Content

9.1 Introduction

This chapter shall be a general guideline for the selection of materials for safety valves. Criteria influencing the material selection are explained. These criteria are

- general function of the individual valve component (pressure retaining, guiding, etc.)
- material codes and standards for materials of pressure vessels
- pressure and temperature ratings
- corrosion, resistance to chemical wear
- wear, erosion

An overview about commonly used materials for safety valves is provided with information on their applications and limits as well as codes and standards regulating material requirements.

9.2 General Considerations for the Main Components of a Safety Valve

Safety valves are considered to be part of the pressure vessel or the pressurized system they protect. The selection of materials must be done carefully. Especially for pressure retaining or containing components the selection of materials is regulated by applicable codes and standards.

9.2.1 Pressure Retaining or Pressure Containing Parts

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

The main pressure retaining or containing part of a safety valve is the body. Also the bonnet and the bolting that connects body and bonnet are considered to be part of the pressure retaining shell of the valve and pressure vessel codes typically do have material requirements for bonnet and bolting.
Failure of these components may result in the hazardous exposure to pressure, temperature or chemicals. All materials for pressure retaining parts must fulfill the requirements of the applicable codes and standards.

Pressure vessel codes normally list allowable materials for pressure retaining parts.

For a detailed definition of pressure retaining or containing components acc. to ASME VIII and PED 2014/68/EU refer to chapter 2 Design Fundamentals.

9.2.2 Not Pressure Retaining or Containing Parts

Parts which are not considered to be pressure retaining may be manufactured from materials that are not listed in pressure vessel codes. Failure of these components may result in premature opening and discharge of the safety valve, but does not have the same consequences like a failure of a pressure retaining component.

9.2.3 Application Criteria Influencing the Material Selection

The criteria that generally influence the material selection of safety valve components are:
- pressure
- temperature
- corrosive media or environment
- application specific codes and standards

9.2.4 Critical Parts for Material Selection

A safety valve has a number of parts that are critical for the safe operation and function of the valve. These parts can be classified in to:

- **pressure retaining parts** – retaining the inlet pressure (body) or outlet pressure (bonnet) including body-to-bonnet bolting
- **guiding parts** – providing alignment of the disc to the nozzle, spindle must be moveable at all times
- **permanently medium wetted parts** – parts permanently in contact with the medium, also providing tightness of the valve
- **spring** – providing the force to keep the valve closed
- **bellows** (balanced design only) – providing back pressure compensation and/or corrosion protection of the guiding part and spring

Figure 9.2.4-1 shows these parts in a conventional and a balanced bellows safety valve design.

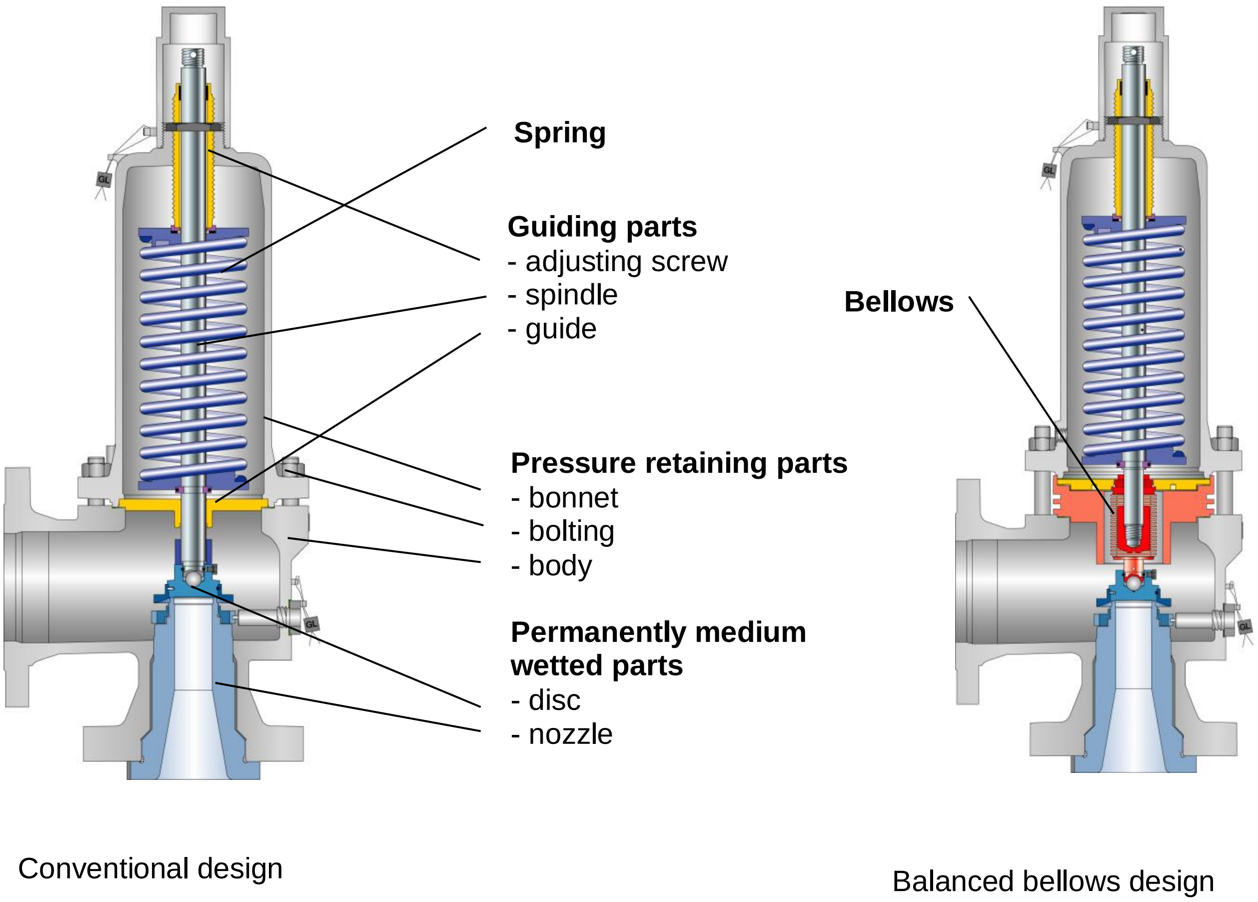


Figure 9.2.4-1: Critical parts for material selection in conventional and balanced bellows designs

Table 9.2.4-1 explains typical materials, product forms and the influence of corrosion on the different components.

Pressure retaining parts: Body / Bonnet	
Effect of Corrosion	Corrosive attack from medium and/or environment. Limited corrosion can be tolerated as long as valve operation and pressure-temperature ratings are not affected.
Typical Materials	Large variety from cast iron, ductile iron, carbon steel, stainless steel, high temperature carbon steels and high alloy materials. Material selection is restricted by applicable codes and standards.
Product form	Mostly castings, but also bar, forgings or welded designs
Pressure retaining parts: Bolting	
Effect of Corrosion	Corrosive attack from environment. Corrosion can typically not be tolerated, because corrosion may result in failure of the pressure retaining shell of the valve.
Typical Materials	Specific bolting materials for pressure purposes must be selected. Material selection is restricted by applicable codes and standards.
Product form	Stud, nut.
Permanently medium wetted parts: Nozzle / Disc	
Effect of Corrosion	Corrosive attack from medium (permanently wetted components). Corrosion can not be tolerated, because corrosion between nozzle and disc may prevent the valve from opening at set pressure.
Typical Materials	Stainless steels, frequently 316 ss is standard material. Hardenable chrome steels or stellited stainless steel for extended product life (erosion).
Product form	Bar, investment castings, forgings
Guiding parts: Guide / Spindle / Adjusting Screw	
Effect of Corrosion	Corrosive attack from medium only when valve opens (not permanently wetted components). Corrosion of guiding surfaces can not be tolerated, because corrosion may prevent the valve from opening at set pressure.
Typical Materials	Stainless steels or chrome steels. In most cases different materials of spindle vs. guide/adjusting screw to avoid galling. Often specific measures to avoid galling like bushing or surface treatment. General material requirements in ASME XIII, Sec. 3.3.
Product form	Bar, investment castings, forgings
Spring	
Effect of Corrosion	Corrosive attack from medium only when valve opens (not permanently wetted), condensate in the valve outlet or from environment with open bonnet designs. Corrosion can typically not be tolerated, because corrosion may result in premature failure of spring.
Typical Materials	Typical materials: carbon steel, stainless steel, tungsten, Inconel X-750, Hastelloy. Specific spring materials must be selected, because main property of a spring material is the coefficient of elasticity.
Product form	Bar
Bellows	
Effect of Corrosion	Corrosive attack from medium only when valve opens (not permanently wetted). Corrosion can not be tolerated, because bellows are made from very thin sheet metal and corrosion may result in premature failure of bellows, eliminating the back pressure compensating effect.
Typical Materials	Stainless steels, frequently 316 ss or Inconel 625 are standard materials, Hastelloy.
Product form	Sheet metal, single or double walled, usually welded to machined end pieces which may be manufactured from a different material

Table 9.2.4-1: Critical parts, effect of corrosion, typical materials and product forms

9.2.5 Full Nozzle Versus Semi Nozzle

Full nozzle designs have the advantage that all permanently wetted components are typically from corrosion resistant stainless steel as a standard. Only in case the valve opens the components at the outlet of the valve will be in contact with the medium.
In semi nozzle designs the body which is normally carbon steel is also permanently wetted.
If carbon steel does not provide sufficient corrosion resistance the full nozzle design with carbon steel body may still provide a good solution when valve opening is expected to be rare. For a semi nozzle design the selection of a body material with higher corrosion resistance would be required.

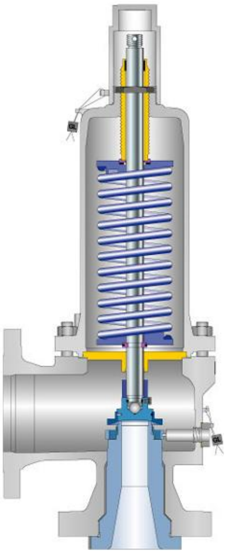


Figure 9.2.5-1: Full nozzle design Type 526

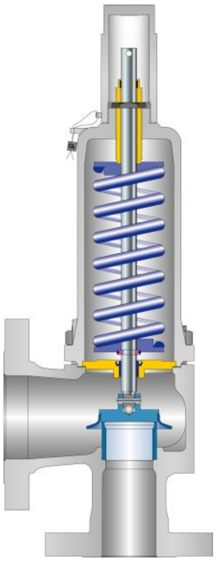


Figure 9.2.5-2: Semi nozzle design Type 441

9.2.6 Piping Material as a Guideline for the Selection of Safety Valve Materials

In some cases all details about the corrosive nature of the medium may not be easily available for a proper and detailed selection of safety valve materials. When the inlet piping material is available however, it can be taken as a rough guideline for the selection of the safety valve body material.
If the inlet piping material is from carbon steel, a safety valve with carbon steel body will be sufficient in most cases.
If the inlet piping material is stainless steel, the body material for semi nozzle designs should also be stainless steel. For full nozzle designs the carbon steel body may still be an option. If carbon steel is selected the user should consider preventive maintenance actions to ensure the outlet of the valve is not affected by corrosive attack after valve discharge or potential valve leakage.

9.3 Pressure Vessel Codes and Material Standards

As mentioned in the previous section, pressure retaining parts must fulfill requirements not only from material standards but also from pressure vessel codes.The general relationship between pressure vessel codes and material standards can be described as follows:
The material standards determine the general properties for the material like chemical composition and mechanical properties acc. to the product form (casting, bar, …). The determination of the scope of testing and documentation is normally left to the purchaser and supplier.
Pressure vessel codes define which materials may be used for the construction of pressure vessels and determine the scope of testing, documentation and limits of application for the individual material, using the material standards as a basis.

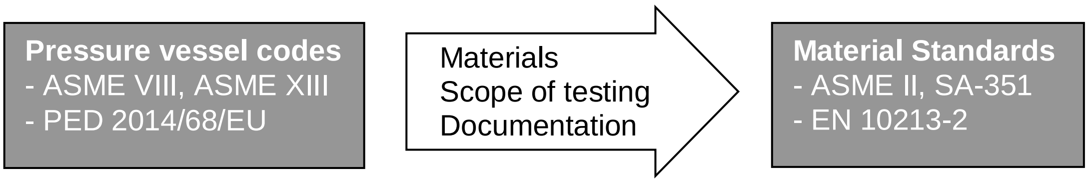


Figure 9.3-1: Relationship between pressure vessel codes and material standards

9.3.1 ASME Code

The ASME code specifies in detail material requirements for the components of a safety valve.

ASME XIII, 3.3.1(a) specifies:
“(a) Materials used in bodies, bonnets, yokes, and body to-bonnet or body-to-yoke bolting shall be as permitted in Section II, Part D by the referencing Code, … .
In addition, the following requirements apply:
(1) For Section VIII, Division 1 (UV Designator) pressure relief valves, the bodies, bonnets, yokes, and body-to bonnet or body-to-yoke bolting shall meet all applicable requirements of Section VIII, Division 1, Subsection C.”

ASME VIII Subsection C determines the requirements for materials to be used in construction of pressure vessels and contains material tables with acceptable materials. Not every material contained in ASME II is allowable per these tables.

Type of material	Subsection C	Material tables
Carbon and Low Alloy Steels	Part UCS	UCS-23
Nonferrous Materials	Part UNF	UNF-23.1 – Aluminum and Aluminum Alloys UNF-23.2 – Copper and Copper Alloys UNF-23.3 – Nickel, Cobalt and High Nickel Alloys UNF-23.4 – Titanium and Titanium Alloys UNF-23.5 – Zirconium
High Alloy Steels	Part UHA	UHA-23
Cast Iron	Part UCI	UCI-23
Cast Ductile Iron	Part UCD	UCD-23

Table 9.3.1-1: Material tables per ASME VIII – Div 1, Subsection C

In addition to the above tables there are so called “Code Cases” which contain further materials acceptable for the construction of pressure vessels. For pressure relief valves especially code case 1750-20 lists a large variety of additional materials.

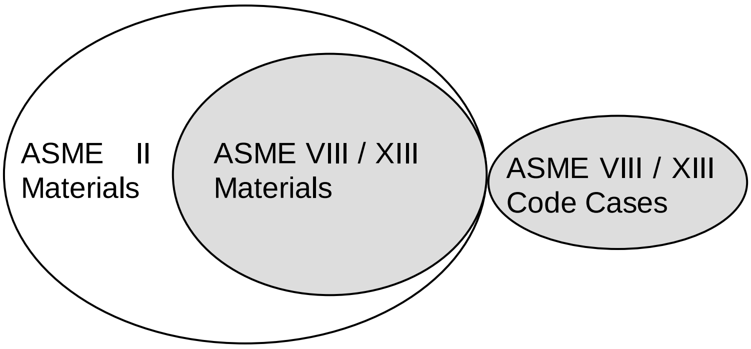


Figure 9.3.1-1: Allowable materials acc. to the ASME Code

The following parts of ASME Section II contain commonly used materials and product forms for materials used in safety valves:

- SA-105 - Specification for carbon steel forgings for piping applications -
- SA 182 - Specification for forged and rolled alloy and stainless steel pipe flanges, forged fittings, and valves and parts for high-temperature service -
- SA-193 - Specification for alloy-steel and stainless steel bolting materials for high-temperature service -
- SA-194 - Specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both -
- SA-216 - Specification for steel castings, carbon, suitable for fusion welding for high-temperature service -
- SA-217 - Specification for steel castings, martensitic stainless and alloy, for pressure-containing parts, suitable for high-temperature service -
- SA-351 - Specification for casting, austenitic, austenitic-ferritic (duplex), for pressure – containing parts -
- SA-352 - Specification for steel castings, ferritic and martensitic, for pressure containing parts, suitable for low temperature service -
- SA-479 - Specification for stainless steel bars and shapes for use in boilers and other pressure vessels. –

9.3.2 AISI and ASTM Material Specifications, UNS, ACI, SUS Number

AISI = American Iron and Steel Institute
ASTM = American Society for Testing and Materials

ASME has adopted many of the ASTM material standards and the number of the ASME material standard is only distinguished by the additional letter S.

As an example:

ASME SA-216 WCB is the ASME II equivalent to ASTM A-216 WCB.

Sometimes AISI or ASTM materials are requested for pressure retaining components of a safety valve.
As defined in ASME XIII 3.3.1(a), for bodies, bonnet and body-to-bonnet bolting
LESER always uses materials according to ASME VIII and ASME II SA specifications or materials defined in ASME code cases like code case 1750-20.

UNS = Unified Numbering System

Extract from www.wikipedia.com: The **Unified Numbering System** (UNS) is an alloy designation system widely accepted in North America. It consists of a prefix letter and five digits designating a material composition. A prefix of S indicates stainless steel alloys, C for copper, brass, or bronze alloys. The UNS is managed jointly by the American Society for Testing and Materials and SAE International. A UNS number alone does not constitute a full material specification because it establishes no requirements for material properties, heat treatment, form, or quality.

UNS Series	Metal type(s)
A00001 to A99999	Aluminum and aluminum alloys
C00001 to C99999	Copper and copper alloys
F00001 to F99999	Cast irons
G00001 to G99999	AISI and SAE carbon and alloy steels (except tool steels)
J00001 to J99999	Cast steels (except tool steels)
N00001 to N99999	Nickel and nickel alloys
R00001 to R99999	Reactive and refractory metals and alloys
S00001 to S99999	Heat and corrosion resistant (stainless) steels

Link to free UNS numbers:
http://www.e-pipe.co.kr/eng/uns_no/linkuns.html

ACI = Alloy Casting Institute

In North America, the common designations for cast stainless steel and nickel-base alloys are descriptive of their chemistry and purpose. This designation system was established by the Alloy Casting Institute (ACI) (Now the Steel Founder's Society of America) and has been adopted by ASTM.
A designation beginning with the letter "C" indicates that the alloy is used primarily for corrosive service; if the first letter is "H", the alloy is used primarily for high temperature service at or above 1200°F (649°C). The second letter indicates the approximate nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram (ASTM A 781, Appendix X1 and Figure X1.1). For C classifications, the single or double digit number following the first two letters indicates the maximum carbon content of the grade (% x 100). For H classifications, this number is the midpoint of the carbon content range in units of 0.01 % with a ±0.05% limit. Other alloying elements, if present, are represented by one or more letters following the number.

For example:
the designation “CF8M” indicates that the grade is corrosion resistant (C), contains between 17% and 21 % chromium and between 8% and 12% nickel (F), a maximum carbon content of 0.08% (8), and molybdenum (M);
the designation “HD” indicates that the grade is heat resistant (H), and contains between 26% and 30% chromium and between 4% and 7% nickel (D).

SUS

Material designation according Japanese JIS standards. In general the grade designation from the equivalent ASTM standard is taken and the three letters “SUS” are added.
Example:
ASTM grade = 316L
JIS grade = SUS 316L

9.3.3 PED 2014/68/EU

The requirements for the main pressure-bearing parts are defined in PED 2014/68/EU, Annex 1, 4. Materials, section 4.2. (b):

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

Materials which comply with harmonized standards

The following listing is an overview of the most important harmonized material standards. This means that materials listed in these standards can be used for main pressure-bearing parts in accordance with PED 2014/68/EU:

- EN 10272 Stainless Steel bars for pressure purposes
- EN 10273 Hot rolled weldable steel bars for pressure purposes with specified elevated temperature
- EN 10028 Flat products made of steels for pressure purposes
  - Part 1: General requirements
  - Part 2: Non-alloy and alloy steels with specified elevated temperature properties
  - Part 3: Weldable fine grain steels, normalized
  - Part 4: Nickel alloyed steels with specified low temperature properties
  - Part 5: Weldable fine grain steels, thermomechanically rolled
  - Part 6: Weldable fine grain steels, quenched and tempered
  - Part 7: Stainless steels
- EN 10213 Steel castings for pressure purposes
  - Part 1: General
  - Part 2: Steel grades for use at room temperature and elevated temperatures
  - Part 3: Steel grades for use at low temperatures
  - Part 4: Austenitic and austenitic-ferritic steel grades
- EN 10222 Steel forgings for pressure purposes
  - Part 1: General requirements for open die forgings
  - Part 2: Ferritic and martensitic steels with specified elevated temperature properties
  - Part 3: Nickel steels with specified low temperature properties
  - Part 4: Weldable fine grain steels with high proof strength
  - Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels

Materials covered by a European approval of pressure equipment materials in accordance with Article 11 (EAM)

The following link contains an overview of materials that have successfully passed an EAM:
http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/published/index_en.htm
Particular material appraisal

The following link contains an overview of materials that have been submitted for an EAM:
http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/submitted/index_en.htm

Particular material appraisal (PMA)

LESER has obtained the following PMA:

Material:	1.4104 acc. to EN 10088-3
Application:	Inlet bodies and outlet bodies of Compact Performance safety valves
PMA-No.:	PMA 1326W126000, Rev.01
Notified body:	TÜV NORD Systems GmbH & Co KG

Material:	B7M acc. to ASME SA-193, 2HM acc. to ASME SA-194
Application:	Studs and nuts for body-to-bonnet and body to top plate bolting
PMA-No.:	PMA 1326W137310-1, Rev.01, PMA 1326W137310-2, Rev.01
Notified body:	TÜV NORD Systems GmbH & Co KG

9.3.3.1 Relevance of Further European Standards Dealing with Materials

The following standards contain requirements relative to materials. This section shall explain their relevance in combination with the PED 2014/68/EU.

EN 13445-2 Unfired Pressure Vessels - Part 2: Materials

EN 13445 shall substantiate the basic safety requirements of the PED 2014/68/EU Annex 1 and specifies the requirements for design, construction, inspection and testing of unfired pressure vessels.
EN 13445-2 specifies the requirements for materials for unfired pressure vessels and supports which are covered by EN 13445-1. Part 2 deals with

- the general philosophy on materials
- material grouping
- low temperature behavior in relation to room temperature performance.

It is limited to steel with sufficient ductility and excludes at present materials operating in the creep range.
Annex A adds a list of all those material grades based upon European base material standards which are accepted to be used for unfired pressure vessels made to this standard
EN 13445-2 is harmonized with PED 2014/68/EU, Annex 1, 4. Materials, section 4.2. (b) and other sections.

ISO 4126 Safety devices for protection against excessive pressure

- Part 1: Safety Valves
  - Materials for pressure retaining bodies must be acc. to Part 7
- Part 7: Common data
  - Determines material groups for pressure-temperature ratings
  - Lists steel materials which are <u>not</u> specified in European material standards. These are specifically ASTM materials

While some parts of ISO 4126, e.g. part 1 are harmonized with PED 2014/68/EU, part 7 is not harmonized with PED 2014/68/EU. Therefore the use of ASTM materials can be assumed to be in compliance with the PED.

EN 1503, Valves - Materials for bodies, bonnets and covers
EN 1503 has replaced the old DIN 3339.

- part 1: Steels specified in European Standards
- part 2: Steels not specified in European Standards (ASTM standards)
- part 3: Cast irons specified in European Standards
- part 4: Copper alloys specified in European Standards

Part 1 lists all steel materials that can be used for body, bonnets and covers of valves and which are specified in European material standards. It includes material groups and applicable material standards for each product form.
Part 2 lists additional steel materials which are <u>not</u> specified in European material standards. These are specifically ASTM materials. It includes material groups and applicable material standards for each product form as well as temperature limits.
EN 1503 is not harmonized with PED 2014/68/EU. Therefore the use of ASTM materials can not be assumed to be in compliance with the PED.

EN 12516, Industrial valves –Shell design strength – Part 1: Tabulation method for steel valve shells

- Refers to material standards for pressure vessel steel
  - European standards: Sheet and plate: EN 10028 -1 through -7, castings: EN 10213-2 through -4, forgings: EN 10222 – 2 through -5
  - ASTM standards: e.g. castings: ASTM A-216, ASTM A-351, sheet and plate: ASTM A-240, bar: ASTM A-479
- Determines material groups for pressure-temperature ratings
- Assigns European materials and ASTM materials to material groups
- Provides pressure/temperature ratings for the material groups (equivalent to ASME 16.34)

Parts of EN 12516-1 are harmonized with PED 2014/68/EU, however it is not harmonized in regard of the Annex 1, 4. Materials, section 4.2. (b), which determines which materials can be used. This means that although EN 12516-1 is listing ASTM materials, the use of ASTM materials can not be assumed to be in compliance with the PED.

EN 1092-1, Flanges and their Joints - Circular Flanges for Pipes, Valves, Fittings and Accessories, PN Designated - Part 1: Steel Flanges

EN 1092-1 contains in Annex D additional materials outside of European material specifications. These are mainly ASTM materials. However it is clearly stated that if these materials are intended to be used in pressure equipment categorie I – IV a EAM or PMA is required,

9.3.3.2 Summary

Within the European system of pressure vessel codes it is not as clearly defined which materials can be used for pressure retaining components as it is in the ASME code. PED 2014/68/EU determines the basic requirements without listing any materials.
It is essential that the EN material standard is harmonized with the PED 2014/68/EU. To which extend a standard is harmonized is documented in the Annex ZA of each harmonized standard. This means that not necessarily the complete content of a standard is harmonized and a detailed review of the harmonized parts of the standard is required.

Code or Standard	Covers materials acc. to		Information contained			
				Temperature limit		
	EN	ASTM	Material group	Min.	Max.	P/T-rating
PED 2014/68/EU	Only general requirements		-	-	-	-
EN 13445-2	√	-	-	√3)	-	-
ISO 4126-7	- 1)	√2)	√	-	√	-
EN 1503-1	√	-	√	-	-	-
EN 1503-2	-	√2)	√	-	√	-
EN 12516-1	√	√2)	√	-	√	√
EN 1092-1	√	√ 2)	√	-	√	√

1): only reference to EN 12516-1 for pressure/temperature ratings is made
2): suitable only if an EAM – European approval of pressure equipment materials in accordance with Article 11 or a PMA – particular material appraisal” is available
3): Table B 2-2

Table 9.3.3.2-1: EN and ISO Codes/ standards covering material requirements

9.3.4 AD-2000 together with TRB

Before the PED 2014/68/EU was introduced the AD-2000 code in combination with TRB rules were the applicable codes and standards for pressure equipment in Germany and were adopted in a number of further European markets. Today the AD-2000 code is still existing and has been modified so that the essential safety requirements of the PED are fulfilled, especially the conformity assessment. In other words: with the application of the AD-2000 code as a whole it is assumed that the requirements of the PED are fulfilled.
Within the AD-2000 code applicable parts referring to materials are:

AD-W2 Materials- Austenitic Steels
AD W3/1 Cast iron with lamellar graphite (grey cast iron) non-alloy and low-alloy
AD W3/2 Cast iron materials- Spheroidal-graphite cast iron non-alloy and low alloy
AD W4 Tubes made from non-alloyed and alloy steels
AD W5 Materials- Cast steels
AD W10 Materials for low temperatures- Ferrous materials

9.3.5 Low temperature applications acc. to AD-W10

Especially AD-W10 contains a useful concept regarding low temperature applications with three different load cases:
Case I: material strength parameters and safety factors may be used up to 100%
Case II: material strength parameters and safety factors may be used up to 75%
Case III: material strength parameters and safety factors may be used up to 25%

Depending on the load cases a further reduction of the lowest temperature without further testing of the material at low temperatures is allowed.

Example carbon steel 1.0619 with a pressure rating of PN40 (40 bar):

Load case	Max. pressure [bar]	Min. temperature [°C]
Case I	40	-10
Case II	30	-60
Case III	10	-85

Table 9.3.5-1: Load cases acc. to AD-W10 for 1.0619

Instead of a minimum temperature of -10°C, 1.0619 may be used down to -85°C, if the pressure does not exceed 10 bar.

9.4 Material Groups and Applications

This section contains definitions of material groups and their general applications.

CAST IRON	
Cast Iron	
General description	Low cost material. Not weldable. Due to the lamellar graphite structure cast iron is relatively brittle. Limited pressure rating up to PN 16 or Class 125.
Chemical composition	Carbon content: > 2% C < 4,5% Other elements: silicon, normally 1-3 %
Typical materials	DIN 1691, 0.6025 (GG-25)
Temperature limits	DIN/EN: -10°C up to 300°C
Applications	Low pressure steam, water
Ductile Iron	
General description	Also called nodular cast iron. Not weldable. Due to its nodular graphite inclusions ductile iron is much more ductile than cast iron and allows higher pressure ratings than cast iron. Pressure rating up to PN 40 or Class 300.
Chemical composition	Carbon content: > 2% C < 4,5% Other elements: silicon, normally 1-3 %
Typical materials	0.7043 (GGG-40.3), 60-40-18
Temperature limits	DIN/EN: -60°C (AD-W10) up to 350°C
Applications	Low pressure steam, water

Table 9.4-1: Properties of cast iron / ductile iron

CARBON STEEL	
Carbon Steel	
General description	Higher ductility than cast iron, weldable. Most common material for pressure vessel design.
Chemical composition	Carbon content: < 0.2% C Other elements: not significant
Typical materials	1.0619 (GP240GH) WCB
Temperature limits	DIN EN: -85°C/-121°F (AD-W10) up to 450°C/842°F ASME: -29°C/-20°F up to 427°C/800°F
Applications	Wide range of applications, standard material as long as temperature or chemical resistance do not require different material. In the chemical and petrochemical industry carbon steel stands for approximately 70% - 80 % of the applications.
High Temperature Carbon Steel / Chrome Molybdenum Steel	
General description	Increased upper temperature limit compared to carbon steel.
Chemical composition	Carbon content: < 0.2% C Other elements: Cr: 0.5 – 1%, Mo: 0.5 – 1,4%, Ni: 0,4 – 1.0%, some grades contain also Cu, Tu or V.
Typical materials	1.7357 (G17CrMo5-5) WC6
Temperature limits	DIN EN: -85°C/-121°F (AD-W10) up to 550°C/1022°F ASME: -29°C/-20°F up to 538°C/1000°F
Applications	Similar to standard carbon steel but temperature above carbon steel limits like in high pressure, high temperature steam applications.
Low Temperature Carbon Steel	
General description	There is no difference in the chemical composition to a standard carbon steel. Different heat treatment and charpy impact test at low temperature (-46°C/-50°F) allow for lower application temperatures.
Chemical composition	Carbon content: < 0.2% C Other elements: not significant
Typical materials	LCB
Temperature limits	ASME: -46°C/-50°F up to 343°C/650°F
Applications	Similar to standard carbon steel, especially under low ambient temperature conditions, as they are found e.g. in Canada or Russia.

Table 9.4-2: Properties of carbon steel

STAINLESS STEEL	
Ferritic Stainless Steel	
General description	Passivation of the surface which provides corrosion resistance. Advantage of ferritic stainless steels vs. austenitic is their resistance against chloride induced intercrystalline corrosion. Ferritic stainless steels are typically magnetic.
Chemical composition	Carbon content: typically < 0,03% C Other elements: Cr > 10.5%, better > 12-13%, up to Cr < 27% and very little Ni, if any to avoid austenitic structure. Most compositions include Mo.
Typical materials	Ferritic materials are typically not used in LESER safety valves
Temperature limits	n/a
Applications	n/a
Austenitic Stainless Steel	
General description	Compared to ferritic stainless steels, austenitic stainless steel can be work hardened and has a higher elongation. The almost temperature independent high toughness makes austenitic stainless steel a preferred material for pressure retaining components. Austenitic stainless steel is typically not magnetic.
Chemical composition	Carbon content: typically < 0,08% C Other elements: > 16% Cr and sufficient Ni and/or Mn to retain an austenitic structure at all temperatures
Typical materials	1.4408/CF8M, 1.4581/CF10M, 1.4404/316L
Temperature limits	DIN EN: -270°C/-454°F up to 550°C/1022°F ASME: -268°C/-450°F up to 538°C/1000°F
Applications	Wide range of applications, standard material when carbon steel is not sufficient. In the chemical and petrochemical industry austenitic stainless steel stands for approximately 15 % of the applications.
Martensitic Stainless Steel	
General description	Martensitic steels have due to their relatively high carbon content high strength and hardness, but are typically brittle and have little toughness. They are magnetic and hardenable by quenching and tempering. Martensitic materials are typically not used for pressure retaining parts like bodies or bonnets.
Chemical composition	Carbon content: 0.1 – 1.2% Other elements: Cr 12 – 18%, Ni < 2%, Mo 0.2 – 1-0,
Typical materials	1.4021/AISI420, 1.4122/MT440
Temperature limits	Not applicable
Applications	Safety valve discs or spindles.
Super Austenitic Stainless Steel	
General description	Super (austenitic) stainless steels contain over 50% non-ferrous elements. Compared to conventional austenitic stainless steels, superaustenitic materials have a superior resistance to pitting and crevice corrosion in environments containing halides.
Chemical composition	Carbon content: < 0.08% Other elements: Cr 19 – 23 %, high Mo contents (>6% for AL-6XN and 254 SMO) and nitrogen additions 0.1 – 0.25% for resistance to chloride pitting and crevice corrosion, Ni 17.5 – 38% ensures better resistance to stress-corrosion cracking.
Typical materials	Alloy AL-6XN / UNS N08367, 254SMO / UNS S31254, Alloy 20 / UNS N08020, 1.4529, 1.4539
Temperature limits	Depending on material
Applications	Originally developed for seawater applications, AL-6XN is used successfully in food, pharmaceutical, and biopharmaceutical processes. 254SMO is used for seawater applications.

Table 9.4-3: Properties of stainless steel

DUPLEX STAINLESS STEEL	
22 Cr Duplex Stainless Steel	
General description	Duplex stainless steels have a grain structure that is ideally 50% austenitic and 50% ferritic. In practise a 40% to 60% ration is still considered a duplex structure. The Ferritic-Austenitic grain structure of duplex stainless steel provides a higher yield and tensile strength and sufficient toughness. Duplex stainless steels show a better resistance against chloride induced intercrystalline corrosion compared to austenitic stainless steels. Duplex materials have a PREN of 30 to 40 while 300 series stainless steels have a PREN of 20 - 25
Chemical composition	Carbon content: C < 0,03% Other elements: Cr 21% - 23%, Ni 4,5% - 6,5%, Mo 2,5% - 3,5%
Typical materials	CD3MN / Gr 4A / UNS J92205, Alloy 2205 / F51 / S31803, 1.4470, 1.4462
Temperature limits	DIN EN: up to / 280°C / 536°F ASME: -46°C/-50°F up to 316°C / 600°F
Applications	Urea plants, Marine and Offshore
25 Cr Super Duplex Stainless Steel	
General description	The 25 Cr grades with 25% Chromium and approx. 7% Nickel are called "SuperDuplex" due to the higher Corrosion resistance. They have PREN > 40, which is considered to be resistant against sea water. Disadvantage of Super Duplex versus Duplex is a more difficult welding, because of heat induced changes of the duplex grain structure.
Chemical composition	Carbon content: C < 0,04% Other elements: Other elements: Cr 24% - 27%, Ni 5% - 8%, Mo 2,5% - 5%
Typical materials	CD3MWCuN / Gr 6A / J93380, UNS S32760 / F55
Temperature limits	DIN EN: up to 250°C / 482°F ASME: -46°C / -50°F up to 316°C / 600°F
Applications	Seawater
Safurex	
General description	SAFUREX is a Duplex material patented by STAMICARBON, the DSM Licensing Center and SANDVIK for the use in urea plants acc. to the process licensed by Stamicarbon. Stamicarbon requires the use of SAFUREX for certain parts of the plant and only certain valve manufacturer are licensed to use the material. The material is recognized in the ASME system under UNS 32906 and applied as per ASME Code Case 2295. Available product forms are bar, forging, pipe, plate, but no casting.
Chemical composition	Carbon content: C < 0,03% Other elements: Other elements: Cr 28% - 30%, Ni 5,8% - 7,5%, Mo 1,5% - 2,6%
Typical materials	SAFUREX UNS 32906
Temperature limits	Not available, Urea processes of STAMICARBON typically run at approximately 200°C
Applications	Urea plants with processes licensend by STAMICARBON.

Table 9.4-4: Properties of duplex stainless steel

Nickel Base Materials	
General description	The primary constituent is nickel instead of iron. However Nickel might be less than 50% of the total composition. Nickel based alloys are used for a wide range of applications and have a large range of alloying elements. They are commonly recognized under the tradenames of the primary manufacturers like Hastelloy®, Inconel®, Incoloy®, Monel®.
Chemical composition	Carbon content: normally below 0.07%, Monel M 35-1 up to 0.35% Other elements: normally Ni > 50%, B-Alloys : Ni < 1,5%, Mo 25 – 33%, C-Alloys: Ni 14 - 23%, Mo 12 – 18%,
Typical materials	CX2MW / UNS N26022, HASTELLOY C-22 / N06022, 2.4602 CW-12MW / UNS N30002, HASTELLOY C-276 / UNS N10276, 2.4686, 2.4819, M35-1 / UNS N24135, MONEL 400 / UNS N04400, 2.4360, CW-6MC / UNS N26625, INCONEL 625 / UNS N06625, 2.4816, 2.4856
Pressure rating	No limitation
Temperature limits	Varies with material
Applications	Hastelloy B-Alloys: for reducing acids Hastelloy C-Alloys: for oxidizing acids

Table 9.4-5: Properties of nickel base materials

Pure Metals	
General description	Occasionally traditional stainless steels or nickel base alloys can not fulfill the corrosions resistance requirements of a specific application. Except for pure Nickel also Titanium, Zirconium or Tantalum may be used for pressure retaining components acc. to ASME code.
Chemical composition	Typically pure metal with little other elements
Typical materials	Nickel, Titanium, Zirconium, Tantalum
Pressure rating	No limitation
Temperature limits	Varies with material
Applications	Titanium: - titanium is advantageous in environments subject to attack by oxidizing media or by chlorides and other chlorine ions - sometimes preferred over Duplex grades in offshore applications. Zirconium: - Acetic Acid Production - MONSANTO carbonylation process - Urea Production (Stripper) - Nitric Acid Applications - Sulfuric Acid Applications - Formic Acid Environments Tantalum: - Tantalum is resistant to all acids with the exception of hot, fuming sulphuric acid (oleum) and hydrofluoric acid. It is only attacked slowly by alkaline solutions.

Table 9.4-6: Properties of pure materials

Materials for pressure retaining components like body, bonnet, bolts must be from materials that are listed in the applicable codes and standards (see…). Therefore not every available material may be used for these components.

9.5 Standard Parts and Materials for LESER Safety Valves

The following table shows the materials that are used in LESER safety valves as a standard. A standard material per LESER definition is available as a materials from stock.

Part	Material Group	Product form	EN Material	ASME/ASTM Material [1)]	Notes
Body / Bonnet	Cast Iron	Casting	0.6025	Cast Iron	max. PN 16
	Ductile Iron	Casting	0.7043	SA 395 - 60-40-18	max. PN 40, ANSI 300
	Carbon Steel	Casting	1.0619	SA 216 – WCB/WCC	
	Carbon Steel	Plate	1.0460 / 1.0425	SA 105	Type 441XXL only
	Low Temp C.S.	Casting	-	SA 352 – LCB/LCC	Type 526
	High Temp C.S.	Casting	1.7357	SA 217 - WC6	
	Chrome Steel	Bar	1.4104	N/A	Compact Performance within PED only
	Stainless Steel	Casting	1.4408	SA 351 - CF8M	
	Stainless Steel	Bar, Forging, Pipe	1.4404	SA 479 / SA 182 / SA 312 - 316L	bonnets, inlet body Compact Performance
	Stainless Steel	Bar	1.4435 – BN2	SA 479 - 316L	series 48X, low Delta Ferrite
	High Temp S.S.	Casting	1.4581	SA 351 - CF10M	Series 458 only
	High Temp S.S.	Bar, Forging, Pipe	1.4571	SA 479 / SA 182 / SA 312 - 316Ti	Type 441XXL only
Bonnet Spacer	Stainless Steel	Bar	1.4404	SA 479 - 316L	
	Carbon Steel	Bar	1.0460	SA 105	
Nozzle	Stainless Steel	Investm. Casting	1.4408	SA 351 - CF8M	
	Stellite	Investm. Casting	1.4408 / Stellite	SA 351 - CF8M Stellite	
	Stainless Steel	Bar	1.4404	SA 479 - 316L	
	Stellite	Bar	1.4404 / Stellite	Sa 479 - 316L / Stellite	
Disc	Chrome Steel	Bar	1.4122	MT 440	hardened stainless steel
	Stainless Steel	Bar	1.4404	SA 479 - 316L	
	Stellite	Bar	1.4404 / Stellite	SA 479 - 316L / Stellite	optional
Studs	Carbon Steel	Stud	1.1181		
	Carbon Steel	Stud	1.7225	SA 193 - B7	
	High Temp Alloy	Stud	1.7709	SA 193 - B16	
	Stainless Steel	Stud	1.4401	SA 193 – B8M	
Nuts	Carbon Steel	Nut	1.0501		
	High Temp Alloy	Nut	1.7258	SA 194 – 7M	
	Stainless Steel	Nut	1.4401	SA 194 - 8M	
Spindle	Chrome Steel	Bar	1.4021	420	
	Stainless Steel	Bar	1.4404	316L	
	Stainless Steel	Bar	1.4404 tenifer	316L tenifer	for higher pressure stainless steel valves
Spring	Carbon Steel	Bar	1.1200	Carbon Steel	
	High Temp Alloy	Bar	1.8159	High Temp Alloy	
	High Temp Alloy	Bar	1.7102	High Temp Alloy	
	Stainless Steel	Bar	1.4310	302	
	Tungsten	Bar	1.2605	Tungsten H12	
	Inconel	Bar	2.4669	Inconel X-750	
Bellows	Stainless Steel	Sheet	1.4571/1.4404	316Ti/316L	bellows flange and tailpiece from 316L
	Inconel	Sheet	2.4856/1.4404	Inconel 625/316L	Type 526 only
	Elastomer		EPDM FDA	EPDM FDA	Series 48X
Gasket	Graphite/S.S.	Gasket	Graphite/1.4401	Graphite/316	
	Reinforced PTFE	Gasket	Gylon	Gylon	optional

1): Material for pressure retaining components are supplied with double material certificate, ASME materials for other components may be equivalent materials only

Table 9.5-1: LESER standard materials

9.5.1 Chemical Composition of Materials acc. to EN Standards

Product form	Standard	Mat. Nr.	C	Si	Mn	P ≤	S ≤	Cr	Ni	Mo	Other	Material Group	
												EN 12516-1	AD-W10
LESER Standard Materials													
Casting	DIN 1691	0.6025	2,9-3,1	1,8-2,0	1,0-1,3	---	---	---	---	---	Approx. analysis	---	---
Casting	DIN 1693	0.7043	3,5-3,7	2,0-2,2	0,25	---	---	---	---	---	Approx. analysis	---	---
Casting	EN 10213-2	1.0619	0.18-0.23	0.60	0.50-1.20	0.030	0.020	---	---	---	---	3 E 0	---
Forging	EN 10222-2	1.0460	0.18-0.23	0.40	0.40-0.90	0.025	0.015	0.30	---	---	Al: 0.015-0.050	---	---
Plate	EN 10028-2	1.0425	0.20	0.40	0.80-1.40	0.025	0.015	0.30	0.30	exactly 0.08	Al: min 0.020, N: 0.012 Cu: 0.30, Nb: 0.020, Ni: 0.30, Ti: 0.03, V: 0.02, Cr+Cu+Mo+Ni ≤ 0.70	3 E 0	---
Casting	EN 10213-2	1.7357	0.15-0.20	0.60	0.50-1.00	0.020	0.020	1.00-1.50	---	0.45-0.65	---	5 E 0	---
Bar	EN 10088-3	1.4104	0.10-0.17	1.00	1.50	0.040	0.15-0.35	15.50-17.50	---	0.20-0.60	---	---	---
Casting	EN 10213-4	1.4408	0.07	1.50	1.50	0.040	0.030	18.00-20.00	9.00-12.00	2.00-2.50	---	14 E 0	3
Investm. Casting	EN 10213-4	1.4408	0.07	1.50	1.50	0.040	0.030	18.00-20.00	9.00-12.00	2.00-2.50	---	14 E 0	3
Bar, Pipe Forging,	EN 10272	1.4404	0.030	1.00	2.00	0.045	0.030	16.50-18.50	10.00-13.00	2.00-2.50	N: ≤ 0.11	13 E 0	3
Bar	EN 10272	1.4435	0.030	1.00	2.00	0.045	0.030	17.00-19.00	12.50-15.00	2.50-3.00	N: ≤ 0.11	---	3
Casting	EN 10213-4	1.4581	0.07	1.50	1.50	0.040	0.030	18.00-20.00	9.00-12.00	2.00-2.50	Nb: 8xC, max. 1.00	15 E 0	---
Bar, Pipe, Forging	EN 10272	1.4571	0.08	1.00	2.00	0.045	0.030	16.50-18.50	10.50-13.50	2.00-2.50	Ti: 5xC to 0.70	15 E 0	3
Bar	EN 10088-3	1.4122	0.33-0.45	1.00	1.50	0.040	0.030	15.50-17.50	1.00	0.80-1.30	---	---	---
Stud	EN 10269	1.1181	0.32-0.39	0.40	0.50-0.80	0.035	0.035	0.40	0.40	0.10	Cr+Mo+Ni ≤ 0.63	---	---
Stud	EN 10269	1.7225	0.38-0.45	0.40	0.60-0.90	0.035	0.035	0.90-1.20	---	0.15-0.30	---	---	---
Stud	EN 10269	1.7709	0.17-0.25	0.40	0.40-0.80	0.030	0.030	1.20-1.50	0.60	0.55-0.80	Al: 0.030, V: 0.20-0.35	---	---
Stud	EN ISO 3506-1	A4-70 (1.4401)	0.08	1.00	2.00	0.045	0.030	16.0-18.5	10.00-15.00	2.00-3.00	C: 1.00	14 E 0	3
Nut	DIN EN 10269	C35 (1.0501)	0.32-0.39	0.15-0.35	0.50-0.80	0.045	0.045	---	---	---	---	---	---
Nut	DIN EN 10269	24 CrMo5 (1.7258)	0.20-0.28	0.15-0.35	0.50-0.80	0.030	0.035	0.90-1.20	---	0.20-0.35	---	---	---
Nut	EN ISO 3506-1	A4-70 (1.4401)	0.08	1.00	2.00	0.045	0.030	16.0-18.5	10.00-15.00	2.00-3.00	C: 1.00	14 E 0	3
Bar	EN 10088-3	1.4021	0.16-0.25	1.00	1.50	0.040	0.030	12.00-14.00	---	---	---	---	---
Spring	EN 10270-1	SH (1.1200)	0.35-1.00	0.10-0.30	0.50-1.20	0.035	0.035	---	---	---	Cu: 0.20	---	---
Spring	EN 10089	1.8159	0.47-0.55	0.40	0.70-1.10	0.025	0.025	0.90-1.20	---	---	V: 0.10-0.25, Cu+10Sn±0.60	---	---
Spring	EN 10089	1.7102	0.51-0.59	1.20-1.60	0.50-0.80	0.025	0.025	0.50-0.80	---	---	Cu+10Sn±0.60	---	---
Spring	EN 10270-3	1.4310	0.05-0.15	2.00	2.00	0.045	0.015	16.00-19.00	6.00-9.50	0.80	N: ≤ 0.11	---	---
Spring	ASTM A681	1.2605 (UNS T20812, Tungsten H12)	0.3-0.4	0.8-1.25	0.2-0.6	0.03	0.03	4.75-5.5		1.25-1.75	W: 1.0-1.7 V: 0.2-0.5	---	---
Spring	ASTM B 637	2.4669 (UNS N07750, Inconel X-750)	0.08	0.5	1.0	---	0.01	14.0-17.0	70.0	---	Al: 0.4-1.0; Co: <=1.0; Nb+Ta: 0.7-1.2, TA:<=0.05; Ti:2.25-2.75; Fe: 5,0-9.0; Cu:<=0.5	---	---

Table 9.5.1-1: Chemical composition LESER standard materials acc. to EN standards

Product form	Standard	EN Mat. Nr.	C	Si	Mn	P ≤	S ≤	Cr	Ni	Mo	Other	Material Group	
												EN 12516-1	AD-W10
Other Common Materials													
Casting	EN 10213-3	1.1131	0.15-0.20	0.60	1.00-1.60	0.020	0.020	---	---	---	---	7 E 0	---
Casting	EN 10213-3:	1.6220	0.17-0.23	0.60	1.00-1.60	0.020	0.020	---	---	---	Ni: max. 0.80	7 E 0	---
Casting	EN 10213-4	1.4308	0.07	1.50	1.50	0.040	0.030	18.00-20.00	8.00-11.00	---	---	11 E 0	3
Casting	EN 10213-2	1.5419	0.15-0.23	0.60	0.50-1.00	0.025	0.020	---	---	0.40-0.60	---	4 E 0	---
Casting	EN 10213-4	1.4409	0.030	1.50	2.00	0.035	0.025	18.00-20.00	9.00-12.00	2.00-2.50	N: 0.20	13 E 0	---
Plate	EN 10028-7	1.4961	0.04-0.10	0.30-0.60	1.50	0.035	0.015	15.00-17.00	12.00-14.00	---	Nb: ≥ 10xC bis 1.20	---	---
Bar	EN 10025	1.0570	0.20, > 40 mm 0.22	0.55	1.60	0.035	0.035	---	---	---	---	---	---
Bar	EN 10273	1.7335	0.08-0.18	0.35	0.40-1.00	0.025	0.010	0.70-1.15	---	0.40-0.60	N: 0.012, Cu: 0.30	5 E 0	---
Forging	EN 10222-2	1.5415	0.12-0.20	0.35	0.40-0.90	0.025	0.015	---	---	0.25-0.35	---	4 E 0	---
Pipe	EN 10216-5	1.4988*	0.04-0.10	0.30-0.60	1.50	0.035	0.015	15.50-17.50	12.50-14.50	1.10-1.50	N: 0.06-0.14, Nb: 10xC bis 1.20, V: 0.60-0.85	---	---
Pipe	EN 10216-5	1.4981*	0.04-0.10	0.30-0.60	1.50	0.035	0.015	15.50-17.50	15.50-17.50	1.60-2.00	Nb: 10xC bis 1.20	---	---
Plate	EN 10028-7	1.4910*	0.04	0.75	2.00	0.035	0.015	16.00-18.00	12.00-14.00	2.00-3.00	N: 0.10-0.18, B: 0.0015-0.0050	---	---
Plate	EN 10028-7	1.4301	0.07	1.00	2.00	0.045	0.015	17.00-19.50	8.00-10.50	---	N: 0.11	11 E 0	3
Plate	EN 10028-7	1.4401	0.07	1.00	2.00	0.045	0.015	16.50-18.50	10.00-13.00	2.00-2.50	N: 0.11	14 E 0	3
Plate	EN 10028-7	1.4541	0.08	1.00	2.00	0.045	0.015	17.00-19.00	9.00-12.00	---	Ti: 5xC bis 0.70	12 E 0	3

*** = not listed in EN 12516-1**

Notes:
- All values are maximum unless otherwise indicated.
- Additional notes about the chemical composition can be found in the respective standard.

Table 9.5.1-2: Chemical composition of further common materials acc. to EN standards

9.5.2 Chemical Composition of Materials acc. to ASME Specifications

Product form	ASME/ ASTM Spec.	ASME Material	C	Si	Mn	P ≤	S ≤	Cr	Ni	Mo	Other	Listed in ASME	
												Sec. VIII	B 16.34 Group
Casting	SA 395	60-40-18	min. 3.00	2.50	---	0.08	---	---	---	---	---	UCD-23	---
Casting	SA 216	WCB	0.30	0.60	1.00	0.04	0.045	0.50	0.50	0.20	Cu: 0.30 V: 0.03	UCS-23	1.1
Plate, Forging	SA 105	SA 105	0.35	0.10-0.35	0.60-1.05	0.035	0.040	0.30	0.40	0.12	Cu: 0.40 V: 0.08	UCS-23	1.1
Casting	SA 352	LCB	0.30	0.60	1.00	0.040	0.045	0.50	0.50	0.20	Cu: 0.30 V: 0.03	UCS-23	1.3
Casting	SA 217	WC6	0.05-0.20	0.60	0.50-0.80	0.04	0.045	1.00-1.50	---	0.45-0.65	---	UCS-23	1.9
Casting	SA 351	CF8M	0.08	1.50	1.50	0.040	0.040	18.0-21.0	9.0-12.0	2.0-3.0	---	UHA-23	2.2
Casting	SA 351	CF10M	0.04-0.10	1.50	1.50	0.040	0.040	18.0-21.0	9.0-12.0	2.0-3.0	---	---	---
Bar	SA 479	316L	0.030	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	---	UHA-23	2.3
Bar	SA 479	316Ti	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	N: 0.10 Ti: 5*(C+N) - 0.70	UHA-23	---
Bar	SA 276	440A	0.60-.075	1.00	1.00	0.040	0.030	16.00-18.00	---	0.75	---	---	---
Bar	SA 276	420	min. 0.15	1.00	1.00	0.040	0.030	12.00-14.00	---	---	---	---	---
Stud	SA 193	B7	0.37-0.49	0.15-0.35	0.65-1.10	0.035	0.040	0.75-1.20	---	0.15-0.25	---	UCS-23	---
Stud	SA 193	B16	0.36-0.47	0.15-0.35	0.45-0.70	0.035	0.040	0.80-1.15	---	0.50-0.65	V: 0.25-0.35 Al: 0.015	UCS-23	---
Stud	SA 193	B8M	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	---	UHA-23	---
Nut	SA 194	2H	min. 0.40	0.40	1.00	0.040	0.050	---	---	---	---	---	---
Nut	SA 194	7M	0.37-0.49	0.15-0.35	0.65-1.10	0.035	0.040	0.75-1.20	---	0.15-0.25	---	---	---
Nut	SA 194	8M	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	---	---	---
Casting	SA 217	WC5	0.05-0.20	0.60	0.40-0.70	0.04	0.045	0.50-0.90	0.60-1.00	0.90-1.20	---	UCS-23	1.7
Casting	SA 217	WC9	0.05-0.18	0.60	0.40-0.70	0.04	0.045	2.00-2.75	---	0.90-1.20	---	UCS-23	1.10
Casting	SA 217	C5	0.20	0.75	0.40-0.70	0.04	0.045	4.00-6.50	---	0.45-0.65	---	UCS-23	1.13
Casting	SA 217	C12	0.20	1.00	0.35-0.65	0.04	0.045	8.00-10.00	---	0.90-1.20	---	UCS-23	1.14
Casting	SA 351	CF8	0.08	2.00	1.50	0.040	0.040	18.0-21.0	8.0-11.0	0.50	---	UHA-23	2.1
Casting	SA 351	CF3	0.03	2.00	1.50	0.040	0.040	17.0-21.0	8.0-12.0	0.50	---	UHA-23	2.1
Casting	SA 351	CF3M	0.03	1.50	1.50	0.040	0.040	17.0-21.0	9.0-13.0	2.0-3.0	---	UHA-23	2.2
Casting	SA 351	CF3MN	0.03	1.50	1.50	0.040	0.040	17.0-21.0	9.0-13.0	2.0-3.0	N: 0.10-0.20	---	---
Casting	SA 351	CG8M	0.08	1.50	1.50	0.040	0.040	18.0-21.0	9.0-13.0	3.0-4.0	---	UHA-23	2.2
Casting	SA 351	CG3M	0.03	1.50	1.50	0.040	0.040	18.0-21.0	9.0-13.0	3.0-4.0	---	---	---
Casting	SA 351	CF8C	0.08	2.00	1.50	0.040	0.040	18.0-21.0	9.0-12.0	0.50	Nb: see Note	UHA-23	2.11
Bar	SA 479	304	0.08	1.00	2.00	0.045	0.030	18.0-20.0	8.0-10.5	---	---	UHA-23	2.1
Bar	SA 479	304L	0.03	1.00	2.00	0.045	0.030	18.0-20.0	8.0-12.0	---	---	UHA-23	2.3
Bar	SA 479	316	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	---	UHA-23	2.2
Bar	SA 479	316Cb	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	N: 0.10 Nb: 10*C-1.10	UHA-23	---
Bar	SA 479	316Ti	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	N: 0.10 Ti: 5*(C+N) -0.70	UHA-23	---
Bar	SA 479	317	0.08	1.00	2.00	0.045	0.030	18.0-20.0	11.0-15.0	3.0-4.0	---	UHA-23	---
Forging	SA 182	317L	0.03	1.00	2.00	0.045	0.030	18.0-20.0	11.0-15.0	3.0-4.0	---	UHA-23	---
Bar	SA 479	321	0.08	1.00	2.00	0.045	0.030	17.0-19.0	9.0-12.0	---	Ti: 5*(C+N) -0.70	UHA-23	2.4
Bar	SA 479	347	0.08	1.00	2.00	0.045	0.030	17.0-19.0	9.0-12.0	---	Nb: 10*C -1.10	UHA-23	2.5

Notes:
- All values are maximum unless otherwise indicated.
- Additional notes about the chemical composition can be found in the respective standard.
- High Alloy and Nickel base materials: see section 9.4
- For equivalent SA specifications depending on product form see section 9.7.1

Table 9.5.2-1: Chemical composition of selected materials acc. to ASME specifications

9.5.3 LESER Standard Materials Versus other Common Materials

This section explains the selection of materials for the main components in LESER safety valves in comparison to other manufacturers.

The following chart compares standard materials for LESERs API series 526 and competitive models.

Component	Type	LESER standard material	Farris	Crosby	Consolidated
Body/Bonnet	5262	1.0619 / SA-216 GR. WCB	SA-216 GR. WCB	SA-216 GR. WCB	SA-216 GR. WCC
	5263	LCB			LCC
	5264	1.4408 / CF8M	SA-351 Gr. CF8M	SA-351 Gr. CF8M	SA-351 Gr. CF8M
	5267	1.7357 / SA-217 GR. WC6	SA-217 GR. WC6	SA-217 GR. WC6	SA-217 GR. WC6
Nozzle	5262 5263 5624	1.4408 / CF8M 1.4408 / CF8M stellited	316 St. St.	316 St. St.	316 St. St.
	5267	1.4408 / CF8M stellited	316 St. St.	316 St. St.	316 St. St.
	Optional	1.4404 / 316L stellited	316 St. St.	316 St. St.	316 St. St.
Disc	5262 5263 5267	1.4122 / hardened stainless steel	316 St. St.	316 St. St.	316 St. St.
	5264	1.4404 / 316L stellited			
Guide with bushing	5262 5263 5267	1.0501 / Carbon Steel 1.4104 tenifer / Chrome steel	316 St.St.	ASTM A297 GR. HE SST	316 St.St.
Guide	5264	1.4404 / 316L	316 St. St.	ASTM A297 GR. HE SST	316 St. St.
Spindle	5264	1.4404 / 316L			
	5262 5263 5267	1.4021 / 420	316 St. St.	416 St. St.	400 Series SS
Spring	5264	1.4310	316 St. St.	316 St. St.	316 St. St.

Table 9.5.3-1: Material comparison of LESER and other manufacturers

9.5.3.1 Body and Bonnet Materials

LCB vs. LCC:

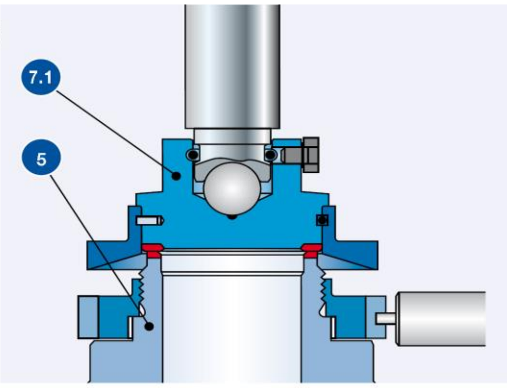
LESER specifies casting with a so called five-fold-material-certificate. This means that chemical analysis and chemical properties of the material are limited in such a way that the material fulfils the material requirements of five different materials at the same time.
These materials are: 1.0619, WCB, WCC, LCB and LCC. Therefore the LCC specification of other manufacturers is automatically covered.
The material supplier certifies all five materials in one single material certificate at the same time. This certification of LCB and LCC requires the performance and certification of a charpy impact test at -46°C.
In other words: If LESER supplies the material LCB this material is at the same time a 1.0619 but with an extended application range for temperatures below -10°C down to – 46°C. For details please refer to LESER Work Standard LDeS 3290.03.

9.5.3.2 Nozzle Materials

LESER uses the casting material 1.4408/ CF8M as a standard material for nozzles of API Series safety valves. Material 1.4404/316L can be configured as an option.
International competitors describe the nozzle material as 316 st.st. in their catalogs. 316 st.st. is used as a synonym for bar or forged 316 and casting CF8M. A stellited sealing surface is always an option associated with additional cost.

Stellited sealing surfaces
LESER automatically supplies the nozzles with stellited sealing surface in the following cases:

- valve size 4M6 or larger
- WC6 body material
- WCB/LCB body material: inlet flange class #600 or higher
- CF8M body material: inlet flange class #900 or higher



Stellite is a cobalt-chromium based, non-ferrous alloy with increased hardness, corrosion resistance and wear resistance up to high temperatures.
Stellited sealing surfaces provide a significantly longer lifetime of the valve seat especially in the following cases:
– high pressure applications, due to the high stress of the sealing surfaces
– high temperature applications to avoid a permanent deformation of the sealing surfaces
– applications with abrasive fluids to increase the wear resistance of the sealing surfaces

Figure 9.5.3.2-1: Stellited sealing surfaces

9.5.3.3 Disc Materials

LESER uses the martensitic material 1.4122 as a standard material for safety valve discs. International competitors use the austenitic material 316 as standard material. To compare the materials this part describes the differences.

Chemical composition of 1.4122 and 316

Standard	Mat. No.	C	Si	Mn	P ≤	S ≤	Cr	Ni	Mo	Other
EN 10088-3	1.4122	0.33 - 0.45	1.00	1.50	0.040	0.030	15.50-17.50	1.00	0.80 - 1.30	---
SA 479	316	0.08	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00 - 3.00	---

Table 9.5.3.3-1: Chemical composition of 1.4122 and 316

1.4122 is a martensitic hardened stainless steel. Due to the relatively high carbon content a high strength and hardness is provided.
316 is an austenitic stainless steel. Due to the content of Cr and Ni content it provides a very good corrosion resistance. However 316 is a relatively soft material.
For uncritical media like steam, water or many gases a disc from 1.4122 provides a perfect solution. Due to its hardness it has a longer lifetime than 316. The combination of a hard disc with a relatively soft material for the nozzle/seat (CF8M or 316L) additionally leads to a better tightness, especially after the valves has opened.

Material	Average Hardness
1.4408/CF8M	14 – 16 HRC
1.4404/316L	16 – 19 HRC
1.4408/CF8M stellited 1.4404/316L stellited	40 HRC
1.4122	42 – 46 HRC

Table 9.5.3.3-2: Hardness of 1.4122 hardened versus austenitic stainless steel

In case corrosive media like chemicals require the corrosion resistance of a 316 stainless steel, LESER supplies a disc of material 316L which is automatically equipped with a stellited sealing surface.

9.5.3.4 Guide Materials

Main task of the guide is to provide alignment for the spindle when the valve has to operate and assure that the spindle is always free to move. It is essential that no corrosion and no galling occurs between spindle and guide.
LESER uses the material combination guide in carbon steel 1.0501 and bushing in 1.4104 tenifer (chrome steel tenifer). The bushing serves as the contact/guiding surface for the spindle.

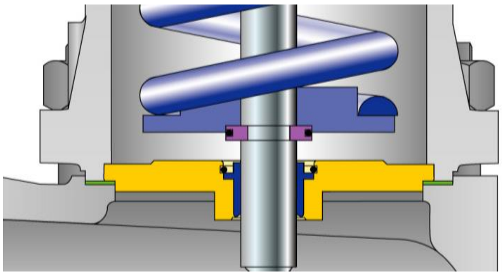


Figure 9.5.3.4-1: Guide with bushing

1.4104 tenifer is a corrosion resistant chrome steel with a tenifer surface hardening treatment. This nitrocarburisation procedure improves the hardness of the material and reduces the friction between a tenifer surface (guide) and a metallic surface (spindle). This leads to a longer lifetime and avoids galling between spindle and guide.

Chemical Composition

Standard	Mat. No.	C	Mn	Si	Cr	Ni	Mo	P ≤	S ≤	Other
EN 10088-3	1.4104	0.10-0.17	1.50	1.00	15.50-17.50	---	0.20-0.60	0.040	0.15-0.35	---
SA 479	316	0.08	2.00	1.00	16.0-18.0	10.0-14.0	2.00-3.00	0.045	0.030	---
ASTM A-297	GR HE	0.20-0.50	2.00	2.00	26.0 -30.0	8.0 -11.0	0.50	0.04	0.04	---

Table 9.5.3.4-1: Chemical composition of 1.4104, 316 and ASTM A-297 GR HE

9.5.3.5 Spindle Materials

LESER uses the martensitic material 1.4021 as a standard material for safety valve spindles. This section compares 1.4021 to the martensitic AISI grade 410 and 416 stainless steel.

LESER sources 1.4021 with a defined heat treatment and hardening procedure, resulting in defined mechanical properties.
AISI 410/416 can be sourced with a variety of heat treatment conditions resulting in completely different mechanical properties.
Only if AISI 410/416 are sourced with a heat treatment resulting in the highest possible tensile and yield strength this material reaches mechanical properties comparable but not superior to 1.4021.

Chemical Composition

Material	Standard	C	Cr	Mn	P	S	Si
1.4021	EN 10088-3	0,16 - 0,25	12 - 14	1,5	0,04	0,015	1
AISI 410	SA 276	0.15	11.5 - 13.5	1	0,04	0,03	1
AISI 416	ASTM A582	0.15	12 - 14	1.25	0.06	0.015	1

Table 9.5.3.5-1: Chemical composition of 1.4021, AISI 410 and AISI 416

The chemical composition of the three materials is almost identical, resulting in comparable chemical resistance.

9.5.3.6 Spring Materials

LESER standard stainless steel spring material is 1.4310. Competitors often use 316 springs as standard (DIN equivalent: 1.4401). This chapter shall compare both materials and give an overview about the range of application for both.

Chemical Composition
The following chemical composition and mechanical properties were taken from referenced material codes for spring wire:

Material		1.4310	1.4401	316
Short name		X10CrNi18-8	X5CrNiMo17-12-2	S 31600
Code		DIN EN 10270-3: 2012-01	DIN EN 10270-3: 2012-01	A 313/A 313M – 03
Chemical composition	C	0,05 - 0,15	max. 0,07	max. 0,07
	Si	max. 2,00	max. 1,00	max. 1,00
	Mn	max. 2,00	max. 2,00	max. 2,00
	P	max. 0,045	max. 0,045	max. 0,045
	S	max. 0,015	max. 0,015	max. 0,03
	Cr	16,0 - 19,0	16,5 - 19,0	16,5 - 18,0
	Mo	max. 0,80	2,00 - 2,50	2,00 - 2,50
	Ni	6,5 - 9,0	10,0 - 13,0	10,5 - 13,5
	N	max. 0,11	max. 0,11	max. 0,10

Table 9.5.3.6-1: Chemical composition of 1.4310, 1.4401 and 316

The only differences lay in the Si, Mo, and Ni- content. The main difference can be found in Mo- and Ni-content which is lower for 1.4310. Molybdenum and nickel as alloying component lead to higher corrosion resistance, mainly when it comes to highly concentrated and hot acids.

Mechanical Properties:
The following tables summarize the mechanical properties from material standards:

Material		1.4310 NS	1.4310 HS	1.4401	316
Short name		X10CrNi18-8	X10CrNi18-8	X5CrNiMo17-12-2	S 31600
Code		DIN EN 10270-3: 2012-01	DIN EN 10270-3: 2012-01	DIN EN 10270-3: 2012-01	A 313/ A 313M – 03
Mechanical properties	Tensile str. Ø5mm [MPa]	1450 - 1670	1550 - 1790	1200 - 1380	1105 - 1310
	Tensile str. Ø10mm [MPa]	1250 - 1440	1350 - 1560	1050 - 1210	895 - 1105

Table 9.5.3.6-2: Mechanical properties of 1.4310, 1.4310HS, 1.4401 and 316 from material standards

Additionally to above mentioned mechanical properties the following values from spring suppliers shall be taken into account, because they are relevant for the design of springs:

	Material	1.4310 NS	1.4310 HS	1.4401	316
	Short name	X10CrNi18-8	X10CrNi18-8	X5CrNiMo17-12-2	S 31600
Mechanical properties	**E-Module**	180000	185000	185000	n.a.
	Rm	1336,1	1440,8	1019	n.a.
	G	71500	73000	69500	n.a.

Table 9.5.3.6-2: Additional mechanical properties of 1.4310, 1.4310HS, 1.4401 and 316

The mechanical properties, especially Rm (tensile strength) and G-module (shear modulus) of LESER's standard material are higher than for 316. This is advantageous for the design of springs, because it allows to design springs with a larger force in a given space (bonnet). This means a higher possible set pressure for a given valve design.

LESER standard springs made of 1.4310 are suitable for a temperature range between -196°C up to +280°C (temperature at the spring, not medium temperature).
As 316 springs have the same temperature range, both materials can be considered to be equal.

Summary
1.4310 provides better mechanical properties with a wider set pressure range. For a large majority of applications 1.4310 provides also a very good corrosion resistance. The only point where 316 offers a benefit is in regards to corrosion resistance when it comes to highly concentrated and hot acids. In those cases a bellows should be selected to protect the spring area.

9.6 High Alloy Materials and Applications

Whenever a standard material like carbon steel or austenitic stainless steel is not sufficient for an application, high alloy materials must be considered for trim and body materials.
There can be various reasons requiring the choice of a non standard material, e.g.

- corrosive medium
- corrosive environment
- high or low temperature
- p/t rating

The list of potential materials is extensive and this section shall provide general guidelines as well as an overview of material options.

9.6.1 High Alloy Material Concept

High alloy materials are typically expensive materials and sourcing and machining of individual components vs. large lot sizes can add further costs. When selecting high alloy materials the user should evaluate the application properly and decide which components of the safety valve shall be made from these materials.
For this decision it is important to analyse if, when and how often the different components of a safety valve come into contact with a corrosive medium or environment and what the consequences of a corrosive attack of these components would be. Limited corrosion of the valve external may be acceptable, whereas corrosion of the spindle and guide can not be accepted.

The following figures and charts shall help to understand the critical areas and components in a safety valve.

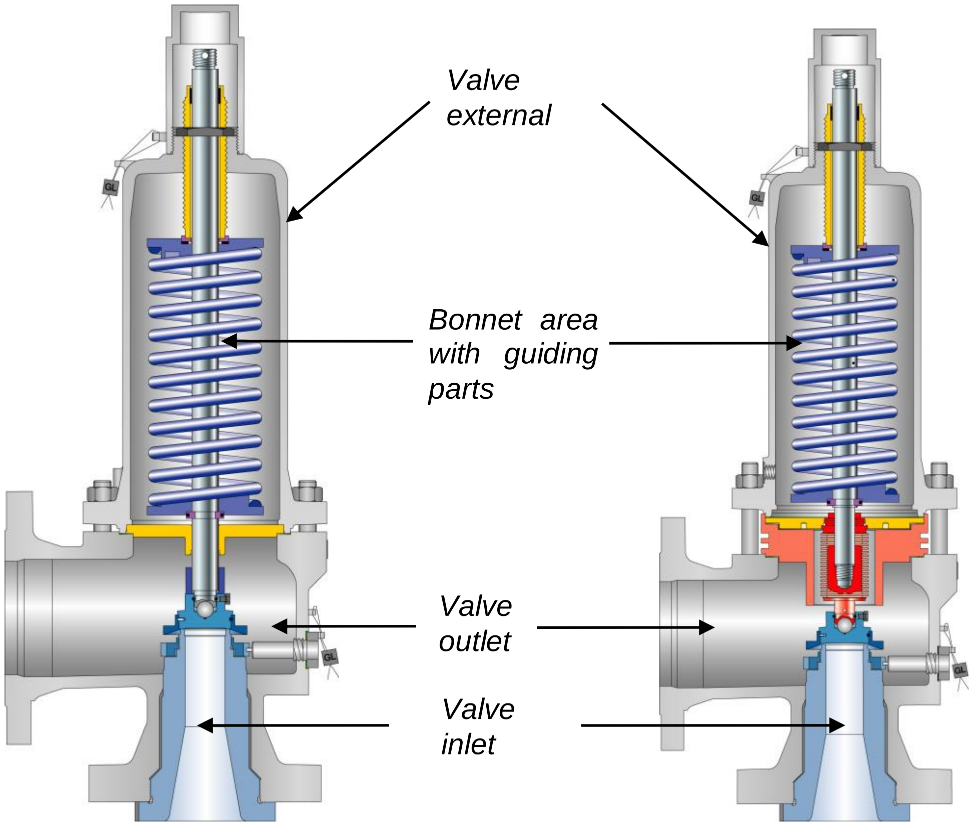


Figure 9.6.1-1: Critical areas and components in a conventional safety valve

Figure 9.6.1-2: Critical areas and components in a balanced bellows safety valve

The different areas of a safety valve can be distinguished regarding corrosion considerations as follows:

<table>
<tr><th>Area</th><th>Conventional Design</th><th>Balanced Bellows Design</th></tr>
<tr><td>Valve inlet</td><td colspan="2">- Permanently medium wetted area
- Corrosion at seat and disc must be avoided to ensure proper opening of the safety valve</td></tr>
<tr><td>Valve outlet</td><td colspan="2">- Not permanently medium wetted area
- Wetted only
• after discharge or
• if safety valve shows leakage (e.g. when operating close to set pressure) or
• if corrosive medium is present also in the discharge system</td></tr>
<tr><td>Bonnet area with guiding parts</td><td>- See “Valve Outlet”
- Corrosion of guide and spindle must be avoided to ensure proper opening of the safety valve</td><td>- The bellows seals and protects the bonnet area and the guiding parts from any medium in the valve outlet
- The only potential for corrosive attack of the guiding parts comes from a corrosive environment (e.g. marine) entering the bonnet through the bonnet vent.</td></tr>
<tr><td>Valve External</td><td colspan="2">Corrosive attack of the body and bonnet from a corrosive environment (e.g. marine, sea water).</td></tr>
</table>

Table 9.6.1-1: Different areas of a conventional design and balanced bellows design

At the end a decision between the cost of a corrosion resistant design and a more frequent maintenance cycle must be made by the user.
To assist making this decision LESER offers different levels for the extent of components in high alloy materials.

9.6.2 The LESER Level Concept

The pictures below visualize the different levels of corrosion protection for a LESER API Series safety valve. Components in red color indicate the high alloy material component within each level.

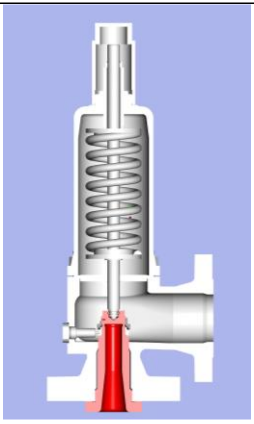
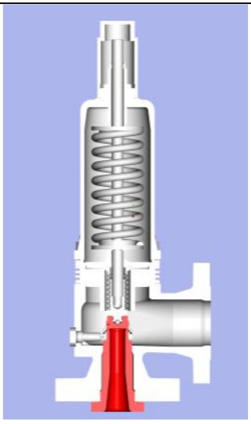
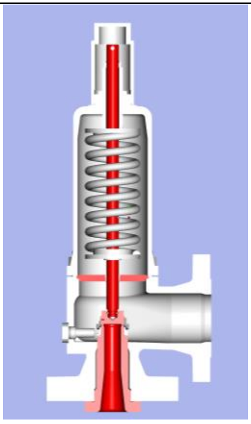
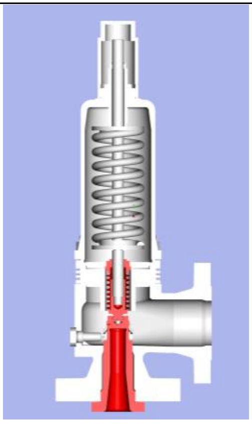
Level 1 **Inlet Wetted parts**		**Level 2** **Inlet Wetted & Guiding parts**	
1.0 Conventional	1.1 Bellows	2.0 Conventional	2.1 Bellows
			

Figure 9.6.2-1: Level 1 and 2 of high alloy material components

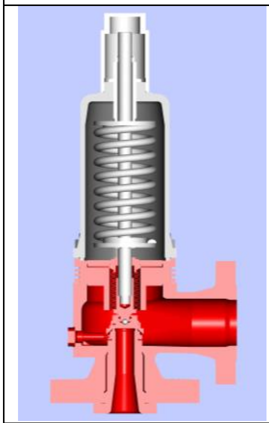
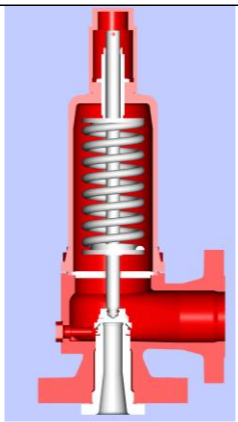
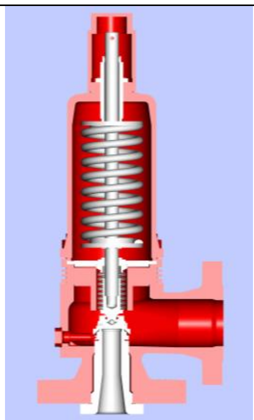
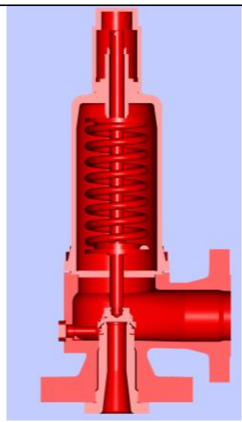
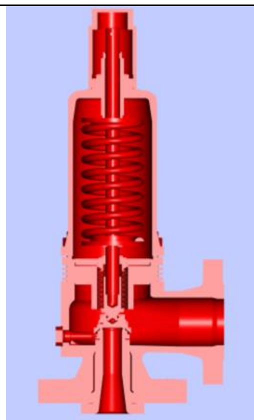
Level 3 - Inlet & Outlet Wetted	**Level 4** **Valve Externals** (body and bonnet)		**Level 5** **Complete Valve**	
3.1 Bellows	4.0 Conventional	4.1 Bellows	5.0 Conventional	5.1 Bellows
				

Figure 9.6.2-2: Level 3, 4 and 5 of high alloy material components

The following chart provides a guideline for the application of the different levels depending on the general operating conditions and maintenance aspects.

Level	Components	Criteria for Selection	Explanation
1	Inlet Wetted parts	- corrosive medium - set pressure much higher than operating pressure - safety valve opening unlikely - immediate maintenance after discharge	When it is very unlikely due to other measures controlling the process that a safety valve will ever open, it may be sufficient to change only the permanently wetted nozzle and disc. The outlet wetted parts can remain standard materials, because it is very unlikely that they ever come in contact with the medium.
2	Inlet Wetted & Guiding parts	- corrosive medium - operating pressure closer to set pressure - safety valve opening more likely - delayed maintenance after discharge	Through a potential opening of the safety valve or small leakage also outlet components might come in to contact with the medium. The most critical parts in the valve outlet for the proper function of the safety are the spindle and the guide which should be changed to a high alloy material, or alternatively be protected by a balanced bellows in a corrosion resistant material.
3	Inlet & Outlet Wetted parts (bellows design only)	- corrosive medium - operating pressure close to set pressure - safety valve opening likely - continuous operation without maintenance after discharge required	All medium wetted components are in a corrosion resistant material. The bellows protects all components above the guide, which can remain in standard materials. Cost effective solution compared to a full valve in high alloy materials.
4	Valve Externals (body & bonnet)	- corrosive environment - high or low temperature	Marine or offshore application may lead to corrosion of the external components of a safety valve while the internal medium wetted components are not affected.
5	Complete Valve	- extremely corrosive medium and/or environment - corrosive attack of any component in the valve is expected - safety valve opening likely - continuous operation without maintenance after discharge	Highest level of corrosion protection, but also expensive.

Table 9.6.2-1: LESER level concept for high alloy materials

9.6.3 LESER High Alloy Material Options

The following table shows a selection of the high alloy materials that are available for the LESER safety valves Series 526 as an option. Further materials are available on request. Materials highlighted in grey are standardized at LESER and available within short delivery time.

Part	Material Group	Product form	EN Material[1)]	ASME / ASTM Material[1)]	UNS	Notes [3)]
Body / Bonnet [2)]	Austenitic S.S.	Casting		SA 351 - CF3M	J92800	low carbon version of CF8M
		Casting		SA 351 - CG8M	J93000	
		Casting	1.4552	SA 351 - CF8C	J92710	
	Duplex	Casting	1.4470	SA 995 – CD3MN	J92205	Gr. 4A, Code Case 2402
	Super Duplex	Casting		SA 995 - CD3MWCuN	J93380	Gr. 6A, Code Case 2244-2
		Casting	1.4517	SA 995 - CD4MCuN	J93372	Gr. 1B, Code Case 1750-20
	Super Austenitic	Casting		SA 351 - CK3MCuN	J93254	Code Case 1750-20, 254 SMO equivalent
		Casting		SA 351 - CN3MN	J94651	AL6XN equivalent
		Casting		SA 351 - CN7M	J95150	Alloy 20 equivalent
	Nickel base	Casting		SA 494 – CX2MW	N26022	Hastelloy C-22 equivalent
		Casting		SA 494 – CW-12MW	N30002	Hastelloy C-276 equivalent
		Casting		SA 494 – M35-1	N24135	Monel 400 equivalent
		Casting		SA 494 – CW-6MC	N26625	Inconel 625 equivalent
Nozzle Disc Spindle Guide	Austenitic S.S.	Bar	1.4404	SA 479 – 316L SA 182 – F316L	S31603	
		Bar	1.4552	SA 479 – 347 SA 182 – F347	S34700	
	Duplex	Bar Forging	1.4462	SA 479 - S31803 SA 182 – F51	S31803	Alloy 2205
	Super Duplex	Bar Forging	1.4501	SA 479 - S32760 SA 182 – F55	S32760	Zeron 100
		Bar Forging	1.4507	SA 479 - S32550 SA 182 – F61	S32550	Alloy 255
	Super Austenitic	Bar Forging	1.4547	SA 479 – S31254 SA 182 – S31254	S31254	254 SMO
		Bar	1.4529	SB 691 / SB 462 - N08367	N08367	AL6XN
		Bar	2.4660	SB 473 / SB 462 - N08020	N08020	Alloy 20
	Nickel base	Bar	2.4610	SB 574 - N06455	N06455	Hastelloy C-4
		Bar	2.4602	SB 574 / SB 564 - N06022	N06022	Hastelloy C-22
		Bar	2.4856	SB 446 – N06625	N06625	INCONEL 625
		Bar	2.4360	SB 164 – N04400	N04400	Monel-400
Studs	Nickel base	Bar	2.4819	SB 574 - N10276	N10276	Hastelloy C-276
		Bar	2.4360	SB 164 – N04400	N04400	Monel 400
		Bar	2.4375	ASTM B 865 – N05500	N05500	Monel K-500
		Bar	2.4856	SB 446 – N06625	N06625	Inconel 625
Nuts	Nickel base	Bar	2.4819	SB 574 - N10276	N10276	Hastelloy C-276
		Bar	2.4360	SB 164 – N04400	N04400	Monel 400
		Bar	2.4375	ASTM B 865 – N05500	N05500	Monel K-500
		Bar	2.4856	SB 446 – N06625	N06625	Inconel 625
Spring	Nickel base	Bar	2.4669	ASTM B637 / AMS 5699 - N07750	N07750	Inconel X-750
		Bar	2.4610	N06455	N06455	Hastelloy C-4
Bellows	Nickel base/ Stainless St.	Sheet	2.4856/ 1.4404	SB 446 – N06625 / SA 479 – 316L	N06625	Bellows from Inconel 625, flange and tailpiece from 316L
	Nickel base	Sheet	2.4856	SB-443 - N06625	N06625	
	Nickel base	Sheet	2.4819	SB-619/SB-622 - N10276 SB 574 - N06455	N10276	Bellows from Hastelloy C 276, flange and tailpiece from Hast. C-4

1) EN materials listed in each line are equivalent materials to the ASME materials. They may or may not be supplied with material double certificate.
2) Some bonnet sizes may be offered in welded design or bar material versus the listed casting material
3) Hastelloy is a trademark of Haynes International, Inc., Inconel, Monel are trademarks of Special Metals Corporation

Table 9.6.3-1: High alloy material options for LESER API Series 526

9.6.4 Corrosion Resistance of Selected High Alloy Materials

A Guide to Aqueous Corrosion-Resistance
(All alloys listed are resistant to chloride cracking)

★ = Good to excellent
☆ = Acceptable
– = Not suitable

	Sulfuric Acid	Hydrochloric Acid	Hydrofluoric Acid	Phosphoric Acid	Nitric Acid	Organic Acids	Alkalines & Salts	Seawater
Nickel 200	☆	☆	★	☆	–	★	★	☆
Nickel 201	☆	☆	★	☆	–	★	★	☆
DURANICKEL® alloy 301	☆	☆	★	☆	–	★	★	☆
MONEL® alloy 400	★	☆	★	★	–	★	★	★
MONEL® alloy R-405	★	☆	★	★	–	★	★	★
MONEL® alloy K-500	★	☆	★	★	–	★	★	★
INCONEL® alloy 600	☆	–	☆	☆	–	★	★	☆
INCONEL® alloy 622	★	★	★	★	★	★	★	★
INCONEL® alloy 625	★	★	★	★	★	★	★	★
INCONEL® alloy 625LCF®	★	★	★	★	★	★	★	★
INCONEL® alloy 686	★	★	★	★	★	★	★	★
INCONEL® alloy 690	☆	☆	★	★	★	★	★	☆
INCONEL® alloy 718	☆	☆	☆	☆	☆	★	★	★
INCONEL® alloy 725™	★	★	★	★	★	★	★	★
INCONEL® alloy C-276	★	★	★	★	☆	★	★	★
INCONEL® alloy G-3	★	★	★	★	★	★	★	★
INCONEL® alloy 050	★	★	★	★	★	★	★	★
INCOLOY® alloy 800	☆	☆	–	☆	★	★	☆	☆
INCOLOY® alloy 825	★	★	★	★	★	★	★	★
INCOLOY® alloy 864™	☆	☆	☆	☆	★	★	★	★
INCOLOY® alloy 925™	★	★	★	★	★	★	★	★
INCOLOY® alloy 020	★	★	★	★	★	★	★	★
INCOLOY® alloy 25-6MO	★	★	☆	★	★	★	★	★
INCOLOY® alloy 028	☆	★	☆	☆	★	★	★	★

["High-Performance Alloys for Resistance to Aqueous Corrosion", Publication from Special Metals Corporation, Huntington, West Virginia, USA]

Table 9.6.4-1: Corrosion resistance of selected high alloy materials

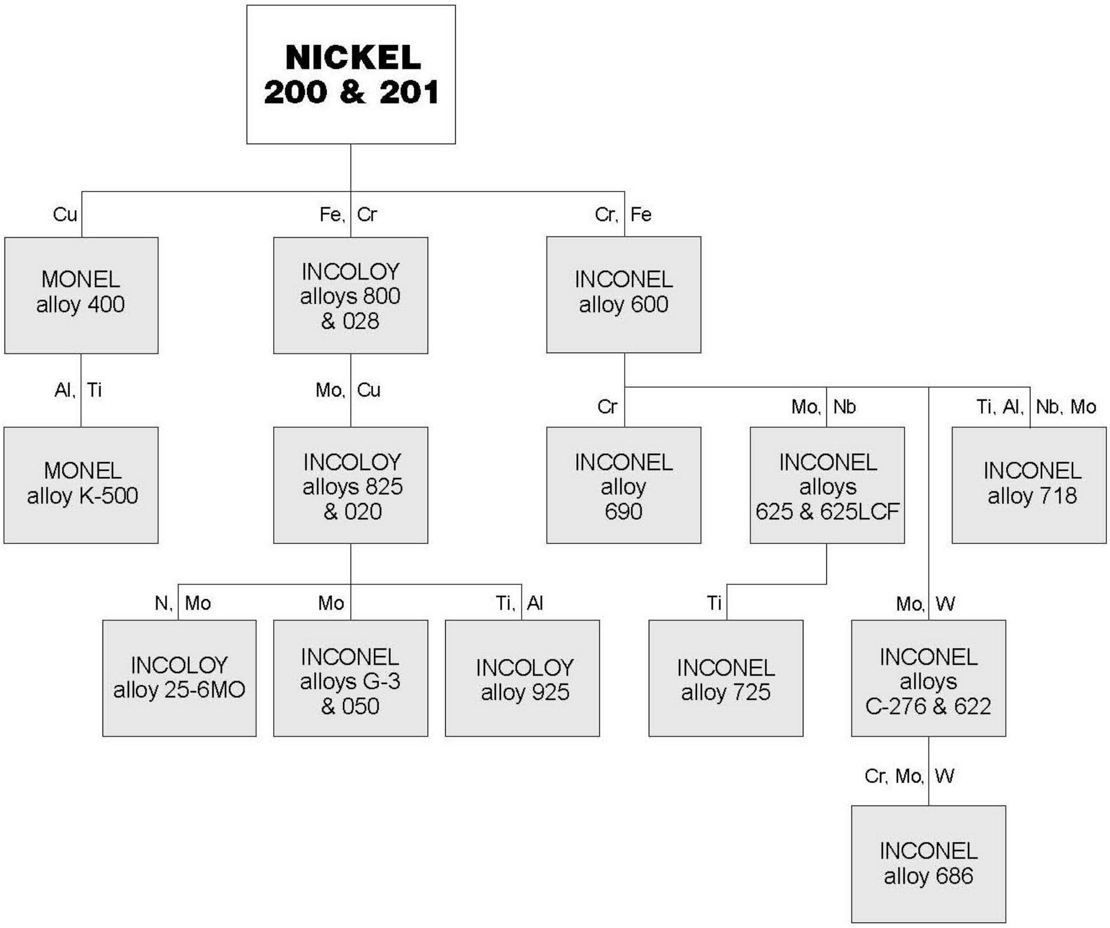
9.6.5 Chemical Compositions of High Alloy Materials

Material	UNS Bar / Casting	Ni min-max	Cr min-max	Mo min-max	Fe min-max	Cu min-max	Other min-max
NICKEL BASE MATERIALS							
HASTELLOY C-4	N06455 / ---	balance	14.0-18.0	14.0-17.0			
HASTELLOY C-22	N06022 / N26022	balance	20.0-22.5	12.5-14.5			2.5-7.0
HASTELLOY C-276	N10276 / N30002	balance	14.5-16.5	15.0-17.0			3.0-8.5
Hastelloy B-2	N10665 / ---	balance		26.0-30.0			
Hastelloy B-3	N10675 / ---	≥ 65.0		27.0-32.0			
Alloy B-4	N10629 / ---	balance		26.0-30.0			
Monel 400	N04400 / N24135	≥ 63.0				28.0-34.0	
Monel K-500	N05500 / ---	≥ 63.0				27.0-33.0	2.7-6.2
Nickel 200	N02200 / N02100	≥ 99.0					
Inconel 600	N06600 / N06040	≥ 72.0	14.0-17.0		6.0-10.0		
Inconel 601	N06601 / ---	58.0-63.0	21.0-25.0		balance		
Inconel 625	N06625 / N26625	≥ 58.0	20.0-23.0	8.0-10.0	0-5.0		3.2-7.1
Inconel X-750	N07750 / ---	≥ 70.0	14.0-17.0		5.0-9.0		3.4-7.5
Incoloy 800	N08800 / ---	30.0-35.0	19.0-23.0		≥ 39.5		
Incoloy 825	N08825 / N08826	38.0-46.0	19.5-23.5		≥22.0		2.1-6.0
22 Cr STANDARD DUPLEX MATERIALS							
Alloy 2205	S31803 / J92205		21.0-23.0		balance		
25 Cr SUPER DUPLEX MATERIALS							
Alloy 2507	S32750 / ---	6.0-8.0	24.0-26.0		balance		
Zeron 100	S32760 / J93380	6.0-8.0	24.0-26.0		balance		
Alloy 255	S32550 / J93372	4.5-6.5	24.0-27.0		balance		
SUPER AUSTENITIC MATERIALS							
254 SMO	S31254 / J93254	17.5-18.5	19.5-20.5	6.0-6.5	balance		
AL6XN	N08367 / J94651	23.5-25.5	20.0-22.0	6.0-7.0	balance		
Alloy 20	N08020 / J95150	32.0-38.0	19.0-21.0		balance		3.6-8.2
Alloy 904	N08925 / ---	24.0-26.0	19.0-21.0	6.0-7.0	balance		
Alloy 904L	N08904 / ---	23.0-28.0	19.0-23.0		balance		
Alloy 926	N08926 / ---	24.0-26.0	19.0-21.0	6.0-7.0	balance		

Notes:
- UNS numbers are linked only if material is listed in ASME VIII.
- Cu is only listed separately if the content is higher than 4 %, else Cu is listed under “Other”.
- Composition is listed only for bar material, the equivalent casting may have a slightly different composition.
- Additional information about the composition can be found in the respective material standard.

Table 9.6.5-1: Chemical composition of selected high alloy materials

The following chart shows the development of nickel-based alloys with multiple alloying additions.



[“High-Performance Alloys for Resistance to Aqueous Corrosion”, Publication from Special Metals Corporation, Huntington, West Virginia, USA]

Figure 9.6.5-1: Development of nickel-based alloys with multiple alloying additions

9.6.6 Alloying Elements and their Function

Nickel – Provides metallurgical stability, improves thermal stability and weldability, improves resistance to reducing acids and caustics, and increases resistance to stress corrosion cracking particularly in chlorides and caustics.

Chromium – Improves resistance to oxidizing corrosives and to high-temperature oxidation and sulfidation, and enhances resistance to pitting and crevice corrosion.

Molybdenum – Improves resistance to reducing acids, and to pitting and crevice corrosion in aqueous chloride containing environments. It contributes to increased high-temperature strength.

Iron – Improves resistance to high-temperature carburizing environments, reduces alloy costs, and controls thermal expansion.

Copper – Improves resistance to reducing acids (particularly non-aerated sulfuric and hydrofluoric) and to salts. Copper additions to nickel-chromium-molybdenum iron alloys provide improved resistance to hydrochloric, phosphoric and sulfuric acids.

Aluminum – Improves resistance to oxidation at elevated temperatures and promotes age hardening.

Titanium – Combines with carbon to reduce susceptibility to intergranular corrosion due to chromium carbide precipitation resulting from heat treatments, and enhances age hardening.

Niobium (Columbium) – Combines with carbon to reduce susceptibility to intergranular corrosion due to chromium carbide precipitation resulting from heat treatments, improves resistance to pitting and crevice corrosion, and increases high temperature strength.

Tungsten – Improves resistance to reducing acids and to localized corrosion, and enhances both strength and weldability.

Nitrogen – Enhances metallurgical stability, improves pitting and crevice corrosion resistance, and increases strength.

Cobalt – Provides increased high-temperature strength, and resistance to carburization and sulfidation.

[“High-Performance Alloys for Resistance to Aqueous Corrosion”, Publication from Special Metals Corporation, Huntington, West Virginia, USA]

The following link provides additional information on alloying elements and their effect on steel:

http://www.stahlschluessel.de/en/info_element__lang.html

9.6.7 Corrosion Types

Pitting Corrosion

Pitting is a form of localised corrosion and is characterised by attacks at small discrete spots on the steel surface. Pitting occurs mainly in the presence of neutral or acidic solutions containing chlorides or other halides. Chloride ions facilitate a local breakdown of the passive layer, especially if there are imperfections in the metal surface.

Crevice corrosion

Crevice corrosion is a form of localised corrosion and occurs under the same conditions as pitting, i.e. in neutral or acidic chloride solutions. However, attack starts more easily in a narrow crevice than on an unshielded surface. Crevices, such as those found at flange joints or at threaded connections, are thus often the most critical sites for corrosion.

Stress corrosion cracking

A material failure may be accelerated by the combined effect of corrosion and mechanical stress. The most common type is transgranular stress-corrosion cracking, SCC, that may develop in concentrated chloride-containing environments. Previously, it was generally considered that an elevated temperature was necessary for SCC to occur. In recent years, however, SCC has been experienced at ambient temperature on standard grade steels like 304(L) or 316(L) that were exposed to high tensile stresses. In these cases the steel surface was contaminated with solid salt deposits and the humidity of the atmosphere was rather high. These two factors resulted in a thin liquid film saturated with chloride. Other contaminants, such as H2S, may increase the risk of SCC in chloride containing environments. Other environments that may give rise to SCC, particularly on low alloy steels, include very alkaline solutions at high temperatures. A typically SCC attack takes the form of thin, branched cracks.

Intergranular corrosion

This type of corrosion may occur if the area around the grain boundaries is less corrosion resistant than the matrix in the medium in question. The classical case is when chromium carbide is precipitated at the grain boundaries. The adjacent matrix will be depleted in chromium and a narrow region around the grain boundary may, therefore, be less corrosion resistant than the rest of the material.

Corrosion fatigue

It is well known that a material subjected to a cyclic load far below the ultimate tensile stress can fail, a process called fatigue. If the metal is simultaneously exposed to a corrosive environment, the failure can take place at even lower loads and after shorter time. Contrary to a pure mechanical fatigue, there is no fatigue limit load in corrosion-assisted fatigue.

[http://www.stainless-steel-world.net]

9.6.8 PREN

Pitting resistance equivalent numbers (PREN) are a theoretical way of comparing the pitting corrosion resistance of various types of stainless steels, based on their chemical compositions. A higher value of the PREN number represents a better resistance.

PREN = %Cr + 3,3*%Mo + 16*%N (+1,65*%W).

This number can be used to rank different materials but does not provide an absolute value for corrosion resistance and is not applicable in all environments.
Sometimes nitrogen is weighted more, with factors of 27 or 30, but as the actual nitrogen levels are quite modest in most stainless steels, this does not have a dramatic effect on ranking.

Typical ranges of PREN	
Material	PREN
300 Series stainless steel	20 - 25
Duplex stainless steel	30 – 40
Super Duplex Super Austenitic	> 40

Table 9.6.8-1: Typical ranges of PREN

PREN > 40 is considered to be resistant against sea water.

9.7 Equivalent Materials

Metallic materials for use in pressure vessels can be furnished as casting, forging, bar or plate. Equivalent materials with similar chemical composition and similar mechanical properties are manufactured according to different specifications and may have different grade designations depending on the product form. This section shall help to identify equivalent materials in different product forms.

9.7.1 Equivalent Material Grades by Product Form – ASME Materials

The following table is based on table 1 of ASME B16.34-2004 and allows to find the equivalent materials depending on the product form. The material groups in this table identify materials with the same pressure temperature ratings per ASME B16.34.

GROUP 1 MATERIALS											
		Forging		Casting		Plates		Bars		Tubular	
Mat. Group	Nominal Designation	Spec	Grade	Spec	Grade	Spec	Grade	Spec	Grade	Spec	Grade
1.1	C-Si	A 105		A 216	WCB	A 515	70	A 105			
	C-Mn-Si	A 350	LF2			A 516	70	A 350	LF2	A 672	C 70
						A 537	Cl.1	A 696	C		B 70
	3 ½ Ni	A350	LF3								
	C-Mn-Si-V	A350	LF6 Cl.1								
1.2	C-Si									A 106	C
	2 ½ Ni			A 352	LC2	A 203	B				
	3 ½ Ni			A 352	LC3	A 203	E				
	C-Mn-Si			A 216	WCC						
				A 352	LCC						
	C-Mn-Si-V	A 350	LF6 Cl.2								
1.3	C							A 675	70		
	C-Si			A 352	LCB	A 515	65			A 672	B 65
	2 ½ Ni					A203	A				
	3 ½ Ni					A203	D				
	C-Mn-Si					A516	65			A 672	C 65
	C-½ Mo			A 217	WC1						
				A 352	LC1						
1.7	C-½ Mo									A 691	CM-75
	½ Cr-½ Mo	A 182	F2					A182	F2		
	Ni-½Cr-½Mo			A 217	WC4						
	¾Ni-Mo-¾Cr			A 217	WC5						
1.9	1¼Cr-½Mo-Si	A182	F11 Cl. 2			A 387	11 Cl. 2	A 182	F11 Cl. 2		
	1¼Cr-½Mo			A 217	WC6			A 739	B11		
1.10	2¼Cr-1Mo	A182	F22 Cl. 3	A 217	WC9	A 387	22 Cl. 2	A182	F22 Cl. 3		
								A 739	B22		
1.13	5Cr-½Mo	A 182	F5a	A 217	C5			A 182	F5a		
1.14	9Cr-1Mo	A 182	F9	A 217	C12			A 182	F9		
1.15	9Cr-1Mo-V	A 182	F91	A 217	C12A	A 387	91 Cl. 2	A 182	F91	A 335	P91

Table 9.7.1-1: Group 1 materials

GROUP 2 MATERIALS											
		Forging		Casting		Plates		Bars		Tubular	
Mat. Group	Nominal Designation	Spec	Grade	Spec	Grade	Spec	Grade	Spec	Grade	Spec	Grade
2.1	18Cr-8Ni	A 182	F304	A 351	CF3	A 240	304	A 182	F304	A312	TP304
		A 182	F304H	A 351	CF8	A 240	304H	A 182	F304H	A312	TP304H
								A 479	304	A 358	304
								A 479	304H	A 376	TP304
										A 376	TP304H
										A 430	FP304
										A 430	FP304H
2.2	16Cr-12Ni-2Mo	A 182	F316	A 351	CF3M	A 240	316	A 182	F316	A 312	TP316
		A 182	F316H	A 351	CF8M	A 240	316H	A 182	F316H	A 312	TP316H
								A 479	316	A 358	316
								A 479	316H	A 376	TP316
										A 376	TP316H
										A 430	FP316
										A 430	FP316H
2.2	18Cr-8Ni			A 351	CF3A						
	18Cr-13Ni-3Mo	A 182	F317			A 240	317			A 312	TP317
		A 182	F317H	A 351	CF8A	A 240	317H			A 312	TP317H
	19Cr-10Ni-3Mo			A 351	CG8M						
2.3	18Cr-8Ni	A 182	F304L			A 240	304L	A 182	F304L	A 312	TP304L
								A 479	304L		
	16Cr-12Ni-2Mo	A182	F316L			A 240	316L	A 182	F316L	A 312	TP316L
								A 479	316L		
2.4	18Cr-10Ni-Ti	A 182	F321			A 240	321	A 182	F321	A 312	TP321
		A 182	F321H			A 240	321H	A 479	321	A 312	TP321H
								A 182	F321H	A 358	321
								A 479	321H	A 376	TP321
										A 376	TP321H
										A 430	FP321
										A 430	FP321H
2.5	18Cr-10Ni-Cb	A 182	F347			A 240	347	A 182	F347	A 312	TP347
		A 182	F347H			A 240	347H	A 182	F347H	A 312	TP347H
		A 182	F348			A 240	348	A 182	F348	A 312	TP348
		A 182	F348H			A 240	348H	A 182	F348H	A 312	TP348H
								A 479	347	A 358	TP347
								A 479	347H	A 376	TP347
								A 479	348	A 376	TP347H
								A 479	348H	A 376	TP348
										A 376	TP348H
										A 430	FP347
										A 430	FP347H
2.6	23Cr-12Ni									A 312	TP309H
						A 240	309H			A 358	309H
2.7	25Cr-20Ni	A 182	F310H			A 240	310H	A 182	F310H	A 312	TP310H
								A 479	310H	A 358	310H
2.8	20Cr-18Ni-6Mo	A 182	F44	A 351	CK3MCuN	A 240	S31254	A 479	S31254	A 312	S31254
										A 358	S31254
	22Cr-5Ni-3Mo-N	A 182	F51			A 240	S31803	A479	S31803	A 789	S31803
										A 790	S31803
	25Cr-7Ni-4Mo-N	A 182	F53			A 240	S32750	A 479	S32750	A 789	S32750
										A 790	S32750
	24Cr-10Ni-4Mo-V			A 351	CE8MN						
	25Cr-5Ni-2Mo-3Cu			A 351	CD4MCuN						
	25Cr-7Ni-3.5Mo-W-Cb			A 351	CD3MWCuN					A 789	S32760
	25Cr-7Ni-3.5Mo-N-Cr-W	A 182	F55			A 240	S32760			A 790	S32760
2.9	23Cr-12Ni					A 240	309S				
	25Cr-20Ni					A 240	310S	A 479	310S		
2.10	25Cr-12Ni			A 351	CH8						
				A 351	CH20						
2.11	18Cr-10Ni-Cb			A 351	CF8C						
2.12	25Cr-20NI			A 351	CK20						

Table 9.7.1-2: Group 2 materials

GROUP 3 MATERIALS											
		Forging		Casting		Plates		Bars		Tubular	
Mat. Group	Nominal Designation	Spec	Grade	Spec	Grade	Spec	Grade	Spec	Grade	Spec	Grade
3.1	35Ni-35Fe-20Cr-Cb	B 462	N08020			B 463	N08020	B 473	N08020	B 464	N08020
										B 468	N08020
3.2	99Ni	B 160	N02200			B 162	N02200	B 160	N02200	B161	N02200
										B 163	N02200
3.3	99Ni-Low C	B 160	N02201			B 162	N02201	B160	N02201		
3.4	67Ni-30Cu	B164	N04400			B 127	N04400	B 164	N04400	B 165	N04400
										B 163	N04400
	60Ni-22Cr-9Mo-3.5Cb	B 564	N04400								
	67Ni-30Cu-S	B 164	N04405					B 164	N04405		
3.5	72Ni-15Cr-8Fe	B 564	N06600			B 168	N06600	B 166	N06600	B 167	N06600
										B 163	N06600
3.6	33Ni-42Fe-21Cr	B 564	N08800			B 409	N08800	B 408	N08800	B 163	N08800
3.7	65Ni-28Mo-2Fe	B 462	N10665			B 333	N10665	B 335	N10665	B 622	N10665
		B 564	N10665								
	64Ni-29.5Mo-2Cr-2Fe-Mn-W	B 462	N10675			B 333	N10675	B 335	N10675	B 622	N10675
		B 564	N10675								
3.8	54Ni-16Mo-15Cr	B 462	N10276			B 575	N10276	B 574	N10276	B 622	N10276
		B 564	N10276								
	60Ni-22Cr-9Mo-3.5Cb	B 564	N06625			B 443	N06625	B 446	N06625		
	62Ni-28Mo-5Fe	B 335	N10001			B 333	N10001	B 335	N10001	B 622	N10001
	70Ni-16Mo-7Cr-5Fe	B 573	N10003			B 434	N10003	B 573	N10003		
	61Ni-16Mo-16Cr	B 574	N06455			B 575	N06455	B 574	N06455	B 622	N06455
	42Ni-21.5Cr-3Mo-2.3Cu	B 425	N08825			B 424	N08825	B 425	N08825	B 423	N08825
	55Ni-21Cr-13.5Mo	B 462	N06022			B 575	N06022	B 574	N06022	B 622	N06022
		B 564	N06022								
	55Ni-23Cr-16Mo-1.6Cu	B 462	N06200			B 575	N06200	B 574	N06200	B 622	N06200
		B 564	N06200								
3.9	47Ni-22Cr-9Mo-18Fe	B 572	N06002			B 435	N06002	B 572	N06002	B 622	N06002
3.10	25Ni-47Fe-21Cr-5Mo	B 672	N08700			B 599	N08700	B 672	N08700		
3.11	44Fe-25Ni-21Cr-Mo	B 649	N08904			B 625	N08904	B 649	N08904	B 677	N08904
3.12	26Ni-43Fe-22Cr-5Mo	B 621	N08320			B 620	N08320	B 621	N08320	B 622	N08320
	47Ni-22Cr-20Fe-7Mo	B 581	N06985			B 582	N06985	B 581	N06985	B 622	N06985
	46Fe-24Ni-21Cr-6Mo-Cu-N	B 462	N08367	A 351	CN3MN	B 688	N08367				
3.13	49Ni-25Cr-18Fe-6Mo	B 581	N06975			B 582	N06975	B 581	N06975	B 622	N06975
	Ni-Fe-Cr-Mo-Cu-Low C	B 564	N08031			B 625	N08031	B 649	N08031	B 622	N08031
3.14	47Ni-22Cr-19Fe-6Mo	B 581	N06007			B 582	N06007	B 581	N06007	B 622	N06007
	40Ni-29Cr-15Fe-5Mo	B 462	N06030			B 582	N06030	B 581	N06030	B 622	N06030
3.15	33Ni-2Fe-21Cr	B 564	N08810			B 409	N08810	B 408	N08810	B 407	N08810
	Ni-Mo			A 494	N-12MV						
	Ni-Mo-Cr			A 494	CW-12MW						
3.16	35Ni-19Cr-1¼ Si	B 511	N08330			B 536	N08330	B 511	N08330	B 535	N08330
3.17	29Ni-20½Cr-3½Cu-2½Mo			A 351	CN7M						
3.18	72Ni-15Cr-8Fe	B 167	N06600								

Table 9.7.1-3: Group 3 materials

9.7.2 Equivalent Material Grades by Product Form – EN Materials

The following table is an extract of table 9 of EN 1092-1 and allows to find the equivalent materials depending on the product form. The material groups in this table identify materials with the same pressure temperature ratings per EN 1092-1.

	Forging		Plates		Casting		Bars		Tubular	
Mat. Group	EN – Spec.	Grade	EN – Spec.	Grade	EN – Spec.	Grade	EN – Spec.	Grade	EN – Spec.	Grade
3E0	---	---	10028-2	1.0345	10213-2	1.0619	10273	1.0345	10216-2 10217-2	1.0345
4E0	10222-2	1.5415	10028-2	1.5415	10213-2	1.5419	10273	1.5415	10216-2 10217-2	1.5415
5E0	10222-2	1.7335	10028-2	1.7335	10213-2	1.7357	10273	1.7335	10216-2	1.7335
11E0	10222-5	1.4301	10028-7	1.4301	10213-4	1.4308	10272	1.4301	10216-5 10217-7	1.4301
12E0	10222-5	1.4541	10028-7	1.4541	---	---	10272	1.4541	10216-5 10217-7	1.4541
13E0	10222-5	1.4404	10028-7	1.4404	10213-4	1.4409	10272	1.4404	10216-5 10217-7	1.4404
13E0	10222-5	1.4435	10028-7	1.4435	---	---	10272	1.4435	10216-5 10217-7	1.4435
13E0	10222-5	1.4539	10028-7	1.4539	10213-4	1.4458	10272	1.4539	10216-5 10217-7	1.4539
13E1	---	---	10028-7	1.4547	---	---	10272	1.4547	10216-5 10217-7	1.4547
14E0	10222-5	1.4401	10028-7	1.4401	10213-4	1.4408	10272	1.4401	10216-5 10217-7	1.4401
15E0	10222-5	1.4571	10028-7	1.4571	---	---	10272	1.4571	10216-5 10217-7	1.4571
15E0	---	---	10028-7	1.4580	10213-4	1.4581	10272	1.4580	10216-5	1.4580
16E0	---	---	---	---	10213-4	1.4517	---	---	---	---
16E0	10222-5	1.4462	10028-7	1.4462	10213-4	1.4470	10272	1.4462	10216-5 10217-7	1.4462
16E0	10222-5	1.4410	10028-7	1.4410	---	---	10272	1.4410	10216-5 10217-7	1.4410
16E0	---	---	---	---	10213-4	1.4469	---	---	---	---

Table 9.7.2-1: Equivalent material grades by product form – EN materials

9.7.3 Equivalent ASME / EN Materials

The following chart shows equivalent materials between ASME and EN specifications. Equivalent means that chemical composition and mechanical requirements do overlap, so that it is possible to fulfill both requirements with one material.
In case of LESER standard (stock) materials LESER will supply a material double certificate, certifying both ASME and EN material in one certificate. For materials procured to order the certificate may show only one material ASME or EN.

CARBON STEEL						
Product form	ASME Spec.	ASME Grade	UNS Number	EN Grade	EN Spec.	Notes
Forging	SA 105	105		1.0460	10222-2	C22.8
Plate	SA 515	70			VdTÜV 350/1	
Bar	SA 105	105			10273	
Tubular						
Casting	SA 216	WCB	J03002	1.0619	10213-2	Supplied with three fold material certificate WCB/WCC/1.0619
Forging						
Plate	SA 515	65				
Bar						
Tubular	SA 672	B 65				
Casting	SA 352	LCB				Supplied with five fold material certificate LCB/LCC/WCB/WCC/ 1.0619

Table 9.7.3-1: ASME / EN equivalent carbon steel

HIGH TEMPERATURE ALLOY CARBON STEEL						
Product form	ASME Spec.	ASME Grade	UNS Number	EN Grade	EN Spec.	Notes
Forging				1.7335	10222-2	
Plate					10028-2	
Bar	SA 739	B11			10273	
Tubular					10216-2	
Casting	SA 217	WC6	J12072	1.7357	10213-2	Supplied with double material certificate WC6/1.7357

Table 9.7.3-2: ASME / EN equivalent high temperature carbon steel

AUSTENITIC STAINLESS STEEL						
Product form	ASME Spec.	ASME Grade	UNS Number	EN Grade	EN Spec.	Notes
Forging	SA 182	F316	S31600	1.4401	10222-5	1.4401/316 and 1.4404/316L are commercially frequently produce as one grade fulfilling all four material standards.
Plate	SA 240	316			10028-7	
Bar	SA 479	316			10272	
Tubular	SA 312	TP316			10216-5 10217-7	
Casting	SA 351	CF8M	J92900	1.4408	10213-4	Supplied with double material certificate CF8M/1.4408
Forging	SA 182	F316L	S31603	1.4404 or 1.4435	10222-5	1.4401/316 and 1.4404/316L are commercially frequently produced as one grade fulfilling all four material standards.
Plate	SA 240	316L			10028-7	
Bar	SA 479	316L			10272	
Tubular	SA 312	TP316L			10216-5 10217-7	
Casting	SA 351	CF3M	J92800	1.4409	10213-4	

Table 9.7.3-3: ASME / EN equivalent stainless steel

SUPER AUSTENITIC STAINLESS STEEL						
Product form	**ASME Spec.**	**ASME Grade**	**UNS Number**	**EN Grade**	**EN Spec.**	**Notes**
Forging	SA 182	F44	S31254	1.4547	10222-5	Commercial designation: 254 SMO, 6Mo Material CK3MCuN: Code Case 1750
Plate	SA 240	S31254			10028-7	
Bar	SA 479				10272	
Tubular	SA 312				10216-5	
Casting	SA 351	CK3MCuN	J93254			
Forging	SB 462	N08367	N08367	1.4529	10222-5	Commercial designation: AL6XN, 6Mo Material 1.4529 is similar but not absolute identical to N08367. Both materials have an overlapping chemical composition for all elements, however N08926 is the full UNS equivalent for 1.4529.
Plate	SB 688				10028-7	
Bar	SB 691				10272	
Tubular	SB 690				10216-5	
Casting	SA 351	CN3MN	J94651			
Forging	SB 462	N08020	N08020	2.4660	n/a	Commercial designation: Alloy 20 Carpenter 20 CB 3™ AL 20™ Carlson Alloy C20™ Nickelvac 23™ Nicrofer 3620 Nb™
Plate	SB 463				17750	
Bar	SB 473				17752	
Tubular	SB 464 SB 468				17751 17751	
Casting	SA 351	CN7M	J95150			

Table 9.7.3-4: ASME / EN equivalent super austenitic stainless steel

DUPLEX / SUPER DUPLEX						
Product form	**ASME Spec.**	**ASME Grade**	**UNS Number**	**EN Grade**	**EN Spec.**	**Notes**
Forging	SA 182	F51	S31803	1.4462	10222-5	Commercial designation: Alloy 2205
Plate	SA 240	S31803			10028-7	
Bar	SA 479				10272	
Tubular	SA 789				10216-5 10217-7	
Casting	SA 995	CD3MN	J92205	1.4470	10213-4	
Forging	SA 182	F55	S32760	1.4501	n/a	Commercial designation: Zeron 100
Plate	SA 240	S32760			10028-7	
Bar	SA 479				10272	
Tubular	SA 790				10216-5 10217-7	
Casting	SA 995	CD3NWCuN	J93380	(1.4508)		1.4508 is obsolete
Forging	SA 182	F61	S32550	1.4507	n/a	Commercial designation: Alloy 255
Plate		S32550			10028-7	
Bar	SA 479				10272	
Tubular					10216-5	
Casting	SA 995	CD4MCuN	J93372	1.4517	10213-4	

Table 9.7.3-5: ASME / EN equivalent duplex / super duplex steel

NICKEL BASE MATERIALS						
Product form	ASME Spec.	ASME Grade	UNS Number	EN Grade	EN Spec.	Notes
Forging	SB 462 / 564	N06022	N06022	2.4602		Commercial designation: Hastelloy C-22 2.4602 chemical composition: DIN 17744
Plate	SB 575				DIN 17750	
Bar	SB 574				DIN 17752	
Tubular	SB-619/622/ 626				DIN 17751	
Casting	SA 494	CX2MW	N26022			
Forging	SB 462 / 564	N10276	N10276	2.4819		Commercial designation: Hastelloy C-276 2.4819 chemical composition: DIN 17744
Plate	SB 575				DIN 17750	
Bar	SB 574				DIN 17752	
Tubular	SB 622				DIN 17751	
Casting	SA 494	CW-12MW	N30002	2.4686		
Forging	SB 574	N06455	N06455	2.4610		Commercial designation: Hastelloy C-4 CW2M is not listed in ASME VIII 2.4610 chemical composition: DIN 17744
Plate	SB 575				DIN 17750	
Bar	SB 574				DIN 17752 VDTÜV 424	
Tubular	SB 622				DIN 17751	
Casting	SA 494	CW2M				
Forging	SB 164	N04400		2.4360	DIN 17754	Commercial designation: Monel 400 2.4360 chemical composition: DIN 17744
Plate	SB 127				DIN 17750	
Bar	SB 164				DIN 17752	
Tubular	SB 165				DIN 17751	
Casting	SA 494	M35-1	N24135			
Forging	SB 546	N06625	N06625	2.4856		Commercial designation: Inconel 625 2.4856 chemical composition: DIN 17744
Plate	SB 443				DIN 17750	
Bar	SB 446				DIN 17752	
Tubular	SB 444				DIN 17751	
Casting	SA 494	CW-6MC	N26625			

Table 9.7.3-6: ASME / EN equivalent nickel base materials

9.8 Resistance Charts

The resistance of materials against the large number of chemicals under various conditions is a field that would exceed the scope of ENGINEERING. This section is limited to provide a number of references that contain helpful information on the corrosion resistance of different materials.

9.8.1 Metallic Materials

Outokumpu:
A free online guide for the corrosion resistance of selected stainless steel, superaustenitic stainless steel and duplex materials:
http://www.outokumpu.com/applications/corrosion/corrstart.asp

Thyssenkrupp:
A free downloadable guide for the corrosion resistance of selected stainless steel and duplex materials:
http://www.nirosta.org/fileadmin/media/PDF/chembest_en.pdf

Special Metals Corporation:
A detailed overview on nickel base materials, their general properties and specifics of their selection depending on different media:
http://www.specialmetals.com/documents/SM%20Aqueous%20Corrosion%20Book.pdf

www.engineeringtoolbox.com:
A free and simplified guide for a variety of different materials groups and chemicals:
http://www.engineeringtoolbox.com/metal-corrosion-resistance-d_491.html

DIN 6601:
Resistance of selected carbon steels and austenitic stainless steels against more than 3000 chemicals.

DECHEMA:

The DECHEMA Corrosion Handbook represents a comprehensive collection of knowledge that is unique both in its scope as well as content. It covers corrosion data and the chemical resistance of all technically important metallic, non-metallic, inorganic and organic materials in contact with more than 1000 aggressive media and 110.000 material-media combinations. The DECHEMA Corrosion Handbook is for purchase:

http://www.dechema.de/en/corrosion.html

9.8.2 Non-Metallic Materials

DuPont:
A free online guide for the chemical resistance of selected elastomers, plastics (registration required):
http://www.dupontelastomers.com/tech_info/chemical.asp

Buerkert:
A free downloadable guide for the chemical resistance of selected elastomers, plastics and steels:
http://www.buerkert.com/media/COM_Chemical_Resistance_Chart.pdf

9.9 Material Certificates and Traceability

9.9.1 Requirements for Material Certificates

PED 2014/68/EU defines in Annex 1, 4. Materials, section 4.3:
"… For the **main pressure-bearing parts** of equipment in categories II, III and IV, this must take the form of a certificate of specific product control.
Where a material manufacturer has an appropriate quality-assurance system, certified by a competent body established within the Community and having undergone a specific assessment for materials, certificates issued by the manufacturer are presumed to certify conformity with the relevant requirements of this section."

9.9.2 Content of a Material Certificate

A material certificate contains always two sections:
- chemical analysis
- mechanical properties

The scope of testing and resulting from this the content of a material certificate is defined by the applicable material standards (EN or ASME), amended by requirements of the purchaser.
European material standards also define the type of material certificate acc. to EN 10204 (see section 9.3) depending on the material, while for ASME specifications typically a 3.1 certificate is expected.

9.9.3 Types of Material Certificates acc. to EN 10204

EN 10204 defines different types of test reports depending on specific or non-specific inspection and different authorities issuing the test report.

Type of Test Report	Specific / Non-Specific Testing	Issued by
Test Report 2.2	Non-Specific	Manufacturer
Inspection Certificate 3.1	Specific	Manufacturer, validated by manufacturer's authorized inspection representative, independent of the manufacturing department
Inspection Certificate 3.2	Specific	Manufacturer's authorized inspection representative, independent of the manufacturing department and either the purchaser's authorized inspection representative or the inspector designated by the official regulations.

Table 9.9.3-1: Material certificates

- Specific testing: tests are performed on the batch which is supplied to the purchaser
- Non-specific testing: tests are performed regularly on the same material but not necessarily on the same batch which is supplied to the purchaser.

9.9.4 Double Material Certificates

Every pressure retaining or containing component like body, bonnet, nozzle, disc supplied by LESER is double material certified acc. to the applicable EN material standard and the corresponding ASME II material.
That means chemical composition and mechanical properties of the supplied material fulfills EN and ASME II requirements at the same time.
This applies to LESER standard materials available from stock. Materials sourced to order like Nickel base materials may supplied with either EN or ASME material certificate, depending on the requirements of the order.

9.9.5 Traceability of Materials

To ensure that the material and the material certificate of a pressure bearing component can always be traced a proper marking of the component is required.
The minimum requirement for the content of marking is
- heat or batch number
- material designation

For casting components the marking is typically provided by the casting supplier on every individual casting. For LESER safety valves this applies to:
- bodies
- bonnets
- lever caps
- nozzles

For components that are machined from bar stock, LESER uses a coding system which allows to trace back the material certificate for each individual part manufactured from a batch of bar material.
For LESER safety valves this applies to:
- nozzles / seat
- inlet bodies / outlet bodies / bonnets (Compact Performance safety valves)
- discs
- caps
- bonnet spacers
- studs / nuts

For each safety valve manufactured by LESER the material certificates of the following components are always recorded with the order:
- body / inlet body
- nozzle / seat
- spring

That means, based only on the serial number of the valve LESER can always trace the material certificate for these components. If further material certificates were ordered also these can easily be traced by valve serial number only. Material certificates for other components can be traced based on the marking of the individual component.

As an example the coding system for a disc is shown below. For details on marking of components, please refer to chapter “Marking” of ENGINEERING.

Part	1	2	3
Disc	GL1	1.4404.316L	CODE3924

Explanation
Material code Number
Material designation DIN/ ANSI
Name of the factory authorized expert

Figure 9.9.5-1: Marking of a disc

9.9.6 Download of Material Certificates

Material certificates for supplied valves can be downloaded from the LESER website:
http://www.leser.com/en/services/certificates.html

For further details, please refer to chapter “Quality and Environmental Management” of ENGINEERING.

9.10 Specific Material Requirements

9.10.1 Carbon Equivalent and Weldability

The Carbon Equivalent (CE) is used for rating of weld-ability of ferritic low alloy steels. It takes into account the equivalent additive effects of carbon and other alloying elements on a particular characteristic of steel.

A commonly used formula to calculate the Carbon Equivalent is based on a publication of the International Institute of Welding (IIW) [Technical Report 1967, IIW Doc. IX-535-67]:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15$$

For this equation the weldability based on a range of CE values can be defined as follows:

Carbon equivalent (CE)	**Weldability**
Up to 0.35	Excellent
0.36–0.40	Very good
0.41–0.45	Good
0.46–0.50	Fair
Over 0.50	Poor

[Ginzburg, Vladimir B.; Ballas, Robert (2000), Flat rolling fundamentals]
[SA-6/SA-6M - Specification For General Requirements For Rolled Structural Steel Bars, Plates, Shapes, And Sheet Piling. ASME BPVC Section II]

9.10.2 Killed or Fully Killed Carbon Steel

The definition of "killed steel" is given in ASTM A 941: "A steel deoxidized to such level that essentially no reaction occurred between carbon and oxygen during solidification." The purpose of the deoxidation is to avoid gas bubbles in the material in order to fulfill the quality requirements given in material standards like ASME SA 216.
Killed/ Fully Killed requirements in general are applicable to “Steel Ingot Casting“ which are then further processed to wrought products. However the main pressure containing components of a safety valve like body and bonnet are in most cases made from steel castings. Typical materials are WCB, WCC, LCB, LCC, 1.0619. The applicable material standards for these cast steel materials like ASME SA 216 , ASME SA 352 or ASME SA 703 actually do not explicitly mention the term killed steel/ fully killed steel.
Nevertheless in order to meet quality standards, today’s casting process in foundries is requiring materials to be always properly deoxidized using strong deoxidizers like Aluminium/ Calcium/ Zirconium/ Titanium to kill the steel melt. Therefore entire deoxidation can be seen as an industry standard in foundries. Furthermore, LESER defines material quality grades which can only be fulfilled with entirely deoxidized steel castings. All carbon steel castings supplied by LESER are consequently considered to be "killed" or, equivalently, "fully killed".

9.10.3 Corrosion Allowance

Other than for pressure vessels or pipelines (see e.g. ASME Code Sec. VIII Div. 1 UG-25) it is not common practice to increase the material thickness of safety valve bodies or nozzle and disc to allow for a certain corrosion. Material selection, especially of nozzle and disc should be such that corrosion does not occur, because it may lead to untightness or malfunction of the safety valve.

9.11 ASME Publications

SA 105, *Carbon Steel Forgings for Piping Components*

SA 106, *Seamless Carbon Steel Pipe for High Temperature Service*

SA 182, *Forged of Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service*

SA 193, *Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service*

SA 194, *Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature-Service or both*

SA 203, *Pressure Vessel Plates, Alloy Steel, Nickel*

SA 204, *Pressure Vessel Plates, Alloy Steel, Molybdenum*

SA 216, *Steel Castings, Carbon Suitable for Fusion Welding, for High-Temperature Service*

SA 217, *Steel Castings, Martensic Stainless and Alloy, for Pressure Containing Parts, Suitable for High-Temperature Service*

SA 240, *Chromium and Chromium-Nickel stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

SA 307, *Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*

SA 320, *Alloy/Steel Bolting Materials for Low Temperature Service*

SA 350, *Carbon and Low-Alloy Steel Forgings, Requiring Notch toughness Testing for Piping Components*

SA 351, *Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure Containing Parts*

SA 352, *Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*

SA 354, *Quenched and Tempered Alloy Steel Bolts, Studs and other Externally Threaded Fasteners*

SA 387, *Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

SA 449, *Quenched and Tempered Steel Bolts and Studs*

SA 453, *High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels*

SA 515, *Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

SA 516, Pressure *Vessel Plates, Carbon Steel, for Moderated- and Lower-Temperature Service*

SA 537, *Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon-Steel*

SA 540, *Alloy-Steel Bolting Materials for Special Applications*

SB 127, *Nickel-Copper Alloy (UNS N04400) Plate, Sheet and Strip*

SB 160, *Nickel Rod and Bar*

SB 162, *Nickel-Plate, Sheep and Strip*

SB 164, *Nickel-Copper Alloy Rod, Bar and Wire*

SB 166, *Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025 and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire*

SB 168, *Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025 and N06045)) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheep, and Strip*

SB 333, *Nickel-Molybdenum Alloy Plate, Sheet, and Strip*

SB 335, *Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*

SB 408, *Nickel-Iron-Chromium Alloy Rod and Bar*

SB 409, *Nickel-Iron-Chromium Alloy, Plate, Sheet, Strip*

SB 424, *Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08821) Plate, Sheet and Strip*

SB 425, *Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Rod and Bar*

SB 434, *Nickel-Molybdenum-Chromium-Iron Alloys (UNS N10003, UNS N10242) Plate, Sheet and Strip*

SB 435, *UNS N06002, UNS N06230, UNS N12160 and UNS R30556 Plate, Sheet, and Strip*

SB 443, *Nickel-Chromium-Molybdenum-Columbium Alloy (N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip*

SB 446, *Nickel-Chromium-Molybdenum-Columbium Alloy (N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Rod and Bar, and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar*

SB 462, *Forged or Rolled UNS N06030, UNS N06022, UNS N06200, UNS N08020, UNS N08024, UNS N08026, UNS N08367, UNS N10276, UNS N10665, UNS N10675 and UNS R20033 Alloy Pipe Flanges, Forged Fittings and Valves and Parts for Corrosive High-Temperature Service*

SB 463, *UNS N08020, UNS N08024 and UNS N08026 Alloy Plate, Sheet and Strip*

SB 473, *UNS N08020, UNS N08024 and UNS N08026 Nickel Alloy Bar and Wire*

SB 511, *Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes*

SB 536, *Nickel-Iron-Chromium-Silicon Alloy (UNS N08330 and N08332) Plate, Sheet, and Strip*

SB 564, *Nickel Alloy Forgings*

SB 572, *UNS N06002, UNS N06230, UNS N12160 and UNS R30556 Rod*

SB 573, *Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003, N10242)*

SB 574, *Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low Carbon Nickel Molybdenum-Chromium-Tantalum, Low-Carbon Nickel Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Rod*

D 575-1999a, *Low Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium Molybdenum-Copper, Low-Carbon Nickel-Chromium-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet and Strip*

SB 581-1997, *Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod*

SB 582-1997, *Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet and Strip*

SB 599-1992 (R1997), *Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Plate, Sheet, and Strip*

SB 620-1998a, *Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet and Strip*

SB 621-1995a, *Nickel Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod*

SB 625-1999, *UNS N08904, UNS N08925, UNS N08031, UNS N08932, UNS N08926 and UNS R20033 Plate, Sheet and Strip*

SB 649-1995, *Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe Cr-Mo-Cu-N Low Carbon Alloys (UNS N08925, UNS N08031 and UNS N08926) and Cr-Ni-Fe-N Low-Carbon Alloy (UNS R20033) Bar and Wire*

SB 672-1995, *Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Bar and Wire*

SB 6881-1996, *Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNS N08367) Plate, Sheet and Strip*

E 29-1993a (1999), *Using Significants Digits in Test Data to Determine Conformance with Specifications*

Publisher: The American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959