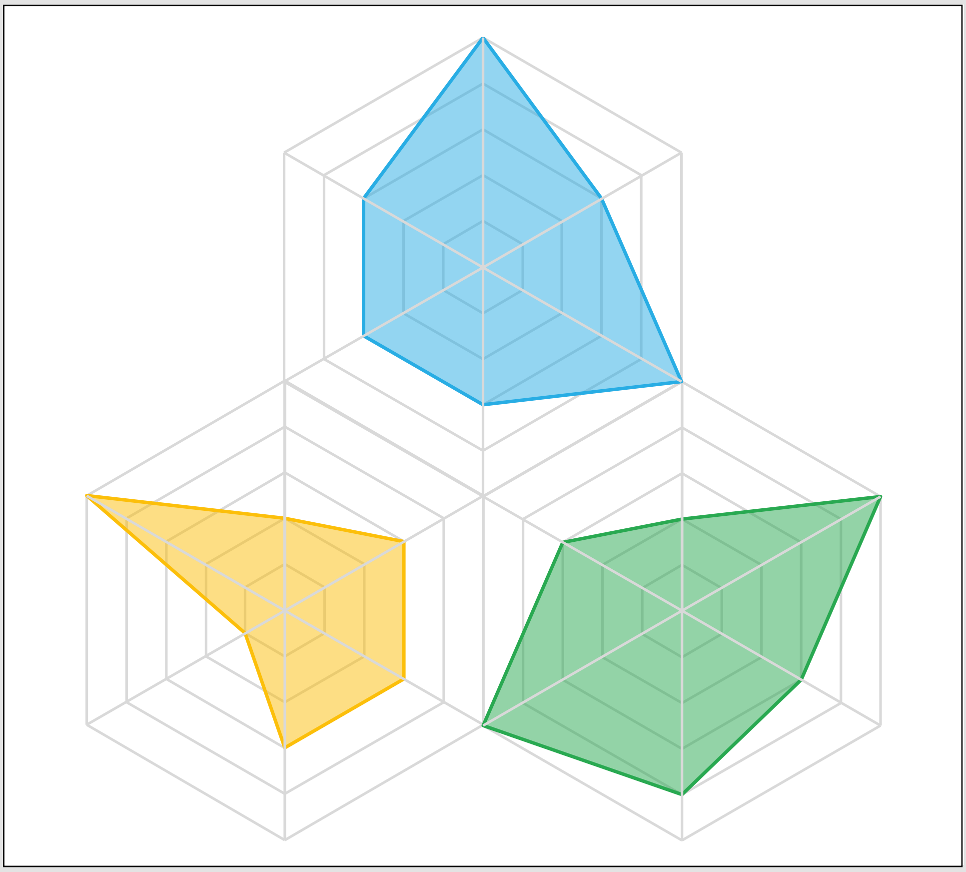
Stahl

Merkblatt 820e

# Guideline on the selection of stainless steels



EDELSTAHL Rost frei ®

Informationsstelle Edelstahl Rostfrei

# About Informationsstelle Edelstahl Rostfrei

The Informationsstelle Edelstahl Rostfrei (ISER) is a joint organisation of companies and institutions from the following sectors

- Stainless steel production (national and european),
- Stainless steel processing,
- Surface finishers,
- Stockholders and service centres,
- Alloying elements industry,
- Services and publishers.

ISER‘s tasks include provision of company-neutral information on properties and applications of stainless steel. The focus of the activities is on

- Practice-oriented, target group-specific technical publications,
- Online information platform,
- Public relations for professional journals and public media,
- Trade Fair participations,
- Performance of training events,
- Establishment of competence centres „Stainless-Steel-Processing“
- Supplier directories,
- Individual reply to technical questions.

All ISER brochures are available for free download at **www.edelstahl-rostfrei.de/publikationen**

# Content



# Imprint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# Introduction

Properties and workability of stainless steels are determined both directly by the alloying elements added and by the microstructure resulting from the respective alloy composition. While pure iron is only present in a body-centred cubic lattice (ferrite) at room temperature and the face-centred cubic austenite structure only occurs at higher temperatures, higher alloyed steels and thus also the stainless steels can have both an austenitic and a ferritic structure as well as a mixture of both at room temperature, depending on the alloy composition and the heat treatment. In addition, a tetragonal-distorted body-centred cubic crystal structure, which is referred to as martensite, can be achieved by specific heat treatment.

According to these microstructural states, the stainless steels are classified into

- ferritic (Cr),
- martensitic (Cr, C/Ni),
- austenitic (Cr, Ni, Mo, possibly Mn, N) and
- austenitic-ferritic (Cr, Ni, Mo, N)

stainless steels. The main alloying elements of these four groups are listed between brackets. Further information can be found in ISER brochures Merkblatt 803 and Merkblatt 821.

The above-mentioned four main groups of stainless steels each exhibit typical material properties. For example, austenitic grades are characterised by particularly good forming properties, while austenitic-ferritic steels (duplex steels) achieve higher strengths. By specifically changing alloy composition, it becomes possible to produce material grades that have comparable properties even across the boundaries of the main groups. However, this usually only applies to individual, selected properties and not to several at the same time. For this reason, a change to another material grade, for example to avoid an expensive alloying element, should not be made without a precise examination of the consequences for the existing area of application. This is because it is usually one of the main alloying elements (with the exception of chromium) that is to be changed, and thus a possible shift to another main group of stainless steels.

The substitution of a material grade should always be application-related and carefully considered. A limited consideration only of individual properties of a grade considered as a substitute could lead to far-reaching problems, quality losses and high cost.

The individual properties of steel grades are often divided into **„strengths“** and **„weaknesses“**. However, this evaluation should always be made regarding the area of application and should not be based on a general assessment. A characteristic can be particularly helpful in one application, while in another case it makes the use of the steel grade impossible. For example, high strength is important to many applications, whereas the usually associated lower forming capacity is less important. For other applications, high strength can be a disadvantage if high forming capacity is required (high forming forces, low drawing capacity).

What „weaknesses“ does a material bring to the application that is selected because of its „strengths“, which are absolutely necessary for the application? To what extent are the different properties of the grade important for the particular application? These questions should be asked when making a decision.

The following diagrams are intended to provide assistance in the selection of stainless steels, whereby the group of martensites is not considered.

The notched bar impact energy is not shown in the diagrams. As the austenitic stainless steels are not susceptible to brittle fracture even at very low temperatures, they can be used e.g. in the construction industry down to - 40 °C without further proof. Ferritic stainless steels, on the other hand, tend to become brittle at significantly higher temperatures. In the construction sector, therefore, at least an impact energy of 40 J must be verified for this group with ISO-V specimens at - 40 °C.

The verification must be carried out in accordance with the information in the German technical approval Z-30.3-6 (ISER brochure "Sonderdruck 862e"). With their notched impact strength and the position of their transition temperature, the austenitic-ferritic stainless steels - due to their microstructure - lie between the two aforementioned groups. Proof, as with ferrites, must also be provided in the construction sector.
Due to the volatility of the prices of alloying elements, costs cannot be discussed further here.

In the „spider web diagrams", the material properties of corrosion resistance, strength, formability, weldability, coefficient of thermal expansion and thermal conductivity are listed for the most common stainless steel grades with a simple grading system. The grades from one to five indicate whether the respective property is rather high or low in comparison to the listed steel grades. However, they should not and cannot represent a valuation of the property, as was already explained earlier in the text with the reference to supposed „strengths" and „weaknesses".

„spider web diagrams" with six material properties **corrosion resistance, strength, formability, weldability, thermal expansion, thermal conductivity.**

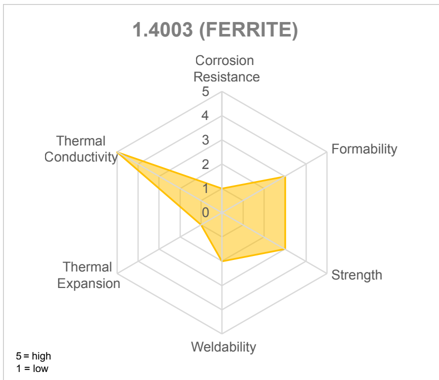
The minimum yield **strength** $R_{p0.2}$ required by the standard DIN EN 10088-2:2014-12 was chosen as the characteristic value for strength (condition C, cold-rolled strip, solution-annealed; exception 1.4501: condition P, hot-rolled sheet, solution-annealed).
For **formability**, the minimum elongation at fracture $A_{80}$ required by the standard DIN EN 10088-2:2014-12 was used as a characteristic value (condition C, cold-rolled strip, solution-annealed; exception 1.4501: condition P, hot-rolled sheet, solution-annealed).

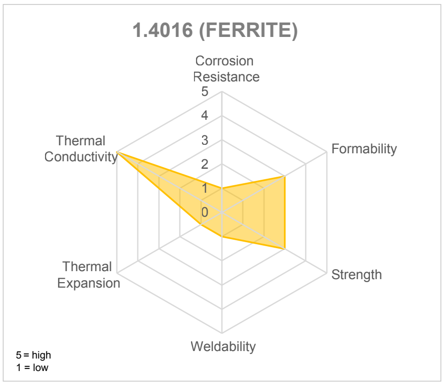
A general quantification of the **corrosion resistance** of stainless steels is difficult. Essentially, localised corrosion occurs (e.g. pitting corrosion, stress corrosion cracking, crevice corrosion, intergranular corrosion), for which, however, there is no all-encompassing key figure. In order to have a quantitative basis for the comparison of stainless steels, the Pitting Resistance Equivalent Number PRE or PREN was used as a measure of resistance to pitting and crevice corrosion.
However, this formula has been empirically determined and can by no means be considered as an electrochemistry law with defined boundary conditions. The effective sum was calculated according to the following formula and applies to the atmospheric range at non-elevated temperature:

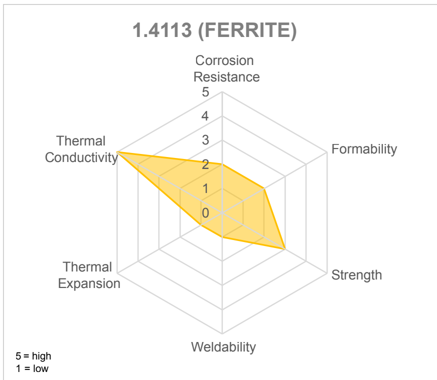
$$PRE = \%Cr + 3.3 \times \%Mo + (X) \times \%N$$

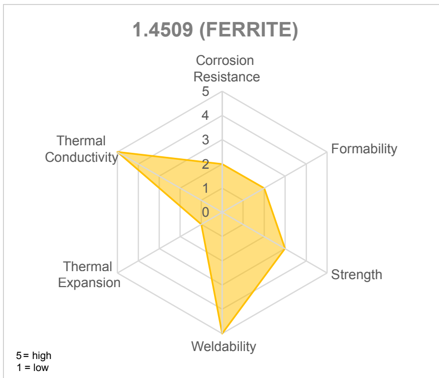
The arithmetic mean values of the limits specified in DIN EN 10088-1:2014-12 for the alloying elements chromium (Cr), molybdenum (Mo) and nitrogen (N) were used for %Cr, %Mo and %N respectively.
The nitrogen factor X was set to zero for grades with less than 3 % Mo, to 30 for all other grades with 3 % Mo or more and to 16 for duplex steels.
For the properties **thermal expansion** (mean thermal expansion coefficient between 20°C and 100°C) and **thermal conductivity**, the corresponding characteristic values from DIN EN 10088-1:2014-12 were used.
A high **weldability** means that no restrictions need to be observed, while a low weldability means that welding is only possible to a limited extent with the observance of numerous conditions.
In the final **figures 1-3**, the corrosion resistance, strength and formability of common grades are plotted against each other in different ways.

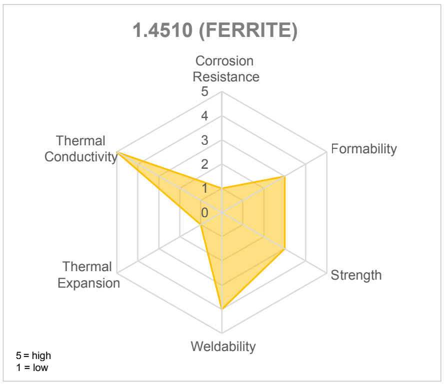
# Ferritic stainless steels

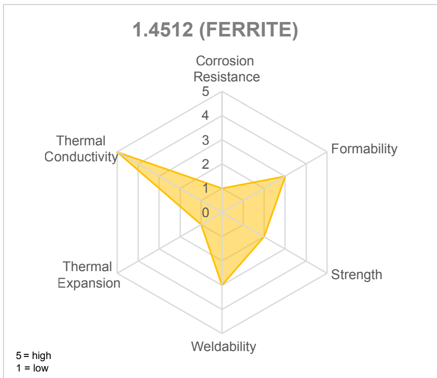


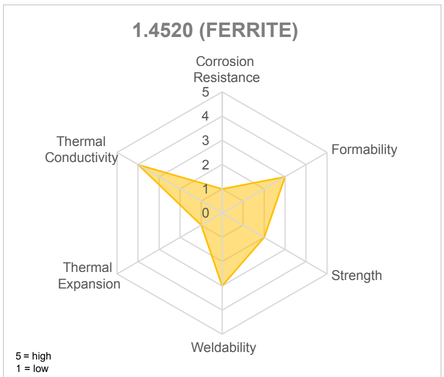



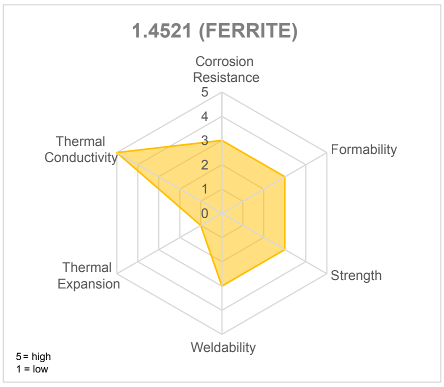



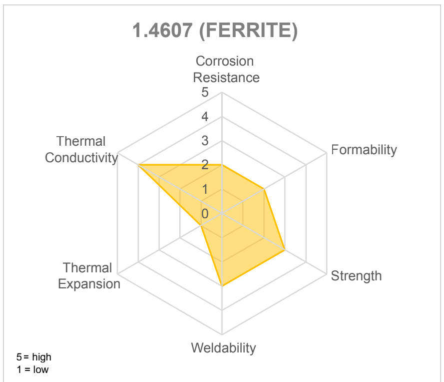



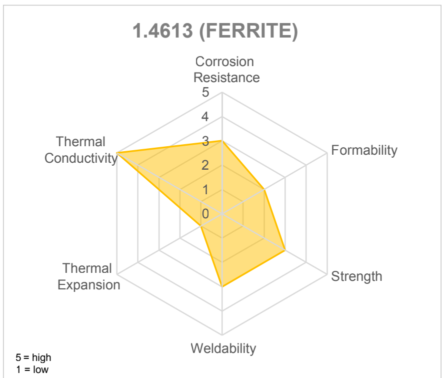



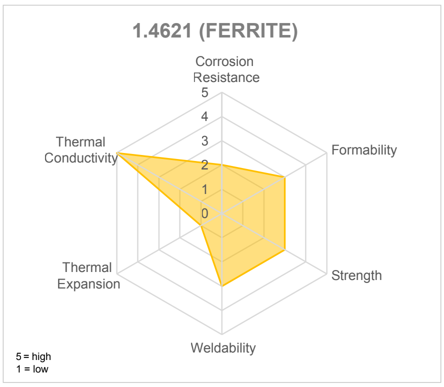



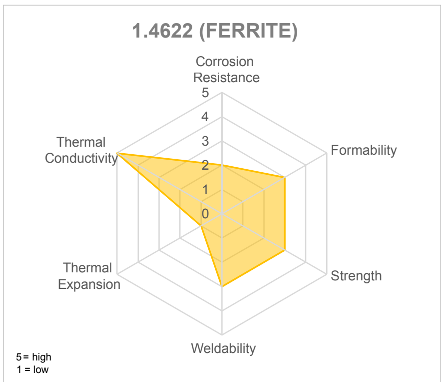



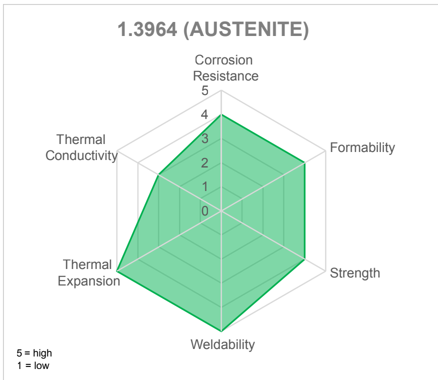



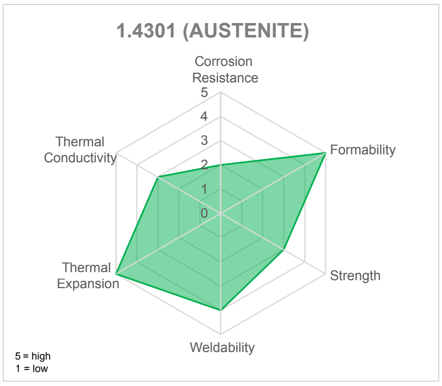



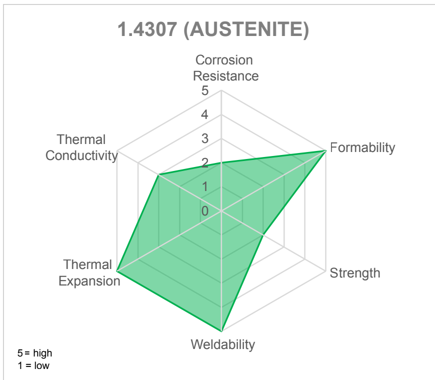



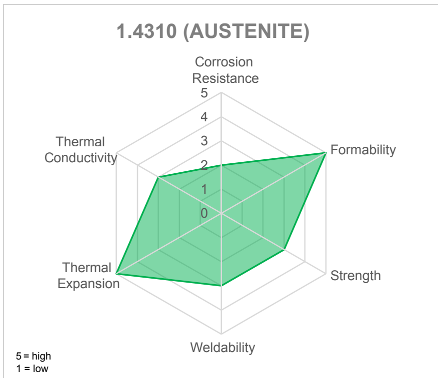



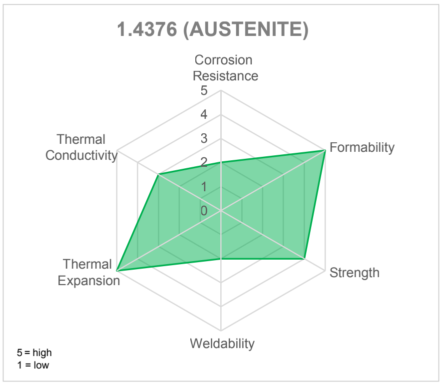
# Austenitic stainless steels

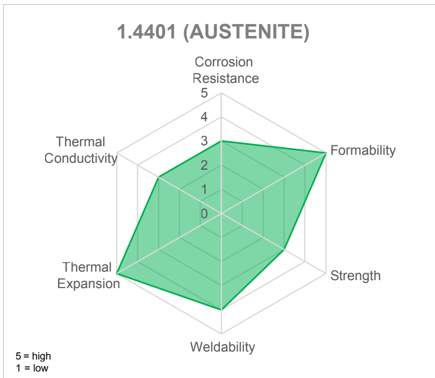


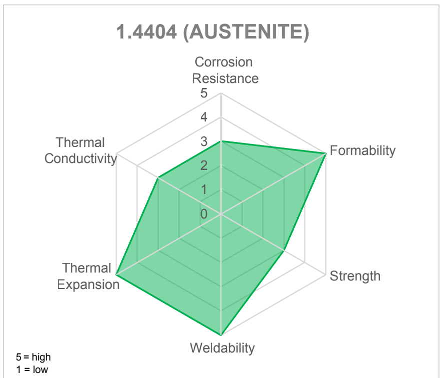



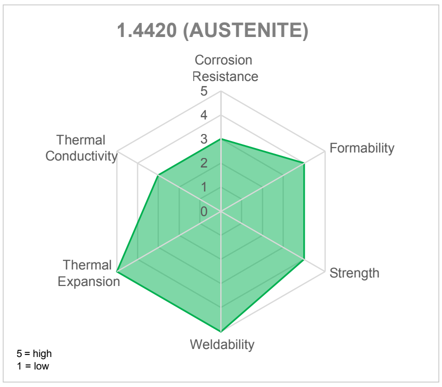



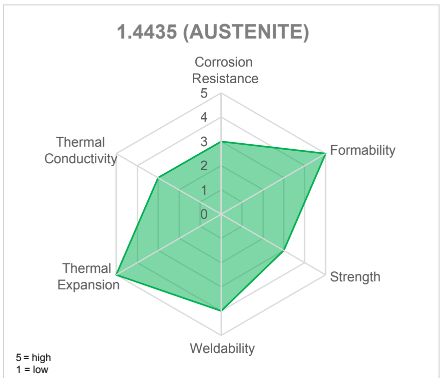



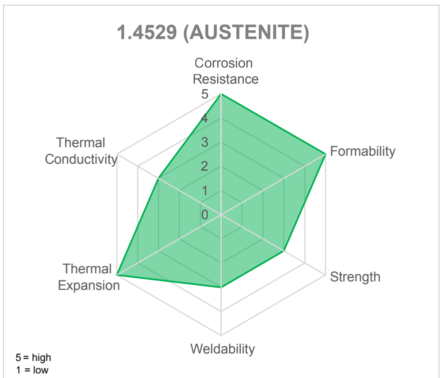



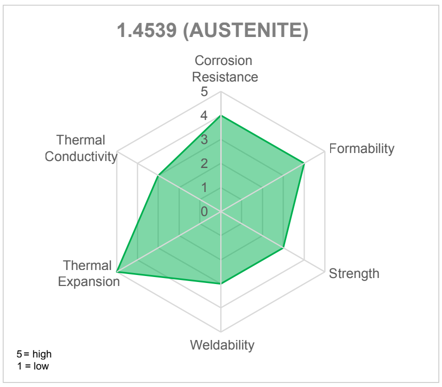



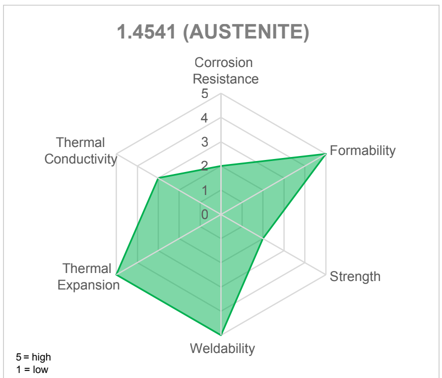



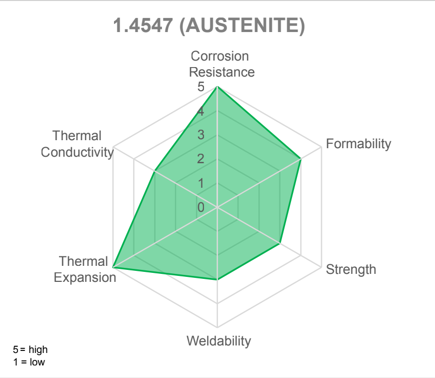



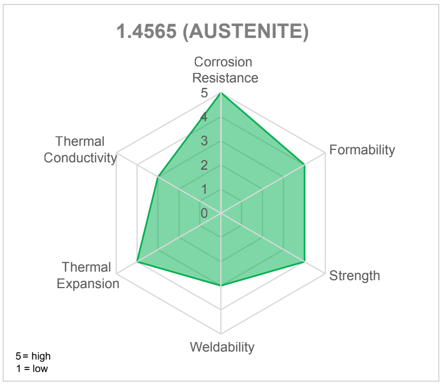



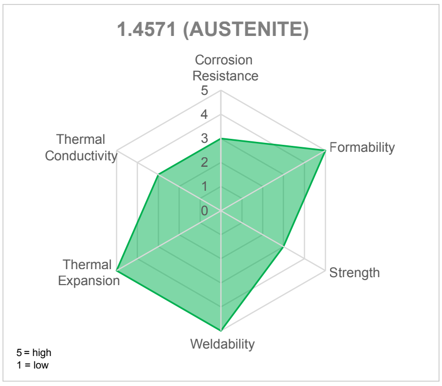



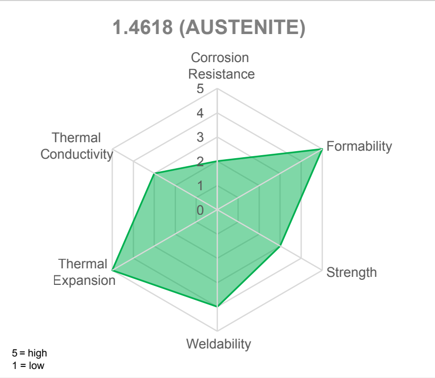



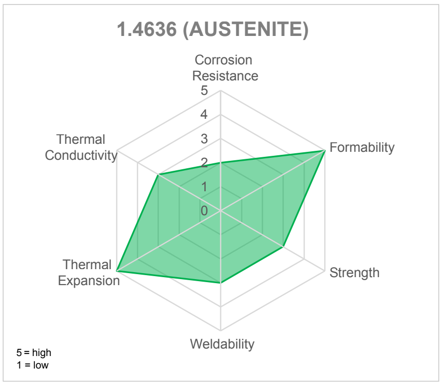



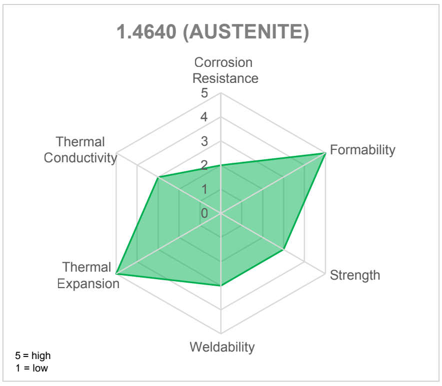

1.4547 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low

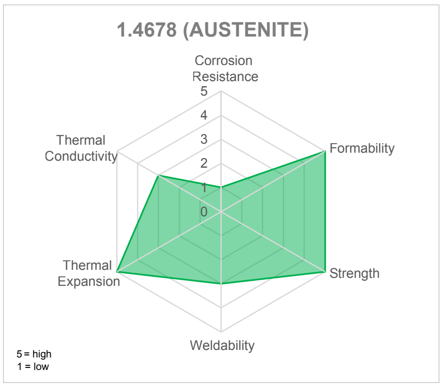

1.4565 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low


1.4571 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low

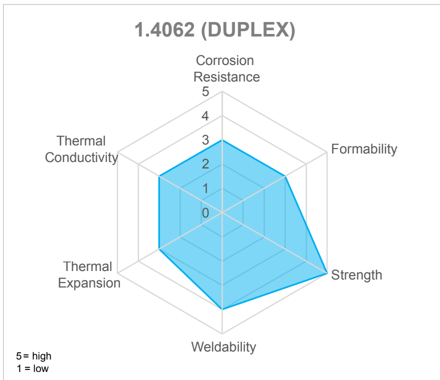

1.4618 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low

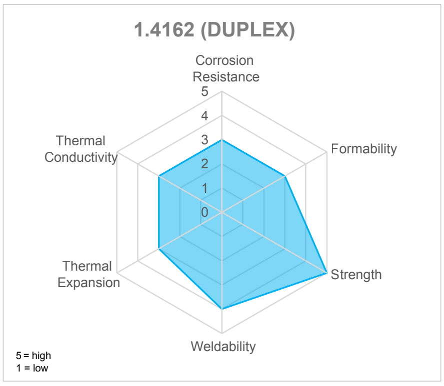

1.4636 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low

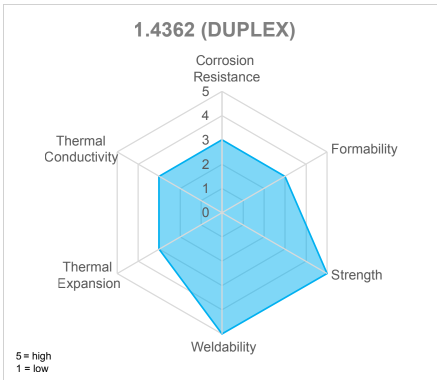

1.4640 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low

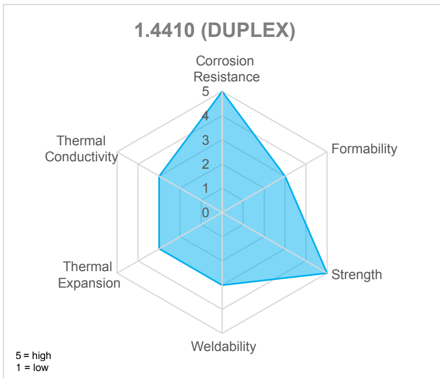

1.4678 (AUSTENITE)
Corrosion Resistance
Formability
Strength
Weldability
Thermal Expansion
Thermal Conductivity
5 = high
1 = low

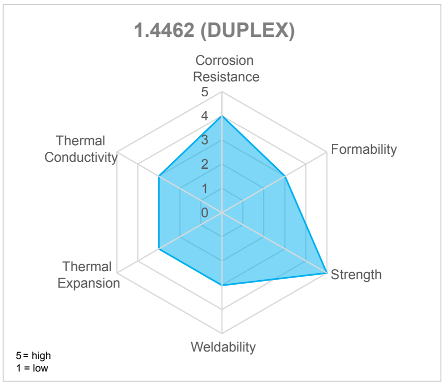
# Austenitic-ferritic stainless steels

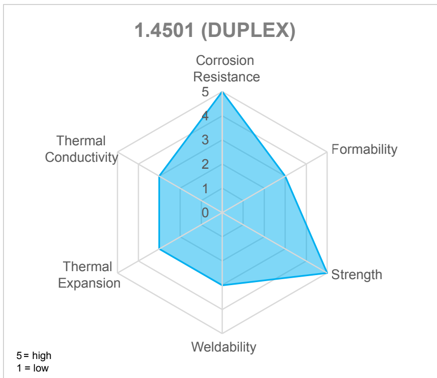


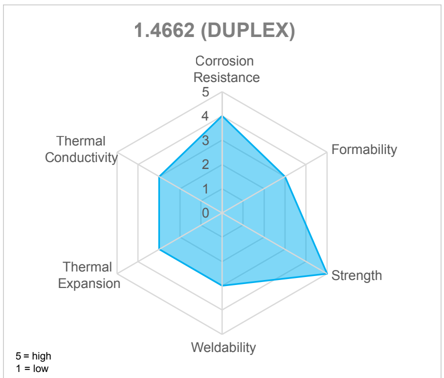



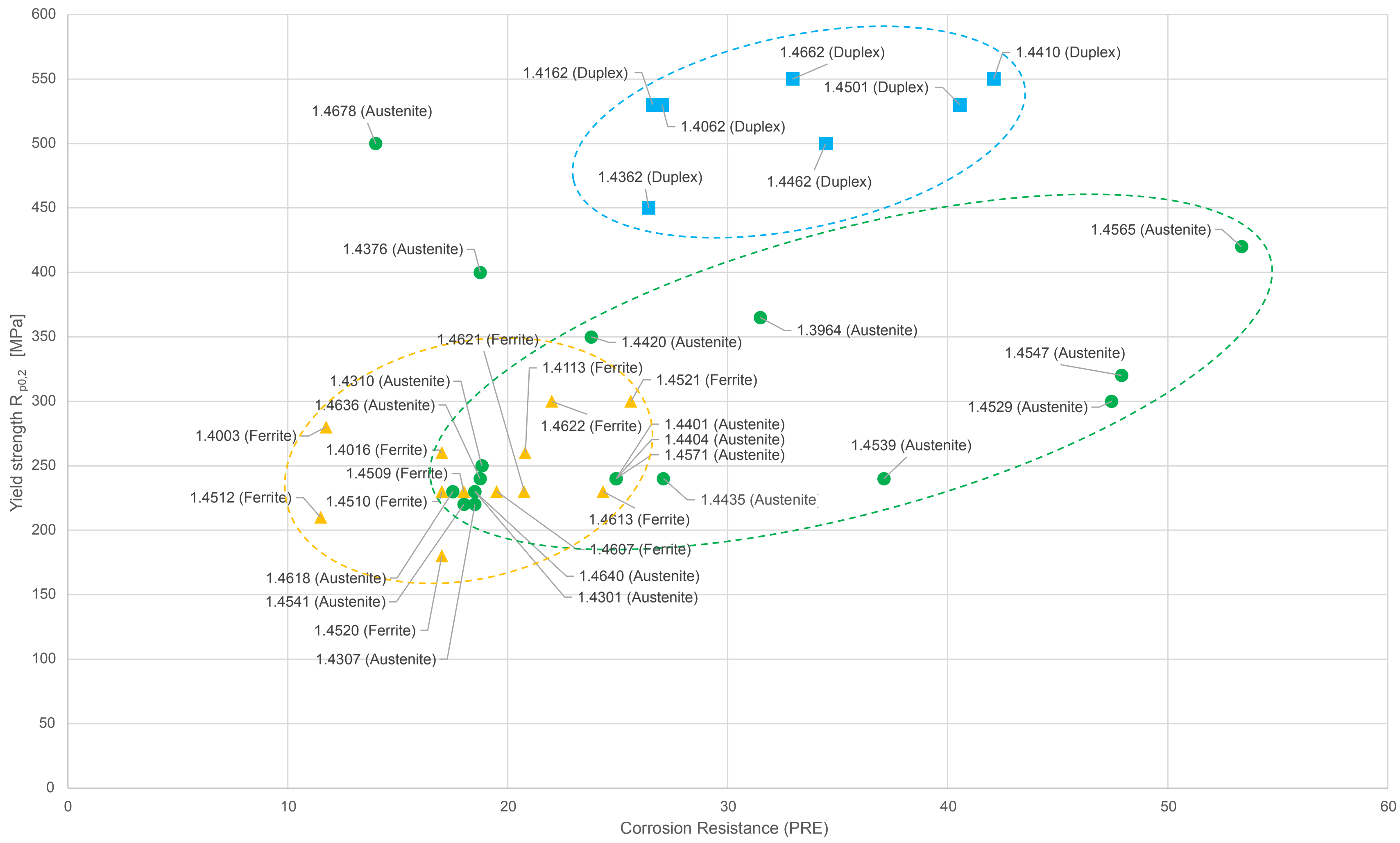



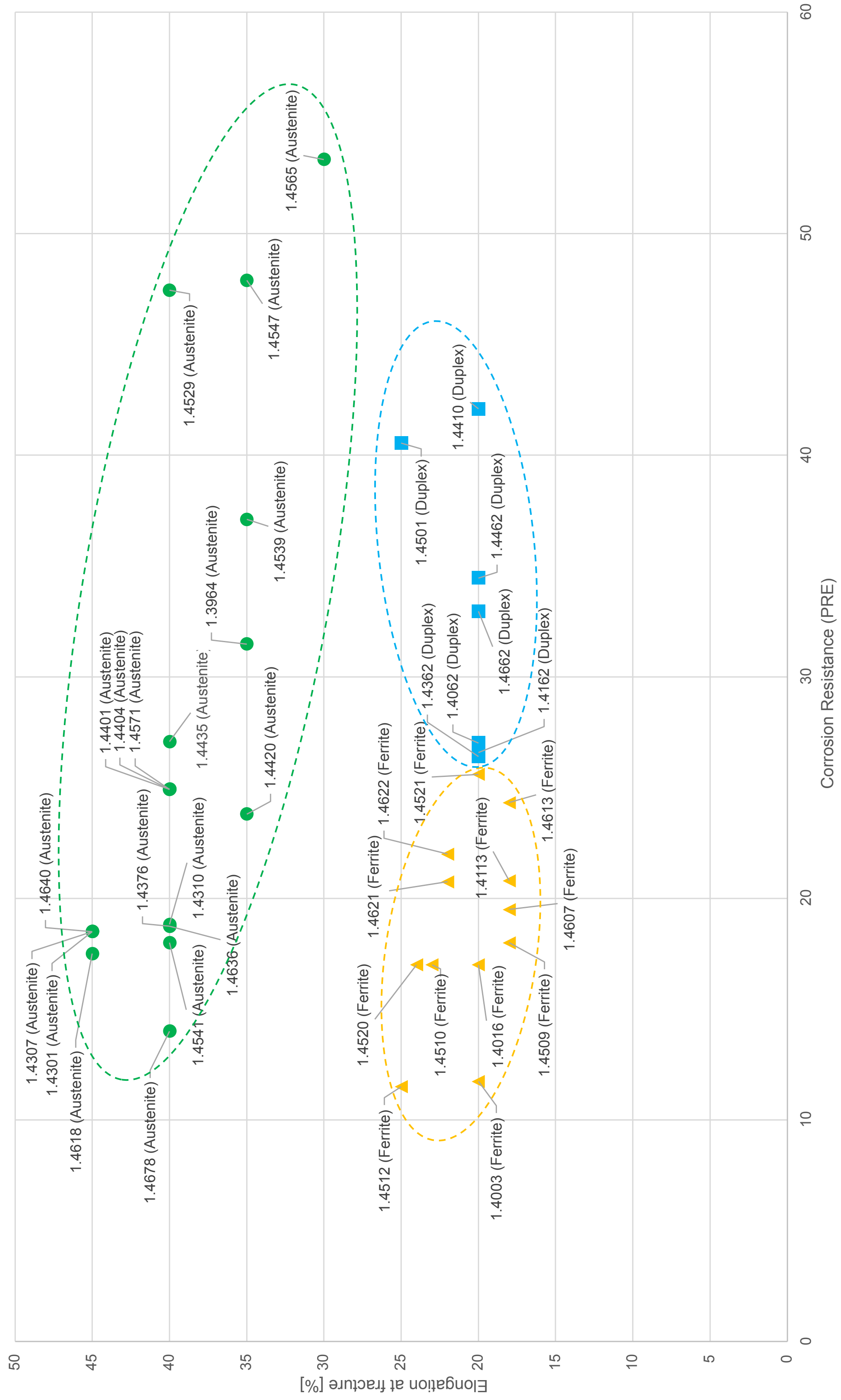





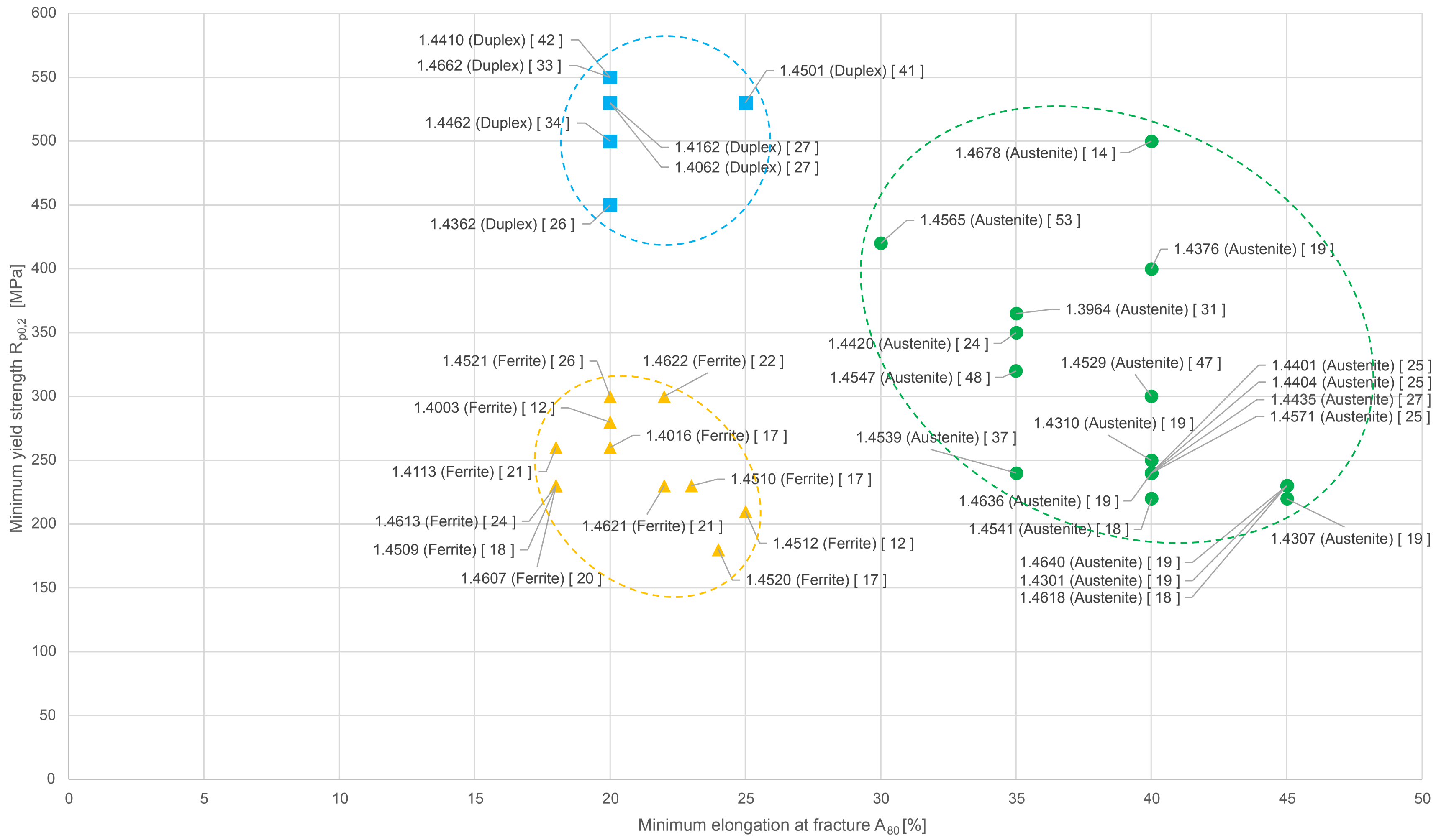

PRE: Pitting Resistance Equivalent Number of the respective grade, calculated from the arithmetic mean of the limits for the alloying elements given in DIN EN 10088-1:2014-12.
PRE = %Cr + 3.3 x %Mo + (X) x %N (nitrogen factor (X) = 0 for grades with less than than 3 % Mo, nitrogen factor (X) = 30 for grades with 3 % Mo or more, nitrogen factor (X) = 16 for duplex steels) |
Minimum yield strength $R_{p0,2}$ from DIN EN 10088-2:2014-12 (condition C, cold-rolled strip, solution-annealed; exception 1.4501: condition P, hot-rolled sheet, solution-annealed)

**Image 1: Strength vs. Corrosion Resistance**




PRE: Pitting Resistance Equivalent Number of the respective grade, calculated from the arithmetic mean of the limits for the alloying elements given in DIN EN 10088-1:2014-12.
PRE = %Cr + 3.3 x %Mo + (X) x %N (nitrogen factor (X) = 0 for grades with less than 3 % Mo, nitrogen factor (X) = 30 for grades with 3 % Mo or more, nitrogen factor (X) = 16 for duplex steels) |
Minimum elongation at fracture $A_{80}$ from DIN EN 10088-2:2014-12 (condition C, cold-rolled strip, solution-annealed; exception 1.4501: condition P, hot-rolled sheet, solution-annealed)

**Image 2: Formability vs. Corrosion Resistance**




[XY]: Pitting Resistance Equivalent Number (PRE) of the respective grade, calculated from the arithmetic mean of the limits for the alloying elements given in DIN EN 10088-1:2014-12.
PRE = %Cr + 3.3 x %Mo + (X) x %N (nitrogen factor (X) = 0 for grades with less than than 3 % Mo, nitrogen factor (X) = 30 for grades with 3 % Mo or more, nitrogen factor (X) = 16 for duplex steels) |
Minimum yield strength $R_{p0,2}$ and minimum elongation at fracture $A_{80}$ from DIN EN 10088-2:2014-12 (condition C, cold-rolled strip, solution-annealed; exception 1.4501: condition P, hot-rolled sheet, solution-annealed)

**Image 3: Strength vs. Formability**

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