.0 | 67.7 | 63.4 | 56.5 | 36.9 | 31.3 | 21.1 | 13.8 | 8.9 | 5.7 |
| 900 | 109.8 | 105.1 | 101.4 | 95.1 | 84.7 | 55.3 | 46.9 | 31.6 | 20.7 | 13.4 | 8.5 |
| 1500 | 183.1 | 175.1 | 169.0 | 158.2 | 140.9 | 92.2 | 78.2 | 52.6 | 34.4 | 22.3 | 14.2 |
| 2500 | 304.9 | 291.6 | 281.8 | 263.9 | 235.0 | 153.7 | 130.3 | 87.7 | 57.4 | 37.2 | 23.6 |

*Table 10.4.1-16: ASME B16.5 –metric units of material group 1.10 (SA 217 Gr. WC9)*

US units

| | Maximum allowable temperature [°F] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | |
| 150 | 290 | 290 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 |
| 300 | 750 | 750 | 750 | 730 | 705 | 665 | 605 | 590 | 570 | 530 | 510 |
| 600 | 1500 | 1500 | 1500 | 1455 | 1410 | 1330 | 1210 | 1175 | 1135 | 1065 | 1015 |
| 900 | 2250 | 2250 | 2250 | 2185 | 2115 | 1995 | 1815 | 1765 | 1705 | 1595 | 1525 |
| 1500 | 3750 | 3750 | 3750 | 3640 | 3530 | 3325 | 3025 | 2940 | 2840 | 2660 | 2540 |
| 2500 | 6250 | 6250 | 6250 | 6070 | 5880 | 5540 | 5040 | 4905 | 4730 | 4430 | 4230 |

*Table 10.4.1-17: ASME B16.5 – US units of material group 1.10 (SA 217 Gr. WC9)*

US units

| | Maximum allowable temperature [°F] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 850 | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | |
| 150 | 65 | 50 | 35 | 20 | - | - | - | - |
| 300 | 485 | 450 | 385 | 265 | 175 | 110 | 70 | 40 |
| 600 | 975 | 900 | 775 | 535 | 350 | 220 | 135 | 80 |
| 900 | 1460 | 1350 | 1160 | 800 | 525 | 330 | 205 | 125 |
| 1500 | 2435 | 2245 | 1930 | 1335 | 875 | 550 | 345 | 205 |
| 2500 | 4060 | 3745 | 3220 | 2230 | 1455 | 915 | 570 | 345 |

*Table 10.4.1-18: ASME B16.5 – US units of material group 1.10 (SA 217 Gr. WC9)*

(1) WC9: Not to be used over 590°C.

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 1.13 (A 217 Gr. C5)**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | |
| 150 | 20.0 | 20.0 | 19.5 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 |
| 300 | 51.7 | 51.7 | 51.7 | 51.5 | 50.3 | 48.6 | 46.3 | 42.9 | 41.4 | 40.3 | 38.9 |
| 600 | 103.4 | 103.4 | 103.4 | 103.0 | 100.3 | 97.2 | 92.7 | 85.7 | 82.6 | 80.4 | 77.6 |
| 900 | 155.1 | 155.1 | 155.1 | 154.6 | 150.6 | 145.8 | 139.0 | 128.6 | 124.0 | 120.7 | 116.5 |
| 1500 | 258.6 | 258.6 | 258.6 | 257.6 | 250.8 | 243.4 | 231.8 | 214.4 | 206.6 | 201.1 | 194.1 |
| 2500 | 430.9 | 430.9 | 430.9 | 429.4 | 418.2 | 405.4 | 386.2 | 357.1 | 344.3 | 335.3 | 323.2 |

*Table 10.4.1-19: ASME B16.5 –metric units of material group 1.13 (A 217 Gr. C5)*

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 400 | 425 | 450 | 475 | 500 | 538 | 550 | 575 | 600 | 625 | 650 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | |
| 150 | 6.5 | 5.5 | 4.6 | 3.7 | 2.8 | 1.4 | - | - | - | - | - |
| 300 | 36.5 | 35.2 | 33.7 | 27.9 | 21.4 | 13.7 | 12.0 | 8.9 | 6.2 | 4.0 | 2.4 |
| 600 | 73.3 | 70.0 | 67.7 | 55.7 | 42.8 | 27.4 | 24.1 | 17.8 | 12.5 | 8.0 | 4.7 |
| 900 | 109.8 | 105.1 | 101.4 | 83.6 | 64.1 | 41.1 | 36.1 | 26.7 | 18.7 | 12.0 | 7.1 |
| 1500 | 183.1 | 175.1 | 169.0 | 139.3 | 106.9 | 68.6 | 60.2 | 44.4 | 31.2 | 20.0 | 11.8 |
| 2500 | 304.9 | 291.6 | 281.8 | 232.1 | 178.2 | 114.3 | 100.4 | 74.0 | 51.9 | 33.3 | 19.7 |

*Table 10.4.1-20: ASME B16.5 –metric units of material group 1.13 (A 217 Gr. C5)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | |
| 150 | 290 | 290 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 |
| 300 | 750 | 750 | 750 | 730 | 705 | 665 | 605 | 590 | 570 | 530 | 510 |
| 600 | 1500 | 1500 | 1500 | 1455 | 1410 | 1330 | 1210 | 1175 | 1135 | 1065 | 1015 |
| 900 | 2250 | 2250 | 2250 | 2185 | 2115 | 1995 | 1815 | 1765 | 1705 | 1595 | 1525 |
| 1500 | 3750 | 3750 | 3750 | 3640 | 3530 | 3325 | 3025 | 2940 | 2840 | 2660 | 2540 |
| 2500 | 6250 | 6250 | 6250 | 6070 | 5880 | 5540 | 5040 | 4905 | 4730 | 4430 | 4230 |

*Table 10.4.1-21: ASME B16.5 – US units of material group 1.13 (A 217 Gr. C5)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 850 | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | |
| 150 | 65 | 50 | 35 | 20 | - | - | - | - |
| 300 | 485 | 375 | 275 | 200 | 145 | 100 | 60 | 35 |
| 600 | 975 | 745 | 550 | 400 | 290 | 200 | 125 | 70 |
| 900 | 1460 | 1120 | 825 | 595 | 430 | 300 | 185 | 105 |
| 1500 | 2435 | 1870 | 1370 | 995 | 720 | 495 | 310 | 170 |
| 2500 | 4060 | 3115 | 2285 | 1655 | 1200 | 830 | 515 | 285 |

*Table 10.4.1-22: ASME B16.5 – US units of material group 1.13 (A 217 Gr. C5)*

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 2.2 (SA 351 Gr. CF8M [(1)])**

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | |
| 150 | 19.0 | 19.0 | 18.4 | 16.2 | 14.8 | 13.7 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 | 5.5 | 4.6 | 3.7 |
| 300 | 49.6 | 49.6 | 48.1 | 42.2 | 38.5 | 35.7 | 33.4 | 31.6 | 30.9 | 30.3 | 29.9 | 29.4 | 29.1 | 28.8 | 28.7 |
| 600 | 99.3 | 99.3 | 96.2 | 84.4 | 77.0 | 71.3 | 66.8 | 63.2 | 61.8 | 60.7 | 59.8 | 58.9 | 58.3 | 57.7 | 57.3 |
| 900 | 148.9 | 148.9 | 144.3 | 126.6 | 115.5 | 107.0 | 100.1 | 94.9 | 92.7 | 91.0 | 89.6 | 88.3 | 87.4 | 86.5 | 86.0 |
| 1500 | 248.2 | 248.2 | 240.6 | 211.0 | 192.5 | 178.3 | 166.9 | 158.1 | 154.4 | 151.6 | 149.4 | 147.2 | 145.7 | 144.2 | 143.4 |
| 2500 | 413.7 | 413.7 | 400.9 | 351.6 | 320.8 | 297.2 | 278.1 | 263.5 | 257.4 | 252.7 | 249.0 | 245.3 | 242.9 | 240.4 | 238.9 |

*Table 10.4.1-23: ASME B16.5 – metric units of material group  2.2 (SA 351 Gr. CF8M)*

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 500 | 538 | 550 | 575 | 600 | 625 | 650 | 675 | 700 | 725 | 750 | 775 | 800 | 816 |
| Class | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | |
| 150 | 2.8 | 1.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 300 | 28.2 | 25.2 | 25.0 | 24.0 | 19.9 | 15.8 | 12.7 | 10.3 | 8.4 | 7.0 | 5.9 | 4.6 | 3.5 | 2.8 |
| 600 | 56.5 | 50.0 | 49.8 | 47.9 | 39.8 | 31.6 | 25.3 | 20.6 | 16.8 | 14.0 | 11.7 | 9.0 | 7.0 | 5.9 |
| 900 | 84.7 | 75.2 | 74.8 | 71.8 | 59.7 | 47.4 | 38.0 | 31.0 | 25.1 | 21.0 | 17.6 | 13.7 | 10.5 | 8.6 |
| 1500 | 140.9 | 125.5 | 124.9 | 119.7 | 99.5 | 79.1 | 63.3 | 51.6 | 41.9 | 34.9 | 29.3 | 22.8 | 17.4 | 14.1 |
| 2500 | 235.0 | 208.9 | 208.0 | 199.5 | 165.9 | 131.8 | 105.5 | 86.0 | 69.8 | 58.2 | 48.9 | 38.0 | 29.2 | 23.8 |

*Table 10.4.1-24: ASME B16.5 – metric units of material group  2.2 (SA 351 Gr. CF8M)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | | | | |
| 150 | 275 | 275 | 235 | 215 | 195 | 170 | 140 | 125 | 110 | 95 | 80 | 65 | 50 | 35 | 20 |
| 300 | 720 | 720 | 620 | 560 | 515 | 480 | 450 | 440 | 435 | 425 | 420 | 420 | 415 | 385 | 365 |
| 600 | 1440 | 1440 | 1240 | 1120 | 1025 | 955 | 900 | 885 | 870 | 855 | 845 | 835 | 830 | 775 | 725 |
| 900 | 2160 | 2160 | 1860 | 1680 | 1540 | 1435 | 1355 | 1325 | 1305 | 1280 | 1265 | 1255 | 1245 | 1160 | 1090 |
| 1500 | 3600 | 3600 | 3095 | 2795 | 2570 | 2390 | 2255 | 2210 | 2170 | 2135 | 2110 | 2090 | 2075 | 1930 | 1820 |
| 2500 | 6000 | 6000 | 5160 | 4660 | 4280 | 3980 | 3760 | 3680 | 3620 | 3560 | 3520 | 3480 | 3460 | 3220 | 3030 |

*Table 10.4.1-25: ASME B16.5 – US units material group  2.2 (SA 351 Gr. CF8M)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1050 | 1100 | 1150 | 1200 | 1250 | 1300 | 1350 | 1400 | 1450 | 1500 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | |
| 150 | - | - | - | - | - | - | - | - | - | - |
| 300 | 360 | 305 | 235 | 185 | 145 | 115 | 95 | 75 | 60 | 40 |
| 600 | 720 | 610 | 475 | 370 | 295 | 235 | 190 | 150 | 115 | 85 |
| 900 | 1080 | 915 | 710 | 555 | 440 | 350 | 290 | 225 | 175 | 125 |
| 1500 | 1800 | 1525 | 1185 | 925 | 735 | 585 | 480 | 380 | 290 | 205 |
| 2500 | 3000 | 2545 | 1970 | 1545 | 1230 | 970 | 800 | 630 | 485 | 345 |

*Table 10.4.1-26: ASME B16.5 – US units of material group  2.2 (SA 351 Gr. CF8M)*

(1) At temperatures over 538°C (1000°F), use only when carbon content is 0.04% or higher
LESER does not specify a minimum carbon content for standard CF8M stock material, therefore the carbon content must be verified respectively specified, if an application at temperatures over 538°C (1000°F) is intended.

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 2.3 (SA 182 Gr. F316L, SA 240 Gr. 316L)**

**Metric units**

| | **Maximum allowable temperature [°C]** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 | 425 | 450 |
| Class | **Maximum pressure [bar]** | | | | | | | | | | | | | |
| 150 | 15.9 | 15.9 | 15.3 | 13.3 | 12.0 | 11.2 | 10.5 | 10.0 | 9.3 | 8.4 | 7.4 | 6.5 | 5.5 | 4.6 |
| 300 | 41.4 | 41.4 | 40.0 | 34.8 | 31.4 | 29.2 | 27.5 | 26.1 | 25.5 | 25.1 | 24.8 | 24.3 | 23.9 | 23.4 |
| 600 | 82.7 | 82.7 | 80.0 | 69.6 | 62.8 | 58.3 | 54.9 | 52.1 | 51.0 | 50.1 | 49.5 | 48.6 | 47.7 | 46.8 |
| 900 | 124.1 | 124.1 | 120.1 | 104.4 | 94.2 | 87.5 | 82.4 | 78.2 | 76.4 | 75.2 | 74.3 | 72.9 | 71.6 | 70.2 |
| 1500 | 206.8 | 206.8 | 200.1 | 173.9 | 157.0 | 145.8 | 137.3 | 130.3 | 127.4 | 125.4 | 123.8 | 121.5 | 119.3 | 117.1 |
| 2500 | 344.7 | 344.7 | 333.5 | 289.9 | 261.6 | 243.0 | 228.9 | 217.2 | 212.3 | 208.9 | 206.3 | 202.5 | 198.8 | 195.1 |

*Table 10.4.1-27: ASME B16.5 – metric units of material group 2.3 (SA 182 Gr. F316L, SA 240 Gr. 316L)*

**US units**

| | **Maximum allowable temperature [°F]** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | | |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | | | |
| 150 | 230 | 230 | 195 | 175 | 160 | 150 | 140 | 125 | 110 | 95 | 80 | 65 | | |
| 300 | 600 | 600 | 510 | 455 | 420 | 395 | 370 | 365 | 360 | 355 | 345 | 340 | | |
| 600 | 1200 | 1200 | 1020 | 910 | 840 | 785 | 745 | 730 | 720 | 705 | 690 | 675 | | |
| 900 | 1800 | 1800 | 1535 | 1370 | 1260 | 1180 | 1115 | 1095 | 1080 | 1060 | 1035 | 1015 | | |
| 1500 | 3000 | 3000 | 2555 | 2280 | 2100 | 1970 | 1860 | 1825 | 1800 | 1765 | 1730 | 1690 | | |
| 2500 | 5000 | 5000 | 4260 | 3800 | 3500 | 3280 | 3100 | 3040 | 3000 | 2940 | 2880 | 2820 | | |

*Table 10.4.1-28: ASME B16.5 – US units of material group 2.3 (SA 182 Gr. F316L, SA 240 Gr. 316L)*

**Material Group: 2.8 (SA 351 Gr. CK3MCuN, SA 351 Gr. CE8MN (1), SA 351 Gr. CD4Mcu (1), SA 351 Gr. CD3MWCuN)**

**Metric units**

| | **Maximum allowable temperature [°C]** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | |
| 150 | 20.0 | 20.0 | 19.5 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 |
| 300 | 51.7 | 51.7 | 51.7 | 50.7 | 45.9 | 42.7 | 40.5 | 38.9 | 38.2 | 37.6 | 37.4 | 36.5 |
| 600 | 103.4 | 103.4 | 103.4 | 101.3 | 91.9 | 85.3 | 80.9 | 77.7 | 76.3 | 75.3 | 74.7 | 73.3 |
| 900 | 155.1 | 155.1 | 155.1 | 152.0 | 137.8 | 128.0 | 121.4 | 116.6 | 114.5 | 112.9 | 112.1 | 109.8 |
| 1500 | 258.6 | 258.6 | 258.6 | 253.3 | 229.6 | 213.3 | 202.3 | 194.3 | 190.8 | 188.2 | 186.8 | 183.1 |
| 2500 | 430.9 | 430.9 | 430.9 | 422.2 | 382.7 | 355.4 | 337.2 | 323.8 | 318.0 | 313.7 | 311.3 | 304.9 |

*Table 10.4.1-29: ASME B16.5 – metric units of material group 2.3 (SA 182 Gr. F316L, SA 240 Gr. 316L)*

**US units**

| | **Maximum allowable temperature [°F]** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | | |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | |
| 150 | | 290 | 260 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | | |
| 300 | | 750 | 745 | 665 | 615 | 580 | 555 | 545 | 540 | 530 | | |
| 600 | | 1500 | 1490 | 1335 | 1230 | 1160 | 1115 | 1095 | 1085 | 1065 | | |
| 900 | | 2250 | 2230 | 2000 | 1845 | 1740 | 1670 | 1640 | 1625 | 1595 | | |
| 1500 | | 3750 | 3720 | 3335 | 3070 | 2905 | 2785 | 2735 | 2710 | 2660 | | |
| 2500 | | 6250 | 6200 | 5560 | 5120 | 4840 | 4640 | 4560 | 4520 | 4430 | | |

*Table 10.4.1-30: ASME B16.5 – US units of material group 2.3 (SA 182 Gr. F316L, SA 240 Gr. 316L)*

(1) This steel may become brittle after service at moderately elevated temperatures. Not to be used over 315° C (600°F)

## Pressure/temperature ratings acc. to ASME B16.5

**Material Group: 2.11 (SA 351 Gr. CF8C)**

**Metric units**

| | MNaximum allowable temperature [°C] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -29 | 38 | 50 | 100 | 150 | 200 | 250 | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | | |
| 150 | 19.0 | 19.0 | 18.7 | 17.4 | 15.8 | 13.8 | 12.1 | 10.2 | 9.3 | 8.4 | 7.4 | 6.5 | 5.5 | 4.6 | 3.7 |
| 300 | 49.6 | 49.6 | 48.8 | 45.3 | 42.5 | 39.9 | 37.8 | 36.1 | 35.4 | 34.8 | 34.2 | 33.9 | 33.6 | 33.5 | 31.7 |
| 600 | 99.3 | 99.3 | 97.5 | 90.6 | 84.9 | 79.9 | 75.6 | 72.2 | 70.7 | 69.5 | 68.4 | 67.8 | 67.2 | 66.9 | 63.4 |
| 900 | 148.9 | 148.9 | 146.3 | 135.9 | 127.4 | 119.8 | 113.4 | 108.3 | 106.1 | 104.3 | 102.6 | 101.7 | 100.8 | 100.4 | 95.1 |
| 1500 | 248.2 | 248.2 | 243.8 | 226.5 | 212.4 | 199.7 | 189.1 | 180.4 | 176.8 | 173.8 | 171.0 | 169.5 | 168.1 | 167.3 | 158.2 |
| 2500 | 413.7 | 413.7 | 406.4 | 377.4 | 353.9 | 332.8 | 315.1 | 300.7 | 294.6 | 289.6 | 285.1 | 282.6 | 280.1 | 278.8 | 263.9 |

*Table 10.4.1-31: ASME B16.5 – metric units of material group 2.11 (SA 351 Gr. CF8C)*

**Metric units**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 500 | 538 | 550 | 575 | 600 | 625 | 650 | 675 | 700 | 725 | 750 | 775 | 800 | 816 |
| **Class** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | |
| 150 | 2.8 | 1.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 300 | 28.2 | 25.2 | 25.0 | 24.0 | 19.8 | 13.9 | 10.3 | 8.0 | 5.6 | 4.0 | 3.1 | 2.5 | 2.0 | 1.9 |
| 600 | 56.5 | 50.0 | 49.8 | 47.9 | 39.6 | 27.7 | 20.6 | 15.9 | 11.2 | 8.0 | 6.2 | 4.9 | 4.0 | 3.8 |
| 900 | 84.7 | 75.2 | 74.8 | 71.8 | 59.4 | 41.6 | 30.9 | 23.9 | 16.8 | 11.9 | 9.3 | 7.4 | 6.1 | 5.7 |
| 1500 | 140.9 | 125.5 | 124.9 | 119.7 | 99.0 | 69.3 | 51.5 | 39.8 | 28.1 | 19.9 | 15.5 | 12.3 | 10.1 | 9.5 |
| 2500 | 235.0 | 208.9 | 208.0 | 199.5 | 165.1 | 115.5 | 85.8 | 66.3 | 46.8 | 33.1 | 25.8 | 20.4 | 16.9 | 15.8 |

*Table 10.4.1-32 – ASME B16.5 – metric units of material group 2.11 (SA 351 Gr. CF8C)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | | | | | | |
| 150 | 275 | 275 | 255 | 230 | 200 | 170 | 140 | 125 | 110 | 95 | 80 | 65 | 50 | 35 | 20 |
| 300 | 720 | 720 | 660 | 615 | 575 | 540 | 515 | 505 | 495 | 490 | 485 | 485 | 450 | 385 | 365 |
| 600 | 1440 | 1440 | 1325 | 1235 | 1150 | 1085 | 1030 | 1015 | 995 | 985 | 975 | 970 | 900 | 775 | 725 |
| 900 | 2160 | 2160 | 1985 | 1850 | 1730 | 1625 | 1550 | 1520 | 1490 | 1475 | 1460 | 1455 | 1350 | 1160 | 1090 |
| 1500 | 3600 | 3600 | 3310 | 3085 | 2880 | 2710 | 2580 | 2530 | 2485 | 2460 | 2435 | 2425 | 2245 | 1930 | 1820 |
| 2500 | 6000 | 6000 | 5520 | 5140 | 4800 | 4520 | 4300 | 4220 | 4140 | 4100 | 4060 | 4040 | 3745 | 3220 | 3030 |

*Table 10.4.1-33: ASME B16.5 – US units of material group 2.11 (SA 351 Gr. CF8C)*

**US units**

| | Maximum allowable temperature [°F] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1050 | 1100 | 1150 | 1200 | 1250 | 1300 | 1350 | 1400 | 1450 | 1500 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | | | |
| 150 | - | - | - | - | - | - | - | - | - | - |
| 300 | 360 | 310 | 210 | 150 | 115 | 75 | 50 | 40 | 30 | 25 |
| 600 | 720 | 625 | 420 | 300 | 225 | 150 | 105 | 80 | 60 | 55 |
| 900 | 1080 | 935 | 625 | 455 | 340 | 225 | 155 | 125 | 95 | 80 |
| 1500 | 1800 | 1560 | 1045 | 755 | 565 | 375 | 255 | 205 | 155 | 135 |
| 2500 | 3000 | 2600 | 1745 | 1255 | 945 | 630 | 430 | 345 | 255 | 230 |

*Table 10.4.1-34: ASME B16.5 – US units of material group 2.11 (SA 351 Gr. CF8C)*

(1) At temperatures over 538°C (1000°F), use only when carbon content is 0.04% or higher
LESER does not stock CF8C material. If an application at temperatures over 538°C (1000°F) is intended this should be specified, so LESER can specify the minimum carbon content for the material.

10.4.2 Pressure/Temperature Ratings acc. to ASME B16.42

ASME B16.42 covers ductile iron pipe flanges.

### Overview of materials and their groups

| LESER standard material | Material group | Other materials of material group |
|---|---|---|
| Ductile Gr. 60-40-18 | ductile iron | Ductile Gr. 65-45-15 |

*Table 10.4.2-1: ASME B16.42 – pressure/temperature ratings acc. to B16.42*

**Material Group: ductile iron (ductile 60-40-18)**

**Metric units**

| | **Maximum temperature [°C]** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | -28.9 | 37.8 | 93.3 | 148.9 | 204.4 | 260 | 315.6 | 343.3 |
| **Class** | **Maximum pressure [bar]** | | | | | | | |
| 150 | 19.6 | 19.6 | 19.2 | 17.7 | 15.8 | 13.8 | 12.1 | 10.2 |
| 300 | 51.1 | 51.1 | 50.1 | 46.6 | 45.1 | 43.8 | 41.9 | 39.8 |

*Table 10.4.2-2 – ASME B16.42 – US units of material group: ductile iron (ductile 60-40-18)*

**US units**

| | **Maximum allowable temperature [°F]** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | -20 | 100 | 200 | 300 | 400 | 500 | 600 | 650 |
| **Class** | **Maximum allowable pressure [psi]** | | | | | | | |
| 150 | 284 | 284 | 278 | 257 | 229 | 200 | 175 | 148 |
| 300 | 741 | 741 | 727 | 676 | 654 | 635 | 608 | 577 |

*Table 10.4.2-3: ASME B16.42 – US units of material group: ductile iron (ductile 60-40-18)–*

10.4.3 Dimensions acc. to ASME B16.5

Flange dimensions are available from ½" to 20". The tables below are sorted by classes in ascending order, showing the type "welding neck". Sizes of l and b were in all tables with metric units calculated (1 inch = 25.4 mm).

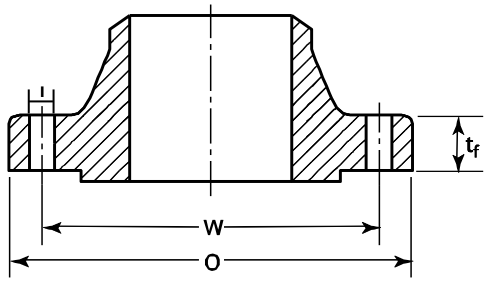



*Figure 10.4.3-1: Welding neck flange*

## Dimensions acc. to ASME B16.5

### Class 150

#### US units [inch]

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. (2) - (4) |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (1), (5) | Bolt hole diameter (1), (5) | Bolting (1), (5) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 3.50 | 2.38 | 5/8 | 4 | 1/2 | 0.38 |
| ¾ | 3.88 | 2.75 | 5/8 | 4 | 1/2 | 0.44 |
| 1 | 4.25 | 3.12 | 5/8 | 4 | 1/2 | 0.50 |
| 1¼ | 4.62 | 3.50 | 5/8 | 4 | 1/2 | 0.56 |
| 1½ | 5.00 | 3.88 | 5/8 | 4 | 1/2 | 0.62 |
| 2 | 6.00 | 4.75 | 3/4 | 4 | 5/8 | 0.69 |
| 2½ | 7.00 | 5.50 | 3/4 | 4 | 5/8 | 0.81 |
| 3 | 7.50 | 6.00 | 3/4 | 4 | 5/8 | 0.88 |
| 4 | 9.00 | 7.50 | 3/4 | 8 | 5/8 | 0.88 |
| 5 | 10.00 | 8.50 | 7/8 | 8 | 3/4 | 0.88 |
| 6 | 11.00 | 9.50 | 7/8 | 8 | 3/4 | 0.94 |
| 8 | 13.50 | 11.75 | 7/8 | 8 | 3/4 | 1.06 |
| 10 | 16.00 | 14.25 | 1 | 12 | 7/8 | 1.12 |
| 12 | 19.00 | 17.00 | 1 | 12 | 7/8 | 1.19 |
| 14 | 21.00 | 18.75 | 1 1/8 | 12 | 1 | 1.31 |
| 16 | 23.50 | 21.25 | 1 1/8 | 16 | 1 | 1.38 |
| 18 | 25.00 | 22.75 | 1 ¼ | 16 | 1 1/8 | 1.50 |
| 20 | 27.50 | 25.00 | 1 ¼ | 20 | 1 1/8 | 1.62 |
| 24 | 32.00 | 29.50 | 1 3/8 | 20 | 1 1/4 | 1.81 |

*Table 10.4.3-1: ASME B16.5 – dimensions of flanges [inch] – class 150*

#### Metric units [mm]

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. (2) - (4) |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (1), (5) | Bolt hole diameter (1), (5) | Bolting (1), (5) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 90 | 60.5 | 15,9 | 4 | 12,70 | 9.6 |
| ¾ | 100 | 69.9 | 15,9 | 4 | 12,70 | 11.2 |
| 1 | 110 | 79.2 | 15,9 | 4 | 12,70 | 12.7 |
| 1¼ | 115 | 88.9 | 15,9 | 4 | 12,70 | 14.3 |
| 1½ | 125 | 98.6 | 15,9 | 4 | 12,70 | 15.9 |
| 2 | 150 | 120.7 | 19,1 | 4 | 15,88 | 17.5 |
| 2½ | 180 | 139.7 | 19,1 | 4 | 15,88 | 20.7 |
| 3 | 190 | 152.4 | 19,1 | 4 | 15,88 | 22.3 |
| 4 | 230 | 190.5 | 19,1 | 8 | 15,88 | 22.3 |
| 5 | 255 | 215.9 | 22,2 | 8 | 19,05 | 22.3 |
| 6 | 280 | 241.3 | 22,2 | 8 | 19,05 | 23.9 |
| 8 | 345 | 298.5 | 22,2 | 8 | 19,05 | 27.0 |
| 10 | 405 | 362.0 | 25,4 | 12 | 22,23 | 28.6 |
| 12 | 485 | 431.8 | 25,4 | 12 | 22,23 | 30.2 |
| 14 | 535 | 476.3 | 28,6 | 12 | 25,4 | 33.4 |
| 16 | 595 | 539.8 | 28,6 | 16 | 25,4 | 35.0 |
| 18 | 635 | 577.9 | 31,8 | 16 | 28,58 | 38.1 |
| 20 | 700 | 635.0 | 31,8 | 20 | 28,58 | 41.3 |
| 24 | 815 | 749.3 | 34,93 | 20 | 31,75 | 46.1 |

*Table 10.4.3-2: ASME B16.5 – dimensions of flanges [mm] – class 150*

*Notes:*

(1) For flange bolt holes, see ASME B16.5 para 6.5
(2) The minimum thickness of these loose flanges, in sizes NPS 3½ and smaller, is slightly greater than the thickness of flanges on fittings, table ASME B16.5 F9, which are reinforced by cast integral with the body of the fitting.
(3) When these flanges are required with flat face, the flat face may be either the full tf-dimension thickness plus 0.06 inch/2 mm., or the tf dimension thickness without the raised face height. See para. ASME B16.5 6.3.2 for additional restrictions.
(4) The flange dimensions illustrated are for regularly furnished 0.06 inch/2 mm raised face (except lapped); for requirements of other facings, see ASME B16.5 figure F7
(5) For spot facing, see ASME B16.5 para 6.6

## Dimensions acc. to ASME B16.5

**Class 300**

**US units [inch]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. (2) - (4) |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (1), (5) | Bolt hole diameter (1), (5) | Bolting (1), (5) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 3.75 | 2.62 | 5/8 | 4 | 1/2 | 0.50 |
| ¾ | 4.62 | 3.25 | 3/4 | 4 | 5/8 | 0.56 |
| 1 | 4.88 | 3.50 | 3/4 | 4 | 5/8 | 0.62 |
| 1¼ | 5.25 | 3.88 | 3/4 | 4 | 5/8 | 0.69 |
| 1½ | 6.12 | 4.50 | 7/8 | 4 | 3/4 | 0.75 |
| 2 | 6.50 | 5.00 | 3/4 | 8 | 5/8 | 0.81 |
| 2½ | 7.50 | 5.88 | 7/8 | 8 | 3/4 | 0.94 |
| 3 | 8.25 | 6.62 | 7/8 | 8 | 3/4 | 1.06 |
| 4 | 10.00 | 7.88 | 7/8 | 8 | 3/4 | 1.19 |
| 5 | 11.00 | 9.25 | 7/8 | 8 | 3/4 | 1.31 |
| 6 | 12.50 | 10.62 | 7/8 | 12 | 3/4 | 1.38 |
| 8 | 15.00 | 13.00 | 1 | 12 | 7/8 | 1.56 |
| 10 | 17.50 | 15.25 | 1 1/8 | 16 | 1 | 1.81 |
| 12 | 20.50 | 17.75 | 1 1/4 | 16 | 1 1/8 | 1.94 |
| 14 | 23.00 | 20.25 | 1 1/4 | 20 | 1 1/8 | 2.06 |
| 16 | 25.50 | 22.50 | 1 3/8 | 20 | 1 1/4 | 2.19 |
| 18 | 28.00 | 24.75 | 1 3/8 | 24 | 1 1/4 | 2.31 |
| 20 | 30.50 | 27.00 | 1 3/8 | 24 | 1 1/4 | 2.44 |
| 24 | 36.00 | 32.00 | 1 5/8 | 24 | 1 1/2 | 2.69 |

*Table 10.4.3-3: ASME B16.5 – dimensions of flanges [inch] – class 300*

**Metric units [mm]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. (2), (3) |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (1), (5) | Bolt hole diameter (1), (5) | Bolting (1), (5) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 95 | 66.7 | 15,9 | 4 | 12,70 | 12.7 |
| ¾ | 115 | 82.6 | 19,1 | 4 | 15,88 | 14.3 |
| 1 | 125 | 88.9 | 19,1 | 4 | 15,88 | 15.9 |
| 1¼ | 135 | 98.4 | 19,1 | 4 | 15,88 | 17.5 |
| 1½ | 155 | 114.3 | 22,2 | 4 | 19,05 | 19.1 |
| 2 | 165 | 127.0 | 19,1 | 8 | 15,88 | 20.7 |
| 2½ | 190 | 149.2 | 22,2 | 8 | 19,05 | 23.9 |
| 3 | 210 | 168.3 | 22,2 | 8 | 19,05 | 27.0 |
| 4 | 255 | 200.0 | 22,2 | 8 | 19,05 | 30.2 |
| 5 | 280 | 235.0 | 22,2 | 8 | 19,05 | 33.4 |
| 6 | 320 | 269.9 | 22,2 | 12 | 19,05 | 35.0 |
| 8 | 380 | 330.2 | 25,4 | 12 | 22,23 | 39.7 |
| 10 | 445 | 387.4 | 28,6 | 16 | 25,4 | 46.1 |
| 12 | 520 | 450.8 | 31,8 | 16 | 28,58 | 49.3 |
| 14 | 585 | 514.4 | 31,8 | 20 | 28,58 | 52.4 |
| 16 | 650 | 571.5 | 34,9 | 20 | 31,75 | 55.6 |
| 18 | 710 | 628.6 | 34,9 | 24 | 31,75 | 58.8 |
| 20 | 775 | 685.8 | 34,9 | 24 | 31,75 | 62.0 |
| 24 | 915 | 812.8 | 41,3 | 24 | 38,10 | 68.3 |

*Table 10.4.3-4: ASME B16.5 – dimensions of flanges [mm] – class 300*

*Notes:*

(1) For flange bolt holes, see ASME B16.5 para 6.5
(2) These flanges may be supplied with a flat face. The flat face may be either the full tf dimension thickness plus 0.06 inch/2 mm or the tf dimension thickness without the raised face height. See para. ASME B16.5 6.3.2 for additional restrictions.
(3) The flange dimensions illustrated are for regularly furnished 0.06 inch/2 mm raised face (except lapped); for requirements of other facings, see ASME B16.5 fig. F-7.
(4) For welding end bevel, see AMSE B 16.5 para. 6.7.
(5) For spot facing, see ASME B16.5 para 6.6

## Dimensions acc. to ASME B16.5

### Class 600

**US units [inch]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 3.75 | 2.62 | 5/8 | 4 | 1/2 | 0.56 |
| ¾ | 4.62 | 3.25 | 3/4 | 4 | 5/8 | 0.62 |
| 1 | 4.88 | 3.50 | 3/4 | 4 | 5/8 | 0.69 |
| 1¼ | 5.25 | 3.88 | 3/4 | 4 | 5/8 | 0.81 |
| 1½ | 6.12 | 4.50 | 7/8 | 4 | 3/4 | 0.88 |
| 2 | 6.50 | 5.00 | 3/4 | 8 | 5/8 | 1.00 |
| 2½ | 7.50 | 5.88 | 7/8 | 8 | 3/4 | 1.12 |
| 3 | 8.25 | 6.62 | 7/8 | 8 | 3/4 | 1.25 |
| 4 | 10.75 | 8.50 | 1 | 8 | 7/8 | 1.50 |
| 5 | 13.00 | 10.50 | 1 1/8 | 8 | 1 | 1.75 |
| 6 | 14.00 | 11.50 | 1 1/8 | 12 | 1 | 1.88 |

*Table 10.4.3-5: ASME B16.5 – dimensions of flanges [inch] – class 600*

**Metric units [mm]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 95 | 66.7 | 15,9 | 4 | 12,70 | 14.3 |
| ¾ | 115 | 82.6 | 19,1 | 4 | 15,88 | 15.9 |
| 1 | 125 | 88.9 | 19,1 | 4 | 15,88 | 17.5 |
| 1¼ | 135 | 98.4 | 19,1 | 4 | 15,88 | 20.7 |
| 1½ | 155 | 114.3 | 22,2 | 4 | 19,05 | 22.3 |
| 2 | 165 | 127.0 | 19,1 | 8 | 15,88 | 25.4 |
| 2½ | 190 | 149.2 | 22,2 | 8 | 19,05 | 28.6 |
| 3 | 210 | 168.3 | 22,2 | 8 | 19,05 | 31.8 |
| 4 | 275 | 215.9 | 25,4 | 8 | 22,23 | 38.1 |
| 5 | 330 | 266.7 | 28,6 | 8 | 25,4 | 44.5 |
| 6 | 355 | 292.1 | 28,6 | 12 | 25,4 | 47.7 |

*Table 10.4.3-6: ASME B16.5 – dimensions of flanges [mm] – class 600*

*Notes:*

(2) For flange bolt holes, see ASME B16.5 para 6.5
(3) For spot facing, see ASME para 6.6

LESER The-Safety-Valve.com

## Dimensions acc. to ASME B16.5

### Class 900

**US units [inch]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | I | Number | b | $t_f$ |
| ½ | Use class 1500 dimensions in these sizes | | | | | |
| ¾ | | | | | | |
| 1 | | | | | | |
| 1¼ | | | | | | |
| 1½ | | | | | | |
| 2 | | | | | | |
| 2½ | | | | | | |
| 3 | 9.50 | 7.50 | 1 | 8 | 7/8 | 1.50 |
| 4 | 11.50 | 9.25 | 1 1/4 | 8 | 1 1/8 | 1.75 |

*Table 10.4.3-7: ASME B16.5 – dimensions of flanges [inch] – class 900*

**Metric units [mm]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | I | Number | b | $t_f$ |
| ½ | Use class 1500 dimensions in these sizes | | | | | |
| ¾ | | | | | | |
| 1 | | | | | | |
| 1¼ | | | | | | |
| 1½ | | | | | | |
| 2 | | | | | | |
| 2½ | | | | | | |
| 3 | 240 | 190.5 | 25,4 | 8 | 22,23 | 38.1 |
| 4 | 290 | 235.0 | 31,8 | 8 | 28,58 | 44.5 |

*Table 10.4.3-8: ASME B16.5 – dimensions of flanges [mm] – class 900*

*Notes:*

(2) For flange bolt holes, see ASME B16.5 para 6.5
(3) For spot facing, see ASME para 6.6

## Dimensions acc. to ASME B16.5

### Class 1500

**US units [inch]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | I | Number | b | $t_f$ |
| ½ | 4.75 | 3.25 | 7/8 | 4 | 3/4 | 0.88 |
| ¾ | 5.12 | 3.50 | 7/8 | 4 | 3/4 | 1.00 |
| 1 | 5.88 | 4.00 | 1 | 4 | 7/8 | 1.12 |
| 1¼ | 6.25 | 4.38 | 1 | 4 | 7/8 | 1.12 |
| 1½ | 7.00 | 4.88 | 1 1/8 | 4 | 1 | 1.25 |
| 2 | 8.50 | 6.50 | 1 | 8 | 7/8 | 1.50 |
| 2½ | 9.62 | 7.50 | 1 1/8 | 8 | 1 | 1.62 |
| 3 | 10.50 | 8.00 | 1 1/4 | 8 | 1 1/8 | 1.88 |
| 4 | 12.25 | 9.50 | 1 3/8 | 8 | 1 1/4 | 2.12 |

*Table 10.4.3-9: ASME B16.5 – dimensions of flanges [inch] – class 1500*

**Metric units [mm]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | I | Number | b | $t_f$ |
| ½ | 120 | 82.6 | 22,2 | 4 | 19,05 | 22.3 |
| ¾ | 130 | 88.9 | 22,2 | 4 | 19,05 | 25.4 |
| 1 | 150 | 101.6 | 25,4 | 4 | 22,23 | 28.6 |
| 1¼ | 160 | 111.1 | 25,4 | 4 | 22,23 | 28.6 |
| 1½ | 180 | 123.8 | 28,6 | 4 | 25,4 | 31.8 |
| 2 | 215 | 165.1 | 25,4 | 8 | 22,23 | 38.1 |
| 2½ | 245 | 190.5 | 28,6 | 8 | 25,4 | 41.3 |
| 3 | 265 | 203.2 | 31,8 | 8 | 28,58 | 47.7 |
| 4 | 310 | 241.3 | 34,9 | 8 | 31,75 | 54.0 |

*Table 10.4.3-10: ASME B16.5 – dimensions of flanges [mm] – class 1500*

*Notes:*

(2) For flange bolt holes, see ASME B16.5 para 6.5
(3) For spot facing, see ASME para 6.6

## Dimensions acc. to ASME B16.5

**Class 2500**

**US units [inch]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 5.25 | 3.50 | 7/8 | 4 | 3/4 | 1.19 |
| ¾ | 5.50 | 3.75 | 7/8 | 4 | 3/4 | 1.25 |
| 1 | 6.25 | 4.25 | 1 | 4 | 7/8 | 1.38 |
| 1¼ | 7.25 | 5.12 | 1 1/8 | 4 | 1 | 1.50 |
| 1½ | 8.00 | 5.75 | 1 1/4 | 4 | 1 1/8 | 1.75 |
| 2 | 9.25 | 6.75 | 1 1/8 | 8 | 1 | 2.00 |
| 2½ | 10.50 | 7.75 | 1 1/4 | 8 | 1 1/8 | 2.25 |
| 3 | 12.00 | 9.00 | 1 3/8 | 8 | 1 1/4 | 2.62 |
| 4 | 14.00 | 10.75 | 1 5/8 | 8 | 1 1/2 | 3.00 |

*Table 10.4.3-11: ASME B16.5 – dimensions of flanges [inch] – class 2500*

**Metric units [mm]**

| Nominal Pipe Size | Connection dimensions | | | | | Thickness min. |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter (2), (3) | Bolt hole diameter (2), (3) | Bolting (2), (3) | | |
| | O | W | l | Number | b | $t_f$ |
| ½ | 135 | 88.9 | 22,2 | 4 | 19,05 | 30.2 |
| ¾ | 140 | 95.2 | 22,2 | 4 | 19,05 | 31.8 |
| 1 | 160 | 108.0 | 25,4 | 4 | 22,23 | 35.0 |
| 1¼ | 185 | 130.2 | 28,6 | 4 | 25,4 | 38.1 |
| 1½ | 205 | 146.0 | 31,8 | 4 | 28,58 | 44.5 |
| 2 | 235 | 171.4 | 28,6 | 8 | 25,4 | 50.9 |
| 2½ | 265 | 196.8 | 31,8 | 8 | 28,58 | 57.2 |
| 3 | 305 | 228.6 | 34,9 | 8 | 31,75 | 66.7 |
| 4 | 355 | 273.0 | 41,3 | 8 | 38,10 | 76.2 |

*Table 10.4.3-12: ASME B16.5 – dimensions of flanges [mm] – class 2500*

*Notes:*

(2) For flange bolt holes, see ASME B16.5 para 6.5
(3) For spot facing, see ASME para 6.6

### 10.4.4 Flange Facings and Finish acc. to ASME B16.5

Forms of flange facings are shown in Fig. 10.4.4-1 and their dimensions in Tab. 10.4.4-1.
For flat face (FF) flange facings see section 4.6.

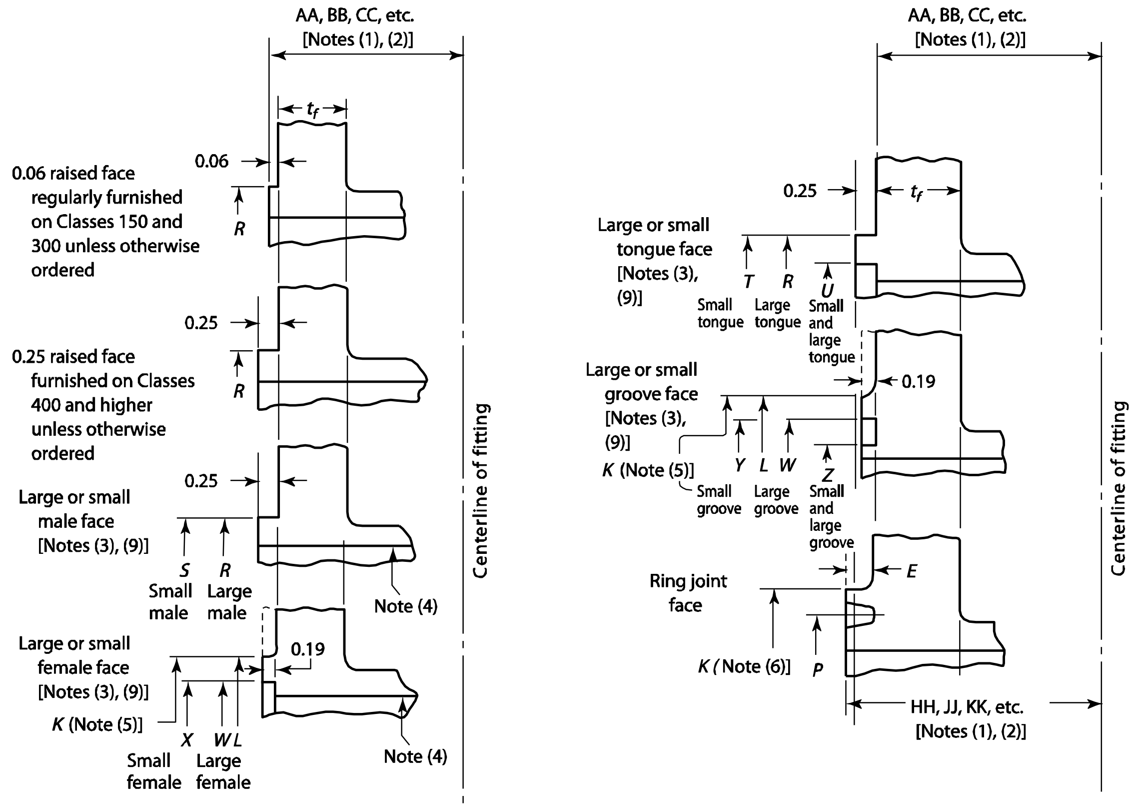



*Figure 10.4.4-1: ASME B16.5 – End flange facings [inch] and their relationship to flange thickness and Center-To-End and End-To-End dimensions*

### Dimensions of facings other than ring joints [inch]

| Nominal pipe size | Outside diameter | | | Inside diameter of LTF and STF | Inside diameter of SMF (4), (10) | Outside diameter | | | Inside Diameter of LGF and SGF | Height | | Depth of groove or female (11), (14) | Minimum outside diameter of raised portion (15), (9) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RF, LMF and LTF | SMF (4), (10) | STF | | | LFF and LGF | SFF (4), (10) | SGF | | RF (11), (12) | SMF, LMF, STF and LTF (11), (13) | | SFF and SGF | LFF and LGF |
| | R | S | T | U | | W | X | Y | Z | | | | K | L |
| ½ | 1.38 | 0.72 | 1.38 | 1.00 | - | 1.44 | 0.78 | 1.44 | 0.94 | - | - | - | 1.75 | 1.81 |
| ¾ | 1.69 | 0.94 | 1.69 | 1.31 | - | 1.75 | 1.00 | 1.75 | 1.25 | - | - | - | 2.06 | 2.12 |
| 1 | 2.00 | 1.19 | 1.88 | 1.50 | - | 2.06 | 1.25 | 1.94 | 1.44 | - | - | - | 2.25 | 2.44 |
| 1¼ | 2.50 | 1.50 | 2.25 | 1.88 | - | 2.56 | 1.56 | 2.31 | 1.81 | - | - | - | 2.62 | 2.94 |
| 1½ | 2.88 | 1.75 | 2.50 | 2.12 | - | 2.94 | 1.81 | 2.56 | 2.06 | - | - | - | 2.88 | 3.31 |
| 2 | 3.62 | 2.25 | 3.25 | 2.88 | - | 3.69 | 2.31 | 3.31 | 2.81 | - | - | - | 3.62 | 4.06 |
| 2½ | 4.12 | 2.69 | 3.75 | 3.38 | - | 4.19 | 2.75 | 3.81 | 3.31 | - | - | - | 4.12 | 4.56 |
| 3 | 5.00 | 3.31 | 4.62 | 4.25 | - | 5.06 | 3.38 | 4.69 | 4.19 | - | - | - | 5.00 | 5.44 |
| 3½ | 5.50 | 3.81 | 5.12 | 4.75 | - | 5.56 | 3.88 | 5.19 | 4.69 | - | - | - | 5.50 | 5.94 |
| 4 | 6.19 | 4.31 | 5.69 | 5.19 | - | 6.25 | 4.38 | 5.75 | 5.12 | - | - | - | 6.19 | 6.62 |
| 5 | 7.31 | 5.38 | 6.81 | 6.31 | - | 7.38 | 5.44 | 6.88 | 6.25 | - | - | - | 7.31 | 7.75 |
| 6 | 8.50 | 6.38 | 8.00 | 7.50 | - | 8.56 | 6.44 | 8.06 | 7.44 | - | - | - | 8.50 | 8.94 |
| 8 | 10.62 | 8.38 | 10.00 | 9.38 | - | 10.69 | 8.44 | 10.06 | 9.31 | - | - | - | 10.62 | 11.06 |
| 10 | 12.75 | 10.50 | 12.00 | 11.25 | - | 12.81 | 10.56 | 12.06 | 11.19 | - | - | - | 12.75 | 13.19 |
| 12 | 15.00 | 12.50 | 14.25 | 13.50 | - | 15.06 | 12.56 | 14.31 | 13.44 | - | - | - | 15.00 | 15.44 |
| 14 | 16.25 | 13.75 | 15.50 | 14.75 | - | 16.31 | 13.81 | 15.56 | 14.69 | - | - | - | 16.25 | 16.69 |
| 16 | 18.50 | 15.75 | 17.62 | 16.75 | - | 18.56 | 15.81 | 17.69 | 16.69 | - | - | - | 18.50 | 18.94 |
| 18 | 21.00 | 17.75 | 20.12 | 19.25 | - | 21.06 | 17.81 | 20.19 | 19.19 | - | - | - | 21.00 | 21.44 |
| 20 | 23.00 | 19.75 | 22.00 | 21.00 | - | 23.06 | 19.81 | 22.06 | 20.94 | - | - | - | 23.00 | 23.44 |
| 24 | 27.25 | 23.75 | 26.25 | 25.25 | - | 27.31 | 23.81 | 26.31 | 25.19 | - | - | - | 27.25 | 27.69 |

*Table 10.4.4-1: ASME B16.5 – Dimensions other than ring joints [inch]*

*Shortcuts:*

| | |
|---|---|
| RF | raised face |
| SMF | small male facing |
| LMF | large male facing |
| SFF | small female facing |
| LFF | large female facing |
| STF | small tongue facing |
| LTF | large tongue facing |
| SGF | small groove facing |
| LGF | large groove facing |

*General Notes table 10.4.4-1:*

(a) For facing requirements for flanges end flanged fittings, see paras. 6.3 and 6.4 and Fig. F7.
(b) For facing requirements for lapped joints, see para. 6.4.3 and Fig. F7
(c) For facing tolerances, see para 7.3

*Notes:*

(1) See ASME B16.5 paras. 6.2 and 6.4
(2) See tables below
(3) See table 10.4.4-1 for dimensions of facings (other than ring joint) and table 10.4.4-2
(4) For small male and female joints, care should be taken in the use of these dimensions to insure that the inside diameter of fitting pipe is small enough to permit sufficient bearing surface to prevent crushing of the gasket (see ASME B16.5 table F4). This applies particularly on lines where the joint is made on the end of the pipe. Threaded companion flanges for small male and female joints are furnished with plain face and are threaded with American Standard Locknut Thread (NPSL).
(5) See ASME B16.5 table F4
(6) See section 4.3 or ASME B16.5 table F5
(7) See ASME B16.5 para. 6.4.3
(8) See ASME B16.5 para. 6.4.3.5 and table F5
(9) Large male and female faces and large tongue and groove are not applicable to class 150 because of potential dimensional conflicts
(10) Inside diameter of fitting should match inside diameter of pipe as specified by purchaser.
(11) See para. 6.4.3 and Fig. F7 for thickness and outside diameter of laps.
(12) Height of raised face either 0.06 in. of 0.25 in.
(13) Height of large and small male and tongue is 0.25 in.
(14) Depth of groove or female is 0.19 in.
(15) Raised portion of full face may be furnished unless otherwise specified an order.

## Dimensions of Ring-Joint Facings [inch]

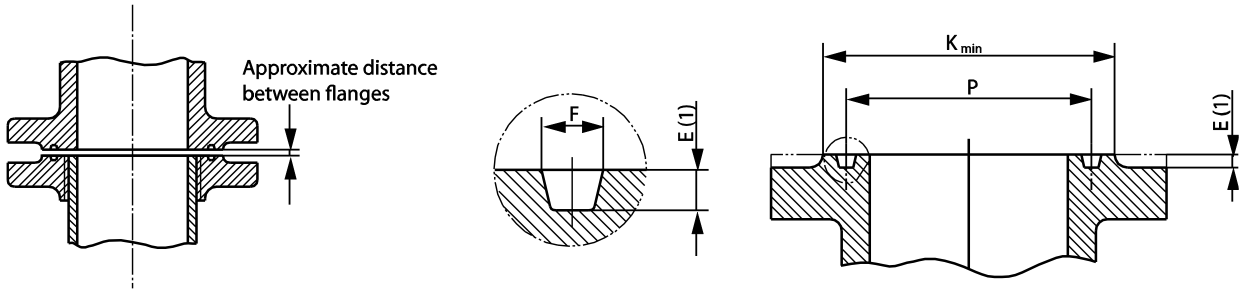



*Figure 10.4.4-2: ASME B16.5 – ring joint facings*

| Nominal Pipe Size | | | | | | Groove Number | Groove Dimensions | | | | Diameter of Raised Portion, K | | | | | Approximate Distance Between Flanges | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class 150 | Class 300 | Class 600 | Class 900 [note (3)] | Class 1500 | Class 2500 | | Pitch Diameter | Depth [note (1)] | Width | Radius at Bottom | Class 150 | Class 300, 600 | Class 900 | Class 1500 | Class 2500 | Class 150 | Class 300 | Class 600 | Class 900 | Class 1500 | Class 2500 |
| | | | | | | | P | E | F | R | | | | | | | | | | | |
| … | ½ | ½ | … | … | … | R11 | 1.344 | 0.219 | 0.281 | 0.03 | … | 2.00 | … | … | … | … | 0.12 | 0.12 | … | … | … |
| … | … | … | … | ½ | … | 12 | 1.562 | 0.250 | 0.344 | 0.03 | … | … | … | 2.38 | … | … | … | … | … | 0.16 | … |
| … | ¾ | ¾ | … | … | ½ | 13 | 1.688 | 0.250 | 0.344 | 0.03 | … | 2.50 | … | … | 2.56 | … | 0.16 | 0.16 | … | … | 0.16 |
| … | … | … | … | ¾ | … | 14 | 1.750 | 0.250 | 0.344 | 0.03 | … | … | … | 2.62 | … | … | … | … | … | 0.16 | … |
| 1 | … | … | … | … | … | 15 | 1.875 | 0.250 | 0.344 | 0.03 | 2.50 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 1 | 1 | … | 1 | ¾ | 16 | 2.000 | 0.250 | 0.344 | 0.03 | … | 2.75 | … | 2.81 | 2.88 | … | 0.16 | 0.16 | … | 0.16 | 0.16 |
| 1¼ | … | … | … | … | … | 17 | 2.250 | 0.250 | 0.344 | 0.03 | 2.88 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 1¼ | 1¼ | … | 1¼ | 1 | 18 | 2.375 | 0.250 | 0.344 | 0.03 | … | 3.12 | … | 3.19 | 3.25 | … | 0.16 | 0.16 | … | 0.16 | 0.16 |
| 1½ | … | … | … | … | … | 19 | 2.562 | 0.250 | 0.344 | 0.03 | 3.25 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 1½ | 1½ | … | 1½ | … | 20 | 2.688 | 0.250 | 0.344 | 0.03 | … | 3.56 | … | 3.62 | … | … | 0.16 | 0.16 | … | 0.16 | … |
| … | … | … | … | … | 1¼ | 21 | 2.844 | 0.312 | 0.469 | 0.03 | … | … | … | … | 4.00 | … | … | … | … | … | 0.12 |
| 2 | … | … | … | … | … | 22 | 3.250 | 0.250 | 0.344 | 0.03 | 4.00 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 2 | 2 | … | … | 1½ | 23 | 3.250 | 0.312 | 0.469 | 0.03 | … | 4.25 | … | … | 4.50 | … | 0.22 | 0.19 | … | … | 0.12 |
| … | … | … | … | 2 | … | 24 | 3.750 | 0.312 | 0.469 | 0.03 | … | … | … | 4.88 | … | … | … | … | … | 0.12 | … |
| 2½ | … | … | … | … | … | 25 | 4.000 | 0.250 | 0.344 | 0.03 | 4.75 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 2½ | 2½ | … | … | 2 | 26 | 4.000 | 0.312 | 0.469 | 0.03 | … | 5.00 | … | … | 5.25 | … | 0.22 | 0.19 | … | … | 0.12 |
| … | … | … | … | 2½ | … | 27 | 4.250 | 0.312 | 0.469 | 0.03 | … | … | … | 5.38 | … | … | … | … | … | 0.12 | … |
| … | … | … | … | … | 2½ | 28 | 4.375 | 0.375 | 0.531 | 0.06 | … | … | … | … | 5.88 | … | … | … | … | … | 0.12 |
| 3 | … | … | … | … | … | 29 | 4.500 | 0.250 | 0.344 | 0.03 | 5.25 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | (4) | (4) | … | … | … | 30 | 4.625 | 0.312 | 0.469 | 0.03 | … | … | … | … | … | … | … | … | … | … | … |
| … | 3 (4) | 3 (4) | 3 | … | … | 31 | 4.875 | 0.312 | 0.469 | 0.03 | … | 5.75 | 6.12 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | … | 3 | 32 | 5.000 | 0.375 | 0.531 | 0.06 | … | … | … | … | 6.62 | … | … | … | … | … | 0.12 |
| 3½ | … | … | … | … | … | 33 | 5.188 | 0.250 | 0.344 | 0.03 | 6.06 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 3½ | 3½ | … | … | … | 34 | 5.188 | 0.312 | 0.469 | 0.03 | … | 6.25 | … | … | … | … | 0.22 | 0.19 | … | … | … |
| … | … | … | … | 3 | … | 35 | 5.375 | 0.312 | 0.469 | 0.03 | … | … | … | 6.62 | … | … | … | … | … | 0.12 | … |
| 4 | … | … | … | … | … | 36 | 5.875 | 0.250 | 0.344 | 0.03 | 6.75 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 4 | 4 | 4 | … | … | 37 | 5.875 | 0.312 | 0.469 | 0.03 | … | 6.88 | 7.12 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | … | 4 | 38 | 6.188 | 0.438 | 0.656 | 0.06 | … | … | … | … | 8.00 | … | … | … | … | … | 0.16 |
| … | … | … | … | 4 | … | 39 | 6.375 | 0.312 | 0.469 | 0.03 | … | … | … | 7.62 | … | … | … | … | … | 0.12 | … |
| 5 | … | … | … | … | … | 40 | 6.750 | 0.250 | 0.344 | 0.03 | 7.62 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 5 | 5 | 5 | … | … | 41 | 7.125 | 0.312 | 0.469 | 0.03 | … | 8.25 | 8.50 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | … | 5 | 42 | 7.500 | 0.500 | 0.781 | 0.06 | … | … | … | … | 9.50 | … | … | … | … | … | 0.16 |
| 6 | … | … | … | … | … | 43 | 7.625 | 0.250 | 0.344 | 0.03 | 8.62 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | … | … | … | 5 | … | 44 | 7.625 | 0.312 | 0.469 | 0.03 | … | … | … | 9.00 | … | … | … | … | … | 0.12 | … |
| … | 6 | 6 | 6 | … | … | 45 | 8.312 | 0.312 | 0.469 | 0.03 | … | 9.50 | 9.50 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | 6 | … | 46 | 8.312 | 0.375 | 0.531 | 0.06 | … | … | … | 9.75 | … | … | … | … | … | 0.12 | … |
| … | … | … | … | … | 6 | 47 | 9.000 | 0.500 | 0.781 | 0.06 | … | … | … | … | 11.00 | … | … | … | … | … | 0.16 |
| 8 | … | … | … | … | … | 48 | 9.750 | 0.250 | 0.344 | 0.03 | 10.75 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 8 | 8 | 8 | … | … | 49 | 10.625 | 0.312 | 0.469 | 0.03 | … | 11.88 | 12.12 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | 8 | … | 50 | 10.625 | 0.438 | 0.656 | 0.06 | … | … | … | 12.50 | … | … | … | … | … | 0.16 | … |

*Table 10.4.4-2: ASME B16.5 – dimension of ring joint facings*

## Dimensions of Ring-Joint Facings (continued) [inch]

| Nominal Pipe Size | | | | | | Groove Number | Groove Dimensions | | | | Diameter of Raised Portion, K | | | | | Approximate Distance Between Flanges | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class 150 | Class 300 | Class 600 | Class 900 [note (3)] | Class 1500 | Class 2500 | | Pitch Diameter | Depth [note (1)] | Width | Radius at Bottom | Class 150 | Class 300, 600 | Class 900 | Class 1500 | Class 2500 | Class 150 | Class 300 | Class 600 | Class 900 | Class 1500 | Class 2500 |
| | | | | | | | P | E | F | R | | | | | | | | | | | |
| … | … | … | … | … | 8 | 51 | 11.000 | 0.562 | 0.906 | 0.06 | … | … | … | … | 13.38 | … | … | … | … | … | 0.19 |
| 10 | … | … | … | … | … | 52 | 12.000 | 0.250 | 0.344 | 0.03 | 13.00 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 10 | 10 | 10 | … | … | 53 | 12.750 | 0.312 | 0.469 | 0.03 | … | 14.00 | 14.25 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | 10 | … | 54 | 12.750 | 0.438 | 0.656 | 0.06 | … | … | … | 14.62 | … | … | … | … | … | 0.16 | … |
| … | … | … | … | … | 10 | 55 | 13.500 | 0.688 | 1.188 | 0.09 | … | … | … | … | 16.75 | … | … | … | … | … | 0.25 |
| 12 | … | … | … | … | … | 56 | 15.000 | 0.250 | 0.344 | 0.03 | 16.00 | … | … | … | … | 0.16 | … | … | … | … | … |
| … | 12 | 12 | 12 | … | … | 57 | 15.000 | 0.312 | 0.469 | 0.03 | … | 16.25 | 16.50 | … | … | … | 0.22 | 0.19 | 0.16 | … | … |
| … | … | … | … | 12 | … | 58 | 15.000 | 0.562 | 0.906 | 0.06 | … | … | … | 17.25 | … | … | … | … | … | 0.19 | … |
| 14 | … | … | … | … | 12 | 59 | 15.625 | 0.250 | 0.344 | 0.03 | 16.75 | … | … | … | … | 0.12 | … | … | … | … | … |
| … | … | … | … | … | … | 60 | 16.000 | 0.688 | 1.312 | 0.09 | … | … | … | … | 19.50 | … | … | … | … | … | 0.31 |
| … | 14 | 14 | 14 | … | … | 61 | 16.500 | 0.312 | 0.469 | 0.03 | … | 18.00 | … | … | … | … | 0.22 | 0.19 | … | … | … |
| … | … | … | … | 14 | … | 62 | 16.500 | 0.438 | 0.656 | 0.06 | … | … | 18.38 | … | … | … | … | … | 0.16 | … | … |
| … | … | … | … | … | … | 63 | 16.500 | 0.625 | 1.062 | 0.09 | … | … | … | 19.25 | … | … | … | … | … | 0.22 | … |
| 16 | … | … | … | … | … | 64 | 17.875 | 0.250 | 0.344 | 0.03 | 19.00 | … | … | … | … | 0.12 | … | … | … | … | … |
| … | 16 | 16 | 16 | … | … | 65 | 18.500 | 0.312 | 0.469 | 0.03 | … | 20.00 | … | … | … | … | 0.22 | 0.19 | … | … | … |
| … | … | … | … | 16 | … | 66 | 18.500 | 0.438 | 0.656 | 0.06 | … | … | 20.62 | … | … | … | … | … | 0.16 | … | … |
| … | … | … | … | … | … | 67 | 18.500 | 0.688 | 1.188 | 0.09 | … | … | … | 21.50 | … | … | … | … | … | 0.31 | … |
| 18 | … | … | … | … | … | 68 | 20.375 | 0.250 | 0.344 | 0.03 | 21.50 | … | … | … | … | 0.12 | … | … | … | … | … |
| … | 18 | 18 | 18 | … | … | 69 | 21.000 | 0.312 | 0.469 | 0.03 | … | 22.62 | … | … | … | … | 0.22 | 0.19 | … | … | … |
| … | … | … | … | 18 | … | 70 | 21.000 | 0.500 | 0.781 | 0.06 | … | … | 23.38 | … | … | … | … | … | 0.19 | … | … |
| … | … | … | … | … | … | 71 | 21.000 | 0.688 | 1.188 | 0.09 | … | … | … | 24.12 | … | … | … | … | … | 0.31 | … |
| 20 | … | … | … | … | … | 72 | 22.000 | 0.250 | 0.344 | 0.03 | 23.50 | … | … | … | … | 0.12 | … | … | … | … | … |
| … | 20 | 20 | 20 | … | … | 73 | 23.000 | 0.375 | 0.531 | 0.06 | … | 25.00 | … | … | … | … | 0.22 | 0.19 | … | … | … |
| … | … | … | … | 20 | … | 74 | 23.000 | 0.500 | 0..781 | 0.06 | … | … | 25.50 | … | … | … | … | … | 0.19 | … | … |
| … | … | … | … | … | … | 75 | 23.000 | 0.688 | 1.312 | 0.09 | … | … | … | 26.50 | … | … | … | … | … | 0.38 | … |
| 24 | … | … | … | … | … | 76 | 26.500 | 0.250 | 0.344 | 0.03 | 28.00 | … | … | … | … | 0.12 | … | … | … | … | … |
| … | 24 | 24 | 24 | … | … | 77 | 27.250 | 0.438 | 0.656 | 0.06 | … | 29.50 | … | … | … | … | 0.25 | 0.22 | … | … | … |
| … | … | … | … | 24 | … | 78 | 27.250 | 0.625 | 1.062 | 0.09 | … | … | 30.38 | … | … | … | … | … | 0.22 | … | … |
| … | … | … | … | … | … | 79 | 27.250 | 0.812 | 1.438 | 0.09 | … | … | … | 31.25 | … | … | … | … | … | 0.44 | … |

*Table 10.4.4-3: ASME B16.5 – dimension of ring joint facings (continued)*

### *General notes:*

(1) Dimensions are in inches
(2) For facing requirements for flanges and flanged fittings, see para. 6.4.1 and Fig. F7
(3) For facing requirements for lapped joints, see para. 6.4.3 and Fig. F7.
(4) See para. 4.2.7 for marking requirements

### *Notes:*

(1) Height of full raised portion is equal to the depth of groove dimension E, but is not subjected to the tolerances for E. Former full-face contour may be used.
(2) Use class 600 in sizes NPS ½ to NPS 3½ for class 400.
(3) Use class 1500 in sizes NPS ½ to NPS 2½ for class 900.
(4) For ring joints with lapped joint flanges in classes 300 and 600, ring and groove number R30 are used instead of R31.

### *Tolerances:*

E (depth) + 0.016, - 0.0
F (width) ± 0.008
P (pitch diameter) ± 0.005
R (radius at bottom)
R ≤ 0.06 + 0.03, - 0.0
R > 0.06 ± 0.03
23 deg (angle) ± ½ deg

### Flange facing finish

All sealing surfaces are machined and have a surface finish which corresponds to the values in Tab. 10.4.4-4 when compared to test specimens by look and feel inspection. See ASME B16.5, 6.4.5 for more information.
ASME B16.5 defines the requirements of sealing surfaces. „Flange facing finishes" are commmented in chapter 6.4.5 in this standard. Furthermore, the forms of sealing surfaces are described in MSS SP-6.

In this context called finishes are:

- Serrated spiral finish

  Continuos spiral rill, which can be produced by face turning with radial feed

- Serrrated concentric finish

  concentric rills, which can be produced by a cog tool with axial traverse speed. The types „serrated spiral finish" and „serrated concentric finish" are equal and can be engineered alternatively.

- Smooth oder non serrated finish

  The effective MSS SP-6 (Edition 2001) does not mention "smooth finish" anymore. In MSS SP-6 (Edition 1980) "Smooth finish" is defined for finishes of contact flanges as "250 µinch (6,3 µm) AARH max.".

  LESER supplies flange facings according to ASME B16.5 – 1996, paragraph 6.4.4.3: "Either a serrated concentric or serrated spiral finish resulting in service finish from 125 µinch to 250 µinch average roughness shall be furnished." This finish meets the requirements of MSS SP-6 (Edition 1980), which is not valid anymore!

- Stock finish

  Stock finish is not defined in any technical standard. If purchase orders show "Stock finish" LESER supplies standard facing according to DIN or ASME (marked with * in table "Flange facings" of each valve series).

The finish of the gasket contact faces shall be judged by visual comparison with $R_a$ standards (see ASME B46.1) and not by instruments having stylus tracers and electronic amplification.

The following table shows the allowed surface roughness in combination with the forms of sealing surfaces:

| Form of surface finish | AARH, $R_a$ | | $R_z$ [µm] | | $Radius_{tool}$ | Roughness | Standard |
|---|---|---|---|---|---|---|---|
| | [µm] | [µinch] | [µm] | [µinch] | [mm] | [mm/rotation] | |
| FF, RF – serrated finish (1)<br>LMF, LFF – serrated finish (1) | 3.2 – 6.3 | 125 – 250 | 12.5 - 25 | 500 – 1000 | > 1.52 (2) | 0.462 – 0.556 (2) | ASME B16.5 |
| RTJ | max 1.6 | max 63 | n/a | n/a | n/a | n/a | ASME B16.5 |
| SGF, STF, SMF, SFF, LGF, LTF | max 3.2 | max 125 | | | | | |
| Smooth finish (non serrated) | max 6.3 | max 250 | max. 25 | 1000 | n/a | n/a | MSS SP-6 |

*Table 10.4.4-4: ASME B16.5 – allowed surface roughness*

*Notes:*
(1) serrated spiral oder serrated concentric finish
(2) LESER: $R_{tool}$ > 1.6 mm, roughness 0.46 – 0.56

AARH: Arithmetic average roughness height $R_a$
Maximum roughness height $R_z$

10.4.5 Flange Ratings acc. to API 526

Besides ASME B16.5 / B16.34 also API 526 lists pressure-temperature ratings for flanges. This section explains the differences between these standards.

Related to the pressure/temperature limits the standards ASME B16.5 / B16.34 and API 526 are identical to a certain extent.

The differences are:

- acc. to API 526 the pressure/temperature limit of the highest flange class in all orifices is lower than the limit in ASME B16.5 / B16.34
- for API orifices L through T the pressure / temperature limits also for lower flange classes deviate from the values of ASME B16.5 / B16.34
- there are less intermediate temperature steps in the API 526.

See chapter 4.1 for ASME and LESER catalogue for API limits.

In case the pressure/temperature limit acc. to API 526 is lower than the limit acc. to ASME B16.5 / B16.34, the LESER type 526 can usually be supplied with a set pressure in accordance with the ASME B16.5 / B16.34 flange rating. The limiting factor however may be the spring chart (LGS 3630).

**Class 300L according to API 526**

A Class 300L flange is dimensionally identical to a Class 300 flange. The maximum set pressure of an API valve with a Class 300L inlet flange however is the same as for a Class 150 flange at ambient temperatures. The difference to a Class 150 inlet flange is that the maximum set pressure is extended to a temperature of 800°F/427°C.

The application area for #300L inlet flanges is shown in the following chart.

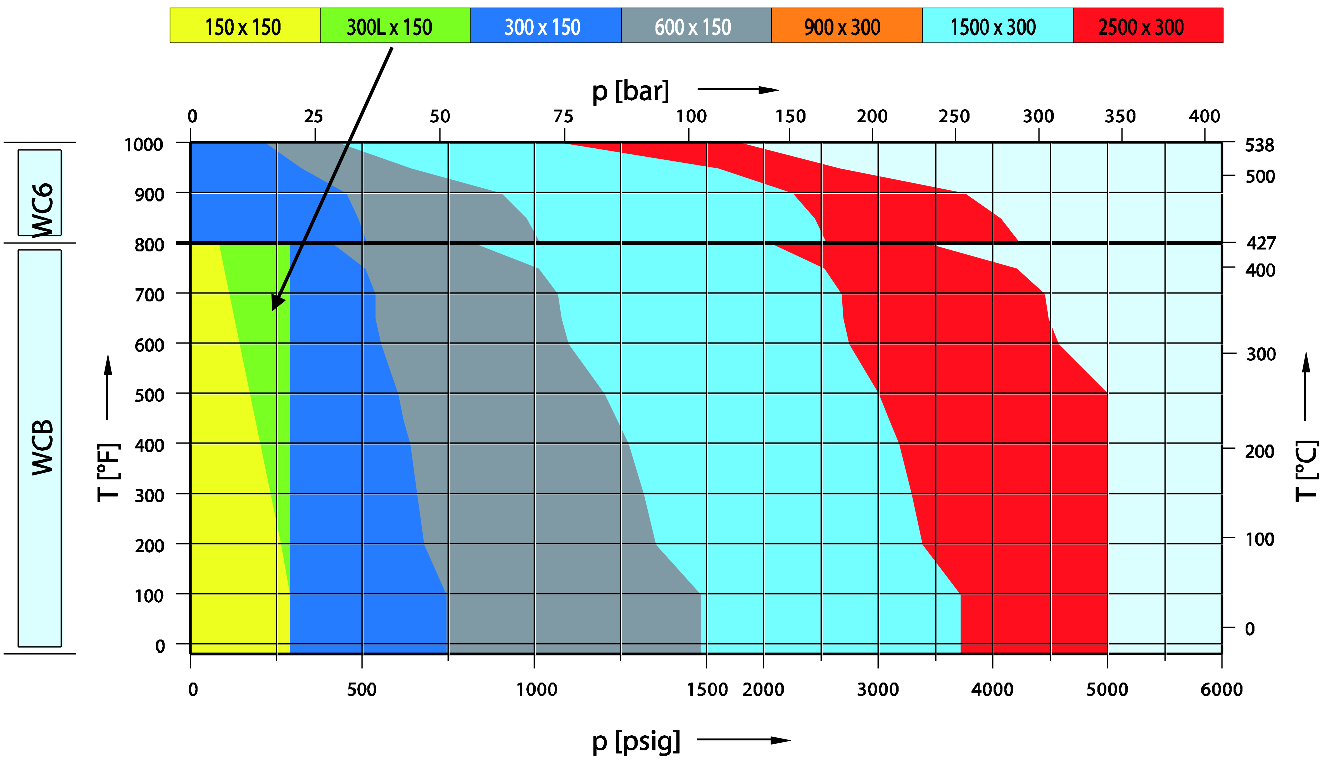



*Figure 10.4.5-1: Application area for #300L inlet flanges*

10.4.6 Cast Iron and Ductile Iron Flanges acc. to ASME B 16.1 and ASME B 16.42

**Cast Iron**

According to ASME B16.1 cast iron equates to class 125 and class 250.
In general flat face flange facing (FF) is required. Cast iron castings for LESER valves generally don't allow to machine a flat face without falling below the minimum thickness of the flange. Therefore class 125 and 250 are not offered by LESER.
Connecting dimensions of class 125 and 250 are equal to class 150 respectively class 300 for steel flanges.

Following connection dimensions of flanges are equal:

| Iron | Steel |
|---|---|
| #125 | #150 |
| #250 | #300 |

*Table 10.4.6-1: Equal connection dimensions of flanges*

**Note:** A flat face flange facing for a carbon steel or stainless steel safety valve can be supplied only after verification and confirmation by LESER.
Flat face flange facing is not possible for

- all full nozzle design, like Type 526 or 458 or Type 488
- Critical Service safety valves Type 447 and 546
- Compact Performance safety valves equipped with flanges

**Ductile Iron**

According to ASME B16.42 ductile Iron equates to class 150 and class 300.

Class 150: Flat Face (FF) or Raised Face (RF)
Class 300: Raised Face (RF)

LESER can supply ductile iron valves, e.g. type 4415 or 4335 with raised face in class 150.

### 10.4.7 LCB, WCB and European Codes & Standards

LESER sources LCB with a fivefold material certificate for WCB, WCC, LCB, LCC and 1.0619. That means chemical composition and mechanical properties of the material fulfill the requirements of all five materials designations.

The applicability of WCB and LCB according to European Standards can be taken from the following EN standards:

1. EN 1503-2: „Valves - Materials for bodies, bonnets and covers“

   Part 2 of this standard contains steels for pressure retaining valve bodies, bonnets and covers which are not part of European material standards. WCB and LCB can be found in table 1, page 5.

2. EN 12516-1: „Industrial valves – shell designs strength – part 1: Calculation method for steel valve shells”

   This part of the EN12516 contains a method to determine the wall thickness of pressure retaining bodies of valves and includes pressure temperature ratings similar to EN 1092-1. 1.0619, WCB and LCB are grouped into different material groups:

| material | material group |
|---|---|
| 1.0619 | 3E0 |
| WCB | 1C1 |
| LCB | 1C3 |

*Table 10.4.7-1: Different matrial groups for wall thickness determination*

   This means also pressure temperature ratings for the materials are different.

**Customer benefit:**

In combination with LESER’s fivefold material certification this results in the following benefit for the customer: in borderline applications where the p/t limits of one material, e.g. 1.0619 are exceeded, the customer may select to use the p/t ratings of a material that meets the requirements due to its higher ratings, e.g. WCB. This may require to change the material designation within the customer’s specification, but does not require any changes of LESER’s products or documentation.

### 10.4.8 Class 400 and Class 4500

**Class 400**

Class 400 is not offered by LESER as a standard, only on request for replacement purposes. It is not available in ASME B16.34. Furthermore the class is not commonly used.

**Class 4500**

Class 4500 is not a flange rating. The class is used for butt weld ends only (see ASME B16.34 for additional information).

The connecting dimensions for butt welded end can be supplied, but not the Class 4500 pressure rating.

10.4.9 Codes and Standards – ASME Flanges

The following is a list of standards and specifications referenced in ASME B16.5.

**ASME Publications**

ASME B16.5, *Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24 metric / inch Standard*

ASME B16.20, *Metallic Gaskets for Pipe Flanges – Ring Joint, Spiral-Wound and Jacketed*

ASME B16.21, *Nonmetallic Flat Gaskets for Pipe Flanges*

ASME B16.34, *Valves – Flanged, threaded and welding end*

ASME PCC-1, *Guidelines for Pressure Boundary Bolted Flange Joint Assembly*

**MSS Publications**

MSS SP-6-2001, *Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings*

MSS SP-9-2001, *Spot Facing for Bronze, Iron and Steel Flanges*

MSS SP-25-1998, *Standard Marking System for Valves, Fittings, Flanges and Unions*

MSS SP-44-R2001, *Steel Pipeline Flanges*

MSS SP-45-1998, *Bypass and Drain Connections*

MSS SP-55-2001, *Quality Standard for Steel Casting for Valves, Flanges and Fittings*

MSS SP-61-1999, *Pressure Testing of Steel Valves*

## 10.5 Flanged Connections acc. to JIS B 2220/2239

There are two main standards covering flanges according to Japanese JIS (Japanese Industrial Standard) standards:

JIS B 2220 edition 2004: steel flanges
JIS B 2239 edition 2004: cast iron flanges

JIS B 2220 and JIS B 2239 contain dimensions as well as pressure temperature ratings.

Please note that the Korean Standard (KS) is identical to JIS.

### 10.5.1 Pressure/Temperature Ratings acc. to JIS B 2220/2239

**Overview of materials and their groups**

| LESER standard materials | | | |
|---|---|---|---|
| **Material** | **Material group** | **Further materials of material group** | |
| SA 395 | D1 | JIS B 8270 FCD-S (1)<br>JIS G 5502 FCD 350<br>JIS G 5502 FCD 400<br>JIS G 5502 FCD 450 | ISO 1083 350-22<br>ISO 1083 400-15<br>ISO 1083 450-10 |
| SA 105<br>SA 216 Gr. WCB | 1.1 | JIS G 3101 SS 400<br>JIS G 4051 S 20 C<br>JIS G 4051 S 25 C<br>JIS G 3201 SF 390A<br>JIS G 3202 SFVC 1<br>JIS G 3201 SF 440A<br>JIS G 3202 SFVC 2A<br>JIS G 5101 SC410<br>JIS G 5151 SCPH 1<br>JIS G 5101 SC 480<br>JIS G 5151 SCPH 11 | ISO 9328-2 PH 290<br>ISO 9328-2 PH 315<br>ISO 9328-2 PH 355<br>ISO 2604-1 F13<br>ISO 2604-1 F18<br>ISO 2604-1 F72<br>ISO 4991 C26-52H<br>SA 515 70<br>SA 516 70<br>SA 537 CL1<br>SA 350 LF2 |
| SA 217 Gr. WC6 | 1.9 | ISO 4991 C32H<br>A 387 11 CL2 | SA 182 F11 CL2<br>SA 182 F12 CL2 |
| SA 351 Gr. CF8M | 2.2 | JIS G 4304 SUS 316<br>JIS G 4305 SUS 316<br>JIS G 3214 SUS F316<br>JIS G 5121 SCS 14A<br>JIS G 5121 SCS 16A<br>ISO 9328-5 X 5 CrNiMo 17 12<br>ISO 9328-5 X 7 CrNiMo 17 12<br>ISO 2604-1 F62<br>ISO 2604-1 F64 | ISO 4991 C57<br>ISO 4991 C60<br>ISO 4991 C61<br>ISO 4991 C61LC<br>SA 240 316<br>SA 240 316H<br>SA 20 317<br>SA 182 F316<br>SA 182 F316H |
| SA 479 Gr. 316L | 2.3 | JIS G 4304 SUS304L<br>JIS G 4305 SUS304L<br>JIS G 3214 SUS F304L<br>JIS G 4304 SUS316L<br>JIS G 4305 SUS316L<br>JIS G 3214 SUS F316L | ISO 9328-5 X 2 CrNi 18 10<br>ISO 9328-5 X 2 CrNiMo 17 12<br>ISO 9328-5 X 2 CrNiMo 17 13<br>ISO 2604-1 F46<br>ISO 2604-1 F59<br>SA 240 304L<br>SA 182 F304L |

*Table 10.5.1-1: JIS – material groups*

## Overview of materials and their groups

| Further materials in standard which are not used by LESER generally | | |
|---|---|---|
| **Material group** | **Further materials of material group** | |
| G1 (2) | | SA 126 A |
| G2 | JIS G 5501 FC 200 | ISO 185 200<br>SA 126 B |
| G3 | JIS G 5501 FC 250 | ISO 185 250 |
| D2 (2) | | ISO 2531 400-5<br>ISO 1083 600-3 |
| M1 | JIS G 5705 FCMB 27-05 | ISO/DIS 5922 BF 27-05<br>ISO/DIS 5922 BF 30-06 |
| M2 | JIS G 5705 FCMB 35-10<br>JIS G 5705 FCMB 35-10S (1) | SA 47 32510<br>ISO/DIS 5922 BF 35-10 |
| 1.3 | JIS G 3203 SFVA F1 | JIS G 5151 SCPH 11 |
| 1.5 | JIS G 3203 SFVA F11A<br>JIS G 5151 SCPH 21 | A 204 A<br>A 204 B<br>A 182 F1<br>A 217 WC1<br>A 352 LC1<br>ISO 9328-2 16 Mo 3<br>ISO 2604-1 F28<br>ISO 4991 C28H |

*Table 10.5.1-2: JIS – material groups (continued)*

*Notes:*

(1) Impact values need not to be considered unless the impact value specified in the material standard requires to be satisfied by the regulation applied

(2) The material group symbols G1 and D2 are shown as information to indicate the configuration of the material group. The numerals of the mechanical properties indicates in ( ) are based on the corresponding standard.

## Divisions

JIS B 2220 distinguishes between Division I, II and III depending on the type and size of flange. Division II is the rating with some limitations put on that of Division I, while Divisions III is the rating with further limitations put on that of Division II.
For flange type WN (welding neck) and IT (integral) generally Division I applies. Therefore only pressure/temperature ratings for Division I are listed in this section of ENGINEERING. The only exemption in the scope of this section is material group: 2.3 (SA 479 Gr. 316L) where Division II applies for JIS 16K and flanges sizes > DN 200, see Table 10.5.1-8.

## Pressure/temperature ratings acc. to JIS B 2220/2239

**Material group: D1 (SA 395)**

| | Maximum temperature [°C] | | | | |
|---|---|---|---|---|---|
| | -10 | 120 | 220 | 300 | 350 |
| **Class** | **Maximum pressure [bar]** | | | | |
| 10K | 14 | 14 | 12 | 10 | - |
| 16K | 22 | 22 | 20 | 18 | 16 |
| 20K | 28 | 28 | 25 | 23 | 20 |

*Table 10.5.1-3: Pressure/temperature ratings acc. to JIS B 2239 – D1*

**Material group: 1.1 (SA 216 Gr. WCB)**

| | Maximum temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_L$ to 120 | 120 | 220 | 300 | 350 | 400 | 425 | 450 | 475 | 490 |
| **Class** | **Maximum pressure [bar]** | | | | | | | | | |
| 10K | 14 | 14 | 12 | 10 | - | - | - | - | - | - |
| 16K | 27 | 27 | 25 | 23 | 21 | 18 (9) | 16 (9) | - | - | - |
| 20K | 34 | 34 | 31 | 29 | 26 | 23 (9) | 20 (9) | - | - | - |
| 30K | 51 | 51 | 46 | 43 | 39 | 34 (9) | 30 (9) | - | - | - |

*Table 10.5.1-4: Pressure/temperature ratings acc. to JIS B 2220 – 1.1*

**Material group: 1.1 (SA 216 Gr. WCB)**

| | Maximum temperature [°C] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_A$ to 120 | 120 | 220 | 300 | 350 | 400 | 425 | 450 | 475 | 490 | 500 | 510 |
| **Class** | **Maximum pressure [bar]** | | | | | | | | | | | |
| 40K | 68 | 68 | 62 | 57 | 52 | 46 (14) | 40 (14) | - | - | - | - | - |
| 63K | 107 | 107 | 97 | 90 | 81 | 72 (14) | 63 (14) | - | - | - | - | - |

*Table 10.5.1-5: Pressure/temperature ratings acc. to JIS B 2220 Annex 6 – 1.1*

**Material group: 2.2 (SA 351 Gr. CF8M)**

| | Maximum temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_L$ to 120 | 120 | 220 | 300 | 350 | 400 | 425 | 450 | 475 | 490 |
| **Class** | **Maximum pressure [bar]** | | | | | | | | | |
| 10K | 14 | 14 | 12 | 10 | - | - | - | - | - | - |
| 16K | 27 | 27 | 25 | 23 | 21 | 18 | 16 | - | - | - |
| 20K | 34 | 34 | 31 | 29 | 26 | 23 | 20 | - | - | - |
| 30K | 51 | 51 | 46 | 43 | 39 | 38 | 36 | 34 (11) | 32 (11) (12) | 30 (11) (12) |

*Table 10.5.1-6: Pressure/temperature ratings acc. to JIS B 2220 – 2.2*

**Material group: 2.3 (SA 479 Gr. 316L) – Division I (≤ DN 200)**

| | Maximum temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_L$ to 120 | 120 | 220 | 300 | 350 | 400 | 425 | 450 | 475 | 490 |
| **Class** | **Maximum pressure [bar]** | | | | | | | | | |
| 10K | 14 | 14 | 12 | 10 | - | - | - | - | - | - |
| 16K | 27 | 27 | 25 | 23 | 21 | 18 | 16 | - | - | - |
| 20K | 34 | 34 | 31 | 29 | 26 | 23 | 20 | - | - | - |
| 30K | 51 | 51 | 46 | 43 | 39 | 38 | 36 | 34(13) | - | - |

*Table 10.5.1-7: Pressure/temperature ratings acc. to JIS B 2220 – 2.3*

**Material group: 2.3 (SA 479 Gr. 316L) – Division II (> DN 200)**

| | Maximum temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_L$ to 120 | 120 | 220 | 300 | 350 | 400 | 425 | 450 | 475 | 490 |
| **Class** | **Maximum pressure [bar]** | | | | | | | | | |
| 16K | 16 | 16 | 16 | 15 | 14 | 13 | 13 | - | - | - |

*Table 10.5.1-8: Pressure/temperature ratings acc. to JIS B 2220 – 2.3*

*General notes:*

(1) $T_L$ is a minimum working temperature which is the normal temperature or below. The minimum working temperature lower than the normal temperature shall be subjected to the agreement between the parties concerned.
$T_A$ is the normal temperature.

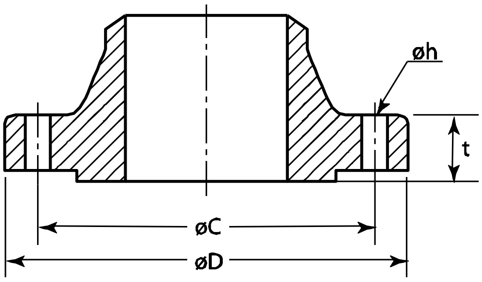
*Notes:*

(9) Not applicable to JIS G 5101 SC 480 of material group 002 and ASTM SA 537 CLI and ISO 9328-2 PH355 of material group 1.1
(11) Not applicable to ASTM SA 351 CF3 and ISO 4991 C46 of material group 021b and 2.1
(12) Not applicable to ASTM SA 351 CF3M of material group 022b and 2.2, ISO 4991 C57, ISO 4991 C60, ISO 4991 C61 and ISO 4991 C61LC
(13) Not applicable to ASTM SA 240 304L of material group 023a and 2.3, ASTM A 182 F304L and ISO 9328-5 X 2CrNi 1810
(14) Not to be applied to SC 480 of material group 002

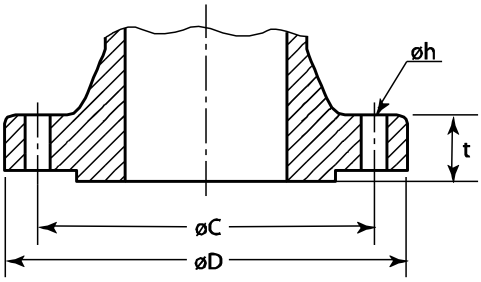
10.5.2 Dimensions acc. to JIS B 2220/JIS 2239

The standards JIS B 2220/JIS B 2239 contain several types of flanges. The flange dimensions depend on different flange types.
Only IT (integral) and WN (welding neck) steel flanges and IT (integral) cast iron flanges in sizes of DN 15 to DN 500 are used by LESER and are listed in the tables below.
The tables are sorted by pressure classes in ascending order. Flanges are generally offered up to nominal pressure of 30K.

**Types of flanges:**




**WN**
**Nominal size 10A – 1500A**




**IT**
**Nominal size 10A – 1500A**

*Figure 10.5.2-1: JIS B 2220 – types of flanges made of steel*

## Dimensions acc. to JIS B 2220/JIS B 2239

### Nominal pressure 10K [mm]

| Nominal size | Connection dimensions | | | | | Thickness of flange | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | C | h | Number | Size | t | |
| | Steel cast iron | | | | | Steel | Cast iron |
| | Type of flange | | | | | | |
| | WN IT | | | | | | IT D1 |
| 15 | 95 | 70 | 15 | 4 | M12 | 12 | 16 |
| 20 | 100 | 75 | 15 | 4 | M12 | 14 | 18 |
| 25 | 125 | 90 | 19 | 4 | M16 | 14 | 18 |
| 32 | 135 | 100 | 19 | 4 | M16 | 16 | 20 |
| 40 | 140 | 105 | 19 | 4 | M16 | 16 | 20 |
| 50 | 155 | 120 | 19 | 4 | M16 | 16 | 20 |
| 65 | 175 | 140 | 19 | 4 | M16 | 18 | 22 |
| 80 | 185 | 150 | 19 | 8 | M16 | 18 | 22 |
| 100 | 210 | 175 | 19 | 8 | M16 | 18 | 24 |
| 125 | 250 | 210 | 23 | 8 | M20 | 20 | 24 |
| 150 | 280 | 240 | 23 | 8 | M20 | 22 | 26 |
| 200 | 330 | 290 | 23 | 12 | M20 | 22 | 26 |
| 250 | 400 | 355 | 25 | 12 | M22 | 24 | 30 |
| 300 | 445 | 400 | 25 | 16 | M22 | 24 | 32 |
| 350 | 490 | 445 | 25 | 16 | M22 | 26 | 34 |
| 400 | 560 | 510 | 27 | 16 | M24 | 28 | 36 |
| 450 | 620 | 565 | 27 | 20 | M24 | 30 | 38 |
| 500 | 675 | 620 | 27 | 20 | M24 | 30 | 40 |

*Table 10.5.2-1: JIS B 2220/JIS B 2239 – dimensions of flanges – pressure class 10K [mm]*

### Nominal pressure 16K [mm]

| Nominal size | Connection dimensions | | | | | Thickness of flange | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | C | h | Number | Size | t | |
| | Steel cast iron | | | | | Steel | Cast iron |
| | Type of flange | | | | | | |
| | WN IT | | | | | | IT D1 |
| 15 | 95 | 70 | 15 | 4 | M12 | 12 | 16 |
| 20 | 100 | 75 | 15 | 4 | M12 | 14 | 18 |
| 25 | 125 | 90 | 19 | 4 | M16 | 14 | 18 |
| 32 | 135 | 100 | 19 | 4 | M16 | 16 | 20 |
| 40 | 140 | 105 | 19 | 4 | M16 | 16 | 20 |
| 50 | 155 | 120 | 19 | 8 | M16 | 16 | 20 |
| 65 | 175 | 140 | 19 | 8 | M16 | 18 | 22 |
| 80 | 200 | 160 | 23 | 8 | M20 | 20 | 24 |
| 100 | 225 | 185 | 23 | 8 | M20 | 22 | 26 |
| 125 | 270 | 225 | 25 | 8 | M22 | 22 | 26 |
| 150 | 305 | 260 | 25 | 12 | M22 | 24 | 28 |
| 200 | 350 | 305 | 25 | 12 | M22 | 26 | 30 |
| 250 | 430 | 380 | 27 | 12 | M24 | 28 | 34 |
| 300 | 480 | 430 | 27 | 16 | M24 | 30 | 36 |
| 350 | 540 | 480 | 33 | 16 | M30x3 | 34 | 38 |
| 400 | 605 | 540 | 33 | 16 | M30x3 | 38 | 42 |
| 450 | 675 | 605 | 33 | 20 | M30x3 | 40 | 46 |
| 500 | 730 | 660 | 33 | 20 | M30x3 | 42 | 50 |

*Table 10.5.2-2: JIS 2220/JIS 2239 – dimensions of flanges – pressure class 16K [mm]*

## Dimensions acc. to JIS B 2220/JIS B 2239

### Nominal pressure 20K [mm]

| Nominal size | Connection dimensions | | | | | Thickness of flange | |
|---|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | | |
| | D | C | h | Number | Size | t | |
| | Steel cast iron | | | | | Steel | Cast iron |
| | Type of flange | | | | | | |
| | WN IT | | | | | | IT D1 |
| 15 | 95 | 70 | 15 | 4 | M12 | 14 | 16 |
| 20 | 100 | 75 | 15 | 4 | M12 | 16 | 18 |
| 25 | 125 | 90 | 19 | 4 | M16 | 16 | 20 |
| 32 | 135 | 100 | 19 | 4 | M16 | 18 | 20 |
| 40 | 140 | 105 | 19 | 4 | M16 | 18 | 22 |
| 50 | 155 | 120 | 19 | 8 | M16 | 18 | 22 |
| 65 | 175 | 140 | 19 | 8 | M16 | 20 | 24 |
| 80 | 200 | 160 | 23 | 8 | M20 | 22 | 26 |
| 100 | 225 | 185 | 23 | 8 | M20 | 24 | 28 |
| 125 | 270 | 225 | 25 | 8 | M22 | 26 | 30 |
| 150 | 305 | 260 | 25 | 12 | M22 | 28 | 32 |
| 200 | 350 | 305 | 25 | 12 | M22 | 30 | 34 |
| 250 | 430 | 380 | 27 | 12 | M24 | 34 | 38 |
| 300 | 480 | 430 | 27 | 16 | M24 | 36 | 40 |
| 350 | 540 | 480 | 33 | 16 | M30x3 | 40 | 44 |
| 400 | 605 | 540 | 33 | 16 | M30x3 | 46 | 50 |
| 450 | 675 | 605 | 33 | 20 | M30x3 | 48 | 54 |
| 500 | 730 | 660 | 33 | 20 | M30x3 | 50 | 58 |

*Table 10.5.2-3: JIS 2220/JIS 2239 – dimensions of flanges– pressure class 20K [mm]*

### Nominal pressure 30K (steel flanges) [mm]

| Nominal size | Connection dimensions | | | | | Thickness of flange |
|---|---|---|---|---|---|---|
| | Outside diameter | Bolt circle diameter | Bolt hole diameter | Bolting | | |
| | D | C | h | Number | Size | t |
| | Type of flange | | | | | |
| | WN IT | | | | | |
| 15 | 115 | 80 | 19 | 4 | M16 | 18 |
| 20 | 120 | 85 | 19 | 4 | M16 | 18 |
| 25 | 130 | 95 | 19 | 4 | M16 | 20 |
| 32 | 140 | 105 | 19 | 4 | M16 | 22 |
| 40 | 160 | 120 | 23 | 4 | M20 | 22 |
| 50 | 165 | 130 | 19 | 8 | M16 | 22 |
| 65 | 200 | 160 | 23 | 8 | M20 | 26 |
| 80 | 210 | 170 | 23 | 8 | M20 | 28 |
| 90 | 230 | 185 | 25 | 8 | M22 | 30 |
| 100 | 240 | 195 | 25 | 8 | M22 | 32 |
| 125 | 275 | 230 | 25 | 8 | M22 | 36 |
| 150 | 325 | 275 | 27 | 12 | M24 | 38 |
| 200 | 370 | 320 | 27 | 12 | M24 | 42 |
| 250 | 450 | 390 | 33 | 12 | M30x3 | 48 |
| 300 | 515 | 450 | 33 | 16 | M30x3 | 52 |
| 350 | 560 | 495 | 33 | 16 | M30x3 | 54 |
| 400 | 630 | 560 | 39 | 16 | M36x3 | 60 |

*Table 10.5.2-4: JIS 2220 – dimensions of flanges made of steel – pressure class 30K [mm]*

## Compatibility of JIS B 2220/JIS B 2239 and ASME B16.5

Its possible to connect JIS flanges with flanges according to ASME B16.5, see the compatibility list below for more information.

| JIS B 2220/JIS B 2239 | ASME B16.5 | Compatibility of drilling template and raised face | Compatibility of outer diameter of flange |
|---|---|---|---|
| DN 50, 10K | NPS 2”, CL 150 | x | |
| DN 50, 16K | NPS 2”, CL 150 | x | |
| DN 65, 10K | NPS 2½”, CL 150 | x | x |
| DN 65, 16K | NPS 2½”, CL 150 | x | x |
| DN 65, 20K | NPS 2½”, CL 150 | x | x |
| DN 80, 10K | NPS 3”, CL 150 | x | x |
| DN 80, 16K | NPS 3”, CL 150 | x | |
| DN 80, 20K | NPS 3”, CL 150 | x | |
| DN 100, 10K | NPS 4”, CL 150 | x | x |
| DN 100, 16K | NPS 4”, CL 150 | x | x |
| DN 125, 10K | NPS 5”, CL 150 | x | x |
| DN 125, 16K | NPS 5”, CL 150 | x | |
| DN 150, 10K | NPS 6”, CL 150 | x | |
| DN 200, 10K | NPS 8”, CL 150 | x | x |
| DN 250, 10K | NPS 10”, CL 150 | x | x |

*Table 10.5.2-5: Compability list for JIS flanges with flanges acc. to ASME B16.5*

### 10.5.3 Codes and Standards – JIS Flanges

JIS B 2001, *Nominal size and bore of valves*

ISO 2531, Ductile *iron pipes, fittings, accessories and their joints for water or gas application*

JIS G 3468, *Large diameter welded stainless steel pipes*

JIS B 2220, *Steel pipe flanges*

JIS B 2239, *Cast iron pipe flanges*

JIS B 2240 *Copper alloy pipe flanges*

JIS B 2241 *Aluminium pipe flanges*

## 10.6 Threaded Connections

This section shall provide an overview about different international thread standards and how they are linked with each other. For more information about available threaded connections and option codes for LESER Compact Performance safety valves see LESERs catalog and price lists.

**Pressure / temperature ratings**

Unlike for flanged connections there are no standards which provide information about pressure-temperature ratings of threaded connections.
On the side of the protected system the wall thickness of the pipe respectively the pipe schedule determines the pressure rating of the pipe.
For the inlet and outlet bodies of the Compact Performance safety valves LESER has performed design strength calculations based on the wall thickness of the body. These calculations are verified during the certification of the safety valves according to PED Directive and ASME Code by the notified bodies TUEV and National Board.
The pressure-temperature ratings for the individual valve types and connections are documented in the Compact Performance catalog and are marked on every inlet body in PN and Class designations.

**Male and female connections**

Generally it can be distinguished between so called male and female connections. The most commonly used combination for safety valves is a male inlet and a female outlet.

Most common
male inlet / female outlet

Alternative
female inlet / female outlet

*Figure 10.6.-1: General view of a safety valve with threaded connections*

**Overview about international thread standards**

A major differentiation between threads is the point of sealing, which can be on the thread or not on the thread by e.g. a sealing ring between the two components.

There are two basic international standards for threaded connections in which a sealed joint is obtained between the flanks of the screw threads.

1. ANSI/ASME B1.20.1 (thread abbreviation “NPT”)
2. International standard ISO 7-1 third edition from 1994 (thread abbreviation “R”)

## Threaded connections - sealing on thread

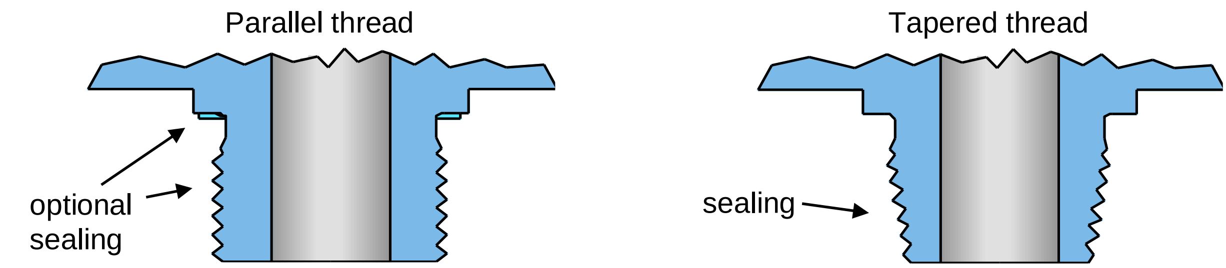



*Figure 10.6-2: Parallel and tapered thread*

| Main standard | Symbol | Form | Thread | | National standards | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Female | Male | DE | GB | US | BR | ZA | JP |
| ANSI / ASME B1.20.1 | NPT | Tapered | x | x | - | - | ANSI / ASME B1.20.1 | NBR 12912 | - | - |
| ANSI / ASME B1.20.3 | NPTF | Tapered | x | x | - | - | ANSI / ASME B1.20.3 | - | - | - |
| | PS | Parallel | x | | - | - | - | - | - | JIS B 0203 (Annex 1) |
| | PT | Tapered | x | x | - | - | - | - | - | JIS B 0203 (Annex 1) |
| ISO 7-1 | R | Tapered | | x | DIN 2999-1 | BS 21 [BSP(T)] | - | NBR 8133 | SABS 1109 | JIS B 0203 |
| ISO 7-1 | Rc | Tapered | x | | - | BS 21 [BSP(T)] | - | NBR 8133 | SABS 1109 | JIS B 0203 |
| ISO 7-1 | Rp | Parallel | x | | DIN 2999-1 | BS 21 [BSP(P)] | - | NBR 8133 | SABS 1109 | JIS B 0203 |
| | Rs (1) | Parallel | | x | - | BS 21 (Annex C) | - | - | - | - |

*Table 10.6-1: Threaded connections sealing on thread*

*Notes:*

(1) a sealing strip is required

## Threaded connections - not sealing on thread

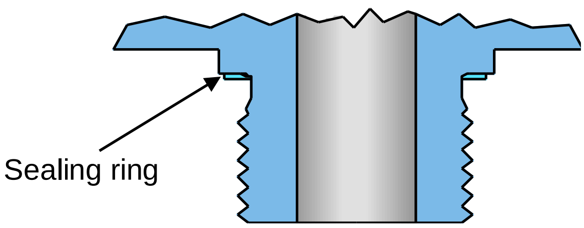



*Figure 10.6-3: Parallel and tapered thread*

| Main standard | Symbol | Form | Thread | | National standards | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Female | Male | DE | GB | US | BR | ZA | JP |
| ISO 228-1 | G | Parallel | x | x | DIN ISO 228-1 | BS 2779 | - | NBR 6414 | SABS 1306 | JIS B 0202 |
| | PS | Parallel | x | x | - | - | - | - | - | JIS B 0202 Appendix |

*Table 10.6-2: Threaded connections not sealing on thread*

### 10.6.1 Threaded Connections acc. to ISO 7-1

**Pipe thread for connections sealing on the thread**

In the case of threaded connections in accordance with ISO 7-1, the male thread is always a tapered thread whereas the female thread may be either parallel or tapered. The thread geometry is historically based on the Whitworth thread (55° thread angle). If one of the listed national standards is needed LESER supplies and certifies the standard ISO 7-1.

The following abbreviations are used:

- R tapered male thread
- $R_c$ tapered female thread
- $R_p$ parallel female thread

National standards

- Federal Republic of Germany – DIN 2999
  DIN 2999 "Pipe threads" for tubes and fittings.
  Special feature: only the parallel female thread is shown in DIN 2999, because tapered female threads are not in standard use in Germany and do not therefore need to be standardized. This is the reason why ISO 7-1 was not published as DIN ISO 7-1 but as national DIN standard
- United Kingdom – BS 21
  BS 21 Pipe threads for tubes and fittings where pressure tight joins are made on threads (metric dimensions)
  BS 21 refers to ISO 7-1 with regard of tolerances. The thread designations have been included unchanged. The types of thread gauges have mainly been defined including – and this is a special British feature – those for testing "long screwed threads" for gas applications. Long screwed threads are extended male threads which can be given the abbreviation RL. The following designations are frequently found: BSP(T) for taper or BSP(P) for parallel threads.
  **Rs**
  In addition, a parallel male thread with the designation Rs is defined for gas applications in Appendix C of BS 21. An additional gasket is required here for sealing at the end face or at the end of thread. The nominal dimensions of this thread correspond to those of ISO 228-1, but a greater thread clearance results from the tolerance values
- Brazil – NBR 8133
  ISO 7-1 is used in Brazil under the number NBR 8133.
  Both the taper and parallel threads are defined in this standard. The designations correspond to the ISO designations.
- South Africa – SABS 1109
  ISO 7-1 is used in South Africa under the number SABS 1109.
  Both the taper and parallel threads are defined in this standard. The designations correspond to the ISO designations.
- Japan – JIS B 0203
  ISO 7-1 is used in Japan under the number JIS B 0203.
  Both the taper and parallel threads are defined in this standard. The designations correspond to the ISO designations.
  **PT, PS**
  In Annex 1 of JIS B 0203 the designations PT and PS are mentioned. PT describes external and internal taper threads. PS describes parallel female thread fitting to taper male threads. Threads up to 6" are exactly the same as mentioned in ISO 7-1. The difference is that ISO 7-1 specifies threads only up to 6" while the annex 1 of JIS B 0203 goes up to 12" threads

**Pipe thread for connections not sealing on the thread in accordance with ISO 228-1 (“G” designation)**

The threads described in ISO 228-1 are parallel threads which correspond to the threads of ISO 7-1 in terms of their thread pitch and thread angle. The essential difference is the parallel male thread of the connection which prevents sealant from being introduced into the thread. Threads in accordance with ISO 228-1 are sealed by gaskets on the end face or on the top end of thread.
ISO 228-1 and ISO 7-1 differ from one another in the tolerance values for the thread. However, in theory an male G thread in accordance with ISO 228-1 can be screwed into an femalel Rp thread in accordance with ISO 7-1.

**ISO 228-1 National Standards**

| | |
|---|---|
| Germany | DIN ISO 228-1 |
| United Kingdom | BS 2779 |
| Brazil | NBR 6414 |
| South Africa | NBR 1306 |
| Japan | JIS B 0202 |

10.6.2 Threaded Connections acc. to ASME B1.20.1/B1.20.3

**Pipe thread for connections sealing on the thread**

**ANSI/ASME B1.20.1 thread abbreviation "NPT"**

In US-influenced markets NPT threads in accordance with ANSI/ASME B1.20.1 are standard. These threads differ from the ISO 7-1 threads in the thread angle (60°) and to some extent in the thread pitch. The male and female threads of NPT threads have a tapered form.

**National standards based on ANSI/ASME B1.20.1**

| | |
|---|---|
| Brazil | NBR 12912 |

**ANSI / ASME B1.20.3, thread abbreviation “NPTF”**

In rare cases a metallic sealing thread is used acc. to ANSI / ASME B1.20.3 as a so called NPTF thread. To accomplish this some modifications of thread form and greater accuracy in manufacture is required.
Nevertheless, according to ANSI / ASME B1.20.3 it is advised to use sealing band. Even the refrigeration industry, where metallic sealings are favoured, accepts usage of additional sealing material (see ANSI B1.20.3, Chapter 1.1 footnote for more information).

**Commonly used shortcuts**

| | |
|---|---|
| FNPT | female NPT |
| MNPT | male NPT |

### 10.6.3 Minimum Inside Diameters for Compact Performance Safety Valves

Compact Performance safety valves can be supplied with a large variety of connections at the inlet and outlet.

When type and size of a connection are selected it must be considered that specific minimum inside diameters at inlet and outlet of the safety valve are required. This applies to all types of connections like threaded, welded of flanged connections.

This means that at no part of the inlet or outlet piping the inside diameter should fall below the listed minimum diameters. Otherwise the flow path would be restricted and the safety valve cannot discharge its full rated capacity or may chatter. Further the minimum wall thickness of an inlet male connection is 2 mm.

| Type | Orifice diameter $d_0$ [mm] | Minimum inside diameter [mm] | |
|---|---|---|---|
| | | Inlet | Outlet |
| 437/438/439 | 6 | 8 | 16 |
| | 10 | 12.5 | |
| 459/462 | 6 | 10 | 26.4 |
| | 9 | 12.5 | |
| | 13 | 15 | |
| | 17.5 | 21 | 34 |

*Table 10.6.3-1: Minimum inside diameters for Compact Performance safety valves*

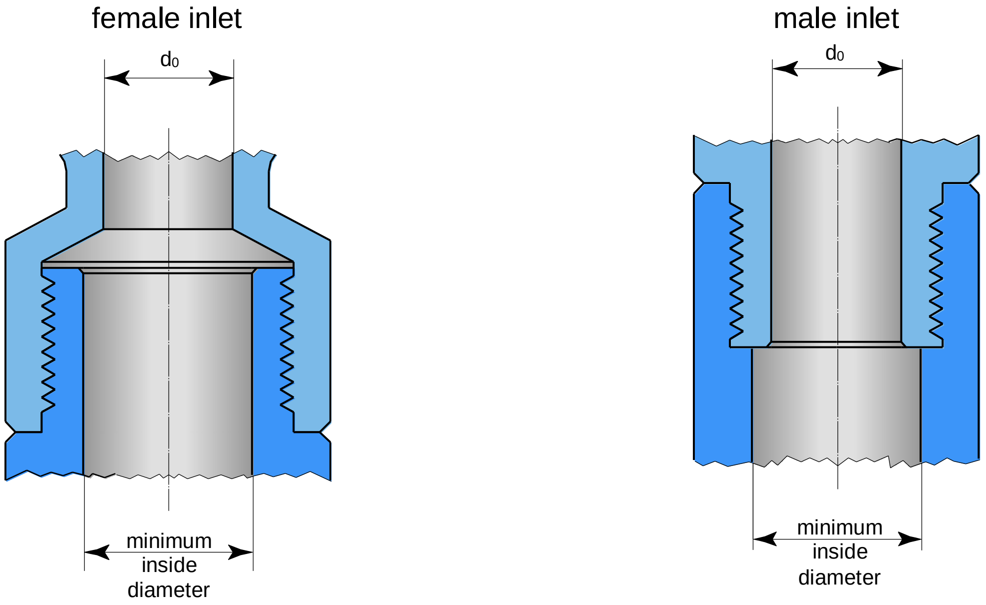



*Figure 10.6.3-1: Minimum inside diameters for female and male inlets*

10.6.4 Codes and Standards – Threaded Connections

ISO 228-1, *Pipe threads where pressure-tight joints are not made on the threads – part 1: dimensions, tolerances and designation*

ANSI B1.2, *Gages and Gaging for Unified Screw Threads*

ANSI B1.7, *Screw Threads: Nomenclature, Definitions, and Letter Symbols*

ANSI B1.20.3, *Dryseal pipe threads [inch]*

ANSI B1.20.4, *Dryseal pipe threads (Metric Translation)*

ANSI B1.20.5, *Gaging for Dryseal pipe threads [inch]*

ANSI B1.20.6M, *Gaging for Dryseal pipe threads (Metric Translation)*

ANSI B2.2, *Brazing procedure and performance Qualification*

ANSI B2.4, *Specification for Welding Procedure and Performance Qualification for Thermoplastics*

ANSI B47.1, *Gage Blanks*

## 10.7 Welding Ends

Welding ends are used for high pressure / high temperature applications, when it becomes difficult to obtain suitable gasket materials for a flanged connection. Valve repair also becomes an issue, because the repair of the valve is in most cases performed in situ.

Recommendation

LESER recommends a savety valve with full nozzle if a welding end is requested. On the one hand the pressure classes are maintained, on the other hand the dimensions of the welding end can be arranged more flexible. Therefore this section is focused on full nozzle valves.

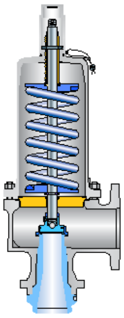


*Figure 10.7-1:LESER type 457*
*With full nozzle and welding end at the inlet*

The following information are necessary to determine the welding end at the safety valve:

- requested material of nozzle (must be weldable to the pipe)
- pipe standard
- wall thickness of pipe
- inner diameter of pipe

**General information**

Following drawing shows the design of an inlet welding end for a full nozzle type safety valve:

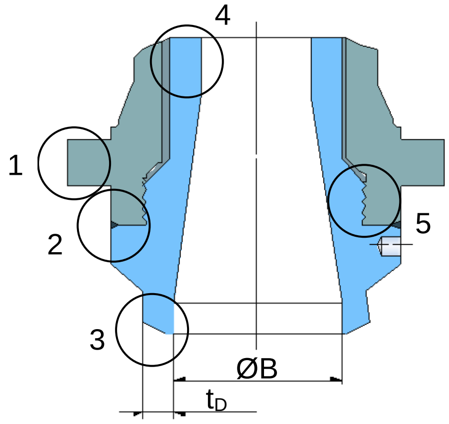



*Figure 10.7.0-2: Inlet welding end*

*Notes:*

(1) collar - necessary to clamp the valve on the test bench
(2) seal weld
(3) welding end acc. to
  - EN
  - ASME
(4) Material
(5) thread

### 10.7.1 Materials for Welding Ends

The nozzle of the safety valve is typically 316L or CF8M. Other materials may be used, but the seat of the safety valve should be corrosion resistant stainless steel. If a carbon steel nozzle is required a stellited seat must be foreseen.

### 10.7.2 Welding Ends acc. to EN 12627

The standard EN 12627 differentiates between two welded joints. Up to a wall thickness of 4 mm a butt joint with square weld can be used. Up to a wall thickness of 22 mm a v-single weld has to be used.

At LESER all connections are welded with a v-single weld up a wall thickness of 22 mm. At higher wallthicknesses multiple welding layers are used.

Exception: Clean Service safety valves Series 48X, which are supplied with a square weld end.

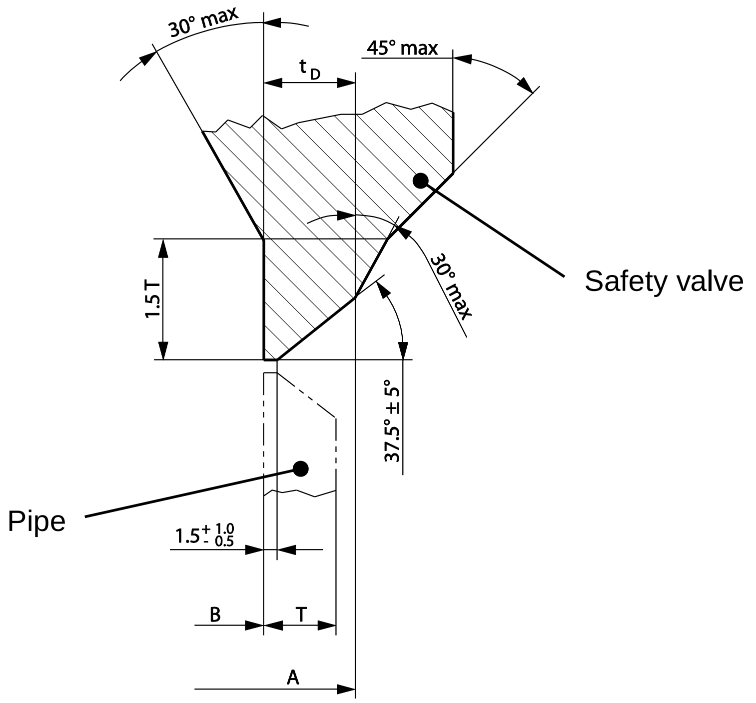



*Figure 10.7.2-1: Welding end with single v weld for connection of pipe with wall thickness up to 22 mm*

Following tables are an extraction of EN 12627. Welding dimensions are available from DN 15 to DN 500.

| Nominal size of valve | ØA | Tolerance |
|---|---|---|
| DN 15 | 22 | +2.5<br>-1 |
| DN 20 | 28 | +2,5<br>-1,5 |
| DN 25 | 35 | |
| DN 32 | 44 | +2,5<br>-2 |
| DN 40 | 50 | |
| DN 50 | 62 | |
| DN 65 | 77 | +2,5<br>-2,5 |
| DN 80 | 91 | |
| DN 100 | 117 | |

| Nominal size of valve | ØA | Tolerance |
|---|---|---|
| DN 125 | 144 | +4<br>-2,5 |
| DN 150 | 172 | |
| DN 200 | 223 | |
| DN 250 | 278 | |
| DN 300 | 329 | |
| DN 350 | 362 | |
| DN 400 | 413 | |
| DN 450 | 464 | |
| DN 500 | 516 | |

*Table 10.7.2-1: Dimensions and tolerances of outside diameter ØA of welding end [mm]*

| Nominal size of valve | DN 8 - DN 250 | DN 300 - DN 450 | DN 500 – DN 1400 |
|---|---|---|---|
| **Tolerance of ØB** | +1<br>-1 | +2<br>-2 | +3<br>-2 |

*Table 10.7.2-2: Tolerance of inside diameter B of welding end [mm]*

### Inside Diameter

The inside diameter B of the welding end has to be equal to the nominal inside diameter of the pipe acc. to ISO 4200, on which it has to be welded.

The standard ISO 4200 provides the basis for the standard EN ISO 1127. Pipe dimensions are equal in both standards.

For pipe dimensions see the following table acc. to ISO 4200.

### Preferenced wall-thickness according to ISO 4200 [mm]

| Outside diameter of pipe | Preferenced wall-thickness | | | | | | |
|---|---|---|---|---|---|---|---|
| | Category | | | | | | |
| | A | B | C | D | E (1) | F | G |
| | Stainless | | | Alloyed, non-alloyed | Stainless, alloyed, non-alloyed | | |
| 10.2 | 1.6 | - | - | | 1.6 | - | - |
| 13.5 | 1.6 | - | - | 1.6 | 2 | - | - |
| 17.2 | 1.6 | - | - | 1.6 | 2 | - | - |
| 21.3 | 1.6 | - | - | 1.8 | 2 | 3.2 | 4 |
| 26.9 | 1.6 | - | - | 1.8 | 2 | 3.2 | 4 |
| 33.7 | 1.6 | 2 | - | 2 | 2.3 | 3.2 | 4.5 |
| 42.4 | 1.6 | 2 | - | 2.3 | 2.6 | 3.6 | 5 |
| 48.3 | 1.6 | 2 | - | 2.3 | 2.6 | 3.6 | 5 |
| 60.3 | 1.6 | 2 | 2.3 | 2.3 | 2.9 | 4 | 5.6 |
| 76.1 | 1.6 | 2.3 | 2.6 | 2.6 | 2.9 | 5 | 7.1 |
| 88.9 | 2 | 2.3 | 2.9 | 2.9 | 3.2 | 5.6 | 8 |
| 114.3 | 2 | 2.6 | 2.9 | 3.2 | 3.6 | 6.3 | 8.8 |
| 139.7 | 2 | 2.6 | 3.2 | 3.6 | 4 | 6.3 | 10 |
| 168.3 | 2 | 2.6 | 3.2 | 4 | 4.5 | 7.1 | 11 |
| 219.1 | 2 | 2.6 | 3.6 | 4.5 | 6.3 | 8 | 12.5 |
| 273 | 2 | 3.6 | 4 | 5 | 6.3 | 10 | - |
| 323.9 | 2.6 | 4 | 4.5 | 5.6 | 7.1 | 10 | - |
| 355.6 | 2.6 | 4 | 5 | 5.6 | 8 | 11 | - |
| 406.4 | 2.6 | 4 | 5 | 6.3 | 8.8 | 12.5 | - |
| 457 | 3.2 | 4 | 5 | 6.3 | 10 | - | - |
| 508 | 3.2 | 5 | 5.6 | 6.3 | 11 | - | - |

*Table 10.7.2 -3: Preferenced wall thickness acc. to ISO 4200*

*Notes:*

(3) Selection of wall-thickness acc. to prior ISO 134

To define the correct welding end, the following information are required:

- pipe dimensions
- material

10.7.3 Welding Ends (Butt welded) acc. to ASME B16.25 and ASME B16.9

Only welding ends for wall thicknesses up to 22 mm are described in this chapter.

There are two used standards at LESER:
ASME B16.25 (2003) for a wall thickness from 3 mm up to 10 mm (see figure 10.7.3-1)
ASME B16.9 (2003) for a wall thickness larger than 10 mm (see figure 10.7.3-2).

In most case ASME B16.25is applied.

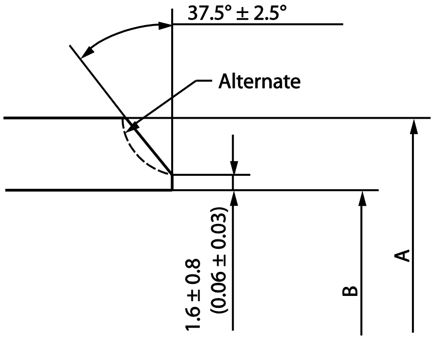



***Figure 10.7.3-1: ASME B16.25 – weld bevel details for GTAW Root Pass with wall thickness from 3 mm up to 10 mm***

*General Notes:*

(a) This detail applies for gas tungsten arc welding (GTAW) of the root pass where nominal wall thickness is over 3 mm (0.12 inch) to 10 mm (0.38 inch) inclusive

(b) Linear dimensions are in millimeters with inch values in parentheses

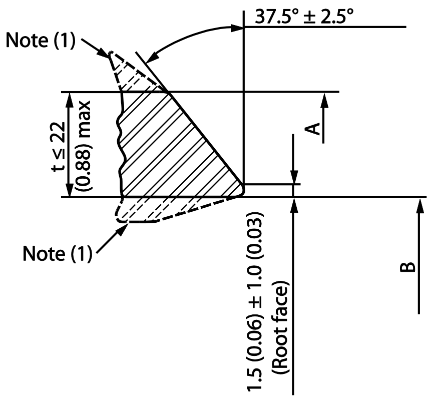



***Figure 10.7.3-2: ASME B16.9 – Plain bevel From x (2) mm up to 22 mm***

*General notes:*

a. Dimensions in parentheses are in inches

b. Other dimensions are in millimeters

*Notes:*

(1) see ASME B16.9 chapter 8 and fig. 1 for transition contours

(2) x = 5 (0.19) for carbon steel or ferritic alloy steel and 3 (0.12) for austenitic alloy steel

## Dimensions of welding ends [mm]

The standard ASME B16.25 describes welding ends from a nominal size of 2½“ up to 36”. This extraction deals only with sizes from 2 ½” up to 16”.
The schedule number is a designation system that combines sizes and wall thicknesses for ordering pipes.

| | O.D. at welding ends | | | |
|---|---|---|---|---|
| Nominal pipe size | Schedule no. (1) | Wrought or fabricated components (1) A | Cast components A | B |
| 2½” | 40 | 73.0 | 75 | 62.5 |
| | 80 | 73.0 | 75 | 59 |
| | 160 | 73.0 | 75 | 54 |
| | XXS | 73.0 | 75 | 45 |
| 3” | 40 | 88.9 | 91 | 78 |
| | 80 | 88.9 | 91 | 73.5 |
| | 160 | 88.9 | 91 | 66.5 |
| | XXS | 88.9 | 91 | 58.5 |
| 3½” | 40 | 101.6 | 105 | 90 |
| | 80 | 101.6 | 105 | 85.5 |
| 4” | 40 | 114.3 | 117 | 102 |
| | 80 | 114.3 | 117 | 97 |
| | 120 | 114.3 | 117 | 92 |
| | 160 | 114.3 | 117 | 87.5 |
| | XXS | 114.3 | 117 | 80 |
| 5” | 40 | 141.3 | 144 | 128 |
| | 80 | 141.3 | 144 | 122 |
| | 210 | 141.3 | 144 | 116 |
| | 160 | 141.3 | 144 | 109-5 |
| | XXS | 141.3 | 144 | 103 |
| 6” | 40 | 168.3 | 172 | 154 |
| | 80 | 168.3 | 172 | 146-5 |
| | 120 | 168.3 | 172 | 140 |
| | 160 | 168.3 | 172 | 132 |
| | XXS | 168.3 | 172 | 124.5 |
| 8” | 40 | 219.1 | 223 | 203 |
| | 60 | 219.1 | 223 | 198.5 |
| | 80 | 219.1 | 223 | 193.5 |
| | 100 | 219.1 | 223 | 189 |
| | 120 | 219.1 | 223 | 182.5 |
| | 140 | 219.1 | 223 | 178 |
| 10” | 40 | 273.0 | 278 | 254.5 |
| | 60 | 273.0 | 278 | 247.5 |
| | 80 | 273.0 | 278 | 243 |
| | 100 | 273.0 | 278 | 236.5 |
| | 120 | 273.0 | 278 | 230 |
| 12” | STD | 323.8 | 329 | 305 |
| | 40 | 323.8 | 329 | 303 |
| | XS | 323.8 | 329 | 298.5 |
| | 60 | 323.8 | 329 | 295 |
| | 80 | 323.8 | 329 | 289 |
| | 100 | 323.8 | 329 | 281 |
| 14” | STD | 355.6 | 362 | 336.5 |
| | 4XS0 | 355.6 | 362 | 333.5 |
| | 60 | 355.6 | 362 | 330 |
| | 80 | 355.6 | 362 | 325.5 |
| 16” | STD | 406.4 | 413 | 387.5 |
| | 40 | 406.4 | 413 | 381 |
| | 60 | 406.4 | 413 | 373 |
| | 80 | 406.4 | 413 | 363.5 |

*Table 10.7.3-1: ASME B16.25 – dimensions of welding ends [mm]*

*Notes:*

(1) Data is from ASME B36.10M or a more precise rounding of the inch dimensions from table I-1. Letter designations signify:
  - (a) STD = standard wall thickness
  - (b) XS = extra-strong wall thickness
  - (c) XXS = double extra-strong wall thickness

### 10.7.4 Welding Ends acc. to ASME B16.11 (Socket welded)

For welding ends acc. to ASME Code in sizes 2” and smaller the socket weld connection is preferred over the butt weld end connection which is standardized for sizes 2 ½” and larger. Socket weld connections apply to Compact Performance Series safety valves, where the socket is formed by the safety valve inlet body as shown below.

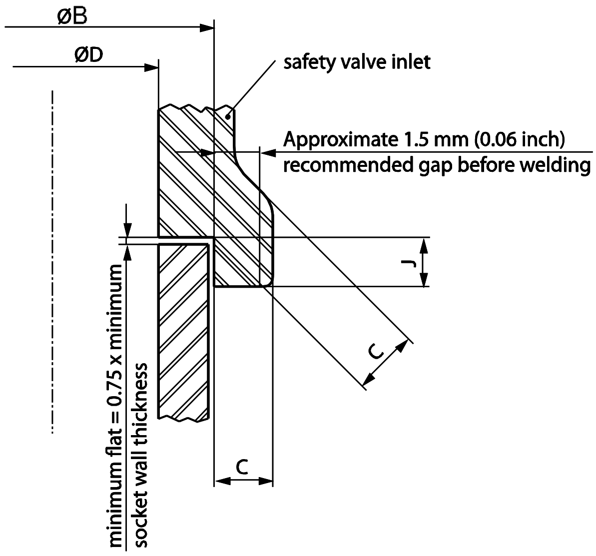



*Figure 10.7.4-1: ASME B16.11 – welding gap and minimum flat dimensions for socket-welding fittings*

**Dimensions of socket-welding fittings**

Table 10.7.4-1 shows the most common sizes of socket-welding fittings as an extract of ASME B16.11. Upper and lower values (see note (1)) are perceived as tolerances.

| DN | Nominal pipe size | Socket bore diameter (1) | Bore diameter of fittings D (1), (3) | | | Socket wall thickness (2), C | | | | | | Min. depth of socket |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Class designation | | | Class designation | | | | | | |
| | | | 3000 | 6000 | 9000 | 3000 | | 6000 | | 9000 | | |
| | | B | | | | Avg. | Min. | Avg. | Min. | Avg. | Min. | J |
| 15 | ½” | 22.2 | 16.6 | 12.5 | 7.2 | 4.67 | 4.09 | 5.97 | 5.18 | 9.35 | 8.18 | 9.5 |
| | | 21.8 | 15.0 | 11.0 | 5.6 | | | | | | | |
| 20 | ¾” | 27.6 | 21.7 | 16.3 | 11.8 | 4.90 | 4.27 | 6.96 | 6.04 | 9.78 | 8.56 | 12.5 |
| | | 27.2 | 20.2 | 14.8 | 10.3 | | | | | | | |
| 25 | 1” | 34.3 | 27.4 | 21.5 | 16.0 | 5.69 | 4.98 | 7.92 | 6.93 | 11.38 | 9.96 | 12.5 |
| | | 33.9 | 25.9 | 19.9 | 14.4 | | | | | | | |
| 32 | 1¼” | 43.1 | 35.8 | 30.2 | 23.5 | 6.07 | 5.28 | 7.92 | 6.93 | 12.14 | 10.62 | 12.5 |
| | | 42.7 | 34.3 | 28.7 | 22.0 | | | | | | | |
| 40 | 1½” | 49.2 | 41.6 | 34.7 | 28.7 | 6.35 | 5.54 | 8.92 | 7.80 | 12.70 | 11.12 | 12.5 |
| | | 48.8 | 40.1 | 33.2 | 27.2 | | | | | | | |
| 50 | 2” | 61.7 | 53.3 | 43.6 | 38.9 | 6.93 | 6.04 | 10.92 | 9.50 | 13.84 | 12.12 | 16.0 |
| | | 61.2 | 51.7 | 42.1 | 37.4 | | | | | | | |

*Table 10.7.4-1: ASME B16.11 – dimensions of socket-welding fittings [mm]*

*General notes:*

Dimensions are in millimeters

*Notes:*

(1) upper and lower values for each size are the respective maximum and minimum dimensions
(2) average of socket wall thickness around periphery shall be no less than listed values. The minimum values are permitted in localized areas
(3) see 6.3 for minimum dimensions of Compact Performance valves

**Correlation of fittings class with schedule number or wall designation of pipe**

Table 10.7.4-2 shows the correlation of the class designation of socket-welding fittings acc. to ASME B16.11 and the schedule number or wall designation of pipes (cp. ASME B36.10M). Nominal wall thickness of schedule 160 and double extra strong pipes of small sizes (⅛", ¼", ⅜") are not defined in ASME B36.10M; for these cases, ASME B16.11 gives a definition.

| Class Designation of Fitting | Type of Fitting | Pipe Used for Rating Basis [Note (1)] | |
|---|---|---|---|
| | | Schedule No. | Wall Designation |
| 3000 | Socket-welding | 80 | XS |
| 6000 | Socket-welding | 160 | … |
| 9000 | Socket-welding | … | XXS |

*Table 10.7.4-2: ASME B16.11 – Correlation of fittings class with schedule number or wall designation of pipe for calculation of ratings [mm]*

*Notes:*

(1) This table is not intended to restrict the use of pipe of thinner or thicker wall with fittings. Pipe actually used may be thinner or thicker in nominal wall than that shown in Table 10.7.4-2. When thinner pipe is used, its strength may govern the rating. When thicker pipe is used (e.g., for mechanical strength), the strength of the fitting governs the rating.

10.7.5 Codes and Standards – welding ends

LDeS 3288.20-EN_Specification for butt welding ends-Compact Performance

EN 29692, *preparation of welded joints*

ASME B1.20.1*, Pipe Threads, General Purpose*

ASME B16.5*, Pipe Flanges and Flanged Fittings*

ASME B16.9*, Factory-Made Wrought Butt welding Fittings*

ASME B16.11*, Forged Fittings, Socket-welding and Threaded*

ASME B16.34M*, Valves – Flanged, Threaded and Welding End*

ASME B36.10M*, Welded and Seamless Wrought Steel Pipe*

## 10.8 Clean Service Connections

This chapter gives an overview about the variety of clean service connections, the allowable pressures and the temperature ranges. There are no pressure/temperature ratings like for EN or ASME flanges, because all connections use elastomer sealing elements, where the type/grade of the elastomer determines the maximum temperature.

LESER does not recommend a certain type of connection. The selection of a connection is up to the user. Please note that the inner diameter is controlling not the outer diameter by reason of cleaning the connection and the pipe. Pipe standards often describe the outer diameter and the wall thickness.

Please refer to the LESER product catalogue for further information about:
- finishing surface of clean service connections
- detailed overview of available connections for individual products.

### 10.8.1 Piping and Connection Standards

The dimensions of the connections are a result of the combination of the different pipe- and connection standards.

Following pipe standards are used in clean service applications:

- BS 4825-1
- DIN 11850
- DIN EN 1127
- ISO 2037

**Pipe dimensions**

Outside diameter of pipe x wall thickness

| | DIN | | ISO | | OD |
|---|---|---|---|---|---|
| Nominal size DN | DIN 11850 | Row | DIN EN 1127 | Nominal size NPS | ISO 2037 (BS 4825/Part 1) |
| 15 | 20 x 2.0 | 3 | 21.3 x 1.6 | - | - |
| 25 | 30 x 2.0 | 3 | 33.7 x 2.0 | 1” | 25.4 x 1.6 |
| 40 | 42 x 2.0 | 3 | 48.3 x 2.0 | 1½“ | 38 x 1.6 |
| 50 | 54 x 2.0 | 3 | 60.3 x 2.0 | 2” | 51 x 1.6 |
| 65 | 70 x 2.0 | 2 | 76.1 x 2.0 | 2½“ | 63.5 x 1.6 |
| 80 | 85 x 2.0 | 2 | 88.9 x 2.3 | 3” | 88.9 x 2.0 |
| 100 | 104 x 2.0 | 2 | 114.3 x 2.6 | 4” | 101.6 x 2.0 |
| 125 | 129 x 2.0 | 2 | 139.7 x 2.6 | 5” | 139.7 x 2.0 |
| 150 | 154 x 2.0 | 2 | 168.3 x 2.6 | 6” | 168.3 x 2.6 |

*Table 10.8.1-1: Dimensions of pipes*

Following connection standards are used:

- DIN 11864-1
- DIN 11864-2
- DIN 11851
- ASME BPE
- Manufacturer standards: APV, NEUMO, Tuchenhagen

Within this section the following shortcuts are used:

- OD tube (outside diameter of tube)
- ID tube (inner diameter of tube)
- WT (wall thickness)

## 10.8.2 Aseptic Flange Connections

**Aseptic flange acc. to DIN 11864 form A**

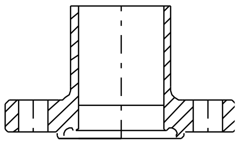
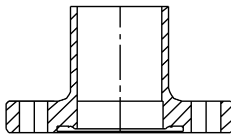
| | **Aseptic flange groove** | | | **Aseptic flange tongue** | | |
|---|---|---|---|---|---|---|
| |  | | |  | | |
| ***LESER*** *Code* | NF | | | BF | | |
| Acc. to | DIN 11864 T2 Form A | | | | | |
| Piping standard | DIN 11850<br>DIN EN ISO 1127<br>BS 4825-1 | | | | | |
| OD of tube [mm] | 12,7 – 41 | 42,4 – 104 | 114,3 – 154 | 12,7 – 41 | 42,4 – 104 | 114,3 – 154 |
| Allowable pressure depending on OD [bar] | 25 | 16 | 10 | 25 | 16 | 10 |

*Table 10.8.2-1: Aseptic flange connections – DIN 11864 form A*

**Aseptic flange acc. to DIN 11864 form B**

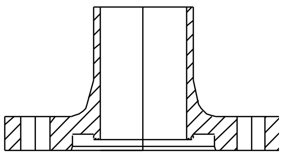
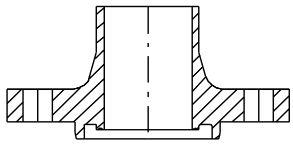
| | **Aseptic flange groove** | | | **Aseptic flange tongue** | | |
|---|---|---|---|---|---|---|
| |  | | |  | | |
| ***LESER*** *Code* | NG | | | BG | | |
| Acc. to | DIN 11864 T2 Form B | | | | | |
| Piping standard | DIN 11850<br>DIN EN ISO 1127<br>BS 4825-1 | | | | | |
| OD of tube [mm] | 12,7 – 41 | 42,4 – 104 | 114,3 – 154 | 12,7 – 41 | 42,4 – 104 | 114,3 – 154 |
| Allowable pressure depending on OD [bar] | 25 | 16 | 10 | 25 | 16 | 10 |

*Table 10.8.2-2: Aseptic flange connections – DIN 11864 form B*

## 10.8.3 Flanged Connections (APV, Tuchenhagen)

**Flange connections acc. to APV, Tuchenhagen**

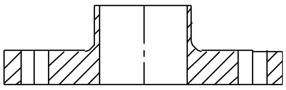
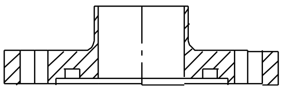
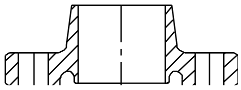
| | **APV-FG1- flange flat face** | | **APV-FN1 flange groove** | | **Varivent flange groove** | |
|---|---|---|---|---|---|---|
| |  | |  | |  | |
| ***LESER*** *Code* | AF | | AN | | TN | |
| Acc. to | APV | | | | Tuchenhagen | |
| Piping standard | DIN 11850 | | | | DIN 11850 | |
| Nominal size | DN 25 – DN 50 | DN 65 – DN 250 | DN 25 – DN 50 | DN 65 – DN 250 | DN 25 - DN 65 | DN 80 - DN 150 |
| Allowable pressure depending on OD [bar] | 40 | 25 | 40 | 25 | 16 | 10 |

*Table 10.8.3-1: Flange connections acc. to APV, Tuchenhagen*

### 10.8.4 Threaded Connections

**Threaded connections acc. to DIN 11864 form A**

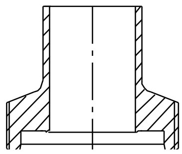
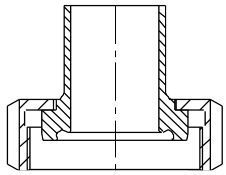
| | Aseptic thread | | Aseptic clamp and nut | | |
| --- | --- | --- | --- | --- | --- |
| |  | |  | | |
| ***LESER** Code* | GS | | BS | | |
| Acc. to | DIN 11864<br>T1 Form A | | | | |
| Piping standard | DIN 11850<br>DIN EN ISO 1127<br>BS 4825-1 | | | | |
| Nominal size | DN 10 – DN 40<br>OD 13,5 – OD 33,7<br>½" - 1½" | DN 50 –DN 100<br>OD 42,4 – OD 88,9<br>2" – 4" | DN 10 – DN 40<br>OD 13,5 – OD 33,7<br>½" – 1½" | DN 50 – DN 65<br>OD 42,4 – OD 60,3<br>2" – 2½" | DN 80 – DN 100<br>OD 76,1 – OD 88,9<br>3" – 4" |
| Allowable pressure depending on OD [bar] | 40 | 25 | 40 | 25 | 16 |

*Table 10.8.4-1: Aseptic thread, aseptic clamp and nut – DIN 11864 form A*

**Threaded connections acc. to DIN 11864 form B**

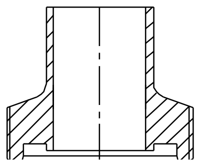
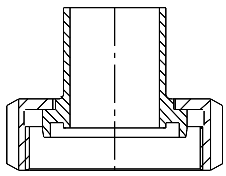
| | Aseptic thread | | Aseptic clamp and nut | | |
| --- | --- | --- | --- | --- | --- |
| |  | |  | | |
| ***LESER** Code* | GT | | BT | | |
| Acc. to | DIN 11864<br>T1 Form B | | | | |
| Piping standard | DIN 11850<br>DIN EN ISO 1127<br>BS 4825-1 | | | | |
| Nominal size | DN 10 – DN 40<br>OD 13,5 – OD 33,7<br>½" - 1½" | DN 50 –DN 100<br>OD 42,4 – OD 88,9<br>2" – 4" | DN 10 – DN 40<br>OD 13,5 – OD 33,7<br>½" – 1½" | DN 50 – DN 65<br>OD 42,4 – OD 60,3<br>2" – 2½" | DN 80 – DN 100<br>OD 76,1 – OD 88,9<br>3" – 4" |
| Allowable pressure depending on OD [bar] | 40 | 25 | 40 | 25 | 16 |

*Table 10.8.4-2: Aseptic thread, aseptic clamp and nut – DIN 11864 form B*

**Threaded connections acc. to DIN 11851**

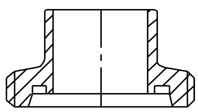
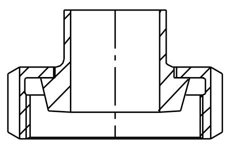
| | Aseptic thread | | | Aseptic clamp and nut | | |
| --- | --- | --- | --- | --- | --- | --- |
| |  | | |  | | |
| ***LESER** Code* | GO | | | KO | | |
| Acc. to | DIN 11851 | | | | | |
| Piping standard | DIN 11850 | | | | | |
| Nominal size | DN 10 – DN 40 | DN 50 – DN 100 | DN 125 – DN 150 | DN 10 – DN 40 | DN 50 – DN 100 | DN 125 – DN 150 |
| Allowable pressure depending on OD [bar] | 40 | 25 | 16 | 40 | 25 | 16 |

*Table 10.8.4-3: Aseptic thread, aseptic clamp and nut – DIN 11851*

### 10.8.5 Sterile Threaded Connections

**Sterile threaded connections acc. to NEUMO**

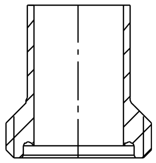
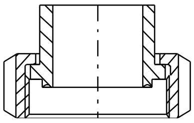
| | **Sterile thread** | **Sterile clamp and nut** |
|---|---|---|
| |  |  |
| ***LESER*** *Code* | GD | BD |
| Acc. to | Neumo | |
| Piping standard | DIN 11850<br>DIN EN ISO 1127 | |
| Allowable pressure depending on OD [bar] | 70 | |

*Table 10.8.5-1: Sterile threaded connections*

### 10.8.6 Clamp Fittings

The following table shows the combination of pipe- and clamp standard, allowable pressure grouped by the LESER clamp code.

| | SO | | DO | | BO | | CO | |
|---|---|---|---|---|---|---|---|---|
| Clamp standard | DIN 32676 | | ISO 2852 | | ASME BPE | | ISO 2852 | |
| Piping standard | DIN 11850 | | DIN EN ISO 1127 | | BS 4825-1 | | ISO 2037 | |
| Allowable pressure [bar] | DN 15 – DN 50 | DN 65 – DN 100 | DN 15 – DN 50 | DN 65 – DN 100 | 1.5" – 2.5" | 3" – 4" | DN 25 – DN 50 | DN 65 – DN 150 |
| | 16 | 10 | 16 | 10 | 16 | 10 | 16[1)] | 10 |

*Table 10.8.6-1: Clamp fitting standards*

1): 16 bar can be exceeded for LESER Type 481, when heavy duty clamps for the connection of the two fittings are used.

Please mind the size of the inner diameter when combining a welding end and a clamp for type 488. The inner diameter of the clamp has to be bigger than the inner diameter of the welding end of the clamp.

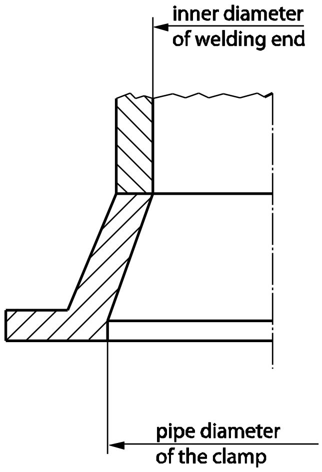



*Figure 10.8.6-1: Prinziple of inner diameter for clamp and welding*

The dimensions are listed in the following subsections.

## Dimensions acc. to DIN 32676 - SO [mm]

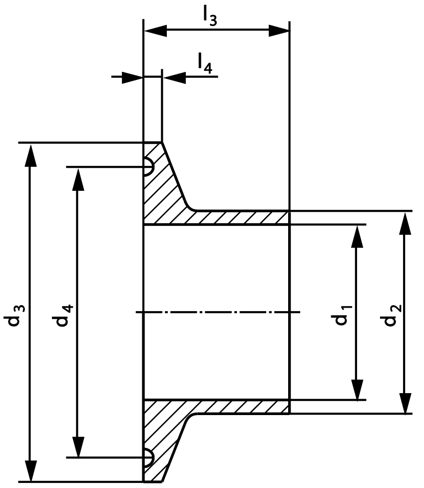



*Figure 10.8.6-2: Sectional drawing of clamp fitting*

| Nominal size (DN) | d1 | d2 | d3 | d4 | l3 | l4 |
|---|---|---|---|---|---|---|
| 10 | 10 | 13<br>14 | 34 | 27.5 | 18 | 2.85 |
| 15 | 16 | 19<br>20 | 34 | 27.5 | 18 | 2.85 |
| 20 | 20 | 23<br>24 | 34 | 27.5 | 18 | 2.85 |
| 25 | 26 | 29<br>30 | 50.5 | 43.5 | 21.5 | 2.85 |
| 32 | 32 | 35<br>36 | 50.5 | 43.5 | 21.5 | 2.85 |
| 40 | 38 | 41<br>42 | 50.5 | 43.5 | 21.5 | 2.85 |
| 50 | 50 | 53<br>54 | 64 | 56.5 | 21.5 | 2.85 |
| 65 | 66 | 70 | 91 | 83.5 | 28 | 2.85 |
| 80 | 81 | 85 | 106 | 97 | 28 | 2.85 |
| 100 | 100 | 104 | 119 | 110 | 28 | 2.85 |
| 125 | 125 | 129 | 155 | 146 | 28 | 5.6 |
| 150 | 150 | 154 | 183 | 174 | 28 | 5.6 |
| 200 | 200 | 204 | 233.5 | 225 | 28 | 5.6 |

*Table 10.8.6-2: Clamp dimensions acc. to DIN 32676 - SO*

*Notes:*

See DIN 32676 table 2 and table 3 for tolerances

### Dimensions acc. to ISO 2852 – Welded-type clamp liner – DO [mm]

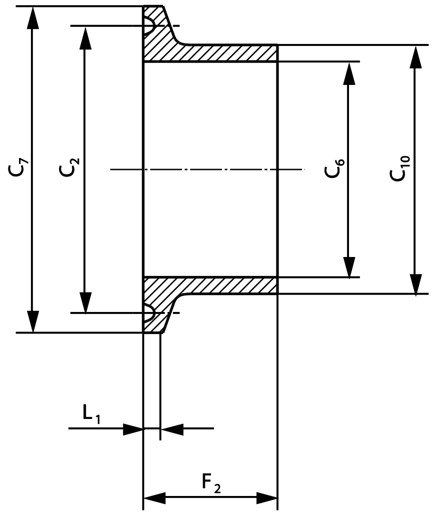



*Figure 10.8.6-3: Sectional drawing of a clamp fitting acc. to ISO 2852 - DO*

| Nominal size | C6 | C10 | C7 | F2 | C2 | L1 |
|---|---|---|---|---|---|---|
| 25 | 22.6 | 25.6 | 50.5 | 21.5 | 43.5 | 2.85 |
| 33.7 | 31.3 | 34.3 | 50.5 | 21.5 | 43.5 | 2.85 |
| 38 | 35.6 | 38.6 | 50.5 | 21.5 | 43.5 | 2.85 |
| 40 | 37.6 | 40.6 | 64 | 21.5 | 56.5 | 2.85 |
| 51 | 48.6 | 51.6 | 64 | 21.5 | 56.5 | 2.85 |
| 63.5 | 60.3 | 64.1 | 77.5 | 21.5 | 70.5 | 2.85 |
| 70 | 66.8 | 70.6 | 91 | 21.5 | 83.5 | 2.85 |
| 76.1 | 72.9 | 76.7 | 91 | 21.5 | 83.5 | 2.85 |
| 88.9 | 84.9 | 89.8 | 106 | 21.5 | 97 | 2.85 |
| 101.6 | 97.6 | 102.5 | 119 | 21.5 | 110 | 2.85 |
| 114.3 | 110.3 | 115.6 | 130 | 28 | 122 | 2.85 |
| 139.7 | 135.7 | 141.2 | 155 | 28 | 146 | 5.6 |
| 168.3 | 163.1 | 170 | 183 | 28 | 174 | 5.6 |
| 219.1 | 213.9 | 221.2 | 233.5 | 28 | 225 | 5.6 |

*Table 10.8.6-3: Camp dimensions acc. to ISO 2852 - DO*

*Notes:*

See ISO 2852 table 1 for tolerances

## Dimensions acc. to ASME BPE – BO [inch]

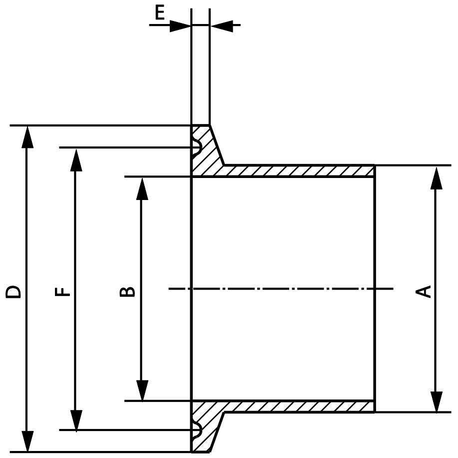



*Figure 10.8.6-4: Sectional drawing of a clamp fitting acc. to ASME BPE -BO*

| Nominal size | tube diameter | ID Bore | Flange diameter | flange thickness | Groove diameter |
|---|---|---|---|---|---|
| | A | B | D | E | F |
| ¼ | 0.250 | 0.180 | 0.984 | 0.143 | 0.800 |
| 3/8 | 0.375 | 0.305 | 0.984 | 0.143 | 0.800 |
| ½ | 0.500 | 0.370 | 0.984 | 0.143 | 0.800 |
| ¾ | 0.750 | 0.620 | 0.984 | 0.143 | 0.800 |
| 1 | 1.000 | 0.870 | 1.984 | 0.112 | 1.718 |
| 1½ | 1.500 | 1.370 | 1.984 | 0.112 | 1.718 |
| 2 | 2.000 | 1.870 | 2.516 | 0.112 | 2.218 |
| 2½ | 2.500 | 2.370 | 3.047 | 0.112 | 2.781 |
| 3 | 3.000 | 2.870 | 3.579 | 0.112 | 3.281 |
| 4 | 4.000 | 3.834 | 4.682 | 0.112 | 4.344 |
| 6 | 6.000 | 5.782 | 6.570 | 0.220 | 6.176 |

*Table 10.8.6-4: Clamp dimensions acc. to ASME BPE - BO*

*Notes:*

See ASME BPE Table DT-5.1 for tolerances

## Dimensions acc. to ISO 2852 – Expanded-type clamp liner – CO [mm]

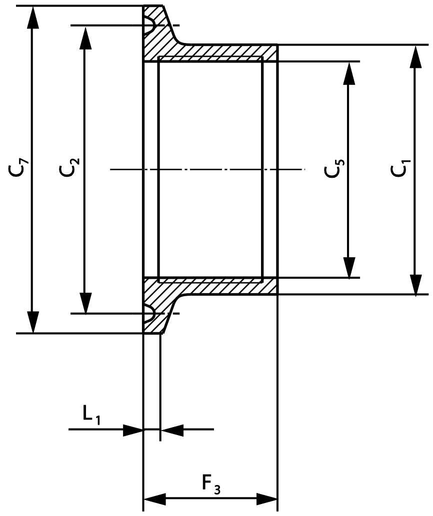



*Figure 10.8.6-5: Sectional drawing of a clamp fitting acc. to ISO 2852 - CO*

| Nominal size | C5 | C1 | C7 | C2 | L1 | F3 |
|---|---|---|---|---|---|---|
| 12 | 12 | 16 | 34 | 27.5 | 2,85 | 16 |
| 12.7 | 12.7 | 16.7 | 34 | 27.5 | 2,85 | 16 |
| 17.2 | 17.2 | 21.2 | 34 | 27.5 | 2,85 | 18 |
| 21.3 | 21.3 | 25.3 | 34 | 27.5 | 2,85 | 20 |
| 25 | 25 | 29 | 50.5 | 43.5 | 2,85 | 20 |
| 33.7 | 33.7 | 38.1 | 50.5 | 43.5 | 2,85 | 20 |
| 38 | 38 | 42.4 | 50.5 | 43.5 | 2,85 | 20 |
| 40 | 40 | 44.8 | 64 | 56.5 | 2,85 | 20 |
| 51 | 51 | 55.8 | 64 | 56.5 | 2,85 | 25 |
| 63.5 | 63.5 | 68.9 | 77.5 | 70.5 | 2,85 | 30 |
| 70 | 70 | 75.8 | 91 | 83.5 | 2,85 | 30 |
| 76.1 | 76.1 | 81.9 | 91 | 83.5 | 2,85 | 30 |

*Table 10.8.6-5: Clamp dimensions acc. to ISO 2852 - CO*

*Notes:*

See ISO 2852 table 2 for tolerances

### Gasket materials

| | Buna-N (U) | EPDM (E) | Fluoro-elastomer (FPM) | Silicone (X) | PTFE (G) |
|---|---|---|---|---|---|
| Hardness, Shore A | 70 | 70 | 70 | 70 | - |
| Tensile strength [bar] | 129.3 | 113.8 | 83.6 | 92.4 | - |
| Elongation [%] | 340 | 317 | 272 | 260 | - |
| temperature range [°C] | -53.9<br>-<br>+93.3 | -51.1<br>-<br>+140 | -28.9<br>-<br>+176.7 | -40<br>-<br>232.2 | -40<br>-<br>+93.3 |

*Table 10.8.6-6: Gasket materials acc. Alfa Laval*

### Definition „Tri-Clamps“

Tri-Clover Tri-Clamp® and Tri-Weld® Fittings are part of Alfa Laval’s product line. They are manufactured in compliance with the actual ASME BPE.

LESER offers CO Clamps which are compatible to Tri-Clamps®. See tables 10.8.6-1 and 10.8.6-7 for differences in dimensions.

### Tri-Clamp dimensions

| **OD** | **ID** | | **WT** | | **A ferrule face** | |
|---|---|---|---|---|---|---|
| [inch] | [inch] | [mm] | [inch] / [gauge] | [mm] / [gauge] | [inch] | [mm] |
| ½ | 0.37 | 9.4 | 0.065 / 16 | 1.7 / 16 | 0.984 | 25.0 |
| ¾ | 0.62 | 15.7 | 0.065 / 16 | 1.7 / 16 | 0.984 | 25.0 |
| 1 | 0.87 | 22.1 | 0.065 / 16 | 1.7 / 16 | 1.984 | 50.4 |
| 1½ | 1.37 | 34.8 | 0.065 / 16 | 1.7 / 16 | 1.984 | 50.4 |
| 2 | 1.87 | 47.5 | 0.065 / 16 | 1.7 / 16 | 2.516 | 63.9 |
| 2½ | 2.37 | 60.2 | 0.065 / 16 | 1.7 / 16 | 3.047 | 77.4 |
| 3 | 2.87 | 72.9 | 0.065 / 16 | 1.7 / 16 | 3.579 | 90.9 |
| 4 | 3.87 | 98.3 | 0.083 / 14 | 2.1 / 14 | 4.682 | 118.9 |

*Table 10.8.6-7: Tri-Clamp dimensions*

### 10.8.7 Connections acc. to EN 1092 and ASME B16.5

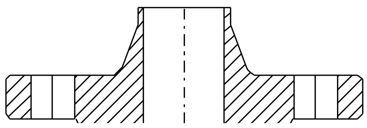
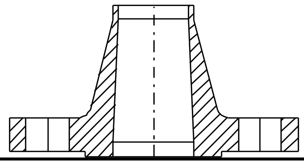
| | **Flange PN 16 Range B1**<br>**EN 1092** | **Flange ANSI CL150 RF**<br>**ASME B16.5** |
|---|---|---|
| |  |  |
| ***LESER*** *Code* | FD | FA |

*Figure 10.8.7-1: Connections acc. to EN 1092 and ASME B16.5*

Clean Service Safety valves can be delivered with flanges according to EN 1092 and ASME B16.5, however these connections are not considered as Clean Service connections.
For further information see EN 1092 and ASME B16.5.

### 10.8.8 Codes and Standards – Clean Service Connections

ISO 2037, *stainless steel tubes for the industry*

ISO 2852, *stainless steel clamp pipe couplings for the food industry*

DIN 405-1, General *purpose knuckle threads - Part 1: Profiles, nominal sizes*

DIN 405-2, *Rundgewinde allgemeiner Anwendung - Teil 2: Abmaße und Toleranzen*

DIN EN ISO 1127, *stainless steel tubes – dimensions, tolerances and conventional masses per unit length*

DIN EN ISO 4288, *Geometrical Product Specifications (GPS) - Surface texture: Profile method - Rules and procedures for the assessment of surface texture*

DIN 11850, *stainless steel tubes for the food and chemical industries – dimensions, materials*

DIN 11851, *Fittings for food, chemical and pharmaceutical industry - Stainless steel screwed pipe connections - Design for rolling in and welding-on*

DIN 11864-1, *Fittings of stainless steel for the aseptic, chemical and pharmaceutical industry - Part 1: Aseptic screwed pipe connection, standard type*

DIN 11864-2, *Stainless steel fittings for the aseptic, chemical and pharmaceutical industries - Part 2: Aseptic flanged pipe connection, standard type*

DIN 11887, *Fittings for food, chemical and pharmaceutical industry - Round thread connections - Design of threaded and conical connection pieces*

DIN 32676, *Fittings for the food, chemical and pharmaceutical industries - Clamp connections for stainless steel tubes - Weld-on type*

ASME-BPE, *Bio processing equipment. The ASME BPE Standard standardizes specifications for the design, manufacture, installation, inspection and acceptance of equipment used in the pharmaceutical and biologic products industries.*

ASTM A 182 / A 182M, Specifications *for forged or rolled alloy and stainless steel pipe flanges, forged fittings, and valves and Parts for High-Temperature Service*

ASTM A 380, *Practice for cleaning, descaling, and passivation of stainless steel parts, equipment and systems*

*BS 4825-1, Stainless steel tubes and fittings for the food industry and other hygienic applications - Specification for tubes*

## 10.9 High Pressure Clamp Connections - Grayloc/Destec

### General

This chapter specifies the assembly of the API-safety valves with a clamp connector on the hub. It describes the design feature of the clamp connector as well as the sealing ring, hub and the pipe dimensions (see Figure 10.9.1-2 for a detailed drawing).

The tables describe the allocation of the clamp to the API-526 Safety Valve. This allocation allows to select the suitable clamp for an existing safety valve or the suitable safety valve for an already existing clamp dimension.

Generally LESER delivers a hub welded to the nozzle. If hub dimensions are available, LESER prefers to machine the hub dimensiond directly to the nozzle.

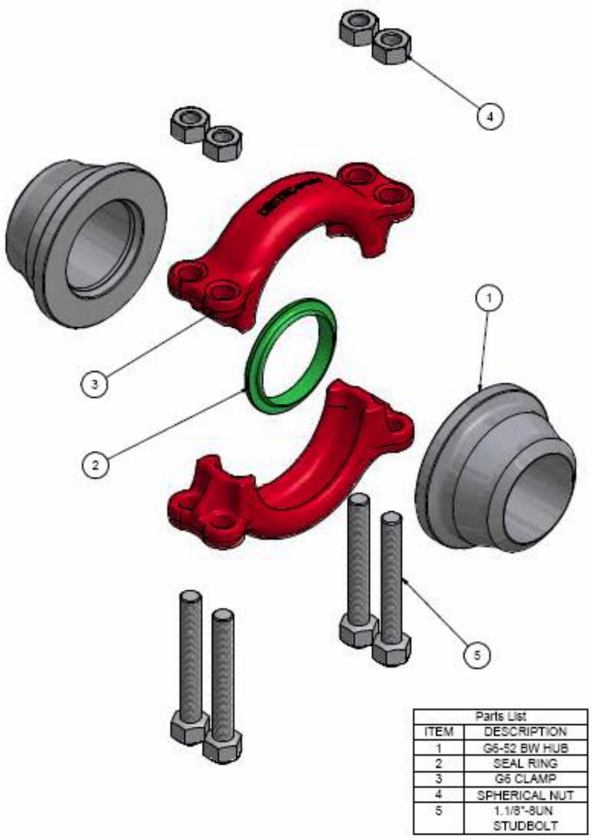



*Figure 10.9-1: GRAYLOC connector*

*Notes:*

LESER supplies only the hub (no.1). It must be welded to the nozzle of the safety valve.
All other components are not scope of supply unless it is specified.

**Background of high pressure clamps**

Compared to conventional ANSI or API ring joint flanges, the clamp connector is significantly lighter and smaller. In addition there is a freedom to rotate the clamp with no bolt hole alignment.

**Field of application**

The simplicity, sealing efficiency and economy of the clamp connector benefit a wide range of industries in various applications:

- Oil and gas production
- Petroleum refining
- Chemical, synthetic fuels and food processing
- Fossil and nuclear power generation
- Aerospace and industrial gas manufacturing
- Coal gasification and liquefaction

**Design**

**General design aspects**

- LESER welds the hub of the clamp to the nozzle of the safety valve
- Nozzle material, hub material and welding filler have to fit to each other according to the welding standards
- The nozzle end of the API safety valve can be machined in hub dimensions if LESER gets a technical drawing of the specified hub
- Further components like clamps, bolts or sealings have to be purchased by the clamp manufacturer or could be attached to the delivery
- The pressure temperature ratings given at the end of this chapter are based on the allowable stress from ASME B31.3-1993 Edition.

**Ordering**

The customer has to supply the following characteristics to define the correct clamp connection:

- Schedule number
- Orifice
- Outer diameter

## Design Predefinitions

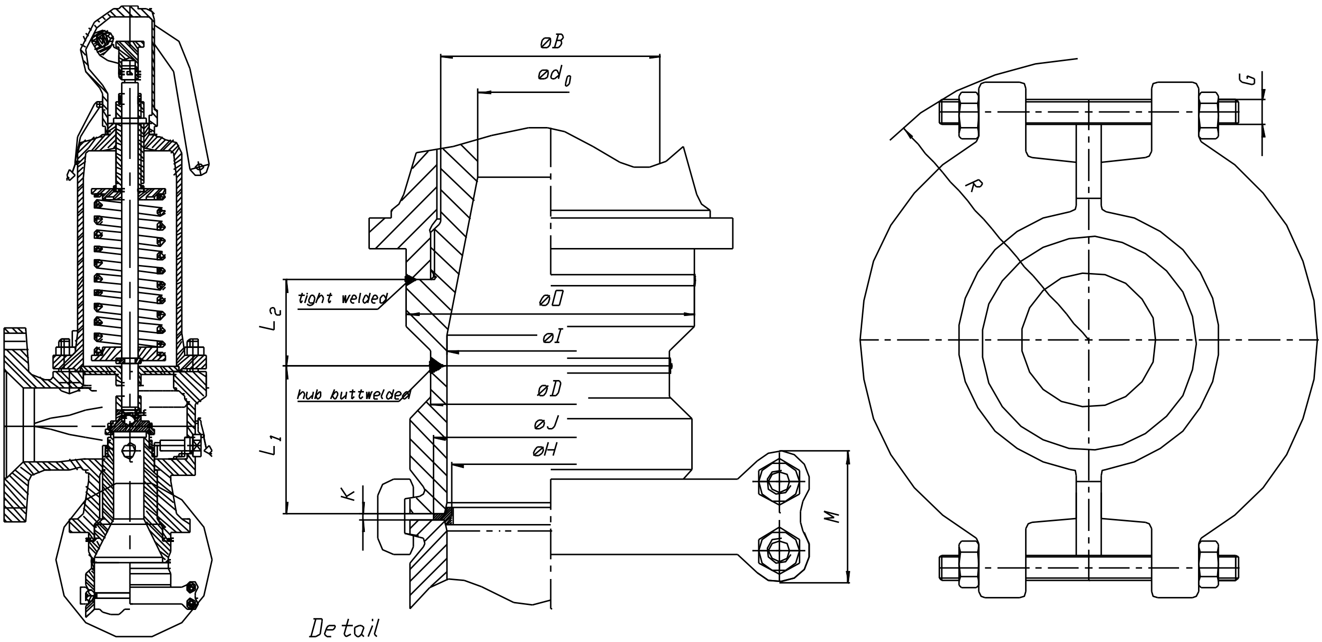



*Figure 10.9-2: The construction views of API-safety valve with a clamp connector*

Indices:

| Pipe | | Clamp | | Nozzle | |
|---|---|---|---|---|---|
| ØD | outer diameter | ØR | clamp clearance | Ødo | orifice diameter |
| ØI | inner diameter | M | clamp width | ØB | outer diameter cylinder |
| | | ØG | bolt diameter | ØI | inner diameter (clamp side) |
| | | ØH | inner diameter of seal ring | ØO | outer diameter |
| | | ØJ | outer diameter of seal ring | L2 | length of butt welded end |
| | | K | rib of seal ring | | |
| | | L1 | length of the hub | | |

### Possible schedules

A selection of possible pipe schedules used for the API 526 safety valve is a prerequisite to establish a selection of clamps for LESER safety valves. Table 10.9.1-1 shows the possible schedules.
The selection of clamps of the manufacturers DESTEC and GRAYLOC are described in Table 10.9-2.

Table 10.9-3 shows the selection of LESER nozzles. Main dimensions are listed in order to align the welding end of the nozzle with the welding end of the hub. Basic principle is the consideration of the pipe dimensions and schedules of the ASME B36.10M.

The schedule number is a system to combine sizes and wall thicknesses which would have an approximately relationship. The schedule numbers are a convenient designation system for use in ordering pipes.

<table>
<tr><th colspan="2">Safety Valve</th><th colspan="6">ASME B36.10M</th></tr>
<tr><th>NPS</th><th>Orifice</th><th>Outer diameter (ØD)</th><th>Max. wall thickness</th><th colspan="4">Possible schedules</th></tr>
<tr><td>1x2</td><td rowspan="2">E</td><td>33.4</td><td>6.4</td><td>-</td><td rowspan="12">160</td><td rowspan="20">80</td><td rowspan="20">40</td></tr>
<tr><td>1½x2</td><td rowspan="3">48.3</td><td rowspan="3">10.2</td><td rowspan="11">XXS</td></tr>
<tr><td>1½x2/3</td><td>F</td></tr>
<tr><td>1½x2/3</td><td rowspan="2">G</td></tr>
<tr><td>2x3</td><td>60.3</td><td>11.1</td></tr>
<tr><td>1½x2/3</td><td rowspan="2">H</td><td>48.3</td><td>10.2</td></tr>
<tr><td>2x3</td><td rowspan="2">60.3</td><td rowspan="2">11.1</td></tr>
<tr><td>2x3</td><td rowspan="2">J</td></tr>
<tr><td>3x4</td><td rowspan="8">114.0</td><td rowspan="4">18.9</td></tr>
<tr><td>3x4</td><td rowspan="2">K</td></tr>
<tr><td>4x6</td></tr>
<tr><td>3x4</td><td rowspan="2">L</td></tr>
<tr><td>4x6</td><td rowspan="7">11.0</td><td rowspan="8">-</td><td rowspan="4">120</td></tr>
<tr><td>4x6</td><td>M</td></tr>
<tr><td>4x6</td><td>N</td></tr>
<tr><td>4x6</td><td>P</td></tr>
<tr><td>6x8</td><td>Q</td><td rowspan="3">168.3</td><td rowspan="4">-</td></tr>
<tr><td>6x8</td><td rowspan="2">R</td></tr>
<tr><td>6x10</td></tr>
<tr><td>8x10</td><td>T</td><td>219.1</td><td>12.7</td></tr>
</table>

*Table 10.9-1: ASME B36.10M pipe schedules for API 526 safety valves*

## Selection of clamps in consideration of the API 526 orifice and NPS

| Safety valve | | Type of clamp connection | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Destec Types | | | | Grayloc Types | | | | |
| | | Schedule | | | | | | | | |
| NPS | Orifice | XXS | 160 | 80 | 40 | XXS | 160 | 120 | 80 | 40 |
| 1x2 | E | G1½-11 | G1-7 | G1-11 | | 1GR5 | 1GR7 | - | 1GR11 | |
| 1½x2 | | | G1½-14 | | | 1½GR11 | | | 1½GR14 | |
| 1½x2/3 | F | | | | | | | | | |
| 1½x2/3 | G | | | | | | | | | |
| 2x3 | | G2-14 | G2-16 or G2-20 | | | 2GR14 | | | 2GR20 | |
| 1½x2/3 | H | G1½-11 | G1½-14 | | | 1½GR11 | | | 1½GR14 | |
| 2x3 | | G2-14 | G2-16 or G2-20 | | | 2GR14 | | | 2GR20 | |
| 2x3 | J | | | | | | | | | |
| 3x4 | | G4-31 | G4 - 34 | G4-40 | | 4GR31 | | 4GR34 | 4GR40 | |
| 3x4 | K | | | | | | | | | |
| 4x6 | | | | | | | | | | |
| 3x4 | L | - | | | | - | | | | |
| 4x6 | | | | | | | | | | |
| 4x6 | M | | | | | | | | | |
| 4x6 | N | | | | | | | | | |
| 4x6 | P | | | | | | | | | |
| 6x8 | Q | | | G6-62<br>G6-54<br>(schedule 120) | | | | - | 6GR62 | |
| 6x8 | R | | | | | | | | | |
| 6x10 | | | | | | | | | | |
| 8x10 | T | | | G8-76 | G8-82 | | | | 8GR76 | 8GR82 |

*Table 10.9-2: Selection of clamps in consideration of the API 526 orifice and NPS*

*Notes:*

Hub size allocation must be limited in order to avoid that the inner diameter of the pipe run-under the diameter of the orifice of the safety valve

| Safety valve | | | Nozzle | | | | Pipe (ASME B36.10M) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ØI of hub and nozzle end | | | | |
| NPS | Orifice | Nozzle part number | Ød0 | ØB | ØO | L2 | ØD | XXS | 160 | 120 | 80 | 40 |
| 1x2 | D/E | 207.20xx.9xxx<br>207.22xx.9xxx<br>207.27xx.9xxx | 14.0 | 42.0 | 48.0 | 38.0 | 33.4 | - | 20.7 | do not exist at the clamp supplier | 23.4 | 26.6 |
| 1½x2 | | | | 56.0 | 62.0 | 43.0 | 48.3 | 27.9 | 33.99 | | 38.1 | 41.0 |
| 1½x2/3 | F | 207.23xx.9xxx | 18.0 | | | | | | | | | |
| | | 207.28xx.9xxx | | | | | | | | | | |
| 1½x2/3 | G | 207.24xx.9xxx | 22.5 | | | 53.0 | | | | | | |
| 2x3 | | 207.32xx.9xxx | | 70.0 | 76.0 | 43.0 | 60.3 | 38.2 | 42.85 | | 49.2 | 52.4 |
| 1½x2/3 | H | 207.25xx.9xxx | 28.3 | 56.0 | 62.0 | 53.0 | 48.3 | 27.9 | 33.99 | | 38.1 | 41.0 |
| 2x3 | | 207.29xx.9xxx | | 72.0 | 78.0 | | 60.3 | 38.2 | 42.85 | | 49.2 | 52.4 |
| | | 207.31xx.9xxx | | 70.0 | 76.0 | | | | 42.85 | | | |
| 2x3 | J | 207.30xx.9xxx | 36.0 | 72.0 | 78.0 | | | | 42.85 | | | |
| 3x4 | | 207.35xx.9xxx | | 110.0 | 116.0 | | 114.0 | 80.1 | 87.3 | | 97.2 | 102.0 |
| 3x4 | K | 207.33xx.9xxx | 43.0 | | | | | | | | | |
| | | 207.33xx.9xxx | | | | | | | | | | |
| 4x6 | | 207.41xx.9xxx | | | | | | | | | | |
| | | 207.42xx.9xxx | | | | | | | | | | |
| 3x4 | L | 207.34xx.9xxx | 53.5 | | | | | | | | | |
| 4x6 | | 207.37xx.9xxx | | 136.0 | 142.0 | | | - | - | 92.05 | 97.18 | 102.26 |
| | | 207.39xx.9xxx | | | | | | | | | | |
| | | 207.43xx.9xxx | | | | | | | | | | |
| 4x6 | M | 207.38xx.9xxx | 60.3 | | | | | | | | | |
| | | 207.44xx.9xxx | | | | | | | | | | |
| 4x6 | N | 207.40xx.9xxx | 66.0 | | | | | | | | | |
| 4x6 | P | 207.45xx.9xxx | 80.0 | | | | | | | | | |
| | | 207.46xx.9xxx | | | | | | | | | | |
| 6x8 | Q | 207.47xx.9xxx | 105.5 | 180.0 | 187.0 | 70.0 | 168.3 | | | - | 146.3 | 154.1 |
| 6x8 | R | 207.48xx.9xxx | 126.0 | | | | | | | | | |
| 6x10 | | 207.57xx.9xxx | | | | | | | | | | |
| 8x10 | T | 207.59xx.9xxx | 161.5 | 234.1 | 241.1 | | 219.1 | | | | 193.7 | 202.7 |

*Table 10.9-3: Selection of API 526 nozzles and predefinition of inlet diameter*

*Notes:*

Min. inner diameter of the pipe must be limited in order to avoid that this diameter under-runs the orifice of the safety valve

## Dimensions – DESTEC clamp

| Safety valve | | DESTEC clamp | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NPS | Orifice | Type of connection | Connection assembly | | | | | | | | | | | |
| | | Dimensions | ØR (mm) | | | | | M (mm) | | | | | ØG | L1 (mm) |
| | | G-Range | XXS | 160 | 120 | 80 | 40 | XXS | 160 | 120 | 80 | 40 | all | |
| 1x2 | D/E | G1-11(80,40) G1-7 (160) | - | 66.7 | - | 66.7 | | - | 58.7 | - | 58.7 | | 1/2” | 44.4 |
| 1½ x2 | | G1½-11 (XXS) G1½-14 (160, 80, 40) | 102 | | | 102 | | 79.4 | | | 79.4 | | 5/8” | 60.3 |
| 1 ½ x 2/3 | F | | | | | | | | | | | | | |
| 1 ½ x 2/3 | G | | | | | | | | | | | | | |
| 2x3 | | G2-14 (XXS) G2-16 (160) G2-20 (80, 40) | 114 | | | 114 | | 89 | | | 89 | | 3/4” | 69.8 |
| 1 ½ x2/3 | H | G1½-11 (XXS) G1 ½ -14 (160, 80, 40) | 102 | | | 102 | | 79.4 | | | 79.4 | | 5/8” | 60.3 |
| 2x3 | | G2-14 (XXS) G2-16 (160) G2-20 (80, 40) | 114 | | | 114 | | 89 | | | 89 | | 3/4” | 69.8 |
| 2x3 | J | | | | | | | | | | | | | |
| 3x4 | | | | | | | | | | | | | | |
| 3x4 | K | G4-31 (XXS) G4-34 (160) G4-40 (80, 40) | 152.4 | | | 152.4 | | 96.9 | | | 96.9 | | 7/8” | 92.1 |
| 4x6 | | | | | | | | | | | | | | |
| 3x4 | L | | | | | | | | | | | | | |
| 4x6 | | G4-40 (80, 40) | - | | | | | - | | | | | | |
| 4x6 | M | | | | | | | | | | | | | |
| 4x6 | N | | | | | | | | | | | | | |
| 4x6 | P | | | | | | | | | | | | | |
| 6x8 | Q | G6-62 (80, 40) | | | | 222.2 | | | | | 122.3 | | 1 1/8” | 117.5 |
| 6x8 | R | | | | | | | | | | | | | |
| 6x10 | | | | | | | | | | | | | | |
| 8x10 | T | G8-76 (80) G8-82 (40) | | | | 250.8 | | | | | 149.2 | | 1 1/4” | 136.5 |

*Table 10.9-4: Dimensions of DESTEC clamps – connection assembly*

| Safety valve | | DESTEC clamp | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NPS | Orifice | Connection dimensions | seal ring | | | | | | | | | | |
| | | | ØH (mm) | | | | | ØJ (mm) | | | | | K (mm) |
| | | G-Range | XXS | 160 | 120 | 80 | 40 | XXS | 160 | 120 | 80 | 40 | all |
| 1x2 | D/E | G1-11(80,40) G1-7 (160) | - | 23 | - | 28.6 | | - | 34.9 | - | 44.4 | | 3.18 |
| 1½ x2 | | G1½-11 (XXS) G1½-14 (160, 80, 40) | 40.9 | | | 40.9 | | 66.7 | | | 66.7 | | 6.3 |
| 1 ½ x 2/3 | F | | | | | | | | | | | | |
| 1 ½ x 2/3 | G | | | | | | | | | | | | |
| 2x3 | | G2-14 (XXS) G2-16 (160) G2-20 (80, 40) | 40.9 | 47.5 | | 52.4 | | 66.7 | 68.3 | | 82.5 | | |
| 1 ½ x2/3 | H | G1½-11 (XXS) G1 ½ -14 (160, 80, 40) | | 40.9 | | 40.9 | | | 66.7 | | 66.7 | | |
| 2x3 | | G2-14 (XXS) G2-16 (160) G2-20 (80, 40) | | 47.5 | | 52.4 | | | 68.3 | | 82.5 | | |
| 2x3 | J | | | | | | | | | | | | |
| 3x4 | | | | | | | | | | | | | |
| 3x4 | K | G4-31 (XXS) G4-34 (160) G4-40 (80, 40) | 82.5 | 93.7 | | 103 | | 114.3 | 127 | | 139.7 | | |
| 4x6 | | | | | | | | | | | | | |
| 3x4 | L | | | | | | | | | | | | |
| 4x6 | | G4-40 (80, 40) | - | | | | | - | | | | | |
| 4x6 | M | | | | | | | | | | | | |
| 4x6 | N | | | | | | | | | | | | |
| 4x6 | P | | | | | | | | | | | | |
| 6x8 | Q | G6-62 (80, 40) | | | | 154 | | | | | 200 | | 9.5 |
| 6x8 | R | | | | | | | | | | | | |
| 6x10 | | | | | | | | | | | | | |
| 8x10 | T | G8-76 (80) G8-82 (40) | | | | 196.7 | 209.6 | | | | 254 | 257 | |

*Table 10.9-5: Dimensions of DESTEC clamp – ring seal*

## Dimensions – GRAYLOC clamp

| Safety valve | | GRAYLOC clamp | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NPS | Orifice | Type of connection | Connection assembly | | | | | | | | | | | |
| | | dimensions | ØR (mm) | | | | | M (mm) | | | | | ØG | L1 (mm) |
| | | G-Range | XXS | 160 | 120 | 80 | 40 | XXS | 160 | 120 | 80 | 40 | all | |
| 1x2 | D/E | 1GR7 (160) 1GR5 (80,40) | - | 66.68 | | 66.68 | | - | 58.75 | | 58.7 | | 1/2" | 44.45 |
| 1½ x2 | | 1½GR14 (XX, 160, 80, 40) | 101.6 | | | 101.6 | | 79.38 | | | 79.38 | | 5/8" | 60.33 |
| 1 ½ x 2/3 | F | | | | | | | | | | | | | |
| 1 ½ x 2/3 | G | | | | | | | | | | | | | |
| 2x3 | | 2GR14 (XX) 2GR20 (160, 80, 40) | 114.3 | | | 114.3 | | 88.9 | | | 88.9 | | 3/4" | 69.85 |
| 1 ½ x2/3 | H | 1½GR14 (XX, 160, 80, 40) | 101.6 | | | 101.6 | | 79.38 | | - | 79.38 | | 5/8" | 60.33 |
| 2x3 | | 2GR14 (XX) 2GR20 (160, 80, 40) | 114.3 | | | 114.3 | | 88.9 | | | 88.9 | | 3/4" | 69.85 |
| 2x3 | J | | | | | | | | | | | | | |
| 3x4 | | 4GR31 (XX) 4GR34 (160) 4GR40 (80, 40) | 152.4 | | | 152.4 | | 103.2 | | | 103.2 | | 7/8" | 92.08 |
| 3x4 | K | | | | | | | | | | | | | |
| 4x6 | | | | | | | | | | | | | | |
| 3x4 | L | | | | | | | | | | | | | |
| 4x6 | | 4GR34 (120) 4GR40 (80, 40) | - | | 152.4 | | | - | | 103.2 | | | | |
| 4x6 | M | | | | | | | | | | | | | |
| 4x6 | N | | | | | | | | | | | | | |
| 4x6 | P | | | | | | | | | | | | | |
| 6x8 | Q | 6GR62 | | | - | 222.25 | | | | 103.2 | 122.25 | | 1 1/8" | 117.48 |
| 6x8 | R | | | | | | | | | | | | | |
| 6x10 | | | | | | | | | | | | | | |
| 8x10 | T | 8GR76 (80) 8GR82 (40) | | | | 250.83 | | | | | 149.22 | | 1 1/4" | 136.53 |

*Table 10.9-6: Dimensions of GRAYLOC connection – clamp assembly*

| Safety valve | | GRAYLOC clamp | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NPS | Orifice | Connection dimensions | Seal ring | | | | | | | | | | | |
| | | | ØH (mm) | | | | | ØJ (mm) | | | | | K (mm) |
| | | G-Range | XXS | 160 | 120 | 80 | 40 | XXS | 160 | 120 | 80 | 40 | all |
| 1x2 | D/E | 1GR7 (160) 1GR5 (80,40) | - | 23.01 | | 28.58 | | - | 34.93 | | 44.04 | | 3.18 |
| 1½ x2 | | 1½GR14 (XX, 160, 80, 40) | 40.89 | | | 40.89 | | 66.68 | | | 66.68 | | 6.35 |
| 1 ½ x 2/3 | F | | | | | | | | | | | | |
| 1 ½ x 2/3 | G | | | | | | | | | | | | |
| 2x3 | | 2GR14 (XX) 2GR20 (160, 80, 40) | 40.89 | 52.4 | | 52.4 | | 66.68 | 82.55 | | 82.55 | | |
| 1 ½ x2/3 | H | 1½GR14 (XX, 160, 80, 40) | 40.89 | | - | 40.89 | | 66.68 | | - | 66.68 | | |
| 2x3 | | 2GR14 (XX) 2GR20 (160, 80, 40) | 40.89 | 52.4 | | 52.4 | | 66.68 | 82.55 | | 82.55 | | |
| 2x3 | J | | | | | | | | | | | | |
| 3x4 | | 4GR31 (XX) 4GR34 (160) 4GR40 (80, 40) | 82.55 | 93.68 | | 103.2 | | 114.3 | 127 | | 139.7 | | |
| 3x4 | K | | | | | | | | | | | | |
| 4x6 | | | | | | | | | | | | | |
| 3x4 | L | | | | | | | | | | | | |
| 4x6 | | 4GR34 (120) 4GR40 (80, 40) | - | | 93.7 | | | - | | 127 | | | |
| 4x6 | M | | | | | | | | | | | | |
| 4x6 | N | | | | | | | | | | | | |
| 4x6 | P | | | | | | | | | | | | |
| 6x8 | Q | 6GR62 | | | - | 154.05 | | | | - | 200.03 | | 9.525 |
| 6x8 | R | | | | | | | | | | | | |
| 6x10 | | | | | | | | | | | | | |
| 8x10 | T | 8GR76 (80) 8GR82 (40) | | | | 197 | 210 | | | | 254 | 257 | |

*Table 10.9-7: Dimensions of GRAYLOC clamps – seal ring*

### Materials

The material of clamp and nozzle varies between

- Stainless Steel SA182-F316/F316L/F316H and
- Carbon Steel SA350 LF2

### Pressure temperature ratings

The following tables contain the pressure temperature ratings for the Destec and Grayloc clamp connector respectively. These ratings are applied for stainless steel A182-F316 and have been calculated using the following preconditions:

- Allowable stresses taken from ANSI B31.3
- Zero corrosion allowance
- Maximum bore through the hub
- Stress analysis to ASME VIII Appendix 24

**DESTEC connector (SA 182 Gr. F316)**

| | Maximum allowable temperature [°C] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | -46 - 20 | 100 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 |
| **Size** | **Maximum allowable pressure [bar]** | | | | | | | | | |
| G 1-5 | 943 | 943 | 886 | 835 | 788 | 762 | 735 | 705 | 682 | 618 |
| G 1-7 | 518 | 518 | 487 | 459 | 433 | 418 | 404 | 387 | 375 | 339 |
| G 1½-14 | 372 | 372 | 360 | 338 | 321 | 309 | 298 | 293 | 287 | 264 |
| G 2-14 | 1013 | 1013 | 980 | 919 | 874 | 841 | 815 | 797 | 782 | 757 |
| G 2-20 | 257 | 257 | 249 | 234 | 222 | 214 | 207 | 202 | 199 | 189 |
| G 4-31 | 460 | 460 | 433 | 408 | 385 | 372 | 359 | 344 | 333 | 302 |
| G 4-34 | 275 | 275 | 266 | 249 | 237 | 228 | 221 | 216 | 212 | 205 |
| G 4-40 | 137 | 137 | 132 | 124 | 118 | 113 | 110 | 108 | 106 | 102 |
| G 6-62 | 199 | 199 | 192 | 180 | 171 | 165 | 160 | 156 | 153 | 144 |
| G 8-76 | 216 | 216 | 203 | 191 | 180 | 174 | 168 | 161 | 156 | 141 |

*Table 10.9-8: Pressure temperature ratings for DESTEC connectors*

**GRAYLOC connector (SA 182 Gr. F316)**

| | Maximum allowable temperature [°C] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 38 | 93 | 149 | 205 | 260 | 316 | 343 | 371 | 400 | 427 | 454 | 482 | 510 | 538 |
| **Size** | **Maximum allowable pressure [bar]** | | | | | | | | | | | | | |
| 1 GR 5 | 1112 | 1112 | 1088 | 999 | 975 | 952 | 932 | 935 | 917 | 902 | 892 | 882 | 872 | 862 |
| 1½ GR 11 | 1032 | 1032 | 1032 | 1010 | 960 | 905 | 884 | 868 | 851 | 837 | 828 | 818 | 809 | 800 |
| 2 GR 14 | 705 | 705 | 705 | 690 | 656 | 618 | 604 | 593 | 582 | 572 | 565 | 559 | 553 | 546 |
| 4 GR 31 | 490 | 490 | 490 | 480 | 456 | 430 | 420 | 412 | 404 | 398 | 393 | 389 | 384 | 380 |

*Table 10.9-9: Pressure temperature ratings for GRAYLOC connectors*

*Notes:*

These ratings represent the allocation to the clamp components.

## 10.10 Compression Fittings

### 10.10.1 Compression Fittings with Cutting Ring acc. to DIN 2353

**Background**

The compression fitting with cutting ring uses the cutted profile of the pipe to seal. It's a metallic sealing without a joint sealer. This sealing is removable, but should not be reattached at the same position of the pipe, because of potential leakage.

A compression fitting with cutting ring is temperature and medium independent, and saves space.

LESER offers this type of connection for Compact Performance safety valves only.

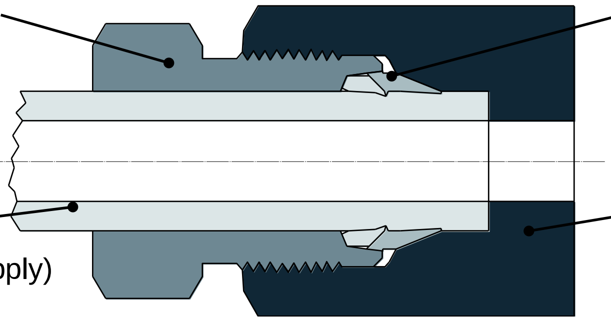



*Figure 10.10.1-1: Exemplary sketch of a compression fitting with cutting ring*

**Compression fittings with cutting ring for LESER Compact Performance safety valves**

The following connections are standardized for LESER Compact Performance safety valves. Other sizes are available on request.

| **Series** | **Rated for a nominal pressure in bar of (1)** | **Pipe dimensions** | **Series 437** | | **Series 459** | | | |
|---|---|---|---|---|---|---|---|---|
| | | Outside diameter x wall thickness | $d_0$ 6 mm | | $d_0$ 13 mm | | $d_0$ 17.5 mm | |
| | | mm | Option Code | | Option Code | | Option Code | |
| | | | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| - | - | 16 x 2.0 | V25 | - | - | - | - | - |
| L | 160 | 22 x 1.5 | - | V26 | - | - | - | - |
| S | 400 | 25 x 2.5 | - | - | V46 | - | - | - |
| L | 100 | 28 x 2.0 | - | - | - | - | V47 | - |

*Table 10.10.1-1: Possible connections for LESER Compact Performance safety valves*

*Notes:*

(1) applies only to steel couplings (cf. DIN 3859-1 for technical delivery conditions)

A progressive – Cutting ring – connection acc. to DIN 2353 / DIN EN ISO 8434-1 is the standard connection LESER uses.

**Materials**

The standard material of compression fittings and couplings shall be stainless steel. Other materials specified in DIN 3859-1 shall be the subject of agreement.

10.10.2 Compression Fitting with Locking Ring (e.g. Parker A-Lok)

**Background**

The fitting uses the area contact pressure to seal. Tubing and fitting materials should be selected to be compatible with the fluid media. Due to thermal expansion characteristics and chemical stability, the tubing should be of the same material as the fitting.

LESER offers this type of connection for threaded valves only. See at the end of this chapter (Swagelok) for information.

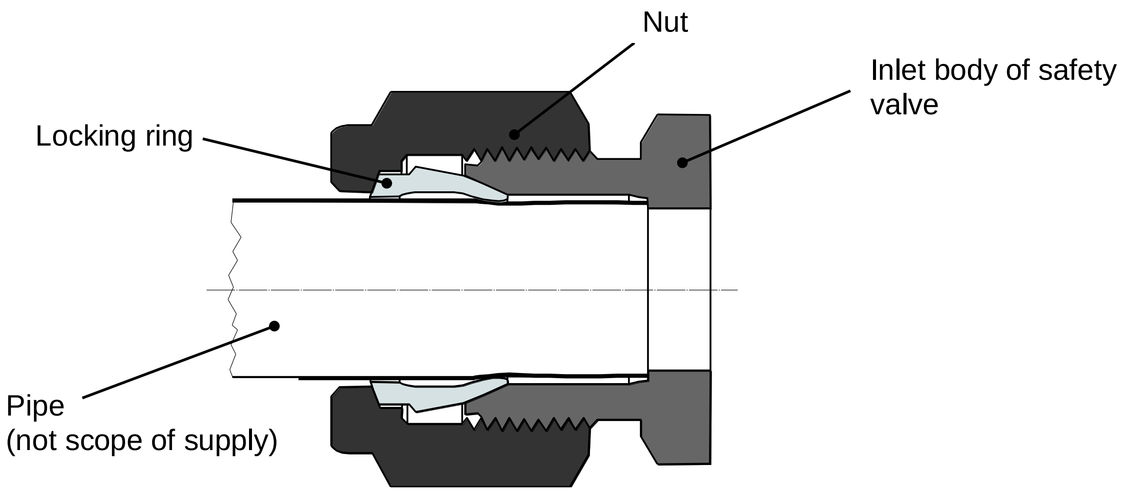



*Figure 10.10.2-1: Exemplary sketch of a compression fitting with locking ring*

**Torque**

The Tube fittings do not twist the tubing during installation. The ferrule designs assure that all make and remake motion is transmitted axially to the tubing. Since no radial movement of the tubing occurs, the tubing is not stressed. The mechanical integrity of the tubing is maintained.

**No Distortion**

In make-up, there is no undue force in an outward direction to distort the fitting body or ferrules to cause interference between the ferrules and nut. This assures that the nut will back-off freely for disassembly and permits a greater number of easy remakes.

### Swagelok

Swagelok is a manufacturer of different pipe connections. Such as compression fittings and VCO (soft sealing), VCR (metallically sealing) connections.

A compression fitting with double locking ring designed by Swagelok is the standard connection LESER uses. It's also called a Mechanical Grip-Type Tube Fitting.

| **Pipe dimensions** | **Series 437** | |
|---|---|---|
| Outside diameter x wall thickness | $d_0$ 10 mm | |
| mm | inlet | outlet |
| 18 x 1.5 | V44 | - |

*Table 10.10.2-1: Possible Swagelok connections at LESER*

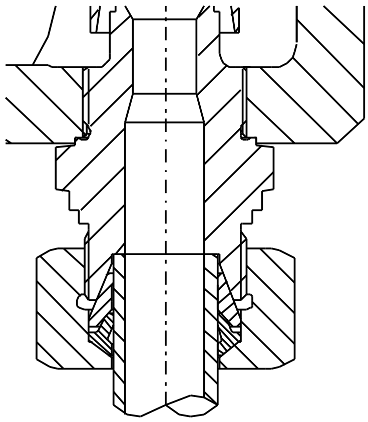


*Figure 10.10.2-2: Swagelok compression fitting with double locking ring*

## 10.11 IG-Flanges

IG Flanges are special types of high pressure flanges according to the High Pressure Engineering Standard of the BASF Group. LESER uses this type of connection in the Compact Performance series.

| Class | Nominal size | Series 437 | | | | Series 459 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $d_0$ 6 mm | | $d_0$ 10 mm | | $d_0$ 6 mm | | $d_0$ 9 mm | | $d_0$ 13 mm | | $d_0$ 17.5 mm | |
| | | Option code | | Option code | | Option code | | Option code | | Option code | | Option code | |
| PN | DN | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| 325 | 10 | W01 | - | - | - | - | - | - | - | - | - | - | - |
| | 16 | W02 | W17 | W02 | W17 | - | - | W02 | - | - | - | - | - |
| | 24 | - | W18 | - | - | W03 | W18 | W03 | W18 | - | - | W03 | - |
| | 30 | - | - | - | - | - | - | - | W19 | - | - | - | - |
| | 45 | - | W20 | - | - | - | - | W05 | W20 | - | - | - | - |
| 500 | 10 | - | - | - | - | W06 | W21 | - | - | - | - | - | - |
| | 16 | - | - | W12 | - | - | - | - | - | - | - | - | - |
| | 24 | - | - | - | - | W08 | - | W08 | - | - | - | - | - |
| | 30 | - | - | - | - | - | - | - | - | - | - | - | - |
| 700 | 10 | W26 | - | - | - | W26 | - | - | - | - | - | - | - |
| | 16 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 24 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 30 | - | - | - | - | - | - | - | - | - | - | - | - |

*Table 10.11 – 1: Possible IG flange connections at LESER*

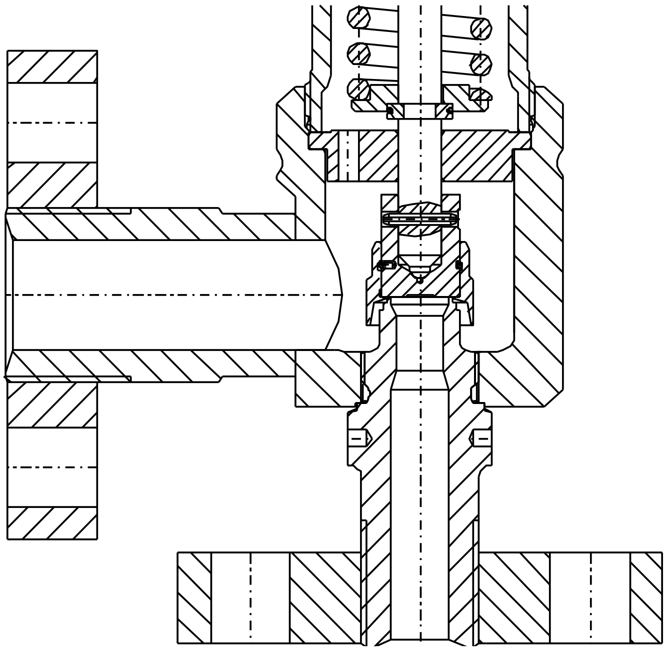


*Figure 10.11 -1: IG-Flange connection*

## 10.12 LESER Specific Details

### 10.12.1 Lap joint flanges

For Compact Performance safety valves LESER provides lap joint flanges, which are not specifed in a standard, but are dimensioned sufficiently in all possible nominal pressure ratings.

The design strength of the socket is calculated according to AD-2000. The flange-thickness is calculated according to AD-2000 B7 and ASME section II with a safety factoraddition of 2 mm.

*Figure 10.12.1-1: Lap joint flanges*

### 10.12.2 Machining of outer flange diameter and flange thickness for cast bodies

LESER is stocking cast bodies for all safety valves. Flange connections for different flange classes (acc. to EN or ASME) can be machined from one cast body, which means that e.g. the flange of the raw casting is designed for ASME Class 600. Depending on the valve size from this casting the flange Class 600, 300 as well as Class 150 may be machined.

| Orifice | Pressure Rating Inlet | | | |
|---|---|---|---|---|
| | 150 | 300L | 300 | 600 |
| D | (1) **103.20** 20/30/40/70 **1 x 2** | | | |
| E | | | | |
| F | (3) **103.24** 20/30/40 | | (4) **103.28** 20/30/40/70 **1 1/2 x 2/3** | |

*Figure 10.12.2-1: Illustration of body patterns versus flange ratings*

ASME B16.34 defines all requirements regarding valves with flanged, threaded, and welding ends. For flanged end dimensions ASME B16.34 references to ASME B16.5 (or 16.47 for large diameters).
ASME B16.5 includes all nominal dimensions to design a flange. For functionally important dimensions tolerances are defined too.
For the outer flange diameter "O" no specific tolerances are defined within the ASME standards.

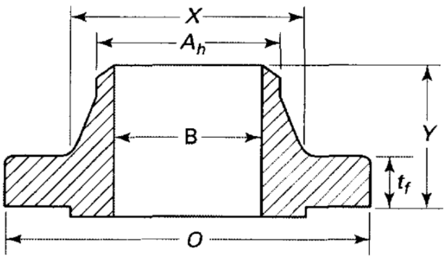



*Figure 10.12.2-2: Flange dimensions*

Therefore the **outer flange diameter** of the cast flanges is left unmachined and can in some cases be larger than the nominal dimensions listed in the applicable standard for welding neck flanges.In addition the outer diameter is used to clamp the body in the CNC machine for a most rigid clamping. This procedure is common industry practice.

The advantages are:

- short lead times from LESER stock, because the number of required raw material items is reduced, increasing the availability of the individual casting
- valve body for smaller flange classes is more solid than required
- centre to face dimensions are always the same independent from the flange standard

The connecting dimensions (bolt holes and raised face) always fulfil the requirements of the applicable standard (EN 1092 or ASME B16.34 / ASME B16.5).

Therefore the assembly of the safety valve with the connecting flanges of the pipework is not affected.

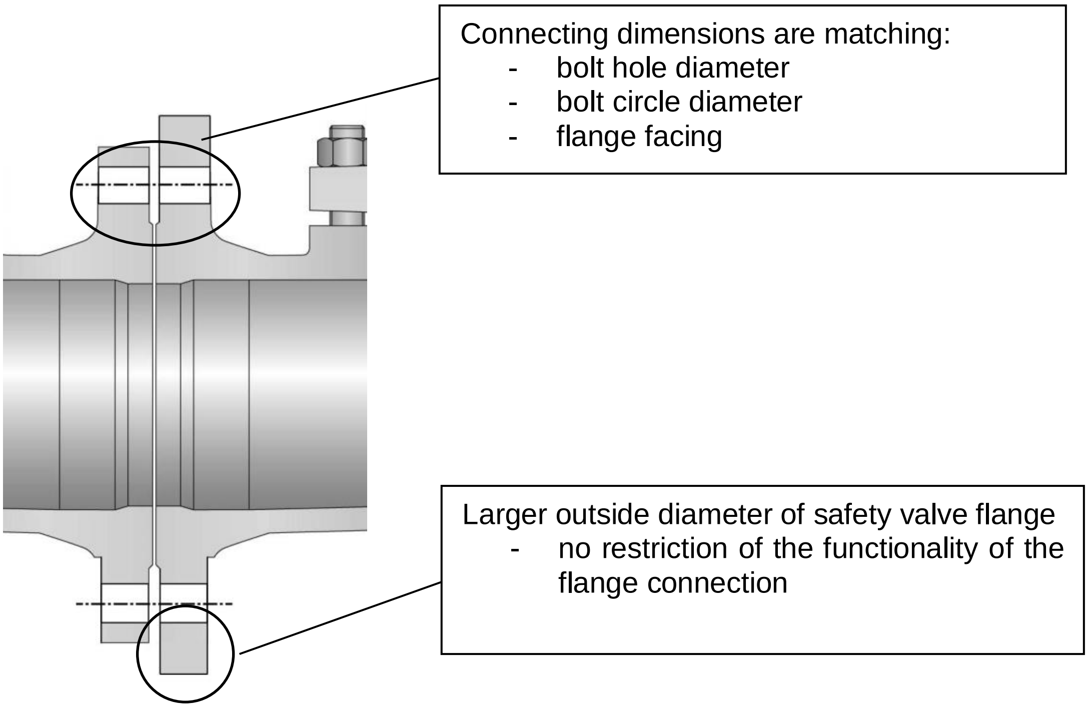



*Figure 10.12.2-3: Illustration safety valve flange and pipe flange*

In case the larger outer diameter is not accepted from an optical standpoint, it can be machined on request and at additional cost. For details on actual flange outer diameters of LESER Type 526 please contact LESER technical sales.

The **flange thickness** of LESER designs according to API standard 526 like Type 526 may exceed the flange thickness as mentioned in ASME / ANSI B16.5. This is fully in accordance with API standard 526, section 2.4. Dimensions, which states that:

“For some valve designs, the inlet raised face height may substantially exceed the nominal dimension specified in ASME. Consult the manufacturer for exact dimensions.”

This statement is valid for all valve types acc. to API 526 (spring loaded and POSV) as well as for all further full nozzle types like 457/458 and 441FN.

The total height of flange thickness plus raised face height (dimension S) can be found in the LESER catalog and in VALVESTAR documentations.

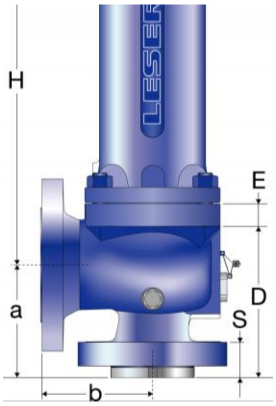



*Figure 10.12.2-4: Flange thickness dimension “S”*

Full nozzle safety valves like LESER API Series 526 exceed the flange thickness stated in ASME B16.5 of the inlet flange due to:

- Height of nozzle sealing face installed in the valve inlet
- The outer diameter of the nozzle thread, screwed into the body inlet, requires a flange thickness larger than specified in ASME / ANSI B16.5 to achieve the required pressure rating.

This results in:

- Valve body is more rigid and therefore less prone to distortion caused by stresses induced by piping loads during installation, this preserves factory seat tightness acc. to API 527
- During installation, bolting requirements should be calculated using the “S” dimension stated in the LESER API catalogue, please do not hesitate to contact us if you need any assistance

Major safety valve manufactures follow the same design philosophy. LESER’s design approval, certified by third party inspection bodies including ASME, National Board and TUEV, have approved the design.

When customers or inspectors insist on having the inlet flange thickness strictly in accordance with ASME tolerances LESER can perform a machining of the flange front side at request and at additional cost. This machining will decrease the “$t_f$” dimension acc. to figure 10.12.2-2, but not change the “S” dimension.

10.12.3 Flattened outlet diameter

Very few outlet flanges in LESER designs are supplied with flattened outlet flanges as shown in the figure below. This is due to the short inlet center to face dimension of the inlet flange. The flattened outlet flange allows:

- backside machining of the inlet flange
- easier fitting of bolts and nuts at the inlet flange

The flattened flange design is not stipulated in the EN 1092 or ASME B16.5 standards, but it causes no decrease of strength in respect to operating pressure and temperature limits compared to standard flanges.

Flanges of all possible nominal pressure ratings are dimensioned sufficiently. This is possible with an increase of the outer diameter and the flange thickness. The design was calculated according to ASME Section VIII Div 1 Appendix 2 (e.g. LESER type 458). All body designs of this series are type tested and approved by TUEV and ASME.

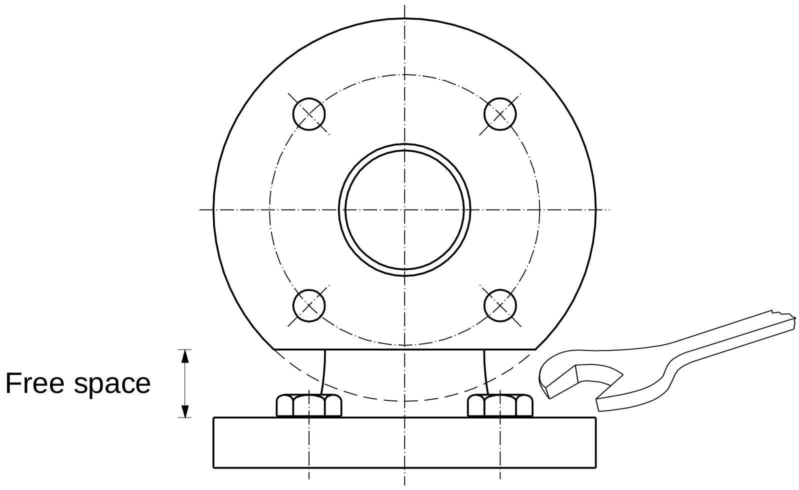



*Figure 10.12.3 -1: Flattered outlet fange design*

## Contents

## 11.1 Introduction

The purpose of this chapter of the LESER Engineering Handbook is to explain

- How does LESER ensure the quality of its products?
- What makes the difference between LESER and most competitors?

Quality Management is a multi-faceted and multi-stage process. LESER therefore focuses its QM activities on several related areas, which are described in detail below:

- LESER's integrated Quality and Environmental Management System
- Requirements for the qualification of suppliers
- Requirements for components that are not manufactured in-house
- Requirements for the qualification of service partners
- Standard quality tests, procedures and certificates
- Quality tests performed on customer's request
- Explanation of LESER's Environmental Management activities

## 11.2 LESER's Integrated Quality and Environmental Management System

LESER is supplying safety valves to customers worldwide and makes sure that the products can be used in most countries without requiring any change.

LESER has summarized the requirements of international codes and standards and has transferred these into

- internal processes
- requirements for suppliers
- requirements for purchased materials

The result is a Quality and Environmental Management System which integrates the requirements of global quality and environmental standards.

This includes the certification according to various regional and international regulations such as:

- ISO 9001
- European Pressure Equipment Directive (PED 97/23/EC)
- ASME VIII Div 1
- ISO 14001
- Chinese Manufacture Licensing System
- EAC Russia, Belarus, Kazakhstan
- IACS
- and others

Thus, the worldwide suitability of LESER's safety valves is ensured without requiring additional regulatory compliance for most countries throughout the world. This system is applied by our worldwide subsidiaries as well.


*Figure 11.2-1: Quality Management Certificates*

### 11.2.1 Quality and Environmental Policy

With our safety valves we protect our clients’ products and facilities and thereby prevent harm to people and the environment.

It is a matter of principle to LESER to provide each of our customers with products and services of the required quality which comply with the customers’ specifications, the current norms and the rules and regulations.

The required quality is achieved as a result of standardized and controlled processes, processes that are shaped and carried out by our staff.

The achieved level of quality is therefore the collective result of the work done by each of our employees and only meets the requirements when every employee carries out the tasks in his/her field of activity self dependently and with quality awareness.

Only by ensuring the quality of our products and processes we can guarantee our objective to provide protection and our financial success.

To achieve the required quality, we work with the regulations and methods specified in our quality management system in accordance with (EN) ISO 9001-2000. This is perpetually being maintained and further developed in order to increase the effectiveness of the regulations and methods.

Environmental issues form a vital part of our planning and implementation activities across the processes of design, material management and production of LESER products.

A reasonable consideration of the environmental impact determines the type and scope of these activities.

LESER is committed to a careful use of resources and strives to continually improve the relevant processes in order to reduce the environmental impact.

### 11.2.2 Management System Overview

LESER Quality Management comprises both the levels of strategic planning and operative quality assurance.

On the strategic planning level, a large number of existing rules and regulations in the form of LESER work standards and working instructions for the operative quality assurance are in place in order to ensure compliance with rules and regulations within the controlled processes.

The operative quality assurance is the scheme which governs day to day operations. Quality coordinators located in the individual operative departments ensure the implementation of quality improving measures in all areas of activity of the order process.

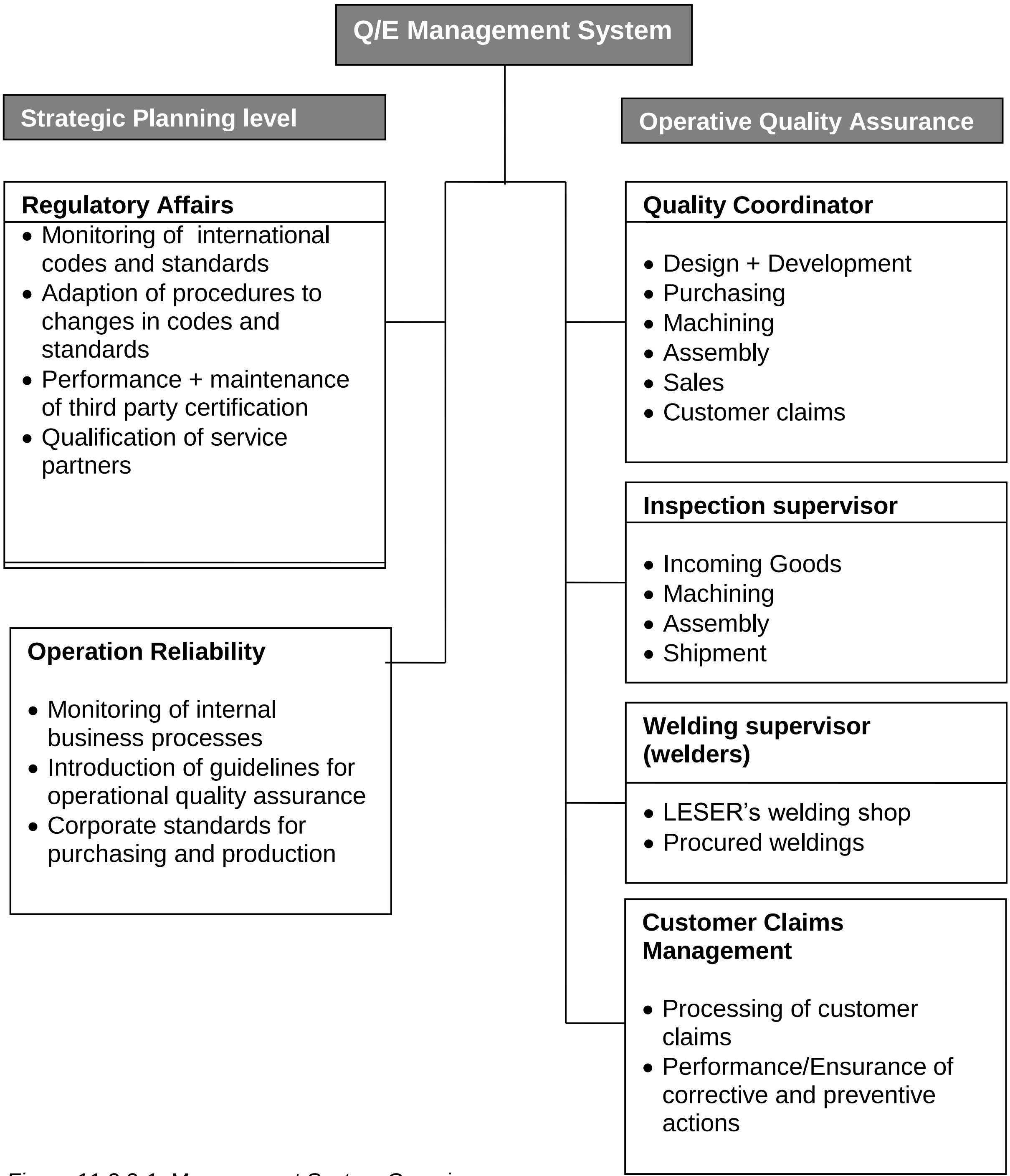



*Figure 11.2.2-1: Management System Overview*

## 11.3 Quality Assurance Activities

The high quality level of LESER safety valves is the result of coordinated processes, starting with product development, through the assurance of high quality purchased materials and high-grade qualified production, combined with coordinated quality assurance measures within each stage of production right up to the field application.

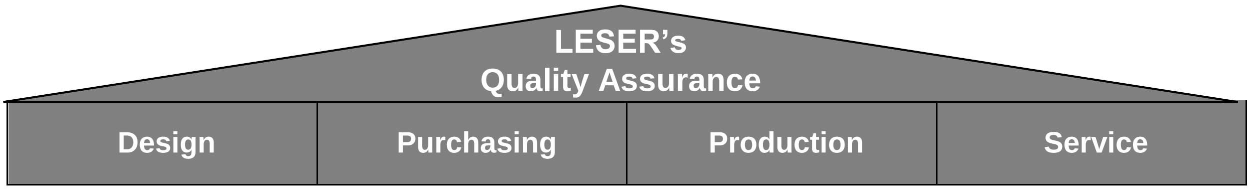



*Figure 11.3-1 Quality Assurance at LESER*

### 11.3.1 Quality Assurance in the Design Process

Quality assurance elements in all stages of product design are of key importance because this is where the greatest potential for cost reduction and quality improvement lies.

For this reason LESER has implemented elements like design reviews, process and design FMEAs (failure mode and effect analysis) into the design process.

Furthermore, product validation testing is conducted on our performance test lab, assuring the high quality of LESER safety valves already at the design stage.

In addition to the product validation testing required for the approval of a safety valve, regular product audits are performed by LESER.
A product audit is performed on production valves and consists of the following checks and verifications:

- capacity and function: performance tests on flow test lab
- set pressure: according to specification
- tightness: according to specification, API 527, LGS 0201
- documentation: order confirmation, LESER CGA, material certificates
- material certificates: compliance of materials with ASME VIII and ASME II, PED 97/23/EC
- marking: consistency between packing, tag and name plate
- valve external: no external damages
- dimensions: dimensional check of critical dimensions
- consistency of information: comparison of information in catalog and LESER order handling system (SAP configurator)

### 11.3.2 Quality Assurance in Purchasing

The requirements for purchased parts are laid down in LESER's corporate purchasing specifications. Examples for these specifications are:

- LDeS 3290.01_EN to LDeS 3290.16_EN: Terms of delivery for casting materials
- LDeS 3040.01: Delivery specification for bar materials
- LDeS 3265.01_EN: Delivery conditions for helical compression springs

These documents summarize the requirements of worldwide codes and standards (e.g. PED and ASME Code) and serve as contractual requirements for all tests and qualifications.

At the beginning of the purchasing process, the first step is the selection and qualification of suppliers.
LESER's requires a stringent qualification of new suppliers and continuous monitoring of established suppliers. LESER uses a comprehensive qualification system established in a supplier development process with the following topics:

- Check required certifications
- Requirements for supplier's quality system certifications, qualifications of staff and processes
- External audits of the supplier's quality management system and manufacturing equipment
- First sample examination process (6 sample lot per each new part)
- Continuous supplier assessment by incoming inspection
- Quality Assurance Agreements with suppliers which are then integrated into the LESER Quality Management System

The following example shows requirements and procedure for the qualification of a new supplier for casting materials:

| Step | Process | Requirement |
|---|---|---|
| 1 | Preselection of supplier | ISO 9001, PED 97/23/EC, LR, GL, DNV, requirements are laid down in LDeS 0017.00 and LGS 0024 |
| 2 | Supplier audit by QM and Purchasing | Verification of requirements above mentioned requirements regarding: certifications, equipment, personnel. |
| 3 | Implementation of LESER specified casting pattern by supplier | Conformity with drawings |
| 4 | Supply of first sample lot to LESER:<br>6 sample lot for each new part with first sample inspection performed by supplier | First sample inspection requirements are laid down in LGS 0215. |
| 5 | First sample inspection process at LESER<br>- review of material certificate, spectral analysis<br>- 100% incoming inspection of samples, dimensional check, ultrasonic or radiographic test<br>- machining of all samples with tools used during serial production: shows possible internal defects<br>- documentation of results in a specific first sample test report form<br>- result: approved, approved with conditions, not approved… | ISO 9001, PED 97/23/EC,<br>ASME VIII App. 10.<br>First sample inspection requirements are laid down in LGS 0215. |
| 6 | Approval of new part for supplier | |

*Table 11.3.2-1: Requirements for supplier qualification*

Should quality deviations occur after the part has been approved, LESER uses a claim management process which secures that corrective and preventive measures are taken by the supplier. LESER's established supplier management system guarantees the LESER specific development of suppliers in order to attain a high quality level.

### 11.3.2.1 Castings Sourced in India or China

LESER is sourcing castings from suppliers in various countries in Europe, Brazil, UAE and a large portion coming from India and China.
Every supplier is going through the approval procedure described above and on every component supplied by the supplier the first sample examination process is performed. Quality control and all machining of castings is performed by LESER in Germany. Together with the quality assurance measures in production described in the following section, LESER ensures that every safety valve that leaves the factory satisfies the quality requirements of our customers and the applicable codes and standards.

### 11.3.3 Quality Assurance in Production

LESER has a high degree of vertical integration compared to other valve manufacturers. Instead of sourcing ready machined components or complete valves in low cost countries, machining, welding, pickling and assembly are integrated in the production process at the factory in Hohenwestedt (Germany). This deep vertical integration allows hands-on access to the processes and quick response times.

This process control is ensured by:

- Quality inspectors and workers in the machining department who are directly responsible for inspections according to specified inspection plans.
- Inspection supervisors trained according to
  - *EN 473 – Non-Destructive Testing – Qualification and Certification of NDT Personnel* and
  - *SNT-TC-1A - Non-Destructive Testing*

  who check the non-destructive inspections for cast and welded parts.
- Welding supervisors who qualify the welding procedures together with external inspectors.
- Quality coordinators who ensure the quality of the individual operational processes and who are especially trained as certified individuals according to ASME VIII UG 117.

### 11.3.4 After Sales Service

After the valves are delivered to the customer LESER the following quality related processes ensure the functionality of the products during the product life cycle:

- Service Partners like assemblers and repair shops receive extensive qualification by LESER and thus serve as contacts for our customers worldwide.
- LESER qualifies and certifies all Service Partners according to its own corporate quality standards.


ZERTIFIKAT

CERTIFICATE

Der Firma / The company

Sample Company

Sample Address

wird bescheinigt, dass sie durch Erfüllung des Anforderungsprofils der LESER-Werknorm 612.07 an LESER-Service-Partner autorisiert ist, im Namen von LESER Einstellungen und Reparaturen an LESER-Sicherheitsventilen durchzuführen.

is certified to fulfil the requirements of LESER Work Standard 612.07 and authorized to repair and adjust LESER safety valves with approval of LESER.

Gültig bis 31. Oktober 2011

Valid until 31st October 2011

Hohenwestedt, den 31. Oktober 2008

Leiter Qualitätsmanagement / Quality Manager:

LESER The Safetv Valve

LESER GmbH & Co. KG D-20537 Hamburg, Wendenstrasse 133-135 D-20506 Hamburg, P.O. Box 26 16 51 Fon +49 (40) 251 65-100 Fax +49 (40) 251 65-500 E-Mail: sales@leser.com www.leser.com

*Figure 11.3.4-1: Service Partner Certificate*

- LESER's repair department at our Hohenwestedt production site ensures the repair even of old valves which have been in service for a long time.
- In case of customer claims LESER's Claims Management immediately makes sure that effective corrective action is taken. Every incident is documented in a report and substantiated by photographs if applicable.
  In case of a claim you can contact LESER by:
  Phone +49 4871 27-122
  Fax +49 4871 27-298
  E-mail: claims@leser.com

## 11.4 Environmental Management

LESER has established, documented and implemented an Environmental Management System according to ISO 14001. The Management System is improved continually.

The System ensures that LESER uses resources carefully and relevant processes are in place to reduce the environmental impact.

Environmental programs and objectives form the basis of the use of environmentally friendly technologies and serve as guidelines not only for ourselves but also for LESER's contractual partners.

Reduction of the environmental impact consists of a large number of small measures. Examples for these measures are:

- over 90 % of LESERs waste products are recycled as per the German environmental laws.
- LESER has also decreased the waste pickups by nearly 50%. The reduction of paper pickups from six to three per week alone saves over 600 travel kilometres per month.

## 11.5 Quality Tests and Test Certificates

LESER offers all relevant types of tests, including tests performed on customers' request and third party inspections. Testing is based on internationally applicable standards and on a large number of national codes and their requirements. There is extensive documentation of test procedures available. LESER issues a variety of certificates, including its own Certificate for Global Application (CGA) which integrates the various compliance certifications for LESER standard tests into one single certificate, certifying global suitability for LESER safety valves. For details about the Certificate for Global Application see section 11.5.5.

### 11.5.1 Types of Test

LESER performs the following types of tests or will arrange for them to be performed by a third party:

- LESER standard tests – required by international codes and standards (see section 11.5.2) Tests are documented with a Certificate for Global Application - CGA, see section 11.5.5.
    - Body strength
    - Set pressure
    - Tightness Seat/Body, etc.
- Material Tests – performed by supplier or external laboratories
    - Strength tests
    - Chemical analysis,
    - NDE tests, etc.
- Additional Tests – performed by LESER on customer's request
- Third Party Inspections – performed by TÜV, classification societies, customer or others

### 11.5.2 Requirements for Standard Tests

The requirements for the LESER standard tests which are certified by the LESER Certificate for Global Application – CGA are based on the following directives:

| Test Description | Directive | Option Code |
|---|---|---|
| LESER Certificate for Global Application - CGA<br>(Inspection Certificate 3.1 according to DIN EN 10204) | ASME Code Sec VIII<br>API 526<br>DIN EN ISO 4126<br>DIN EN 12266 1/2<br>PED 97/23/EG<br>AD 2000-A2<br>VDTÜV SV 100 | H03 |

*Table 11.5.2-1: Requirements for standard tests*

### 11.5.3 Procedures

LESER's test procedures are documented in LESER global standards - LGS. The standards contain detailed information about:

| | | |
|---|---|---|
| * Applicability | * Scope and definition | * Test reference |
| * Test equipment | * Test procedure | * Acceptance criteria |
| * Personal qualification | * Documentation | * Standard references |

The following are examples for procedures, as documented in LESER procedural standards:

| Test | LESER Procedural Standard |
|---|---|
| Overview | LGS 0200 |
| Body tightness | LGS 0201 and LGS 0209 |
| Hydrostatic pressure test | LGS 0209 |
| NDE-tests | LGS 0203 to LGS 0206 |
| Material identification test | LGS 0207 |
| Seat Tightness | LGS 0201 |

*Table 11.5.3-1: Tests and Procedural Standards*

The description of all test procedures can be downloaded from the LESER download portal on the LESER website: www.leser.com

### 11.5.4 Test Certificates According to EN 10204

According to the EN 10204 standard LESER offers three different types of certificates as follows:

Test report 2.2

Document in which the manufacturer declares that the products supplied are in compliance with the requirements of the order and in which he supplies test results based on non-specific inspection.

Inspection Certificate 3.1

Document issued by the manufacturer in which he declares that the product supplied are in compliance with the requirements of the order and in which he supplies test results.

The test unit and the tests to be carried out are defined by the product specification, the official regulation and corresponding rules and/or the order.

The document is validated by the manufacturer's authorized inspection representative, independent of the manufacturing department.

Inspection Certificate 3.2

Document prepared by both the manufacturer's authorized inspection representative, independent of the manufacturing department and either the purchaser's authorized inspection representative or the inspector designated by the official regulations and in which they declare that the products supplied are in compliance with the requirements of the order and in which test results are supplied.

The majority of the certificates issued by LESER are Inspection Certificates 3.1.

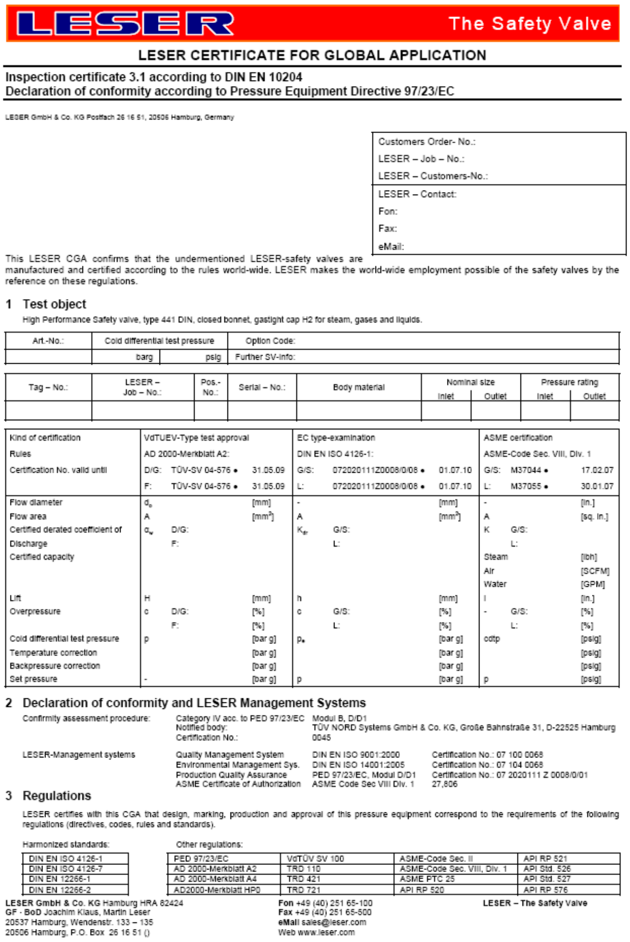
### 11.5.5 Standard Test – LESER Certificate for Global Application (CGA)

LESER offers a Certificate for Global Application (CGA) which confirms that LESER safety valves are manufactured and certified according to combined international regulatory standards. This ensures the worldwide suitability of LESER safety valves.

By issuing the CGA LESER certifies that the design, marking, production and approval of the pressure equipment correspond to the requirements of regulations which are listed under “directive”.
Further to the CGA, LESER offers to issue an inspection certificate 3.1 according to DIN EN 10204 for each test on request.
All named tests are applied for each individual safety valve which leaves the factory, regardless if the CGA is issued or not.

The shipment of certificates (LESER CGA or single inspection certificates) will be carried out together with the safety valves, if not specified otherwise.
On request, LESER will also dispatch the certificates by e-mail, fax or mail as well.
All certificates already ordered by the customer can be downloaded from the LESER Download Portal at “www.leser.com”.
To order additional inspection certificates please contact the LESER Certificate service via e-mail to: certificate@leser.com.

Customers can order the LESER CGA by specifying option code “H03”.



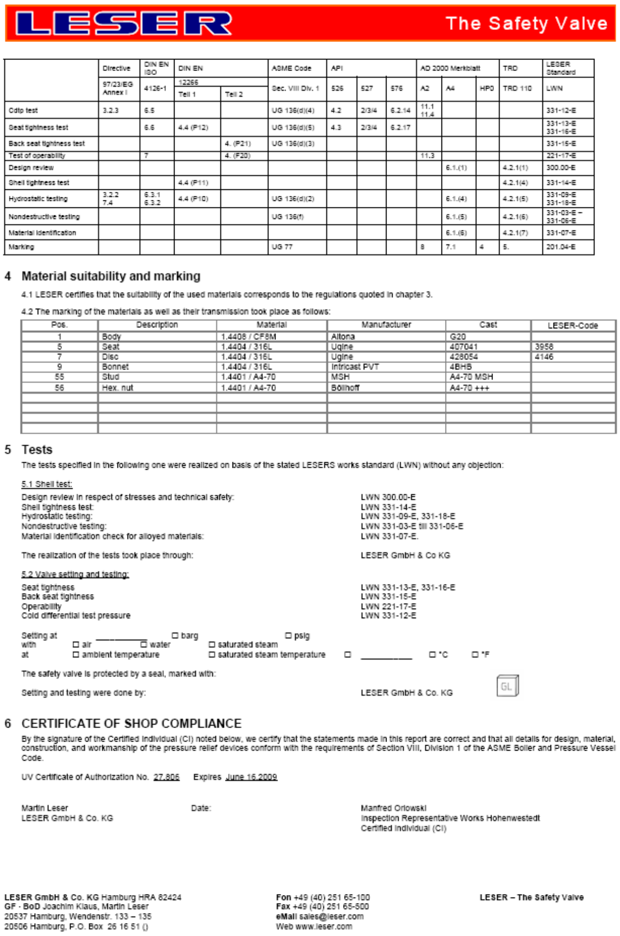




*Table 11.5.5-1: Certificate for Global Application*

The following table lists all tests whose certification is included in the LESER CGA.

| Standard Tests - LESER Certificate for Global Application (CGA) | | | |
|---|---|---|---|
| **Test** | **Directive** | **Procedure** | **Option code[1)]** |
| **Test pressure** | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Testing of cold differential test pressure with air | DIN EN ISO 4126-4<br>DIN EN ISO 4126-1, chapter 7.2<br>ASME Code Section I, PG-72<br>ASME Code Section VIII, Div. 1 UG 134;Ad 2000-Merkblatt A2, chapter 11 | LGS 0202 | N05 |
| **Component strength test** | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Hydrostatic testing 1,5 x PN | DIN EN ISO 4126-1;<br>ASME Code Sec. VII Div. 1, UG 136(d)(2) | LGS 0209 | M68 |
| **Surface crack test** | | | |
| Surface crack testing in accordance with AD 2000-Merkblatt A4, chapter 6 and ASME code section VIII, Div. 1, UG 136 is usually conducted as random testing and can be certified with LESER CGA.<br><br>Surface crack testing can be conducted using varying methods (magnetic particle testing, red-white colour dye penetrant testing, or fluorescent penetrant testing). LESER determines the corresponding test method for the component and substance.<br><br>Inspection certificate 3.1 acc. to DIN EN 10204: Surface crack test | AD 2000-Merkblatt A4, chapter 6<br>ASME Code, Section VIII Div.1, UG 136 | LGS 0203<br>LGS 0204 | N52<br>N53<br>N54 |
| **Tightness** | | | |
| Overview of different tightness test | | LGS 0201 | |
| **Seat tightness test** | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Seat tightness test with air, bubble test - Standard tightness requirements | DIN EN ISO 4126-1<br>DIN EN 12266-1,<br>ASME Code Section VIII Div. 1, UG 136(d)(5); API 527 | LGS 0201 | M66 |
| Inspection certificate 3.1 acc. to DIN 10204: Seat tightness with air, test fluid | | LGS 0201 | M22 |
| **Pressure retaining body** | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Shell tightness test | DIN EN 12266-1, 4.2 | LGS 0201 | M18 |
| **Back seat tightness test (tightness outwards)** | | | |
| **Flanged Safety valves**<br>Inspection certificate 3.1 acc. to DIN EN 10204: Back seat tightness test with test fluid | DIN EN 12266-2, test P21 ASME Code Section VIII, Part UG-136(d) | LGS 0201 | M28 |
| **Compact Performance Safety valves**<br>Inspection certificate 3.1 acc. to DIN EN 10204: Back seat tightness test, dipping procedure | | LGS 0201 | M78 |
| **Design review of safety valve** | | | |
| Design review in respect of stresses and technical safety<br>Inspection certificate 3.1 acc. to DIN EN 10204: Design review | AD 2000-Merkblatt A4, chapter 6 par. 6.1<br>TRD 110, chapter 4.2 | WI 3300.00 | M85 |

| Standard Tests - LESER Certificate for Global Application (CGA) | | | |
|---|---|---|---|
| **Test** | **Directive** | **Procedure** | **Option code[1)]** |
| **Material identification check (PMI)** | | | |
| Material identification check in accordance with AD 2000-Merkblatt A4, chapter 6, par. 6.1 (6) is usually conducted as random testing and can be certified with LESER CGA. LESER determines the corresponding test method for the component and material.<br><br>Inspection certificate 3.1 acc. to DIN EN 10204: Material identification check (PMI) | AD 2000-Merkblatt A4, chapter 6, par. 6.1(6) | LGS 0207 | N55<br>N56<br>N57<br>N1A<br>N1B<br>N1C<br>N1D<br>N1E<br>N1F<br>N1G<br>N1H<br>N1J |
| **Body volume check** | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Ultrasonic test | AD 2000-Merkblatt A4,chapter 6<br>ASME Code, Section VIII Div. 1, UG-136 | LGS 0205 | M56 |

*Table 11.5.5-2: Standard tests*

1): Option code to order a 3.1 test certificate for the individual test

### 11.5.6 Specific Tests at LESER

For specific tests at LESER which are not performed as a standard and which can be ordered individually, see column “Option Code” in the following table.

| Specific Tests at LESER | | | |
|---|---|---|---|
| **Test** | **Directive** | **Procedure** | **Option Code** |
| **Body strength test** | | | |
| Hydrostatic testing according to customer specification<br>Inspection certificate 3.1 acc. to DIN EN 10204 included | Customer specification (Please note: Test pressure and test duration must be specified.) | LGS 0209 | M01 |
| **Tightness** | | | |
| Overview of different tightness test | | LGS 0201 | |
| Seat tightness test with air, bubble test<br>- Increased tightness requirements<br>Inspection certificate 3.1 acc. to DIN EN 10204 included | DIN EN ISO 4126-1; DIN EN 12266-1,<br>ASME Code Section VIII Div. 1, UG 136(d)(5);<br>API 527 | LGS 0201 | J86 |
| **Tightness: Helium leakage test** | | | |
| Back seat tightness test with helium<br>Inspection certificate 3.1 acc. to DIN EN 10204 included | DIN EN 12266-2, Test P21<br>ASME Code Section VIII, Part UG-136(d) | LGS 0201 | N64 |
| Seat tightness test with helium, overpressure procedure - Inspection certificate 3.1 acc. to DIN EN 10204 included | DIN EN ISO 4126-1<br>DIN EN 12266-1, Test P12<br>ASME Code Section VIII, Part UG-136(d)<br>API 527 | LGS 0201 | N62 |
| Seat tightness test with helium, leakage detection in vacuum - Inspection certificate 3.1 acc. to DIN EN 10204 included | | LGS 0201 | M86 |
| **Testing of substances** | | | |
| Testing that all parts are free of oil and grease - Inspection certificate 3.1 acc. to DIN EN 10204 included | LGS 0210 | LGS 0210 | J85 |
| **Surface crack test** | | | |
| **Clean Service Safety valves** | | | |
| The surface qualities for LESER Clean Service Safety valves are defined as LESER Surface Grades (LSG), and assigned to the individual valves by the Clean finish, HyClean finish, and Sterile finish surface packages. | | | |
| LESER surface packages<br>- Clean finish<br>- HyClean finish<br>- Sterile finish | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Surface roughness | DIN EN ISO 11866<br>ASME BPE 2002 Part SD | LGS 0214 | N04 |
| | | | |

| | | | |
|---|---|---|---|
| **Surface roughness for components according to customer specification** | | | |
| Testing of surface roughness Inspection certificate 3.1 acc. to DIN EN 10204, included – components to be specified by customer | Customer specification | LGS 0214 | N04 |
| **Testing of components** | | | |
| **Spring loaded safety valves** | | | |
| Specification acc. to NACE MR0175 - 2003 Inspection certificate 3.1 acc. to DIN EN 10204, included components: body, seat / nozzle and disc | NACE Standard MR0175-2003 | LDeS 3001.91 | N78 |
| Specification acc. to NACE MR0103 - 2012 Inspection certificate 3.1 acc. to DIN EN 10204, included components: body, seat / nozzle and disc | NACE Standard MR0103-2012 | LDeS 3001.91 | N77 |
| **Pilot operated safety valves** | | | |
| Specification acc. to NACE MR0175 – 2003 Inspection certificate 3.1 acc. to DIN EN 10204 included components: body, seat, disc, pilot body and manifold block | NACE Standard MR0175-2003 | LDeS 3001.91 | R70 |
| Specification acc. to NACE MR0103 – 2012 Inspection certificate 3.1 acc. to DIN EN 10204 included components: body, seat, disc, pilot body and manifold block | NACE Standard MR0103-2012 | LDeS 3001.91 | R93 |
| **Body volume check** | | | |
| Inspection certificate 3.1 acc. to DIN EN 10204: Radiographic test | AD 2000-Merkblatt A4,chapter 6 ASME Code, Section VIII Div. 1, UG-136 | LGS 0206 | M80 |

*Table 11.5.6-1: Specific Tests*

### 11.5.7 TÜV Inspection Certificate for Setting of Safety Valves

In accordance to AD 2000-Merkblatt A2 chapter 11.4 the set pressure of each safety valve shall be determined.
This may be achieved using neutral media. A certificate specifying the set pressure, the test medium, the test temperature and the marking shall be issued with respect to this. In the case of safety valves as safety accessories for pressure vessels, this is done by the relevant third party.

The inspection certificate for setting of safety valves is issued by an independent inspector from the notified body TÜV-Nord, Registration-No. CE 0045.

This TÜV certificate is an inspection certificate 3.2 according to DIN EN 10204 for setting of safety valves. It provides confirmation that an inspector from the TÜV-Nord has examined the set pressure.

The inspection certificate can be ordered using option code M33.

| TÜV-Certificate valve setting | | |
|---|---|---|
| **Test** | **Directive** | **Option code** |
| **Test Pressure** | | |
| Inspection certificate 3.2 according to DIN EN 10204 for setting of safety valves | AD 2000-Merkblatt A2 chapter 11.4<br>AD 2000-Merkblatt HP 512R chapter 5<br>HP 512 chapter 7<br>DRG 97/23/EG, annex I chapter 3.2.3 | M33 |

*Table 11.5.7-1: TÜV-Certificate*

### 11.5.8 Material Test Certificates

For the quality traceability of materials test certificates according to EN 10204 2.2, 3.1 or 3.2 can be provided. The certificates are issued by the material manufacturer.

| Material Test Certificates | | |
|---|---|---|
| **Component** | **Certificate type** | **Option code** |
| **Compact Performance Safety Valves** | | |
| Inlet body | DIN EN 10204-3.1 | H01 |
| Outlet body | DIN EN 10204-3.1 | L34 |
| Inlet flange | DIN EN 10204-3.1 | L22 |
| Outlet flange | DN EN 10204-3.1 | N3B |
| Outlet adaptor | DN EN 10204-3.1 | N3A |
| **Flanged safety valves** | | |
| Body | DIN EN 10204-3.1 | H01 |
| Type 5267 body (WC6/1.7357) | DIN EN 10204-3.2 | H09 |
| Type 4587 body (WC6/1.7357) | DIN EN 10204-3.2 | H09 |
| Type 447 Outlet body | DIN EN 10204-3.1 | L34 |
| **Change-over valves** | | |
| Body / flange elbow | DIN EN 10204-3.1 | Y41 |
| Stud bolt | DIN EN 10204-3.1 | N07 |
| Nuts | DIN EN 10204-3.1 | N08 |
| **POSV** | | |
| **Main valve** | | |
| O-Ring (Pos. 60+67) | DIN EN 10204-2.2 | H2H |
| Piston | DIN EN 10204-3.1 | R75 |
| Top plate | DIN EN 10204-3.1 | R76 |
| Piston guide | DIN EN 10204-3.1 | R77 |
| Spring Pos. 59 | DIN EN 10204-3.1 | H2K |
| **Pilot** | | |
| Body | DIN EN 10204-3.1 | R78 |
| Bonnet | DIN EN 10204-3.1 | R79 |
| Manifold block | DIN EN 10204-3.1 | R84 |
| **Options** | | |
| Field test connector | DIN EN 10204-3.1 | R88 |
| Supply filter | DIN EN 10204-3.1 | R89 |
| **Other components** | | |
| Stellring | DIN EN 10204-2.2 | H2D |
| Federteller | DIN EN 10204-2.2 | H2F |
| Druckschraube | DIN EN 10204 | H2G |
| Dichtring | DIN EN 10204 | H2H |
| Arretierschraube | DIN EN 10204 | H2J |
| Bonnet | DIN EN 10204-3.1 | L30 |
| Cap / lifting device | DIN EN 10204-3.1 | L31 |
| Seat / nozzle | DIN EN 10204-3.1 | L59 |
| Disc | DIN EN 10204-3.1 | L23 |
| Guide | DIN EN 10204 | N95 |
| Bonnet spacer | DIN EN 10204 | H2E |
| Spindle | DIN EN 10204 | N94 |
| Bellows (metal) | DIN EN 10204 | N96 |
| Bellows (elastomer) | DIN EN 10204 | N96 |
| Stud | DIN EN 10204-3.1 | N07 |
| Nuts | DIN EN 10204-3.1 | N08 |
| Spring | DIN EN 10204-3.1 | L60 |

*Table 11.5.8-1: Material test certificates*

### 11.5.9 Third Party Inspections

LESER offers the following inspections:

- Inspection by TÜV
- Inspection by customer's representative
- Inspection by Classification Societies

Examples for normal Classification Society Inspection of set pressure test are as follows:

| Third Party Inspections | | |
|---|---|---|
| **Inspections, tests** | **Option code** | **Delivery time of certificates** |
| Det Norske Veritas (DNV) | M45 | with safety valves |
| Germanischer Lloyd (GL) | M47 | 2 weeks after shipment |
| Lloyd's Register EMEA (LREMEA) | M48 | 3 weeks after shipment |
| American Bureau of Shipping (ABS) | M38 | 7 weeks after shipment |
| Bureau Veritas (BV) | M43 | 7 weeks after shipment |
| Registro Italiano Navale (RINA) | M50 | 2 weeks after shipment |
| others | | 7 weeks after shipment |

*Table 11.5.9-1: Third Party Inspections*

Delivery time of certificates: LESER provides the relevant certificates immediately after receiving them from the inspection organisation.

### 11.5.10 Download of Certificates

Certificates are usually shipped together with the product. In the real world, however, documents may get lost or simply do not arrive where they are needed.
Therefore LESER offers a convenient online download of every inspection certificate or material test certificate which was ordered with the safety valve under www.leser.com, menu item "Certificates".

On our website two different logins are provided for the download of certificates for an individual valve or for a complete order.

**Certificates for an individual valve**
Required login data:

- Serial No.: serial number of the individual valve, see nameplate or LESER shipping documentation
- Article No: 8-digit LESER article number, see nameplate or LESER order confirmation / shipping documentation

**Certificates for a complete order**
Required login data:

- Customer No: Your LESER customer number, see LESER order confirmation or shipping documents
- LESER Job No: see LESER order confirmation or shipping documents

If your certificate was not ordered with the valve it will not be listed. In this case please order the required certificate with the certificate request form LESER on the website and contact LESER by
Fax +49 (4871) 27 - 296
E-mail certificate@leser.com

LESER The-Safety-Valve.com

## Contents

## 12.1 Introduction

A number of worldwide recognised codes and standards require specific markings on the nameplate and body of the safety valve. The scope of this chapter is to provide an overview about the markings on LESER safety valves and to describe which information can be found where on the safety valve.

Markings that are required by codes and standards as well as LESER standard markings are considered “standard” at LESER. Additional markings on customer request are listed as “Option Code” in this document.

## 12.2 Purpose of Markings

Markings on safety valves have different purposes. The following table lists some purposes exemplarily:

| Purpose | Example |
|---|---|
| Identification of approvals | TÜV-approval no.; UV-Stamp |
| Identification of the valve | Model-No., Serial-No., Tag-No. |
| Tracing of materials | Heat-No., Material Code-No. |
| Identification of performance features | Coefficient of discharge, capacities |
| Identification of sizes | Nominal diameter |
| Identification of the pressure rating | PN, CL |
| Identification of the application | Steam, gases, liquids |
| Product liability | Stamped seal |
| Material identification | Material designation |
| Identification of parts | Part-No. |
| Identification of service conditions | Set pressure, CDTP, back pressure, temperature |
| Identification of manufacturer | LESER |
| Identification of casting supplier | A |

*Table 12.2-1: Purpose of markings*

## 12.3 Markings on Nameplates

Every safety valve has to be marked with a name plate. Several codes and standards contain requirements for the marking of nameplates, e.g.:

- ISO 4126-1, chapter 10.2
- ASME Section XIII, chapter 3.9
- AD Merkblatt 2000 A2, chapter 9
- VdTÜV Merkblatt SV100, chapter 8
- API 526, Appendix B

These codes and standards differ in some requirements. LESER combines these requirements and uses only one nameplate which fulfils all requirements.
The LESER Name plate for Global Application NGA is the first name plate worldwide, which fulfils all requirements of the leading international codes and standards. Basically the LESER NGA is valid worldwide, but additional country-specific requirements e.g. for Russia or Canada have to be considered.

Fixing of NGA
The LESER Name plate for Global Application is spot welded at the bonnet of the safety valve, or at the outlet body (Series 437 and Type 481).

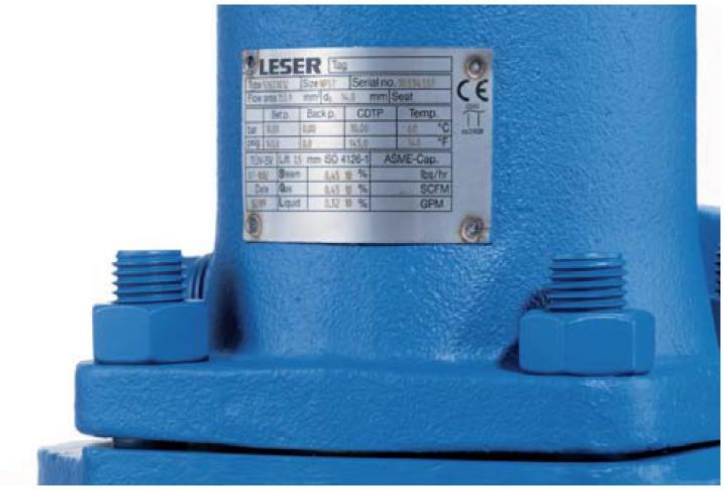



*Figure 12.3-1: LESER Nameplate for Global Application “NGA”*

### 12.3.1 Current LESER Nameplates for Spring Loaded Safety Valves

**LESER-Nameplate for global application "NGA", valid since January 2009**
Dimensions: 60 x 40 mm/ 2,36 x 1,58 in

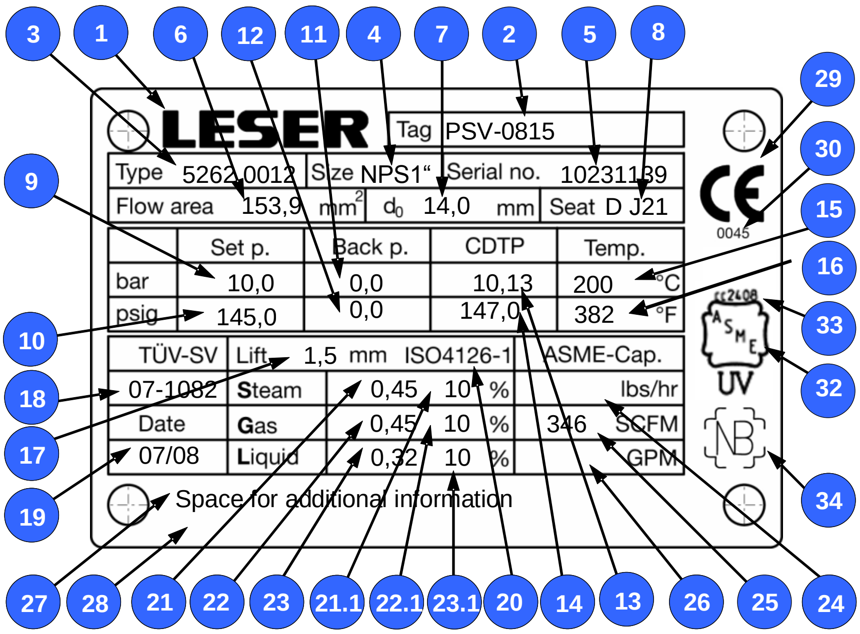



*Figure 12.3.1-1: LESER Nameplate for Global Application "NGA", valid since January 2009*

For an explanation of the individual nameplate entries refer to table 12.3.1-1.

| No. | Field name | Description | ISO 4126-1 | VdTÜV/ AD2000 A2 | ASME XIII | API 526 | Standard/ Option Code |
|---|---|---|---|---|---|---|---|
| 1 | LESER | Name of manufacturer | | | X | X | * |
| 2 | Tag | Optional marking of valve (customer's specifications) | | | | | * |
| 3 | Type | Type number (article number) | X | | X | X | * |
| 4 | Size | Nominal diameter | | X | X | X | * |
| 5 | Serial no. | Internal No. for Identification of the safety valve | | | | X | * |
| 6 | Flow area | Flow area in $mm^2$ | X | | | | * |
| 7 | do | Flow diameter in mm | | X | | | * |
| 8 | Seat | Identification of the soft seal material<br>Code letter O-Ring-Disc + Option code<br>No entry: metal-to-metal | | | | X | * |
| 9 | Set p. - bar | Set pressure of the safety valve in bar | X | X | | | * |
| 10 | Set p. - psig | Set pressure of the safety valve in psig | | | X | X | * |
| 11 | Back p. - bar | Back pressure in bar | | | | | * 3) |
| 12 | Back p. - psig | Back pressure in psig | | | | X | * 3) |
| 13 | CDTP - bar | Cold differential test pressure in bar | X | | | | * |
| 14 | CDTP - psig | Cold differential test pressure in psig | | | X | X | * |
| 15 | Temp. - °C | Temperature in °C (for CDTP) | | | | | * |
| 16 | Temp. - °F | Temperature in °F (for CDTP) | | | | | * |
| 17 | Lift -mm | Smallest lift / reduced lift when lift restriction in mm | X | | | | * |
| 18 | TÜV-SV | TÜV Approval No. according to the VdTÜV-Merkblatt + List number | X | X | | | * |
| 19 | Date | Date of manufacturing Month/Year | | X | X | | * |
| 20 | ISO 4126-1 | Number of the standard | X | | | | * |
| 21 | Steam | Certified coefficient of discharge for steam ($K_{dr}$/ $\alpha_w$) / reduced coefficient of discharge when lift restriction | X | X | | | * |
| 21.1 | Steam | Opening pressure difference in % | X | X | | | * |
| 22 | Gas | Certified coefficient of discharge for gases($K_{dr}$/ $\alpha_w$) / reduced coefficient of discharge when lift stopper | X | X | | | * |
| 22.1 | Gas | Opening pressure difference in % | X | X | | | * |
| 23 | Liquid | Certified coefficient of discharge for liquids ($K_{dr}$/ $\alpha_w$)/ reduced coefficient of discharge when lift restriction | X | X | | | * |
| 23 | Liquid | Opening pressure difference in % | X | X | | | * |
| 24 | ASME-Cap. lbs/h | Capacity for steam 1) | | | X | X | N68 |
| 25 | ASME-Cap. SCFM | Capacity for gases (explicitely: air @ 60°F) 1) | | | X | X | N68 |
| 26 | ASME-Cap. GPM | Capacity for liquids (explicitely: water @ 70°F) 1) | | | X | X | N68 |
| 27/ 28 | Customised | Space for additional customised information, e.g.<br>Option codes bellows, oil and grease-free<br>If repaired valve: Repair-No.<br>Used for pressures in non code units | | | | | M16/ M17 |
| 29 | CE | CE-Marking | X | X | | | * |
| 30 | 0045 | Registration number of the notified body | X | X | | | * |
| 31 | π | Sign of conformity π acc. to directive 1999/36/EG about Transportable Pressure Equipment Directive 0 (TPED) | | | | | 2) |
| 32 | ASME + UV | ASME + UV-Stamp | | | X | | N68 |
| 33 | cc2408 | Code case 2408 for UV-Stamp (UV-stamp is lasered) | | | X | | N68 |
| 34 | NB | Marking of National Board | | | X | | N68 |

*Table 12.3.1-1: Description of nameplate markings*

* = Standard
1) Capacity is marked only for one medium (steam, air or water) according to the service medium of the valve
2) Since January 2012 no longer applied
3) The maximum value of the superimposed back pressure (constant + variable) is marked on the nameplate.

## 12.3.2 Obsolete LESER Nameplates

LESER has improved the nameplates and continuously adapted to the national and international standards. The following overview of the nameplates is to lighten the identification of older LESER safety valves. In special cases it might help to make a picture of the mane plate and/ or the complete safety valve.

**Nameplate before 1990**

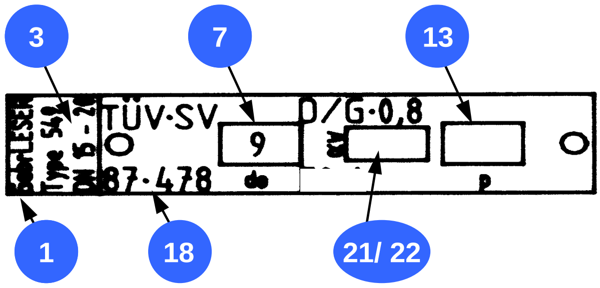



*Figure 12.3.2-1: LESER Nameplate before 1990*

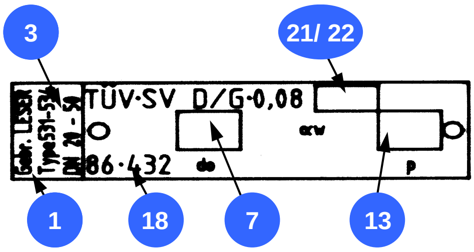



*Figure 12.3.2-2: LESER Nameplate before 1990*

**Nameplate between beginning of 1990 and end of 1997**

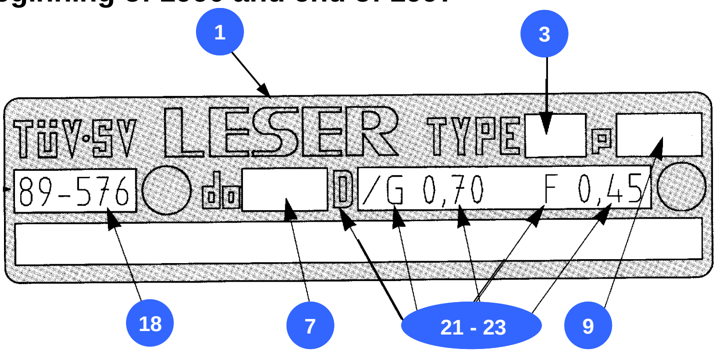



*Figure 12.3.2-3: LESER Nameplate 1990 - 1997*

**Nameplate with UV-Stamp, valid up to July 2002**

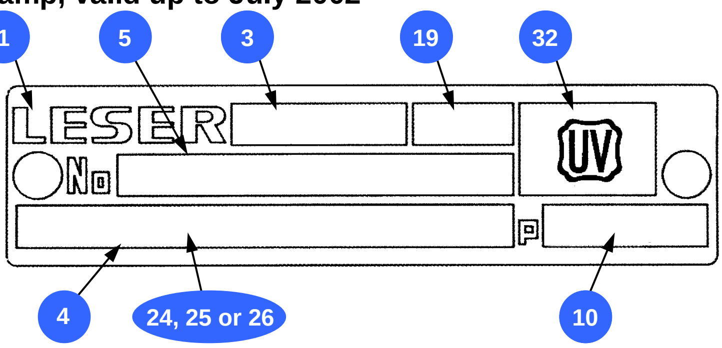



*Figure 12.3.2-4: LESER Nameplate with UV stamp until July 2002*

**LESER-Nameplate "ASME", valid since July 2002 until 2011**

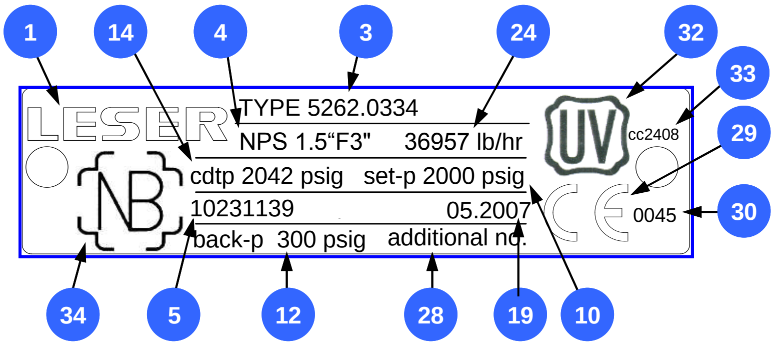



*Figure 12.3.2-5: LESER Nameplate "ASME", valid since July 2002 until March 2011*

**LESER-Nameplate "CE", valid since 1998 until 2011**

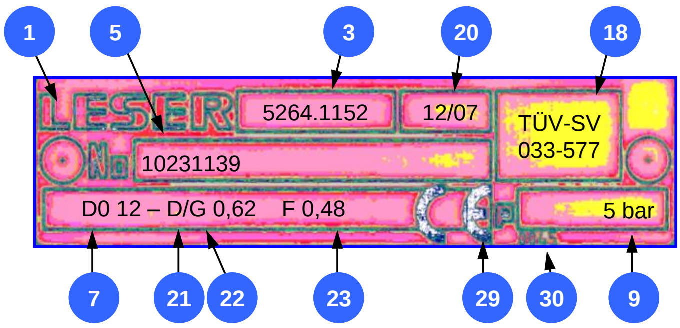



*Figure 12.3.2-6: LESER Nameplate "CE", valid since 1998 until March 2011*

## 12.4 Safety Valve Tag

Dimensions: 85 x 126 mm/ 3,35 x 4,96 in

Attached to every LESER safety valve is a conditionally weatherproof tag. It gives a brief overview about the safety valve and order data for easy identification of the safety valve. It provides additional information to the information on the name plate, e.g. all option codes describing the configuration of the safety valves. Also the installed spring part number is printed on the tag.

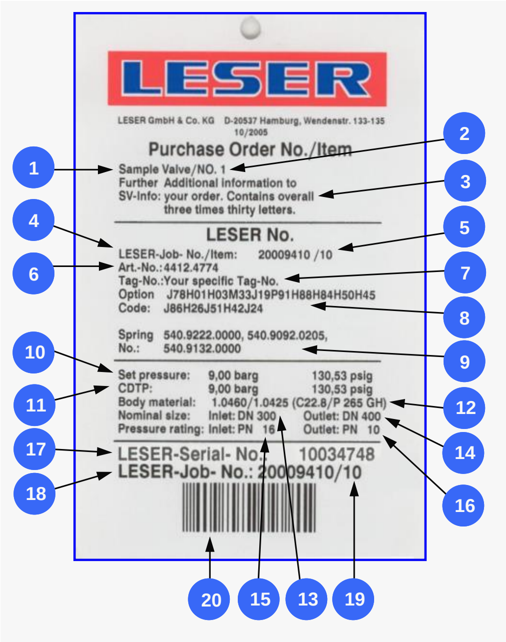



*Figure 12.4-1: LESER Safety valve tag*

The tag is fastened with a plastic clip at the bore hole of the lifting lever respectively at a bore hole of the outlet flange. It may remain at the valve or be stored in a proper location for documentation and future reference.

| No. | Field name | Description | Standard/ Option Code |
|---|---|---|---|
| 1 | Purchase Order No. | Your order number | * |
| 2 | Item | Your item number | M25 |
| 3 | Further SV-Info | Space for your optional information as e.g. installation location, etc. (max. 3 x 30 letters) | M25 |
| 4 | LESER-Job-No. | LESER-Job-Number | * |
| 5 | LESER-item-No. | LESER item number | * |
| 6 | Art.-No. | Article-Number | * |
| 7 | Tag.-No. | Your optional marking of the valve (max. 30 letters) | * |
| 8 | Option Code | All option codes for the safety valve; identify connections and options. | * |
| 9 | Spring No. | Spring(s) fitted in safety valve | * |
| 10 | Set pressure | Set pressure of valve | * |
| 11 | CDTP | Cold differential test pressure | * |
| 12 | Body material | Material of safety valve body | * |
| 13 | Nominal size - Inlet | Description of safety valve connection | * |
| 14 | Nominal size - Outlet | Description of safety valve connection | * |
| 15 | Pressure rating - Inlet | Description of safety valve connection | * |
| 16 | Pressure rating - Outlet | Description of safety valve connection | * |
| 17 | Serial-No. | Number for identification | * |
| 18 | LESER-Job-No. | LESER-Job-Number. | * |
| 19 | Item-No. | LESER-Job-Number | * |
| 20 | Barcode | For LESER-internal identification of the item | * |

*Table 12.4-1: Description of tag markings*

* = Standard information is contained on the tag as a standard
Option Code = information is added to the tag by applying the Option Code

## 12.5 Markings on the Safety Valve

Different parts of the safety valve have to be marked with specific information. In different standards the marking of the body is defined, e.g.:

- ISO 4126-1, chapter 10
- ASME Code Section XIII
- AD Merkblatt 2000 A4, chapter 7
- VdTÜV Merkblatt SV100, chapter 8

These standards differ in some requirements. It is shown which of the stated standards requires which information on the safety valve. LESER combines these requirements so every safety valve can be used worldwide.
Furthermore LESER provides the customer to add optional markings on the safety valve.

### 12.5.1 Markings on Flanged Safety Valves

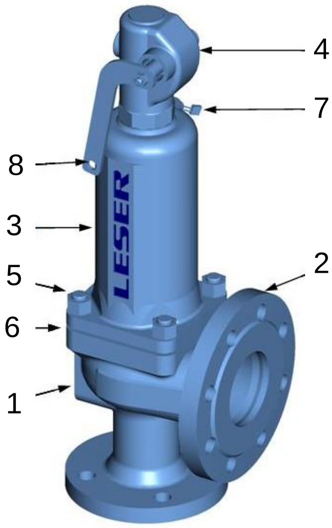



*Figure 12.5.1-1: Flanged Safety Valve*

| No. | Parts of safety valve | Markings on Safety valve | ISO 4126-1 | AD 2000 A2 | ASME XIII | Standard/ Option Code |
|---|---|---|---|---|---|---|
| 1 | Body | Mark of valve manufacturer ("GL") | X | X | | * |
| | | Material-No. | X | X | | * |
| | | LESER-Part-ID | | | | * |
| | | Arrow (flow direction) | X | | | * |
| | | Date of casting | | X | | * |
| | | Nominal diameter (inlet) DN/ NPS | X | X | X | * |
| | | Nominal pressure (inlet) PN/ CL | | X | | * |
| | | Heat No. | | | | * |
| | | Foundry sign | | X | | * |
| 2 | Outlet flange | Optional customised marking with stamps: | | | | |
| | | Stamped, top of outlet flange | | | | M26 |
| | | Stamped, outlet flange sideward | | | | M39 |
| | | Stamped, bottom of outlet flange | | | | M42 |
| | | Stamped, inlet flange sideward | | | | M31 |
| | | Stamped, 10 mm-type height | | | | M32 |
| 3 | Bonnet | Material-No. | X | X | | * |
| | | Mark of valve manufacturer ("GL") | X | X | | * |
| | | LESER-Part-ID | X | | | * |
| | | Date of casting | | X | | * |
| 4 | Lifting device/ cap | Material-no. | X | X | | * |
| | | Mark of valve manufacturer ("GL") | X | X | | * |
| | | LESER Part-ID | | | | * |
| | | LESER material code (cap) or date of casting (lever) | | | | * |
| 5 | Stud/ Hex. Nut | Property class | | | | * |
| | | Manufacturers sign | | | | * |
| 6 | Nameplate | For details please see "Nameplates", Section 3 | X | X | X | * |
| 7 | Seal | Stamp of "GL", "TÜV", a classification society or an authorised assembler | X | X | X | * |
| 8 | Location for safety valve tag | For details please see "Safety valve tag", Section 4 | | | | * |

*Table 12.5.1-1: Markings on flanged safety valves*

* = Standard information is contained on the tag as a standard
Option Code = information is added to the tag by applying the Option Code

### 12.5.2 Markings on Threaded Safety Valves

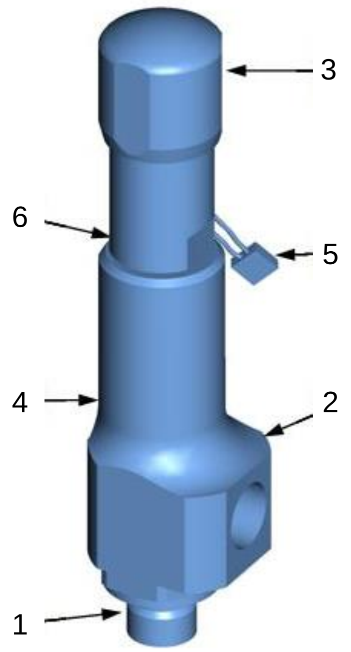



*Figure 12.5.2-1: Threaded safety valve*

| No. | Parts on safety valve | Markings on Safety valve | | ISO 4126-1 | AD 2000 A2 | ASME XIII | Standard/ Option Code |
|---|---|---|---|---|---|---|---|
| 1 | Body | Mark of valve manufacturer ("GL") | | X | X | | * |
| | | Nominal diameter (inlet) DN/ NPS | | X | X | X | * |
| | | Nominal pressure (inlet) PN/ CL | | | X | | * |
| | | Material-No. | | X | X | | * |
| | | "GL" works inspector sign | | | | | * |
| | | LESER material code | | | | | * |
| | | Optional customised stamps, inlet body | | | | | M27 |
| 2 | Outlet Body | Mark of valve manufacturer ("GL") | | | X | | * |
| | | Material-No. | | X | X | | * |
| | | LESER-Part-ID | | | | | * |
| | | Arrow flow direction | | X | | | * |
| | | If milled: | LESER-Code | | | | * |
| | | If casted: | Date of casting | | X | | * |
| | | | Heat no. | | | | * |
| | | | Foundry sign | | X | | * |
| 3 | Lifting device/ cap | Material-No. | | X | X | | * |
| | | Mark of valve manufacturer ("GL") | | X | X | | * |
| | | LESER-Part-ID | | | | | * |
| | | If milled: | LESER-Code | | | | * |
| | | If casted: | Date of casting; Heat no. | | X | | * |
| 4 | Nameplate | For details please see "Nameplates" Section 3 | | X | X | X | * |
| 5 | Seal | Stamp of "GL", "TÜV", a classification society or an authorised assembler | | X | X | X | * |
| 6 | Location for safety valve tag | For details please see "Safety valve tag" Section 4 | | | | | * |

*Table 12.5.2-1: Markings on threaded safety valves*

* = Standard information is contained on the tag as a standard
Option Code = information is added to the tag by applying the Option Code

## 12.6 Optional Customised Markings

LESER also offers the following optional markings:

| Optional marking | Further information |
|---|---|
| Marking on nameplate deviating from standard | Please see 12.3.1 "Current LESER Nameplates for Spring Loaded Safety Valves"; field 27, 28 |
| Additional information on the safety valve tag | Please see 12.4 "Safety Valve Tag" ; field 2, 3 |
| Additional information on flanged safety valves | Please see 12.5.1 "Marking on Flanged Safety Valves" field 2 |
| Additional information on threaded safety valves | Please see 12.5.2 "Marking of threaded safety valves" field 1 |
| Marking with stainless steel tag | Please see 12.6.1 |
| Marking with tag provided by customer | Please see 12.6.2 |

*Table 12.6-1: Optional markings*

### 12.6.1 Marking with Stainless Steel Tag

Dimensions W x H [mm]: 58 x 15

An additional stainless steel tag can be used for further information, e.g. customer specific tag-number. The customer defines the input. Depending on the amount of letters it is chosen automatically between a tag with one line (1 x 15 letters) and three lines (3 x 15 letters).

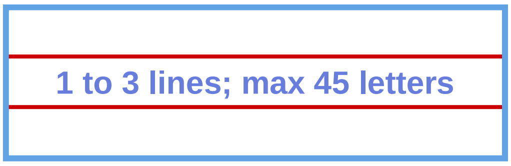



*Figure 12.6.1-1: Marking on stainless steel tag*

There are different possibilities to fix the additional stainless steel tag on the safety valve:

| Fixing of tags | Option Code |
|---|---|
| With sealing wire in the area of bonnet/cap – lifting device | M29 |
| Spot welded on outlet flange | N69 |
| Spot welded at backside of body | M24 |
| Fixing with grooved pins, top of outlet flange | N11 |
| Fixing with grooved pins instead of spot welding at backside of body | M30 |

*Table 12.6.1-1: Option codes for fixing the stainless steel tag*

### 12.6.2 Marking with Tag Provided by Customer

It is possible to attach a customer specific tag on the valve. To choose this item please use Option Code J75. Please supply the tag latest two weeks before the date of delivery to:

LESER GmbH & Co.KG
Abt. PP – Sonderbearbeitung
Itzehoer Straße 63 – 65
24594 Hohenwestedt
Germany
☏ +49-487127-0

To assign your specific tag to your safety valve please specify following data along with your tag:

- LESER Job-Number (see order confirmation)
- Line item number
- Specific customer tag number, if one item number contains several safety valves with different tag numbers

## 12.7 Markings on Internal Parts

In accordance with national and international standards every pressure containing part of LESER safety valves is marked permanently. The marking ensures the material identification and the material traceability as a minimum. Material traceability is ensured by a four digit LESER material code number. This number in combination with the material designation allows to identify the correct material certificate for the individual part.
If a material certificate is requested for an individual part after the valve was supplied please use the request form "Request for material test report" from the LESER homepage. For detailed questions please contact certificate@leser.com.

### 12.7.1 Markings of Disc

*Figure 12.7.1-1: Markings of disc*

| Part | 1 | 2 | 3 |
|---|---|---|---|
| Disc | GL1 | 1.4404.316L | CODE3924 |

| Explanation |
|---|
| Material code Number (3) |
| Material designation DIN/ ANSI (2) |
| Name of the factory authorized expert (1) |

### 12.7.2 Markings of Disc – Short Code for Small Sizes


*Figure 12.7.2-1: Markings of disc – short code*

| Part | 1 | 2 | 3 |
|---|---|---|---|
| Disc | 4 | C | 127 |

| Explanation |
|---|
| Material code Number (3) |
| Soft seal material marked by a code letter (2)<br>M = metallic seal<br>K = CR (Neoprene)<br>D = EPDM<br>L = FKM (Viton)<br>N = NBR (Perbunan) |
| Classification of the material by a number (1)<br>3 = 1.4122<br>4 = 1.4404/ 316L<br>6 = 1.4404/ 316L stellited<br>7 = special material |

### 12.7.3 Markings of the Soft Seal Material on the Disc

In case of a soft sealing disc the soft sealing material is marked by a code letter on the disc as described below. In addition the LESER NGA nameplate is marked with the same code letter, see section 12.3.1.

| Soft seal material marked by a code-letter |
|---|
| K = CR (Neoprene)<br>D = EPDM<br>L = FKM (Viton)<br>N = NBR (Perbunan) |

*Table 12.7.3-1: Code letters for soft seal materials*

There are three possibilities to mark the material code of the soft sealing on the disc. Basically the code letter is stamped underneath the disc

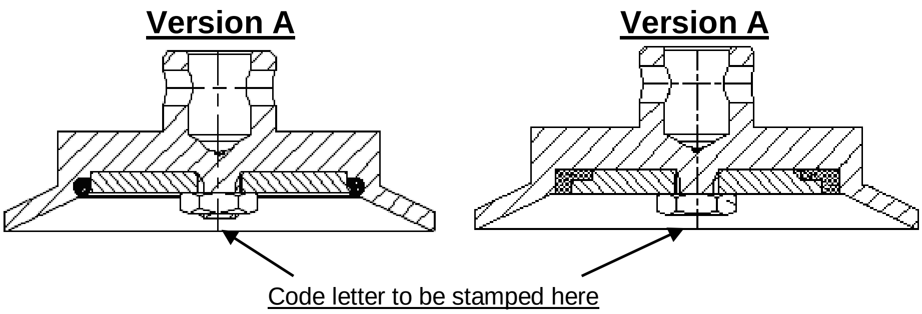



*Figure 12.7.3-1: Location of code letter for soft seal*

This applies for the following types:

| Type | DN | $d_0$ | Marking version |
|---|---|---|---|
| 427/429 | 20 -150 | 18 - 92 | A |
| 431/433 | 20 -150 | 18 - 92 | A |
| 440-442 | 20 -150 | 18 -125 | A |
| 455-458 | 25 -150 | 15 -110 | A |
| 488 | 25 -100 | 23 - 92 | A |
| 526 | 25-200 | 14-161.5 | A |
| 532/534 | 20 -150 | 20 -125 | A |

*Table 12.7.3-2: Marking versions – type related*

In some cases a marking underneath the disc is unfavourable, like discs with sealing plate or if the sealing surface is vulcanized. Then the code letters are placed sideways.

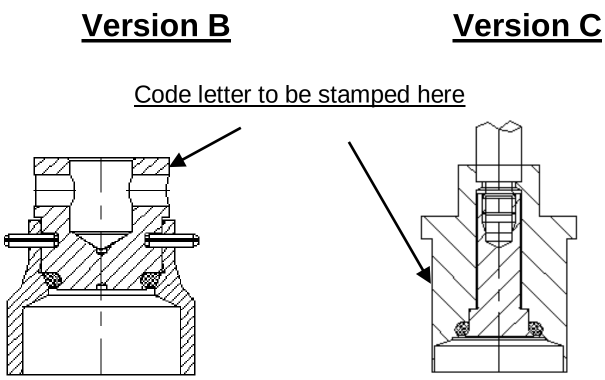



*Figure 12.7.3-2: Location of code letter for soft seal*

This applies for the following types:

| Type | DN | $d_0$ | Marking version |
|---|---|---|---|
| 431/433 | 15 | 12 | B |
| 437/439 | - | 10 | B |
| 438 | - | 10 | C |
| 460 | 15-20 | 13-17.5 | B |
| 459/462 | - | 9 – 17.5 | B |
| 481 | - | 10 | C |

*Table 12.7.3-3: Marking versions – type related*

## 12.7.4 Markings of Nozzle

*Figure 12.7.4-1: Markings of nozzle*

| Part | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Nozzle | GL1 | d0 28,3 | CL600 PN 160 | 1.4404.316L | CODE3019 |

| Explanation |
|---|
| Material code Number |
| Material name DIN/ ANSI |
| Nominal pressure |
| Flow diameter |
| Name of the factory authorised expert |

## 12.7.5 Markings of Inlet body

*Figure 12.7.5-1: Markings of inlet body*

| Part | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Inlet body | GL1 | G1 | $d_0$ 10 | PN320 CL2500 | 1.4404.316L | CODE4023 |

| Explanation |
|---|
| Material code Number |
| Material name DIN/ ANSI |
| Nominal pressure |
| Flow diameter |
| Nominal diameter/ Connection thread |
| Name of the factory authorized expert |

### 12.7.6 Markings of Spring

The standard ISO 4126-7 chapter 7 defines the marking of safety valve springs.
LESER marks its springs in three different ways:

1. By pad printing
2. By engraving
3. With tag (only for springs d ≤ 3 mm)

Directly on the spring the middle part of the part number consisting of the count number and material code is stated. These four digits are sufficient to identify the spring.

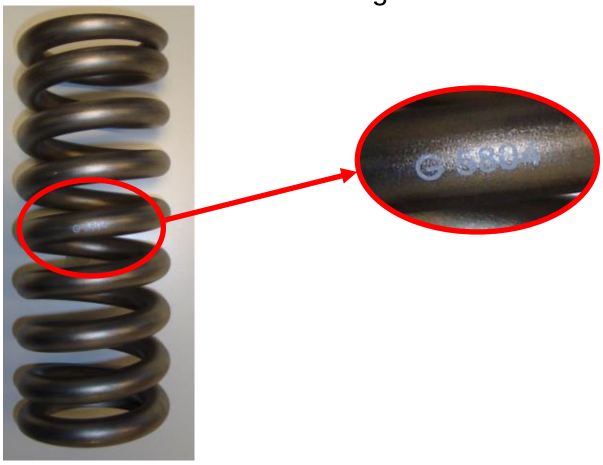


*Figure 12.7.6-1: Markings of spring*

| Part | 1 | 2 | 3 |
|---|---|---|---|
| Spring | G | 580 | 4 |

| Explanation |
|---|
| Material code (3) |
| Count no. (2) |
| Spring Supplier code (1) |

The marking on the spring allows to identify the complete LESER part number as listed in all spring charts. For identification the count number plus material code is needed. The 11 digit part number of a spring is arranged as follows:

| Part | 1 | | 2 | 3 | | 4 |
|---|---|---|---|---|---|---|
| Spring | 540 | . | 580 | 4 | . | XXXX |

| Explanation |
|---|
| Defines characteristics of the spring (4) |
| Material code<br>For standard materials:<br>1 = 1.1200 Steel<br>2 = 1.8159/ 1.7102 Heat resistant steel<br>4 = 1.4310 Stainless steel (3) |
| Count number (2) |
| Part group number<br>540 = standard spring (1) |

To find the complete part number of the spring please refer to the relevant spring chart.

## 12.8 Obsolete LESER Safety Valves

LESER continuously redesigns and enhances its safety valves to provide the customer with the latest state of technology. In some cases types were replaced by new ones. For orientation the obsolete type and the corresponding current type are listed. The obsolete LESER type number can be found on the nameplate.

| Obsolete LESER safety valve | Last year of production | Current LESER safety valve |
|---|---|---|
| Type 521 | 1993 | Type 421 |
| Type 538 | 2002 | Type 438 |
| Type 539 | 2005 | Type 437 |
| Type 541/ 542 | 1990 | Type 441 |
| Type 547 | 2004 | Type 447 |
| Type 549 | 1998 | Type 459 |
| Type 550 | 1997 | Type 450 |
| Type 560 | 1997 | Type 460 |
| Type 561/ 562 | 1998 | Type 462 |
| Type 451/ 452 | 1996 | Type 455/ 456 |
| Type 453/ 454 | 1996 | Type 457/ 458 |
| Type 448 | 2004 | Type 488 |
| Type 449 | 2001 | Type 484 |

*Table 12.8-1: List of the obsolete and current corresponding LESER safety valves*

## Contents

## 17.1 Introduction

Safety valves are safety devices and must be able to operate at all times. In order to minimize the likelihood of failures, care should be taken in

- selecting the proper type of safety valve and options
- selecting the suitable materials for the application (see chapter 9 Materials)
- selecting the correct size of the safety valve (see chapter 7 Sizing)
- correct installation and handling of the safety valve (see chapter 6 Installation and Plant Design)

In practice the user may encounter various problems with the operation of a safety valve. If an unacceptable problem is found, it needs to be determined if it is a potential safety issue which requires immediate attention or an undesired operation condition, e.g. a performance issue.

The purpose of this chapter is to give an overview of common safety issues and operational problems, their possible symptoms and causes along with the immediate actions and preventive measures recommended by LESER. This overview does not claim to be complete. For detailed information do not hesitate to contact LESER or an authorized LESER service partner. You will find your contact person at the LESER-Homepage: www.leser.com.

**CAUTION! ACHTUNG! ATTENTION! ATENCÍON! 留神**

**Do not remove the seal wires in an effort to adjust and/ or repair a safety valve if you are not authorized!**
**Safety valves are safety devices and improper repair may cause damage to equipment and serious injury or death!**
**The seal wires may only be removed by LESER or authorized personnel.**

## 17.2 How this Chapter is Organised

The following table shows how the information in this chapter is organised. Using the table as a starting point, try first to identify the observable symptom in the list below and then go to the page indicated on the right. This page contains details about possible causes, immediate actions and preventive measures for the symptom.
For your convenience, the symptoms have been grouped into Problem Areas (e.g. “Leakage”, “Opening/Closing”) and can be looked up in a Problem Area Chart using their symptom number and description.

Classification of symptoms:

- Symptoms marked with a small sign ⚠ are potential safety issues, e.g. “The safety opens too late”
- Symptoms not marked are issues regarding the performance of the safety which not necessarily result in a safety issue, e.g. “The safety is leaking”

However each symptom in each application has to be considered individually to decide whether it is a safety issue or not.

The last section of this chapter deals with typical mistakes and their effects that may occur as a result of improper and/or unauthorized repair.

## 17.3 Problem Areas, Symptoms, Immediate Actions and Preventive Measures

The following charts show detailed information on individual symptoms, including background information, if required („Note”), possible causes, immediate actions and preventive measures. The symptoms are grouped into problem areas.



*Table 17.3-1: Problem Areas and Symptoms*



*Table 17.3-2: Typical Mistakes as a Result of Unauthorized Repair*

## 17.3.1 Leakage

*Figure 17.3.1-1: Symptom 1 – Disc worn out due to permanent leakage*

**Symptom 1: The Safety Valve Seat is Leaking**

**Explanation:**
Seat leakage is the escape of fluid between the seat and disc. Seat leakage may or may not be audible or visible. Unacceptable seat leakage is defined as a leakage exceeding the limits of API Standard 527 at 90% of the set pressure or below. Leakage is not the same as simmering (see symptom 3, "The Safety Valve is Simmering").

**Standard tests at LESER:**
Every safety valve is leak tested by LESER at 90% of the set pressure according to LESER standard LGS 0201which is based on API Standard 527.

| No. | Failure Cause | Action / *Preventive measure* |
|---|---|---|
| 1 | Damaged seat/ disc | Repair or replace seat/ disc |
| | | *Ensure periodical maintenance* |
| 2 | Foreign matter between disc and seat | Clean or repair safety valve |
| | | *Small damages might be compensated by the use of soft seals.* |
| 3 | Corrosion in the inlet pipe may produce rust particles between seat and disc | Clean or repair safety valve/ Repair inlet pipe |
| | | *Ensure periodical maintenance of inlet pipe* |
| 4 | Soft seat materials unsuitable for application | Replace soft seat or disc |
| | | *Replace soft seat material by suitable material* |
| 5 | Seat and disc is damaged by improper handling/ transport | Repair or replace seat and disc – Check safety valve for further damages |
| | | *Review LESER's operating instructions manual for correct handling* |
| 6 | The safety valve has simmered | Repair or replace seat/ disc |
| | | *For details see symptom 3, "The safety valve is simmering"* |
| 7 | Excessive pipe loads or momentum caused by improper valve installation, e.g. stress by thermal expansion of pipes | Check or repair safety valve |
| | | *Check assembly of pipe system and install safety valve free of stress* |

*Table 17.3.1-1: Symptom 1 – The Safety Valve Seat is Leaking*

## Symptom 2: The Safety Valve Body or Shell is Leaking

**Explanation:**
Body shell leakage may occur between body and bonnet, bonnet and cap or, at in threaded valves, between inlet body and body.

**Standard tests at LESER:**
All LESER safety valves leave the factory 100% shell tightness tested acc. to LGS 0201 which fulfils the requirements of DIN EN ISO 12266-1, sect. 4.2 test P11.

| No. | Failure Cause | Action | *Preventive measure* |
|---|---|---|---|
| 1 | Safety valves with threaded connections: Excessive pipe loads or momentum caused by improper valve installation, e. g. stress by thermal expansion of pipes | Check or repair safety valve | *Check assembly of pipe system and install safety valve free of stress* |
| 2 | Porous body gasket | Replace gasket | *Ensure periodical maintenance* |
| 3 | Back pressure exceeds limits of the safety valve | Replace safety valve with a safety valve suitable for the application | |
| 4 | Loosened nuts and bolts due to vibrations | Tighten the screws | *Reduce maintenance interval* |
| 5 | Very low viscosity medium | Check or repair safety valve | *Use Gylon or Halar gaskets* |

*Table 17.3.1-2: Symptom 2 – The Safety Valve Body or Shell is Leaking*

## Symptom 3: The Safety Valve is Simmering

**Explanation:**
Simmer is the audible or visible escape of compressible fluid between the seat and disc which may occur at an inlet static pressure below the set pressure prior to opening (API 520 1.2.3.3 o). LESER defines simmering at an inlet static pressure >90% of the set pressure. Permanent simmering is undesirable as it will lead to wear of the seat/disc and permanent loss of medium. Simmering is a typical part of the operating characteristic for safety valves with a set a set pressure defined as pop.

**Standard tests at LESER:**
As the set pressure definition of all LESER safety valves is “Initial audible discharge”, there is no inherent simmering below the set pressure. This is verified during the set pressure adjustment acc. to LGS 0202, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME XIII, 3.6.3. LESER uses only the upper tolerance of the allowed set pressure tolerance of ±3%.

| No. | Failure Cause | Action | *Preventive measure* |
|---|---|---|---|
| 1 | Operating pressure too close to set pressure | Check or repair seat/ disc | *Reduce operating pressure and/or increase set pressure* |
| 2 | Line vibrations | Check or repair seat/ disc | *Eliminate any vibrations at the safety valve affecting the safety valve* |
| 3 | Pressure peaks | Check or repair seat/ disc | *Eliminate pressure peaks by measures suitable for dampening pulsation* |

*Table 17.3.1-3: Symptom 3 – The Safety Valve is Simmering*

### 17.3.2 Opening/ Closing

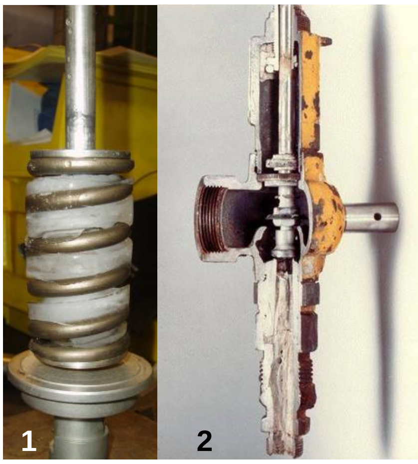



*Figure 17.3.2-1: Symptom 6 - Frozen condensate in the bonnet*
*Figure 17.3.2-2: Symptom 6 - Hardened medium in the inlet area*

**Symptom 4: The Safety Valve Opens too Early**

**Explanation:**
The safety valve opens at a pressure below the required set pressure minus tolerance.
**Standard tests at LESER:**
Set pressure adjustment acc. to LGS 0202, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME XIII, 3.6.3. LESER uses only the upper tolerance of the allowed set pressure tolerance of ±3%.

| No. | Failure Cause | Action | *Preventive measure* |
|---|---|---|---|
| 1 | Temperature or back pressure not taken into account | Reset the safety valve | *Review CDTP (Cold Differential Test Pressure) correction in order to achieve the correct set pressure for the operating condition.* |
| 2 | Operating pressure too close to set pressure | Reset the safety valve | *Reduce operating pressure and/ or increase set pressure, if possible*<br>*Use a supplementary loading system or a pilot operated safety valve* |
| 3 | The temperature at the spring is too high | Replace spring | *Replace spring material by suitable material*<br>*Use an open bonnet or stainless steel bellows and bonnet spacer* |
| 4 | Spring demineralized by condensate and fractured – steam service | Replace spring – change material | *Use a stainless steel spring or an open bonnet* |

*Table 17.3.2-1: Symptom 4 – The Safety Valve Opens too Early*

**Symptom 5: The Safety Valve Opens too Late**

⚠ **Explanation:**
The safety valve opens at a pressure above the required set pressure plus tolerance.
**Standard tests at LESER:**
Set pressure adjustment acc. to LGS 0202, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME XIII, 3.6.3. LESER uses only the upper tolerance of the allowed set pressure tolerance of ±3%.

| No. | Failure Cause | Action / *Preventive measure* |
|---|---|---|
| 1 | Temperature is below range | Reset the safety valve<br>*Recalculate CDTP correction in order to achieve the correct set pressure for the operating condition* |
| 2 | Set pressure selected incorrectly | Reset the safety valve<br>*Reduce set pressure if possible* |
| 3 | Superimposed back pressure not taken into account | Reset the safety valve<br>*Adjust safety valve to the conditions as present:*<br>*- Correct CDTP if back pressure is constant*<br>*- Select stainless steel bellows if back pressure is variable* |
| 4 | Disc and seat are stuck together due to adhesive medium | Clean or repair safety valve<br>*Regular lifting of the safety valve with lifting lever.*<br>*Use a heating jacket or bursting disk* |
| 5 | Choice of a unsuitable soft sealing | Replace disc – change material<br>*Select a correct soft sealing* |
| 6 | During test safety valve does not reach the CDTP temperature | Wait until safety valve has heated up properly |
| 7 | Disc and seat are stuck together in steam service | Repair or replace seat/ disc<br>*Ensure periodical lifting*<br>*If ferritic materials are involved, use different materials for seat and disc* |

*Table 17.3.2-2: Symptom 5 – The Safety Valve Opens too Late*

**Symptom 6: The Safety Valve Does not Open**

⚠ **Explanation:**
The safety valve does not open although the pressure is above the required set pressure plus tolerance.
**Standard tests at LESER:**
Set pressure adjustment acc. to LGS 0202, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME XIII, 3.6.3. LESER uses only the upper tolerance of the allowed set pressure tolerance of ±3%.

| No. | Failure Cause | Action / *Preventive measure* |
|---|---|---|
| 1 | CDTP incorrect or not regarded | Reset safety valve<br>*Review CDTP correction in order to achieve the correct set pressure for the operating condition* |
| 2 | Bonnet is soiled by medium - guide and spindle are stuck | Repair or replace internal parts<br>*Use stainless steel bellows* |
| 3 | Bonnet is corroded by medium - guide and spindle are stuck | Repair or replace internal parts<br>*Use stainless steel bellows* |
| 4 | Medium is hardened in the inlet area | Repair or replace safety valve<br>*Change dimensions of the inlet pipe to obtain a shorter, wider inlet*<br>*Use a heating jacket or bursting disc* |

| Symptom 6: The Safety Valve Does not Open (Continued) | | |
|---|---|---|
| No. | Failure Cause | Action |
| | | *Preventive measure* |
| 5 | Condensate or medium is frozen in the bonnet | Check or repair internal parts |
| | | *Use stainless steel bellows to avoid medium in the bonnet*<br>*Allow proper drainage of bonnet, body and outlet pipe*<br>*Use a heating jacket* |
| 6 | Protective cover for the flange not removed | Remove the protective cover for the flange |
| | | *Before installation: remove covers* |
| 7 | Test gag still in place | Remove test gag |

*Table 17.3.2-3: Symptom 6 – The Safety Valve Does not Open*

| Symptom 7: The Safety Valve Closes too Late | | |
|---|---|---|
| | **Explanation:**<br>The safety valve does not close within the blow down limits of the applicable codes and standards.<br>**Standard tests at LESER:**<br>Every safety valve is leak tested by LESER at 90% of the set pressure according to LESER standard LGS 0201 which is based on API Standard 527. | |
| No. | Failure Cause | Action |
| | | *Preventive measure* |
| 1 | Adjusting ring position too close to disc | Screw down the adjusting ring |
| | | *Keep the adjusting ring fixed in the lowest position (applies only to LESER API series 526 safety valves)* |
| 2 | Spring material unsuitable for temperature | Replace spring |
| | | *Replace material by suitable material* |
| 3 | Spring relaxed | Replace spring - change material |
| | | *Ensure periodical maintenance* |

*Table 17.3.2-4: Symptom 7 – The Safety Valve Closes too Late*

| Symptom 8: The Safety Valve Does not Close | | |
|---|---|---|
| | Explanation:<br>The safety valve does not close at all, but remains open far below the set pressure.<br>**Standard tests at LESER:**<br>Every safety valve is leak tested by LESER at 90% of the set pressure according to LESER standard LGS 0201 which is based on API Standard 527. | |
| No. | Failure Cause | Action |
| | | *Preventive measure* |
| 1 | Spring broken due to<br>- medium/ corrosion<br>- steam operation | Replace spring – change material |
| | | *Use stainless steel spring, stainless steel bellows and/ or an open bonnet*<br>*Allow proper drainage of of bonnet, body and outlet pipe* |
| 2 | Foreign matter between disc and seat | Clean or repair safety valve |
| | | *Small damages of the sealing surface might be compensated by the use of soft seals.* |
| 3 | Spindle and guide are galled | Repair or replace safety valve |
| | | *Avoid chattering; see also symptom 9, "The safety valve is chattering/ fluttering"* |

*Table 17.3.2-5: Symptom 8 – The Safety Valve Does not Close*

### 17.3.3 Operation/ Function

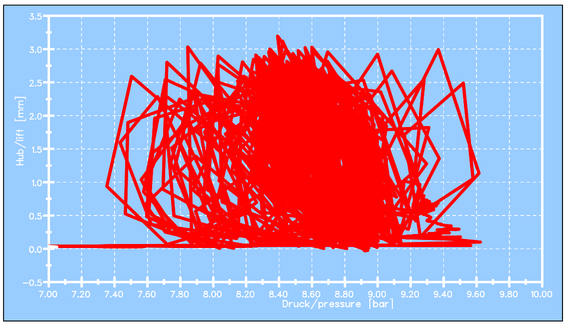



*Figure 17.3.3-1: Symptom 9 - Safety valve is chattering*

**Symptom 9: The Safety Valve Is Chattering/ Fluttering**

**Explanation:**
Chatter refers to the abnormally rapid reciprocating motion of the pressure relief valve disc where the disc contacts the pressure relief valve seat during cycling… Flutter is similar to chatter except that the disc does not come into contact with the seat during cycling. (API 520-1, 3.3.3.1.2)

Note: What is the difference between chattering/ fluttering and frequent opening?
Chattering and fluttering must be distinguished from the 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.
The root causes for frequent opening are:

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

Frequent opening is generally not a safety issue – the safety valve does what it is supposed to do.
By contrast, the symptoms of chattering or fluttering ARE safety issues. A chattering or fluttering safety valve does not discharge its full rated capacity and may cause the pressure in the system to increase.

| No. | Failure cause | Action | *Preventive measure* |
|---|---|---|---|
| 1 | Excessive pressure loss in the inlet pipe | Repair safety valve | *Recalculate pressure loss and change inlet pipe dimensions to obtain a shorter, wider, smoother inlet with less bends.*<br>*Adjust the safety valve's capacity to the conditions present by means of lift restriction*<br>*Apply an O-ring damper*<br>*Check gaskets of inlet flange connection* |
| 2 | Excessive built-up back pressure in the outlet pipe | Repair safety valve | *Change outlet pipe dimensions to obtain a shorter, wider, smoother inlet*<br>*Adjust the safety valve's capacity to the required capacity by means of lift restriction*<br>*Use stainless steel bellows*<br>*Check gaskets of outlet flange connection* |
| 3 | Valve is oversized for the application, leading to failure causes 1 or 2 | Repair safety valve | *Resize safety valve*<br>*Use an O-ring damper or lift restriction* |
| 4 | Gasket for inlet/ outlet flange connection is incorrectly fitted and restricting the flow path, leading to failure causes 1 or 2 | Change or refit gasket properly | *Check if gaskets are fitted properly* |

| Symptom 9: The Safety Valve is Chattering/ Fluttering (Continued) | | |
|---|---|---|
| No. | Failure cause | Action<br>*Preventive measure* |
| 5 | Too large weld roots restrict flow path | Repair safety valve/ repair inlet pipe; remove too large weld roots |
| | | *Change pipe inlet dimensions to obtain a shorter, wider inlet* |

*Table 17.3.3-1: Symptom 9 – The Safety Valve is Chattering/ Fluttering*

| Symptom 10: The Safety Valve is Fully Open; Pressure is Rising Above Maximum Relieving Pressure | | |
|---|---|---|
| ⚠ | **Explanation:**<br>Although the safety valve is fully opened, the pressure in the vessel rises above the maximum allowable accumulation pressure (typically MAWP+10%). | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | Medium conditions/ back pressure correction not properly considered | Install a sufficiently sized safety valve |
| | | *Select the correct size for the safety valve* |
| 2 | Excessive pressure loss in the inlet pipe | Reduce losses by changing the piping to obtain a shorter, wider, smoother inlet |
| | | *Check welding and gaskets of flange connections*<br>*See also symptom 9* |

*Table 17.3.3-2: Symptom 10 – The Safety Valve is Fully Open; Pressure is Rising Above Maximum Relieving Pressure*

| Symptom 11: The Safety Valve does not Achieve its Maximum Lift | | |
|---|---|---|
| ⚠ | **Explanation:**<br>Lift is the actual travel of the disc from the closed position when a valve is relieving. (API 520 1.2.2.8)<br>Maximum lift must be achieved at max. 10% overpressure. | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | Foreign matter trapped between spindle and guide | Clean or repair safety valve. |
| | | *Use stainless steel bellows or bursting disc* |
| 2 | Built up back pressure is too high | Check or repair safety valve<br>Reduce built up back pressure by using a shorter, wider outlet pipe |
| | | *Use a stainless steel bellows* |
| 3 | The safety valve is operating in the partial load range | No action required, if 10% overpressure is not exceeded |
| | | |

*Table 17.3.3-3: Symptom 11 – The Safety Valve does not Achieve its Maximum Lift*

### 17.3.4 Corrosion/ Wear

*Figure 17.3.4-1: Symptom 12 - Strong corrosion in a safety valve*

| Symptom 12: The Safety Valve Shows Strong Internal Corrosion | | |
|---|---|---|
| ⚠ | **Explanation:**<br>Corrosion is the oxidation of metal surfaces under the influence of its surrounding medium. Corrosion is critical to the operation of a safety valve especially if pressure containing or moving parts are affected. Limited corrosion might be acceptable, provided it does not affect the operability of the safety valve or the pressure containing properties of body or bonnet.<br>Corrosion in the inlet pipe may affect the safety valve in several ways: Rust particles can be located between seat and disc producing leakage (see symptom 1). Corrosion may cause narrowing of the inlet pipe which can lead to excessive pressure loss and therefore chattering (see symptom 9). | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | Disc/ Seat material unsuitable for the medium | Replace Seat/ Disc<br>*Use suitable material, e.g. high alloy materials*<br>*Ensure periodical maintenance* |
| 2 | Spindle/ guide material unsuitable for the medium | Replace spindle/ guide<br>*Use suitable material, e.g. high alloy materials*<br>*Install stainless steel or high alloy bellows for protection*<br>*Reduce maintenance intervals* |
| 3 | Spring material unsuitable for the medium | Replace spring<br>*Check material choice with regard to temperature and medium*<br>*Install stainless steel or high alloy bellows for protection*<br>*Ensure periodical maintenance* |
| 4 | Body/ bonnet material unsuitable for the medium | Repair or replace safety valve<br>*Use suitable material, e.g. high alloy materials*<br>*Ensure periodical maintenance*<br>*Use Critical Service valves*<br>*Use bursting discs* |

*Table 17.3.4-1: Symptom 12 – The Safety Valve Shows Strong Internal Corrosion*

| Symptom 13: The Safety Valve Shows Strong External Corrosion | | | |
|---|---|---|---|
| ⚠ | **Explanation:** Corrosion is the oxidation of metal surfaces under the influence of its surrounding medium. Corrosion is critical to the operation of a safety valve especially if pressure containing parts are affected. Limited corrosion might be acceptable, provided it does not affect the operability of the safety valve or the pressure containing properties of body or bonnet. Likewise, fading of external paint in special applications is not critical to the functioning of the safety valve. | | |
| No. | Failure cause | Action<br>*Preventive measure* | |
| 1 | Corrosive environment (e.g. marine or offshore) | Repair or replace safety valve<br>*Use multi layer or epoxy coating or Duplex stainless steel materials* | |

*Table 17.3.4-2: Symptom 13 – The Safety Valve Shows Strong External Corrosion*

| Symptom 14: The Safety Valve Shows Wear between Spindle and Guide | | |
|---|---|---|
| ⚠ | **Explanation:** Wear is the erosion of material from a solid surface by the action of another solid. This symptom frequently goes undetected until maintenance. | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | The safety valves has chattered | Repair safety valve<br>*See also symptom 9, “The safety valve is chattering“* |
| 2 | The safety valve is soiled | Repair safety valve<br>*Use stainless steel bellows* |

*Table 17.3.4-3: Symptom 14 – The Safety Valve Shows Wear between Spindle and Guide*

| Symptom 15: The Safety Valve Shows Damaged Sealing Surfaces | | |
|---|---|---|
| | **Explanation:** Sealing surfaces are damaged in a way that the tightness of the safety valve is affected. This symptom frequently goes undetected until the safety valve is disassembled for maintenance. | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | The safety valve has simmered or leaked – the operating pressure is too close to the set pressure | Repair or replace seat/ disc<br>*Increase set pressure if possible and/ or reduce the operating pressure* |
| 2 | The safety valves has chattered | Repair safety valve<br>*For details see symptom 9 “The safety valve is chattering/ fluttering”* |
| 3 | Solid matter in liquid | Clean or repair safety valve<br>*Use hardened or stellited seat/ disc* |
| 4 | Rust or particles in steam or gas application | Repair safety valve<br>*Clean vessel before start-up of the facility* |

*Table 17.3.4-4: Symptom 15 – The Safety Valve Shows Damaged Sealing Surfaces*

### 17.3.5 Symptoms in Special Applications

*Figure 17.3.5-1: Symptom 16 - Corroded stainless steel bellows*

| Symptom 16: The Stainless Steel Bellows Fails Regularly | | |
|---|---|---|
| ⚠ | **Explanation:**<br>A stainless steel bellows is used to protect the moving parts and to compensate for back pressure. It is a damageable part because it is thin-walled. Failure reasons can be: corrosion, too high temperatures or an exceed of the allowable cycles in case the safety valve is chattering of fluttering. The risk involved in damages to the stainless steel bellows is the loss of the back pressure compensation so that the set pressure rises. For the static back pressure limits of stainless steel bellows to be considered, refer to the LESER catalog. | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | Value of static back pressure too high for the installed stainless steel bellows | Replace stainless steel bellows<br>*Install stronger stainless steel bellows* |
| 2 | Material of bellows unsuitable for the application | Replace stainless steel bellows – change material<br>*Use high alloy materials, like Hastelloy* |
| 3 | Extensive chattering/ fluttering | Replace stainless steel bellows<br>*For details please see symptom 9, “The safety valve is chattering/ fluttering”* |
| 4 | Too high temperature | Replace stainless steel bellows – change material<br>*Use high alloy materials, like Hastelloy* |
| 5 | Frozen condensate in the stainless steel bellows | Check or replace stainless steel bellows<br>*Proper drainage of bonnet, body and outlet pipe* |
| 6 | Corrosion | Replace stainless steel bellows – change material<br>*Use high alloy materials, like Inconel* |

*Table 17.3.5-1: Symptom 16 – The Stainless Steel Bellows Fails Regularly*

| Symptom 17: The Safety Valve Cannot Be Lifted Manually | | |
|---|---|---|
| ⚠ | **Explanation:**<br>A lifting device allows venting a safety valve in order to check operability. The lifting device must allow lifting the safety valve at an operating pressure above 75% (ASME XIII 3.2.7(a)) of set pressure. | |
| No. | Failure cause | Action<br>*Preventive measure* |
| 1 | The operating pressure is too low compared to the set pressure | No action possible, see explanation above. |
| 2 | If failure cause no. 1 not applicable check symptom 6 “The safety valve does not open” | |

*Table 17.3.5-2: Symptom 17 – The Safety Valve Cannot Be Lifted Manually*

| Symptom 18: The Safety Valve Cannot Be Lifted Pneumatically (Lifting Device H8) | | |
|---|---|---|
| ⚠ | **Explanation:**<br>The pneumatic lifting device H8 allows Cleaning In Place (CIP) or Sterilizing In Place (SIP). Applying air pressure to the lifting device will lift the spindle, which will open the safety valve and allow a steam or cleaning solution to flush through the valve. | |
| No. | Failure cause | Action |
| | | *Preventive measure* |
| 1 | Insufficient air supply pressure | Check air supply pressure |
| | | *In the Clean Service catalog, check "selection chart H8"*<br>*Use a double piston actuator* |
| 2 | Air supply line is blocked | Clean air supply line |
| | | *Use clean air or filters* |
| 3 | If failure cause no. 1 or 2 not applicable check symptom 6 "The safety valve does not open" | |

*Table 17.3.5-3: Symptom 18 – The Safety Valve Cannot Be Lifted Pneumatically (Lifting Device H8)*

## 17.4 Typical Mistakes as a Result of Unauthorized Repair

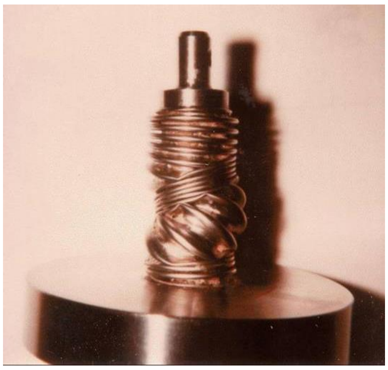


*Figure 17.4-1: Twisted stainless steel bellows*

Safety valves are safety devices and improper repair may cause damage to equipment and serious injury or death! The following table lists typical mistakes that are made when repair is performed by unauthorized or untrained personnel or when maintenance instructions are not followed.

| No. | Mistake | Effect |
|---|---|---|
| 1 | Assembly of incorrect spring | 1. Spring is too soft: Safety valve closes too late<br>2. Spring is too strong: Safety valve opens too late |
| 2 | Spring is compressed to solid after assembly | Safety valve does not open or does not achieve the required lift |
| 3 | Wrong disc is mounted | Overpressure and blow down of the safety valve may be outside the limits of codes and standards |
| 4 | Due to excessive machining of seat/ disc the tolerances of the critical dimensions may be ex-ceeded | Overpressure and blow down of the safety valve may be outside the limits of codes and standards |
| 5 | After repair lifting aid was not reinstalled | Overpressure and blow down of the safety valve may be outside the limits of codes and standards |
| 6 | After repair lift restriction was not reinstalled | The safety valve will blow off with a higher capacity. Excessive pressure loss in the inlet and outlet line may occur as well as chattering |
| 7 | During assembly the spindle was not secured against rotation:<br>→ the stainless steel bellows is twisted | Safety valve does not open<br>Sealing surfaces of seat and disc are damaged. |
| 8 | Unsuitable or insufficient grease is used for the lubrication of the actuator of the pneumatic lifting device H8 | The Lifting device H8 fails; the safety valve continues to function |
| 9 | Lifting lever left in open position<br>- lever with knob<br>- H4 for Clean Service | The safety valves stays open |

*Table 17.4-1: Typical Mistakes as a Result of Unauthorized Repair*