



## Characteristics

Grade 2304 is a lean Duplex stainless steel with general corrosion resistance similar or better than 316L, but with yield strength nearly double that of austenitic stainless steels.

### Characteristic properties:

- High mechanical strength
- Good weldability
- Good corrosion resistance
- High resistance to Stress Corrosion Cracking (SCC)
- Good machinability
- Very good wear and abrasive resistance
- Low thermal expansion
- Good fatigue properties
- Temperature range -40°C to 250°C

## Dimensions

Tubular products in grade 2304 are not stock standard, but can be manufactured in most common standard sizes within Outokumpu Stainless Tubular Products product range.

### Tubes, Pipes and Butt Weld Fittings

- OD: 17.2-1219.0 mm
- WT: 1.5-25.4 mm
- Lengths: up to 12 m

### Heat exchanger tubes

- OD: 12.0-114.3 mm
- WT: 0.6-4.0 mm
- Lengths: up to 15 m

## Executions

### Tubes, Pipes and Butt Weld Fittings

- Welded with- or without filler metal
- Unannealed, pickled
- Solution annealed and pickled
- With- or without BCW (Bead Cold Worked)
- Bevelled ends according to standards

### Heat exchanger tubes

- No BCW for laser welded tubes, h max = 0.15 mm
- Tig welded tubes are BCW
- Solution annealed and pickled

## Corrosion resistance

With 2304's Duplex microstructure, a low nickel and high chromium contents, the alloy has improved stress corrosion resistance properties compared to the 304L and 316L standard austenitic grades. For more details see eg. Outokumpu data sheet for Duplex Stainless Steel and Outokumpu Corrosion Handbook at our web site [www.outokumpu.com](http://www.outokumpu.com).

## Microstructure / Ferrite content

The balanced chemical composition of 2304 results in a microstructure containing approximately equal amount of ferrite and austenite in the microstructure after annealing in a temperature about 950-1050°C. By determining the ferrite content in the weld, it is ensured that the welding and/or annealing has been done properly.

The general opinion is that a too high ferrite content, i.e. > 70 % decreases the toughness and pitting resistance, and a too low ferrite content, i.e. < 25 % decreases the SCC-resistance.

## Product Standards

### Europe

- EN 10296-2 Welded SS tubes for general purposes.
- EN 10217-7 Welded SS tubes for pressure purposes.
- EN 10253-3: Butt-welding pipe fittings. Wrought austenitic and austenitic-ferritic (Duplex) stainless steels without specific inspection requirements.
- EN 10253-4: Butt-welding pipe fittings. Wrought austenitic and austenitic-ferritic (Duplex) stainless steels with specific inspection requirements.

### USA

- ASTM A 789 Welded and seamless F/A SS heat exchanger tubes.
- ASTM A 790 Welded and seamless F/A SS pipe.
- ASTM A 928 F/A SS pipe fusion welded with filler metal.
- ASTM A 815 Wrought ferritic, Duplex, martensitic stainless steel piping fittings.

## Weld factor

Type of weld process and NDT	EN 13480-3		ASME B31			
	EN 10217-7 / EN 10253-4	EN 10296-2 / EN 10253-3	A 789	A 790	A 798	A 928
EFW, 100 % ET	1.0	-	0.8	0.8	0.8	0.8
EFW, 100 % RT	1.0	-	1.0	1.0	1.0	1.0
EFW, spot RT	-	0.85	-	-	-	0.9
EFW, double butt	-	0.7	0.85	0.85	0.85	0.85
EFW, single butt	-	0.7	0.8	0.8	0.8	-

EFW = Electric Fusion Welded      ET = Eddy Current Test      RT = Radiographic Test

The joint coefficient (z used in EN standards) or Joint quality factor (Ej, used in ASME standards) is used for calculation of the wall thickness for welded tubes. The type of welding process, amount and type of NDT decide the factor.

## Chemical composition, % (Typical values)

Outokumpu	EN	ASME/UNS	C	Cr	Ni	Mo	N	Others	PRE*
4307	1.4307	304L	0.02	18.1	8.1	-	-	-	18
4404	1.4404	316L	0.02	17.2	10.1	2.1	-	-	24
LDX 2101®	1.4162	S32101	0.03	21.5	1.5	0.3	0.22	5Mn	26
<b>2304</b>	<b>1.4362</b>	<b>S32304</b>	<b>0.02</b>	<b>23</b>	<b>4.8</b>	<b>0.3</b>	<b>0.10</b>	-	<b>26</b>
2205	1.4462	S32205**	0.02	22	5.7	3.1	0.17	-	35
2507	1.4410	S32750	0.02	25	7	4	0.27	-	43

\* PRE = % Cr + 3.3 % Mo + 16 % N (The formula is used as a ranking tool to estimate pitting corrosion resistance in the material).

\*\* Also available as S31803.

## Pressure vessel approvals

### Europe

The Pressure Equipment Directive (PED) regulates the use of stainless steel pipe and fittings in most European countries. OSTP fulfils the Directive, and is an approved manufacturer of welded Duplex stainless tubular products.

### Outside Europe

Pressure vessel regulations are authorized to ASME. ASME Section II, Part D Table 2A, shows design values for tube and pipe. ASME B31.1 Power Piping and ASME B31.3 Process Piping state design for approved pipe material.

## Fabrication

### Welding

Common welding methods for tubular products are:

- MMA, SMAW (Shielded Metal Arc Welding)
- TIG, GTAW (Gas Tungsten Arc Welding)
- MIG, MAG, GMAW (Gas Metal Arc Welding)
- FCAW (Flux-Cored Arc Welding)
- PAW (Plasma Arc Welding)
- SAW (Submerged Arc Welding)

The general recommendation for shield and plasma gas is pure Argon (TIG/PAW). An addition of 1-2 % nitrogen in the shielding gas for TIG and PAW methods will improve the pitting corrosion resistance in the weld. As backing/purging gas the general recommendation is pure Ar or Formier gas (90 % N<sub>2</sub> and 10 % H<sub>2</sub>).

General filler recommendation for steel grade 2304 can be found in the table below.

Welding without filler metal not followed by post heat treatment will reduce the corrosion resistance and is therefore not recommended.

See Outokumpu Welding Handbook for more information (available from 2010).

### Cold forming

Since the yield strength is about twice that of standard austenitic grades, a higher initial force is necessary in operations such as bending or expanding tubes into tube sheets. The spring back effect is also more pronounced.

### Heat treatment

Normal annealing temperature is 950-1050°C followed by rapid cooling. The microstructure of 2304 Duplex is very stable compared to molybdenum-containing Duplex stainless steels.

Intermetallic phases will only form after several hours at around 700°C.

## Applications

- Chloride containing environments
- Welded pipe systems within Pulp and Paper-, Chemical and Petrochemical-, Water Treatment Industries
- Transportation
- Architecture, Building and Construction
- Heat exchanger tubes

## Design

The allowable design values are about twice those for standard austenitic steels. This means that the possibility of designing thinner walls can save costs. Lower cost for material, transport, welding and maintenance. Please use our Press Calculation Tool on [www.outokumpu.com](http://www.outokumpu.com), to discover the weight saving possibilities and other benefits of Duplex stainless steel.

## General filler recommendation for Duplex stainless steels

Outokumpu	EN	ASTM / UNS	Welding consumables	
			Covered electrodes ISO 3581 / ISO 14172	Wires ISO 14343 / ISO 18274
LDX 2101®	1.4162	S32101	23 7 NL or 22 9 3 NL	23 7 NL or 22 9 3 NL
<b>2304</b>	<b>1.4362</b>	<b>S32304</b>	<b>23 7 NL or 22 9 3 NL</b>	<b>23 7 NL or 22 9 3 NL</b>
2205	1.4462	S2205/S31803	22 9 3 NL	22 9 3 NL
2507	1.4410	S32750	25 9 4 NL	25 9 4 NL

## Mechanical properties (At room temperature)

Outokumpu	Min values acc. to EN 10028-7:2007									Min values according to ASTM A240-07		
	R <sub>p0.2</sub> , MPa			R <sub>m</sub> , MPa			A <sub>80</sub> , %			R <sub>p0.2</sub> , MPa	R <sub>m</sub> , MPa	A <sub>5</sub> , %
	P	H	C	P	H	C	P	H	C			
4307	200	200	220	500	520	520	45	45	45	170	485	40
4404	220	220	240	520	530	530	45	40	40	170	485	40
LDX 2101®	450*	480*	530*	650*	680*	700*	30*	30*	20*	530 (t ≤ 5.0 mm) / 450 (t > 5.0 mm)	700 (t ≤ 5.0 mm) / 650 (t > 5.0 mm)	30
<b>2304</b>	<b>385/400</b>	<b>385/400</b>	<b>405/420</b>	<b>630</b>	<b>600</b>	<b>600</b>	<b>25</b>	<b>20</b>	<b>20</b>	<b>400</b>	<b>600</b>	<b>25</b>
2205	445/460	445/460	485/500	640	700	700	25	25	20	450	655	25
2507	515/530	515/530	535/550	730	750	750	20	20	20	550	795	15

\* Min values according to EN 10088-4:2009

P = Hot rolled plate

H = Hot rolled strip

C = Cold rolled coil and strip

## Physical properties

Outokumpu	Density, g/cm <sup>3</sup>	Modulus of elasticity, GPa	Poisson's ratio $\nu = -\epsilon_{trans} / \epsilon_{longitudinal}$	Average linear expansion at RT -
				100°C x10 <sup>-6</sup> / °C
4307	7.9	200	0.3	16.0
4404	8.0	200	0.3	16.0
LDX 2101®	7.8	200	0.3	13.0
<b>2304</b>	<b>7.8</b>	<b>200</b>	<b>0.3</b>	<b>13.0</b>
2205	7.8	200	0.3	13.0
2507	7.8	200	0.3	13.0

Outokumpu is a global leader in stainless steel with the vision to be the undisputed number one. Customers in a wide range of industries use our stainless steel and services worldwide. Being fully recyclable, maintenance-free, as well as very strong and durable material, stainless steel is one of the key building blocks for sustainable future.

What makes Outokumpu special is total customer focus – all the way, from R&D to delivery. You have the idea. We offer world-class stainless steel, technical know-how and support. We activate your ideas.

[www.outokumpu.com](http://www.outokumpu.com)