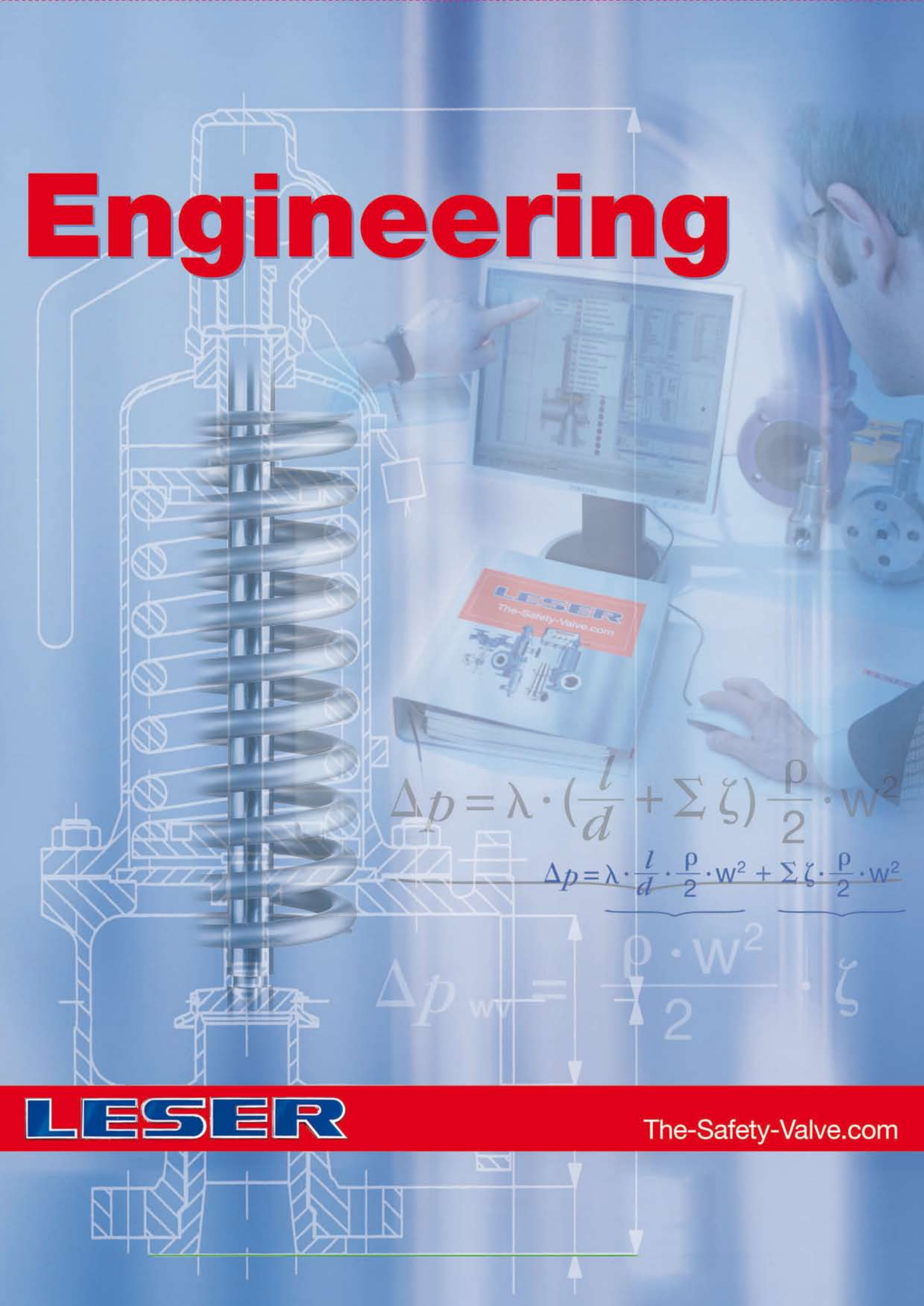
Engineering



LESER

The-Safety-Valve.com

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 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.

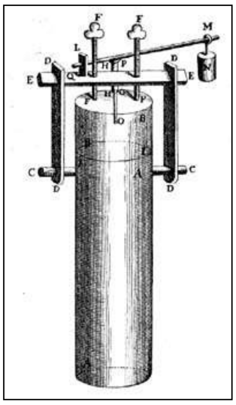


Figure 1.1-1:
Early Safety Valve by Denis Papin

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

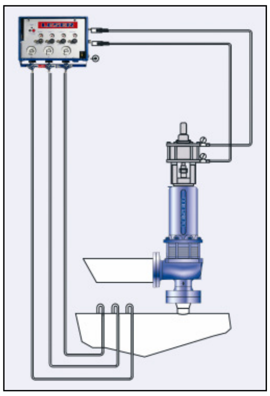


Figure 1.1-5:
Controlled Safety Valve

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

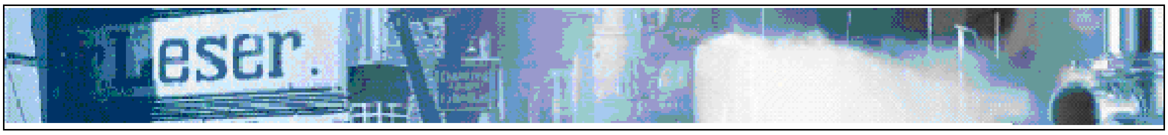
LESER was founded in 1818 as a brass foundry in Hamburg, Germany. In 1885 LESER designed and produced its first safety valve. Since the 1970s LESER has specialized in this product. LESER is now a fifth generation family-owned business and the market leader for industrial safety valves throughout Germany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

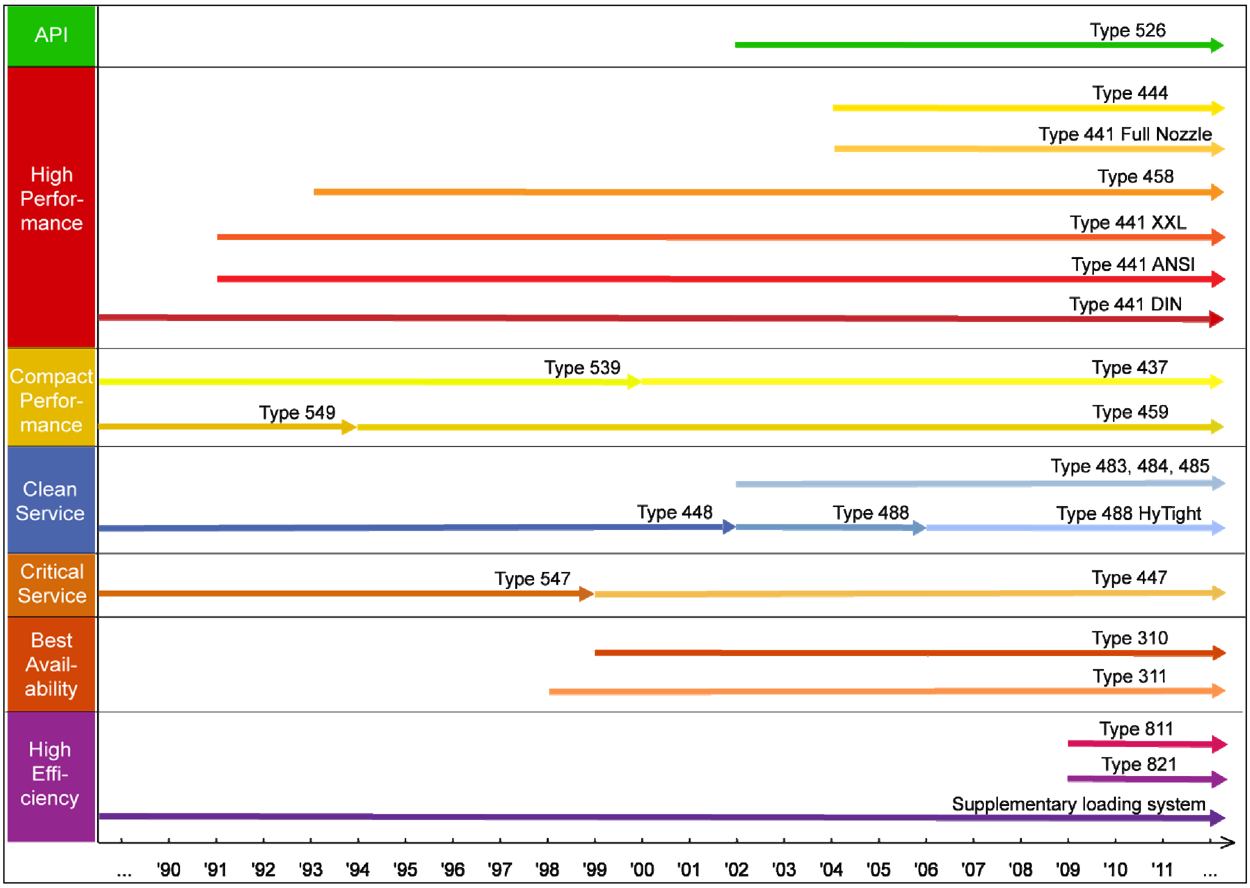


Figure 1.2.1-1: Product development and innovation at LESER

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

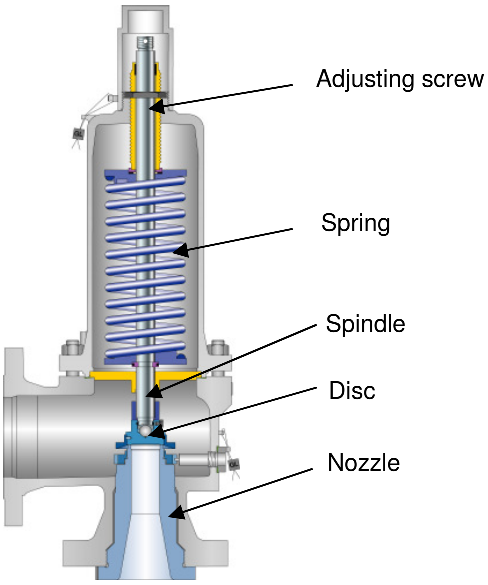


Figure 1.5.1-1: Safety valve

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.

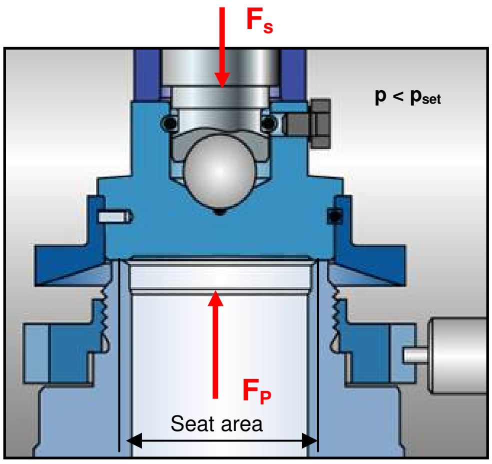


Figure 1.5.1-2: Valve closed

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

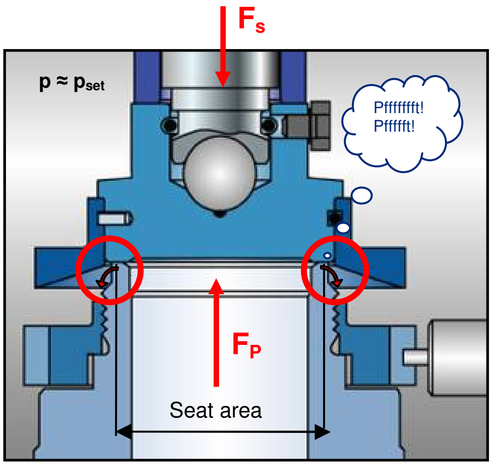
$F_p < F_s$

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.

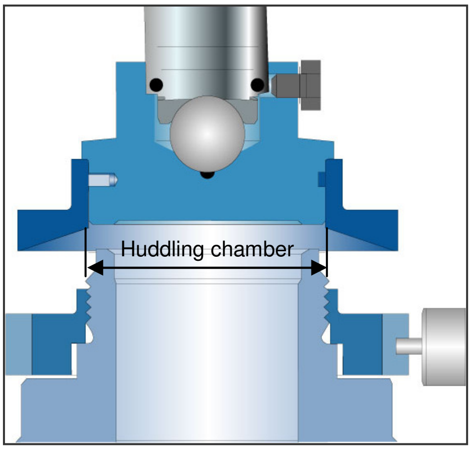


Figure 1.5.2-2: Huddling chamber

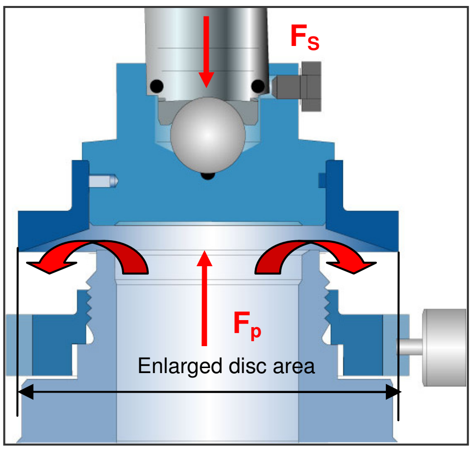


Figure 1.5.2-3: Valve flowing

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.

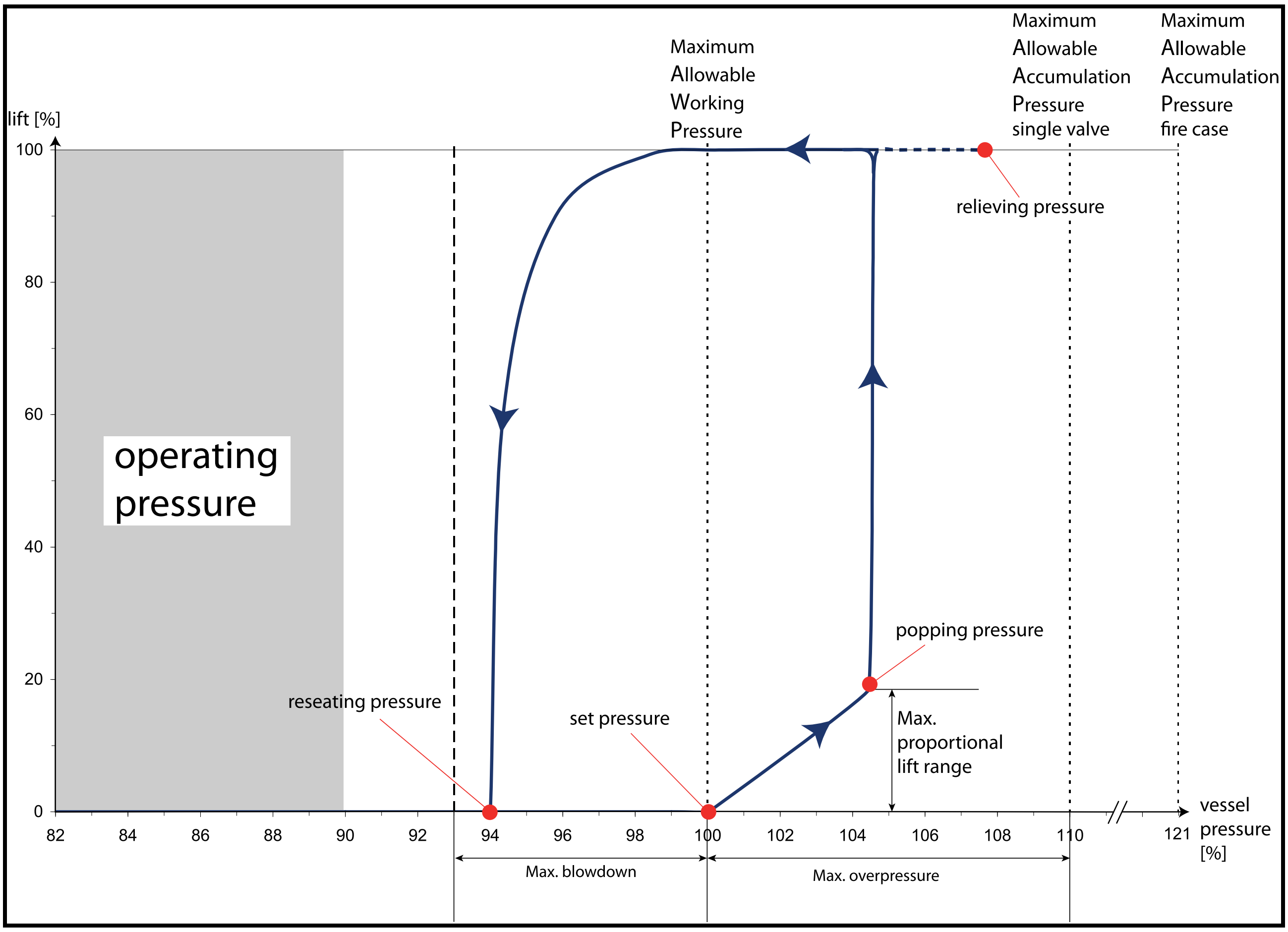


Figure 1.5.4-1: Operation of a Series 526 API safety valve with adjusting ring and initial audible discharge set pressure definition

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:

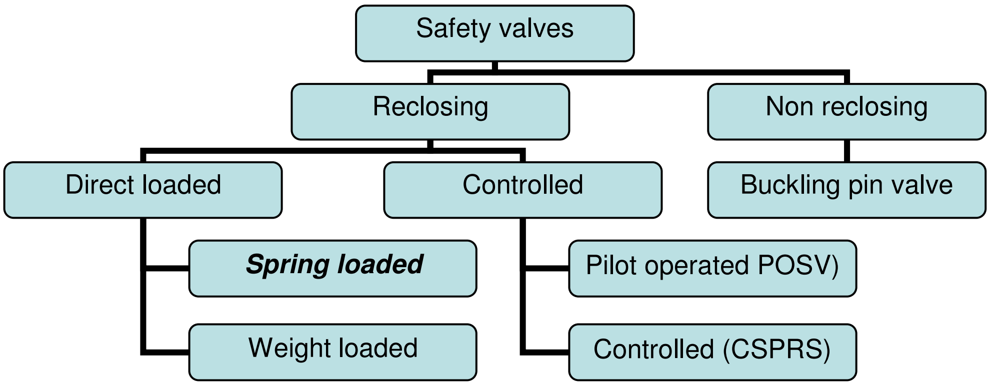


Figure 2.2-1: Loading principles of safety valves

- 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 VIII 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.

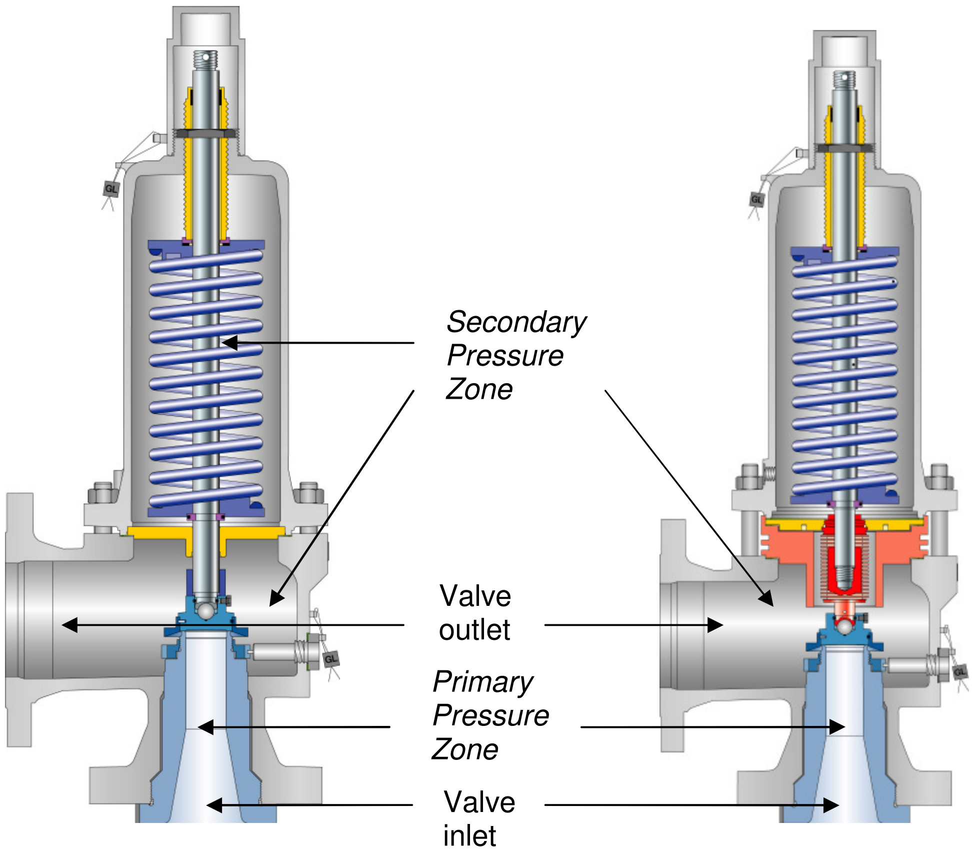


Figure 2.3-1 :Pressure zones in a conventional safety valve

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

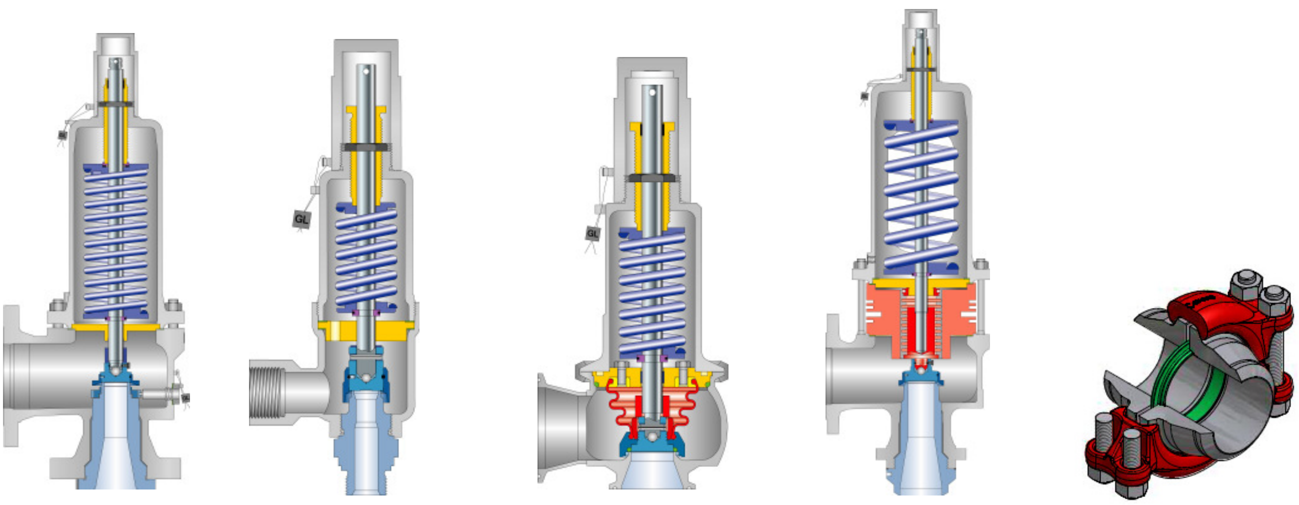
Standard	Other common designation	Originates from
ASME B 1.20.1 - NPT		America
ASME B1.20.3 – NPTF		America
ISO 7-1 – R	BS 21, BSP-T	Europe
ISO 7-1 – Rp	BS 21, BSP-P	Europe
ISO 228-1 - G	BS 2779	Europe

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®

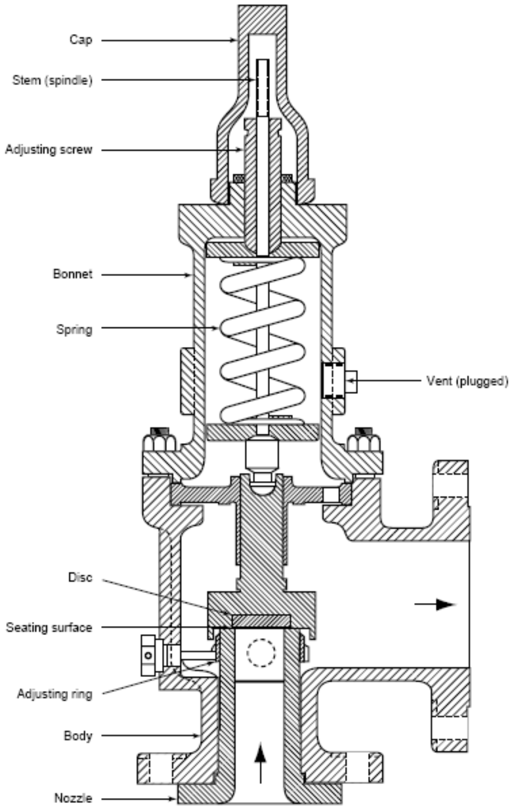
Figure 2.4.3-1: Typical connections for safety valves

2.5 Conventional and Balanced Safety Valves

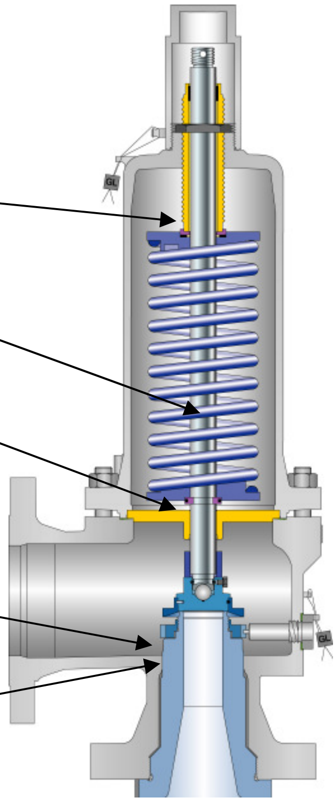
2.5.1 Conventional Safety Valves

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



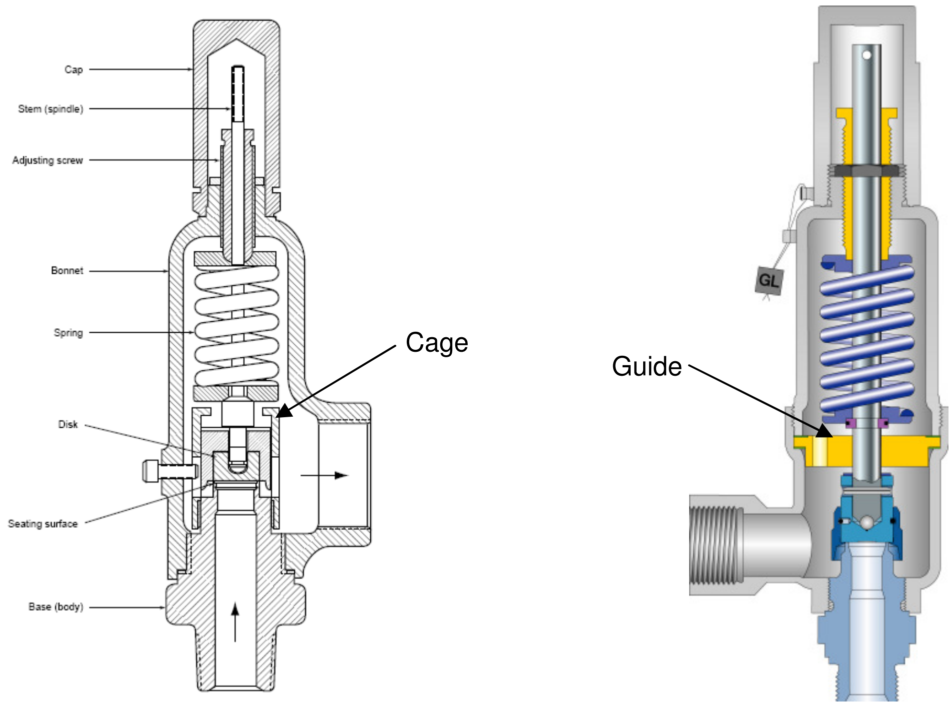
LESER API Series 526:
Improvements in the design

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

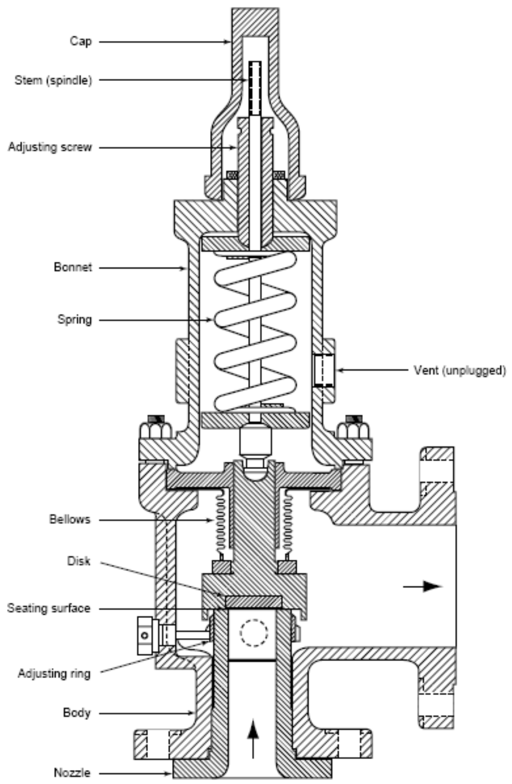
The API 520-1 figure 5 shows a typical design for a conventional threaded safety valve.
Compared with the typical design there are some major improvements in the LESER design:

- 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

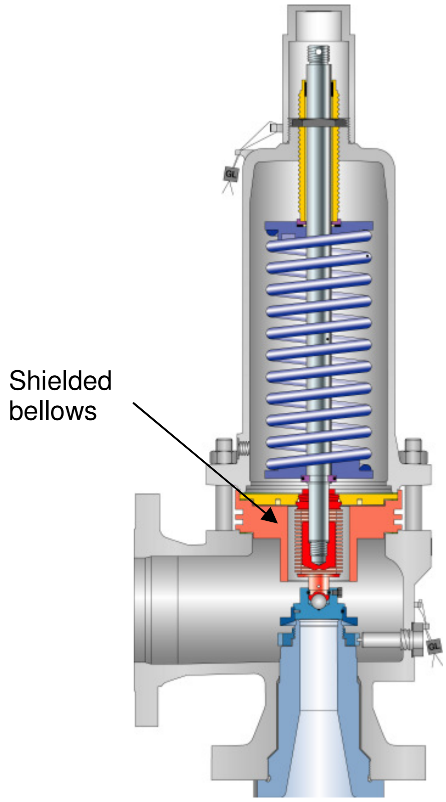
2.5.2 Balanced Safety Valves

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



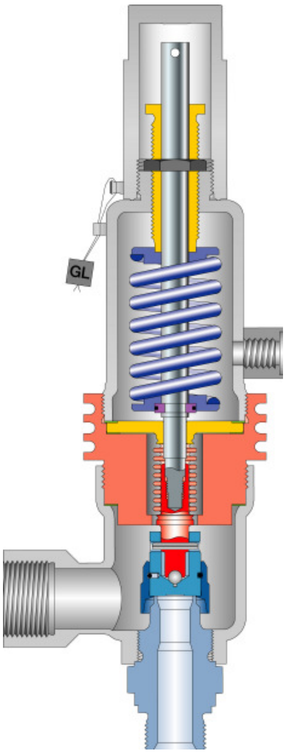
LESER API Series 526:
Improvements in the design

Figure 2.5.2-1: Balanced safety valves - flanged

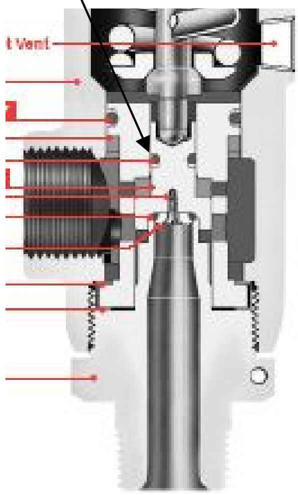
The API 520 figure 3 shows a typical design for a balanced flanged safety valve.
The LESER API Series 526 complies with all requirements of API 520-1 and API 526. Compared with the typical design there are some major improvements in the LESER design:

- 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



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

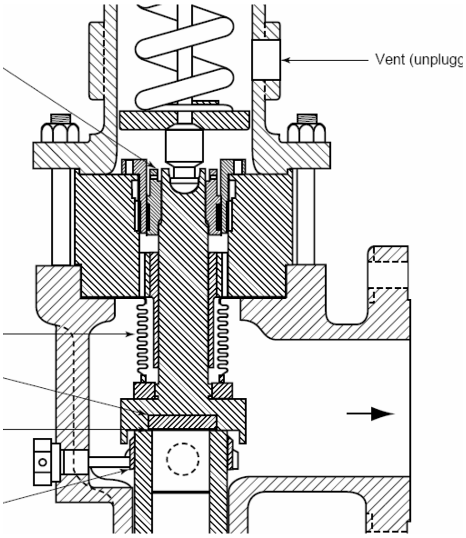


Figure 2.5.3-1: API 520-1, Figure 4

Balanced-bellows pressure relief valve with an 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.
Currently the balanced piston design is not offered by LESER.

2.6 Parts of a Spring Loaded Safety Valve

2.6.1 Parts of a Conventional Spring Loaded Safety Valve – Flanged

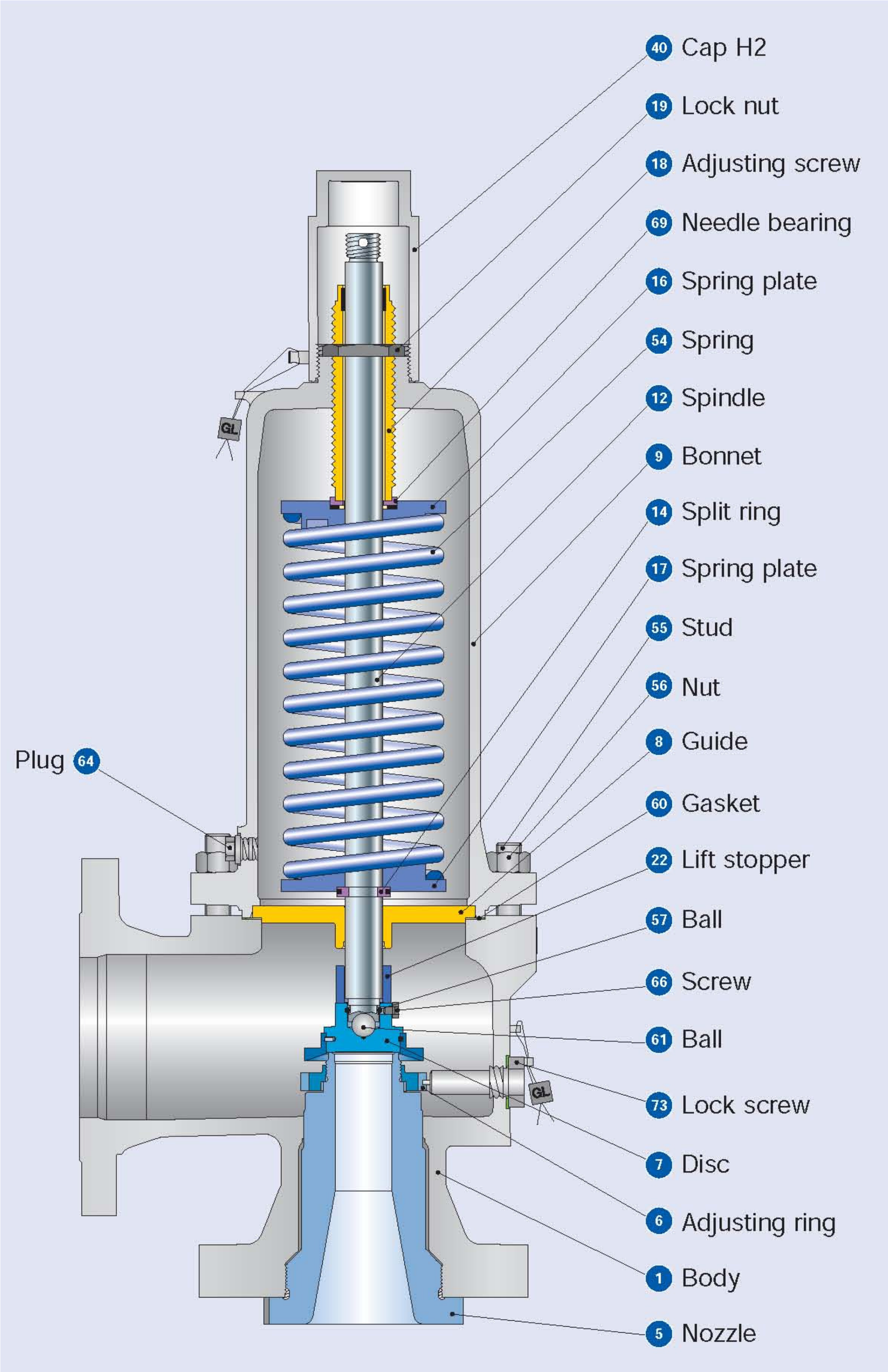


Figure 2.6.1-1: Parts of a Conventional Spring Loaded Safety Valve – Flanged

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

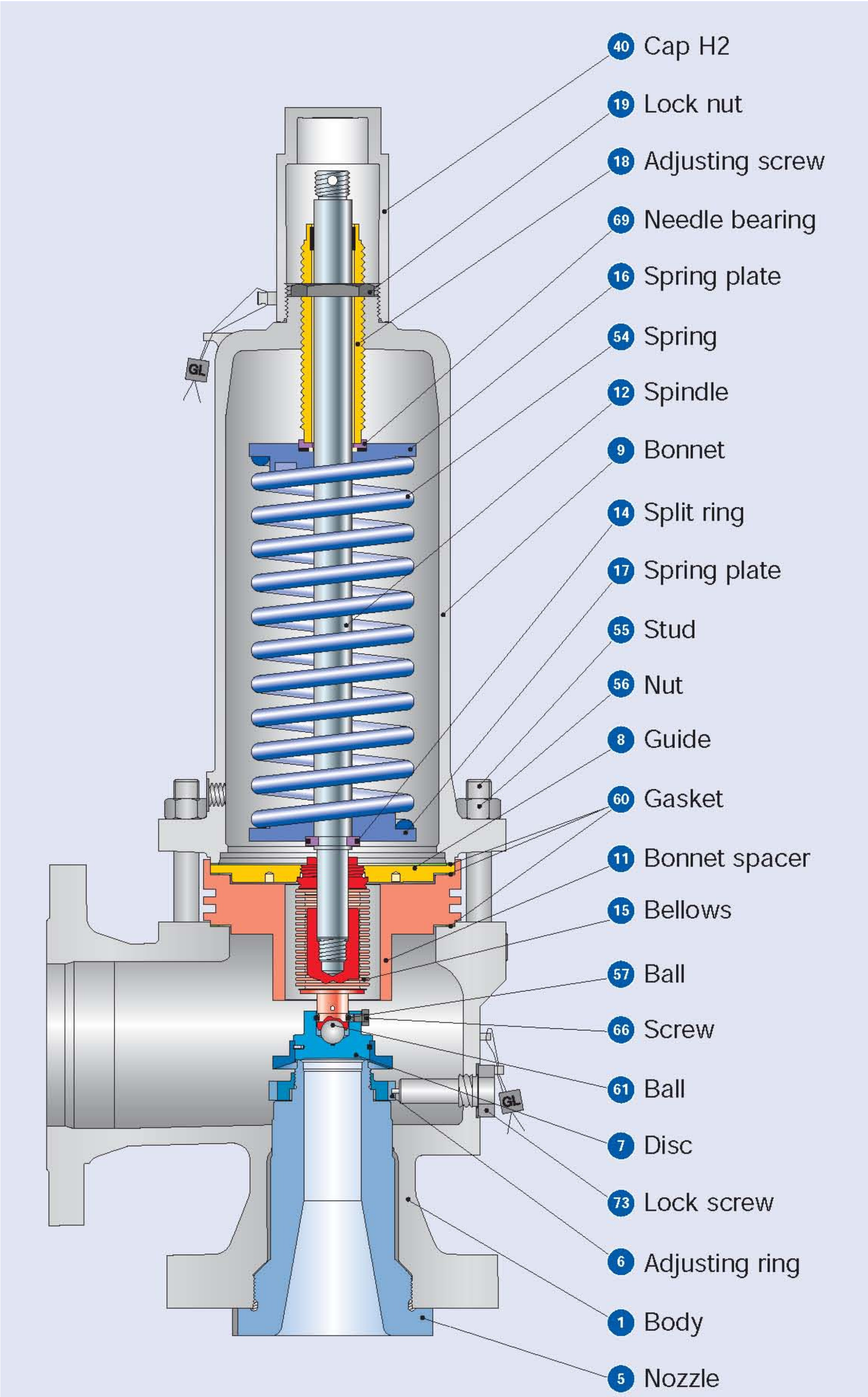


Figure 2.6.2-1: Parts of a Balanced Bellows Spring Loaded Safety Valve - Flanged

2.6.3 Parts of a Conventional Spring Loaded Safety Valve – Threaded

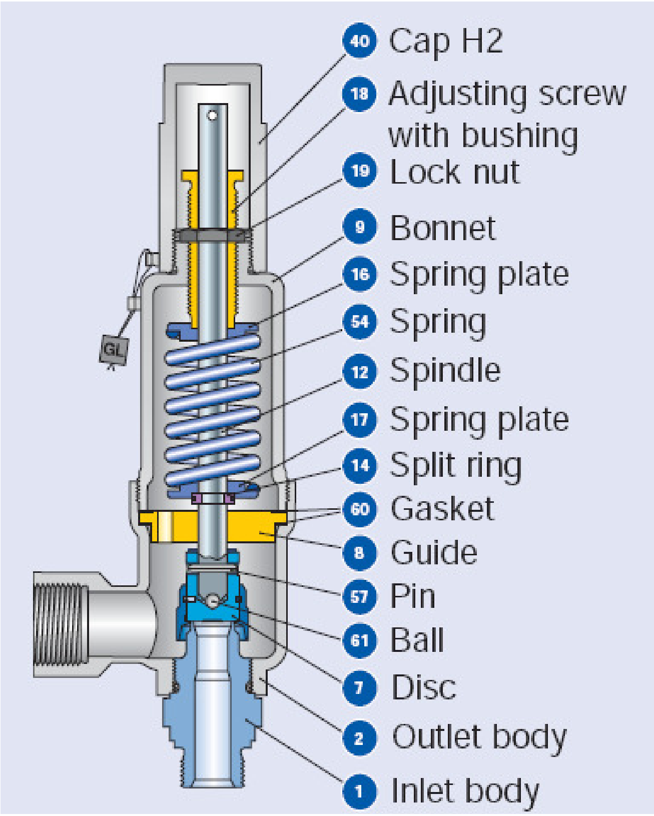


Figure 2.6.3-1: Parts of a conventional spring loaded safety valve - threaded

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

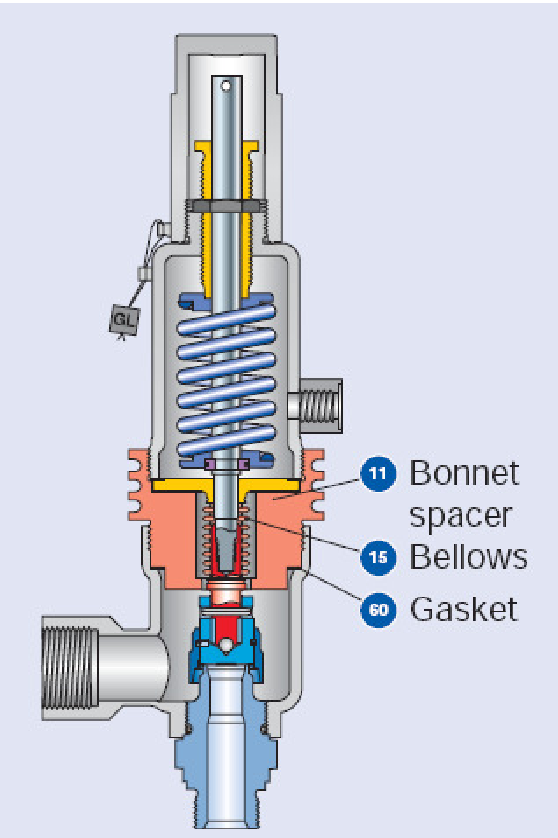


Figure 2.6.4-1: Parts of a balanced bellows spring loaded safety valve - threaded

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 ASME VIII

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 VIII UG 136(b)(3) gives the following definition:
“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 – Div. 1).”

The reason why the ASME VIII 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 VIII, UG 136(d)(2) gives the following definition:

(a) “The pressure containing parts of each valve shall be hydrostatically tested at a pressure at least 1.5 times the design pressure of the parts. Parts meeting the following criteria shall be exempt from hydrostatic testing:
  (1) the applied stress under hydrostatic test conditions does not exceed 50% of the allowable stress; and
  (2) the part is not cast or weld
(e) Valve components downstream of the disc and fully contained within the body are exempt from hydrostatic testing.”

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 97/23/EC

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 97/23/EC nor 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 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"

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 97/23/EC, 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 - risk of excessive spring compression with coils approaching each other, resulting in restricted lift - pressure accumulation in the vessel above acceptable levels due to restricted lift
Set pressure below spring range	- increased overpressure - 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.

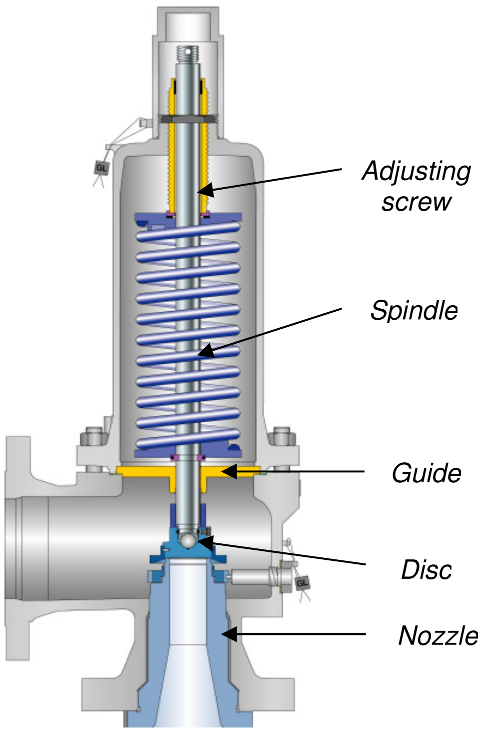


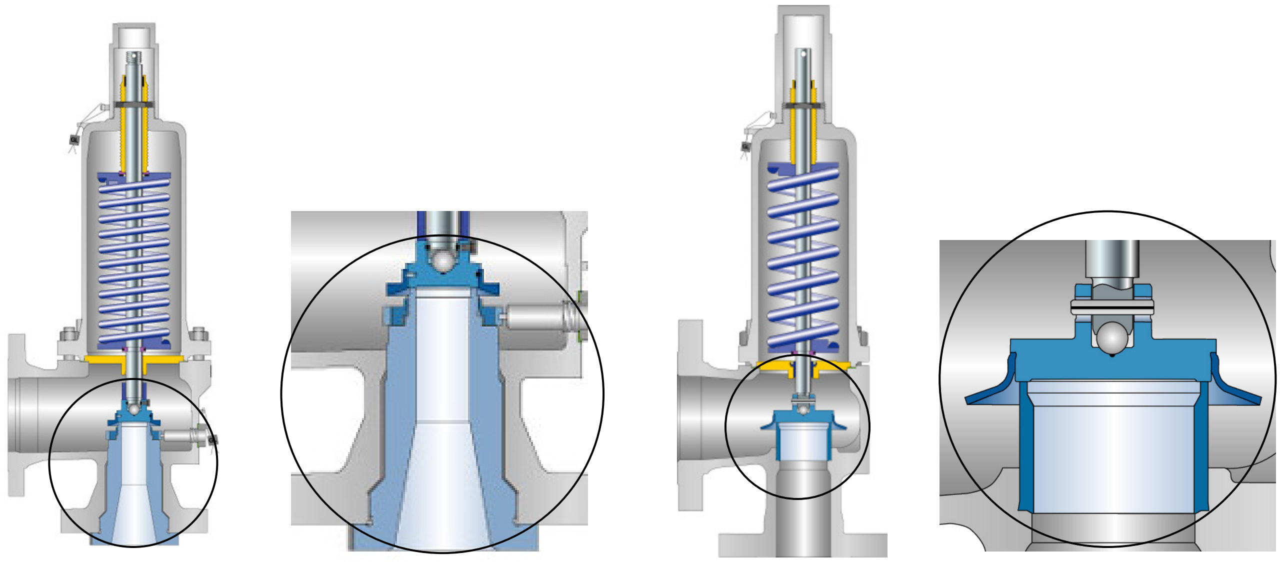
Figure 2.6.9-1 Parts providing alignment

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 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. A carbon steel body material can be selected for non corrosive applications, e.g. utility, air, steam, water. 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

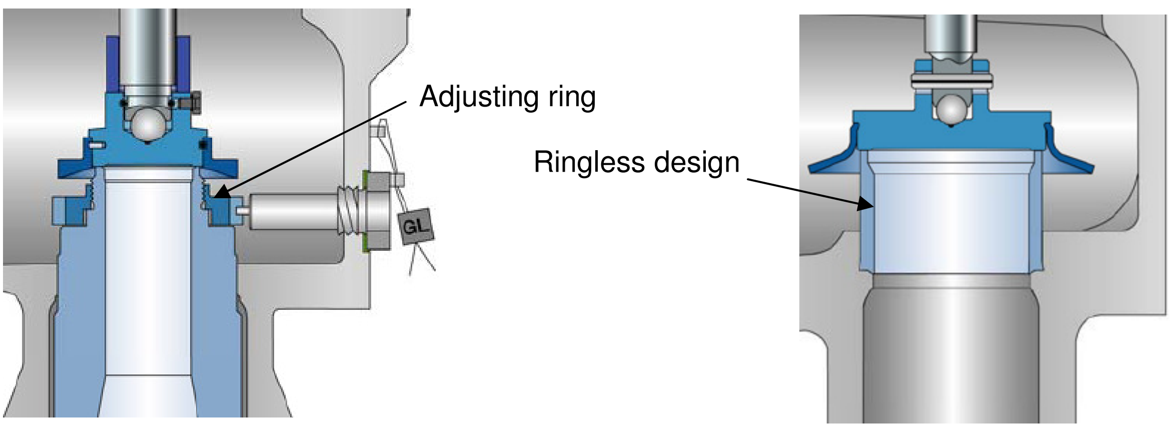
In the USA the majority of flanged valves are equipped with one or two adjusting rings, positioned around the nozzle and/or the disc. The position of these rings is usually factory set to meet overpressure and blowdown requirements of the applicable codes. The position of the rings can be adjusted to 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 VIII requirements (see also section 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.

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.

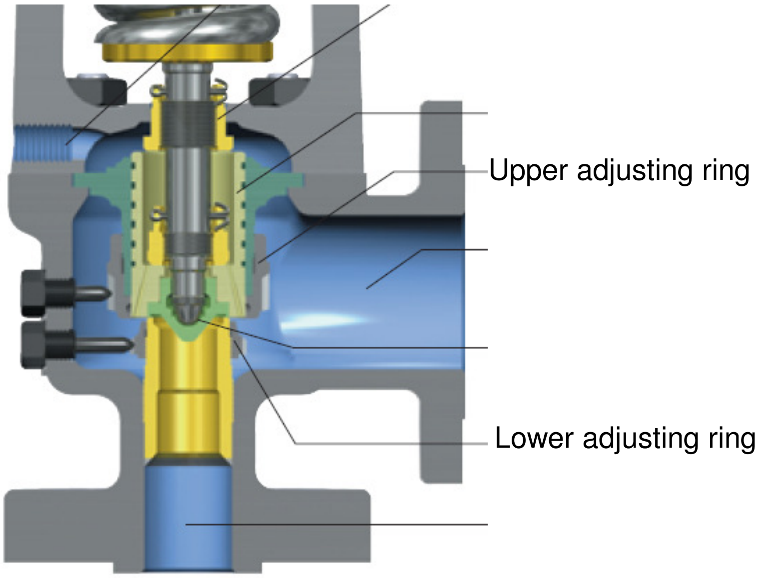


Figure 2.8.3-1: Typical ASME I safety valve design with two adjusting rings

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 VIII, PED 97/23 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 VIII 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 VIII, 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 VIII will be fully open at 5% on a steam/gas application with a blowdown of 10%.

Overpressure Requirements (max. values)						
	Code Requirements			Certified Values for LESER Types		
Medium	ASME VIII	ISO 4126-1	AD 2000 A2[1)]	441	459	526
Steam/Gas	+10%	+10%	+5% full lift +10% other	+5%	+5%	+10%
Liquid	+10%	+10%	+5% full lift +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 VIII	ISO 4126-1	AD 2000 A2	441	459	526
Steam/Gas - ringless design	No requirement	-15%	-10%	-10%	-10%	-7%
Steam/Gas - 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

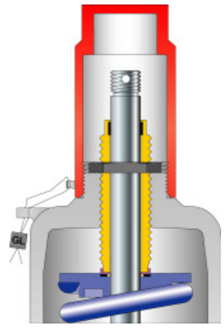
2.10.2 Lifting Devices

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 VIII 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.

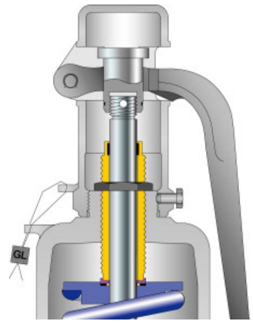
Certain codes require the installation of lifting levers for specific applications. The following chart provides an overview about the code requirements.

Code	Section	Requirement to use lifting devices	Omission of lifting device
ASME VIII	UG-136 (a) (3)	Each pressure relief valve on - air - water over 140°F (60°C) - or steam service shall have a substantial lifting device which when activated will release the seating force on the disc when the pressure relief valve is subjected to a pressure of at least 75% of the set pressure of the valve.	Code Case 2203: - the user has a documented procedure … for the periodic removal of pressure relief valve for inspection and repair as necessary - the omission is specified by the user - 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. Information in ISO 4126-9, section 9: 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 TRD 421 TRD 721	4.3 4.3 4.4	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.

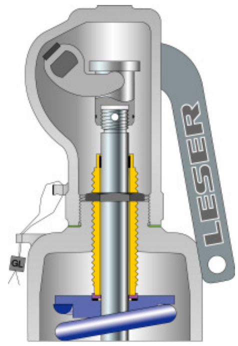
Table 2.10.2-1: Lever requirements in codes and standards



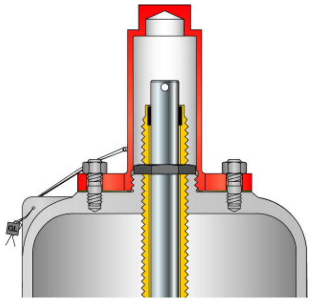
Plain Cap H2
- gastight -



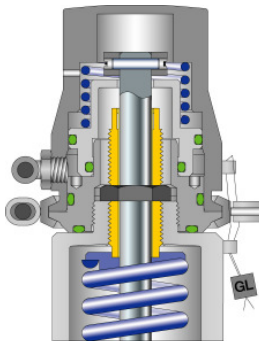
Plain lever H3-
- not gastight -



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

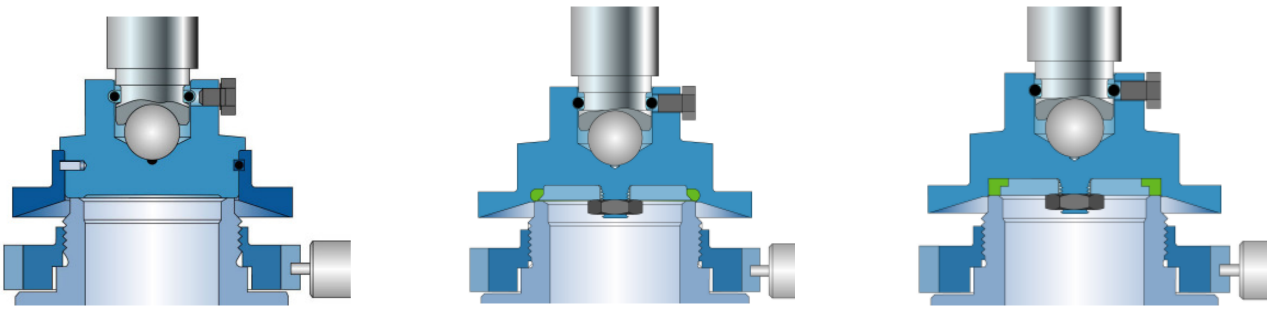
The standard design for safety valves is to be equipped with a metal to metal seat, which covers the largest variety of applications with regard to pressure/temperature combinations.

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 and chapter 8 of ENGINEERING.



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 1	ISO 4126 Part 4	ISO 4126 Part 9	AD 2000-A2	
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. The symbol is *C*.

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

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

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

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

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

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

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

6.2 Installation of the Safety Valve

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

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

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

6.2.1 Correct Connections

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

6.2.2 Gaskets

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

6.2.3 Flow Direction

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

- Flow direction arrow on the body

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

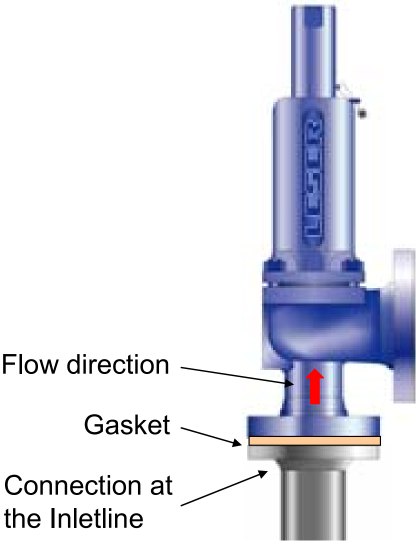


Figure 6.2.3-1: Flow direction

6.2.4 Location of the Safety Valve

6.2.4.1 Distance to Pressure Source

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

6.2.4.2 Distance to Other Valve Equipment

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

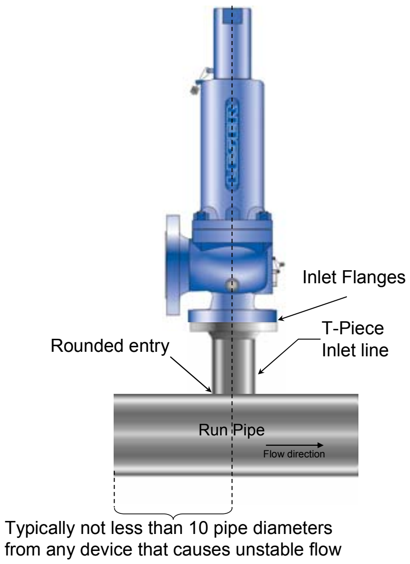


Figure 6.2.4.2-1: Distance to other valve equipment acc. to API 520 part II

6.2.4.3 Sources of Irritation

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

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

[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)]

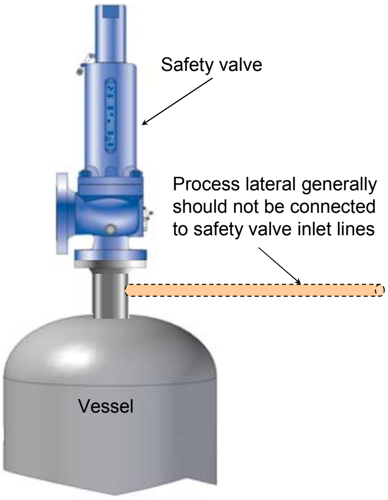


Figure 6.2.4.4-1: Process lateral acc. to API 520 part II

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.

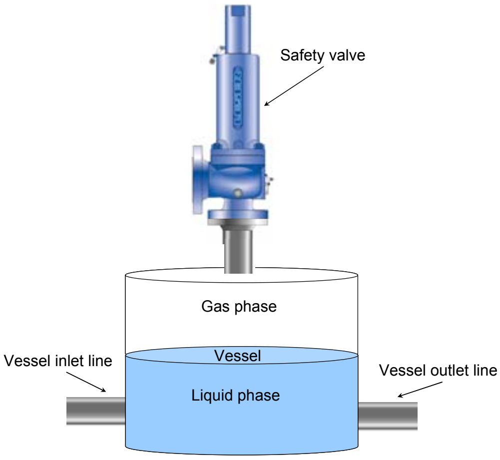


Figure 6.2.4.5-1: Partly filled vessel

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

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

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

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

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

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

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

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

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

LESERs design enables horizontal installation due to:

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

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

6.2.6 Unfavourable Environmental Conditions

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

6.2.7 Impurities

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

6.2.8 Inlet Stresses that Originate from Installation

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

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

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

6.2.9 Insulation

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

6.2.10 Heating

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

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

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

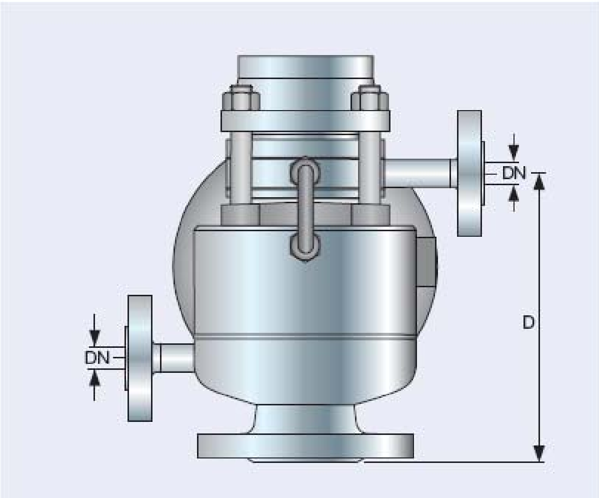


Figure 6.2.10-1: LESER Safety Valves with heating jacket - balanced bellows design

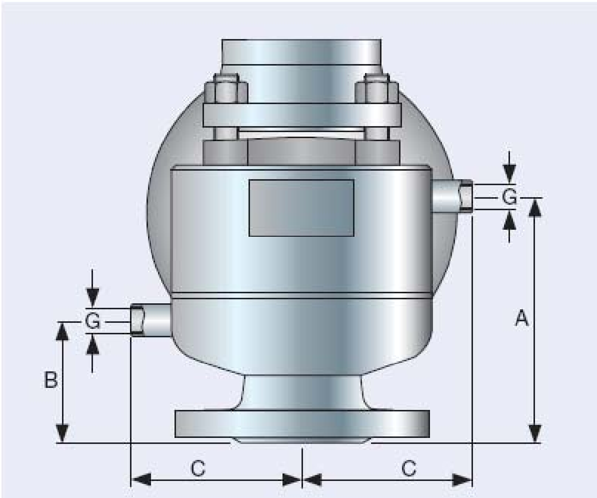


Figure 6.2.10-2: Leser Safety Valves with heating jacket – conventional design

6.2.11 Testing and Inspection of Safety Valves before Installation

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

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

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

6.2.11.1 Pressure Test before Operation

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

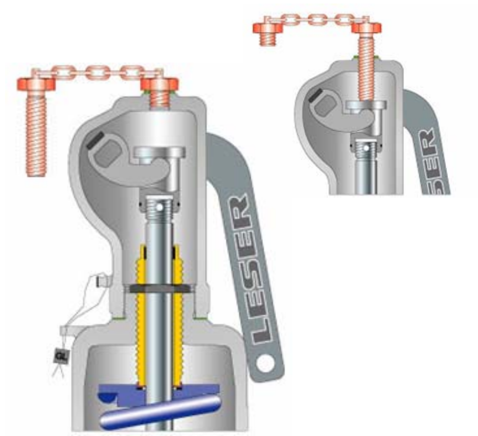
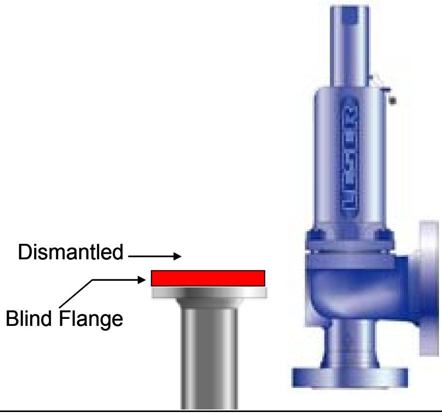
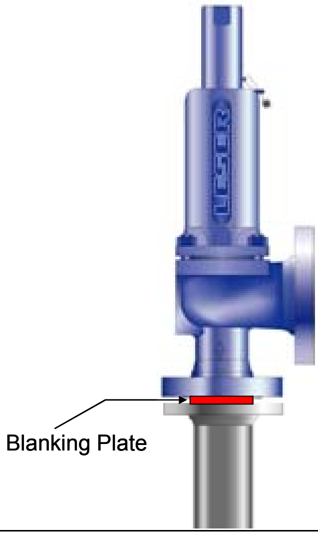
Possibility	Figure	Description
Test gag		The test gag blocks the spindle and keeps the safety valve tight while the system pressure exceeds the set pressure. Advantage: It is possible to perform pressure tests in a system without dismantling the safety valve. After testing, the test gag must be removed! 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. After testing, the blanking plate must be removed! Otherwise the safety valve cannot protect the system against unallowable overpressure.

Table 6.2.11.1-1:Options for the hydraulic pressure test

6.2.12 Recommendation for Testing and Inspection during Operation

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

6.2.12.1 Inspection Intervals for LESER Safety Valves

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

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

1. Determination of an ininitial inspection time interval:

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

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

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

3. Adapting the inspection time interval

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

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

6.2.12.2 Statements in Codes and Standards

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

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

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

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

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

The following testing periods for category IV pressure equipment (including safety valves) are defined in section 15:

- External inspection: 2 Years
- Internal inspection: 5 Years
- Strength inspection: 10 Years

6.2.13 Storage and Handling of Safety Valves

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

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


Figure 6.2.13-1: Individual cardboard box


Figure 6.2.13-2: Tied-down on a pallet


Figure 6.2.13-3 Wooden crate

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

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


Figure 6.2.13-4: Outside label on a cardboard box

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

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

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

6.2.14 Spare Parts Recommendation

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

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

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

Remarks for the following tables

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

Spare Parts for product group API

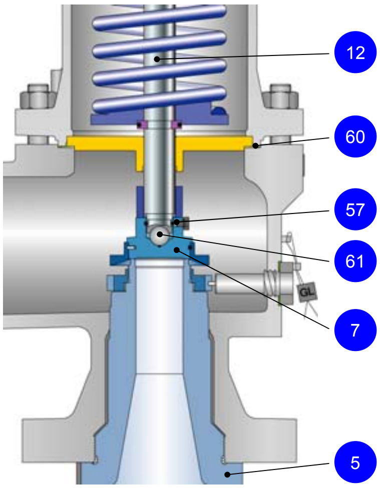


Figure 6.2.14-1: Spare parts API series 526 - Conventional Design

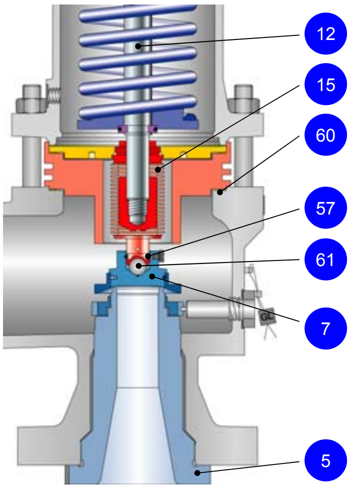


Figure 6.2.14-2: - Balanced Bellows Design

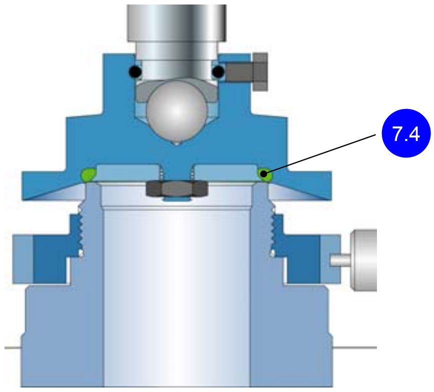


Figure 6.2.14-3: - O-Ring Disc Design

General components

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

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

Balanced bellows design and soft seat design

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

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

Spare Parts for product group High Performance/ Modulate Action

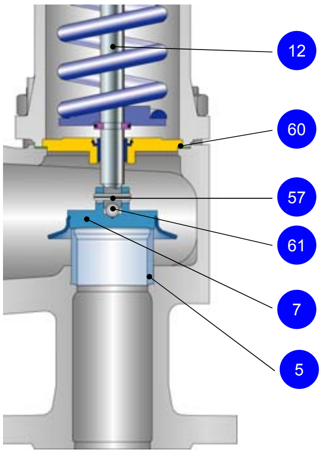


Figure 6.2.14-4: Spare parts High Performance/ Modulate Action -Conventional Design

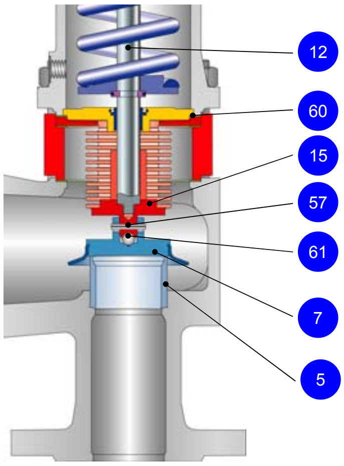


Figure 6.2.14-5: - Balanced Bellows Design

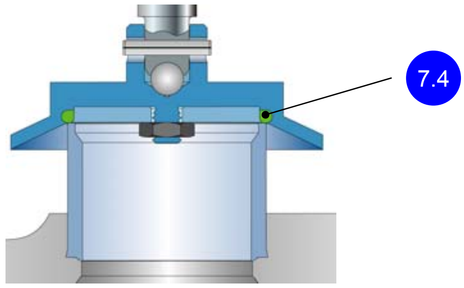


Figure 6.2.14-6: - O-Ring Disc Design

General components

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

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

Balanced bellows design and soft seat design

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

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

Spare Parts for product group Compact Performance

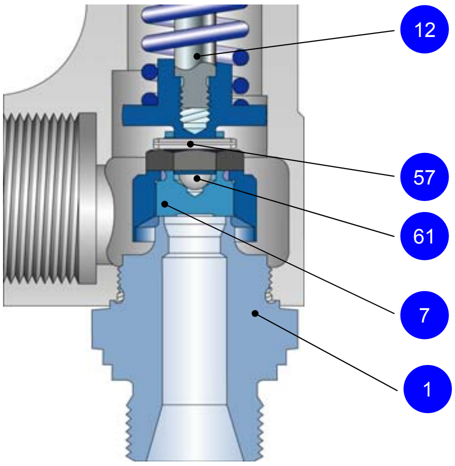


Figure 6.2.14-7: Spare parts Compact Performance -Conventional Design

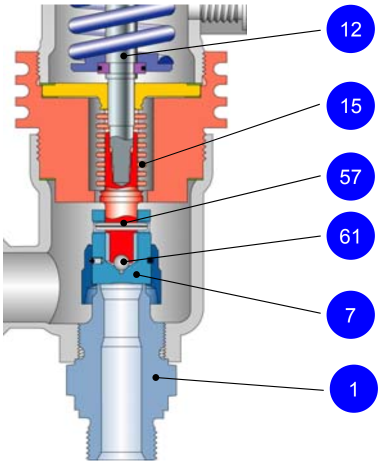


Figure 6.2.14-8: - Balanced Bellows Design

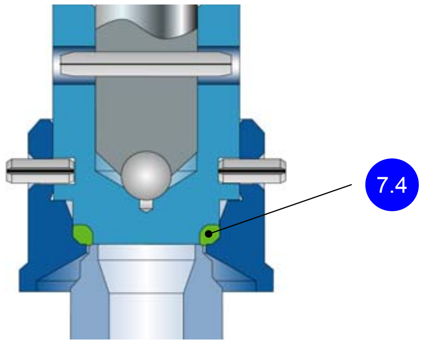


Figure 6.2.14-9: - O-Ring Disc Design

General components

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

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

Balanced bellows design and soft seat design

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

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

Spare Parts for Clean Service Design

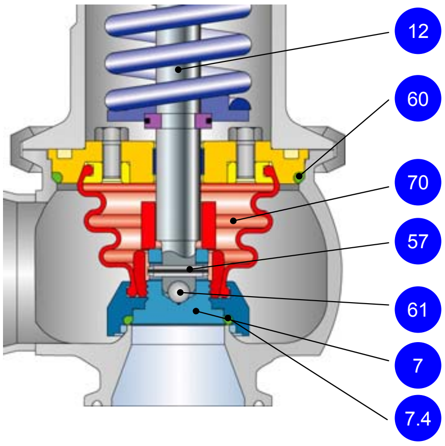


Figure 6.2.14-10: Spare parts for Clean Service design

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

Table 6.2.14-7: Spare parts Clean Service

Spare Parts for Critical Service

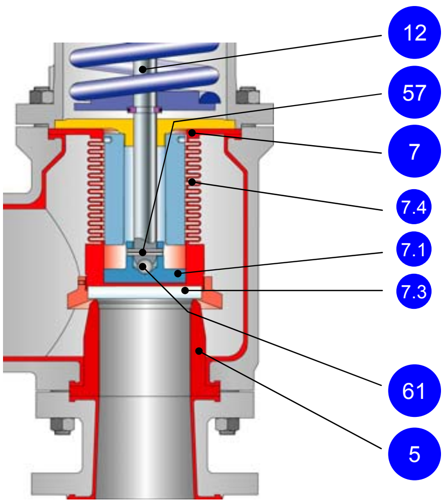


Figure 6.2.14-11: Spare parts Critical Service

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

Table 6.2.14-8: Spare parts Critical Service

6.3 Plant Design – Inlet Line

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

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

6.3.1 Correct Sizing of the Inlet Line

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

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

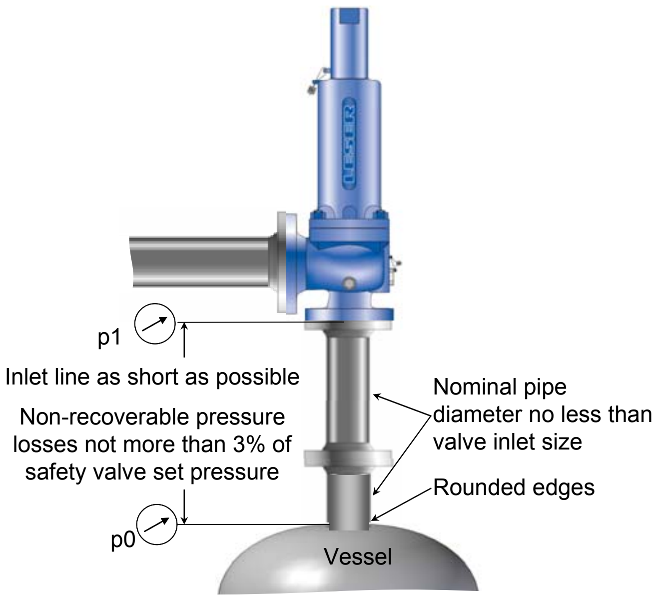


Figure 6.3.1-1: General guidelines for inlet lines

6.3.2 Pressure Loss - The 3%-Criterion

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

Code/ Standard	Pressure loss in the inlet line
ISO 4216-9	“Unless otherwise specified by national codes or regulations, the inlet line shall be so designed that the total pressure loss to the valve inlet does not exceed 3 % of the set pressure of the safety device, or one third of the blow down, whichever is less.”
API 520 Part II	“When a pressure-relief valve is installed on a line directly connected to a vessel, the total non-recoverable pressure loss between the protected equipment and the pressure-relief valve should not exceed 3 percent of the set pressure with the discharged maximum mass flow. 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

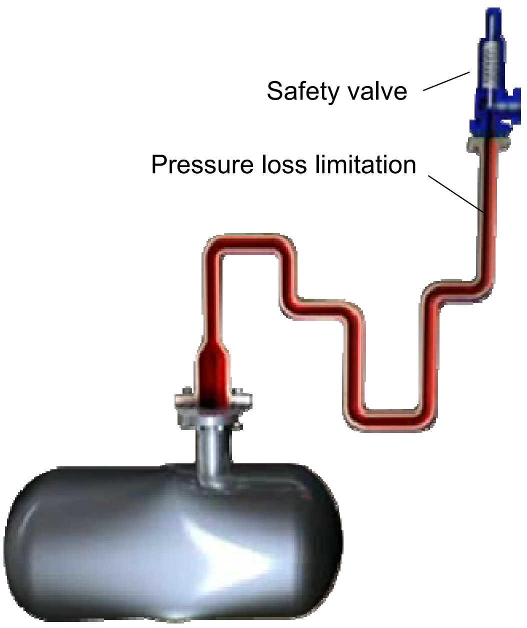


Figure 6.3.2.1-1: Incorrect sizing of inlet line

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.

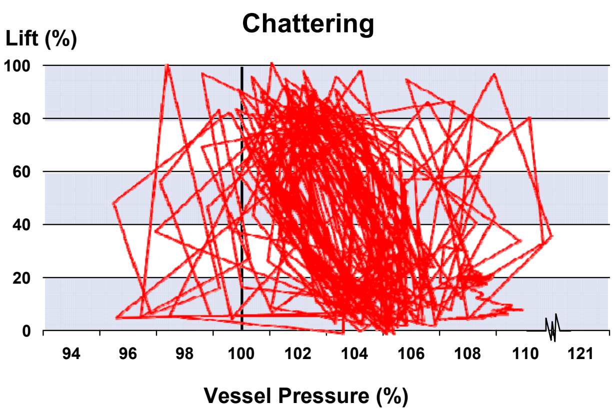


Figure 6.3.2.3-1: Chattering

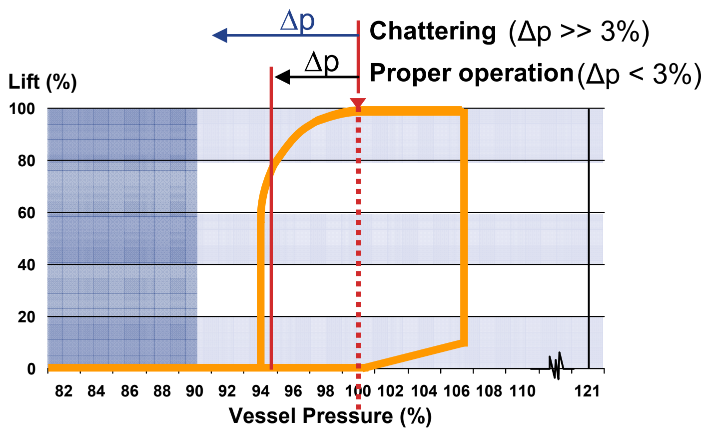


Figure 6.3.2.3-2: Effect of pressure loss

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

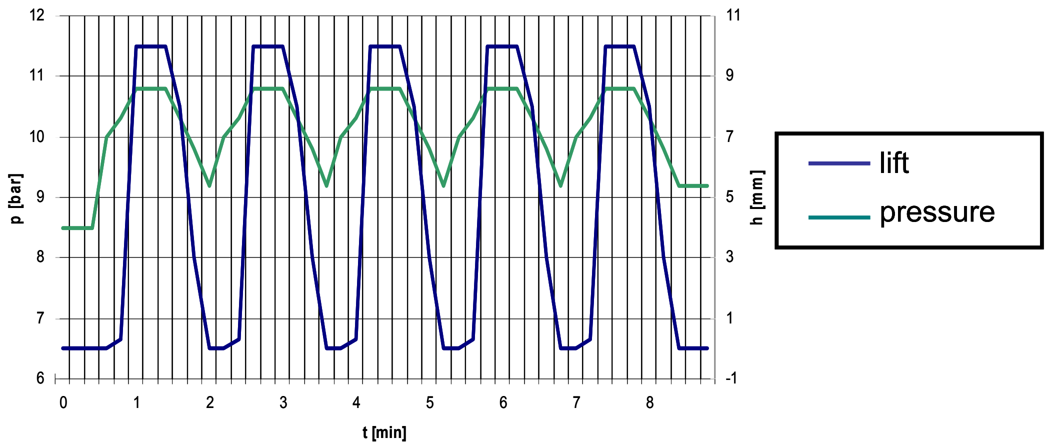


Figure 6.3.2.3-3: Frequent opening

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, Octobre 2006, Section 6.1.1

Change-over Valves

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

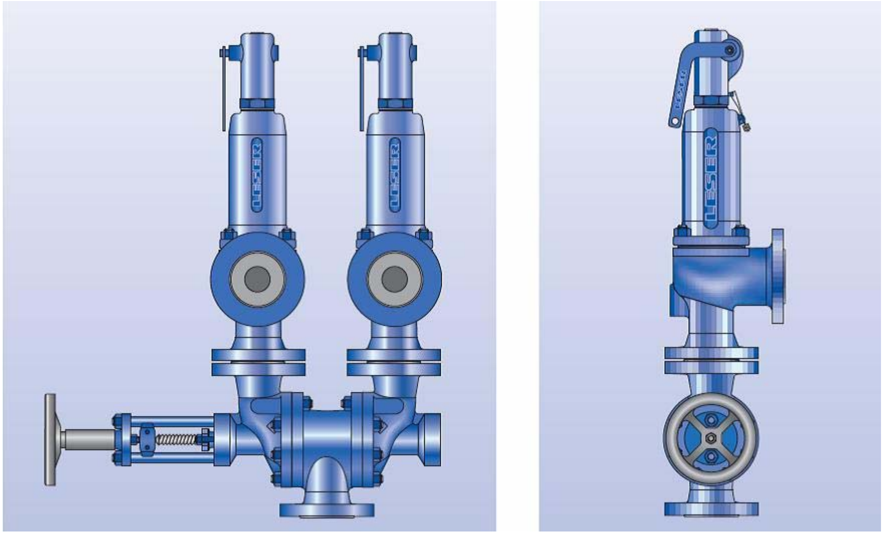


Figure 6.3.6-2: Inlet sided combination

6.4 Plant Design - Outlet Line

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

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

6.4.1 Correct Sizing of the Outlet Line

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

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

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

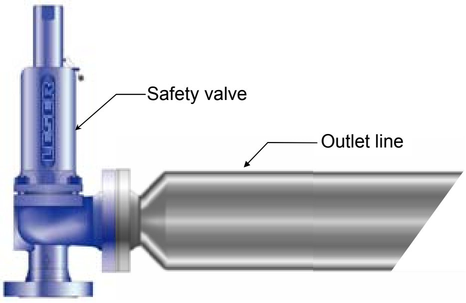


Figure 6.4.1-1: Sizing of the outlet line

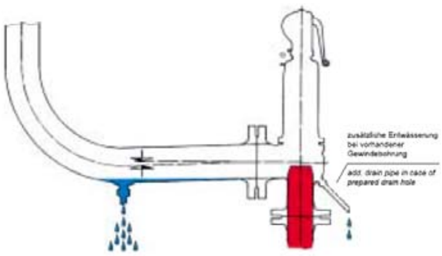


Figure 6.4.1-2: Correct drainage

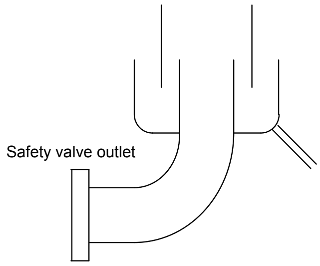


Figure 6.4.1-3: Drip Pan Elbow

2. Consideration should be given to
    - the type of discharge system used
    - the back pressure on the safety valve
    - the set pressure relationship of multiple safety valves in the system
3. Adequate drainage of the outlet line to achieve a proper safety valve performance. All LESER safety valves have a self-draining body, so that normally no medium or condensate will stay inside the safety valve. The following directions should be followed:
    - The drainage should always run via the outlet line, which should be self-draining just as the LESER safety valve.
    - At the lowest point of the outlet line sufficient drainage (min. 50mm/ 2”) should be installed for discharging condensate (Figure 6.4.1-2)
    - To avoid back-flow, a drip pan elbow can be used (Figure 6.4.1-3)
    - Some standards require an additional drain hole within the safety valve, e.g. API 526. In general, LESER safety valves don’t need these additional drainage holes due to the self-draining bodies.
    - Drain holes without function should be closed.
4. Selection of proper material to avoid fracture in consequence of freezing during the discharge
5. The outlet line has to be supported properly to avoid stress and damages at the safety valve

6.4.1.1 Discharge to the Atmosphere

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

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

6.4.2 Condensation in the Outlet Line

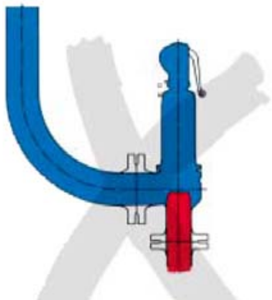


Figure 6.4.2-1: wrong drainage

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

- ► The outlet line is bent upwards directly at the safety valve without a drainage hole (Figure 6.4.2-1).
- ► The outlet line discharges to the atmosphere and rain or condensate is able to flow down the outlet line toward the safety valve.

6.4.3 Freezing of the Outlet Line

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

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

6.4.4 Back Pressure

6.4.4.1 Definitions

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

Back Pressure = Built-up + Superimposed

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

Figure 6.4.4.1-1:
Without Back Pressure

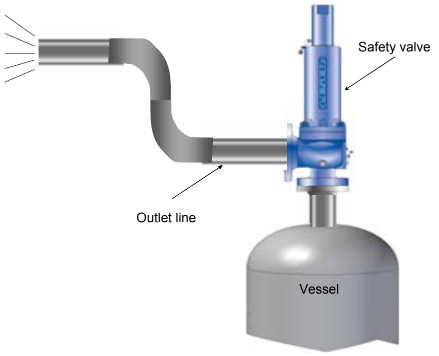


Figure 6.4.4.1-2:
Built-up Back Pressure

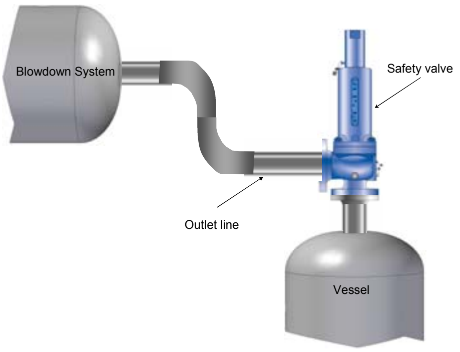


Figure 6.4.4.1-3:
Superimposed Back pressure

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

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

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

6.4.4.2 Types of Back Pressure and Required Actions

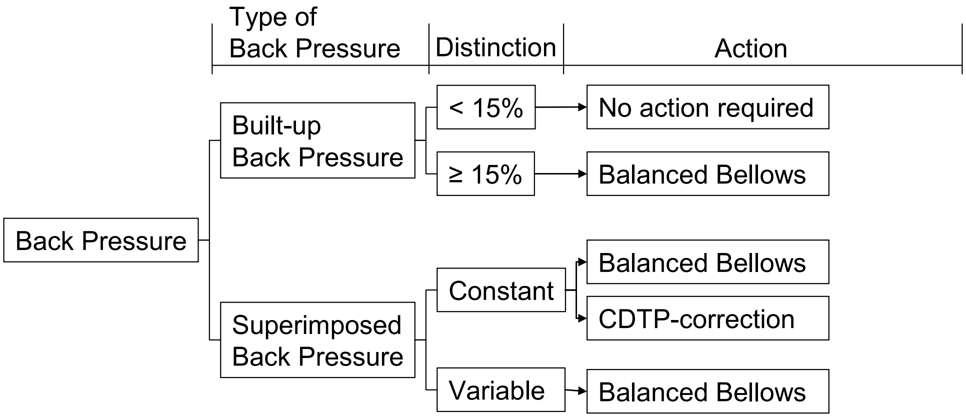


Figure 6.4.4.2-1: Differences of back pressure types and required actions

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

Built-up Back Pressure

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

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

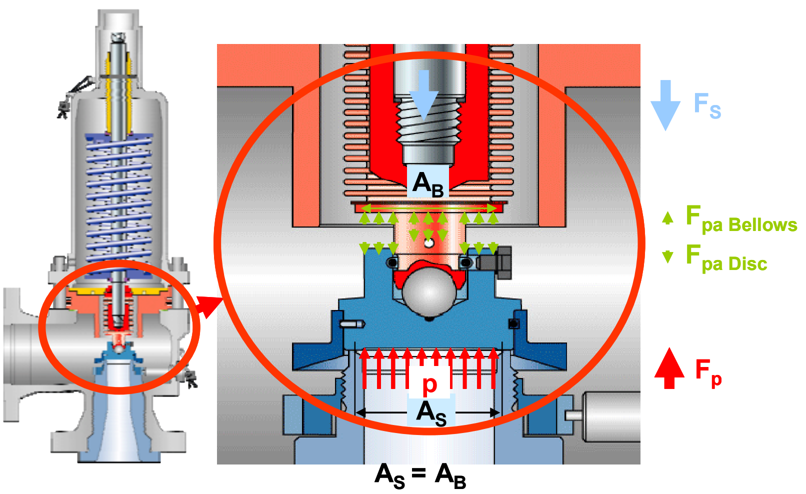
Note: API 520 defines the built- up back pressure limit for conventional safety valves to 10%.

Constant Superimposed Back Pressure

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

<u>Compensation by balanced bellows</u>

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



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

Figure 6.4.4.2-2: Function of balanced bellows

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

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

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

Pressure form	Pressure
Set pressure	10 bar
Superimposed back pressure	2 bar
Differential pressure (CDTP) → Setting of safety valve	8 bar

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

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

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

6.4.5 Accessories in the Outlet Line

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

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

For details please see API 520 Part II sec. 6.3.1

The block/stop valve solution has some disadvantages:

- The handling and the interlocking system are complicated and therefore not foolproof
- The installation height is very large

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

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

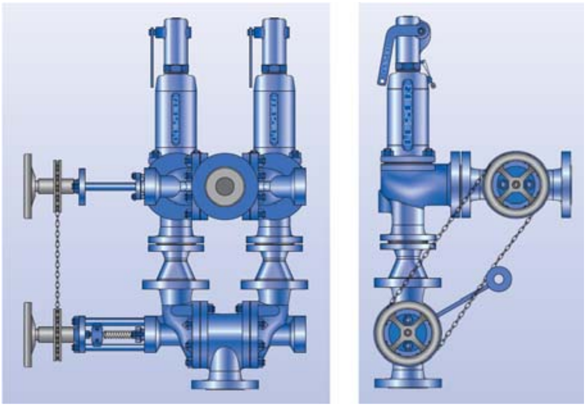


Figure 6.4.5-1: Lockable combination

6.5 Calculations Regarding Installation or Plant Design

6.5.1 Calculation of the Pressure Loss

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

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

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

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

Table 6.5.1.1-1: Symbols ISO 4126-9

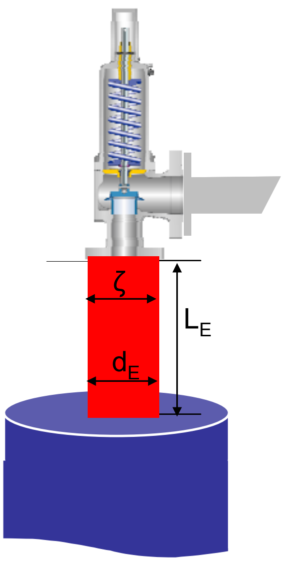


Figure 6.5.1.1-1: Safety valve with inlet line

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 ζ_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:

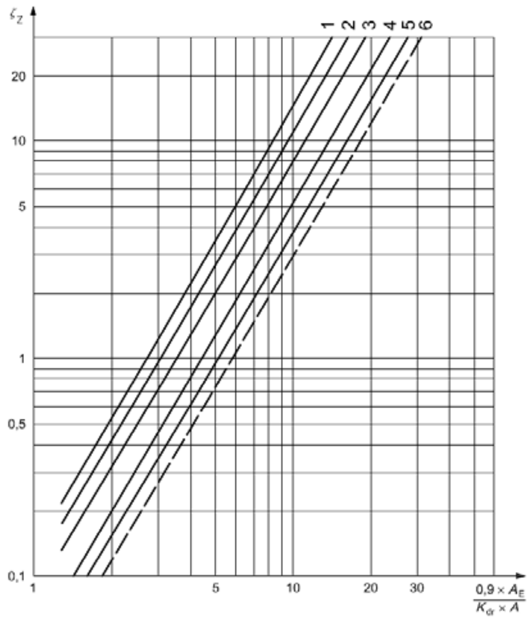
$$L_E = (\zeta_Z - \sum \zeta_I) \times \frac{d_E}{\lambda} \qquad (6.5.1.1\text{-}1)$$

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:

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

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

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

or

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

where

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

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

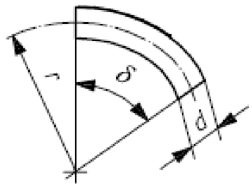
► For liquid:

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

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

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

Pipe bend

	$\frac{r}{d}$	Resistance coefficient ζ_l for diameter d equal to mm				
		20	50	100	200	500
For $\delta = 90°$, $\zeta_{l,\delta=90}$ from table	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
For $\delta \neq 90°$, $\zeta_{l,\delta\neq 90} = \zeta_{l,\delta=90}\sqrt{\frac{\delta}{90°}}$	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

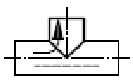
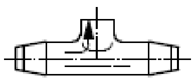
Inlet pipe nozzle

	Description	Resistance coefficient, ζ_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, ζ_l
	referred to reduced cross-section	0,1

Right-angle tees

	Description	Resistance coefficient, ζ_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 ζ 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
α_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
ζ_Z	Allowable pressure loss coefficient	-
ζ_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 ζz of the supply line and thus its maximum length L_E.

Calculation equations for the allowable pressure loss coefficient ζ_Z of the supply line are:

► For gases

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

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

► For liquids

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

In this case the surface ratio f_E is

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

Using the sum of the pressure loss coefficient ζ_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

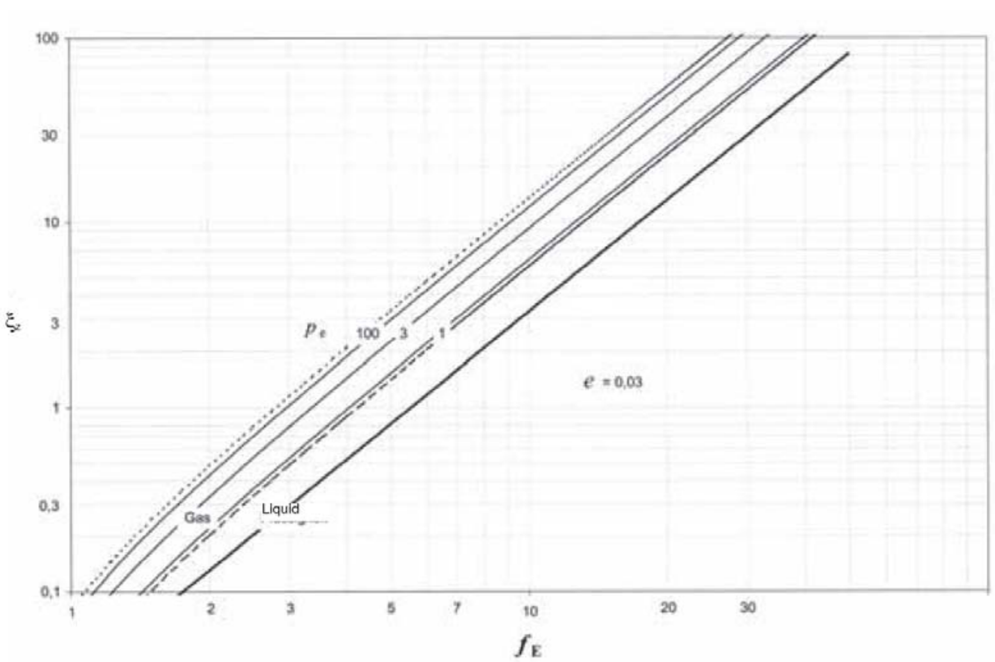


Figure 6.5.1.2-1: Allowable pressure loss coefficient ζ_Z of the inlet line to a safety valve over the surface ratio f_E for various response pressures p_e at a permissible supply pressure loss of 3% (e = 0.03) relative to the static pressure p_{a0} = p_u = 1 bar abs. for various isentropic exponents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

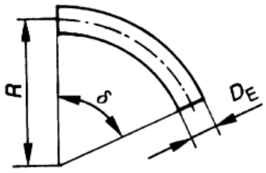
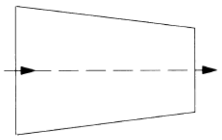
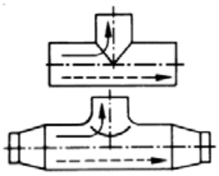
<table>
<tr><td rowspan="13">Pipe bends

for $\delta \neq 90°$</td><td colspan="6">Deflection losses for δ = 90° and K = 70 µm</td></tr>
<tr><td>D_E
R/D_E</td><td>20</td><td>50</td><td>100</td><td>200</td><td>500</td></tr>
<tr><td>1,0</td><td>0,42</td><td>0,33</td><td>0,27</td><td>0,24</td><td>0,19</td></tr>
<tr><td>1,25</td><td>0,35</td><td>0,28</td><td>0,23</td><td>0,20</td><td>0,16</td></tr>
<tr><td>1,6</td><td>0,29</td><td>0,23</td><td>0,19</td><td>0,17</td><td>0,14</td></tr>
<tr><td>2</td><td>0,25</td><td>0,19</td><td>0,16</td><td>0,14</td><td>0,12</td></tr>
<tr><td>2,5</td><td>0,22</td><td>0,17</td><td>0,15</td><td>0,13</td><td>0,10</td></tr>
<tr><td>3,15</td><td>0,20</td><td>0,15</td><td>0,13</td><td>0,11</td><td>0,10</td></tr>
<tr><td>4</td><td>0,18</td><td>0,14</td><td>0,12</td><td>0,10</td><td>0,10</td></tr>
<tr><td>5</td><td>0,16</td><td>0,12</td><td>0,10</td><td>0,10</td><td>0,10</td></tr>
<tr><td>6,3</td><td>0,14</td><td>0,11</td><td>0,10</td><td>0,10</td><td>0,10</td></tr>
<tr><td>8</td><td>0,12</td><td>0,10</td><td>0,10</td><td>0,10</td><td>0,10</td></tr>
<tr><td>10</td><td>0,14</td><td>0,11</td><td>0,10</td><td>0,10</td><td>0,10</td></tr>
<tr><td rowspan="4">Supply line nozzle</td><td colspan="5"></td><td>ζ_i</td></tr>
<tr><td colspan="5">well rounded</td><td>0,1</td></tr>
<tr><td colspan="5">edge cut normally</td><td>0,25</td></tr>
<tr><td colspan="5">edge sharp or pierced pipe</td><td>0,5</td></tr>
<tr><td>Progressive cross-sectional construction
</td><td colspan="5">relative to the constricted cross-section</td><td>0,1</td></tr>
<tr><td rowspan="4">Right-angled T-pieces
</td><td colspan="3" rowspan="2">Connection pieces
Sharp-edge
Case-hardened</td><td colspan="2">In the gate</td><td>0,35[3)]</td></tr>
<tr><td colspan="2">In the branch</td><td>1,28[3)]</td></tr>
<tr><td colspan="3" rowspan="2">Connection pieces necked out or superimposed inlet chamfered[1)]</td><td colspan="2">In the gate</td><td>0,2[3)]</td></tr>
<tr><td colspan="2">In the branch</td><td>0,75[3)]</td></tr>
<tr><td colspan="6">Change over valve/ blocking device</td><td>2)</td></tr>
<tr><td colspan="6">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</td><td></td></tr>
</table>

Table 6.5.1.2-3: Pressure loss coefficients

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

6.5.2 Calculation of the Built-up Back Pressure

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

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

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

Used Symbols	Designation	Units
P_b	Back pressure	MPa abs
P_u	Pressure at outlet of pipe end: superimposed back pressure, often atmospheric	MPa abs
P_0	Relieving pressure	MPa abs
P_C	Critical outlet pressure	MPa abs
K_{dr}	Certified derated coefficient of discharge (Kd × 0,9)	-
ζ_A	Pressure loss coefficient ζA of the discharge pipe with elbows, silencer or other fittings.	-
ζ_{AZ}	Allowable pressure loss coefficient of the discharge pipe	-
ζ_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

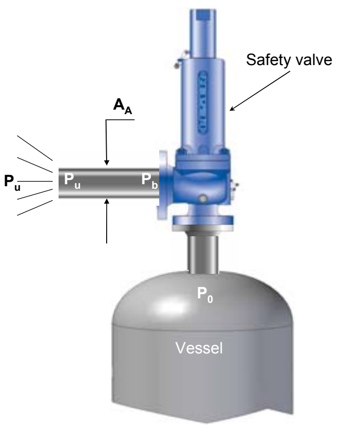
Table 6.5.2.1-1: Symbols ISO 4126-9

The built-up back pressure P_b in the valve outlet is generated during discharge as a result of the pressure loss coefficients ζ_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, ζ_{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.

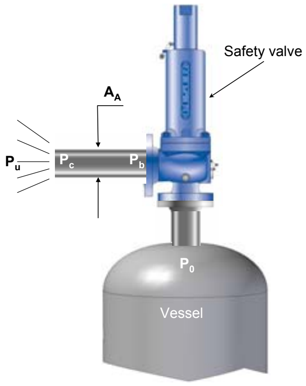


Figure 6.5.2.1-2: Case of steam gases or vapour

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 = ρ x H x 10-7 (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	-
ζ_i	Pressure loss coefficient for pipe and fitted parts	-
ζ_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 ζ_Z of the blow-out line, the following applies, analogous to section 6.5.1.2.

► **for gases** (where a > 0.14 and ζ_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}.

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

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

► **for liquids**

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

f_A is calculated corresponding to f_E in section 6.5.1.2:

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

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

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

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

6.5.3 Calculation of the Reaction Force

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

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

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

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

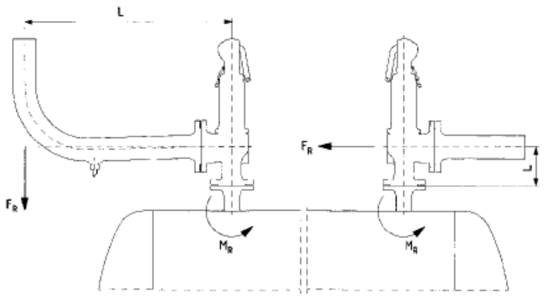


Figure 6.5.3-1: Reaction Force

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

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

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

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

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

Table 6.5.3.1-1: Symbols ISO 4126-9

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

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

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

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

Table 6.5.3.2-1: Symbols API 520 Part II

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

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

In metric units

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

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

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

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

Table 6.5.3.3-1: Symbols AD 2000-A2

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

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

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

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

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

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

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

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

LESER Note: Explanation of the formula:

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

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

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

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

6.5.4 Calculation of the Noise Emission

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

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

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

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

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

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

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

Table 6.5.4.1-1: Symbols ISO 4126-9

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

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

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

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

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

6.5.4.2 Calculation of the Noise Emission According to API 521

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

Table 6.5.4.2-1: Symbols API 521

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

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

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

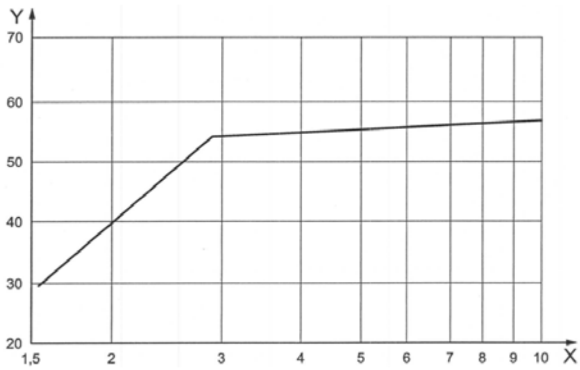


Figure 6.5.4.2-1: Sound pressure level at 30m (100ft) from the stack tip (Y = $L_{30\ (100)}$)

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

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

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

In SI units:

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

In USC units

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

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

In SI units:

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

In USC units:

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

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

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

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

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

Table 6.5.4.3-1: Symbols VDI 2713

The calculation of the noise level for steam:

$$L_W = 17 \cdot \lg(\frac{q'_m}{20}) + 50 \lg T - 15 \qquad (6.5.4.3\text{-}1)$$

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

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

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 VIII Division 1; UG-127 3b
EN ISO 4126-3
API 520 Part II, Sec.: 4.6
AD 2000-Merkblatt A1, Sec 5.4.2

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

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

6.6.1.1 Design of the Bursting Disc Combination

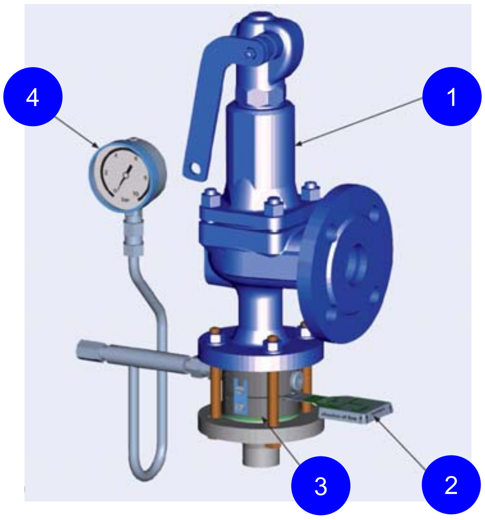


Figure 6.6.1.1-1: Safety valve and bursting disc in combination

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

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

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

2. Bursting Disc Holder

Function

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

Technical design

As a bursting disc holder, LESER uses a two-piece holder, which is intended for a reverse buckling-pin bursting disc and consists of inlet and outlet components. The sealing of the bursting disc is done metallically within the holder by a special sealing edge. The space between the bursting disc and the safety valve is monitored for accumulated pressure. For this purpose, the discharge side of the holder is designed with a laterally positioned connection for the space monitoring device. LESER offers the two-piece holder in two differing designs:

– Design S: Two-piece holder for safety valve with semi nozzle
– Design HS: Two-piece holder for safety valves with full nozzle

The design of the discharge side of the holder, always ensures the release of the total orifice area of the bursting disc.

3. Bursting Disc

Function

The bursting disc is the pressure bearing and pressure reacting component of a bursting disc device. It is non-reclosing relief device.

Technical design

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

4. Space Monitoring Device and pressure gauge

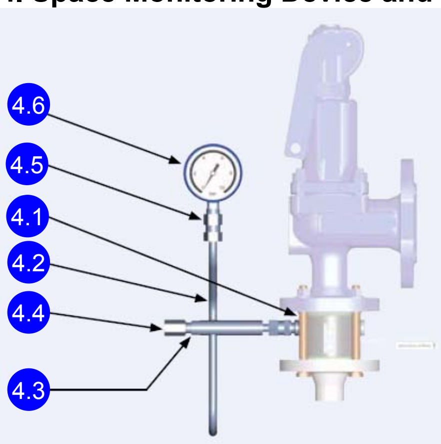


Figure 6.6.1.1-2: Space monitoring device

Function

For safety valves and bursting discs in combination, a space monitoring device must be provided according to codes and standards. It has the function of

1. showing if the bursting disc has ruptured.
2. ensuring the ventilation of the space between the bursting disc and the safety valve seat. Without ventilation, back pressure could build up, which would affect the bursting pressure.

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

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

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

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

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

6.6.1.2 Installation and Maintenance

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

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

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

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

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

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

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

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

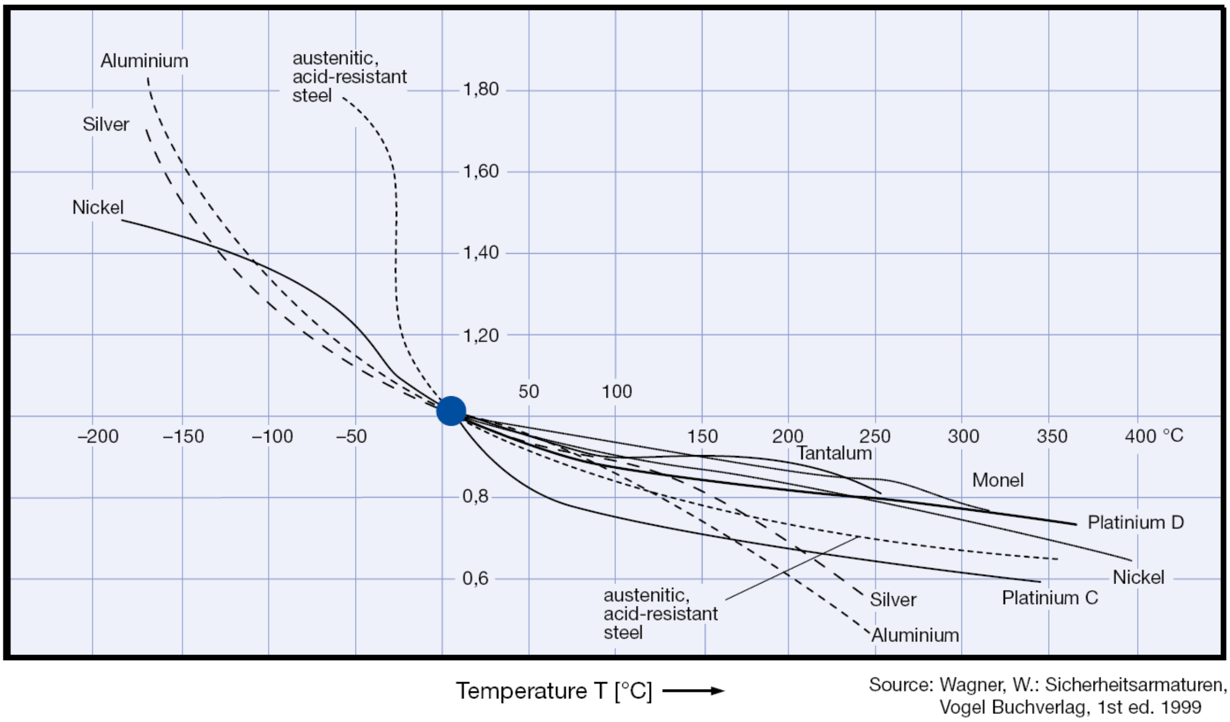


Figure 6.6.1.2-1: Bursting pressure alterations in connection with the temperature

6.6.2 Combination Safety Valve and Change-over Valve

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

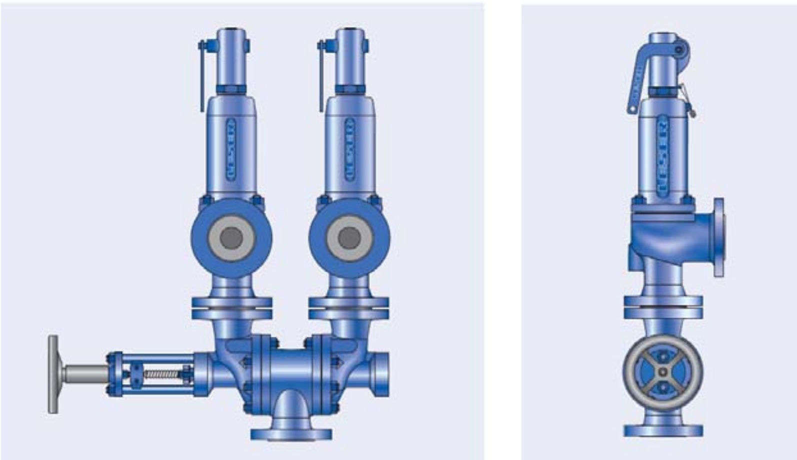


Figure 6.6.2-1: Inlet sided combination

6.6.2.1 Advantages of LESER Change-over Valves

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

6.6.2.2 Applications of Change-over Valves

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

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

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

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

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

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

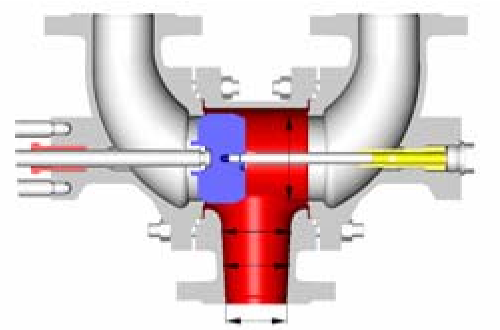


Figure 6.6.2.2-1: Enhanced flow path

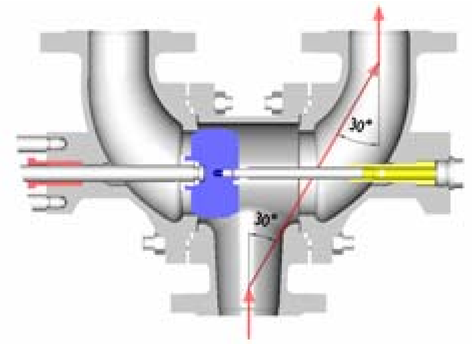


Figure 6.6.2.2-2: Angle of inclination

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

6.6.2.3 Pressure loss coefficient

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

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

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

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

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

6.6.2.4 Pressure Loss Calculation for Change-over Valves

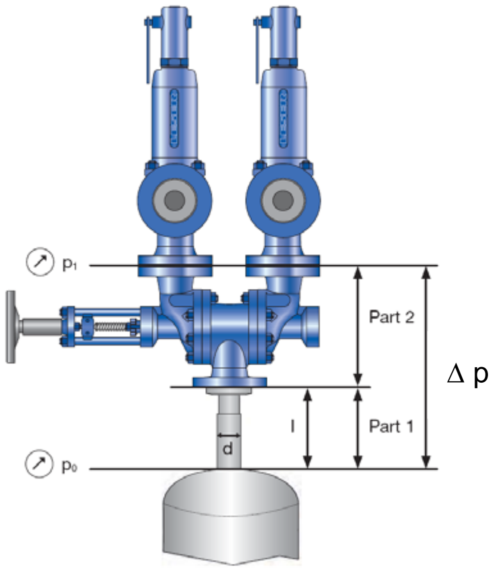


Figure 6.6.2.4-1: Pressure loss

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

The general pressure loss is calculated by this formula:

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

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

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

Table 6.6.2.4-1: Symbols for pressure loss calculation

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

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

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

6.6.2.5 Change-over Valve Combinations

Inlet Sided Combination

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

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

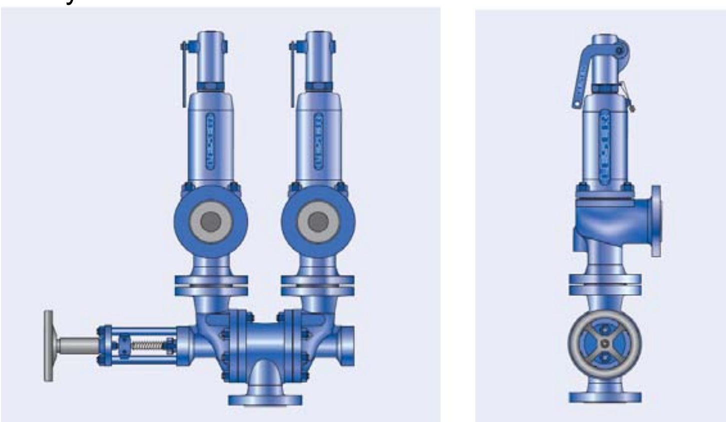


Figure 6.6.2.5-1: Inlet sided combination

Lockable Combination
Two change-over valves installed both at the inlet as well as the outlet of the safety valve are called a lockable combination. The changeover valves must have the same nominal diameter so that assembly is possible. The size of the change-over valve at the inlet is determined by the size of the change-over valve installed at the outlet.
The two change-over valves are connected through a chain wheel and chain. That way, it is guaranteed that the stand-by safety valve is closed off both at the inlet as well as the outlet.
Please note that each hand wheel must be retightened separately when closing in order to compensate for the play in the chain and hand wheel. Only that way is it guaranteed that the side to be shutoff is tightly closed both at the inlet as well as the outlet of the safety valve.
The combination is used for applications if the safety valves are connected to a common blowdown system.

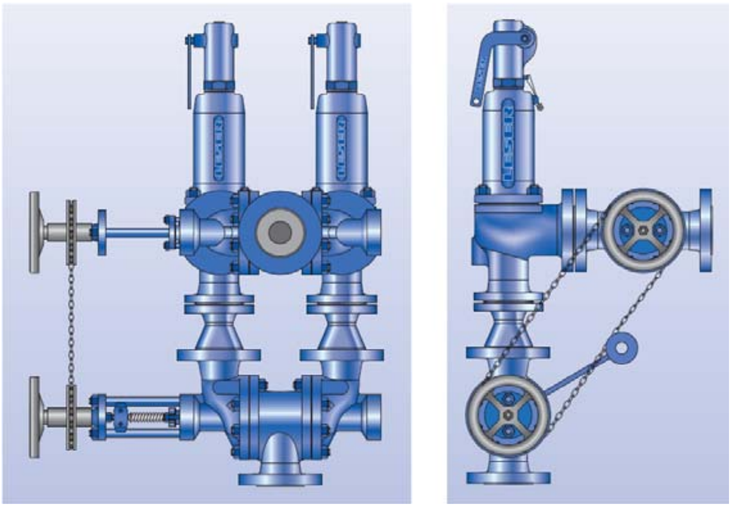


Figure 6.6.2.5-2: Lockable combination

6.6.3 Pressure Reducing Valves

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

6.7 Referenced Codes and Standards

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

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 VIII	2008
ASME Section I	2008
API RP 520	2000
API 521	2007
ISO 4126-1	2004
TRD 421	1998
TRD 721	1997
AD Merkblatt 2000-A2	2006

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 & VIII and API RP 520, incl. two-phase flow sizing from Appendix D, fire case and thermal expansion of entrapped liquids from API 521
- ISO 4126-1
- AD Merkblatt 2000-A2 (2006) as well as TRD 421 and TRD 721

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 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 VIII (2008) and API RP 520 (2000), ISO 4126-1 (2004), ISO 4126-7 (2004)

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]
Δh_{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)	[--]
ρ	Density	[kg/m³]
μ	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 ρ 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 (6.02214×10^{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.

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

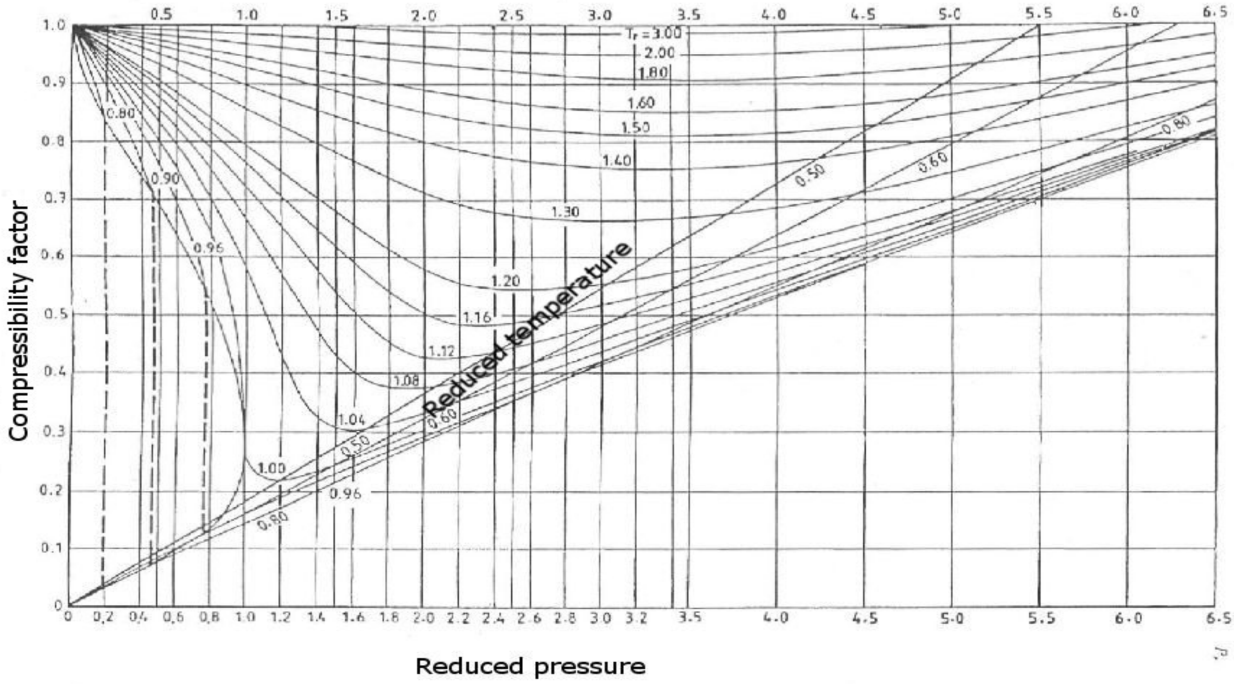


Figure 7.2.2-1: Compressibility factor Z in DIN EN ISO 4126-7, Page 26

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] http://www.nist.gov/srd/nist23.htm

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*

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

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	$p_b \le p_c$
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.

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

Table 7.2.3-1 lists the critical pressure ratios for some gases at 20°C and atmospheric pressure (source: ISO 4126-7, 2004).

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 ρ 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 μ 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.

$$\mathrm{Re} = \frac{Q_m}{\mu}\sqrt{\frac{4}{\pi}\frac{1}{A_{orifice}}} \qquad \textit{(Eq. 7.2.4-1)}$$

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 4126-1 and in API RP 520.

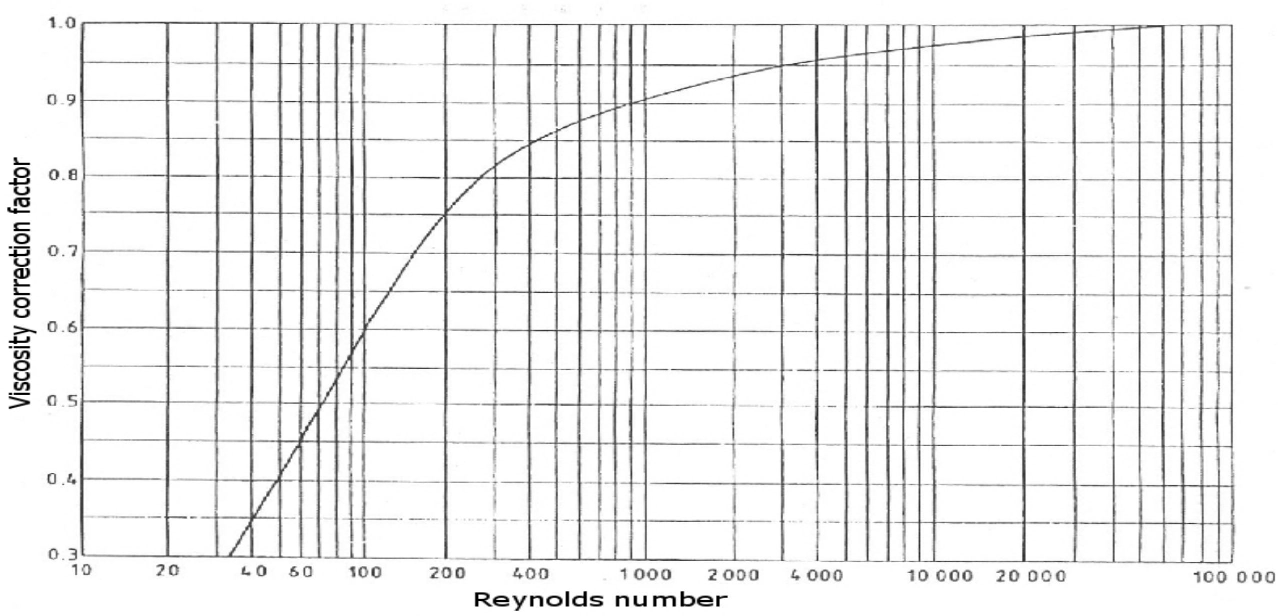


Figure 7.2.4-1: Viscosity correction factor in DIN EN ISO 4126-7, Page 29

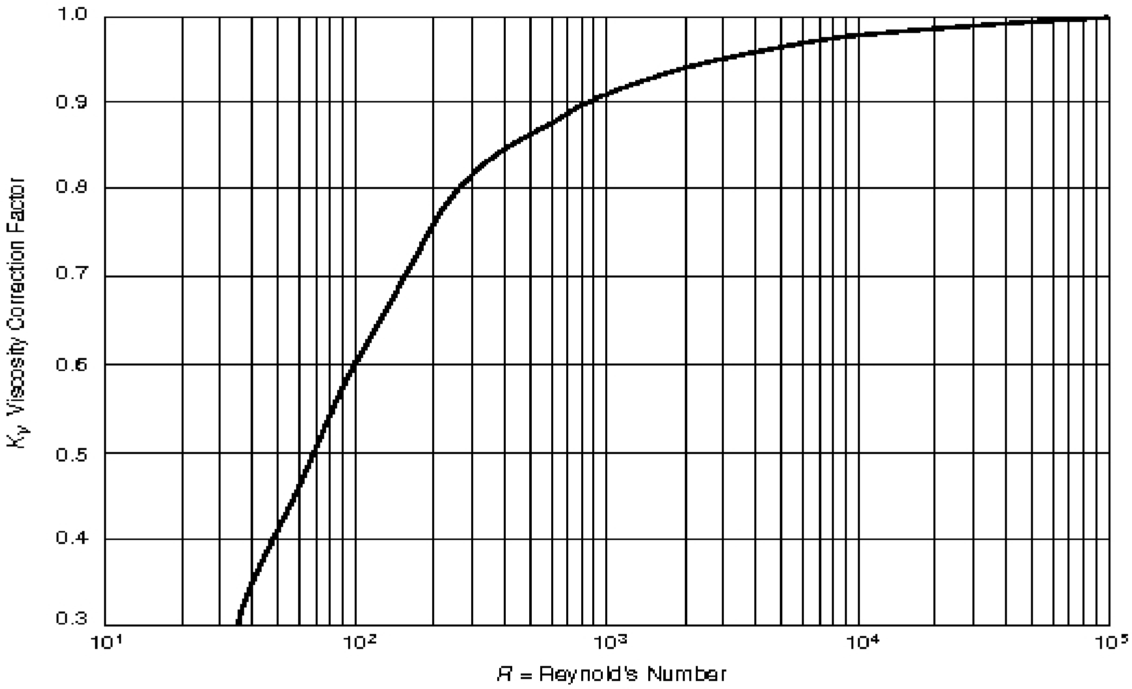


Figure 7.2.4-2: Viscosity correction factor in API RP 520, Page 54

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.

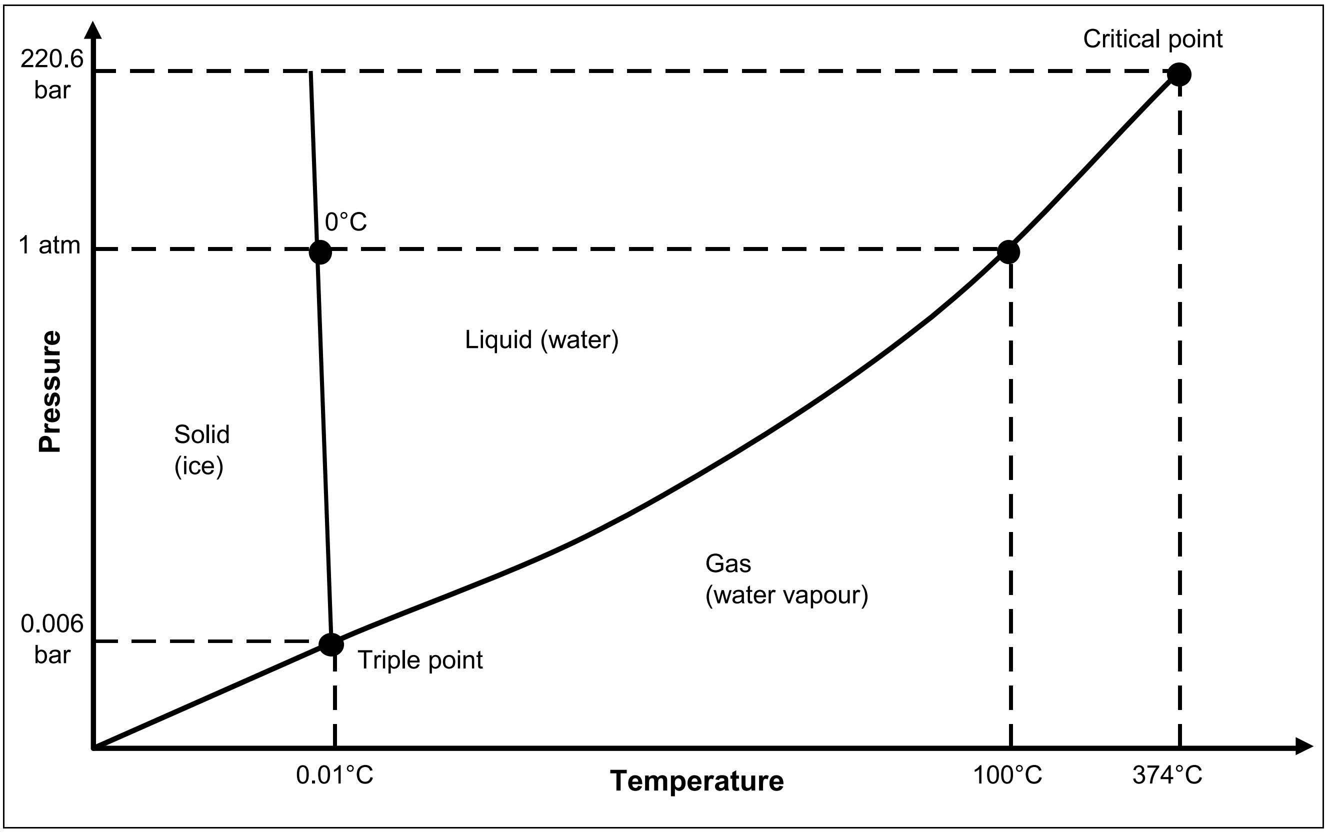


Figure 7.2.5-1: Phase diagram for water

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.

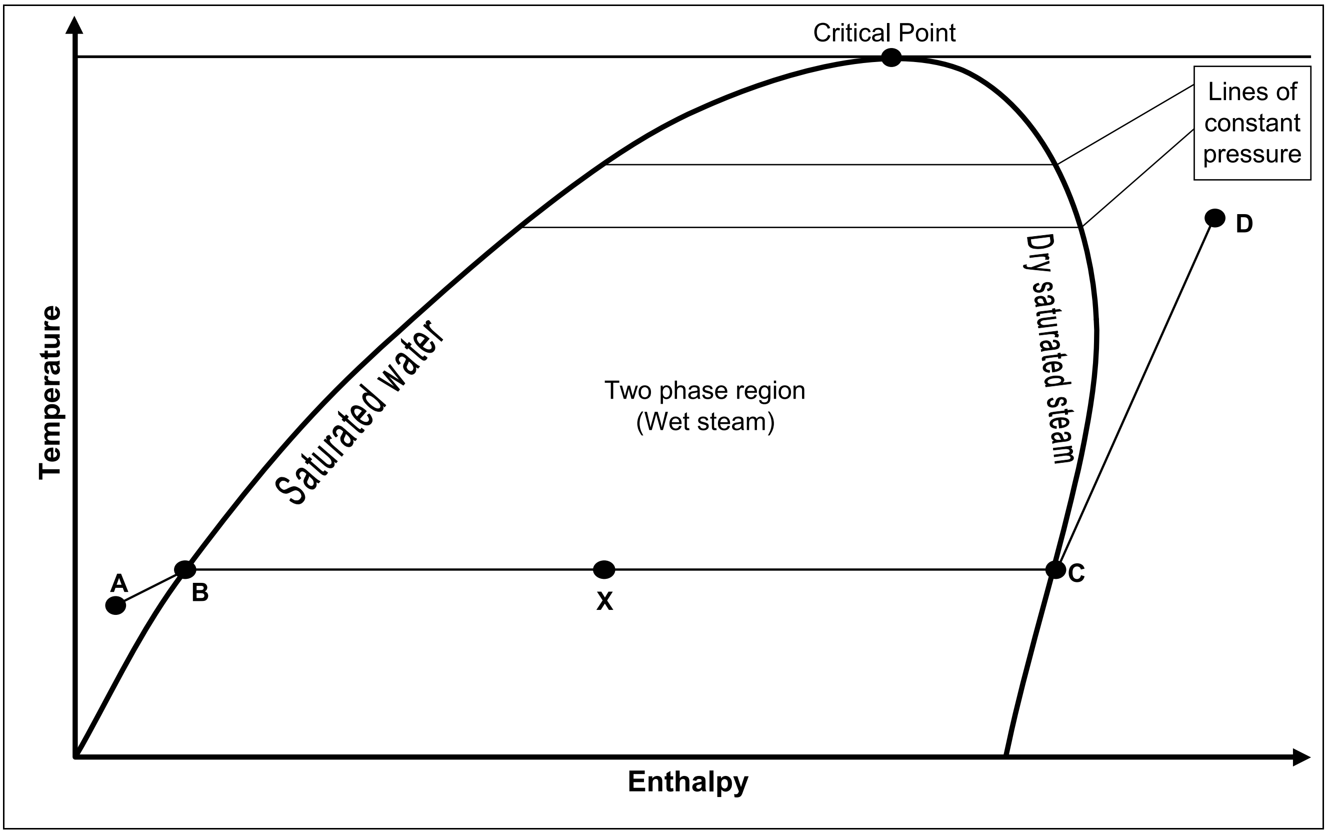


Figure 7.2.5-2: Saturation diagram for water and steam.

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 VIII (2008) and API RP 520 (2000), ISO 4126-1 (2004), AD Merkblatt 2000-A2 (2006).

Medium	Unit	ASME VIII / API RP 520	ISO 4126-1	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**	$A = \frac{1}{735}\frac{W}{F_2 K_c K_d}\sqrt{\frac{T\ Z}{M\ P_1}\frac{1}{P_1 - P_2}}$	$A = \frac{Q_m}{p_0 C\ K_b K_{dr}}\sqrt{\frac{T_0 Z}{M}}$	
	SI	$A = \frac{17.9 \times W}{F_2 K_d K_c}\sqrt{\frac{ZT}{M \times P_1(P_1 - P_2)}}$		
Steam	**US**	$A = \frac{1}{51.5}\cdot\frac{W}{P_1 K_b K_c K_d K_N K_{SH}}$	$A = \frac{1}{0.2883}\frac{Q_m}{C\ K_{dr}}\sqrt{\frac{v}{p_0}}$	$A_0 = \frac{x\ q_m}{\alpha_w p_0}$
	SI	$A = \frac{190.5 \times W}{P_1 K_d K_b K_c K_N K_{SH}}$		
Liquids	**US**	$A_{corr} = \frac{1}{38}\cdot\frac{Q}{K_c K_d K_v K_w}\sqrt{\frac{G}{P_1 - P_2}}$	$A = \frac{1}{1.61}\frac{Q_m}{K_{dr} K_v}\sqrt{\frac{v}{p_0 - p_b}}$	$A_0 = 0.6211\frac{q_m}{\alpha_w\sqrt{\rho(p_0 - p_a)}}$
	SI	$A = \frac{11.78 \times Q}{K_d K_w K_c K_v}\sqrt{\frac{G1}{P_1 - P_2}}$		
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 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 4126-1:

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*)
α_w : Certified discharge coefficient (*LESER catalog*)
ψ : 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 Code Sect. VIII and API RP 520 and API 521

The information contained in this section is based on following editions of codes and standards: ASME Section VIII (2008), API RP 520 (2000), API 521 (2007), API 526 (2002), API Standard 2000 (1998), API Standard 2510 (2001), ISO 23251(2007), prEN 14015-1 (2000)

7.4.1 Premise on ASME Section VIII 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 VIII UG-131).

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: Feb. 2009
http://www.nationalboard.org/SiteDocuments/NB18/PDFs/NB18ToC.pdf

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 VIII*".

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 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. VIII LESER API Series 526
	$K_{d-effective}$ [-]	K_{actual} [-]
Gas, vapors, steam	0.975	0.455 (Orifice D) 0.801 (Orifice E-T)
Liquid	0.65	0.343 (Orifice D) 0.579 (Orifice E-T)
Two-phase flows	0.85	No certification procedure

Orifice letter	API RP 520 Effective discharge area		ASME VIII Actual discharge area LESER API Series 526	
	[in^2]	[mm^2]	[in^2]	[mm^2]
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 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). 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). 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	--
μ	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

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

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

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

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

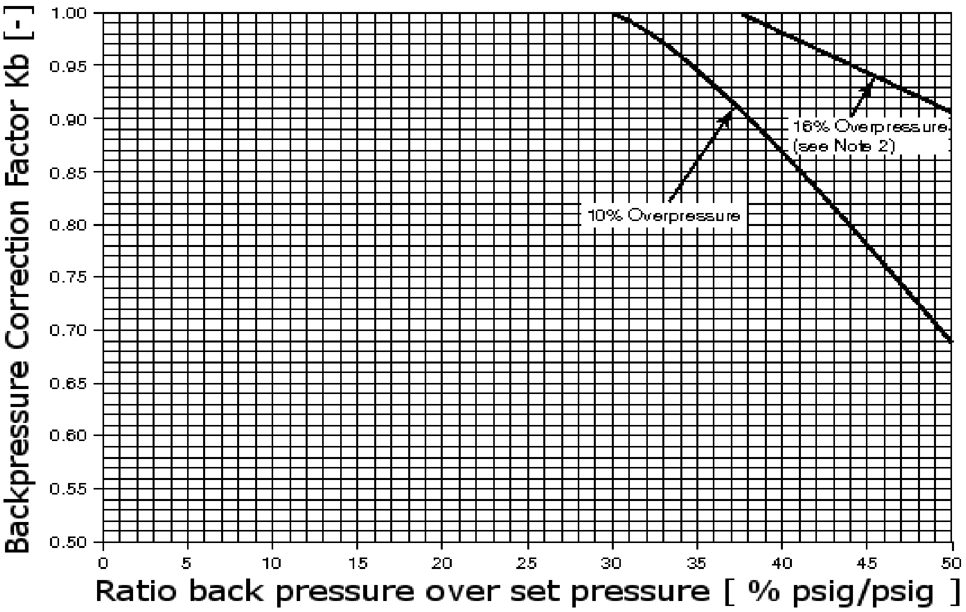


Figure 7.4.3-1: Back pressure correction factor for gases and vapors K_b from API RP 520, Page 37

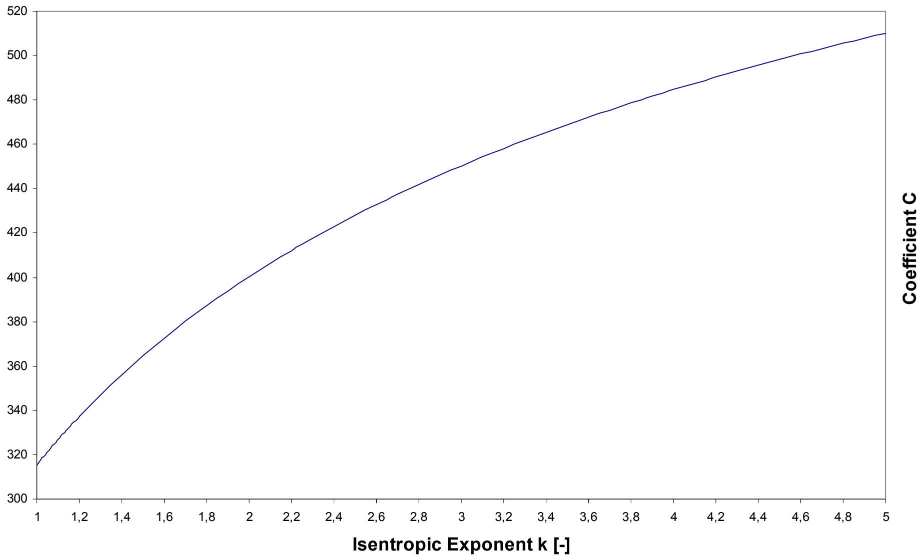


Figure 7.4.3-2: Coefficient C in function of the specific heat ratio from API RP 520, Page 44.

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

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

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

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

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*

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

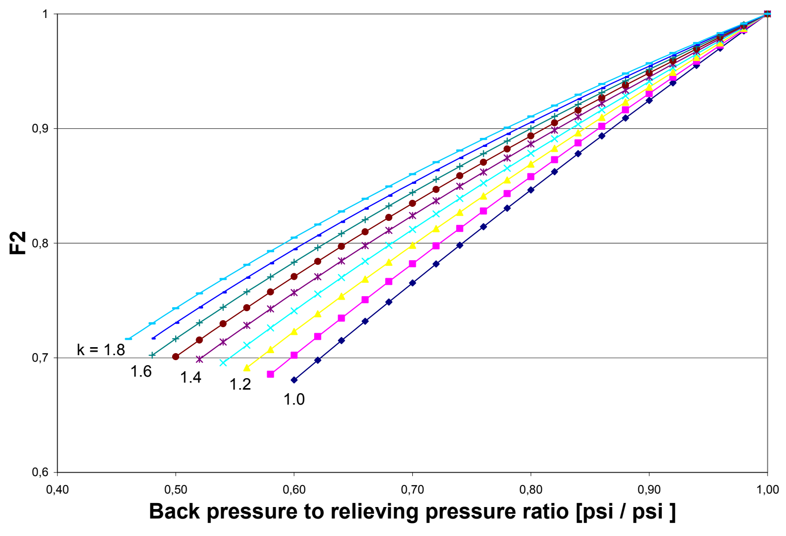


Figure 7.4.4-1: Coefficient F_2 in function of the ratio of absolute back pressure on absolute relieving pressure for various specific heat ratios.

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*

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

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

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

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.*

$$K_v = \left(0.9935 + \frac{2.878}{\mathrm{Re}^{0.5}} + \frac{342.75}{\mathrm{Re}^{1.5}}\right)^{-1} \ldots \textit{(Eq. 7.4.6-2)}$$

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.

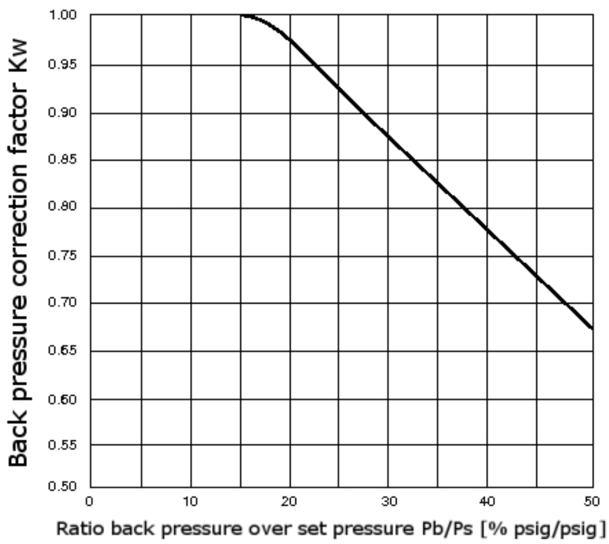


Figure 7.4.6-1: Back pressure correction factor for liquids K_w from API RP 520, Page 38

7.4.7 Two-Phase Flows according to API RP 520, 7th Edition, 2000, Appendix D

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	[--]
η_a	Ratio between ambient pressure and relieving pressure	[--]
η_c	Ratio between critical pressure and relieving pressure	[--]
η_s	Ratio between saturation pressure at relieving temperature and relieving pressure	[--]
ρ_{l0}	Density of the liquid at the inlet of the safety valve	lb/ft³
ρ_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
ω	Omega Parameter	[--]
ω_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.

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

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

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.

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

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 <u>*critical*</u>

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

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

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

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

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

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 ω_s. For multi-component systems with nominal boiling range less than 150°F ω_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 $T_r \leq 0.9$ and $p_r \leq 0.5$ ω_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 ω_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* (flashing occurs before the valve throat)
$P_s < P_0 \frac{2 \cdot \omega_s}{1 + 2 \cdot \omega_s}$	*high subcooling region* (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.

7.4.8 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 is fully introduced in the new standard[5] ISO 23251. 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 Par. 5.14, ISO 23251 Par. 5.14)
- ✓ External Fire Case (API 521 Par. 5.15, ISO 23251 Par 5.15)

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 (in ISO 23251 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.

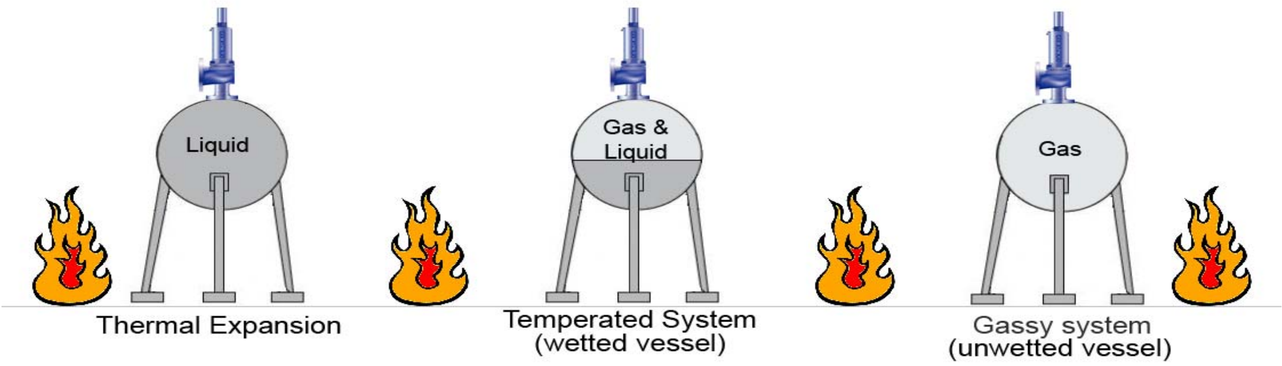


Figure: 7.4.8-1: Hydraulic (thermal) expansion and fire case

[5] ISO 23251 Petroleum and natural gas industries – Pressure relieving and depressuring systems, 2007

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]
α_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	--	--
ϕ	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

* The sizing formulas in ISO 23251 are identical to those in API 521, which are expressed in US Units. Conversion factors to specified SI units have been not yet provided. The application of the formula using US units is therefore 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. 5.14.2.

$$q = \frac{1}{500}\frac{\alpha_v \cdot \phi}{d \cdot c} \quad \text{(API 521)} \qquad \textit{(Eq. 7.4.8.2-1)}$$

$$q = \frac{1}{1000}\frac{\alpha_v \cdot \phi}{d \cdot c} \quad \text{(ISO 23251)} \qquad \textit{(Eq. 7.4.8.2-2)}$$

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)	α_v [1/°F]	α_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 14015-1[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, 1998.

[7] prEN 14015-1: 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, 2000.

[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 ✓ Partially filled ($F < L$) ✓ Totally filled ($F = L$)	$A_{wet} = \pi \cdot D \cdot \left[\frac{D}{4} + F_{eff} \right]$ $A_{wet} = \pi \cdot D \cdot \left[\frac{D}{2} + F_{eff} \right]$
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.

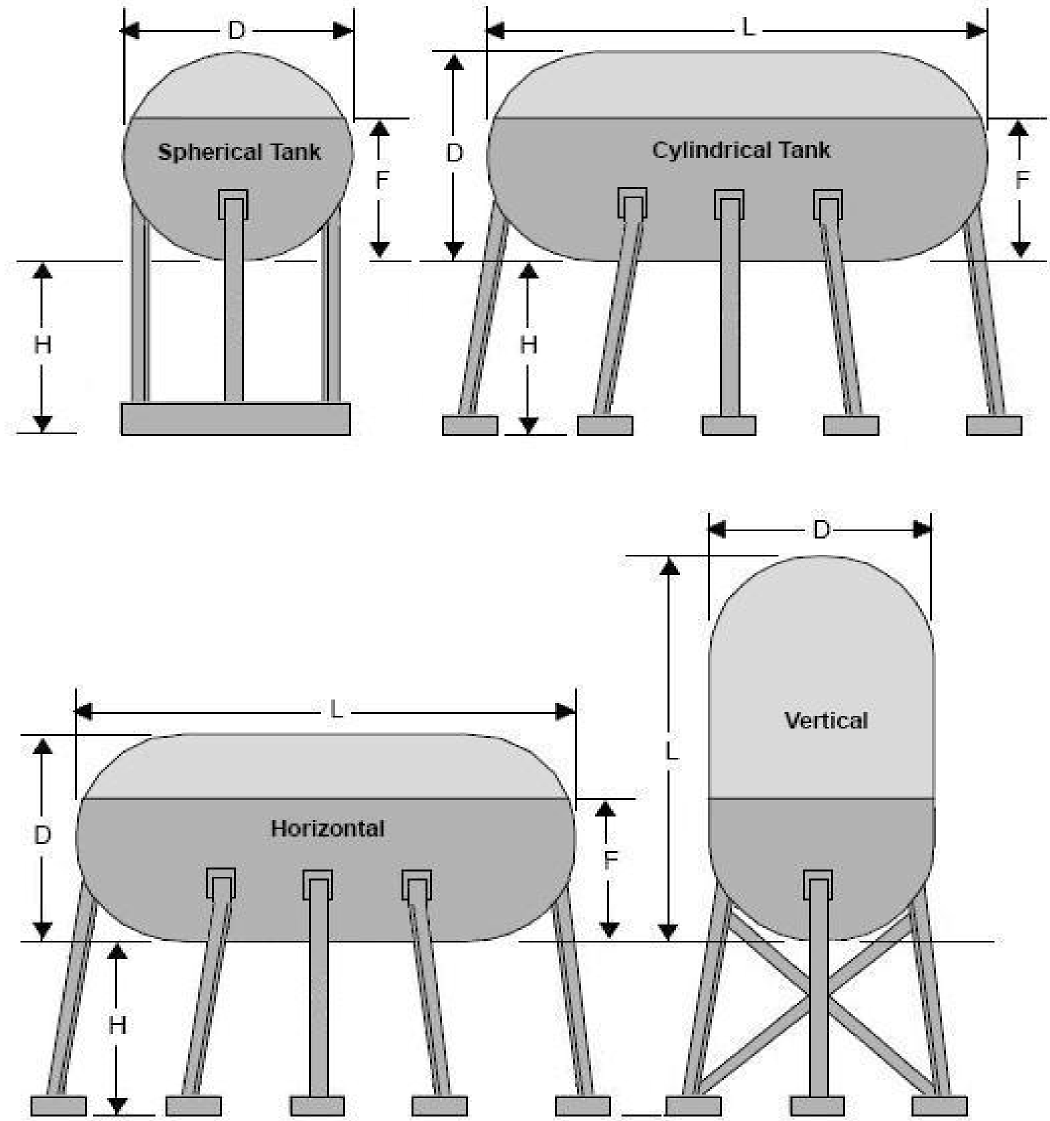


Figure 7.4.8.3-1 : Possible positions of wetted vessels, partially filled with liquids

The angle β 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)

$$F_{eff} = \min(25\ \ ft; F) - H \quad \text{(API 521)} \quad \textit{(Eq. 7.4.8.3-4)}$$

$$F_{eff} = \min(7.6\ \ m; F) - H \quad \text{(ISO 23521)} \quad \textit{(Eq. 7.4.8.3-5)}$$

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

$$A = \frac{F'A'}{\sqrt{P_1}} \quad \text{(Eq. 7.4.8.4-1)}$$

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. 7.4.3-3.

$$F' = \frac{0.1406}{C \cdot K_d}\left[\frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}}\right] \quad \text{(Eq. 7.4.8.4-2)}$$

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

$$T_1 = T_n \frac{P_1}{P_n} \quad \text{(Eq. 7.4.8.4-3)}$$

For plates made of alloys the gas mass flow rate can be calculated from Eq. 7.4.8.4-4

$$W = 0.1406\sqrt{M\ P_1}\left(A'\frac{(T_w - T_1)^{1.25}}{T_1^{1.1506}}\right) \quad \text{(Eq. 7.4.8.4-4)}$$

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, sec. 3.5.2, page 39-40 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 on Page 39 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 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

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = 520\sqrt{1.19\left(\frac{2}{1.19+1}\right)^{\frac{1.19+1}{1.19-1}}} = 336.22\frac{\sqrt{lb \cdot lb_{mol} \cdot °R}}{lb_f \cdot hr}$$

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 <u>effective discharge area</u> 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 <u>actual discharge area</u> 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 **<u>LESER Type 526 1E2 (5262.0172)</u>**.

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 effective 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 actual 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 **LESER Type 526 6R8 (5262.6652)**.

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 effective 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 **LESER Type 526 3K6 (5262.2053).**

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

$$K_v = \left(0.9935 + \frac{2.878}{\mathrm{Re}^{0.5}} + \frac{342.75}{\mathrm{Re}^{1.5}}\right)^{-1} = \left(0.9935 + \frac{2.878}{357.9^{0.5}} + \frac{342.75}{357.9^{1.5}}\right)^{-1} = 0.8359$$

The corrected (effective minimum) discharge area for the viscous liquid is then

$$A_{corr} = \frac{1}{38} \cdot \frac{Q}{K_c K_d K_v K_w} \sqrt{\frac{G}{P_1 - P_2}} = \frac{1}{38} \cdot \frac{79.25}{1 \cdot 0.65 \cdot 1 \cdot 0.8359} \sqrt{\frac{1.26}{159.5}} = 0.3413\ in^2$$

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

$$\mathrm{Re} = 279.6 \qquad K_v = 0.807 \qquad A_{corr} = 0.353\ \ in^2$$

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.

$$A_{prel} = 0.320\ \ in^2 \qquad \mathrm{Re} = 252.65 \qquad K_v = 0.794 \qquad A_{corr} = 0.403\ \ in^2$$

The required valve, incl. the flanges, is **LESER Type 526 1½G3 (5262.0452)**.

7.4.9.6 Two-Phase Flow - Saturated Liquid and its Saturated Vapor

Example 7.4.9.6. A safety valve must be sized for a two-phase flow of saturated water at 10 bar g (145 psig). The mass flow rate to be delivered is 125 000 kg/h (275 600 lb/hr).

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 saturation temperature ($T_{sat} = 830°R$) is the temperature at the inlet of the safety valve. At that temperature the physical properties for saturated water and steam are

	Metric units	US units
v_{v0}	0.1632 m³/kg	2.6142 ft³/lb
v_{l0}	0.0011386 m³/kg	0.01824 ft³/lb
h_{vl0}	1984.3 kJ/kg	853.667 Btu/lb
C_p	4.440 KJ/(kg K)	1.06116 Btu/(lb°R)

The Omega Parameter for the case of saturated liquid at inlet ($x_0 = 0$) is calculated from Eq. 7.4.7.1-1

$$\omega = \frac{x_0 v_{v0}}{v_0} \cdot \left(1 - 0.37 \frac{P_1 \cdot v_{vl0}}{h_{vl0}}\right) + 0.185 \frac{C_p T_0 P_1}{v_0} \left(\frac{v_{vl0}}{h_{vl0}}\right)^2 = 0 + 0.185 \frac{1.0605 \cdot 830 \cdot 174.2}{0.01824} \left(\frac{2.6142 - 0.01824}{8536.66}\right)^2$$
$$\omega = 14.39$$

The critical pressure ratio is the solution of Eq. 7.4.7.1-4, calculated by means of an iterative trial and error procedure. For $\omega > 2$ a good approximation[9] is given by the following explicit solution
$$\eta_c = 0.55 + 0.217 \ln \omega - 0.046 \ln^2(\omega) + 0.004 \ln^3(\omega) = 0.877$$

Which leads to the (fluid dynamical) critical pressure ratio of
$$P_c = 174.2 \, psi \cdot 0.877 = 152.84 \, psi$$

The flow is critical, since $P_c > P_a$ and therefore the mass flux is given by Eq. 7.4.7.1-5
$$G = 68.09 \cdot \eta_c \cdot \sqrt{\frac{1}{\omega} \frac{P_1}{v_0}} = 68.09 \cdot 0.877 \cdot \sqrt{\frac{1}{14.39} \cdot \frac{174.2}{0.01824}} = 1539.06 \ \ \frac{lb}{s \cdot ft^2}$$

The minimum required effective orifice area is calculated from Eq. 7.4.7.1-7
$$A = 0.04 \cdot \frac{1}{K_b K_c K_d} \cdot \frac{W}{G} = 0.04 \cdot \frac{1}{1 \cdot 1 \cdot 0.85} \cdot \frac{275600}{1539.06} = 8.427 \ \ in^2$$

which leads to the selection of an orifice **6Q8** ($A = 11.050 \ \ in^2$) **(5262.6572)**.

[9] J.C. Leung *Venting of runaway reactions with gas generation,* **AIChE J.**, 1992, 38, 5, 723-732

7.4.9.7 Two-Phase Flow - Highly Subcooled Liquid and a Gas.

Example 7.4.9.7. A safety valve must be sized for a mixture of air and water ($x_0 = 0.10$) at 10 bar g (145 psig) and 25°C (536.67°R) for the mass flow rate of 125 000 kg/h (275 600 lb/hr).

Solution. The relieving pressure is again 174.2 psi. The required fluid properties at the relieving conditions (174.2 psi ; 536.67°R) are

	Metric units	US units
v_{v0}	0.0698 m³/kg	1.1184 ft³/lb
v_{l0}	0.0010029 m³/kg	0.016065 ft³/lb
v_0	1984.3 kJ/kg	853.667 Btu/lb
k	1.4	1.4

The specific volume of the mixture is given as

$$v_0 = x_0 v_{v0} + (1 - x_0) v_{l0} = 0.1 \cdot 1.1184 + 0.9 \cdot 0.016065 = 0.1263 \quad ft^3/lb$$

The Omega Parameter is calculated from Eq. 7.4.7.2-1

$$\omega = \frac{x_0 v_{vg0}}{v_0 k} = \frac{0.1 \cdot 1.1184}{0.1263 \cdot 1.4} = 0.6325$$

The iterative solution of Eq. 7.4.7.1-4 with this value of the Omega-parameter gives a critical pressure ratio of $\eta_c = 0.5464$, which corresponds to a critical pressure of $P_c = 95.24 \ \ psi$

The flow is again critical and the mass flow rate can be calculated again from Eq. 7.4.7.1-5

$$G = 68.09 \cdot \eta_c \cdot \sqrt{\frac{1}{\omega} \frac{P_1}{v_0}} = 68.09 \cdot 0.5464 \cdot \sqrt{\frac{1}{0.6325} \cdot \frac{174.2}{0.1263}} = 1737.4 \quad \frac{lb}{s \cdot ft^2}$$

The minimum required effective orifice area is calculated from Eq. 7.4.7.1-7

$$A = 0.04 \cdot \frac{1}{K_b K_c K_d} \cdot \frac{W}{G} = 0.04 \cdot \frac{1}{1 \cdot 1 \cdot 0.85} \cdot \frac{275600}{1737.4} = 7.46 \ \ in^2$$

which leads again to the selection of an orifice **6Q8** ($A = 11.050 \ \ in^2$) **(5262.6572)**.

7.4.9.8 Two-Phase Flow - Subcooled Liquid

Example 7.4.9.8. It is required to size a safety valve for a heating oil at a set pressure of 12 bar g (174.0 psig) and 400°C (1211.7 R) with a flow rate of 12.5 m³/h (55.03 gpm). The back pressure is 2 bar.

Solution. The relieving pressure is

$$P_1 = P_{set} + \Delta P_{overpressure} + P_{atm} = 174.0 \ \ psig + 17.4 \ \ psig + 14.7 \ \ psi = 206.1 \ \ psi$$

The saturation pressure at 400°C , P_s, is 10.89 kPa (158 psi) and therefore the medium enters the safety valve subcooled ($P_1 > P_s$). The (thermodynamic) critical point is 500°C (1391.7°R) and 33.1 bar (480 psi).

The physical properties of the mixture at saturated conditions and the liquid properties at inlet condition for the calculation of the Omega-parameter are given in the table here below.

	Metric units	US units
v_{vls}	0.02388 m³/kg	0.38182 ft³/lb
h_{vls}	206.2 kJ/kg	88.7 Btu/lb
ρ_{l0}	687 kg/m³	42.888 lb/ft³
C_p	2650 J/(kg K)	0.633 Btu/(lb R)

The value of the Omega Parameter is calculated by means of Eq. 7.4.7.3-1, since $T_r = 0.87 < 0.9$ and $P_r = 0.43 < 0.5$.

$$\omega_s = 0.185 \rho_{l0} C_p T_0 P_s \left(\frac{v_{vls}}{h_{vls}} \right)^2 = 0.185 \cdot 42.888 \cdot 0.633 \cdot 1211.7 \cdot 158 \cdot \left(\frac{0.38182}{88.7} \right)^2 = 17.82$$

Determination of the extension of the subcooling region

$$P_1 \frac{2 \cdot \omega_s}{1 + 2 \cdot \omega_s} = 206.1 \cdot \frac{2 \cdot 17.82}{1 + 2 \cdot 17.82} = 200.5 \ \ psi \rightarrow \text{high subcooling region!!!}$$

This highly subcooled flow is critical since $P_s > P_a$ and therefore the critical mass flux is

$$G = 96.3 \left[\rho_{l0} \cdot (P_1 - P_s) \right]^{0.5} = 96.3 \left[42.888 \cdot (206.1 - 158) \right]^{0.5} = 4373.88 \ \ lb / \left(ft^2 s \right)$$

The minimum required effective area of the safety valve from Eq. 7.4.7.3-3 is

$$A = 0.3208 \frac{1}{K_b K_c K_d} \frac{Q \cdot \rho_{l0}}{G} = 0.3208 \frac{1}{1 \cdot 1 \cdot 0.65} \frac{55.03 \cdot 42.888}{4373.88} = 0.2668 \ \ in^2$$

which is satisfied by choosing the orifice **1½F2**($A = 0.307 \ \ in^2$) **(5262.0302)** as the minimum effective area.

7.4.9.9 Hydraulic (Thermal) Expansion acc. to API 521

Example 7.4.9.9. 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 as shown in the previous example. However, for such a small flow rate the smallest safety valve, orifice **1D2 (5262.0012)**, is by far enough.

7.4.9.10 External Fire acc. to API 521 - Unwetted Walls

Example 7.4.9.10. 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 **$1\frac{1}{2}$G3 (5262.0452)**.

7.4.9.11 External Fire acc. to API 521 - Wetted Walls

Example 7.4.9.11. 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 4126-1

The information contained in this section is based on following editions of codes and standards: ISO 4126-1 (2004), ISO 4126-7 (2004), ISO 23251 (2007).

7.5.1 Introduction

ISO 4126-1 is a Standard for the sizing and the certification of safety valves. 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[10] ISO 23251, which is based on the API 521 (2007). 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 4126-1 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]
μ	Dynamic viscosity	[Pa s]
v	Specific volume at actual relieving pressure and temperature	[m^3/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 4126-1

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%.

$$p_0 = p_{set} + \Delta\ p_{over} + p_{amb} \quad \textit{(Eq. 7.5.2-1)}$$

[10] ISO 23251 Petroleum, petrochemical and natural gas industries – pressure-relieving and depressurising systems, 2007

7.5.3 Saturated or Superheated Steam - Critical Flow

$$A = \frac{1}{0.2883} \frac{Q_m}{C\ K_{dr}} \sqrt{\frac{v}{p_0}} \quad \textit{(Eq. 7.5.3-1)}$$

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 [11].

7.5.4 Wet Steam

$$A = \frac{\sqrt{x}}{0.2883} \frac{Q_m}{C\ K_{dr}} \sqrt{\frac{v}{p_0}} \quad \textit{(Eq. 7.5.4-1)}$$

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 at lower dryness fraction.

$$A = \frac{Q_m}{p_0 C\ K_{dr}} \sqrt{\frac{ZT_0}{M}} \quad \textit{(Eq. 7.5.5-1)}$$

7.5.6 Gaseous Media - Subcritical Flow

$$A = \frac{Q_m}{p_0 C\ K_b K_{dr}} \sqrt{\frac{ZT_0}{M}} \quad \text{(}\textit{Eq}\text{. 7.5.6-1)}$$

with

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_0}\right)^{2/k} - \left(\frac{p_b}{p_0}\right)^{(k+1)/k}\right]}{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}} \quad \text{(}\textit{Eq}\text{. 7.5.6-2)}$$

7.5.7 Liquids

$$A = \frac{1}{1.61} \frac{Q_m}{K_{dr} K_v} \sqrt{\frac{v}{p_0 - p_b}} \quad \text{(}\textit{Eq}\text{. 7.5.7-1)}$$

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

$$\mathrm{Re} = \frac{1}{3.6} \frac{Q_m}{\mu} \sqrt{\frac{4}{\pi\ A}} \quad \text{(}\textit{Eq}\text{. 7.5.7-2)}$$

Two phase flow is not yet covered by ISO 4126, however F Dis ISO 4126-part 10 covering two phase flow will be published soon.

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[11] ISO 4126-7 Safety devices for protection against excessive pressure – Part 7: common data, 2004.

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 Par. 7.3.3.3 allows the manufacturer to restrict the lift to a value larger than either 30 % of the unrestricted lift or 1 mm, whichever is greater.
However, in case the optimal lift is less than 30 % but more than 1 mm, consult the following section for AD-2000 Merkblatt A2. The application of the AD-2000 Merkblatt A2 is in compliance with PED requirements.
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[12] 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.

[12] VdTÜV-Merkblatt Sicherheitsventil 100, *Richtlinie für die Baumusterprüfung von Sicherheitsventilen im Geltungsbereich der Richtlinie 97/23/EG (Drückgeräte-Richtlinie)*,2006

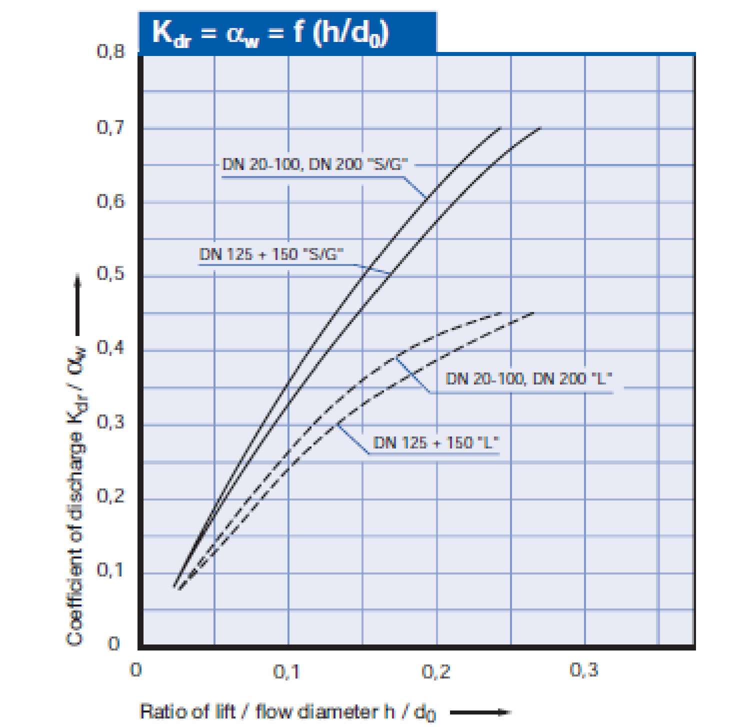


Figure 7.5.8-1 Discharge coefficient K_{dr} for gases in function of the lift h over flow diameter d_o for LESER Type 441

7.5.9 Discharge Coefficient of Valves at High Back Pressures

ISO 4126-1 Section 7.3.3.4 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.

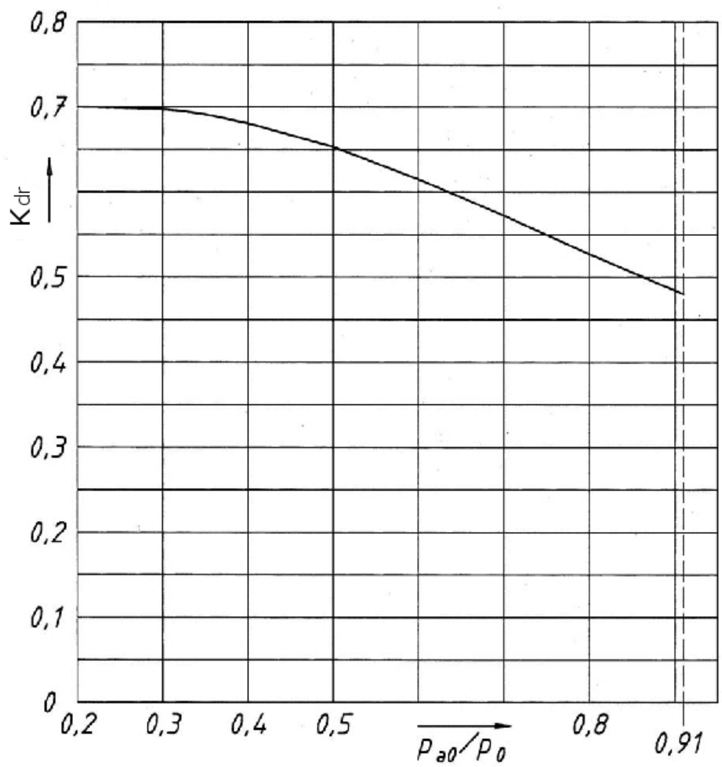


Figure 7.5.9-1 Discharge coefficient K_{dr} for gases in function of the ratio of the absolute back pressure P_{a0} on the relieving P_0 pressure for LESER Type 441

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

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[13] 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

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**).

[13] 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

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 4126-1.

$$Q_m = 5l/s \cdot 1260kg/m^3 \cdot 3600s/hr = 22680kg/hr$$

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?

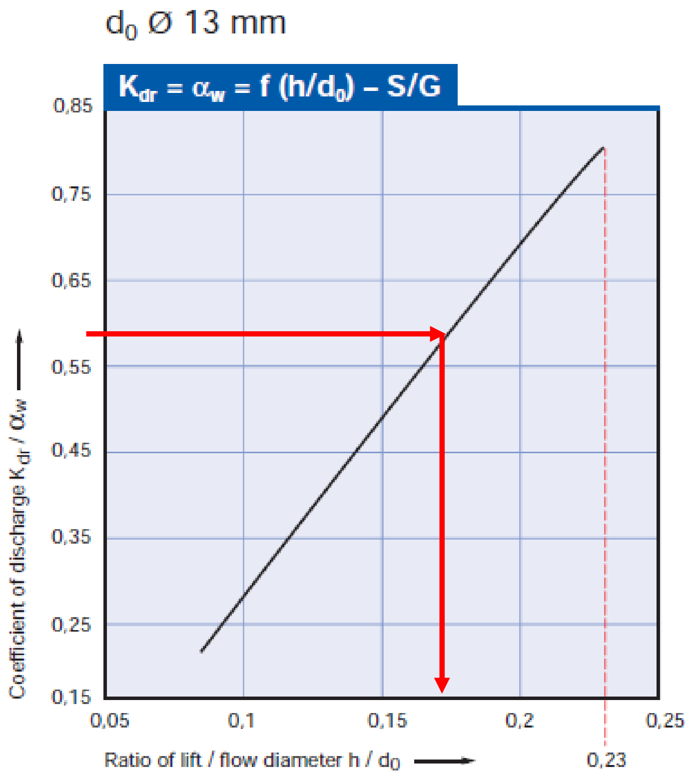
Solution. As a result from Example 7.5.10.1 a flow area of 133 mm² (d_0 = 13 mm) is chosen. However, from the process data the actual discharged mass flow acc. to Eq. 7.5.5.1-1 is much larger than the required one and exactly it is

$$Q_{m\ real} = p_0 C\ A\ K_{dr}\sqrt{\frac{M}{ZT_0}} = 61.51 \cdot 2.553 \cdot 133 \cdot 0.81\sqrt{\frac{28.03}{0.712 \cdot 328.15}} = 5859.6\ \frac{kg}{h}$$

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 Fig. 2 on Page 05/20 of the LESER Catalog Compact Performance, reported here below.



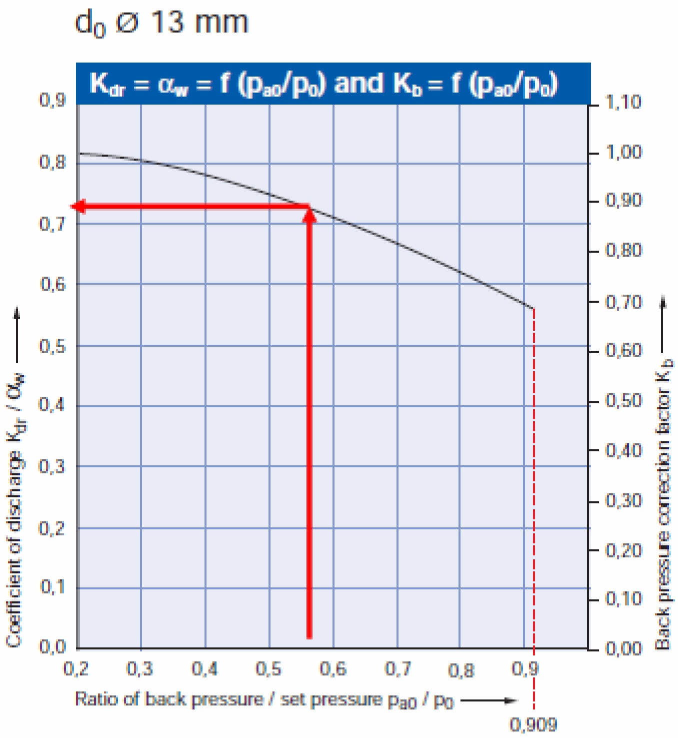
7.5.10.8 Determination of the Discharge Coefficient for Higher Back Pressures

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 Fig. 8 on Page 05/20 of 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 2006.**

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) 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]
Y	Outflow function (two-phase flows)	--
x	Pressure medium coefficient (gas flows) Vapour void fraction (two-phase flows)	[h mm² bar/kg] --
Z	Compressibility factor of the medium in the pressure chamber (see Par. 3.21)	--
α_w	Certified discharge coefficient	--
ψ	Outflow function (gas flows)	--
ρ	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

$$A_0 = 0.1791 \frac{q_m}{\psi\ \alpha_w p_0} \sqrt{\frac{T\ Z}{M}}$$ (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

$$A_0 = \frac{x\ q_m}{\alpha_w p_0}$$ *(Eq. 7.6.3-1)*

The pressure medium coefficient x is defined in Eq. 7.6.3-2

$$x = 0.6211 \frac{\sqrt{p_0 v}}{\psi}$$ *(Eq. 7.6.3-2)*

The values of the specific volume and the isentropic exponent for the calculation of ψ 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.

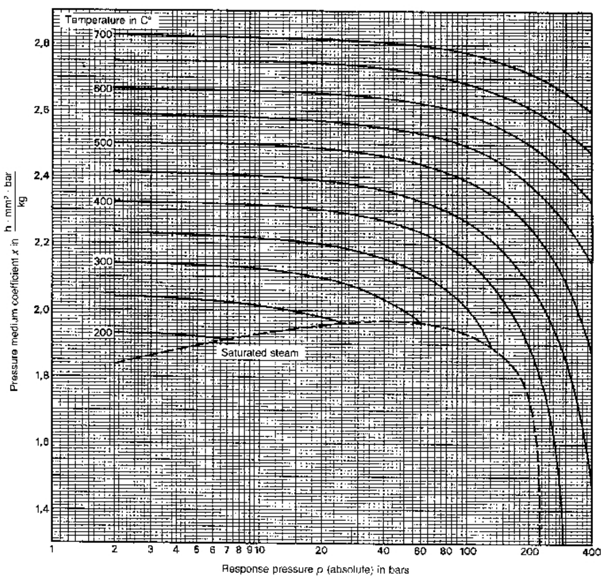


Fig. 7.6.3-1 Pressure medium coefficient for steam in function of the response pressure (set pressure)

7.6.4 Non-Boiling Liquids

$$A_0 = 0.6211 \frac{q_m}{\alpha_w \sqrt{\rho \left(p_0 - p_a\right)}} \quad \text{(Eq. 7.6.4-1)}$$

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 4126-1 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 without a percentage limitation as in ISO 4126-1. 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 4126-1. A lift restriction below 30 % of the maximum lift is allowed as long as it is more than 1 mm.

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 α_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 ψ 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 4126-1, 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 ψ 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 VIII (2008), EN 13136 (2001), ISO 4126-1 (2004), ISO 21013-3 (2006), prEN 12693 (1996)

ASME Section VIII, ISO 4126-1 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 4126-1. 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
$Q_m = 3.6W/L = 3.6 \cdot 15000/417.274 = 129.4$ kg/h

7.7.2 Sizing acc. to EN 13136

The standard EN 13136[14] 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]
φ	Density of heat flow rate	[kW/m²]
η_v	Volumetric efficiency estimated at suction pressure and discharge pressure equivalent to the safety valve setting	[--]
ρ_{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 prEN 12693[15] covers the case of compressors running against a closed discharge valve.

[14] EN 13136 Refrigerating systems and heat pumps – Pressure relief devices and their associated piping – Method for calculation, 2001.
[15] pr EN12693 Refrigerating systems and heat pumps – Safety and environmental requirements – Refrigerant compressors, 1996.

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 VIII (2008), API RP 520 (2000), API 521 (2007), ISO 4126-1 (2004), ISO 4126-7 (2004), ISO 23251(2007)

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.

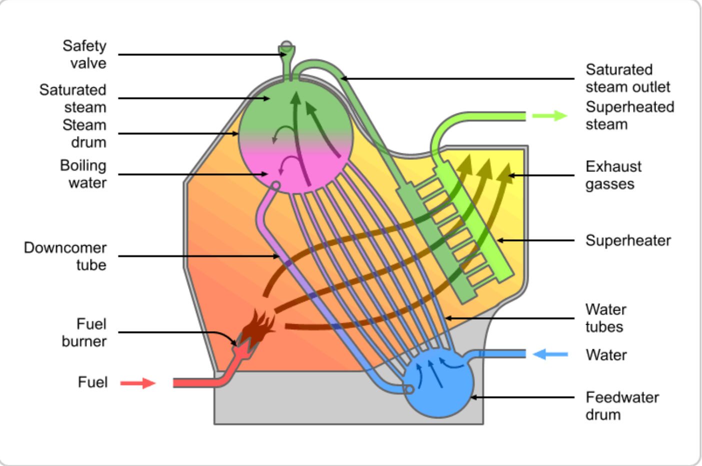


Fig. 7.8.1-1 Marine type tube boiler for steam generation: steam generator (feedwater drum, steam drum, downcomer tube) and superheater (Source : Wikipedia Images)

Acc. to EN 12952-10[16] (2002) 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 (EN 12952-10, Par 5.1.2). 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.

[16] Water-tube boilers and auxiliary installations – Part 10: Requirements for safeguards against excessive pressure, 2002.

Tube boiler steam generator	Position of safety valve in EN 12952-10 (2002)
Steam generator (feedwater and steam drum)	For a generator with no superheater the safety valves or the main valve of CSPRS[17] valves must be placed on the steam side (EN 12952-10, Par. 5.1.3). 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, Par. 5.1.1).
Non-isolable superheater 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, Par. 5.1.5).
Isolable superheater 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, Par. 5.1.6).

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, Par. 5.1.7).

In EN 12952-10[18] (2002) 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, Par. 5.2.1), 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, Par 5.2.2). 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, Par. 5.2.3). 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, Par 5.2.5).

[17] CSPRS : Controlled Safety Pressure Relief Systems

[18] Water-tube boilers and auxiliary installations – Part 10: Requirements for safeguards against excessive pressure, 2002.

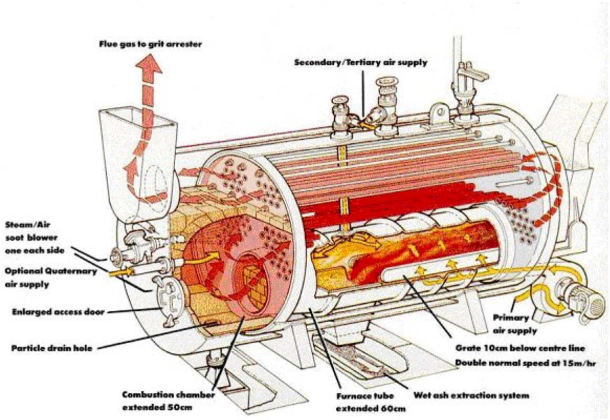


Figure 7.8.1-2 Shell boiler ; Source: RISE , Murdoch University, Perth (AUS)

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[19] (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 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). 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 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 4126-1 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

[19] 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 Section 7.5.5). 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 Par. 5.10.3 for input control valves or Par. 5.10.4 for output control valves.

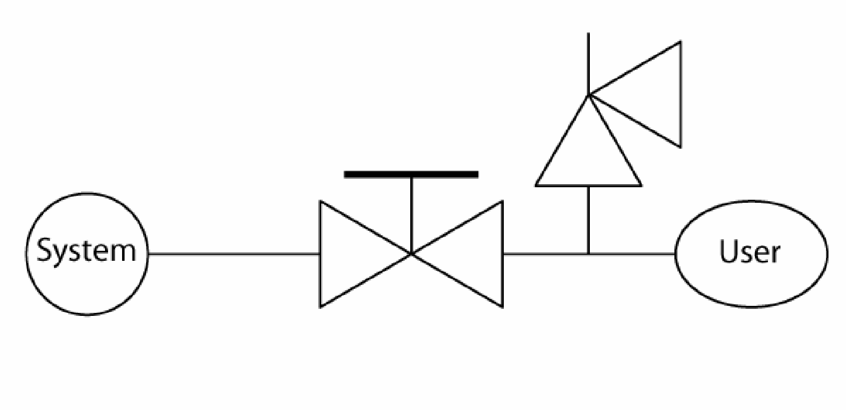


Fig. 7.8.3-1: Example of protection against malfunction of control valve

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 Par. 2.3.13 and ISO 23251 Par 4.13.12 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)

As long as the standard ISO/FDIS 4126-10 is not in power, 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.

$$A_0 = \left(\frac{0.6211 \frac{\sqrt{p_0 v}}{\psi} \frac{h-h'}{r}}{K_{dD} p_0} + \frac{0.6211\sqrt{v}\left(1-\frac{h-h'}{r}\right)}{K_{dL}\sqrt{p_0 - p_a}} \right) \quad (7.8.6\text{-}1)$$

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	m³/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 Section 7.3.6.2.1.1* and Fig. 32
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 (2008) Table 7 on Page 55 or in ISO 4126-7 (2004) Table 4 on Page 25. Further references are written in Chapter 10.
Viscosity Liquid – μ, v	0 mPa s 0 m²/s 0 mm²/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 VIII (2008) and API RP 520 (2000)

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

From \ To	°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				
From \ To	°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

From \ To	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

From \ To	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)								
From \ To	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 VIII 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	$9.869*10^{-6}$	$9.869*10^{-3}$	9.869	0.0680	0.00132	0.9678	$9.678*10^{-5}$
bar	1.01325	1	10^{-5}	0.01	10	0.068948	$1.3332*10^{-3}$	0.980665	$9.80665*10^{-5}$
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	$9.80665*10^{-3}$
MPa	0.101325	0.1	10^{-6}	0.001	1	$6.8948*10^{-3}$	$1.3332*10^{-4}$	0.0980665	$9.80665*10^{-6}$
psi	14.696	14.50	$1.450*10^{-4}$	0.145	145.0	1	0.0193	14.22	0.001422
torr (mmHg (0°C))	760.000	750.06	$7.5006*10^{-3}$	7.5006	7500.6	51.715	1	735.56	0.073556
kg_f/cm^2 (= kgsi)	1.0332276	1.0197	$1.01972*10^{-5}$	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: v)			
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[20] (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

[20] 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 VIII (2008) and API RP 520 (2000), EN 13136 (2001), ISO 4126-7 (2004)

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

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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:

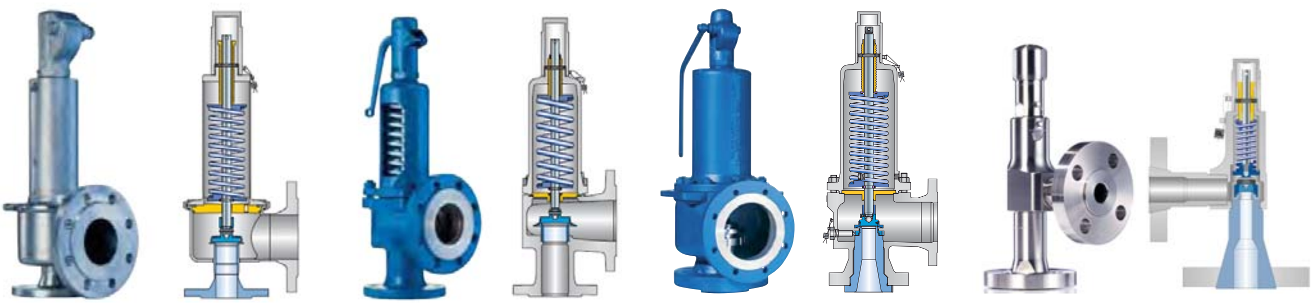
- selected soft good options
- spring chart and spring materials
- approvals
- design

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**

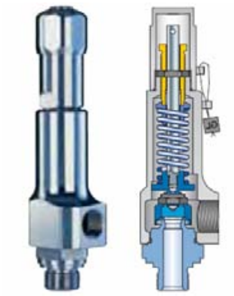
Figure 10.2-1: Four main types of flange connection

10.2.3 Threaded Connections

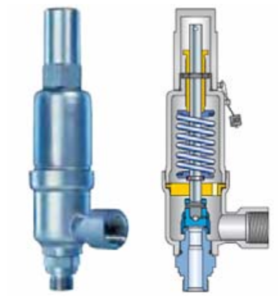
Threaded connections can be selected according to ASME B 1.20.1 (NPT), DIN ISO 228 (G) and other standards.

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



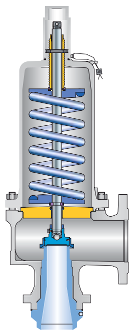
Threaded connection (inlet male, outlet female)
LESER type 459

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 connenction at the inlet

10.2.5 Clean Service Connections

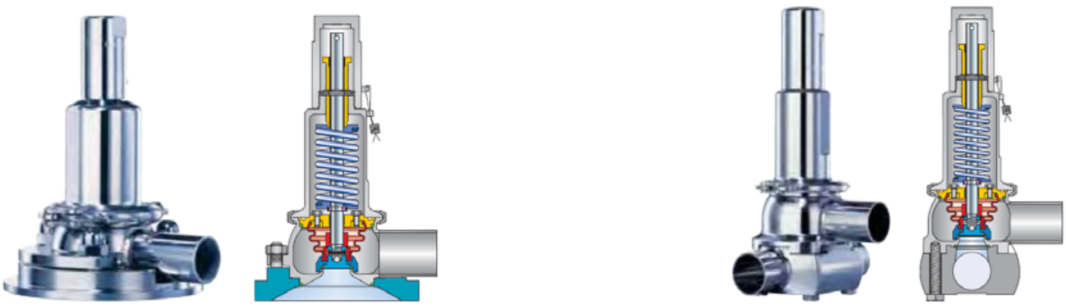
Clean Service safety valves can have different connections:

- 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**

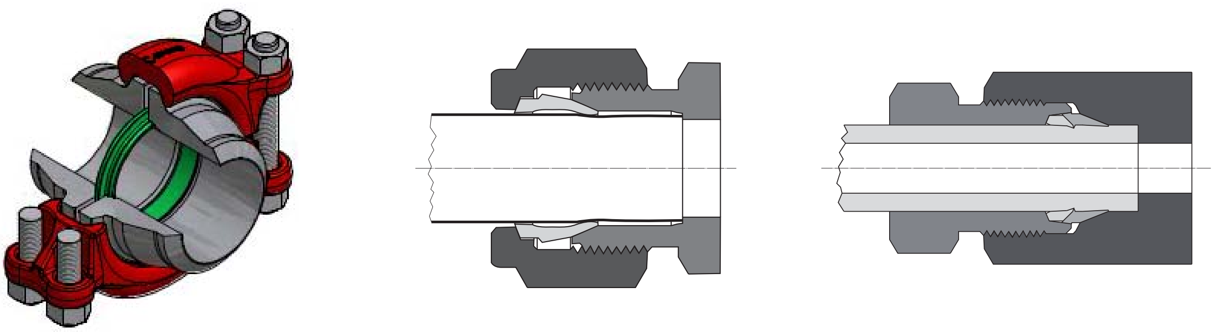
Figure 10.2.5-2: Different connections for LESER's clean service

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 spezial 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 ISO 1083 grade 250
0.7043	Ductile iron	ISO 1083 grade 350-22 ISO 1083 grade 400-15 ISO 1083 grade 400-18 EN 545 grade 420-5 ISO 1083 grade 500-7 ISO 1083 grade 600-3
1.0425 1.0460 1.0619	3E0	1.0345 1.0348 1.0352 1.0625 ASME SA 105
1.7357	5E0	1.7335 ASME SA 217 WC 6 ASME SA 217 C 5 ASME SA 335 P 12 ASME SA 182 F11 Cl 1/Cl 2/Cl 3 ASME SA 182 F12 Cl 1/Cl 2 ASME SA 387 11 ASME SA 387 12
1.4404	13E0	1.4432 1.4435 1.4458 1.4539 1.4563 1.4918
1.4408	14E0	1.4401 1.4436 ASME SA 351 CF8M ASME SA 312 TP316 ASME SA 312 TP 316 L/H ASME SA 182 F 316 ASME SA 182 F 316 L/H ASME SA 240 316 ASME SA 240 316 L/H
1.4581	15E0	1.4571 1.4580 ASME SA 240 316 Ti
Additional materials		
Material	**Material group**	**Further materials of material group**
1.4462 1.4470	16E0	1.4362 1.4410 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 ISO 5922 B 32-12	ISO 5922 B 35-10
1E0	1.0432	ASME SA 106 B
1E1	1.0038	
3E1	1.0425 1.0426 1.0481 ASME SA 216 WCB ASME SA 216 WCC	ASME SA 333 6 ASME SA 515 70 ASME SA 516 70 ASME SA 537 CL1
4E0	1.5415 1.5419	ASME SA 217 WC 1 ASME SA 182 F1 ASME SA 204 A/B
6E0	1.7375 1.7380 1.7383	ASME SA 217 C 12 ASME SA 335 P5/P9/P22 ASME SA 182 F5/F9/F22 Cl 1/F22 Cl 3 ASME SA 387 5/9/22
6E1	1.7362+NT1 1.7365	1.7366
7E0	1.0488 1.1104	1.1131 1.6220
7E1	1.0566	1.1106
7E2	1.5637 1.5682 1.6212	1.6228 1.6217
7E3	1.5637 1.5638 1.5662 1.5680	1.6217 ASME SA 352 LC 2/LC 3/LC 8 ASME 350 LF 3 ASME SA 203 A/E
8E0	1.0488	1.1104
8E2	1.0477 1.0478	1.0487 ASME SA 350 LF 2 Cl 1/Cl 2
8E3	1.0562 1.0565	1.0571 1.8867
9E0	1.4922	1.4931
9E1	1.4903	
10E0	1.4307 1.4306 1.4335	ASME SA 351 CF 8 ASME SA 312 TP 304 L/TP 304/ TP 304 H ASME SA 182 F 304/F 304 L/F 304 H ASME SA 240 304/304 L/304 H
10E1	1.4311	
11E0	1.4301	1.4948
12E0	1.4541 1.4550 1.4940 1.4941 1.4912	1.4961 ASME SA 312 TP 321/TP 321 H ASME SA 182 F 321/321 H ASME SA 240
13E1	1.4406 1.4429 1.4439	1.4529 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 room tempreture.

Material Group: cast iron (0.6025)

	Maximum allowable temperature [°C]							
	-10	120	150	180	200	250	300	350
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 room 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 97/23/EC 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 1.0460 1.0619 1.4404 1.4581	-10	-60	-85
1.4408	-200	-255	-273
1.4462	-40	-60	-60

Table 10.3.1-12: Overview of minimum tempretures for different load cases

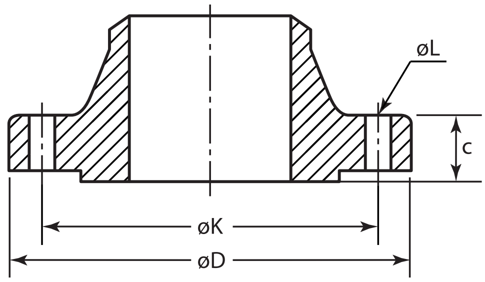
10.3.2 Dimensions acc. to EN 1092

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.

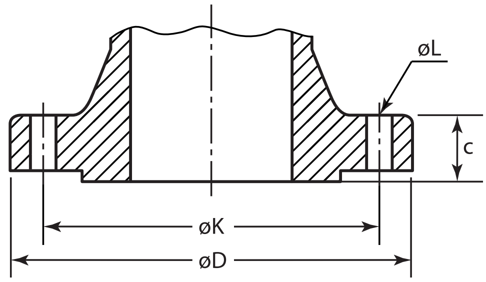
This is only an extraction of standard EN 1092-1/-2.

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:



Type 11



Type 21

Figure 10.3.2-1: EN1092-1 – types of flanges made of steel

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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 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 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 (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 21						11	21	11	21
15									14	
20									16	
25									16	
32									18	
40	use nominal pressure of PN40 for this size									
50										
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 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 flangethickneses 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 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 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 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.

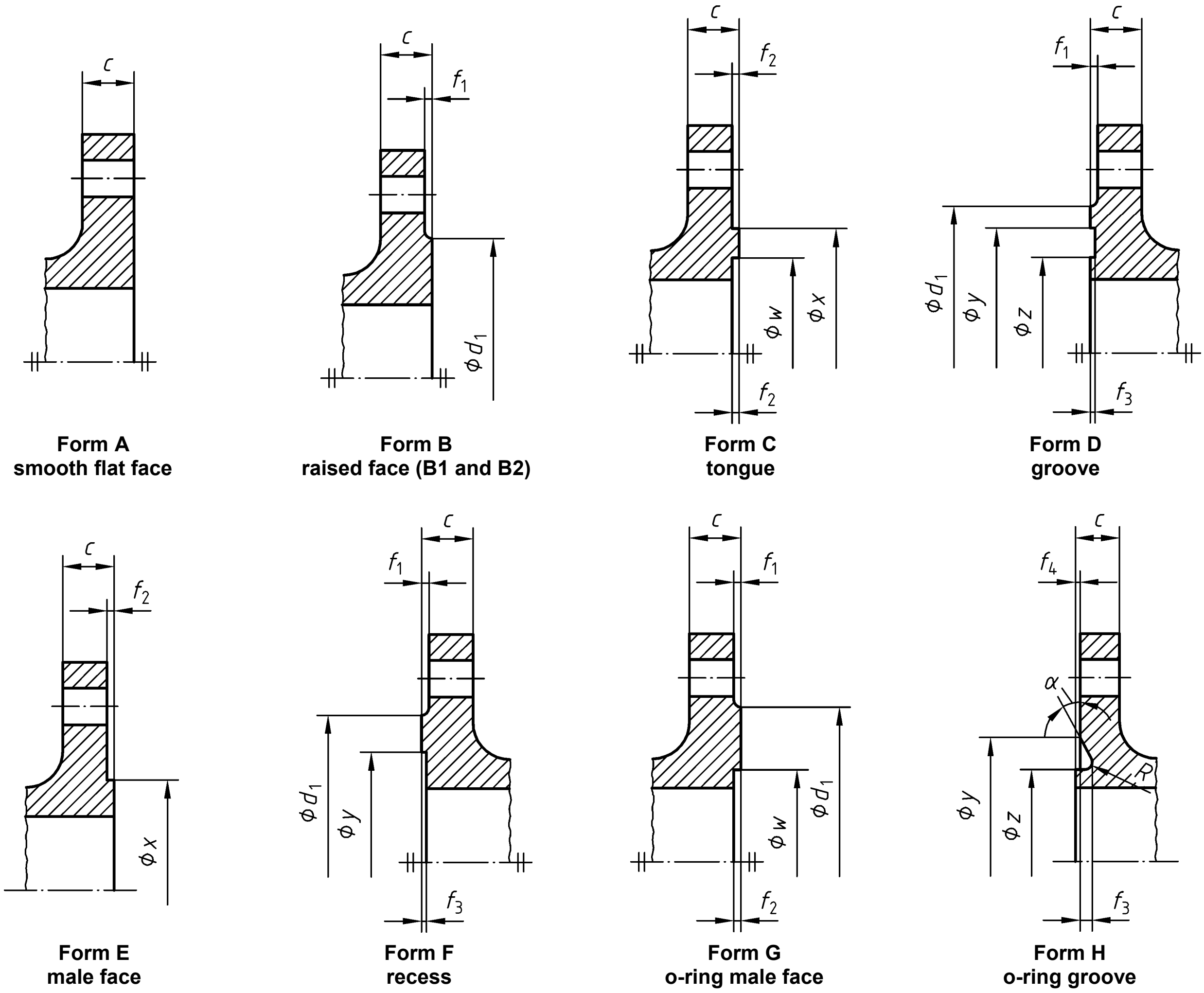


Figure 10.3.3-1: EN 1092 – forms of flange facings

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 DN 4 to DN 1000	≤ PN 100 DN 10 to DN 2000
2513	-	male face und recess	DN 10 to DN 1000	≤ PN 100 DN 10 to DN 2000
2514	-	male face with groove and recess	DN 10 to DN 3000	≤ PN 100 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 Specific Details

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 10.3.6-1: Lap joint flanges

Machining of flange thickness and outer flange diameter 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. The flange thickness and the outer flange diameter are generally not machined and can be larger than the dimensions listed in the applicable standard for welding neck flanges. The outer diameter of the cast flanges is left unmachined, because the diameter is used to clamp the body in the CNC machine. The connecting dimensions (bolt holes and raised face) always fulfil the requirements of the EN 1092 or ASME B16.34 / ASME B16.5 standard.

This procedure is common industry practice and allows to maintain the same centre to face dimensions independent from the flange standard. The function and the assembly of the safety valve is not affected and the customer benefits from less cost. In case the larger outer diameter is not accepted from an optical standpoint, it can be machined on request and at additional cost.

Flange dimensions of LESER Type 526 as well as Series 458 exceed flange dimension as mentioned in ASME / ANSI B16.5 and DIN EN 1092. This exceed is in accordance with API Standard 526, Section 2.4. Dimensions: “For some valve designs, the inlet raised face height may substantially exceed the nominal dimension specifi ed in ASME / ANSI B16.5 (and DIN EN 1092). Consult the manufacturer for exact dimension.
The reason for this exceed is:
- height of nozzle placed in the inlet of valve
- due to the outer diameter of the nozzle thread fl ange thickness has to be thicker than normal ASME / ANSI B16.5 and DIN EN 1092 dimension to achieve the required pressure rating.

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.

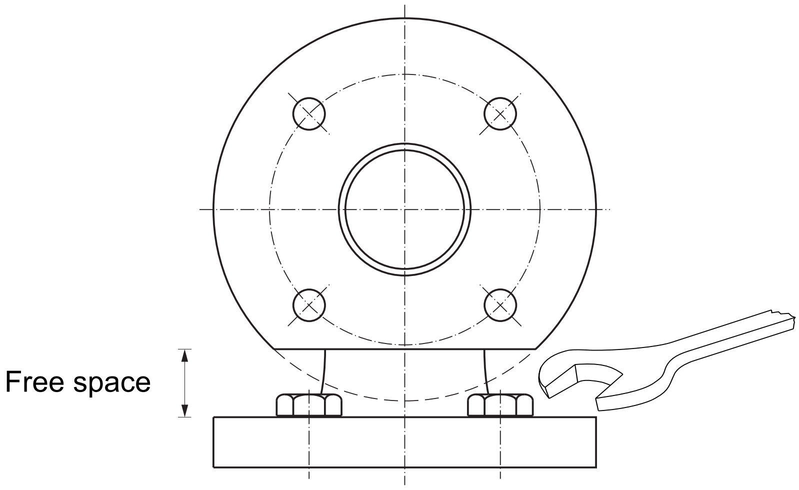


Figure 10.3.6 -2: Flattered outlet fange design

10.3.7 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.

10.3.8 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			
SA 105 (1) SA 216 Gr. WCB (1)	1.1	SA 350 Gr. LF2 (1) SA 350 Gr. LF6 Cl. (4) SA 350 Gr. LF3 SA 515 Gr. 70 (1) SA 516 Gr. 70 (1), (2) 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. (2) Not to be used over 455°C (850°F) (3) Not to be used over 370°C (700°F) (4) Not to be used over 260°C (500°F)
SA 352 LCB (3)	1.3	SA 217 Gr. WC1 (4), (5) SA 352 Gr. LC1 (3) SA 515 Gr. 65 (1) SA 515 Gr. 65 (1), (2) SA 203 Gr. A (1) 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). (2) Not to be used over 455°C (850°F) (3) Not to be used over 340°C (650°F) (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). (5) Use normalized and tempered material only
SA 217 Gr. WC6 (1), (3)	1.9	SA 182 Gr. F11 Cl. 2 (1), (2) SA 387 Gr. 11 Cl. 2 (2)	(1) Use normalized and tempered material only (2) Permissible, but not recommend for prolonged use above 590°C (1100°F) (3) Not to be used over 590°C (1100°F)
SA 351 Gr. CF8M (1)	2.2	SA 182 Gr. F316 (1) SA 182 Gr. F316H SA 182 Gr. F317 (1) SA 351 Gr. CF3M (2) SA 351 Gr. CG8M (3) SA 240 Gr. 316 (1) SA 240 Gr. 316H SA 240 Gr. 317 (1)	(1) At temperatures over 538°C (1000°F), use only when carbon content is 0.04% or higher (2) Not to be used over 455°C (850°F) (3) Not to be used over 538°C (1000°F)
SA 182 Gr. F316L SA 240 Gr. 316L	2.3	SA 182 Gr. 304L (1) 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) SA 352 Gr. LCC (2)	1.2	SA 350 Gr. LF6 Cl.2 (3) SA 352 Gr. LC2 SA 352 Gr. LC3 SA 203 Gr. B (1) 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). (2) Not to be used over 340°C (650°F) (3) Not to be used over 260°C (500°F)
SA 217 Gr. WC5 (1)	1.7	SA182 Gr. F2 (2) SA 217 Gr. WC4 (1), (2)	(1) Use normalized and tempered material only. (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) SA 387 Gr. 22 Cl. 2 (2)	(1) Use normalized and tempered material only (2) Permissible, but not recommend for prolonged use above 590°C (1100°F) (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 (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 SA 351 Gr. CE8MN (1) SA 351 Gr. CD4MCu (1) SA 351 Gr. CD3MWCuN (1)	2.8	SA 182 Gr. F44 SA 182 Gr. F51 (1) SA 182 Gr. F53 (1) SA 240 Gr. S31254 SA 240 Gr. S31803 (1) 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

LESER

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 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 SA 182 Gr F304H SA 351 Gr CF3	SA 351 Gr CF8 SA 240 Gr 304 SA 240 Gr 304H
2.4	SA 182 Gr F321 SA 182 Gr F321H	SA 240 Gr 321 SA 240 Gr 241H
2.5	SA 182 Gr F347 SA 182 Gr F347H SA 182 Gr F348 SA 182 Gr F348H	SA 240 Gr 347 SA 240 Gr 347H SA 240 Gr 348 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 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 SB 462 Gr. N10675	SB 333 Gr. N10665 SB 333 Gr. N10675
3.8	SB 462 Gr. N10276 SB 564 Gr. N06625 SB 335 Gr. N10001 SB 573 Gr. N10003 SB 574 Gr. N06455 SB 564 Gr. N08825 SB 462 Gr. N06022 SB 462 Gr. N06200	SB 575 Gr. N10276 SB 443 Gr. N06625 SB 333 Gr. N10001 SB 434 Gr. N10003 SB 575 Gr. N06455 SB 424 Gr. N08825 SB 575 Gr. N06022 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 SB 581 Gr. N06985 SB 462 Gr. N08367 SA 351 Gr. CN3MM	SB 620 Gr. N08320 SB 582 Gr. N06985 SB 688 Gr. N08367
3.13	SB 581 Gr. N06975 SB 564 Gr. N08031	SB 582 Gr. N06975 SB 625 Gr. N08031
3.14	SB 581 Gr. N06007 SB 462 Gr. N06030	SB 582 Gr. N06007 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).

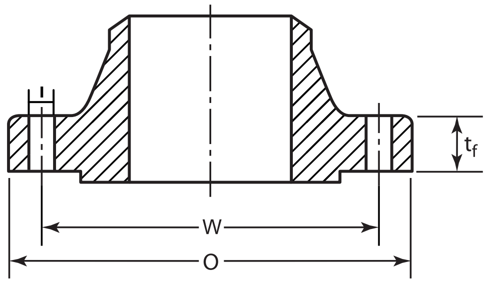


Figure 10.4.3-1: Welding neck flange

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	I	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	I	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	I	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	I	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

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	I	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	I	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.

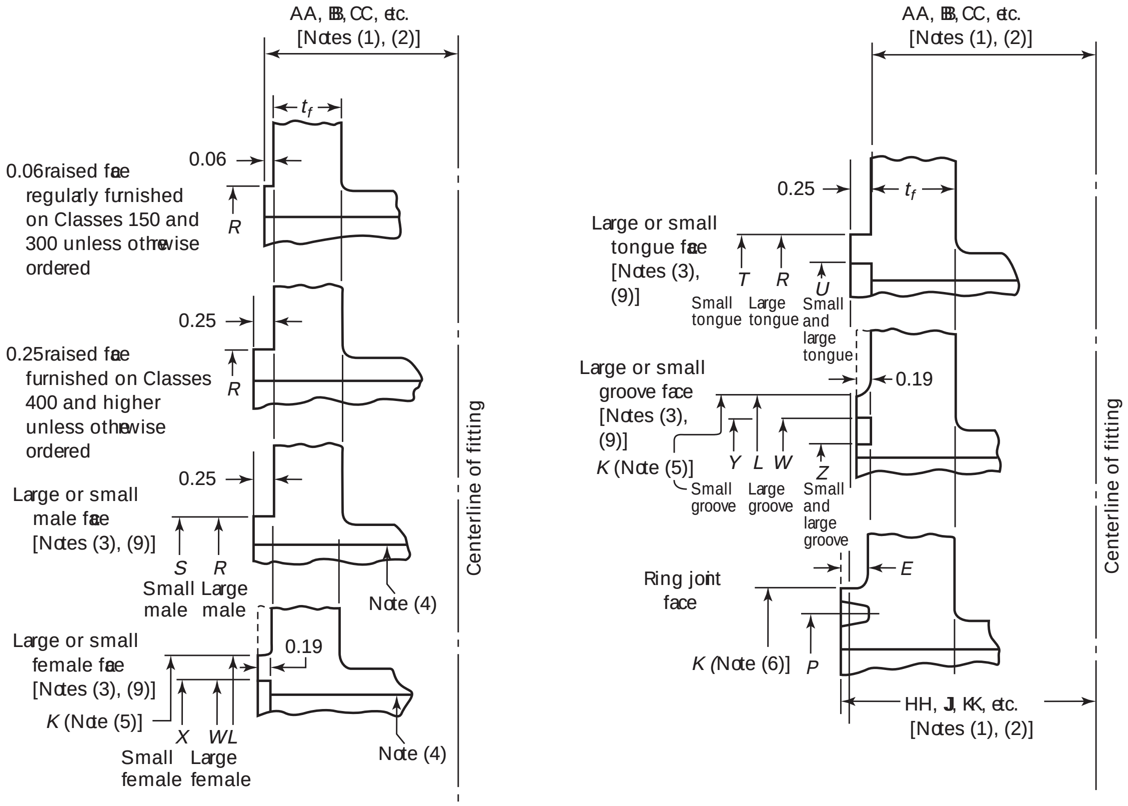


Figure 10.4.4-1: ASME B16.5 – End flange facings [inch] and their relationship to flange thickness and Center-To-End and End-To-End dimensions

Dimensions of facings other than ring joints [inch]

Nom-inal 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]

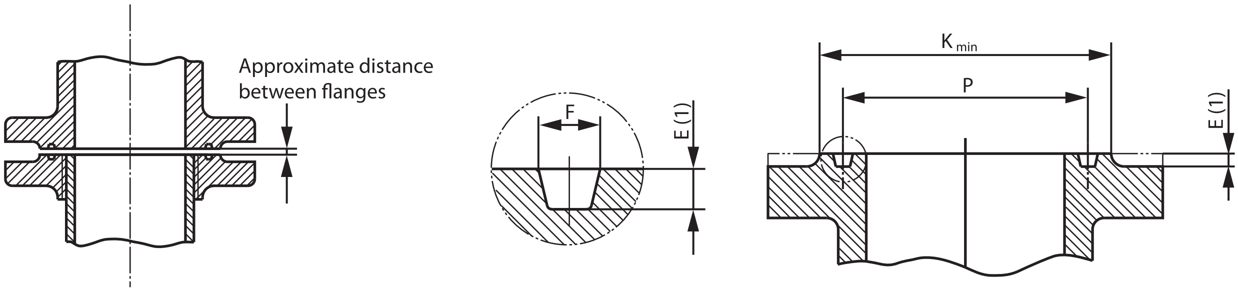


Figure 10.4.4-2: ASME B16.5 – ring joint facings

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 P	Depth [note (1)] E	Width F	Radius at Bottom R	Class 150	Class 300, 600	Class 900	Class 1500	Class 2500	Class 150	Class 300	Class 600	Class 900	Class 1500	Class 2500
…	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)	3.2 – 6.3	125 – 250	12.5 - 25	500 – 1000	> 1.52 (2)	0.462 – 0.556 (2)	ASME B16.5
LMF, LFF – serrated finish (1)							
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.

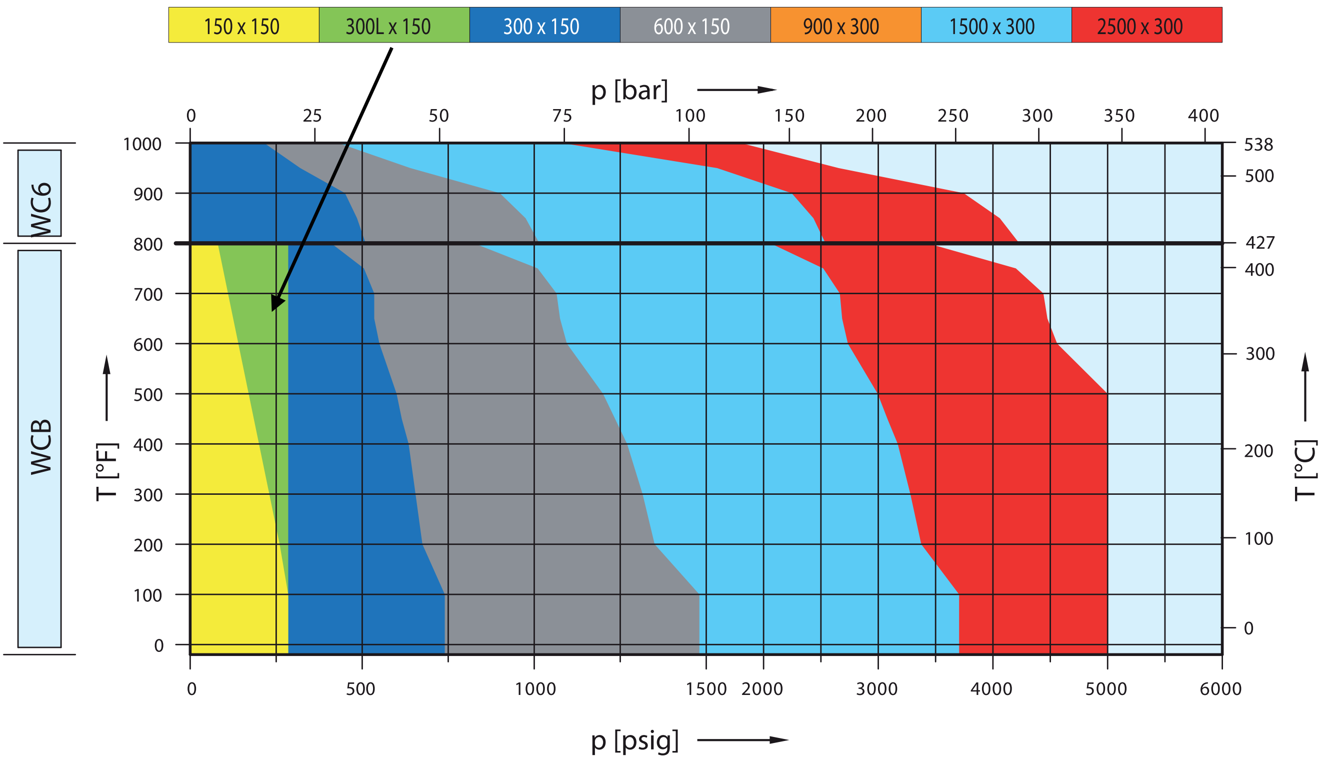
See chapter 4.1 for ASME and LESER catalogue for API limits.

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 (LWN 060.30 and LWN 062.30).

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.



Figute 10.4.5-1: Application area for #300L inlet flages

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 LESER Specific Details

Lap joint flanges

See section 3.6 for more information

Machining of flange thickness and outer flange diameter for cast bodies

See section 3.6 for more information

Flattened outlet diameter

See section 3.6 for more information

Inlet flange dimensions of full nozzle safety valves

Flange thickness 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."

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

All 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 / inspectors insist on having the inlet flange thickness strictly in accordance with ASME tolerances LESER is happy to perform back spot facing. Execution of spot facing is standardized in manufacturer standard practice MSS SP-9, edition 1997. Regarding the depth of the spot facing the standard gives the following information:

"2.6 The depth of spot face is not given in the standard as the requirement is covered in the various flange fitting standards."

The flange fitting standard states that: MSS SP-9.2.3
"… the resulting wall thickness shall not be less then the minimum required thickness specified in the appropriate standard."

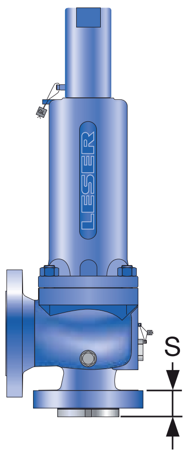


Figure 10.4.9.-1
EN 1092
dimension "s"

10.4.10 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) JIS G 5502 FCD 350 JIS G 5502 FCD 400 JIS G 5502 FCD 450	ISO 1083 350-22 ISO 1083 400-15 ISO 1083 450-10
SA 105 SA 216 Gr. WCB	1.1	JIS G 3101 SS 400 JIS G 4051 S 20 C JIS G 4051 S 25 C JIS G 3201 SF 390A JIS G 3202 SFVC 1 JIS G 3201 SF 440A JIS G 3202 SFVC 2A JIS G 5101 SC410 JIS G 5151 SCPH 1 JIS G 5101 SC 480 JIS G 5151 SCPH 11	ISO 9328-2 PH 290 ISO 9328-2 PH 315 ISO 9328-2 PH 355 ISO 2604-1 F13 ISO 2604-1 F18 ISO 2604-1 F72 ISO 4991 C26-52H SA 515 70 SA 516 70 SA 537 CL1 SA 350 LF2
SA 217 Gr. WC6	1.9	ISO 4991 C32H A 387 11 CL2	SA 182 F11 CL2 SA 182 F12 CL2
SA 351 Gr. CF8M	2.2	JIS G 4304 SUS 316 JIS G 4305 SUS 316 JIS G 3214 SUS F316 JIS G 5121 SCS 14A JIS G 5121 SCS 16A ISO 9328-5 X 5 CrNiMo 17 12 ISO 9328-5 X 7 CrNiMo 17 12 ISO 2604-1 F62 ISO 2604-1 F64	ISO 4991 C57 ISO 4991 C60 ISO 4991 C61 ISO 4991 C61LC SA 240 316 SA 240 316H SA 20 317 SA 182 F316 SA 182 F316H
SA 479 Gr. 316L	2.3	JIS G 4304 SUS304L JIS G 4305 SUS304L JIS G 3214 SUS F304L JIS G 4304 SUS316L JIS G 4305 SUS316L JIS G 3214 SUS F316L	ISO 9328-5 X 2 CrNi 18 10 ISO 9328-5 X 2 CrNiMo 17 12 ISO 9328-5 X 2 CrNiMo 17 13 ISO 2604-1 F46 ISO 2604-1 F59 SA 240 304L 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 SA 126 B
G3	JIS G 5501 FC 250	ISO 185 250
D2 (2)		ISO 2531 400-5 ISO 1083 600-3
M1	JIS G 5705 FCMB 27-05	ISO/DIS 5922 BF 27-05 ISO/DIS 5922 BF 30-06
M2	JIS G 5705 FCMB 35-10 JIS G 5705 FCMB 35-10S (1)	SA 47 32510 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 JIS G 5151 SCPH 21	A 204 A A 204 B A 182 F1 A 217 WC1 A 352 LC1 ISO 9328-2 16 Mo 3 ISO 2604-1 F28 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.

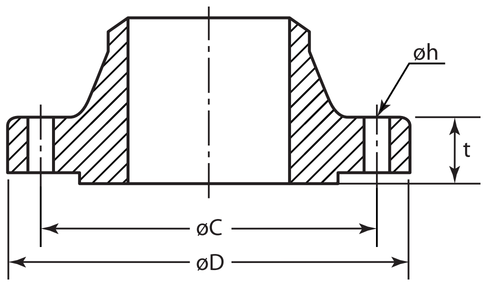
Notes:

(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

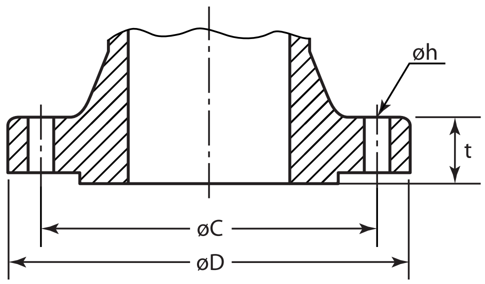
10.5.2 Dimensions acc. to JIS B 2220/JIS 2239

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

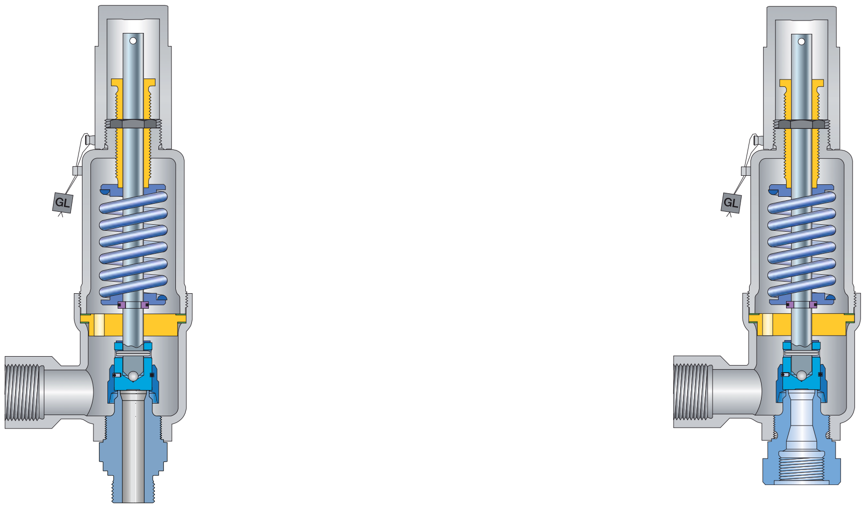


Figure 10.6.-1: General view of a safety valve with threaded connections

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

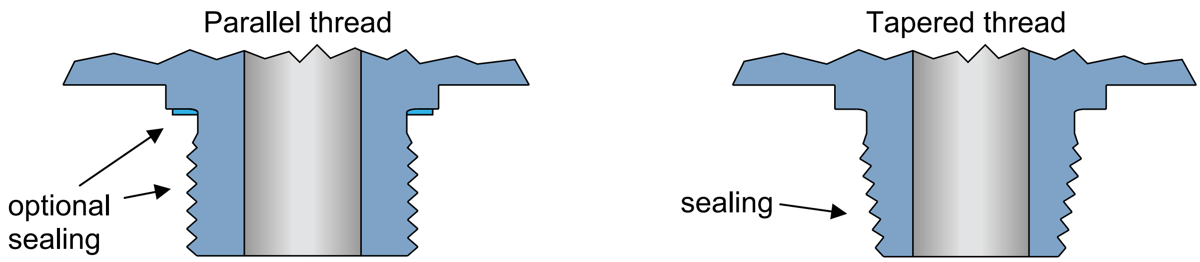


Figure 10.6-2: Parallel and tapered thread

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

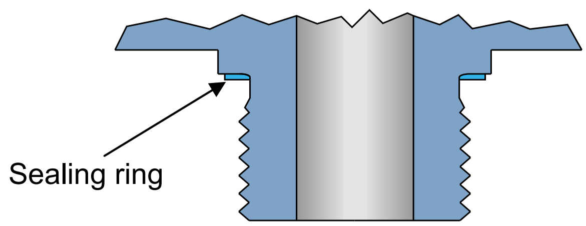


Figure 10.6-3: Parallel and tapered thread

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

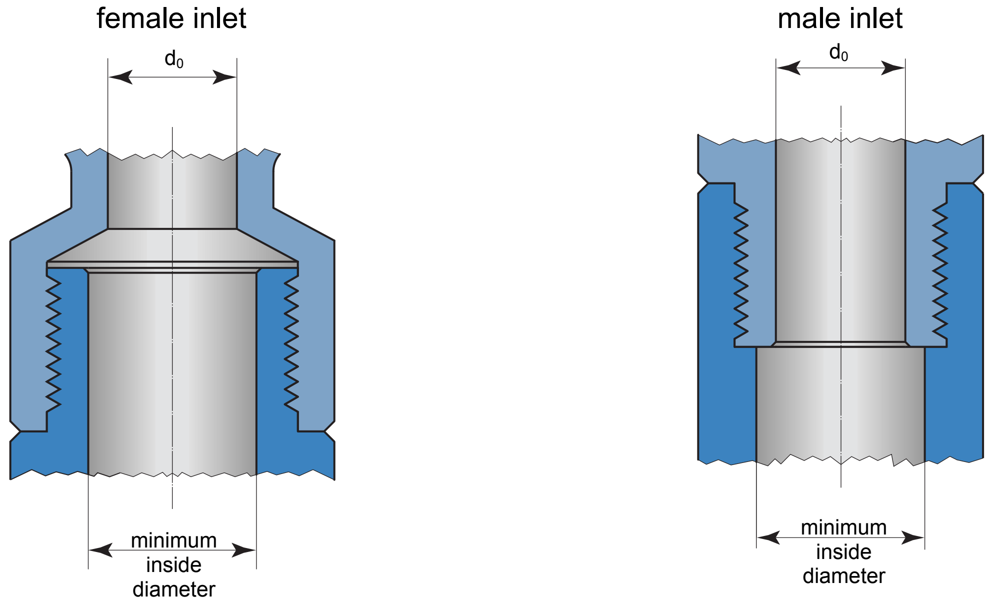


Figure 10.6.3-1: Minimum inside diameters for female and male inlets

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.

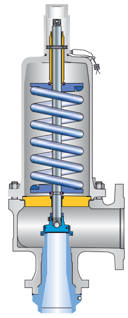


Figure 10.7-1:LESER type 457
With full nozzle and welding end at the inlet

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:

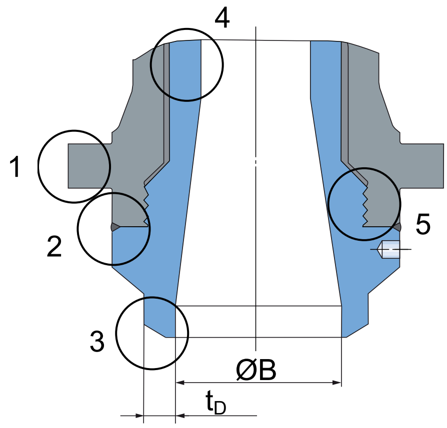


Figure 10.7.0-2: Inlet welding end

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.

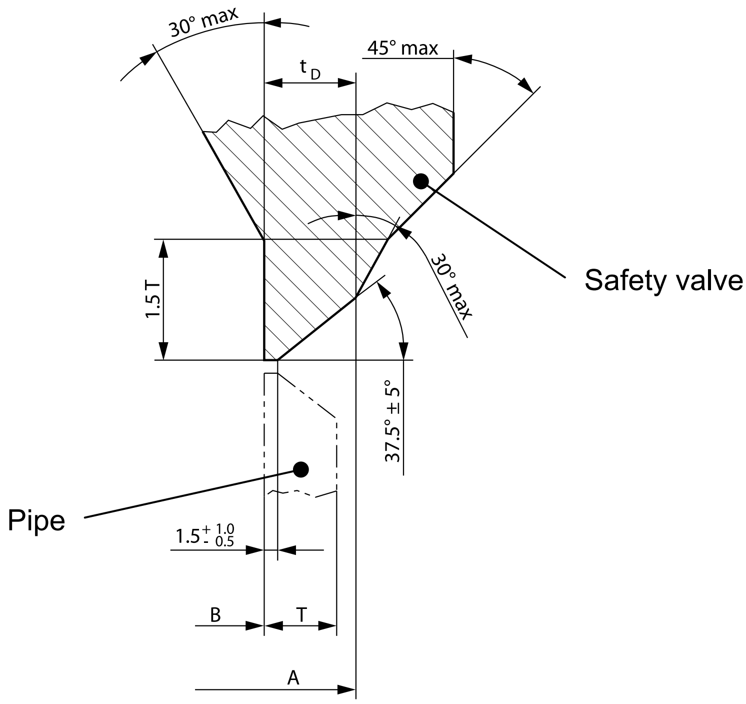


Figure 10.7.2-1: Welding end with single v weld for connection of pipe with wall thickness up to 22 mm

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 -1
DN 20	28	+2,5 -1,5
DN 25	35	
DN 32	44	+2,5 -2
DN 40	50	
DN 50	62	
DN 65	77	+2,5 -2,5
DN 80	91	
DN 100	117	

Nominal size of valve	ØA	Tolerance
DN 125	144	+4 -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 -1	+2 -2	+3 -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.

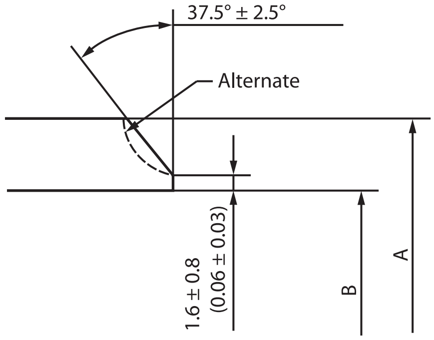


Figure 10.7.3-1: ASME B16.25 – weld bevel details for GTAW Root Pass with wall thickness from 3 mm up to 10 mm

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

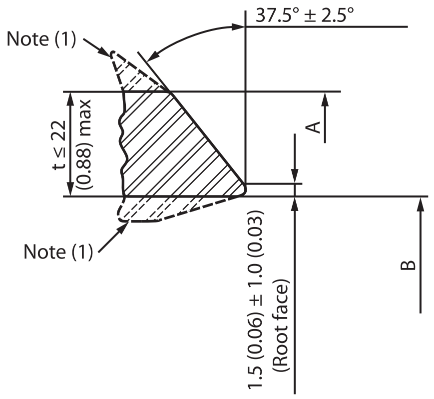


Figure 10.7.3-2: ASME B16.9 – Plain bevel From x (2) mm up to 22 mm

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.

Nominal pipe size	Schedule no. (1)	O.D. at welding ends: Wrought or fabricated components (1) A	O.D. at welding ends: 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.

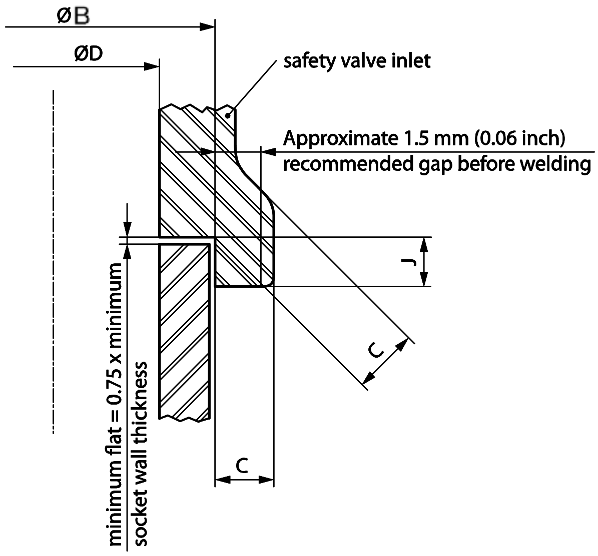


Figure 10.7.4-1: ASME B16.11 – welding gap and minimum flat dimensions for socket-welding fittings

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) B	Bore diameter of fittings D (1), (3)			Socket wall thickness (2), C						Min. depth of socket J
			Class designation			Class designation						
			3000	6000	9000	3000		6000		9000		
						Avg.	Min.	Avg.	Min.	Avg.	Min.	
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

LWN 288-20-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

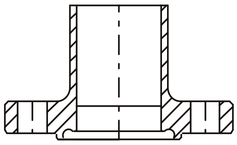
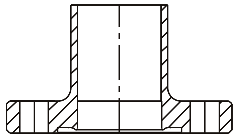
	Aseptic flange groove			**Aseptic flange tongue**		
						
LESER *Code*	NF			BF		
Acc. to	DIN 11864 T2 Form A					
Piping standard	DIN 11850 DIN EN ISO 1127 BS 4825-1					
OD of tube [mm]	12,7 – 41	42,4 – 104	114,3 – 154	12,7 – 41	42,4 – 104	114,3 – 154
Allowable pressure depending on OD [bar]	25	16	10	25	16	10

Table 10.8.2-1: Aseptic flange connections – DIN 11864 form A

Aseptic flange acc. to DIN 11864 form B

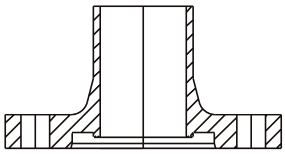
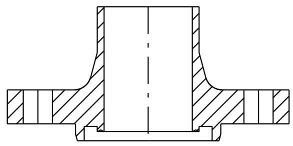
	Aseptic flange groove			**Aseptic flange tongue**		
						
LESER *Code*	NG			BG		
Acc. to	DIN 11864 T2 Form B					
Piping standard	DIN 11850 DIN EN ISO 1127 BS 4825-1					
OD of tube [mm]	12,7 – 41	42,4 – 104	114,3 – 154	12,7 – 41	42,4 – 104	114,3 – 154
Allowable pressure depending on OD [bar]	25	16	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

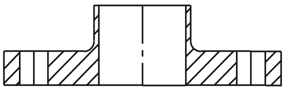
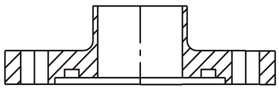
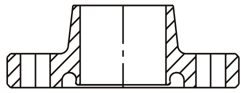
	APV-FG1- flange flat face		**APV-FN1 flange groove**		**Varivent flange groove**	
						
LESER *Code*	AF		AN		TN	
Acc. to	APV				Tuchenhagen	
Piping standard	DIN 11850				DIN 11850	
Nominal size	DN 25 – DN 50	DN 65 – DN 250	DN 25 – DN 50	DN 65 – DN 250	DN 25 - DN 65	DN 80 - DN 150
Allowable pressure 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

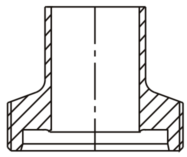
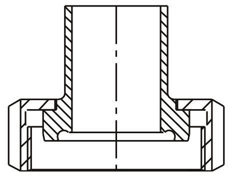
	Aseptic thread		Aseptic clamp and nut		
					
***LESER* Code**	GS		BS		
Acc. to	DIN 11864 T1 Form A				
Piping standard	DIN 11850 DIN EN ISO 1127 BS 4825-1				
Nominal size	DN 10 – DN 40 OD 13,5 – OD 33,7 ½" - 1½"	DN 50 –DN 100 OD 42,4 – OD 88,9 2" – 4"	DN 10 – DN 40 OD 13,5 – OD 33,7 ½" – 1½"	DN 50 – DN 65 OD 42,4 – OD 60,3 2" – 2½"	DN 80 – DN 100 OD 76,1 – OD 88,9 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

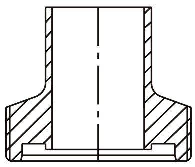
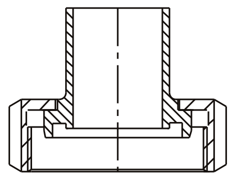
	Aseptic thread		Aseptic clamp and nut		
					
***LESER* Code**	GT		BT		
Acc. to	DIN 11864 T1 Form B				
Piping standard	DIN 11850 DIN EN ISO 1127 BS 4825-1				
Nominal size	DN 10 – DN 40 OD 13,5 – OD 33,7 ½" - 1½"	DN 50 –DN 100 OD 42,4 – OD 88,9 2" – 4"	DN 10 – DN 40 OD 13,5 – OD 33,7 ½" – 1½"	DN 50 – DN 65 OD 42,4 – OD 60,3 2" – 2½"	DN 80 – DN 100 OD 76,1 – OD 88,9 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

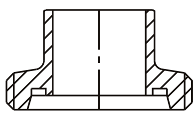
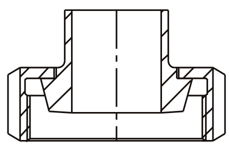
	Aseptic thread			Aseptic clamp and nut		
						
***LESER* Code**	GO			KO		
Acc. to	DIN 11851					
Piping standard	DIN 11850					
Nominal size	DN 10 – DN 40	DN 50 – DN 100	DN 125 – DN 150	DN 10 – DN 40	DN 50 – DN 100	DN 125 – DN 150
Allowable pressure depending on OD [bar]	40	25	16	40	25	16

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

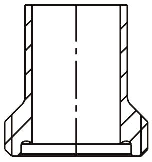
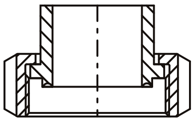
	Sterile thread	Sterile clamp and nut
		
LESER *Code*	GD	BD
Acc. to	Neumo	
Piping standard	DIN 11850 DIN EN ISO 1127	
Allowable pressure depending on OD [bar]	70	

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.

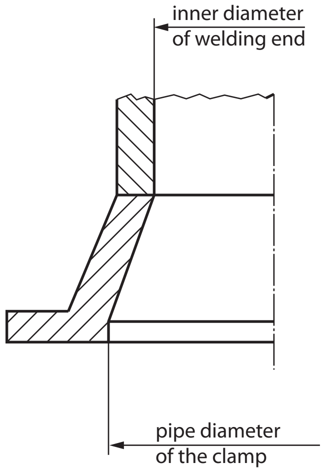


Figure 10.8.6-1: Prinziple of inner diameter for clamp and welding

The dimensions are listed in the following subsections.

Dimensions acc. to DIN 32676 - SO [mm]

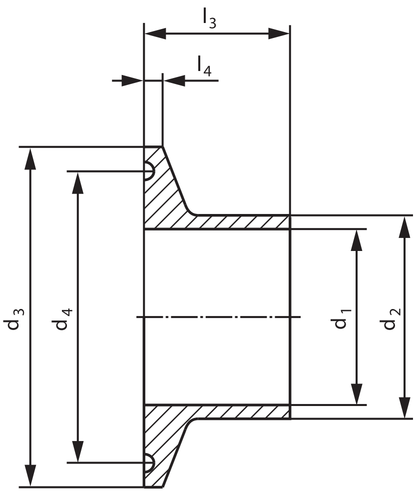


Figure 10.8.6-2: Sectional drawing of clamp fitting

Nominal size (DN)	d1	d2	d3	d4	l3	l4
10	10	13 14	34	27.5	18	2.85
15	16	19 20	34	27.5	18	2.85
20	20	23 24	34	27.5	18	2.85
25	26	29 30	50.5	43.5	21.5	2.85
32	32	35 36	50.5	43.5	21.5	2.85
40	38	41 42	50.5	43.5	21.5	2.85
50	50	53 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]

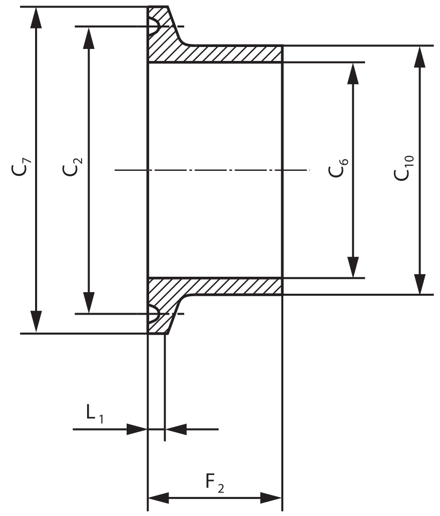


Figure 10.8.6-3: Sectional drawing of a clamp fitting acc. to ISO 2852 - DO

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]

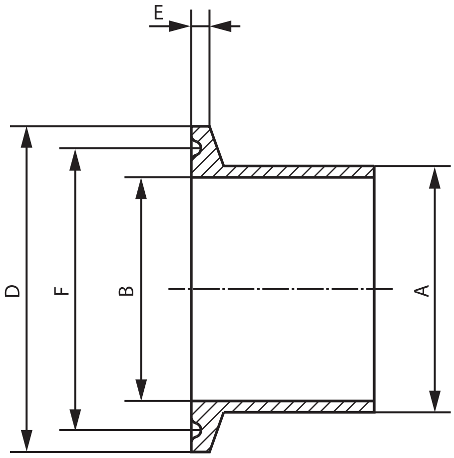


Figure 10.8.6-4: Sectional drawing of a clamp fitting acc. to ASME BPE -BO

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]

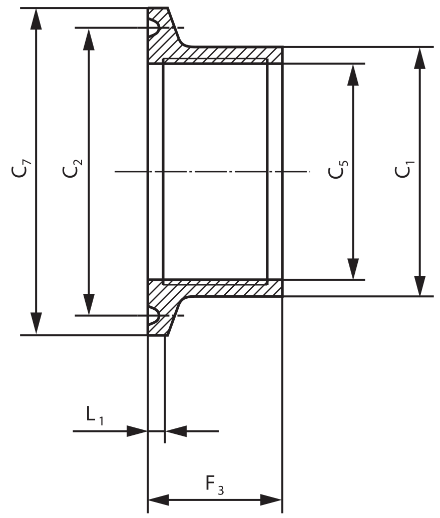


Figure 10.8.6-5: Sectional drawing of a clamp fitting acc. to ISO 2852 - CO

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 - +93.3	-51.1 - +140	-28.9 - +176.7	-40 - 232.2	-40 - +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

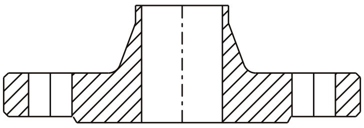
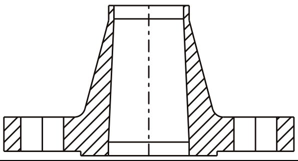
	Flange PN 16 Range B1 **EN 1092**	**Flange ANSI CL150 RF** **ASME B16.5**
		
LESER *Code*	FD	FA

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

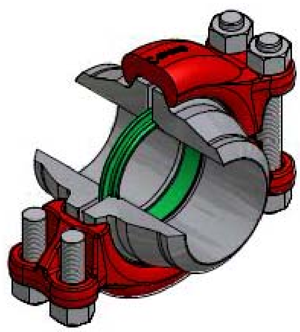
10.9 High Pressure Clamp Connections - Grayloc/Destec

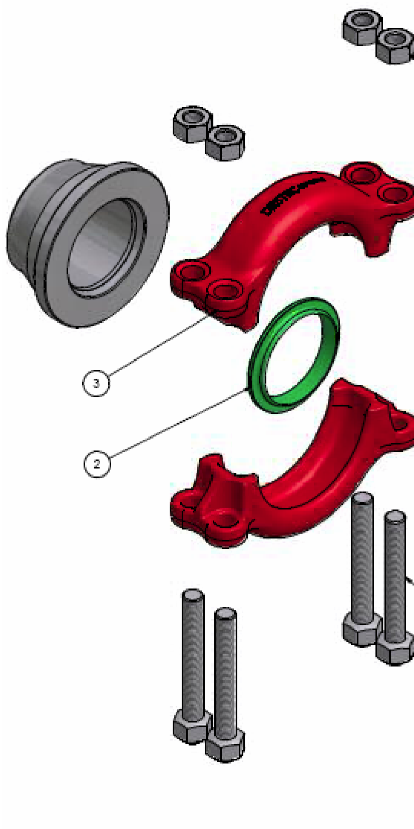
General

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.





Parts List	
ITEM	DESCRIPTION
1	G6-52 BW HUB
2	SEAL RING
3	G6 CLAMP
4	SPHERICAL NUT
5	1.1/8"-8UN STUDBOLT

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

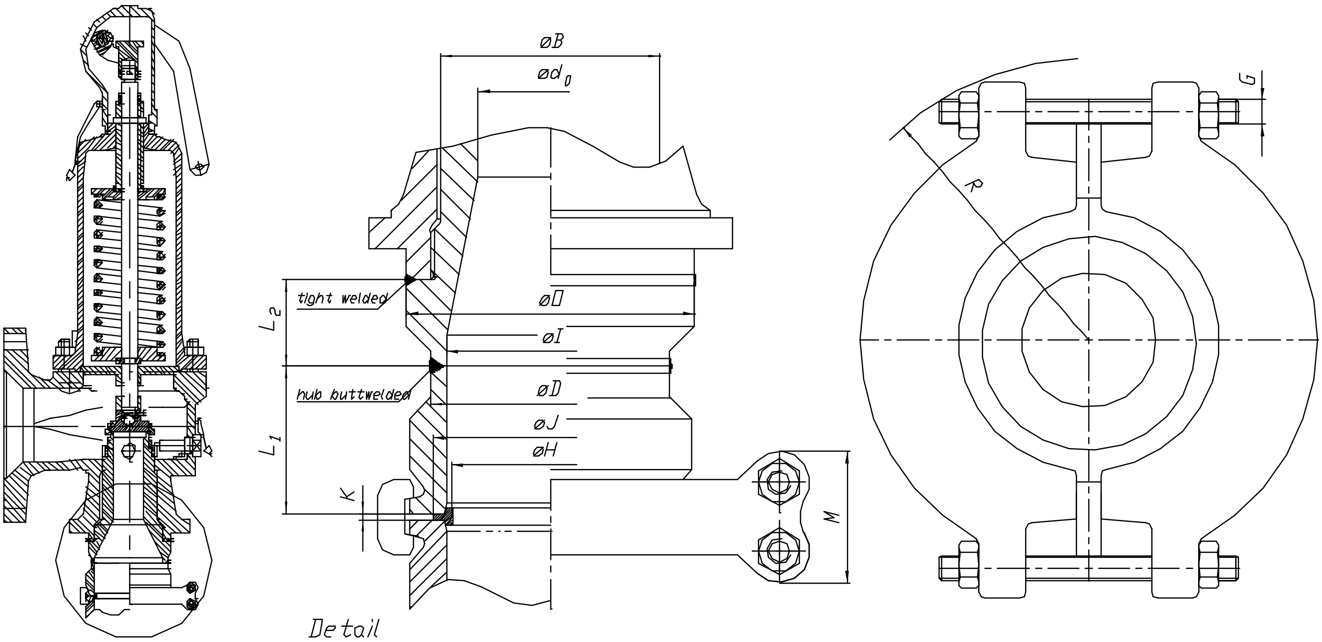


Figure 10.9-2: The construction views of API-safety valve with a clamp connector

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.

Safety Valve		ASME B36.10M					
NPS	Orifice	Outer diameter (ØD)	Max. wall thickness	Possible schedules			
1x2	E	33.4	6.4	-	160	80	40
1½x2		48.3	10.2	XXS			
1½x2/3	F						
1½x2/3	G						
2x3		60.3	11.1				
1½x2/3	H	48.3	10.2				
2x3		60.3	11.1				
2x3	J						
3x4		114.0	18.9				
3x4	K						
4x6							
3x4	L						
4x6			11.0	-	120		
4x6	M						
4x6	N						
4x6	P						
6x8	Q	168.3			-		
6x8	R						
6x10							
8x10	T	219.1	12.7				

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

<table>
<tr><th colspan="2">Safety valve</th><th colspan="9">Type of clamp connection</th></tr>
<tr><th rowspan="3">NPS</th><th rowspan="3">Orifice</th><th colspan="4">Destec Types</th><th colspan="5">Grayloc Types</th></tr>
<tr><th colspan="9">Schedule</th></tr>
<tr><th>xxs</th><th>160</th><th>80</th><th>40</th><th>xxs</th><th>160</th><th>120</th><th>80</th><th>40</th></tr>
<tr><td>1x2</td><td rowspan="2">E</td><td rowspan="4">G1½-11</td><td>G1-7</td><td colspan="2">G1-11</td><td>1GR5</td><td>1GR7</td><td rowspan="8">-</td><td colspan="2">1GR11</td></tr>
<tr><td>1½x2</td><td colspan="3" rowspan="3">G1½-14</td><td colspan="2" rowspan="3">1½GR11</td><td colspan="2" rowspan="3">1½GR14</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>G2-14</td><td colspan="3">G2-16 or G2-20</td><td colspan="2">2GR14</td><td colspan="2">2GR20</td></tr>
<tr><td>1½x2/3</td><td rowspan="2">H</td><td>G1½-11</td><td colspan="3">G1½-14</td><td colspan="2">1½GR11</td><td colspan="2">1½GR14</td></tr>
<tr><td>2x3</td><td rowspan="2">G2-14</td><td colspan="3" rowspan="2">G2-16 or G2-20</td><td colspan="2" rowspan="2">2GR14</td><td colspan="2" rowspan="2">2GR20</td></tr>
<tr><td>2x3</td><td rowspan="2">J</td></tr>
<tr><td>3x4</td><td rowspan="4">G4-31</td><td rowspan="4">G4 - 34</td><td colspan="2" rowspan="8">G4-40</td><td colspan="2" rowspan="4">4GR31</td><td rowspan="8">4GR34</td><td colspan="2" rowspan="8">4GR40</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 colspan="2" rowspan="8">-</td><td colspan="2" rowspan="8">-</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 colspan="2" rowspan="3">G6-62
G6-54
(schedule 120)</td><td rowspan="4">-</td><td colspan="2" rowspan="3">6GR62</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>G8-76</td><td>G8-82</td><td>8GR76</td><td>8GR82</td></tr>
</table>

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

<table>
<tr><th colspan="3">Safety valve</th><th colspan="4">Nozzle</th><th colspan="6">Pipe (ASME B36.10M)</th></tr>
<tr><th rowspan="2">NPS</th><th rowspan="2">Orifice</th><th rowspan="2">Nozzle part number</th><th rowspan="2">Ød0</th><th rowspan="2">ØB</th><th rowspan="2">ØO</th><th rowspan="2">L2</th><th rowspan="2">ØD</th><th colspan="5">ØI of hub and nozzle end</th></tr>
<tr><th>XXS</th><th>160</th><th>120</th><th>80</th><th>40</th></tr>
<tr><td>1x2</td><td rowspan="2">D/E</td><td rowspan="2">207.20xx.9xxx
207.22xx.9xxx
207.27xx.9xxx</td><td rowspan="2">14.0</td><td>42.0</td><td>48.0</td><td>38.0</td><td>33.4</td><td>-</td><td>20.7</td><td rowspan="16">do not exist at the clamp supplier</td><td>23.4</td><td>26.6</td></tr>
<tr><td>1½x2</td><td rowspan="4">56.0</td><td rowspan="4">62.0</td><td rowspan="3">43.0</td><td rowspan="4">48.3</td><td rowspan="4">27.9</td><td rowspan="4">33.99</td><td rowspan="4">38.1</td><td rowspan="4">41.0</td></tr>
<tr><td rowspan="2">1½x2/3</td><td rowspan="2">F</td><td>207.23xx.9xxx</td><td rowspan="2">18.0</td></tr>
<tr><td>207.28xx.9xxx</td></tr>
<tr><td>1½x2/3</td><td rowspan="2">G</td><td>207.24xx.9xxx</td><td rowspan="2">22.5</td><td>53.0</td></tr>
<tr><td>2x3</td><td>207.32xx.9xxx</td><td>70.0</td><td>76.0</td><td>43.0</td><td>60.3</td><td>38.2</td><td>42.85</td><td>49.2</td><td>52.4</td></tr>
<tr><td>1½x2/3</td><td rowspan="3">H</td><td>207.25xx.9xxx</td><td rowspan="3">28.3</td><td>56.0</td><td>62.0</td><td rowspan="18">53.0</td><td>48.3</td><td>27.9</td><td>33.99</td><td>38.1</td><td>41.0</td></tr>
<tr><td rowspan="2">2x3</td><td>207.29xx.9xxx</td><td>72.0</td><td>78.0</td><td rowspan="3">60.3</td><td rowspan="3">38.2</td><td>42.85</td><td rowspan="3">49.2</td><td rowspan="3">52.4</td></tr>
<tr><td>207.31xx.9xxx</td><td>70.0</td><td>76.0</td><td>42.85</td></tr>
<tr><td>2x3</td><td rowspan="2">J</td><td>207.30xx.9xxx</td><td rowspan="2">36.0</td><td>72.0</td><td>78.0</td><td>42.85</td></tr>
<tr><td>3x4</td><td>207.35xx.9xxx</td><td rowspan="6">110.0</td><td rowspan="6">116.0</td><td rowspan="14">114.0</td><td rowspan="6">80.1</td><td rowspan="6">87.3</td><td rowspan="6">97.2</td><td rowspan="6">102.0</td></tr>
<tr><td rowspan="2">3x4</td><td rowspan="4">K</td><td>207.33xx.9xxx</td><td rowspan="4">43.0</td></tr>
<tr><td>207.33xx.9xxx</td></tr>
<tr><td rowspan="2">4x6</td><td>207.41xx.9xxx</td></tr>
<tr><td>207.42xx.9xxx</td></tr>
<tr><td>3x4</td><td rowspan="4">L</td><td>207.34xx.9xxx</td><td rowspan="4">53.5</td></tr>
<tr><td rowspan="3">4x6</td><td>207.37xx.9xxx</td><td rowspan="8">136.0</td><td rowspan="8">142.0</td><td rowspan="12">-</td><td rowspan="12">-</td><td rowspan="8">92.05</td><td rowspan="8">97.18</td><td rowspan="8">102.26</td></tr>
<tr><td>207.39xx.9xxx</td></tr>
<tr><td>207.43xx.9xxx</td></tr>
<tr><td rowspan="2">4x6</td><td rowspan="2">M</td><td>207.38xx.9xxx</td><td rowspan="2">60.3</td></tr>
<tr><td>207.44xx.9xxx</td></tr>
<tr><td>4x6</td><td>N</td><td>207.40xx.9xxx</td><td>66.0</td></tr>
<tr><td rowspan="2">4x6</td><td rowspan="2">P</td><td>207.45xx.9xxx</td><td rowspan="2">80.0</td></tr>
<tr><td>207.46xx.9xxx</td></tr>
<tr><td>6x8</td><td>Q</td><td>207.47xx.9xxx</td><td>105.5</td><td rowspan="3">180.0</td><td rowspan="3">187.0</td><td rowspan="4">70.0</td><td rowspan="3">168.3</td><td rowspan="4">-</td><td rowspan="3">146.3</td><td rowspan="3">154.1</td></tr>
<tr><td>6x8</td><td rowspan="2">R</td><td>207.48xx.9xxx</td><td rowspan="2">126.0</td></tr>
<tr><td>6x10</td><td>207.57xx.9xxx</td></tr>
<tr><td>8x10</td><td>T</td><td>207.59xx.9xxx</td><td>161.5</td><td>234.1</td><td>241.1</td><td>219.1</td><td>193.7</td><td>202.7</td></tr>
</table>

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		G4-31 (XXS) G4-34 (160) G4-40 (80, 40)	152.4					96.9						
3x4	K													
4x6														
3x4	L					152.4					96.9		7/8"	92.1
4x6														
4x6	M	G4-40 (80, 40)												
4x6	N													
4x6	P													
6x8	Q		-					-						
6x8	R	G6-62 (80, 40)				222.2					122.3		1 1/8"	117.5
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		
1 ½ x 2/3	F												
1 ½ x 2/3	G												
2x3		G2-14 (XXS) G2-16 (160) G2-20 (80, 40)		47.5		52.4			68.3		82.5		
1 ½ x2/3	H	G1½-11 (XXS) G1 ½ -14 (160, 80, 40)	40.9	40.9		40.9		66.7	66.7		66.7		
2x3		G2-14 (XXS) G2-16 (160) G2-20 (80, 40)		47.5		52.4			68.3		82.5		6.3
2x3	J				-					-			
3x4		G4-31 (XXS) G4-34 (160) G4-40 (80, 40)	82.5	93.7				114.3	127				
3x4	K												
4x6													
3x4	L					103					139.7		
4x6													
4x6	M	G4-40 (80, 40)											
4x6	N												
4x6	P												
6x8	Q		-					-					
6x8	R	G6-62 (80, 40)				154					200		9.5
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 Z

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.

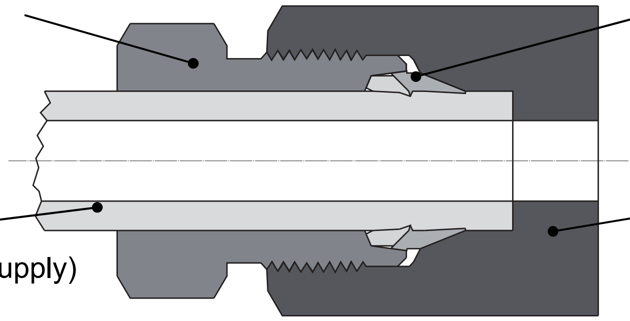


Figure 10.10.1-1: Exemplary sketch of a compression fitting with cutting ring

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.

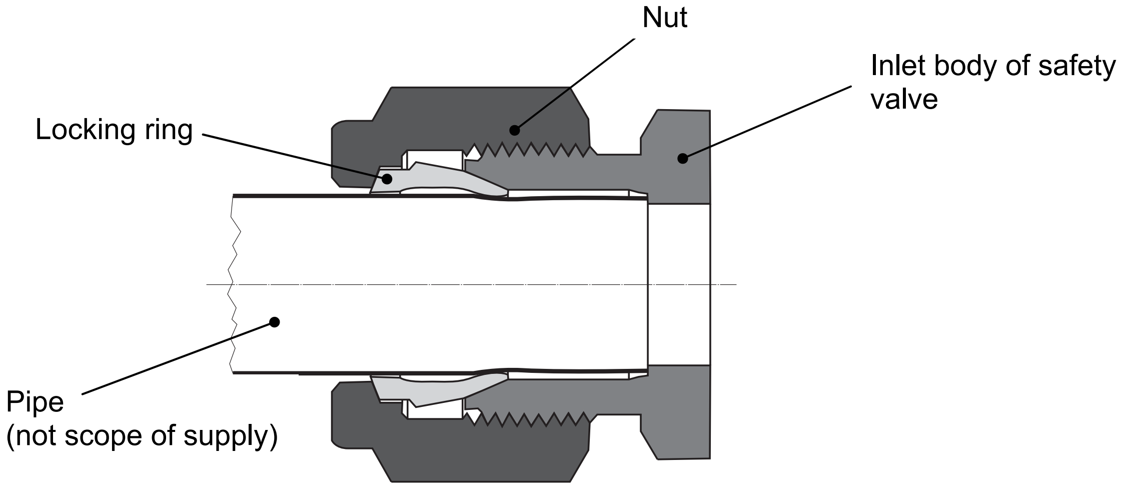


Figure 10.10.2-1: Exemplary sketch of a compression fitting with locking ring

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

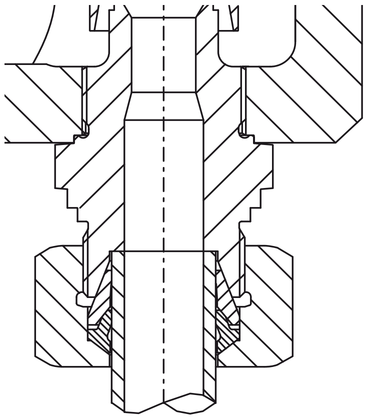


Figure 10.10.2-2: Swagelok compression fitting with double locking ring

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

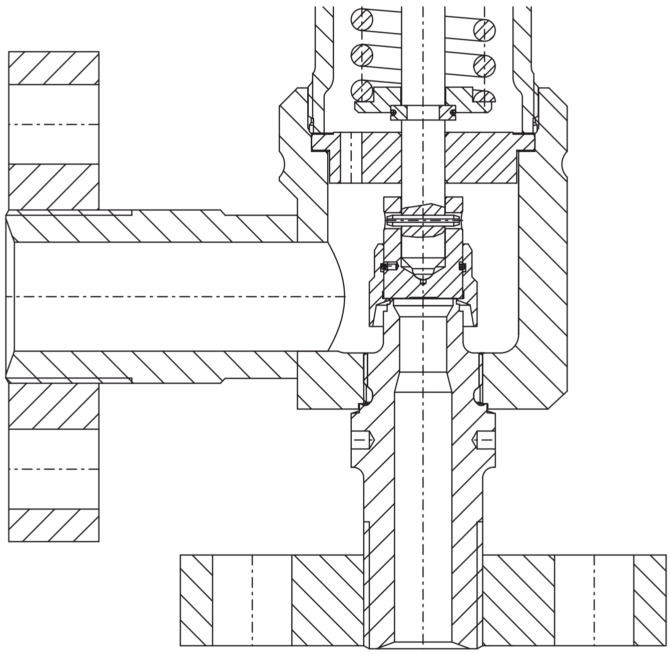


Figure 10.11 -1: IG-Flange connection

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
- KTA 1401
- Chinese Manufacture Licensing System
- GOST Russia
- GOST Kazakhstan
- PROMATOMNADZOR (Belarus)
- 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.

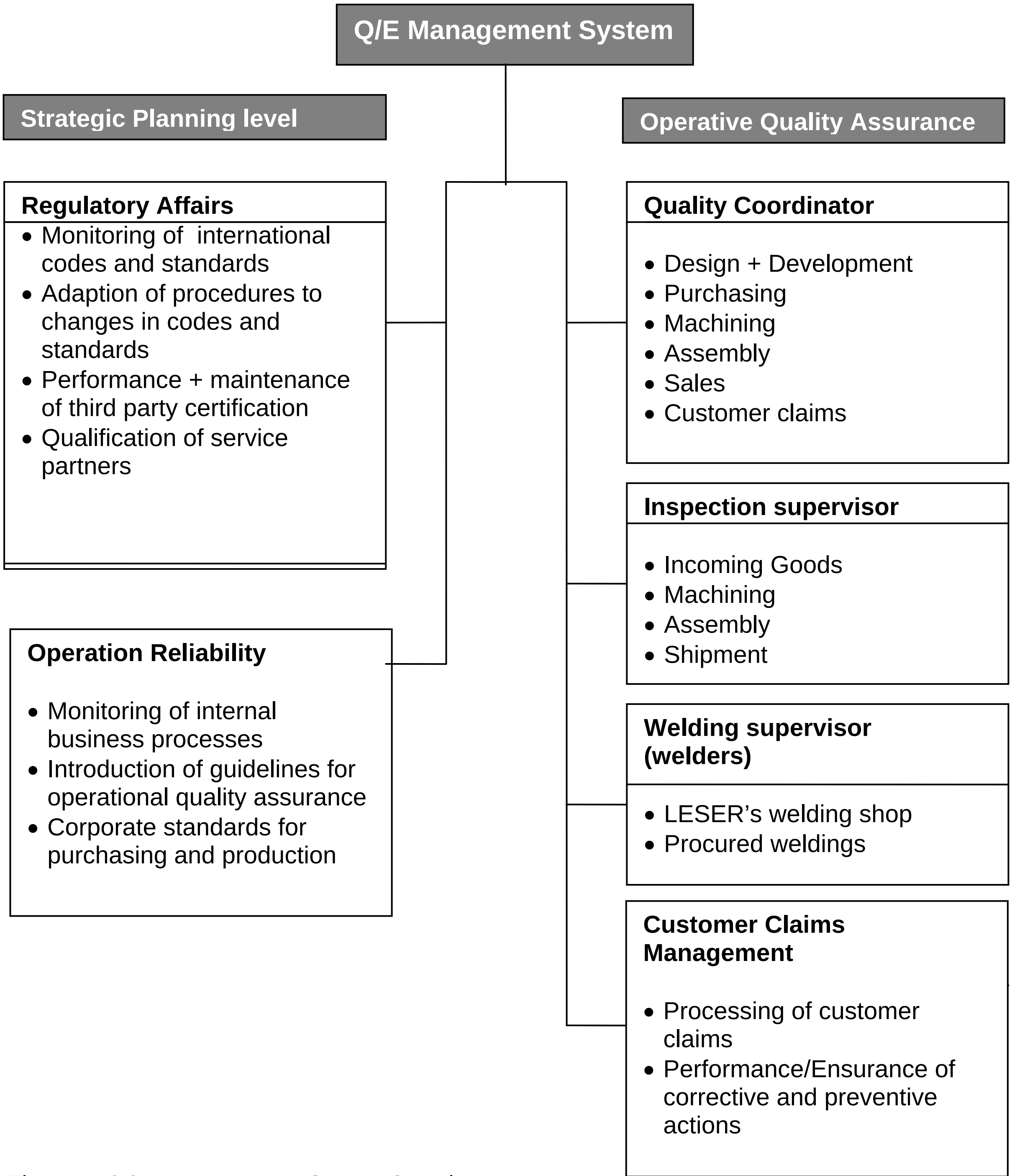


Figure 11.2.2-1: Management System Overview

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.

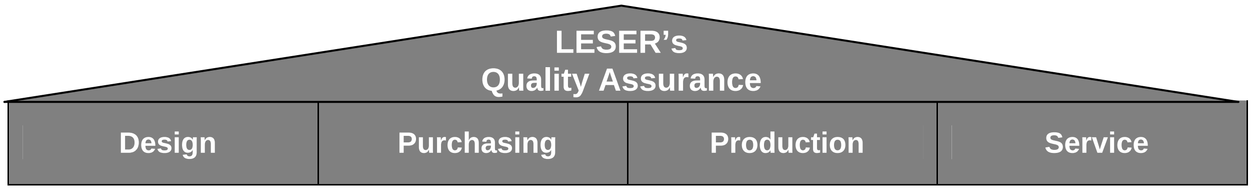


Figure 11.3-1 Quality Assurance at LESER

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, LWN 220.01
- 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:

- LWN 290.01 through LWN 290.08: Purchasing specification for casting materials
- LWN 040.01: Purchasing specification for bar materials
- LWN 265.01: Purchasing specification for 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 LWN 612.24 and 612.28
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: 6 sample lot for each new part with first sample inspection performed by supplier	First sample inspection requirements are laid down in LWN 221.15.
5	First sample inspection process at LESER - review of material certificate, spectral analysis - 100% incoming inspection of samples, dimensional check, ultrasonic or radiographic test - machining of all samples with tools used during serial production: shows possible internal defects - documentation of results in a specific first sample test report form - result: approved, approved with conditions, not approved…	ISO 9001, PED 97/23/EC, ASME VIII App. 10. First sample inspection requirements are laid down in LWN 221.15.
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. Castings are not sourced in 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. 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.

Gültig bis 31. Oktober 2011

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.

Valid until 31st October 2011

Hohenwestedt, den 31. Oktober 2008

Leiter Qualitätsmanagement / Quality Manager:

LESER The Safety 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 (Inspection Certificate 3.1 according to DIN EN 10204)	ASME Code Sec VIII API 526 DIN EN ISO 4126 DIN EN 12266 1/2 PED 97/23/EG AD 2000-A2 VDTÜV SV 100	H 03

Table 11.5.2-1: Requirements for standard tests

11.5.3 Procedures

LESER's test procedures are documented in LESER work standards - LWN. 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
Body tightness	LWN 331.14
Hydrostatic strength test	LWN 331.09/331.18
NDE-tests	LWN 331.03 to 331.06
Material identification test	LWN 331.07
Seat Tightness	LWN 331.13/331.16

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.

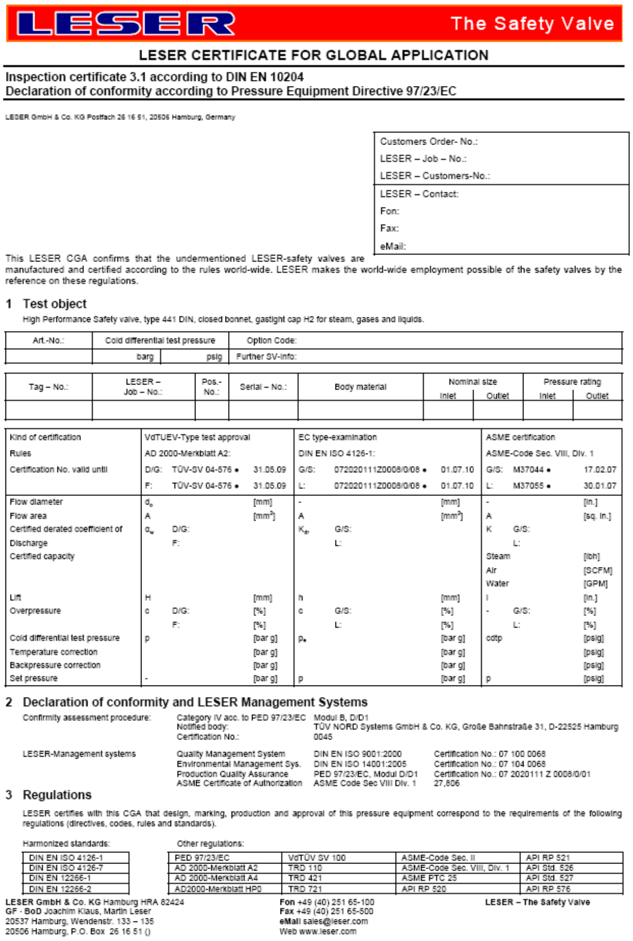
11.5.5 Standard Test – LESER Certificate for Global Application (CGA)

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".



LESER The Safety Valve

LESER CERTIFICATE FOR GLOBAL APPLICATION

Inspection certificate 3.1 according to DIN EN 10204
Declaration of conformity according to Pressure Equipment Directive 97/23/EC

LESER GmbH & Co. KG Postfach 26 16 51, 20506 Hamburg, Germany

Customers Order- No.:
LESER – Job – No.:
LESER – Customers-No.:
LESER – Contact:
Fon:
Fax:
eMail:

This LESER CGA confirms that the undermentioned LESER-safety valves are manufactured and certified according to the rules world-wide. LESER makes the world-wide employment possible of the safety valves by the reference on these regulations.

1 Test object

High Performance Safety valve, type 441 DIN, closed bonnet, gastight cap H2 for steam, gases and liquids.

Art.-No.:	Cold differential test pressure		Option Code:
	barg	psig	Further SV-Info:

Tag – No.:	LESER – Job – No.:	Pos.-No.:	Serial – No.:	Body material	Nominal size Inlet	Nominal size Outlet	Pressure rating Inlet	Pressure rating Outlet

Kind of certification	VdTUEV-Type test approval	EC type-examination	ASME certification
Rules	AD 2000-Merkblatt A2:	DIN EN ISO 4126-1:	ASME-Code Sec. VIII, Div. 1
Certification No. valid until	D/G: TÜV-SV 04-576 • 31.05.09 F: TÜV-SV 04-576 • 31.05.09	G/S: 072020111Z0008/0/08 • 01.07.10 L: 072020111Z0008/0/08 • 01.07.10	G/S: M37044 • 17.02.07 L: M37055 • 30.01.07
Flow diameter	d_o [mm]	- [mm]	- [in.]
Flow area	A [mm²]	A [mm²]	A [sq. in.]
Certified derated coefficient of Discharge	α_w D/G: F:	K_{dr} G/S: L:	K G/S: L:
Certified capacity			Steam [lbh] Air [SCFM] Water [GPM]
Lift	H [mm]	h [mm]	l [in.]
Overpressure	c D/G: [%] F: [%]	c G/S: [%] L: [%]	- G/S: [%] L: [%]
Cold differential test pressure	p [bar g]	p_e [bar g]	cdtp [psig]
Temperature correction	[bar g]	[bar g]	[psig]
Backpressure correction	[bar g]	[bar g]	[psig]
Set pressure	- [bar g]	p [bar g]	p [psig]

2 Declaration of conformity and LESER Management Systems

Confirmity assessment procedure:	Category IV acc. to PED 97/23/EC Notified body: Certification No.:	Modul B, D/D1 TÜV NORD Systems GmbH & Co. KG, Große Bahnstraße 31, D-22525 Hamburg 0045	
LESER-Management systems	Quality Management System	DIN EN ISO 9001:2000	Certification No.: 07 100 0068
	Environmental Management Sys.	DIN EN ISO 14001:2005	Certification No.: 07 104 0068
	Production Quality Assurance	PED 97/23/EC, Modul D/D1	Certification No.: 07 2020111 Z 0008/0/01
	ASME Certificate of Authorization	ASME Code Sec VIII Div. 1	27,806

3 Regulations

LESER certifies with this CGA that design, marking, production and approval of this pressure equipment correspond to the requirements of the following regulations (directives, codes, rules and standards).

Harmonized standards:

DIN EN ISO 4126-1
DIN EN ISO 4126-7
DIN EN 12266-1
DIN EN 12266-2

Other regulations:

PED 97/23/EC	VdTÜV SV 100	ASME-Code Sec. II	API RP 521
AD 2000-Merkblatt A2	TRD 110	ASME-Code Sec. VIII, Div. 1	API Std. 526
AD 2000-Merkblatt A4	TRD 421	ASME PTC 25	API Std. 527
AD2000-Merkblatt HP0	TRD 721	API RP 520	API RP 576

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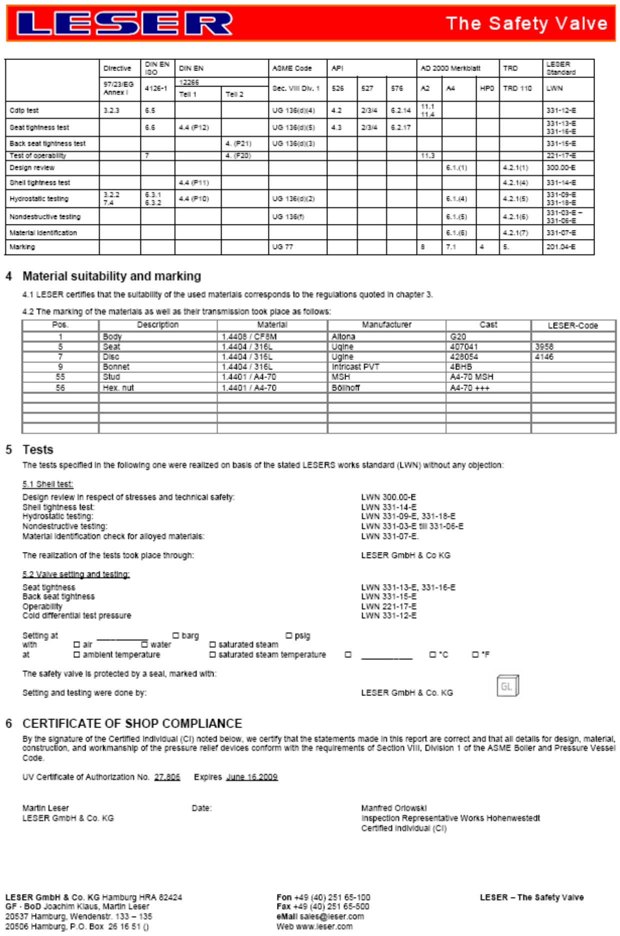
LESER – The Safety Valve



LESER The Safety Valve

	Directive	DIN EN ISO	DIN EN		ASME Code	API			AD 2000 Merkblatt			TRD	LESER Standard
	97/23/EG Annex I	4126-1	12266 Teil 1	Teil 2	Sec. VIII Div. 1	526	527	576	A2	A4	HP0	TRD 110	LWN
Cdtp test	3.2.3	6.5			UG 136(d)(4)	4.2	2/3/4	6.2.14	11.1 11.4				331-12-E
Seat tightness test		6.6	4.4 (P12)		UG 136(d)(5)	4.3	2/3/4	6.2.17					331-13-E 331-16-E
Back seat tightness test				4. (P21)	UG 136(d)(3)								331-15-E
Test of operability		7		4. (F20)					11.3				221-17-E
Design review										6.1.(1)		4.2.1(1)	300.00-E
Shell tightness test			4.4 (P11)									4.2.1(4)	331-14-E
Hydrostatic testing	3.2.2 7.4	6.3.1 6.3.2	4.4 (P10)		UG 136(d)(2)					6.1.(4)		4.2.1(5)	331-09-E 331-18-E
Nondestructive testing					UG 136(f)					6.1.(5)		4.2.1(6)	331-03-E – 331-06-E
Material identification										6.1.(6)		4.2.1(7)	331-07-E
Marking					UG 77				8	7.1	4	5.	201.04-E

4 Material suitability and marking

4.1 LESER certifies that the suitability of the used materials corresponds to the regulations quoted in chapter 3.

4.2 The marking of the materials as well as their transmission took place as follows:

Pos.	Description	Material	Manufacturer	Cast	LESER-Code
1	Body	1.4408 / CF8M	Altona	G20	
5	Seat	1.4404 / 316L	Ugine	407041	3958
7	Disc	1.4404 / 316L	Ugine	428054	4146
9	Bonnet	1.4404 / 316L	Intricast PVT	4BHB	
55	Stud	1.4401 / A4-70	MSH	A4-70 MSH	
56	Hex. nut	1.4401 / A4-70	Böllhoff	A4-70 +++	

5 Tests

The tests specified in the following one were realized on basis of the stated LESERS works standard (LWN) without any objection:

5.1 Shell test:

Design review in respect of stresses and technical safety: LWN 300.00-E
Shell tightness test: LWN 331-14-E
Hydrostatic testing: LWN 331-09-E, 331-18-E
Nondestructive testing: LWN 331-03-E till 331-06-E
Material identification check for alloyed materials: LWN 331-07-E.

The realization of the tests took place through: LESER GmbH & Co KG

5.2 Valve setting and testing:

Seat tightness LWN 331-13-E, 331-16-E
Back seat tightness LWN 331-15-E
Operability LWN 221-17-E
Cold differential test pressure LWN 331-12-E

Setting at ________ ☐ barg ☐ psig
with ☐ air ☐ water ☐ saturated steam
at ☐ ambient temperature ☐ saturated steam temperature ☐ ________ ☐ °C ☐ °F

The safety valve is protected by a seal, marked with:

Setting and testing were done by: LESER GmbH & Co. KG

6 CERTIFICATE OF SHOP COMPLIANCE

By the signature of the Certified Individual (CI) noted below, we certify that the statements made in this report are correct and that all details for design, material, construction, and workmanship of the pressure relief devices conform with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

UV Certificate of Authorization No. 27.806 Expires June 16.2009

Martin Leser
LESER GmbH & Co. KG

Date:

Manfred Orlowski
Inspection Representative Works Hohenwestedt
Certified Individual (CI)

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Web www.leser.com
LESER – The Safety Valve

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 4126-1, chapter 7.2 ASME Code Section I, PG-72 ASME Code Section VIII Div. 1, UG 134; Ad 2000-Merkblatt A2, chapter 11	LWN 331-12	N05
Body strength test			
Inspection certificate 3.1 acc. to DIN EN 10204: Hydrostatic testing 1,5 x PN	DIN EN ISO 4126-1: ASME Code Sec. VIII Div. 1, UG 136(d)(2)	LWN 331-09	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. 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. Inspection certificate 3.1 acc. to DIN EN 10204: Surface crack test	AD 2000-Merkblatt A4, chapter 6 ASME Code, Section VIII Div.1, UG 136	LWN 331-03 LWN 331-04	M44
Tightness			
Overview of different tightness test		LWN 331-17	
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; DIN EN 12266-1, ASME Code Section VIII Div. 1, UG 136(d)(5); API 527	LWN 331-13	M66
Inspection certificate 3.1 acc. to DIN 10204: Seat tightness with air, test fluid	DIN EN ISO 4126-1; DIN EN 12266-1, ASME Code Section VIII Div. 1, UG 136(d)(5); API 527	LWN 331-13	M22
Pressure retaining body			
Inspection certificate 3.1 acc. to DIN EN 10204: Shell tightness test	DIN EN 12266-1, 4.2	LWN 331-14	M18
Back seat tightness test (tightness outwards)			
Flanged Safety valves 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)	LWN 331-15	M28
Compact Performance Safety valves Inspection certificate 3.1 acc. to DIN EN 10204: Back seat tightness test, dipping procedure		LWN 331-15	M78
Design review of safety valve			
Design review in respect of stresses and technical safety Inspection certificate 3.1 acc. to DIN EN 10204: Design review	AD 2000-Merkblatt A4, chapter 6 par. 6.1 TRD 110, chapter 4.2	LWN 300-00	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. Inspection certificate 3.1 acc. to DIN EN 10204: Material identification check (PMI)	AD 2000-Merkblatt A4, chapter 6, par. 6.1(6)	LWN 331-07	M46
Body volume check			
Inspection certificate 3.1 acc. to DIN EN 10204: Ultrasonic test	AD 2000-Merkblatt A4,chapter 6 ASME Code, Section VIII Div. 1, UG-136	LWN 331-05	M56
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	LWN 331-06	M80

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 Inspection certificate 3.1 acc. to DIN EN 10204 included	Customer specification (Please note: Test pressure and test duration must be specified.)	LWN 331-18	M01
Tightness			
Overview of different tightness test		LWN 331-17	
Seat tightness test with air, bubble test - Increased tightness requirements Inspection certificate 3.1 acc. to DIN EN 10204 included	DIN EN ISO 4126-1; DIN EN 12266-1, ASME Code Section VIII Div. 1, UG 136(d)(5); API 527	LWN 331-13	J86
Tightness: Helium leakage test			
Back seat tightness test with helium Inspection certificate 3.1 acc. to DIN EN 10204 included	DIN EN 12266-2, Test P21 ASME Code Section VIII, Part UG-136(d)	LWN 331-15	N64
Seat tightness test with helium, overpressure procedure - Inspection certificate 3.1 acc. to DIN EN 10204 included	DIN EN ISO 4126-1 DIN EN 12266-1, Test P12 ASME Code Section VIII, Part UG-136(d) API 527	LWN 331-16	N62
Seat tightness test with helium, leakage detection in vacuum - Inspection certificate 3.1 acc. to DIN EN 10204 included		LWN 331-16	M86
Testing of substances			
Testing that all parts are free of oil and grease - Inspection certificate 3.1 acc. to DIN EN 10204 included	LWN 331-10	LWN 331-10	J85
Testing that all parts are free of paint-wetting impairment substances (PWIS-free) - Inspection certificate 3.1 acc. to DIN EN 10204 included	LWN 331-11	LWN 331-11	J74
Surface crack test			
Surface crack testing to components can be conducted according to customer specifications. Components such as discs, seat/nozzle and bodies/inlet bodies are to be specified by the customer. LESER determines the corresponding test method for the component and material. The tests conducted on the individual components are verified with an inspection certificate 3.1 according to DIN EN 10204.			
Inspection certificate 3.1 acc. to DIN EN 10204: Surface crack test	AD 2000-Merkblatt A4, chapter 6 ASME Code, Section VIII Div 1, UG 136	LWN 331-03 LWN 331-04	
- Disc			N52
- Seat / nozzle			N53
- Body / inlet body			N54

Specific Tests at LESER			
Test	**Directive**	**Procedure**	**Option Code**
Surface roughness			
Clean Service Safety valves			
The surface qualities for LESER Clean Service Safety valves are defined in LWN 325-14 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 - Clean finish - HyClean finish - Sterile finish			B50-B79
Inspection certificate 3.1 acc. to DIN EN 10204: Surface roughness	DIN EN ISO 11866 ASME BPE 2002 Part SD	LWN 331-01	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	Customer specification	LWN 331-01	N04
Testing of components			
Specification acc. to NACE Inspection certificate 3.1 acc. to DIN EN 10204 included Components: Body, seat / nozzle and disc	NACE Standard MR0175-2003	LWN 331-08	N78
Material identification check			
Customer-specific Material identification checking to components can be conducted according to customer specifications. The components such as discs, seat / nozzle and bodies / inlet bodies are to be specified by the customer. The tests conducted on the individual components are verified with an inspection certificate 3.1 according to DIN EN 10204.			
Material identification check (PMI) Inspection certificate 3.1 acc. to DIN EN 10204 included	AD 2000-Merkblatt A4, chapter 6, par. 6.1 (6)	LWN 331-07	
- Disc			N55
- Seat / Nozzle			N56
- Body / inlet body			N57

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 AD 2000-Merkblatt HP 512R chapter 5 HP 512 chapter 7 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 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
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
Other components		
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
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 LWN 248.26 (download from website) and contact LESER by
Fax +49 (4871) 27 - 296
E-mail certificate@leser.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. In several standards the marking of nameplates is defined, e.g.:

- ISO 4126-1, chapter 10.2
- ASME Code Section VIII, Div 1, UG-129
- AD Merkblatt 2000 A2, chapter 9
- VdTÜV Merkblatt SV100, chapter 8
- API 526, Appendix B

These standards differ in some requirements. LESER combines these requirements and uses one nameplate. The LESER safety valves have global approvals and with the Nameplate for Global Application “NGA” the safety valve can be used worldwide. Some safety valves are too small for this nameplate. In these cases LESER uses two different smaller nameplates: the nameplates “ASME” and “CE”. These nameplates are used for following types:

- Series 437 and type 481
- Type 483, 484, 485 d_0 = 13mm

For the identification of the safety valve the serial number is sufficient.

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

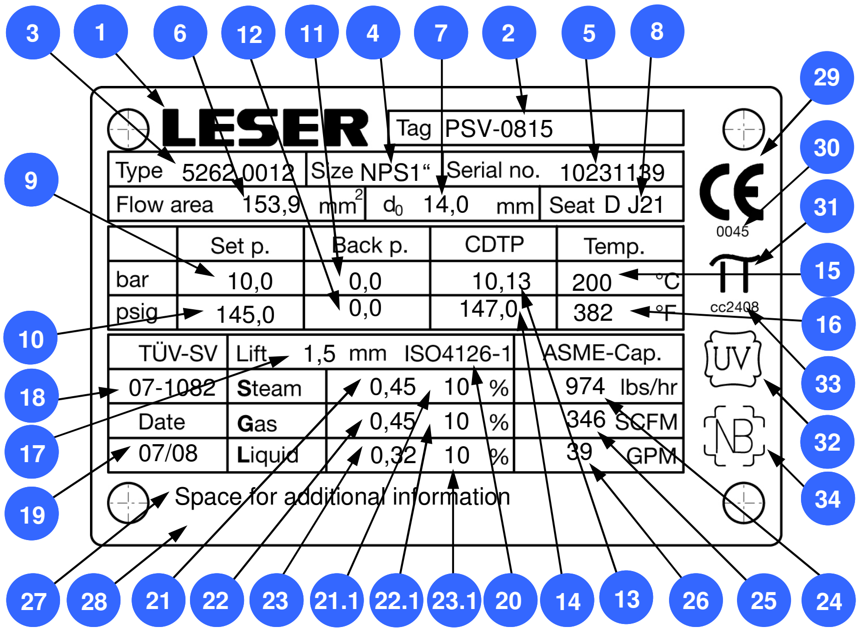


Figure 12.3.1-1: LESER Nameplate for Global Application “NGA”, valid since January 2009

LESER-Nameplate “ASME”, valid since July 2002
Dimensions: 58 x 15mm/ 2,29 x 0,59 in
Acc: to ASME Sec: VIII; Marking NB UV

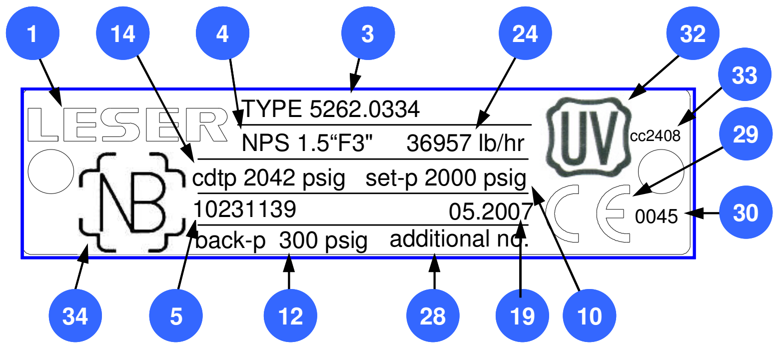


Figure 12.3.1-2: LESER Nameplate “ASME”, valid since July 2002

LESER-Nameplate “CE”, valid since 1998
Dimensions: 58 x 15mm/ 2,29 x 0,59 in

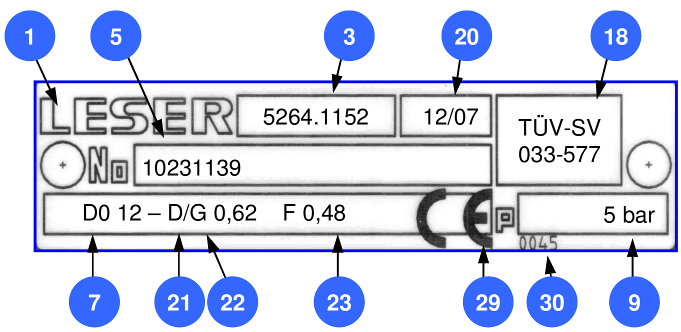


Figure 12.3.1-3: LESER Nameplate “CE”, valid since 1998

No.	Field name	Description	ISO 4126-1	VdTÜV/ AD2000 A2	ASME VIII	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 mm²	X				*
7	do	Flow diameter in mm		X			*
8	Seat	Identification of the soft seal material Code letter O-Ring-Disc + Option code 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					*
12	Back p. - psig	Back pressure in psig				X	*
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}/ α_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}/ α_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}/ α_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			X	X	*
25	ASME-Cap. SCFM	Capacity for gases			X	X	*
26	ASME-Cap. GPM	Capacity for liquids			X	X	*
27	Customised	Space for additional customised information, e.g. Option codes bellows, oil and grease-free If repaired valve: Repair-No. Used for pressures in non code units					M16
28	Customised	Space for additional customised information					M16 1) M25 2)
29	CE	CE-Marking	X	X			*/ N70 3)
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)					*
32	UV	UV-Stamp			X		*
33	cc2408	Code case 2408 for UV-Stamp (UV-stamp is lasered)			X		*
34	NB	Marking of National Board			X		*

Table 12.3.1-1: Description of nameplate markings

* = Standard
1) Optional on ASME Nameplates
2) For nameplate “NGA”
3) For nameplate “ASME”

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

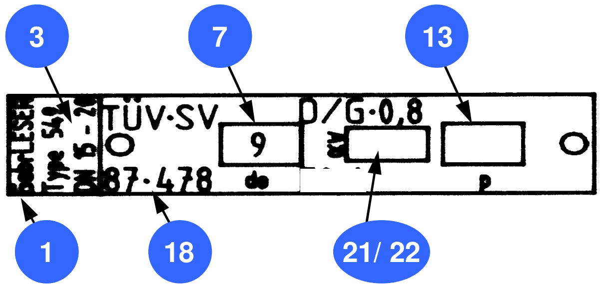


Figure 12.3.2-1: LESER Nameplate before 1990

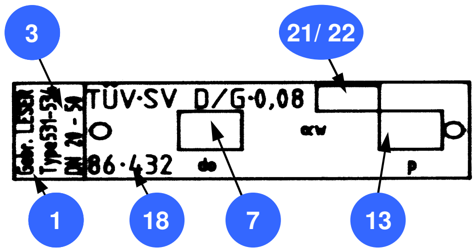


Figure 12.3.2-2: LESER Nameplate before 1990

Nameplate between beginning of 1990 and end of 1997

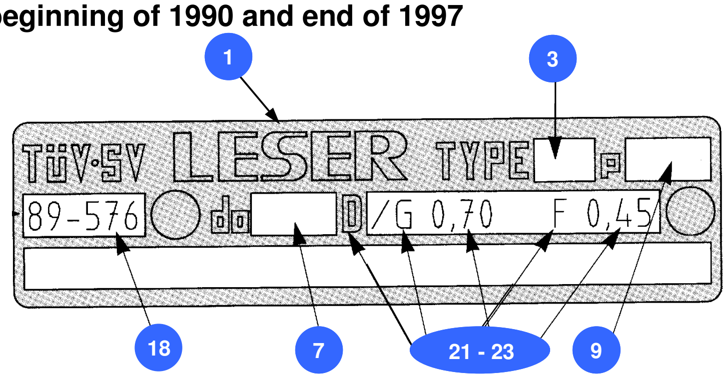


Figure 12.3.2-3: LESER Nameplate 1990 - 1997

Nameplate with UV-Stamp, valid up to July 2002

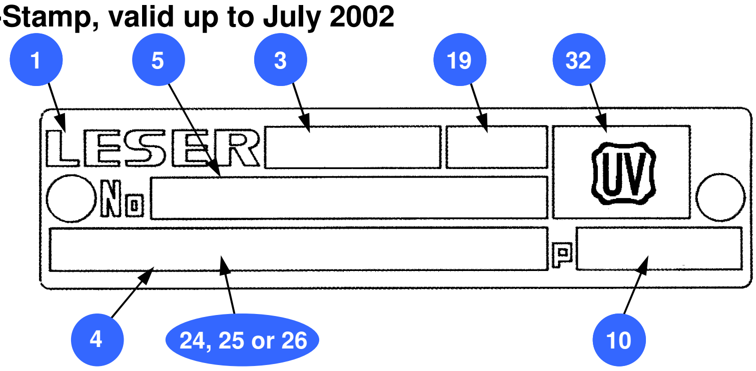
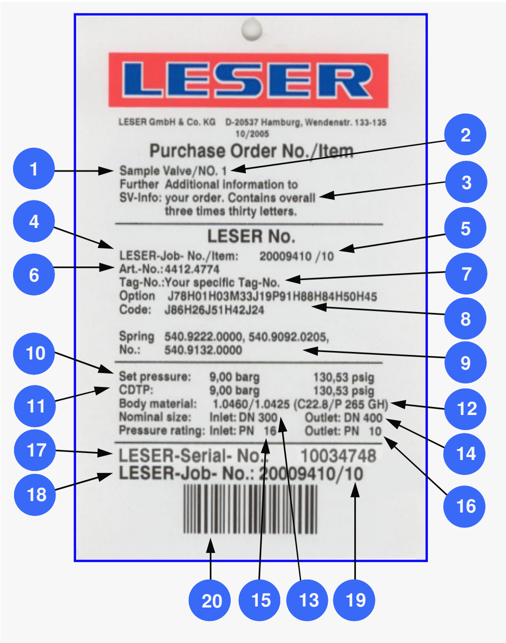


Figure 12.3.2-4: LESER Nameplate with UV stamp until July 2002

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.



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.

Figure 12.4-1: LESER Safety valve tag

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 VIII, Div 1, UG-129
- 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

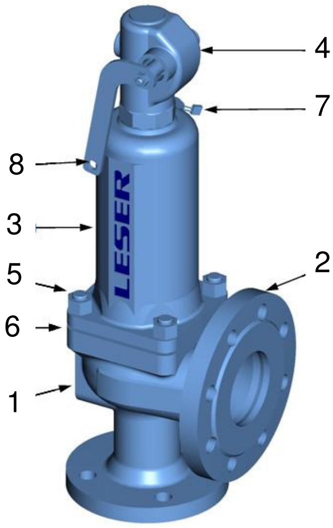


Figure 12.5.1-1: Flanged Safety Valve

No.	Parts of safety valve	Markings on Safety valve	ISO 4126-1	AD 2000 A2	ASME VIII	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, for details refer to LWN 308.04		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

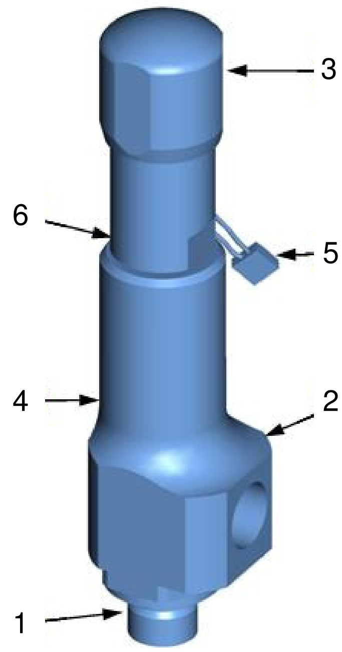


Figure 12.5.2-1: Threaded safety valve

No.	Parts on safety valve	Markings on Safety valve		ISO 4126-1	AD 2000 A2	ASME VIII	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, for details refer to LWN 308.04		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).

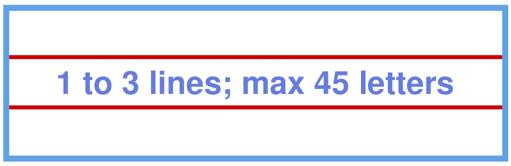


Figure 12.6.1-1: Marking on stainless steel tag

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
Material designation DIN/ ANSI
Name of the factory authorized expert

12.7.2 Markings of Disc – Short Code for Small Sizes

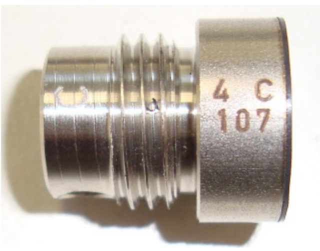


Figure 12.7.2-1: Markings of disc – short code

Part	1	2	3
Disc	4	C	127

Explanation
Material code Number
Soft seal material marked by a code letter M = metallic seal K = CR (Neoprene) D = EPDM L = FKM (Viton) N = NBR (Perbunan)
Classification of the material by a number 3 = 1.4122 4 = 1.4404/ 316L 6 = 1.4404/ 316L stellited 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) D = EPDM L = FKM (Viton) 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

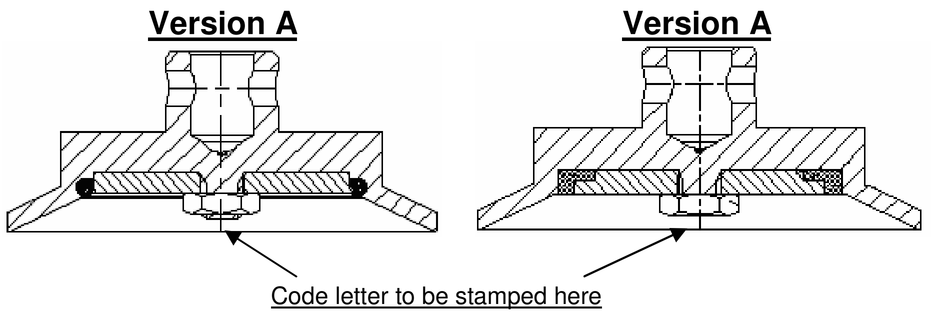


Figure 12.7.3-1: Location of code letter for soft seal

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.

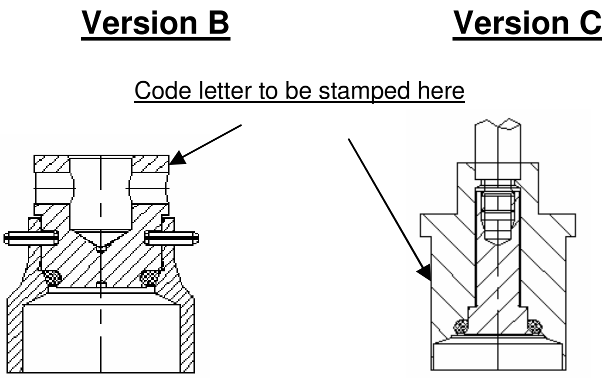


Figure 12.7.3-2: Location of code letter for soft seal

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.

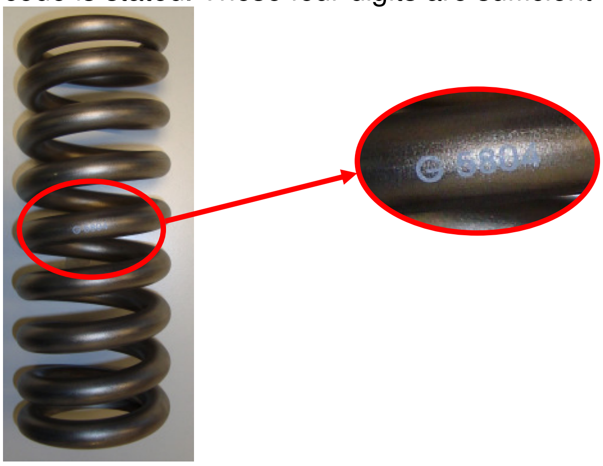


Figure 12.7.6-1: Markings of spring

Part	1	2	3
Spring	G	580	4

Explanation
3 → Material code
2 → Count no.
1 → Spring Supplier code

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	
4 → Defines characteristics of the spring	
3 → Material code For standard materials: 1 = 1.1200 2 = 1.8159/ 1.7102 4 = 1.4310	 Steel Heat resistant steel Stainless steel
2 → Count number	
1 → Part group number 540 = standard spring	

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 (see chapter 8 Selection)
- 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 LWN 220.01 which 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 LWN 331.14 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 LWN 220.04, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME Code, Section VIII, UG 134 (d) (1). 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

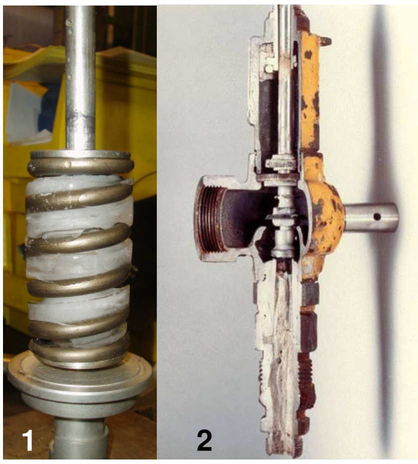


Figure 17.3.2-1: Symptom 6 - Frozen condensate in the bonnet
Figure 17.3.2-2: Symptom 6 - Hardened medium in the inlet area

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 LWN 220.04, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME Code, Section VIII, UG 134 (d) (1). 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 *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 *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 LWN 220.04, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME Code, Section VIII, UG 134 (d) (1). 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	*Recalculate CDTP correction in order to achieve the correct set pressure for the operating condition*
2	Set pressure selected incorrectly	Reset the safety valve	*Reduce set pressure if possible*
3	Superimposed back pressure not taken into account	Reset the safety valve	*Adjust safety valve to the conditions as present:* - *Correct CDTP if back pressure is constant* - *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	*Regular lifting of the safety valve with lifting lever.* *Use a heating jacket or bursting disk*
5	Choice of a unsuitable soft sealing	Replace disc – change material	*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	*Ensure periodical lifting* *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 LWN 220.04, in accordance with DIN EN ISO 4126-1, sect. 7.2.1 a) and ASME Code, Section VIII, UG 134 (d) (1). 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	*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	*Use stainless steel bellows*
3	Bonnet is corroded by medium - guide and spindle are stuck	Repair or replace internal parts	*Use stainless steel bellows*
4	Medium is hardened in the inlet area	Repair or replace safety valve	*Change dimensions of the inlet pipe to obtain a shorter, wider inlet* *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* *Allow proper drainage of bonnet, body and outlet pipe* *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: The safety valve does not close within the blow down limits of the applicable codes and standards. **Standard tests at LESER:** Every safety valve is leak tested by LESER at 90% of the set pressure according to LESER standard LWN 220.01 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: The safety valve does not close at all, but remains open far below the set pressure. **Standard tests at LESER:** Every safety valve is leak tested by LESER at 90% of the set pressure according to LESER standard LWN 220.01 which is based on API Standard 527.	
No.	Failure Cause	Action *Preventive measure*
1	Spring broken due to - medium/ corrosion - steam operation	Replace spring – change material *Use stainless steel spring, stainless steel bellows and/ or an open bonnet* *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

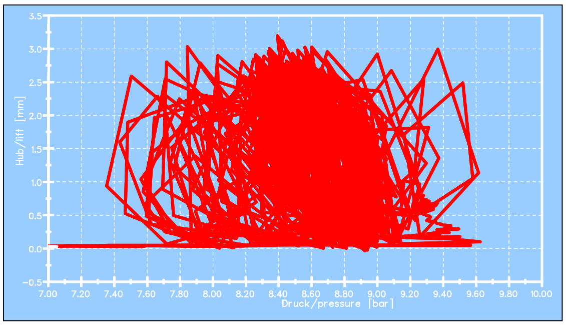


Figure 17.3.3-1: Symptom 9 - Safety valve is chattering

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. *Adjust the safety valve's capacity to the conditions present by means of lift restriction* *Apply an O-ring damper* *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 *Adjust the safety valve's capacity to the required capacity by means of lift restriction* *Use stainless steel bellows* *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 *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	*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:** 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	*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* *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:** Lift is the actual travel of the disc from the closed position when a valve is relieving. (API 520 1.2.2.8) Maximum lift must be achieved at max. 10% overpressure.		
No.	Failure cause	Action	*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 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:** 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. 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 *Preventive measure*
1	Disc/ Seat material unsuitable for the medium	Replace Seat/ Disc *Use suitable material, e.g. high alloy materials* *Ensure periodical maintenance*
2	Spindle/ guide material unsuitable for the medium	Replace spindle/ guide *Use suitable material, e.g. high alloy materials* *Install stainless steel or high alloy bellows for protection* *Reduce maintenance intervals*
3	Spring material unsuitable for the medium	Replace spring *Check material choice with regard to temperature and medium* *Install stainless steel or high alloy bellows for protection* *Ensure periodical maintenance*
4	Body/ bonnet material unsuitable for the medium	Repair or replace safety valve *Use suitable material, e.g. high alloy materials* *Ensure periodical maintenance* *Use Critical Service valves* *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 *Preventive measure*
1	Corrosive environment (e.g. marine or offshore)	Repair or replace safety valve *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 *Preventive measure*
1	The safety valves has chattered	Repair safety valve *See also symptom 9, "The safety valve is chattering"*
2	The safety valve is soiled	Repair safety valve *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 *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 *Increase set pressure if possible and/ or reduce the operating pressure*
2	The safety valves has chattered	Repair safety valve *For details see symptom 9 "The safety valve is chattering/ fluttering"*
3	Solid matter in liquid	Clean or repair safety valve *Use hardened or stellited seat/ disc*
4	Rust or particles in steam or gas application	Repair safety valve *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:** 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 *Preventive measure*
1	Value of static back pressure too high for the installed stainless steel bellows	Replace stainless steel bellows *Install stronger stainless steel bellows*
2	Material of bellows unsuitable for the application	Replace stainless steel bellows – change material *Use high alloy materials, like Hastelloy*
3	Extensive chattering/ fluttering	Replace stainless steel bellows *For details please see symptom 9, "The safety valve is chattering/ fluttering"*
4	Too high temperature	Replace stainless steel bellows – change material *Use high alloy materials, like Hastelloy*
5	Frozen condensate in the stainless steel bellows	Check or replace stainless steel bellows *Proper drainage of bonnet, body and outlet pipe*
6	Corrosion	Replace stainless steel bellows – change material *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:** 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 Sec. VIII) of set pressure.	
No.	Failure cause	Action *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:** 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"* *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

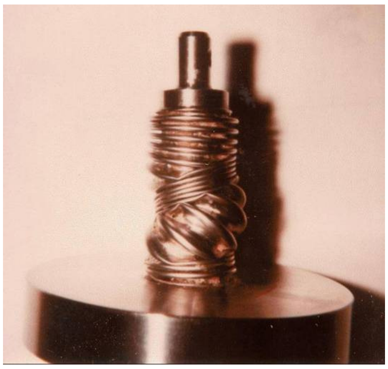


Figure 17.4-1: Twisted stainless steel bellows

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 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: → the stainless steel bellows is twisted	Safety valve does not open 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 - lever with knob - H4 for Clean Service	The safety valves stays open

Table 17.4-1: Typical Mistakes as a Result of Unauthorized Repair