Datasheet updated 2014-01-29 12:21:53 (supersedes all previous editions)

# Sandvik 316

## (Plate and sheet)

Sandvik 316 is a molybdenum-alloyed austenitic chromium-nickel steel.

### STANDARDS

- ASTM 316
- UNS S31600
- EN number 1.4436*
- EN name X 3 CrNiMo 17-13-3*
- W.Nr. 1.4436
- DIN X 5 CrNiMo 17 13 3
- SS 2343
- AFNOR Z 2 CND 17.13
- BS 316S13
- JIS 316

**Product standards**
- ASTM A240, A480

**Approval**
* Valid for sheet/plate, strip, semifinished products, bars, rods and sections for general purposes (not for pressure purposes).

### CHEMICAL COMPOSITION (NOMINAL) %

| C | Si | Mn | P | S | Cr | Ni | Mo | N |
|---|---|---|---|---|---|---|---|---|
| 0.08 | 0.75 | 2.0 | 0.045 | 0.03 | 16.0-18.0 | 10.0-14.0 | 2.0-3.0 | 0.10 |

### FORMS OF SUPPLY

**Plate Sheet and Coil**
Plate Sheet and Coil are delivered in the solution annealed and pickled condition.
Sheet may be supplied as annealed and pickled, polished or in the bright-annealed condition
The size ranges available are given below Sizes in Stock.

**Plate sheet and coil**
Sandvik 316/316L Plate, sheet and coil is stocked in a wide range of sizes according to ISO and ASTM.
Details of our stock programme are given below:

**Sandvik Australia's Stock Program**
**Plate (No1/2B Finish)**
Thickness Range - 3mm - 100mm
Widths - 1220mm,1500mm,2000mm,2500mm,3000mm

**Sheet (2B/No4 Finish)**
Thickness Range - 0.55mm - 3mm
Widths - 750mm, 900/915mm, 1200/1219mm, 1250mm, 1500mm, 1524mm, 2000mm
Lengths - 1800/1829mm, 2400/2438mm, 2500mm, 3000/3048mm, 3600/3650mm, 4000mm, 5000mm, 6000mm

**Coil (2B/No4/No1 Finish)**
Thickness Range - 0.55mm - 10mm
Widths - 750mm, 900/915mm, 1000/1050mm, 1200/1219mm, 1250mm, 1500/1524mm,2000mm

### MECHANICAL PROPERTIES

**At 20°C**

**METRIC UNITS**

| Proof strength | | Tensile strength | Elong. | | Hardness |
|---|---|---|---|---|---|
| $R_{p0.2}$[a] | $R_{p1.0}$[a] | $R_m$ | A[b] | $A_{2"}$ | |
| MPa | MPa | MPa | % | % | HRB |
| ≥205 | ≥250 | 515 | ≥40[c] | ≥35 | ≤95 |

**At 68°F**

**IMPERIAL UNITS**

| Proof strength | | Tensile strength | Elong. | | Hardness |
|---|---|---|---|---|---|
| $R_{p0.2}$[a] | $R_{p1.0}$[a] | $R_m$ | A[b] | $A_{2"}$ | |
| ksi | ksi | ksi | % | % | HB |
| ≥30 | ≥36 | 75 | ≥40[c] | ≥35 | ≤217 |

1 MPa = 1 N/mm$^2$

a) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% offset yield strength, respectively.

b) Based on $L_0 = 5.65 \sqrt{S_0}$ where $L_0$ is the original gauge length and $S_0$ the original cross-section area.

c) NFA 49-117, 49-217 with min 45% can be fulfilled on request.

The impact strength (Charpy V) at -60 °C (-75 °F) is min. 150 J (110 ft-lb).

**At high temperatures**

**METRIC UNITS**

| Temperature | Proof strength | |
|---|---|---|
| | $R_{p0.2}$ | $R_{p1.0}$ |
| °C | MPa | MPa |
| | min. | min. |
| 50 | 200 | 230 |
| 100 | 180 | 215 |
| 150 | 165 | 195 |
| 200 | 150 | 180 |
| 250 | 140 | 170 |
| 300 | 135 | 160 |
| 350 | 130 | 155 |
| 400 | 125 | 150 |
| 450 | 120 | 145 |
| 500 | 120 | 145 |
| 550 | 115 | 140 |
| 600 | 110 | 135 |

**IMPERIAL UNITS**

| Temperature | Proof strength | |
|---|---|---|
| | $R_{p0.2}$ | $R_{p1.0}$ |
| °F | ksi | ksi |
| | min. | min. |
| 200 | 26 | 31 |
| 400 | 21 | 26 |
| 600 | 19 | 23 |
| 800 | 18 | 21 |
| 1000 | 17 | 20 |

**CREEP STRENGTH**

| Temperature | | Creep-rupture strength | | | |
|---|---|---|---|---|---|
| | | 10 000 h | (ISO-values) | 100 000 h | |
| °C | °F | MPa | ksi | MPa | ksi |
| | | approx. | approx. | approx. | approx. |
| 550 | 1020 | 255 | 37.0 | 177 | 25.7 |
| 575 | 1065 | 215 | 31.0 | 137 | 19.9 |
| 600 | 1110 | 172 | 24.9 | 108 | 15.7 |
| 625 | 1155 | 137 | 19.9 | 86 | 12.5 |
| 650 | 1200 | 108 | 15.7 | 64 | 9.3 |
| 675 | 1245 | 83 | 12.0 | 46 | 6.7 |
| 700 | 1290 | 64 | 9.3 | 33 | 4.8 |
| 725 | 1335 | 49 | 7.1 | 25 | 3.6 |
| 750 | 1380 | 37 | 5.4 | 18 | 2.6 |

**PHYSICAL PROPERTIES**

Density: 8.0 g/cm$^3$, 0.29 lb/in$^3$

**THERMAL CONDUCTIVITY**

| Temperature °C | W/m °C | Temperature °F | Btu/ft h°F |
|---|---|---|---|
| 20 | 14 | 68 | 8 |
| 100 | 15 | 200 | 8.5 |
| 200 | 17 | 400 | 10 |
| 300 | 18 | 600 | 10.5 |
| 400 | 20 | 800 | 11.5 |
| 500 | 21 | 1000 | 12.5 |
| 600 | 23 | 1100 | 13 |

**SPECIFIC HEAT CAPACITY**

| Temperature °C | J/kg °C | Temperature °F | Btu/lb °F |
|---|---|---|---|
| 20 | 485 | 68 | 0.11 |
| 100 | 500 | 200 | 0.12 |
| 200 | 515 | 400 | 0.12 |
| 300 | 525 | 600 | 0.13 |
| 400 | 540 | 800 | 0.13 |
| 500 | 555 | 1000 | 0.13 |
| 600 | 575 | 1100 | 0.14 |

**THERMAL EXPANSION [1)]**

| Temperature °C | Per °C | Temperature °F | Per °F |
|---|---|---|---|
| 30-100 | 16.5 | 86-200 | 9.5 |
| 30-200 | 17 | 86-400 | 9.5 |
| 30-300 | 17.5 | 86-600 | 10 |
| 30-400 | 18 | 86-800 | 10 |
| 30-500 | 18 | 86-1000 | 10 |
| 30-600 | 18.5 | 86-1200 | 10.5 |
| 30-700 | 18.5 | 86-1400 | 10.5 |

1) Mean values in temperature ranges ($x10^{-6}$)

**MODULUS OF ELASTICITY [1)]**

| Temperature °C | MPa | Temperature °F | ksi |
|---|---|---|---|
| 20 | 200 | 68 | 29.0 |
| 100 | 194 | 200 | 28.2 |
| 200 | 186 | 400 | 26.9 |
| 300 | 179 | 600 | 25.8 |
| 400 | 172 | 800 | 24.7 |
| 500 | 165 | 1000 | 23.5 |

1) $x10^3$

## CORROSION RESISTANCE

Grade 316 has good resistance in:

- Organic acids at high concentrations and moderate temperatures
- Inorganic acids, e.g. phosphoric and sulphuric acids, at moderate concentrations and temperatures. The steel can also be used in sulphuric acid of concentrations above 90% at low temperature.
- Salt solutions, e.g. sulphates, sulphides and sulphites
- Caustic environments

**Stress corrosion cracking**
Austenitic steels are susceptible to stress corrosion cracking. This may occur at temperatures above about 60°C (140°F) if the steel is subjected to tensile stresses and at the same time comes into contact with certain solutions, particularly those containing chlorides. Such service conditions should therefore be avoided. Conditions when plants are shut down must also be considered, as the condensates which are then formed can develop conditions that lead to both stress corrosion cracking and pitting.

In applications demanding high resistance to stress corrosion cracking, austenitic-ferritic steels, such as Sandvik SAF 2304 or SAF 2205 are recommended. See data sheets S-1871-ENG and S-1874-ENG.

**Intergranular corrosion**
Sandvik 3r60(Grade 316L) has a low carbon content and therefore better resistance to intergranular corrosion than steels of type AISI 316. The TTC-diagram, Figure 1, shows the result of corrosion testing for 24 hours in boiling Strauss solution (12% sulphuric acid, 6% copper sulphate). The resistance to grain boundary attack is much

better for AISI 316L than for AISI 316. This is an advantage in complicated welding operations.

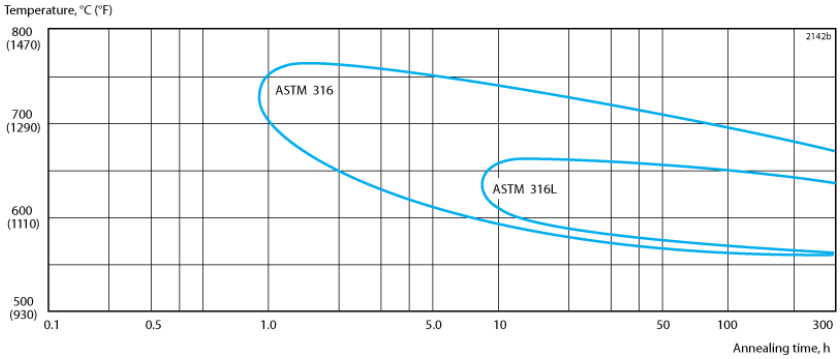


Figure 2. TTC-diagram for Sandvik 3R60 (AISI 316L) and AISI 316.

**Pitting and crevice corrosion**
Resistance to these types of corrosion improves with increasing molybdenum content. Sandvik 3R60(Grade 316L), containing about 2.6% Mo, has substantially higher resistance to attack than these steels of type AISI 304 and also better resistance than ordinary AISI 316/316L steels with 2.1% Mo.

**Gas corrosion**
Sandvik 3R60 can be uses in

- Air up to 850°C (1560°F)
- Steam up to 750°C (1380°F)

Creep behaviour should also be taken into account when using the steel in the creep range.

In flue gases containing sulphur, the corrosion resistance is reduced. In such environments the steel can be used at temperatures up to 600-750 °C (1100-1380 °F) depending on service conditions. Factors to consider are whether the atmosphere is oxidising or reducing, i.e. the oxygen content, and whether impurities such as sodium and vanadium are present.

## HEAT TREATMENT

Material is delivered in heat treated condition. If additional heat treatment is needed after further processing the following is recommended.

**Stress relieving**
850-950°C (1560-1740°F), cooling in air

**Solution annealing**
1000-1100°C (1830-2010°F), rapid cooling in air or water.

## WELDING

The weldability of Grade 316 is good. Suitable welding methods are manual metal-arc welding with covered electrodes and gas-shielded arc welding with the TIG and MIG methods as first choice. Preheating and post-weld treatment are not normally necessary.

Since the material has low thermal conductivity and high thermal expansion, welding must be carried out with a low heat input and with welding plans well thought out in advance so that the deformation of the welded joint can be kept under control. If, despite these precautions, it is foreseen that the residual stresses might impair the function of the weldment, we recommend that the entire structure be stress relieved. See under Heat treatment.

As filler metals for gas-shielded arc welding we recommend wire electrodes and rods Sandvik 19.12.3.L, 19.12.3.LSi. In shielded metal-arc welding (SMAW) covered electrodes Sandvik 19.12.3.LR, 19.12.3.LRV or 19.12.3.LRHD are recommended. If flux cored arc welding is preferred, the electrodes 19.12.3.LT or 19.12.3.LVT should be used.

## BENDING

Annealing after cold bending is not normally necessary, but this point must be decided with regard to the degree of bending and the operating conditions. Heat treatment, if any, should take the form of stress relieving or solution annealing, see under Heat treatment.

Hot bending is carried out at 1100-850°C (2010-1560°F) and should be followed by solution annealing.

## APPLICATIONS

Grade 316 is used for a wide range of industrial applications where steels of type AISI 304 and 304L have insufficient corrosion resistance. Typical examples are: heat exchangers, condensers, pipelines, cooling and heating coils in the chemical, petrochemical, pulp and paper and food industries.