outokumpu

Stainless steels for high service temperatures

Outokumpu Therma range datasheet

General characteristics

The Therma range contains 12 products for use in applications with high service temperatures (≥ 550 °C/1020 °F). Ferritic stainless steels have resistance to sulfur containing hot gases and lower thermal expansion. Austenitic stainless steels have resistance to carburizing and nitriding/low oxygen hot gas and higher creep strength.

Key products

Outokumpu name	Typical applications	Product forms
Therma 253 MA A stainless steel with excellent oxidation and creep resistance in cyclic conditions that is best employed in temperatures up to 1150 °C/2100 °F. There is a slight susceptibility to embrittlement during continuous operation between 600–850 °C/1110–1560 °F.	• Oil industry equipment • Conveyor belts • Refractory anchors • Expansion bellows • Radiant tubes • Rotary kilns • Exhaust manifolds • Power generation applications • Cyclone dip tubes • Impact separators • Bell furnaces • Muffle furnaces • Automotive components • Tube shields • Heat treatment trays • Dampers • Recuperator tubes for the steel industry • Large-scale bakery ovens • Valves and flanges	C, H, P, B, R, S, T
Therma 310S/4845 A product with very good oxidation resistance in general and good oxidation resistance in mildly cyclic conditions that is best employed in temperatures up to 1050°C/1920°F. There is a slight susceptibility to embrittlement during continuous operation between 600–850 °C/1110–1560 °F.	• Furnace equipment • Oil industry equipment • Heat treatment baskets • Heat exchanges • Steam boilers • Thermowells • Automotive components • Valves and flanges	C, H, P, B, R, S, T

Resistance to sulfur containing gases, lower thermal expansion

Outokumpu name	Typical applications	Product forms
Therma 4713 A low-alloyed stainless steel best employed at 550–800 °C/1020–1470 °F when you need higher mechanical loading compared to other ferritic grades. Offers good resistance against sulfur attack compared to nickel-alloyed grades.	• Furnace equipment • Air heaters • Annealing boxes • Conveyor belts • Thermowells	C, H, P, S
Therma 4724 A low-alloyed product with improved oxidation resistance in temperatures up to 850 °C/1560 °F.	• Furnace equipment • Thermal boiler components • Grids • Burner nozzles • Conveyor belts • Thermowells	C, H, P, S
Therma 4742 A stainless steel with very good oxidation resistance in temperatures up to 1000 °C/1830 °F, but which begins to be subject to embrittlement at temperatures above 950 °C/1740 °F.	• Grids • Burner nozzles • Conveyor belts • Chains • Machine parts • Cement processing equipment	P, H, C, S

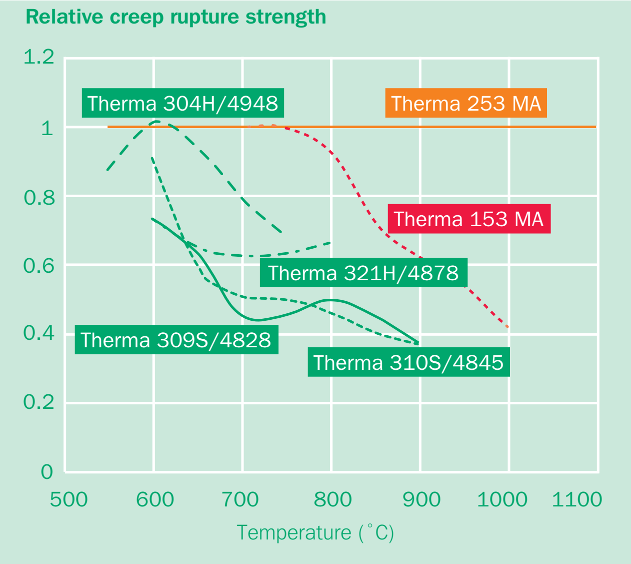
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength

Outokumpu name	Typical applications	Product forms
Therma 304H/4948 A Core 304/4301 variant with improved high-temperature creep strength that is best employed in temperatures up to 750 °C/1380 °F. Offers good formability and weldability.	• Tubes • Pressure vessels • Valves and flanges	C, H, P, B, R, S, T
Therma 321H/4878 A heat-resistant stainless steel with comparable wet corrosion resistance to Core 321/4541 that is best employed in temperatures up to 850 °C/1560 °F.	• Furnace equipment • Case hardening boxes • Valves and flanges	P, H, C, B, R, S, T
Therma 347H A product with excellent long-term creep resistance at at 550–600 °C/1020–1110 °F and comparable wet corrosion resistance to Core 347/4550.	• Oil refineries • Fired heater tubes • Boiler casings • Pressure Vessels • Reactor Vessels • Welded Tubes • Fittings • Stack liners • Tanks for storing organic chemicals • Furnace heating elements • Tanks for thermal storage • Valves and flanges	P, H, C, B, R, S, T
Therma 4828 A product with improved oxidation resistance in temperatures up to 1000 °C/1830 °F. There is a slight susceptibility to embrittlement during continuous operation atbetween 600–850 °C/1110–1560 °F.	• Furnace equipment (especially supporting parts) • Annealing and hardening boxes • Air heaters • Exhaust systems • Automotive components such as turbochargers • Valves and flanges	C, H, P, B, S

Outokumpu name	Typical applications	Product forms
Therma 309S/4833 A stainless steel with improved oxidation resistance in temperatures up to 1000 °C/1830 °F. There is a slight susceptibility to embrittlement during continuous operation at 600–850 °C/1110–1560 °F.	• Furnace equipment • Annealing boxes • Thermowells • Baffle plates • Pots for quenching salt • Valves and flanges	C, H, P, B, R, S, T
Therma 153 MA A stainless steel with excellent oxidation and creep resistance in cyclic conditions that is best employed in temperatures up to 1050 °C/1920 °F. This product has an excellent resistance to embrittlement.	• Recuperators • Conveyor belts • Expansion bellows • Power generation applications • Cyclone dip tubes • Bell furnaces • Muffle furnaces • Automotive components • Tube shields • Heat treatment trays • Dampers • Valves and flanges	C, P, R, S, T
Therma 314/4841 A product with excellent oxidation resistance in temperatures up to 1150 °C/2100 °F. There is a high susceptibility to embrittlement during continuous operation at 600–950 °C/1110–1740 °F	• Furnace equipment • Superheater suspensions • Enameling grates and hardening boxes • Valves and flanges	C, H, P, B, R, S

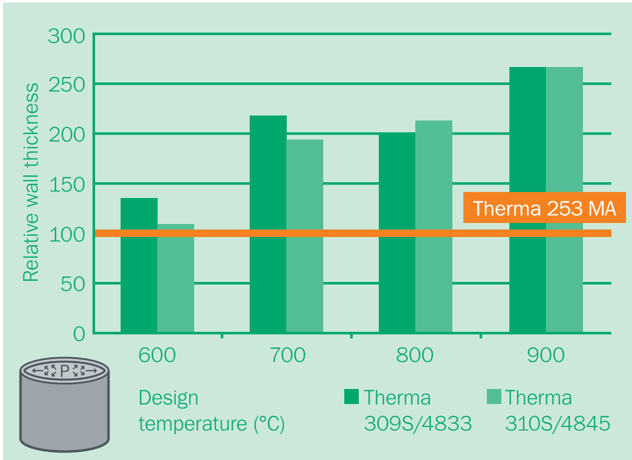
Product forms:
C = Cold rolled coil and sheet
H = Hot rolled coil and sheet
P = Quarto plate
B = Bar
R = Wire rod
S = Semifinished (bloom, billet, ingot & slab)
T = Pipe

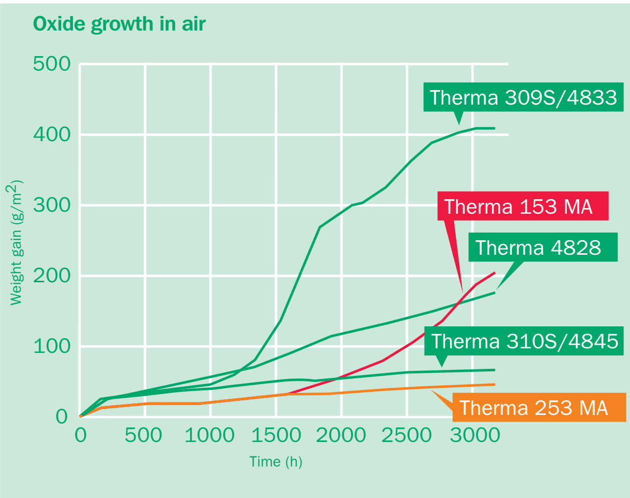
Product performance comparison



100,000 hours creep rupture strength, relative to Therma 253 MA.

Therma 310S/4845 and Therma 314/4841 rings collapsed due to their own weight. 1000 °C/1830 °F, 35 hours, 1 mm/0.04 in thickness.





Oxide growth in air at 1000 °C/1830 °F, 165 hour cycles for austenitic high temperature steels.

Outokumpu name	EN/ASTM	Max. service temperature Ta max for air (EN 10095)	Creep rupture strength	Structural stability	Resistance to hot gases			
					Sulfur containing		Carburizing	Nitriding/ low oxygen
					Reducing	Oxidizing		
Key products								
Therma 253 MA	1.4835/S30815	1150 °C/2100 °F	★★★★★	★★★	★★	★★★★	★★★	★★★
Therma 310S/4845	1.4845/310S	1050 °C/1920 °F	★★★	★★	★	★★★	★★★	★★★★
Resistance to sulfur containing hot gases, lower thermal expansion								
Therma 4713	1.4713/–	800 °C/1470 °F	★	★★★★	★★★★	★★★★	★	★
Therma 4724	1.4724/–	850 °C/1560 °F	★	★★★	★★★★	★★★★	★	★
Therma 4742	1.4742/–	1000 °C/1830 °F	★	★	★★★★★	★★★★★	★	★
Resistance to carburizing and nitriding/low oxygen hot gas, higher creep strength								
Therma 304H/4948	1.4948/304H	750 °C/1380 °F	★★★	★★★	★★	★★★	★	★
Therma 321H/4878	1.4878/321H	850 °C/1560 °F	★★★	★★★★	★★	★★★	★	★
Therma 347H	–/347H	700 °C/1290 °F	★★★	★★★★	★★	★★★	★	★
Therma 4828	1.4828/–	1000 °C/1830 °F	★★★	★★	★	★★★	★★	★★★
Therma 309S/4833	1.4833/309S	1000 °C/1830 °F	★★★	★★★	★	★★★	★★	★★★
Therma 153 MA	1.4818/S30415	1050 °C/1920 °F	★★★★	★★★★	★★	★★★★	★★	★★
Therma 4841/314	1.4841/314	1150 °C/2100 °F	★★★	★	★	★★★	★★★★	★★★★

Note: the more stars a product has, the better its properties in that category.

Products and dimensions

To find the minimum and maximum thickness and width by surface finish for a specific product in the Therma range, please visit **steelfinder.outokumpu.com**

Chemical composition

The chemical composition is given as % by mass.

Outokumpu name	C	Ni	Cr	Mo	N	Others	Family
Key products							
Therma 253 MA	0.09	11	21	–	0.17	Si, Ce	A
Therma 310S/4845	0.05	19.1	25.5	–	–	–	A
Resistance to sulfur containing gases, lower thermal expansion							
Therma 4713	0.06	–	6.5	–	–	Al, Si	F
Therma 4724	0.07	–	12.5	–	–	Al, Si	F
Therma 4742	0.07	–	17.5	–	–	Al, Si	F
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength							
Therma 304H/4948	0.05	8.3	18.1	–	–	–	A
Therma 321H/4878	0.05	9.1	17.3	–	–	Ti	A
Therma 347/347H	0,05	9,5	17,5	–	–	Nb	A
Therma 4828	0.05	11.2	19.3	–	–	Si	A
Therma 309S/4833	0.06	12.3	22.3	–	–	–	A
Therma 153 MA	0.05	9.1	18.5	–	0.15	Si, Ce	A
Therma 314/4841	0.06	19.2	24.3	–	–	Si	A

Table uses Outokumpu typical values. The required standard will be fully met as specified in the order.

For the chemical composition list for different standards by stainless steel product, see **steelfinder.outokumpu.com**

Corrosion resistance

Therma range ferritics

Aqueous corrosion

As their main purpose is to withstand corrosion at high temperatures, Therma range ferritic stainless steels are not expected to perform well in low-temperature environments. Consequently, they are not resistant to acid condensates.

High-temperature corrosion

The extent to which a material is resistant to hot gases is closely related to its composition. Alloy content determines whether or not a protective oxide layer can be maintained or formed to begin with, or if other detrimental reactions could occur.

A number of high-temperature corrosion types are described below. Insensitivity to reducing sulfurous gases is the most exceptional feature of Therma range ferritic stainless steels. Since industrial environments usually consist of a mixture of several aggressive gases, a compromise has to be made when choosing the product.

Oxidation

In oxidizing environments, a protective oxide layer is likely to be formed on the metallic surface. If the layer is tight and adherent, it can prevent other aggressive elements in the environment from attacking and reacting with the steel. However, the layer can grow in thickness due to constant oxidation. The resulting porous layer will allow gases to penetrate through to the base material through pores or cracks. Silicon and aluminum are both beneficial for oxidation resistance. Low thermal expansion and high thermal conductivity of the ferritic base material reduces changes in volume and thus spalling of the protective layer.

Sulfur attacks

As a rule, ferritic steels perform better than austenitic steels in oxidizing and reducing sulfurous environments. Sulfur dioxide and hydrogen sulfide are possible compounds in sulfur-containing process gases or fuels.

In oxidizing environments, attack can be delayed as long as the existing oxide scale is continuous and dense. However, scaling temperatures are up to 200 °C/390 °F lower than in air. Thus, the oxide layer can grow faster and be less compact – forming undesirable pores and cracks – and spall. With ferritic material there is no risk of formation of low-melting-point nickel sulfides. The liquid phase can destroy the remaining oxide layer and inhibit further passivation of an austenite.

Additionally, eutectic phases precipitated at 650 °C/1200 °F – preferably on grain boundaries – weaken the structure and lead to rapid destruction of austenitic material. In reducing sulfurous environments the oxygen activity may be sufficient to form a protective oxide layer, provided the chromium content is higher than 25%. As this is not typical in heat-resistant austenitic steels, the types of catastrophic corrosion attacks described above will be the consequence. It is therefore recommended to use ferritic material in reducing sulfur environments.

Carbon and nitrogen pick-up

In terms of resistance to carburization, austenitic steels show more favorable results than ferritic steels due to their high nickel content. Formation of chromium carbides or chromium nitrides embrittles the material. Additionally, the surrounding matrix becomes chromium-depleted and thus less able to form an oxide layer, which consequently reduces the scaling resistance of the material. Silicon has a beneficial effect on both carbon and nitrogen pick-up. Aluminum is only favorable in terms of carburization. The high nitrogen affinity of aluminum results in aluminum nitrides retarding the formation of a protective alumina, leading to premature failure of the material.

Molten metals

In terms of molten metals, nickel is the most susceptible element to dissolution. Austenitic material is bound to fail when, for example, molten copper penetrates the grain boundaries. Therma range ferritic steels are expected to show good compatibility with molten copper. Final resistance will, of course, depend on the composition of the molten metal.

Therma range austenitics

Aqueous corrosion

Since most high-temperature materials are optimized with regard to strength and corrosion resistance at elevated temperatures, their resistance to low-temperature wet corrosion may be less satisfactory. Components made of high-temperature material should therefore be designed and used so that acid condensates are not formed, or at least so that any such condensates are drained away. As Therma 321H/4878 is a titanium-stabilized stainless steel, it will probably show the best resistance to aqueous intergranular corrosion.

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 environment, when such a layer cannot be created or maintained, the corrosion resistance of the material will be determined by its alloy content. A number of high-temperature corrosion types are discussed below. Since industrial environments usually consist of a mixture of several aggressive gases, a compromise has to be made when choosing the product.

Oxidation

When a material is exposed to an oxidizing 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, oxidation behavior 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. until the scaling temperature is reached.

The alloying elements that are most beneficial for oxidation resistance are chromium, silicon, and aluminum. A positive effect has also been achieved with small additions of so-called reactive elements such as yttrium, hafnium, and rare earth metals. These affect the oxide growth so that the formed layer is thinner, tougher, and more adherent, thus offering better protection. The reactive element effect is especially favorable under conditions with varying temperatures, where the differences between the thermal expansion/contraction of the metal and the oxide induce stresses in the boundary layer, thereby increasing the risk of scaling. This explains the relatively high oxidation resistance of the MA products in the Therma range.

The existence of water vapor in the environment reduces the resistance to oxidation and therefore the maximum service temperature by up to 100 °C/210 °F. Other, more aggressive components in the environment will lead to even greater reductions in the maximum service temperature.

Molybdenum has a positive effect on corrosion properties at room temperature and moderately elevated temperatures, but can lead to so-called catastrophic oxidation at temperatures exceeding approximately 750 °C/1380 °F.

Sulfur attacks

Various sulfur compounds are often present in flue gases and other process gases. As a rule, they have a highly detrimental effect on the useful life of the exposed components. Sulfides 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, aluminum, and/or reactive elements.

Under so-called reducing conditions, the oxygen activity of the gas can still be sufficiently high to enable the formation of a protective oxide layer, provided that the chromium content of the material is sufficiently high (> 25%). If this is not the case, low-melting-point nickel sulfides can be formed instead. Under such circumstances, a nickel-free (or low-nickel) material should be selected.

Carbon and nitrogen pick-up

In small amounts, the pick-up of carbon and/or nitrogen can improve certain properties of a material and is therefore used to enhance properties such as surface hardness and resistance to wear and/or fatigue.

However, excessive pick-up of either element has an adverse effect on the material. In addition to the fact that the carbides or nitrides formed have an embrittling effect, they generally have a higher chromium content than the steel itself. The corresponding chromium depletion in the adjoining metal will reduce the oxidation resistance.

The best protection against this type of corrosion is a dense oxide layer; consequently, strong oxide formers such as chromium and silicon are beneficial alloying elements. Aluminum is favorable with regard to carbon pick-up, but its high nitrogen affinity causes a significant reduction in the protective effect of the aluminum oxide under strongly nitriding conditions. In certain applications, however, a high carbon and/or nitrogen activity is combined with a low-oxygen content, whereby protective oxide layers cannot be formed.

Under such conditions, the bulk composition of the material will determine the pick-up resistance. The most advantageous alloying element in this case is nickel, but silicon also has a positive effect.

In certain applications with high carbon activity, low oxygen activity, and moderately high temperatures, a type of catastrophic carburization referred to as metal dusting can occur, manifesting itself as a disintegration of the material into particles of graphite, metal, and oxide.

The risk of carbon pick-up increases when the material is subjected to alternating carburizing and oxidizing environments. This can occur in carburizing furnaces or heat-treatment furnaces if there are oil residues on the material being heat treated, or during decoking in petrochemical industry processes. The risk of nitrogen pick-up is particularly high in furnaces working at high temperatures with oxygen-free gases consisting of cracked ammonia or other nitrogen/hydrogen mixtures.

Halogens

Gases containing halogens or hydrogen halides are very aggressive to most metallic materials at higher temperatures. Aluminum and, in particular, nickel appear to increase the resistance to corrosion in most gases containing halogens. Chromium and molybdenum, on the other hand, can have either a positive or a negative effect depending on the composition of the gas.

Molten salts

In certain industrial processes, molten salts are used deliberately. These salts easily dissolve existing protective oxide layers and can therefore be very aggressive. However, since the conditions are well known and relatively constant, it is possible to keep the effects of corrosion at an acceptable level by accurate process control and optimum material selection (a high nickel content is often favorable).

However, the detrimental effects of undesirable molten salts can be much worse. The most important example of these effects is caused by deposits on the fire side of various heat-transfer surfaces. This type of problem is difficult to reduce or solve by material selection. Instead, modifications should be made in operational conditions and maintenance procedures.

Erosion

Erosion is a very complex phenomenon in which not only the properties of the construction material are significant, but also those of the eroding particles – for example, hardness, temperature, velocity, and angle of impact.

Generally, an adherent, tough, and ductile oxide layer is required for good erosion resistance. Experience has shown that rare earth metal additions improve these properties and thus improve the erosion resistance at high temperatures.

Mechanical properties

Elevated temperature yield strength $R_{p0.2}$ (MPa) according to EN 10095 minimum values

Outokumpu name	Temperature °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
Key products													
Therma 253 MA	280	230	198	185	176	170	165	160	155	150	145	140	130
Therma 310S/4845	–	140	128	116	108	100	94	91	86	85	84	82	–
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength													
Therma 304H/4948*	–	157	142	127	117	108	103	98	93	88	83	78	–
Therma 321H/4878	–	162	152	142	137	132	127	123	118	113	108	103	–
Therma 4828	–	140	128	116	108	100	94	91	86	85	84	82	–
Therma 309S/4833	–	140	128	116	108	100	94	91	86	85	84	82	–
Therma 153 MA	245	200	178	165	156	150	145	140	135	130	125	120	110

*Values according to EN 10028-7

Elevated temperature yield strength $R_{p1.0}$ (MPa) according to EN 10095 minimum values

Outokumpu name	Temperature °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
Key products													
Therma 253 MA	315	265	230	215	206	200	195	190	185	180	175	170	155
Therma 310S/4845	–	185	167	154	146	139	132	126	123	121	118	114	–
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength													
Therma 304H/4948*	–	191	172	157	147	137	132	127	122	118	113	108	–
Therma 321H/4878	–	201	191	181	176	172	167	162	157	152	147	142	–
Therma 4828	–	185	167	154	146	139	132	126	123	121	118	114	–
Therma 309S/4833	–	185	167	154	146	139	132	126	123	121	118	114	–
Therma 153 MA	280	235	208	195	186	180	175	170	165	160	155	150	135

*Values according to EN 10028-7

Elevated temperature tensile strength R_m (Mpa) according to EN 10095 minimum values

Outokumpu name	Temperature °C												
	50	100	150	200	250	300	350	400	450	500	550	600	700
Key products													
Therma 253 MA	630	585	560	545	538	535	533	530	515	495	472	445	360
Therma 310S/4845	–	470	450	430	420	410	405	400	385	370	350	320	–
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength													
Therma 304H/4948*	–	440	410	390	385	375	375	375	370	360	330	300	–
Therma 321H/4878	–	410	390	370	360	350	345	340	335	330	320	300	–
Therma 4828	–	470	450	430	420	410	405	400	385	370	350	320	–
Therma 309S/4833	–	470	450	430	420	410	405	400	385	370	350	320	–
Therma 153 MA	570	525	500	485	478	475	473	470	455	435	410	385	300

*Values according to EN 10028-7

Creep rupture strength $R_{km\ 10,000}$ (MPa mean values) according to EN 10095

Outokumpu name	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
Key products													
Therma 253 MA	–	250	157	98	63	41	27	18	13	9.5	7	5.5	4
Therma 310S/4845	–	–	130	65	40	26	18	13	8.5	–	–	–	–
Resistance to sulfur containing hot gases, lower thermal expansion													
Therma 4713	100	–	35	–	9.5	–	4.3	–	1.9	–	–	–	–
Therma 4724	100	–	35	–	9.5	–	4.3	–	1.9	–	–	–	–
Therma 4742	100	–	35	–	9.5	–	4.3	–	1.9	–	–	–	–
Resistance to carburizing and nitriding/low oxygen gas. higher creep strength													
Therma 304H/4948*	250	191	132	87	55	34	–	–	–	–	–	–	–
Therma 321H/4878	–	–	142	82	48	27	15	–	–	–	–	–	–
Therma 4828	–	–	120	70	36	24	18	13	8.5	–	4	–	–
Therma 309S/4833	–	–	120	70	36	24	18	13	8.5	6.5	–	–	–
Therma 153 MA	–	250	157	98	63	41	25	16	10	–	–	–	–
Therma 314/4841	–	–	130	65	40	28	20	14	10	–	–	–	–

*Values according to EN 10028-7

Creep rupture strength $R_{km\ 100,000}$ (MPa mean values) according to EN 10095

Outokumpu name	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
Key products													
Therma 253 MA	–	160	88	55	35	22	15	11	8	5.5	4	3	2.3
Therma 310S/4845	–	–	80	33	18	11	7	4.5	3	–	–	–	–
Resistance to sulfur containing hot gases, lower thermal expansion													
Therma 4713	55	–	20	–	5	–	2.3	–	1	–	–	–	–
Therma 4724	55	–	20	–	5	–	2.3	–	1	–	–	–	–
Therma 4742	55	–	20	–	5	–	2.3	–	1	–	–	–	–
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength													
Therma 304H/4948*	192	140	89	52	28	15	–	–	–	–	–	–	–
Therma 321H/4878	–	–	65	36	22	14	10	–	–	–	–	–	–
Therma 4828	–	–	65	35	16	10	7.5	5	3	–	–	–	–
Therma 309S/4833	–	–	65	35	16	10	7.5	5	3	–	–	–	–
Therma 153 MA	–	160	88	55	35	22	14	8	5	3	1.7	–	–
Therma 314/4841	–	–	80	33	18	11	7	4.5	3	–	–	–	–

*Values according to EN 10028-7

Creep deformation strength $R_{A1\ 1,000}$ (MPa mean values) according to EN 10095

Outokumpu name	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
Key products													
Therma 253 MA	–	230	126	74	45	28	19	14	10	7	5	3.5	2.5
Therma 310S/4845	–	–	90	52	30	17.5	10	6	4	–	–	–	–
Resistance to sulfur containing hot gases, lower thermal expansion													
Therma 4713	80	–	27,5	–	8,5	–	3,7	–	1,8	–	–	–	–
Therma 4724	80	–	27,5	–	8,5	–	3,7	–	1,8	–	–	–	–
Therma 4742	80	–	27,5	–	8,5	–	3,7	–	1,8	–	–	–	–
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength													
Therma 304H/4948*	147	121	94	61	35	24	–	–	–	–	–	–	–
Therma 321H/4878	–	–	85	50	30	17.5	10	–	–	–	–	–	–
Therma 4828	–	–	80	50	25	15.5	10	6	4	–	–	–	–
Therma 309S/4833	–	–	70	47	25	15.5	10	6.5	5	–	–	–	–
Therma 153 MA	–	200	126	74	42	25	15	8.5	5	3	1.7	–	–
Therma 314/4841	–	–	95	60	35	20	10	6	4	–	–	–	–

*Values according to EN 10028-7

Creep deformation strength $R_{A1\ 10,000}$ (MPa mean values) according to EN 10095

Outokumpu name	Temperature °C												
	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
Key products													
Therma 253 MA	–	150	80	45	26	16	11	8	6	4.5	3	2	1.2
Resistance to sulfur containing hot gases, lower thermal expansion													
Therma 4713	50	–	17.5	–	4.7	–	2.1	–	1	–	–	–	–
Therma 4724	50	–	17.5	–	4.7	–	2.1	–	1	–	–	–	–
Therma 4742	50	–	17.5	–	4.7	–	2.1	–	1	–	–	–	–
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength													
Therma 304H/4948*	114	96	74	43	22	11	–	–	–	–	–	–	–
Therma 153 MA	–	135	80	45	26	15	9	5	3	1.8	1	–	–

*Values according to EN 10028-7

Therma range ferritics

At room temperature, Therma range ferritic stainless steels have mechanical properties equal to their austenitic counterparts. When subjected to high temperatures (greater than 600 °C/1110 °F), the creep strength drops, possibly to only a quarter of the value shown by Therma range austenitic steels in the same conditions. Therefore, the loads applied to the component should be taken into consideration during dimensioning and construction.

Therma range austenitics

While Therma range austenitic steels are mainly optimized 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 yield strength values for constructions used at temperatures up to approximately 550 °C/1020 °F. For higher temperatures, average creep strength values are used.

Fatigue

Service conditions at elevated temperatures are rarely constant. In most cases, a component will be subjected to both varying loads and temperatures, which can eventually lead to fatigue failure.

Isothermal fatigue can be subdivided into two groups: High Cycle Fatigue (HCF), which is stress controlled with low amplitudes, and Low Cycle Fatigue (LCF), which is strain controlled with large amplitudes. HCF mainly occurs in rotating and/or vibrating components, while LCF is primarily a result of transients during start-ups, shut-downs, and major changes in service conditions. LCF gives a shorter life than HCF.

Pure thermal fatigue in a component is caused by thermal gradients and the corresponding differences in (internally constrained) thermal expansion.

The most complex situation is when temperature and load vary simultaneously. This is known as ThermoMechanical Fatigue (TMF). A simplified test for these conditions consists of letting the temperature and stress/strain vary in phase or 180 °C/350 °F out of phase. In the results from the in phase TMF test series, ageing has a beneficial effect on the fatigue life of (nitride forming) Therma 253 MA, while the effect is detrimental for Therma 4845 due to sigma phase precipitation.

Physical properties

Outokumpu name	Density [kg/dm³]	Modulus of elasticity at 20 °C [GPa]	Coefficient of thermal expansion 20–100 °C [10^{-6} / K]	Thermal conductivity at 20 °C [W/(m*K)]	Thermal capacity at 20 °C [J/(kg*K)]	Electrical resistivity at 20 °C [Ω*mm² / m]
Key products						
Therma 253 MA	7.8	200	17	15	500	0.85
Therma 310S/4845	7.9	196	15.5	15	500	0.85
Resistance to sulfur containing gases, lower thermal expansion						
Therma 4713	7.7	–	11.5	23	450	0.7
Therma 4724	7.7	–	10.5	21	500	0.75
Therma 4742	7.7	–	10.5	19	500	0.93
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength						
Therma 304H/4948	7.9	200	16.3	17	450	0.71
Therma 321H/4878	7.9	196	17	15	500	0.73
Therma 4828	7.9	196	16.5	15	500	0.85
Therma 309S/4833	7.9	196	16	15	500	0.78
Therma 153 MA	7.8	200	16.5	21	500	0.85
Therma 314/4841	7.9	–	15.5	15	500	0.9

Outokumpu name	Density [lb_m/in³]	Modulus of elasticity [psi]	Coefficient of thermal expansion 68-212 °F [µin / (in* °F)]	Thermal conductivity [Btu/(hr*ft* °F)]	Thermal capacity [Btu/(lb_m* °F)]	Electrical resistivity [µΩ*in]
Key products						
Therma 253 MA	0.282	29 * 10^6	9.44	8.7	0.119	33.46
Therma 310S/4845	0.285	28.4 * 10^6	8.61	8.7	0.119	33.46
Resistance to sulfur containing gases, lower thermal expansion						
Therma 4713	0.278	–	6.39	13.3	0.107	27.56
Therma 4724	0.278	–	5.83	12.1	0.119	29.53
Therma 4742	0.278	–	5.83	11	0.119	36.61
Resistance to carburizing and nitriding/low oxygen gas, higher creep strength						
Therma 304H/4948	0.285	29 * 10^6	9.06	9.8	0.107	27.95
Therma 321H/4878	0.285	28.4 * 10^6	9.44	8.7	0.119	28.74
Therma 4828	0.285	28.4 * 10^6	9.17	8.7	0.119	33.46
Therma 309S/4833	0.285	28.4 * 10^6	8.89	8.7	0.119	30.71
Therma 153 MA	0.282	29 * 10^6	9.17	12.1	0.119	33.46
Therma 314/4841	0.285	–	8.61	8.7	0.119	35.43

Standards and approvals

The most commonly used international product standards are given in the table below. For a full list of standards by product, see **steelfinder.outokumpu.com**

Standards	
EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10095	Heat resisting steels and nickel alloys
EN 10302	Creep resisting steels and nickel alloys
ASTM A167	Stainless and heat-resisting Cr-Ni steel plate/sheet/strip
ASTM A240 / ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purpose
ASTM A276	Stainless and heat-resisting steel bars/shapes

Standards	
ASTM A312 / ASME SA-312	Seamless and welded austenitic stainless steel pipe
ASTM A314	Standard specification for stainless steel billets and bars for forging
ASTM A358 / ASME SA-358	Electric fusion-welded austenitic Cr-Ni alloy steel pipe for high temperature
ASTM A409 / ASME SA-409	Welded large diameter austenitic pipe for corrosive or high-temperature service
ASTM A473	Stainless steel forgings for general use
ASTM A479 / ASME SA-479	Stainless and heat-resisting steel bars and shapes for use in boilers and other pressure vessels

Fabrication

Therma range ferritics

Formability and machining

Generally, ferrites are difficult to form in the cold condition. They are formable at room temperature when sheets are no thicker than 3 mm/0.11 in (6 mm/0.23 in for Therma 4713). Thicker Therma 4713 and Therma 4724 plates must be preheated and formed within the temperature range 250–300 °C/480–570 °F. Therma 4742 should be heated up to 800–900 °C/1470–1650 °F to avoid formation of any brittle phases. Generally, the minimum radius for bending deformation can be taken as double thickness. Machining is considered to be less problematic due to the low strain hardening rates of these products.

Welding

For ferrites, the same precautions as for carbon steels should normally be taken. Preheating of the joints to 200–300 °C/480–570 °F is necessary for plates thicker than 3 mm/0.11 in. Due to grain growth in the heat affected zone (HAZ), heat input should be minimized. Gas-shielded welding methods such as GTA (TIG), plasma arc, and GMA (MIG) are preferred. Pure argon should be used as the shielding gas.

Matching filler material has a detrimental effect on the ductility, which is why austenitic welding consumables, e.g. 307, 309 or 310 are recommended. If the weld will be exposed to a sulfurous environment, overlay welding with a matching ferritic filler will be necessary.

Heat treatment

Heat treatment is only necessary after severe cold working; otherwise it is not necessary, as the material will be exposed to high temperatures during service.

Therma range austenitics

Hot and cold forming

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

Machining

The relatively high hardness of austenitic stainless steels and their ability to strain harden must be taken into consideration in connection with machining. For more detailed data on machining, please see the Outokumpu machining guidelines available for Therma 310S/4845, Therma 153 MA, and Therma 253 MA, or contact us at **outokumpu.com/contacts**

Welding

Outokumpu high-temperature steels have good or very good weldability and can be welded using the following methods:

- Shielded metal arc (SMA) welding with covered electrodes. When welding Therma 253 MA, Avesta welding 253 MA-NF electrodes are recommended for applications at 650 °C–950 °C/1200–1740 °F. The absence of ferrite provides a stable, ductile microstructure in the weld metal. The 253 MA electrode can be used for applications at temperatures over 950 °C/1740 °F.
- Gas shielded welding, e.g., GTA (TIG), plasma arc, and GMA (MIG). Pure argon is normally used as the shielding gas for TIG, while Ar + 0.03% NO or Ar + 30% He +2-2.5% CO_2 is recommended for MIG welding. TIG/MIG weld joints have been found to give the best creep resistance compared with other weld processes.
- Submerged arc (SA) welding. Compared with Therma 310S/4845, the risk of hot cracking is lower when welding Therma 253 MA. Basic fluxes are preferred.

Some general recommendations for the welding of Therma range austenitic steels:

1. Oxide layer on a component already exposed to high temperature must be removed by brushing or grinding before welding.
2. Penetration into the base material is lower for high-temperature steels compared with standard stainless steels such as Core 304/4301 or Supra 316L/4404. The molten filler materials are also less fluid. This necessitates somewhat greater bevel angles (60–70°) and a slightly increased root gap (2–3 mm/0.07–0.11 in) compared with standard austenitic stainless steels.

Heat treatment

Heat treatment after hot or cold forming, or welding, will often not be necessary because the material will be exposed to high temperatures during service. However, if that is not sufficient, the best option is proper solution annealing, with the second best being stress-relief annealing.

Components in which the material has become embrittled during service will benefit from a rejuvenating solution anneal before any maintenance work – for example, straightening or repair welding is carried out.

For more information, see the Outokumpu Welding Handbook, available from our sales offices.

outokumpu.com/contacts

Contacts and enquiries

Contact us

Our experts are ready to help you choose the best stainless steel product for your next project.

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.

1565EN-GB:1. May 2015. Erweko, Finland.

outokumpu classic			outokumpu pro					
Moda	Core	Supra	Forta	Ultra	Dura	Therma	Prodec	Deco
Mildly corrosive environments	Corrosive environments	Highly corrosive environments	Duplex & other high strength	Extremely corrosive environments	High hardness	High service temperatures	Improved machinability	Special surfaces

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