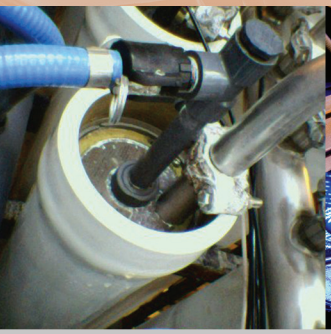
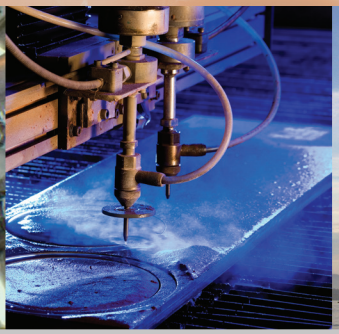
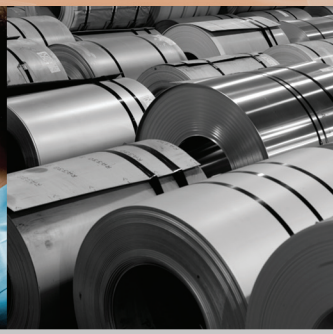
ROLLED ALLOYS

DATA SHEET ZERON® 100
UNS S32760

THE GLOBAL LEADER IN SPECIALTY ALLOYS

ALLOYS AND PROCESSING

ROLLED ALLOYS

ZERON® 100 Data Sheet

Contents

Specifications

UNS	S32760 (J93380 Castings)
W.Nr./EN	1.4501 (1.4508 Castings)
ASME	B16.5, B16.34, B16.47, B31.3, Section VIII Division 1 Case 2244-2, 2245-1, Section III Division 1 Case N-564-2
ASTM	A 182 (Grade F55), A 240, A 276, A 314, A 473, A 479, A 789, A 790, A 815, A 890, A 928, A 988, A 995,
EUROPEAN	EN 10028-7, EN 10088-2, EN 10088-3, EN 10272, EN 10216-5, EN 10217-7
NACE	ISO 15156 / MR0175 Part 3
API	5LC
BSI	PD 5500 - Enquiry Case 5500/87

Chemical Composition, %

Alloy	Min Wrought (Cast)	Max Wrought (Cast)
Chromium (Cr)	24.0	26.0
Nickel (Ni)	6.0 (6.5)	8.0 (8.5)
Molybdenum (Mo)	3.0	4.0
Tungsten (W)	0.5	1.0
Copper (Cu)	0.5	1.0
Nitrogen (N)	0.2	0.3
Silicon (Si)	–	1.0
Carbon (C)	–	0.03
Manganese (Mn)	–	1.00
Phosphorus (P)	–	0.03
Sulfur (S)	–	0.01 (0.025)
Iron (Fe)	Balance	

Applications

- Oil and gas industry applications: process, seawater, firewater and subsea pipework systems with associated risers, manifolds, pressure vessels, valves and heat exchangers
- Pollution control
- Pulp and paper
- Power generation
- Flue-gas desulfurization
- Chemical, pharmaceutical
- Desalination
- Mining and mineral industries
- Marine industries

Features

- Guaranteed corrosion performance ($PRE_N \geq 40$)*
- High resistance to pitting and crevice corrosion
- Excellent resistance to stress corrosion cracking in both chloride and sour environments
- High resistance to erosion corrosion and corrosion fatigue
- Excellent mechanical properties
- Possibilities for weight reduction over austenitic, standard duplex and nickel base alloys
- Good weldability

* $PRE_N = \%Cr + 3.3 \times \%Mo + 16 \times \%N$

Performance Profile

ZERON 100 is a highly alloyed super duplex stainless steel for use in aggressive environments. Its combination of properties makes ZERON 100 the optimum choice in a range of industries. ZERON 100 is highly resistant to corrosion in a wide range of organic and inorganic acids. The copper content gives excellent resistance to corrosion in many non-oxidizing acids. This alloy is also highly resistant to strong alkalis.

ZERON 100 is not recommended for uses which involve extended exposure to temperatures greater than 572°F (300°C) as this causes a substantial reduction in toughness.

It should be noted that the UNS S32760 designation merely specifies a broad compositional range, whereas the composition of ZERON 100 is tightly controlled in strict accordance with the requirements of our in house "MDS" specifications. This ensures a consistent quality product is produced, and the stated corrosion, mechanical and physical properties are maintained.

ZERON 100 is stocked in a variety of sizes of pipe, fittings, flanges, plate and bar. ZERON 100 is also available as forgings, hot isostatically pressed components, seam welded tubing (for control lines, heat exchanger tubing, instrumentation tubing etc.), wire, wirelines, welding wire and covered electrodes.

In some standards, such as ISO 15156 / NACE MR0175 and BS 4515-2, a slightly different PRE_N formula is used that includes tungsten:
$PRE_N = \%Cr + 3.3(\%Mo + 0.5 \times \%W) + 16 \times \%N$.
With this formula ZERON 100 has a $PRE_N > 41$.

Mechanical Properties

The following guaranteed minimum properties are available in the solution annealed condition.

Room Temperature

Table 1 - Mechanical Properties at Room Temperature

	Wrought (UNS S32760)	Cast (UNS J93380)
Yield Strength (0.2% offset)	80 ksi (550 MPa)	65 ksi (450 MPa)
Tensile Strength	109 ksi (750 MPa)	101 ksi (700 MPa)
Elongation in 50mm	25%	25%
Hardness	28 HRC Max	24 HRC Max

ZERON 100 Pipe work for reverse osmosis applications.

Elevated Temperature

Table 2 - Forgings, Bar and Plate up to 1.18" (30mm)

Temp, °F (°C)	Yield Strength, 0.2% offset ksi (MPa)	Tensile Strength ksi (MPa)
68 (20)	80 (550)	109 (750)
122 (50)	73 (500)	105 (725)
212 (100)	68 (470)	102 (700)
302 (150)	65 (450)	99 (680)
392 (200)	62 (430)	97 (670)
482 (250)	58 (400)	94 (650)
572 (300)	56 (385)	92 (635)

Table 3 - Plate 1.22 to 2.76" (31 to 70mm)

Temp, °C (°F)	Yield Strength, 0.2% offset ksi (MPa)	Tensile Strength ksi (MPa)
68 (20)	550 (80) 550	109 (750)
122 (50)	470 (68) 470	102 (700)
212 (100)	430 (62) 430	97 (670)
302 (150)	400 (58) 400	90 (620)
392 (200)	380 (55) 380	88 (610)
482 (250)	370 (54) 370	87 (600)
572 (300)	360 (52) 360	86 (590)

The properties for forgings are typical values for section thicknesses up to 11.81" (300mm) solid or 9.84" (250mm) in an annulus with a minimum bore of 3.94" (100mm).

As the properties from forgings are very dependent upon the product route and the actual forging ratio, then properties and design are by agreement for other than standard items.

Table 4 - Cast Mechanical Properties at Elevated Temperatures

Temp, °C (°F)	Yield Strength, 0.2% offset ksi (MPa)	Tensile Strength ksi (MPa)
68 (20)	65 (450)	101 (700)
122 (50)	59 (410)	98 (675)
212 (100)	55 (380)	94 (650)
302 (150)	52 (360)	91 (630)
392 (200)	51 (350)	87 (600)
482 (250)	48 (330)	83 (570)
572 (300)	46 (320)	78 (540)

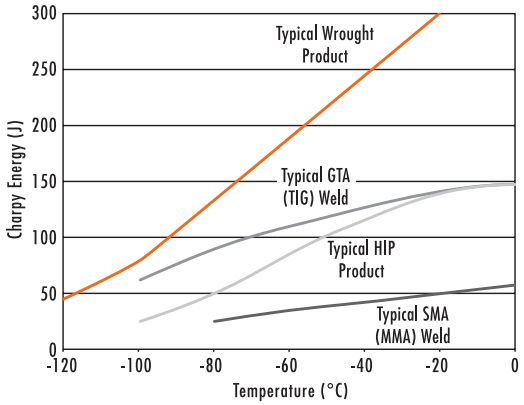
Impact Strength

ZERON 100 has good impact strength. There is no true ductile brittle transition, just a gradual decrease in impact energy as the temperature is lowered. The impact energy varies according to product type and production route. Some typical values are shown in Figure 1 on the following page. The impact strength of welded ZERON 100 is slightly less than that of parent metal (See also figure 1).

Present data suggests that 30 ft. lbf (40J) is a suitable acceptance criterion for duplex stainless steels and Figure 1 shows that 40J is achievable with all product forms of ZERON 100 down to very low temperatures.

However, to obtain good impact toughness after welding, a higher level of impact toughness is required in the parent metal. ZERON 100 typically has a Charpy toughness ≥ 70J at -58°F (-50°C).

Figure 1 - Typical Charpy Impact toughness transition curves



Fasteners

Solution annealed ZERON 100 has a high strength level which is satisfactory for many fastener applications. For applications requiring higher tensile properties, ZERON 100 is available in two additional grades: ZERON 100 FG meets the minimum tensile properties specified in ASTM A 193-B7 and additionally has a Charpy impact toughness of 30 ft. lbf (40 Joules) minimum at -50°C (-58°F). ZERON 100 FLT meets the minimum tensile and Charpy impact properties specified in ASTM A 320-L7. Both ZERON 100 FG and FLT meet the requirements of ASTM A 276 S32760 Condition S.

Physical Properties

Density

The density of both wrought and cast ZERON 100 is 7840 kg/m^3 or 489 lb/ft^3 (7.84g/cm^3) at 68°F (20°C).

Specific Heat

Typical specific heats for both wrought and cast ZERON 100.

Table 5 - Specific Heat

Temp, °F (°C)	Specific Heat,	
	J Kg^{-1} K^{-1}	Btu/lb °F
68 (20)	482	0.115
212 (100)	500	0.119
302 (150)	513	0.122
392 (200)	523	0.125
482 (250)	535	0.128
572 (300)	547	0.130

Thermal Conductivity

Typical values for wrought ZERON 100.

Table 6 - Thermal Conductivity

Temp, °F (°C)	Thermal Conductivity	
	Wm^{-1} K^{-1}	Btu/hr ft °F
68 (20)	12.9	7.5
212 (100)	14.4	8.4
302 (150)	15.4	8.9
392 (200)	16.3	9.5
482 (250)	17.3	10.1
572 (300)	18.2	10.6

Thermal Expansion

The typical thermal expansion coefficient of wrought and cast ZERON 100 is much lower than that of austenitic stainless steel and reasonably close to that of carbon steel, as follows:

Table 7 - Linear Thermal Expansion - SI Metric Units

	Linear Thermal Expansion Coefficient, 10^{-6} K^{-1}		
Temp, °C	20-100	20-200	20-300
ZERON 100	12.8	13.3	13.8
Carbon Steel	11.5	12.2	12.9
Austenitic Stainless Steel	16.8	17.2	17.6

Table 8 - Linear Thermal Expansion - Inch Pound Units

	Linear Thermal Expansion Coefficient, 10^{-6} in/in °F		
Temp, °F	70-200	70-400	70-600
ZERON 100	7.1	7.4	7.7
Carbon Steel	6.4	6.8	7.2
Austenitic Stainless Steel	9.3	9.6	9.8

Resistivity

Typical values of resistivity are shown below.

Table 9 - Typical Resistivity Values

Temp, °F (°C)	Resistivity, 10^{-6} Ohm m	
	Wrought ZERON 100	Cast ZERON 100
68 (20)	0.851	0.916
212 (100)	0.897	0.955
302 (150)	0.927	0.980
392 (200)	0.956	1.005
482 (250)	0.985	1.030
572 (300)	1.014	1.055

Magnetic Permeability

At room temperature the peak relative magnetic permeability of ZERON 100 is typically 29.

Young's Modulus

The modulus is a function of austenite/ferrite ratio and production route. Variations of ± 5% are found with both wrought and cast products. The typical value for ZERON 100 at room temperature is 29,000 ksi (200 GPa). The Young's Modulus decreases slightly with increasing temperature as shown below.

Temp,°F (°C)	68 (20)	212 (100)	392 (200)	572 (300)
Young's Modulus, ksi (GPa)	29,000 (200)	28,100 (194)	27,000 (186)	26,100 (180)

Poisson's Ratio

The typical value for ZERON 100 at room temperature is 0.32

Corrosion Resistance

General Corrosion

ZERON 100 is highly resistant to corrosion in a wide range of organic and inorganic acids. The copper content gives excellent resistance to corrosion in many non-oxidizing acids. Figure 2 shows the typical performance for ZERON 100 in sulfuric acid compared to some other stainless steels. Figure 3 shows similar data for hydrochloric acid. Commercial acid applications often contain chlorides and other impurities which can cause corrosion of some stainless steels. ZERON 100 offers much improved corrosion performance in these environments.

Figure 2 - Iso-corrosion curves 0.004 ipy (0.1mm/y) for some stainless steels in Sulfuric Acid

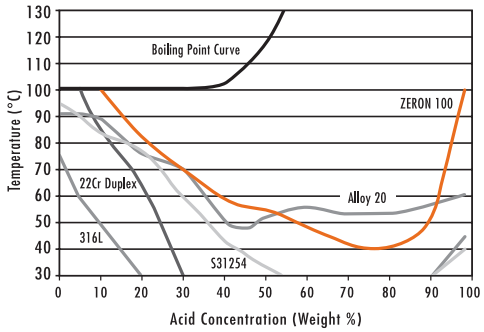
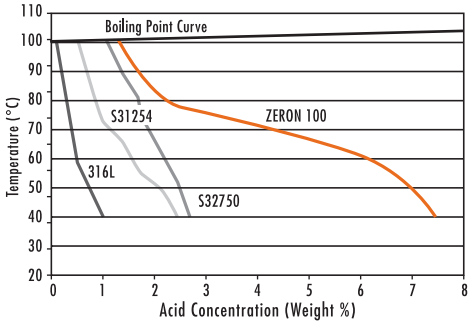


Figure 3 - Iso-corrosion curves 0.004 ipy (0.1mm/y) for some stainless steels in Hydrochloric Acid



ZERON 100 is also highly resistant to strong alkalis. The production of caustic soda results in hot, strong solutions and even in 60 wt% caustic soda, ZERON 100 has very low corrosion rates (<0.004 ipy). Caustic soda is often found with chlorides in extraction processes and even with 10g/L chloride, ZERON 100 has excellent corrosion resistance. Three years service experience of fabricated ZERON 100 pipework in 2M caustic soda with chlorides at 446°F (230°C) has been excellent.

Pitting Corrosion

Exposure to 6% $FeCl_3$ for 24 hours in accordance with ASTM G48 method A to determine the maximum temperature at which no pitting occurs (the critical pitting temperature, CPT), has given the following results:

Solution annealed wrought and cast ZERON 100: 158-176°F (70-80°C) depending on product form and manufacturing route.

ZERON 100 welded with ZERON 100X filler metal: 95-140°F (35-60°C), depending on the welding variables, i.e. process, joint geometry, procedure etc.

These values are for single exposure testing; testing a single specimen at a series of increasing temperatures gives a higher CPT value.

Crevice Corrosion

The resistance to localized corrosion is often assessed by use of the PRE_N number (%Cr + 3.3 x %Mo + 16 x %N). ZERON 100 is made to a minimum PRE_N of 40, ensuring a guaranteed and high resistance to pitting and crevice corrosion. ZERON 100 has been in service in seawater since 1986 as castings, and since 1989 as wrought pipes and fittings giving satisfactory performance.

At sea water temperatures above ambient, 68°F (20°C), the risk of crevice corrosion increases. ZERON 100 resists crevice corrosion up to 131°F (55°C) but is limited by the pitting resistance of the welds to about 104°F (40°C). With the application of post weld surface treatments, seawater temperatures up to 149°F (65°C) have been handled successfully.

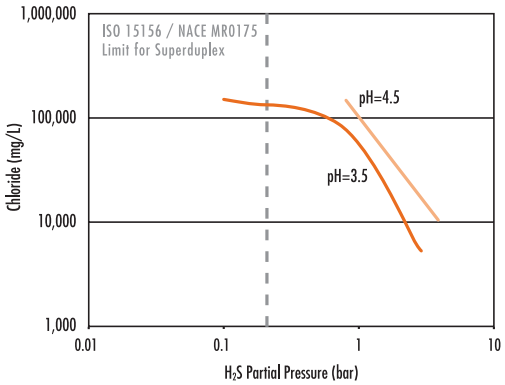
Repassivation

Short term elevated temperatures upsets are not uncommon in cooling water circuits. Laboratory tests and field experience have shown that ZERON 100 does not suffer crevice corrosion easily during short upsets and, when corrosion does initiate, repassivation occurs readily on cooling, and at temperatures higher than the normal operating temperature of 104°F (40°C). Super austenitic steels and super duplex steels that do not contain copper and tungsten have lower repassivation temperatures than normal operating temperatures, so any corrosion that is initiated during the upset will continue to propagate when the system reaches normal operating conditions once more.

Stress Corrosion Cracking

ZERON 100 has excellent resistance to stress corrosion cracking (SCC) in both chloride environments, and process environments containing H_2S and CO_2. ZERON 100 is listed in ISO 15156 / NACE MR0175 part 3 as being suitable in sour service at 0.2 bar partial pressure of H_2S. In brines with lower chloride contents ZERON 100 can tolerate much higher pressures of H_2S, as shown in Figure 4. As the pH, at temperature and pressure, increases, so does the resistance to sulfide SCC (Figure 4).

Figure 4 - Limits of use for ZERON 100 in brines containing H_2S



Hydrogen Embrittlement

In common with all high strength steels, duplex and super duplex stainless steels can be susceptible to hydrogen embrittlement if stressed above the specified minimum yield strength in the presence of hydrogen. Hydrogen embrittlement therefore becomes an area for consideration when these steels are used subsea with conventional cathodic protection. However, the proper application of normal design stress criteria and coating technology has allowed many subsea projects to utilize duplex and super duplex stainless steels successfully for a number of years.

Manufacturing

Heat Treatment

ZERON 100 should be solution annealed in the temperature range 2012-2084°F (1100-1140°C) followed by water quenching.

Hot Forming

Hot forming of ZERON 100 should be carried out in the temperature range 2012-2336°F (1100°C-1280°C). It is recommended that this is followed by solution annealing and water quenching. Components should subsequently be pickled or fully machined.

Cold Forming

ZERON 100 can be adequately cold formed by various processes but the high mechanical properties should be taken into account. It is recommended that any cold work in excess of 10%-15% is removed by solution annealing and water quenching.

It should be noted that cold working above these limits can result in hardness levels above those specified in standards such as ISO 15156 / NACE MR0175 for cold worked superduplex.

Welding

Where a solution anneal and quench as a post-weld heat treatment is to be carried out, ZERON 100 is usually welded with matching composition consumables (ZERON 100M). With overalloyed consumables (ZERON 100X), no post-weld heat treatment is necessary. Corrosion and mechanical properties similar to the parent metal can be obtained following recommended procedures. A separate brochure on the optimum parameters for a range of welding operations is available from our Sales Department as bulletin number 105.

Machining

ZERON 100 requires a little more care in machining than the 300 series austenitics. If heavy or uneven machining to tight tolerances is to be carried out on wrought ZERON 100 components, machining should be carried out in stages. As a last resort, a stress relieving heat treatment can be applied but this can result in a reduction of toughness and corrosion resistance.

Applications

The properties outlined in this data sheet, combined with the availability of a wide range of product forms, make ZERON 100 ideally suited for use in a wide range of industries including oil and gas, marine, mining and metallurgical, desalination, flue gas desulfurization, chemical and process.

ZERON 100 Pipe used in an offshore oil platform riser.

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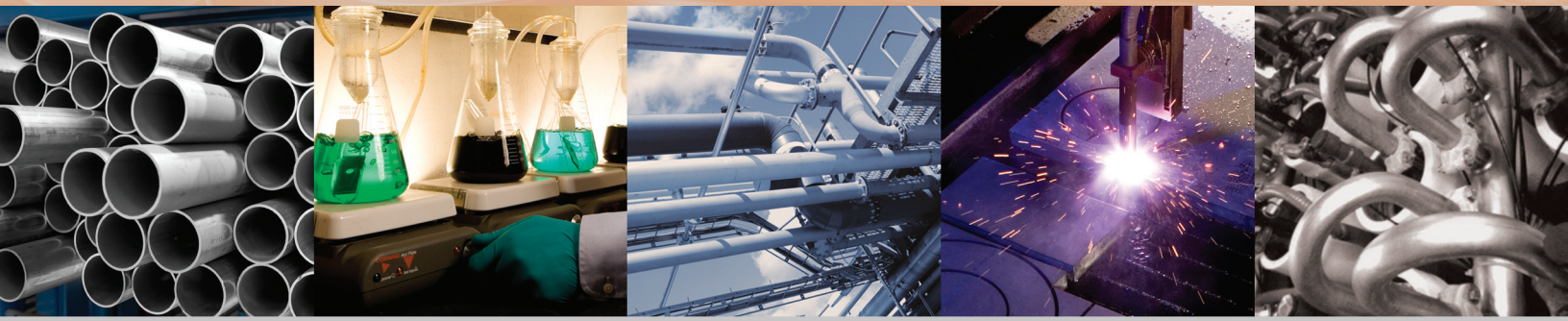

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