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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.

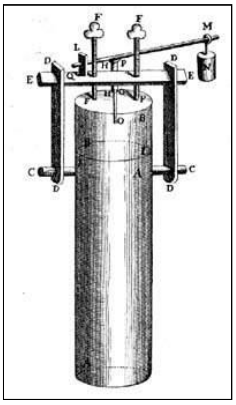


Figure 1.1-1: Early Safety Valve by Denis Papin

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

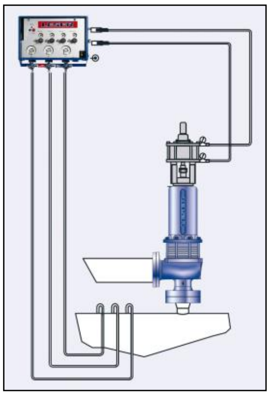


Figure 1.1-5: Controlled Safety Valve

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

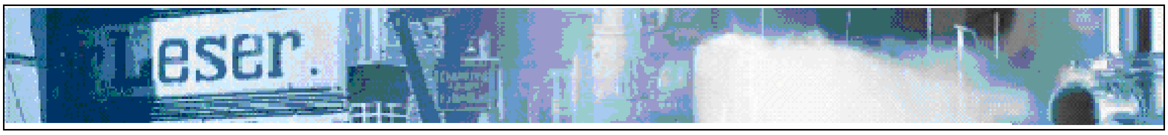
LESER was founded in 1818 as a brass foundry in Hamburg, Germany. In 1885 LESER designed and produced its first safety valve. Since the 1970s LESER has specialized in this product. LESER is now a fifth generation family-owned business and the market leader for industrial safety valves throughout Germany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

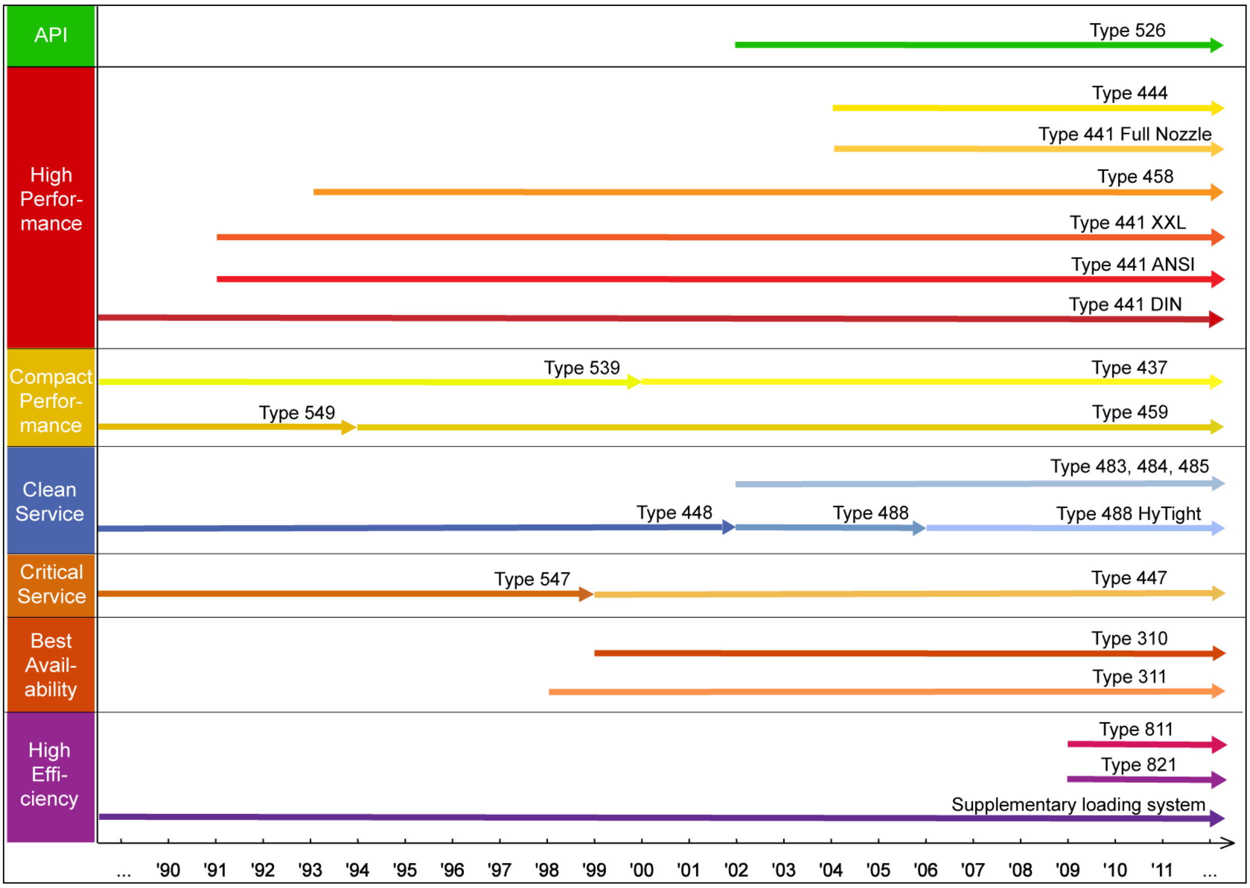


Figure 1.2.1-1: Product development and innovation at LESER

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

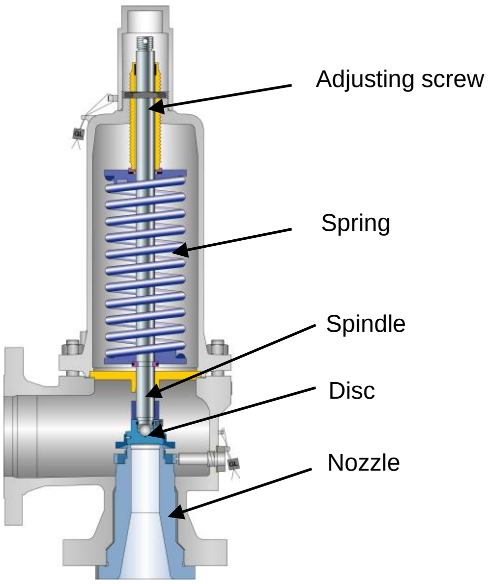


Figure 1.5.1-1: Safety valve

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.

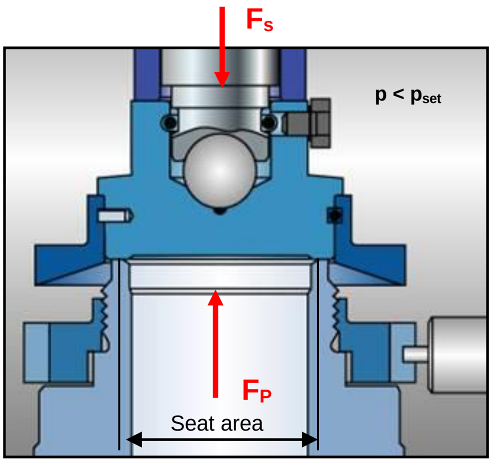


Figure 1.5.1-2: Valve closed

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

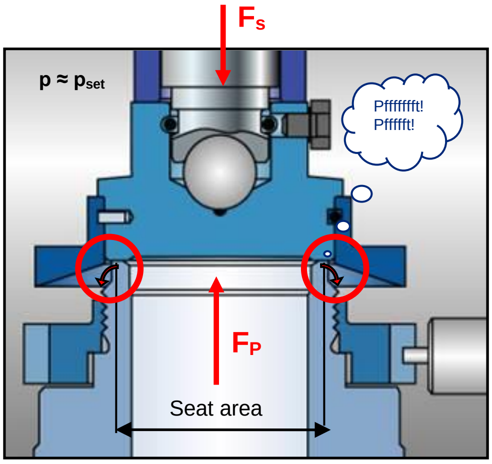
$F_p < F_s$

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.

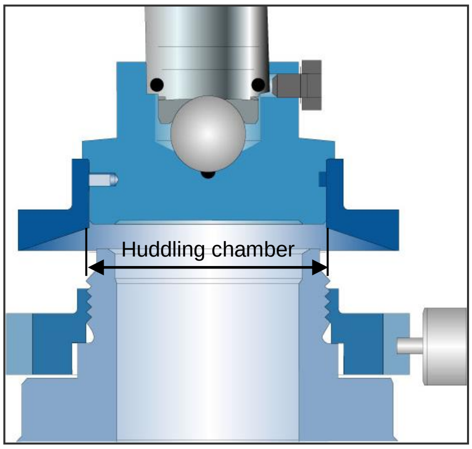


Figure 1.5.2-2: Huddling chamber

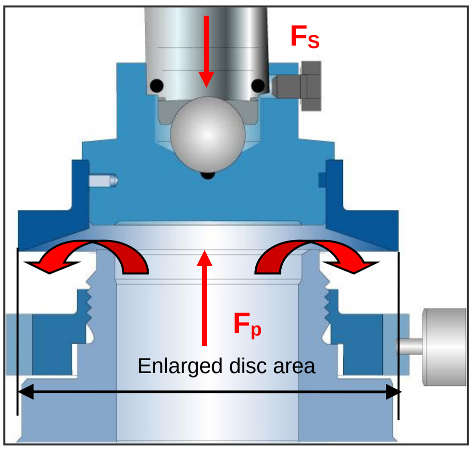


Figure 1.5.2-3: Valve flowing

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.

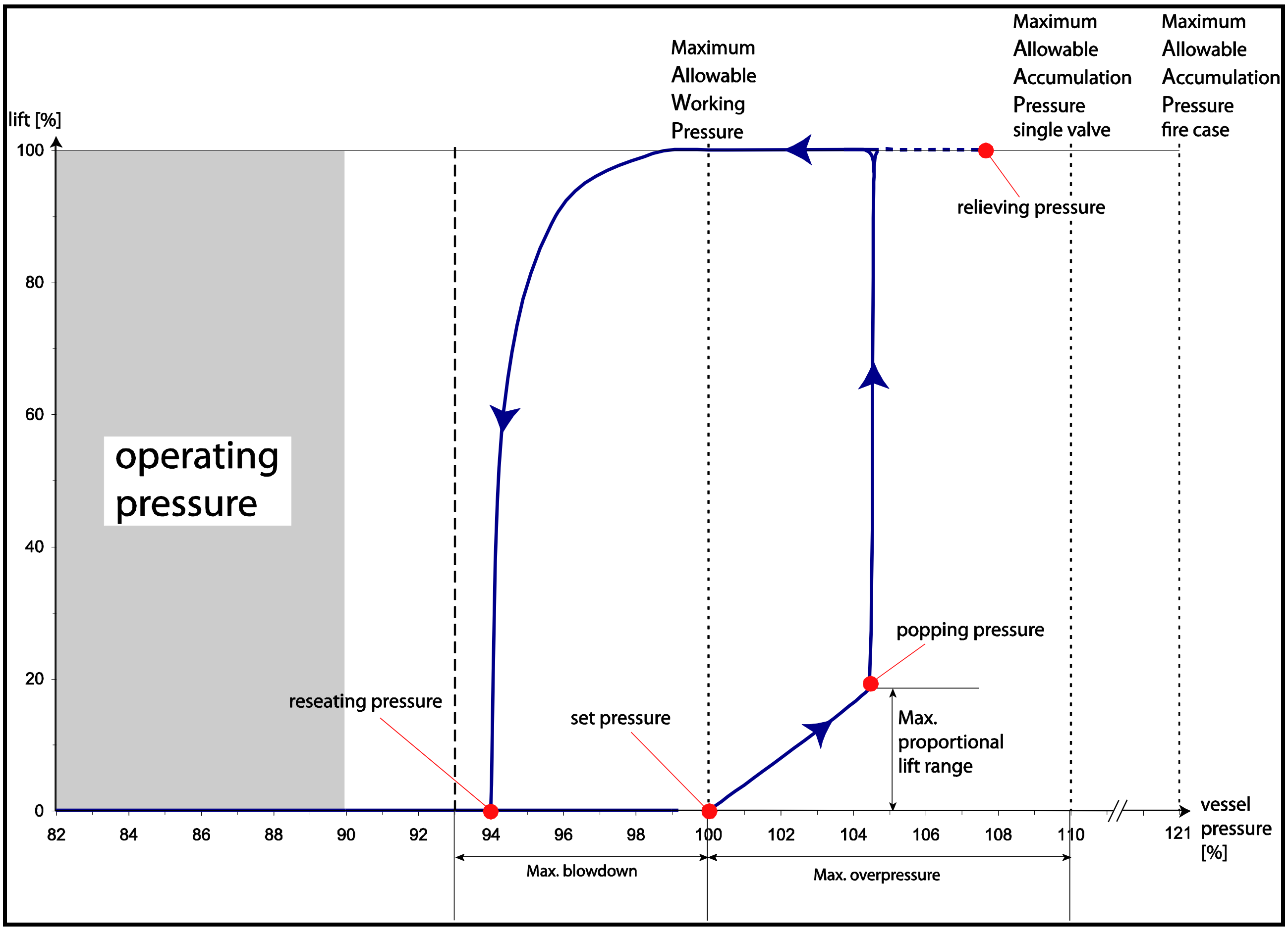


Figure 1.5.4-1: Operation of a Series 526 API safety valve with adjusting ring and initial audible discharge set pressure definition

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.