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# Supra 316plus® – for reduced costs and improved performance across a wide range of temperatures




Outokumpu has developed Supra 316plus® (EN 1.4420, ASTM UNS S31655) as an enhanced version of ASTM 316L (EN 1.4404). In addition to being especially cost-effective and stable in price, this austenitic molybdenum-alloyed stainless steel offers improved performance over a wide range of temperatures from cryogenic to elevated temperatures. It is especially suited for LNG applications as well as equipment supporting the fast-growing hydrogen economy. Here are the key things you need to know about Supra 316plus®.

## Enhanced corrosion resistance – even with lower levels of nickel and molybdenum

The key feature of Supra 316plus® is the reduced levels of molybdenum and nickel. While this might be expected to impact its corrosion resistance, it is better than standard 316L due to the increased chromium and nitrogen content. Table 1 summarizes the effect of the main alloying elements.

| | |
|---|---|
| Chromium (Cr) | The most important alloying element that gives stainless steel its basic corrosion resistance. |
| Nickel (Ni) | Promotes an austenitic microstructure and generally increases ductility and toughness as well as reducing corrosion rates. |
| Molybdenum (Mo) | Significantly increases resistance to both uniform and localized corrosion. |
| Nitrogen (N) | Significantly increases mechanical strength and resistance to localized corrosion. |

**Table 1** The role of the main alloying elements in stainless steel



Extensive testing has shown that Supra 316plus® offers a considerable improvement over typical austenitic Mo-alloyed grades. This is illustrated by two vital measures, PRE (pitting resistance equivalent number) and CPT (critical pitting temperature).

PRE is a predictive measurement of a stainless steel's resistance to localized pitting corrosion based on its chemical composition. It is calculated from the formula PRE = %Cr + 3.3 x %Mo + 16 x %N. In general, the higher the PRE-value, the better. The PRE for Supra 316plus® is 26, while for 316L it is 24.

The CPT indicates the increased susceptibility of a metal to pitting corrosion with a corresponding increase in temperature. The CPT for Supra 316plus® is 35°C, while for 316L it is 20°C. Figure 1 shows a comparison of the CPT for different stainless steel grades.

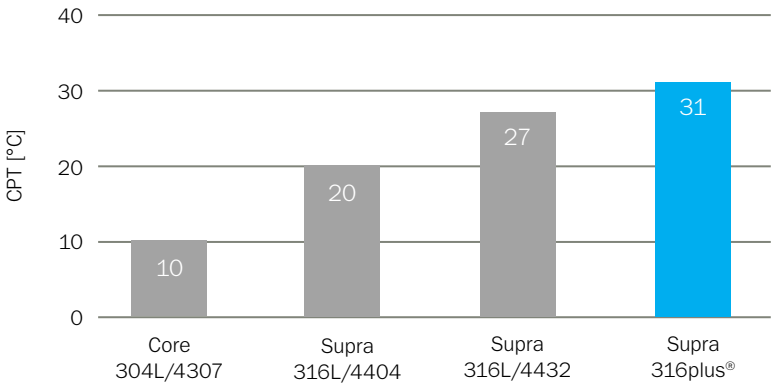



**Figure 1** Comparison of CPT for stainless steel grades

The low carbon content (<0.03 %) also prevents the precipitation of Cr carbides, avoiding intergranular corrosion in welds.





## A cost-effective solution for better performance

In addition to offering a cost-effective alternative to 316L, Supra 316plus® is actually stronger – its yield strength ($R^{p0.2}$) at room temperature is over 380 MPa, an improvement of some 30% over 316L. There is also a corresponding increase in tensile strength ($R^m$) to over 700 MPa.

This improved strength makes it possible to use thinner gauges that enable products to be produced with less material. It also saves weight and therefore helps reduce carbon footprint.

## Excellent fatigue resistance

Supra 316plus® has excellent fatigue properties, with a fatigue strength of ~390 MPa (tested on 3mm specimens). This compares with a fatigue strength of ~310 MPa for 316L.

## Performance at higher temperatures

Supra 316plus® can be applied across the same range of temperatures as 316L, from -196°C to 550°C. However, at high temperatures it offers superior performance. At 550°C, Supra 316plus® has a yield strength ($R^{p0.2}$) of 150 MPa compared with 100 MPa for 316L. At the same temperature its $R^m$ is 445 MPa against 360 MPa for 316L. This means that Supra 316plus® can be utilized over a wider temperature range.

For elevated temperature applications, designers tend to specify ASTM 316Ti (EN 1.4571), which is a titanium-stabilized alternative to 316L. However, this additional cost may not be necessary, since over the temperature range 20°C to 550°C, Supra 316plus® outperforms 316Ti in terms of yield strength. This is illustrated in Figure 2.

An added advantage is that Supra 316plus® has exactly the same thermal conductivity and coefficient of thermal expansion as 316L.

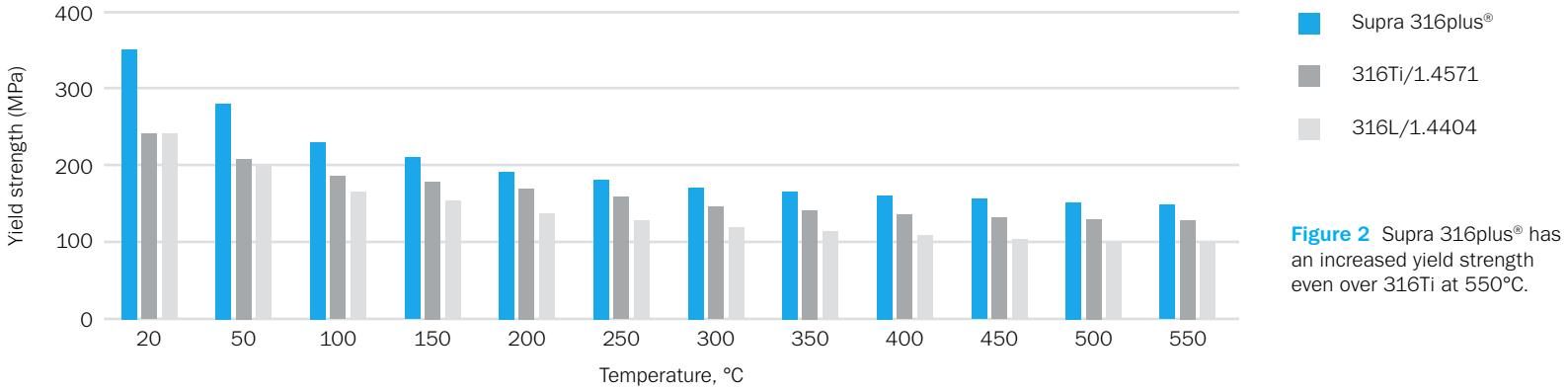



**Figure 2** Supra 316plus® has an increased yield strength even over 316Ti at 550°C.





## Cryogenic capability

When temperatures fall, Supra 316plus® offers important performance benefits over 316L in terms of higher energy absorption, strength and proof stress ($R^{p0.2}$), while its ductility is only decreased slightly. These properties, illustrated in Figure 3, make Supra 316plus® ideally suited for arctic, liquid natural gas (LNG) and cryogenic applications .

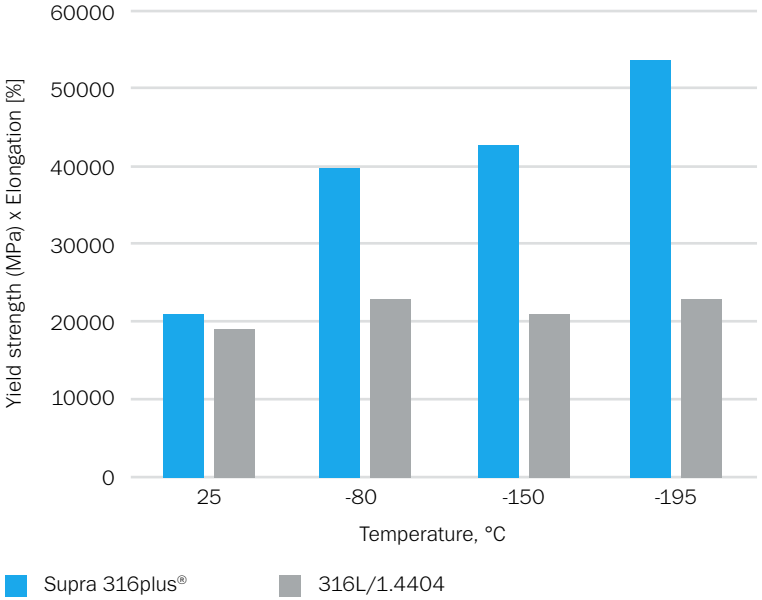



**Figure 3** Supra 316plus® has superior strength and ductility at cryogenic temperatures

## Ready for the hydrogen economy

The cryogenic capability of Supra 316plus® makes it suitable for many storage and transportation applications where hydrogen is liquified. Furthermore, it is ideal when gaseous hydrogen is compressed at high pressures. In some materials, this could result in hydrogen embrittlement, where the diffusion of the gas into the surface eventually leads to cracking. The stable austenitic microstructure of Supra 316plus® reduces this risk.

## Forming and welding

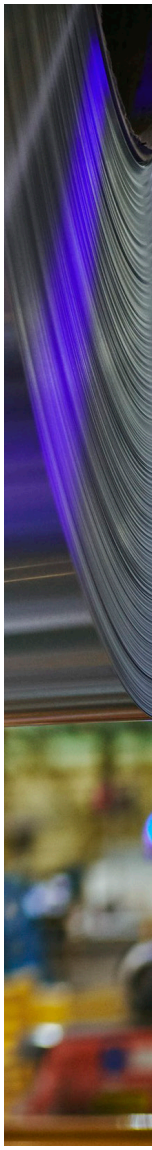
Supra 316plus® can be formed in the same way as 316L using typical forming processes like folding, bending, drawing, etc. It also has excellent weldability and is suitable for the full range of conventional welding methods.

## Reduced costs and price stability

In contrast to 316L, an important advantage of Supra 316plus® is that its pricing is more stable. This is because it contains a lower level of expensive alloying elements - such as nickel and molybdenum that, historically, are also volatile in price.

## A wide range of applications

Supra 316plus® has been adopted by customers for a wide range of applications including heat exchangers, water treatment, piping, process and storage tanks, and indoor and outdoor architectural installations.



# Full commercial and technical support

Outokumpu experts can provide comprehensive support to help you adopt Supra 316plus®, from identifying a clear business case, to sampling, testing and prototyping through to volume manufacturing. Supra 316plus® is effectively a drop-in replacement for 316L.

# Commitment to sustainability and a lower carbon footprint

Sustainability is integrated into all of Outokumpu's operations, activities and decision making, from the purchasing of raw materials to production and logistics, and Outokumpu's stainless steel has the highest recycled content in the industry. Switch to Supra 316plus® and you can be sure that your steel has a low carbon footprint. An added advantage is that the improved performance of Supra 316plus® can often help components to be lighter, saving raw materials and reducing the energy used for transportation.

# A well proven solution

Many Outokumpu customers across a range of industries are already enjoying the benefits of changing over to Supra 316plus®. Here are some case studies:

Supra 316plus® in liquid transport containers »

Parcitank says "salud" to Supra 316plus® »

# Available in a range of product forms

Supra 316plus® is available in a range of product forms and surface finishes including:

- Cold rolled coil, strip and sheet
- Hot rolled coil, strip and sheet

# Standards and approvals

Supra 316plus® complies with global standards and approvals as shown in Figure 4.

| Standards and approvals | |
|---|---|
| EN 10028-7:2016 | Flat products made of steels for pressure purposes – Part 7: Stainless steels |
| EN 10088-2:2024 | Technical delivery conditions for sheet / plate and strip of corrosion resisting steels for general purposes |
| PED Directive 2014/68/EU | European Pressure Equipment Directive |
| ASTM A240/A240M-17 | Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications |
| ASME BPVC | UNS S31655 Austenitic Steel, alloy Plate, Sheet, and Strip Section VIII, Division 1 |
| AD 2000-Merkblatt W2 | Available Particular Material Appraisal (PMA) for AD 2000-Merkblatt W2 (Only Tornio) |
| Lloyd's Register approval | Certificate No: MD00/1165/0008/1. Steelmaking, Semi-Finished Products, Plates, Hot Rolled Coil and Coil |
| DNV-GL approval | Certificate No: AMMM00001DW. Steelmaking and Rolled Steel Products |
| ASTM A249/A249M-16a | Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes |
| ASTM A269/A269M-15a | Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service |
| ASTM A358/A358M-15 | Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications |
| ASTM A554-16 | Standard Specification for Welded Stainless Steel Mechanical Tubing |
| ASTM A312/S312M-17 | Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes |
| NACE | NACE MR0103 / ISO 17945 and NACE MR0175/ISO 15156-1 / NACE MR0175/ISO 15156-3 |

**Figure 4** Supra 316plus® standards and approvals

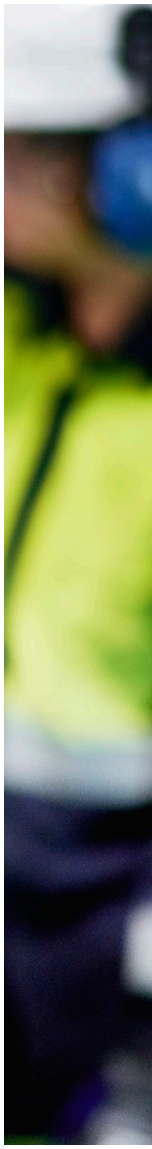


# In summary – why Supra 316plus® outperforms 316L

Figure 5 summarises why you should consider Supra 316plus® as a cost-effective alternative for 316L. Supra 316plus® also provides superior performance over a wide temperature range.

| | 316L | Supra 316plus® |
|---|---|---|
| Strength | ★★★ | ★★★★★ |
| Corrosion resistance | ★★★ | ★★★★ |
| High temperature strength | ★★★ | ★★★★ |
| Low temperature strength | ★★★ | ★★★★★ |
| Fatigue resistance | ★★ | ★★★ |
| Formability | ★★★★ | ★★★★ |
| Hydrogen embrittlement resistance | ★★★ | ★★★★★ |
| Cost and price volatility | ★★ | ★★★★ |

**Figure 5** Summarising the relative performance of Supra 316plus® against 316L



# Working towards a world that lasts forever

We work with our customers and partners to create long lasting solutions for the tools of modern life and the world's most critical problems: clean energy, clean water, and efficient infrastructure. Because we believe in a world that lasts forever.



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