

2304 High Strength Duplex Welded Stainless Tubular Products

Characteristics

Grade 2304 is a lean Duplex stainless steel with general corrosion resistance similar or better than 316L (PRE), but with a 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 generally manufactured in most common standard sizes within OSTP's product range and to client tailored needs by agreement.

Tubes, Pipes and Butt Weld Fittings

- OD: 21.3–1219.0 mm
- WT: 1.5–25.4 mm
- Lengths: up to 12 m

Tubes below 21.3 mm OD and tubes with wall thickness below 1.5 mm or length over 12 m on special request.

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 Work) – Tubes Only
- Bevelled ends according to standards

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 928
EFW, 100 % ET	1.0	-		0.8	0.8	0.8
EFW, 100 % RT	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
EFW, single butt	-	0.7		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 (E_j, 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
2304	1.4362	S32304	0.02	23	4.8	0.3	0.10	-	26
LDX 2404™	1.4662	S82441	0.02	24	3.6	1.6	0.27	3Mn	33
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.



Corrosion resistance

With 2304's Duplex microstructure, a low nickel and high chromium content, the alloy has improved stress corrosion resistance properties compared to the 304L and 316L standard austenitic grades. For more details see e.g. Outokumpu data sheet for Duplex Stainless Steel and Outokumpu Corrosion Handbook.

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 10217-7: Welded steel tubes for pressure purposes –Technical delivery conditions Part 7: Stainless steel tubes
- EN 10296-2: Welded circular steel tubes for mechanical and general engineering purposes –Technical delivery conditions Part 2: Stainless steel
- EN 10253-3: Butt-welding pipe fittings Part 3: Wrought austenitic and austenitic-ferritic (Duplex) stainless steels without specific inspection requirements.
- EN 10253-4: Butt-welding pipe fittings Part 4: Wrought austenitic and austenitic-ferritic (Duplex) stainless steels with specific inspection requirements.

USA

- ASTM A 789: Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
- ASTM A 790: Seamless and Welded Ferritic/Austenitic Stainless Steel Pipes
- ASTM A 928: Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe electric fusion welded with addition of filler metal
- ASTM A 815: Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings

Pressure vessel requirements

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 shielding 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 corrosion resistance in the weld. As backing/purging gas the general recom-

mendation is Formier gas (90% N₂ and 10% H₂), pure Argon could also be used but the addition of nitrogen enhances the corrosion resistance of the weld. When material thickness requires more than one run, the interpass temperature has to be below 150°C.

General filler recommendation for steel grade 2304 can be found in the table below. Welding without filler metal not followed by post-weld heat treatment will reduce the corrosion resistance and is therefore not recommended. Welding against other steel grades is also possible when suitable filler metal and shielding/backing gas is used. See Outokumpu Welding Handbook for more information.

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.

For example during tube bending operations the minimum recommended bending radius is $\geq 2.5 \times OD$. However, this requires good quality bending machine, tooling and qualified operator.

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 Pressure Calculation Tool on www.ostp.biz, to discover the weight saving possibilities and other benefits of Outokumpu 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
2304	1.4362	S32304	23 7 NL or 22 9 3 NL	23 7 NL or 22 9 3 NL
LDX 2404™	1.4662	S82441	22 9 3 NL	22 9 3 NL
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 A240-10		
	R _{p0.2} , MPa			R _m , MPa			A ₈₀ , %			R _{p0.2} , MPa	R _m , MPa	A ₅₁ , %
	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*	465*	515*	650*	680*	700*	30*	30*	25/30*	530 (t ≤ 5.0 mm) / 450 (t > 5.0 mm)	700 (t ≤ 5.0 mm) / 650 (t > 5.0 mm)	30
2304	385/400	385/400	405/420	630	600	600	25	20	20	400	600	25
LDX 2404™	480**	550**	550**	680**	750**	750**	25**	25**	25/20**	540 (t < 10 mm) / 480 (t ≥ 10 mm)	740 (t < 10 mm) / 680 (t ≥ 10 mm)	25
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 EAM-0045-01:2012/01 ** Min values according to EAM 641E Ed.2
P = Hot rolled plate H = Hot rolled strip C = Cold rolled coil and strip

Physical properties

Outokumpu	Density, g/cm ³	Modulus of elasticity, GPa	Poisson's ratio $\nu = -\epsilon_{trans} / \epsilon_{longitudinal}$	Average linear expansion at RT 100°C x 10 ⁻⁶ /°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
2304	7.8	200	0.3	13.0
LDX 2404™	7.7	205	0.3*	13.0
2205	7.8	200	0.3	13.0
2507	7.8	200	0.3	13.0

* 0.3 is the typical Duplex value. Grade specific value are in the process of being established for LDX 2404™.

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OSTP is a joint-venture between Tubinoxia and Outokumpu Group. OSTP manufactures the broadest range of stainless steel tubular products:

PROCESS PIPES

- Jakobstad, Finland
- Riyadh, Saudi Arabia

HEAVY WALL PIPES

- Storfors, Sweden

BUTT WELDED FITTINGS

- Örnsköldsvik, Sweden
- Jakobstad, Finland

PROCESS EQUIPMENT

- ÖMV, Örnsköldsvik, Sweden

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