



NUCL™ 304 B4

NUCL™ 304 B4: A natural boron (1% wt mini) alloyed 304 stainless steel

Isotope B_{10} has the property to capture neutrons produced by nuclear reactions. Natural boron contains about 19.9 at% or 18.45 wt% of B_{10} isotope, the remaining being B_{11} isotope. **NUCL™ 304 B4** grade is a 304 stainless steel obtained by ingot casting and alloyed with 1 to 1,24 wt% natural boron additions.

In order to avoid ferrite grain which reduces the ductility of the alloy, **NUCL™ 304 B4** grade has been overalloyed in nickel when compared to 304 grades. The ingots rolled into plates are considered for nuclear applications like nuclear spent fuel transport and storage.

PROPERTIES

STANDARDS

- > EURONORM: EN 1.4306 Bor - 01 Ind.00
- > ASTM: A887 304 B4 : Type 304 B4 Grade B

CHEMICAL ANALYSIS - WEIGHT %

Typical values

C	Cr	Ni	Mn	Si	B	Others
.013	18.5	12.5	.8	.3	1.1	N = .10 max

Natural boron content for NUCL™ 304 B4 included in the 1 - 1.24 wt%.

Other chemistries including boron content may be specified.

PHYSICAL PROPERTIES

Density: 7.8 kg/dm³

Interval temperature (°C)	Thermal expansion ($\alpha \times 10^{-6} K^{-1}$)	T °C (°F)	Resistivity ($\mu\Omega \cdot cm$)	Thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	Specific heat ($J \cdot kg^{-1} \cdot K^{-1}$)	Young modulus E (GPa)	Shear modulus G (GPa)
20 - 100	17	20 (68)	95	15	500	200	75
20 - 200	17.5	100 (212)	97	16	500	190	73
20 - 300	18	200 (392)	104	17.5	520	180	70
		500 (572)	111	19	530	170	67

MECHANICAL PROPERTIES

Tensile properties

a- Minimum values

°C	°F	Y.S. 0.2%		Y.S. 1%		UTS		Elongation
		MPa	ksi	MPa	ksi	MPa	ksi	%
20	68	210	31	225	33	515	75	16
350	662	190	28	205	30	435	63	10

b - Typical values

°C	°F	Y.S. 0.2%		Y.S. 1%		UTS		Elongation
		MPa	ksi	MPa	ksi	MPa	ksi	%
20	68	310	45	325	47	610	88	19
350	662	260	38	270	39	520	75	20

Hardness max values: Brinell: 217; Rockwell B: 95

STRUCTURE

NUCL™ 304 B4 grade has a fully austenitic stainless steel microstructure with precipitated boron enriched particles. The nickel content has been increased to avoid the presence of ferritic grains. Nevertheless, due to the high concentration of boron enriched particles, the ductility is reduced and the steel is not easy to form.

The alloy is very sensitive to crack propagations. Smooth surfaces are to be considered for forming operations. In order to optimize the microstructure, including the boron distribution, the steel is cast in small ingots. Rapid solidification is thus obtained. Hot workability is poor even on solution annealed plates. Solution - annealing heat treatments will be performed to a temperature of 1040°C (1900°F) minimum. For about 2 minutes per millimeter thickness and followed by water quenching or rapid cooling. Higher boron contents will result in higher density of boron enriched particles and thus reduce ductility.

This is particularly the case for conventional wrought metallurgy. Powder metallurgy makes it possible to obtain a near - optimal dispersion of the boron. The ductility is also enhanced. Finally, since only B₁₀ isotope are of interest to capture the neutrons. B₁₀ enriched grades are considered.

This makes it possible to increase the B₁₀ content without having very high total boron contents and thus higher ductility. Nevertheless B₁₀ isotope is very expensive.

Grades	Boron	Y.S.		UTS		Elongation
	Wt%	MPa	ksi	MPa	ksi	%
NUCL™ 304 B	.20 - .29	205	30	515	75	40
NUCL™ 304 B1	.30 - .49	205	30	515	75	35
NUCL™ 304 B2	.50 - .74	205	30	515	75	27
NUCL™ 304 B3	.75 - .99	205	30	515	75	19
NUCL™ 304 B4	1.00 - 1.24	205	30	515	75	16
NUCL™ 304 B5*	1.25 - 1.49	205	30	515	75	13
NUCL™ 304 B6*	1.5 - 1.74	205	30	515	75	9
NUCL™ 304 B7*	1.75 - 2.25	205	30	515	75	6

Minimum values for conventional wrought products. Powder metallurgy make it possible to improve the ductility

*Please, consult. Powder metallurgy is to be considered for plates.

IN SERVICE CONDITIONS

CORROSION RESISTANCE

The NUCL™ 304 B4 grade performs almost like UR™ 304L when considering corrosion resistance properties. When needed, molybdenum additions are sometimes considered to increase the corrosion resistance properties.

DELIVERY CONDITIONS

SIZE RANGE

	Hot rolled plates
Thickness	8 up to 80 mm 0.31" to 3"
Width	Up to 2000 mm Up to 80"
Length	Up to 10000 mm Up to 32.8"

Other sizes are available on request, please consult.

PLATE PROCESSING

HOT FORMING

Hot forming should be carried out in a temperature range of 1150 - 950°C (2100 - 1750°F) followed by rapid quench. After hot forming, it is required to restore the ductility by a solution annealing heat treatment. Special precautions must be taken during heat treatment and/or hot forming to avoid local mechanical damages. The alloy is very sensitive to crack propagations when stress concentrations occur on scratches.

COLD FORMING

NUCL™ 304 B4 grade has limited ductility at room temperature. Cold forming is possible (bendings...) but one should considerer smooth surfaces since crack propagation may occur rapidly on local surface defects. After cold deformation, a full annealing heat treatment (1040 - 1080°C / 1900 - 1975°F) followed by rapid quench is recommended to restore the ductility and reduce stress concentrations. Pickling solutions or acceptable pastes for 304(L) grades may be used. The pickling time required is equivalent to that of 304 (18-10) grades. Nitric acid may be considered for pickling (10% HNO₃ - 2% HF) as well as diluted nitric acid for repassivation . Over etching is to be avoided since the microstructure contains a lot of boron enriched particles.

WELDING

NUCL™ 304 B4 grade is weldable with 308L filler metal. Welds configuration and processes which use high dilution rate i.e. 0.6% boron minimum content in the weld metal are preferred. Low boron contents in the weld melt make the weld very sensitive to hot cracking. For those reasons, GTAW or PLASMA weldings are to be used when possible.

AGREEMENTS

NUCL™ 304 B4 grade has been successfully controlled by french CEA/SGN, and german BAM TÜV organisms. It has also been supplied to USA.



APPLICATIONS

NUCL™ 304 B4 grade is mainly used for nuclear applications:

- > Container casks, racks for transportation (trucks, trains)
- > Racks for nuclear pools
- > Neutron absorber plates (safety aspects)



YOUR CONTACTS

Nathalie Mottu - Bellier

Tel. +33 3 85 80 53 02

nathalie.mottubellier@arcelormittal.com

<http://industeel.arcelormittal.com>

Industeel France

Le Creusot Plant

56 rue Clemenceau

F - 71202 Le Creusot Cedex

Technical data and information are to the best of our knowledge at the time of printing. However, they may be subject to some slight variations due to our ongoing research programme on steels. Therefore, we suggest that information be verified at time of enquiry or order. Furthermore, in service, real conditions are specific for each application. The data presented here are only for the purpose of description, and considered as guarantees when written formal approval has been delivered by our company. Further information may be obtained from the address opposite.