outokumpu
high performance stainless steel

Therma 304H/4948

EN 1.4948, ASTM TYPE 304H / UNS S30409

General characteristics

Stainless steel grade with wet corrosion resistance and improved high-temperature strength (creep resisting steel). Good formability and weldability. Commonly used for tubes and pressure vessels.

A common feature of Outokumpu high temperature steels is that they are designed primarily for use at temperatures exceeding ~550 °C, i.e. in the temperature range where creep strength as a rule is the dimensioning factor and where HT corrosion occurs. Optimising steels for high temperatures has meant that their resistance to aqueous corrosion has been limited. All steels are austenitic, resulting in relatively high creep strength values.

Typical applications

Outokumpu high temperature steels can be and have been used in a number of applications where the temperature exceeds 550°C, e.g. for equipment and components within:

- Tubes
- Pressure vessels
- Iron, steel, and non-ferrous industries
- Engineering industry
- Energy conversion plants
- Cement industry

Products & dimensions

Cold rolled products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
2D	Cold rolled, heat treated, pickled	0.50-6.35	35-1610	0.50-6.35	35-1610
2G	Ground	0.60-4.00	35-1530	0.60-4.00	35-1530
2J	Brushed or dull polished	0.50-3.00	35-1530	0.50-3.00	35-1530
2K	Satin finish	0.50-4.00	35-1530	0.50-4.00	35-1530

Continous hot rolled products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
1D	Hot rolled, heat treated, pickled	2.40-9.20	50-1610	2.40-9.20	50-1610

Quarto plate products, available dimensions (mm)

Surface finish	Coil / Strip		Plate / Sheet	
	Thickness	Width	Thickness	Width

1D	Hot rolled, heat treated, pickled			5.00-130.00	400-3200

Chemical composition

The chemical composition is given as % by mass.

	C	Mn	Cr	Ni	Mo	N	Other
Typical	**0.05**		**18.1**	**8.3**			
ASME II A SA-240	0.04-0.10	≤2.00	18.0-20.0	8.0-10.5			
ASTM A240	0.04-0.10	≤2.00	18.0-20.0	8.0-10.5			
EN 10028-7	0.04-0.08	≤2.00	17.00-19.00	8.00-11.00		≤0.10	
IS 6911	0.04-0.10	≤2.00	18.0-20.0	8.0-10.5	≤0.70		

Corrosion resistance

Aqueous corrosion

Since most high-temperature materials are optimised with regard to strength and corrosion resistance at elevated temperatures, their resistance to electrochemical low-temperature corrosion may be less satisfactory. Components made of high-temperature material should therefore be designed and operated so that acid condensates are not formed, or at least so that any such condensates are drained away.

High-temperature corrosion

The resistance of a material to high-temperature corrosion is in many cases dependent on its ability to form a protective oxide layer. In a reducing atmosphere, when such a layer cannot be created (or maintained), the corrosion resistance of the material will be determined by the alloy content of the material.

Oxidation

When a material is exposed to an oxidising environment at elevated temperatures, a more or less protective oxide layer will be formed on its surface. Even if oxidation is seldom the primary cause of high-temperature corrosion failures, the oxidation behaviour is important, because the properties of the oxide layer will determine the resistance to attack by other aggressive elements in the environment.The oxide growth rate increases with increasing temperature until the rate of oxidation becomes unacceptably high or until the oxide layer begins to crack and spall off, i.e. the scaling temperature is reached. The alloying elements that are most beneficial for oxidation resistance are chromium, silicon, and aluminium. A positive effect has also been achieved with small additions of so-called (re)active elements, e.g. ttrium, hafnium, rare earth metals (REM, e.g. Ce and La). These affect the oxide growth so that the formed layer will be thinner, tougher, and more adherent and thus more protective.

Sulphur attacks

Various sulphur compounds are often present in flue gases and other process gases. As a rule, they have a very detrimental effect on the useful life of the exposed components. Sulphides can nucleate and grow due to kinetic effects even under conditions where only oxides would form from a thermodynamic point of view. In existing oxide layers, attacks can occur in pores and cracks. It is therefore essential that the material is able to form a thin, tough, and adherent oxide layer. This requires a high chromium content and preferably also additions of silicon, aluminium, and/or reactive elements.

Pitting corrosion resistance		Crevice corrosion resistance
PRE	CPT	CCT
18		

PRE Pitting Resistant Equivalent calculated using the formula: PRE = %Cr + 3.3 x %Mo + 16 x %N
CPT Corrosion Pitting Temperature as measured in the Avesta Cell (ASTM G 150), in a 1M NaCl solution (35,000 ppm or mg/l chloride ions).
CCT Critical Crevice Corrosion Temperature is the critical crevice corrosion temperature which is obtained by laboratory tests according to ASTM G 48 Method F

For more information see Outokumpu Corrosion Handbook or contact Outokumpu.

Mechanical properties

Whilst Outokumpu high temperature steels are mainly optimised for oxidation and high temperature corrosion resistance, they also have good mechanical properties, partly due to their austenitic structure and partly due to certain alloying elements. Design values are usually based on minimum proof strength values for constructions used at temperatures up to around 550°C. For higher temperatures, mean creep strength values are used.

Cold rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 1 mm)								
ASME II A SA-240	≥ 205		≥ 515				≤ 201	
ASTM A240	≥ 205		≥ 515			≤ 92HRB	≤ 201	
EN 10028-7	≥ 230	≥ 260	530 - 740	≥ 45				
IS 6911	≥ 205		≥ 515			≤ 92HRB	≤ 201	

Hot rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 4 mm)								
ASME II A SA-240	≥ 205		≥ 515				≤ 201	
ASTM A240			≥ 515				≤ 201	
IS 6911	≥ 205		≥ 515			≤ 92HRB	≤ 201	

Hot rolled quarto plate	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 15 mm)	**290**	**330**	**600**	**55**				
ASME II A SA-240	≥ 205		≥ 515			≤ 92HRB	≤ 201	
ASTM A240	≥ 205		≥ 515			≤ 92HRB	≤ 201	
EN 10028-7	≥ 190	≥ 230	510 - 710	≥ 45				
IS 6911	≥ 205		≥ 515			≤ 92HRB	≤ 201	

Wire rod	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1] %	Impact strength J	Rockwell	HB	HV
Typical	**290**	**330**	**600**	**55**				

[1]Elongation according to EN standard:
A_{80} for thickness below 3 mm.
A for thickness = 3 mm.
Elongation according to ASTM standard $A_{2"}$ or A_{50}.

Physical properties

Data according to EN 10088

Density kg/dm³	Modulus of elasticity GPa	Thermal exp. at 100 °C 10^{-6}/°C	Thermal conductivity W/m°C	Thermal capacity J/kg°C	Electrical resistance µΩm	Magnetizable
7.9	200	16,3	17	450	0.71	No

Fabrication

Like other austenitic steels, heat-resistant steels can also be formed in cold condition. However, as a result of their relatively high nitrogen content, the mechanical strength of certain steels is higher and consequently greater deformation forces will be required.

Machining

The relatively high hardness of austenitic steels and their ability to strain harden must be taken into consideration in connection with machining. For more detailed data on machining, please contact Outokumpu, Avesta Research Centre.

Welding

The steels have good or very good weldability. To ensure weld metal properties (e.g. strength, corrosion resistance) equivalent to those of the parent metal, a filler material with a matching composition should preferably be used. In some cases, however, a differing composition may improve e.g. weldability or structural stability. Gas shielded welding has resulted in the best creep properties for welds. When MAG welding is carried out with wire, a power source with pulse current may be necessary to obtain good weldability.

More information

A number of publications regarding this steel grade are available for downloading from our publications system. The downloads can be found under Products/Useful Tools Online/Publications. Below are a few publications that might be of interest.

High Temperature Austenitic Stainless Steel
Material datasheet presenting the properties for Outokumpu austenitic grades suitable for high temperature applications

Acom 2010 Ed:2
Materials performance in simulated waste combustion environments
R. Pettersson. J. Flyg. P. Viklund.
High temperature corrosion under simulated biomass deposit conditions
R. Pettersson. J. Flyg. P. Viklund.
Stainless steels in waste and biomass power plant applications
R. Pettersson. A. Bergquist. J. Flyg. B. Beckers.

Standards & approvals

The most commonly used international product standards are given in the table below.

Standard	Designation
ASME SA-240M Code Sect. II. Part A	TYPE 304H / UNS S30409
ASTM A240/A240M	TYPE 304H / UNS S30409
EN 10028-7, PED 2014/68/EU	1.4948
IS 6911, AMENDMENT NO. 2	ISS 304H

Contacts & Enquiries

Contact your nearest sales office

www.outokumpu.com/contacts

Working towards forever.

We work with our customers and partners to create long lasting solutions for the tools of modern life and the world's most critical problems: Clean energy, clean water and efficient infrastructure. Because we believe in a world that lasts forever.

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