Avesta Welding

The

AVESTA WELDING MANUAL

Practice and products for stainless steel welding

Reflecting excellence

The Avesta Welding Manual

Practice and products for stainless steel welding

Avesta
Welding

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Preface

Avesta Welding AB is part of a group that is at the forefront of stainless steel technology. Designed to aid the selection of the most appropriate consumables and methods for welding stainless steels, it is hoped that the Avesta Welding Manual reflects this position.

Stainless steel welding is a complex mixture of metallurgy, chemistry, geometry and aesthetics. The weld's properties, e.g. corrosion resistance, have to be correct and the right surface finish has to be achieved. Consequently, the best materials and welding methods have to be chosen. Besides giving details of recommended filler metals for all kinds of steels, this manual also gives assistance in selecting the optimum welding methods and techniques.

The manual is based on over 70 years of experience in making, using and welding stainless steels. One major element in this has been the development of electrodes and welding wires for high-alloy steels and specific applications. In writing this manual, the knowledge contributed by a wide range of experts has proved vital. Similarly, close collaborations with our customers have provided indispensable insights and information.

It is my belief that the Avesta Welding Manual will be a valuable tool in all stainless steel welding. Our intention was to write the world's most useful welding manual. To this end, certain themes have been prioritised above others. That is why we will be delighted to hear from customers and users – not only with queries and questions, but also with opinions and suggestions.

Avesta, November 2004

Jacob Sandberg
President, Avesta Welding

Avesta
Welding
An Outokumpu Stainless company

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This is Avesta Welding

A subsidiary of Outokumpu Stainless, one of the world's leading producers of stainless steels, Avesta Welding has its headquarters in Avesta. This Swedish town has a long history of stainless steel production. Ever since the 1920's, welding consumables have also been developed and produced here.

Avesta Welding manufactures a wide range of covered electrodes, flux cored wires and solid wires for the MIG, TIG and SA welding of standard and special grades of stainless steel. The two production units are located in Avesta, Sweden, and Jakarta, Indonesia.

Cleaning and pickling products for stainless steels are produced in Malmö, Sweden, by Avesta Finishing Chemicals.

Avesta Welding's research and development activities are closely coordinated with those of Outokumpu Stainless. This joint approach enables the companies to give the best possible advice on the selection of stainless steels, welding consumables and methods – customers can be certain that all factors are taken into consideration.

Being a part of Outokumpu Stainless, Avesta Welding has unparalleled control over the raw materials going into its products. Combined with long experience and rigorous quality control, this gives Avesta Welding a unique advantage when it comes to supporting customers all around the world.

1 Stainless steels

Introduction

By definition, a stainless steel must contain a minimum of 10.5% chromium. Alloyed with sufficient chromium, steel absorbs oxygen from the air (or from aerated aqueous solutions) to form and maintain a thin, transparent oxide layer. Being passive, the layer dramatically decreases corrosion. Anything that blocks the ready access of oxygen to the stainless steel surface (dirt, grease, oil, paint, coatings, etc.) interferes with the formation of the passive layer and results in local reduction of corrosion resistance. The layer forms spontaneously when the environment is sufficiently rich in oxidants. Defects on the metal surface (e.g. scratches) repassivate spontaneously. Chromium oxide is the main constituent of stainless steel's passive layer.

A steel's mechanical properties (corrosion resistance, weldability, etc.) are largely determined by its microstructure. This, in turn, is determined by the steel's chemical composition. As per EN 10088, stainless steels can be divided into the basic, microstructure-dependent groups or families given below.

- **Ferritic and ferritic-martensitic steels**
- **Martensitic and precipitation hardening steels**
- **Austenitic steels**
- **Austenitic-ferritic (duplex) steels**

The rest of this chapter gives a brief introduction to some common stainless steels and their weldability. Tables 1.1 to 1.6 give the grades and properties of these steels as well as the relevant global standards.

Stainless steel microstructure is very well described and predicted by constitution diagrams. Of these, the Schaeffler-DeLong diagram (normally referred to as the DeLong diagram) is presently the most used. An example is given in figure 1.1.

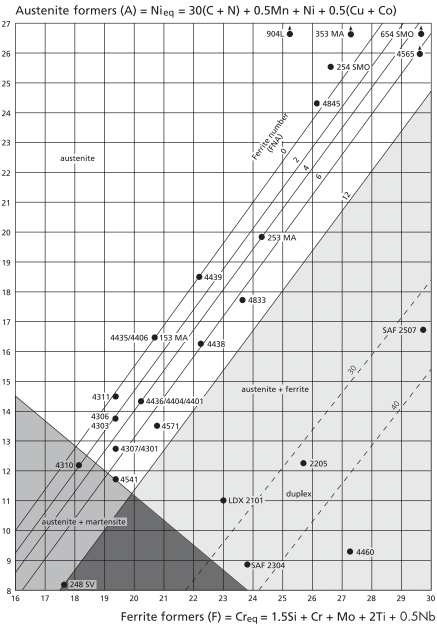


Figure 1.1. DeLong diagram for stainless steels

For further details, see "The importance of ferrite".

Ferritic stainless steels

Microstructure and chemical composition

Ferritic stainless steels are, in principle, ferritic at all temperatures. They are normally alloyed with 13 – 18% chromium (though chromium content can be as high as 29%) and low levels of the austenite formers carbon and nickel. To tie up the carbon in the steel, they are also sometimes alloyed with stabilisers such as titanium or niobium. Figure 1.2 shows the microstructure of a ferritic stainless steel.

Ferritic stainless steels, and especially high-alloy ferritic stainless steels, tend to lack toughness at low temperatures. Due to sigma phase formation, they may also embrittle

Figure 1.2. The microstructure of a ferritic stainless steel

with long exposure in the 475 to 950°C temperature range.

Corrosion resistance

Modern ferritic stainless steels (e.g. type 430) have a low carbon content. Their resistance to atmospheric corrosion, organic acids, detergents and alkaline solutions is good (comparable to that of type 304).

Ferritic stainless steels tend to be relatively weak at high temperatures. However, the oxidation resistance of type 430 is satisfactory up to 850°C and high-alloy ferritic stainless steels such as ASTM 446 can be used at temperatures up to 1,000°C.

The resistance of ferritic stainless steels in chloride containing environments and strong acids is moderate.

Mechanical properties

Compared to the common austenitic grades, ferritic stainless steels have higher yield strength but lower tensile strength. Their elongation at fracture is only about half that of the austenitic stainless steels.

Weldability

The weldability of ferritic stainless steels depends heavily on their chemical compositions. Due to the generally high (C+N)/Cr ratio, which led to martensite formation and embrittlement in the heat-affected zone (HAZ), the "old types" of steel had rather poor weldability. The risk of cracking in the HAZ was a barrier to their use in engineering applications. Another problem was the precipitation of chromium carbides along the grain boundaries. This sometimes led to intergranular corrosion.

Today's ferritic stainless steels normally have a low (C+N)/Cr ratio. This is especially true of grades such as 439 and 444, which have added stabilisers. Modern ferritic stainless steels are entirely ferritic at all temperatures. Consequently, weldability is much improved. However, all ferritic stainless steels are susceptible to grain growth in the HAZ. This decreases ductility and, as a result, heat input must be kept to a minimum during welding. Ferritic stainless steels are also somewhat sensitive to hydrogen embrittlement. Thus, moist electrodes and shielding gases that contain hydrogen are to be avoided.

Most ferritic stainless steels can be welded with either ferritic or austenitic fillers. Popular fillers, especially for welding thick gauge material, are Avesta 308L and 309L (for 430 and lesser grades) and Avesta 316L (for molybdenum alloyed grades such as 444).

Applications

Vehicle exhaust systems are a typical application for 12Cr stainless steels alloyed with titanium or niobium (e.g. 409). The 18Cr ferritic stainless steels are used primarily in household utensils, decorative and coated panels and vehicle components.

High-alloy ferritic stainless steels with a chromium content of 20 – 28% have good resistance to sulphurous gases and are widely used in high temperature applications, e.g. flues and furnaces.

Figure 1.3. Vehicle exhaust system – a typical application for ferritic stainless steel. Courtesy of Ferrita AB.

Steel grades, chemical composition, products

Table 1.1

		International steel number/name			Outokumpu	Outokumpu chemical composition, typical %						Products
		EN	ASTM	JIS	steel name	C	N	Cr	Ni	Mo	Others	
WET CORROSION AND GENERAL SERVICE	Ferritic	1.4016	430	SUS 430	4016	0.04	–	16.5	–	–	–	P N B R
		1.4510	S43035	SUS 430LX	4510	0.04	–	18	–	–	Ti	R
	Mart.	1.4021	S42010	SUS 420J1	4021	0.20	–	13	–	–	–	H N B R
		1.4028	420	SUS 420J2	4028	0.30	–	12.5	–	–	–	N R
		1.4418	–	–	248 SV	0.03	0.04	16	5	1	–	P B R
	Duplex	1.4162	S32101	–	LDX 2101®	0.03	0.22	21.5	1.5	0.3	5Mn	On request
		1.4362	S32304	–	SAF 2304®	0.02	0.10	23	4.8	0.3	–	P H C
		1.4462	S32205	–	2205	0.02	0.17	22	5.7	3.1	–	P H C N B R
		1.4410	S32750	–	SAF 2507®	0.02	0.27	25	7	4	–	P C
	Austenitic	1.4310	301	SUS 301	4310	0.10	0.03	17	7	–	–	H C N B R
		1.4318	301LN	SUS 301L	4318	0.02	0.14	17.7	6.5	–	–	H C
		1.4372	201	SUS 201	4372	0.05	0.15	17	5	–	6.5Mn	H C N R
		1.4307	304L	SUS 304L	4307	0.02	0.06	18.1	8.3	–	–	P H C N B R
		1.4301	304	SUS 304	4301	0.04	0.05	18.1	8.3	–	–	P H C N B R
		1.4311	304LN	SUS 304LN	4311	0.02	0.14	18.1	10.3	–	–	P H C N B R
		1.4541	321	SUS 321	4541	0.04	0.01	17.3	9.1	–	Ti	P H C N B R
		1.4305	303	SUS 303	4305	0.05	0.06	17.3	8.2	–	S	B R
		1.4306	304L	SUS 304L	4306	0.02	0.04	18.2	10.1	–	–	P H C N B R
		1.4303	305	SUS 305J1	4303	0.02	0.02	17.7	11.2	–	–	H C N B R
		1.4567	S30430	SUS XM7	4567	0.01	0.02	17.7	9.7	–	3.3Cu	B R
		1.4404	316L	SUS 316L	4404	0.02	0.04	17.2	10.1	2.1	–	P H C N B R
		1.4401	316	SUS 316	4401	0.04	0.04	17.2	10.2	2.1	–	P H C N B R
		1.4406	316LN	SUS 316LN	4406	0.02	0.14	17.2	10.3	2.1	–	P H C N B R
		1.4571	316Ti	SUS 316Ti	4571	0.04	0.01	16.8	10.9	2.1	Ti	P H C N B R
		1.4432	316L	SUS 316L	4432	0.02	0.05	16.9	10.7	2.6	–	P H C N B R
		1.4436	316	SUS 316	4436	0.04	0.05	16.9	10.7	2.6	–	P H C N B R
		1.4435	316L	SUS 316L	4435	0.02	0.06	17.3	12.6	2.6	–	P H C N B R
		1.4429	S31653	SUS 316LN	4429	0.02	0.14	17.3	12.5	2.6	–	P C
		1.4438	317L	SUS 317L	4438	0.02	0.07	18.2	13.7	3.1	–	P H C N B R
		1.4439	S31726	–	4439	0.02	0.14	17.8	12.7	4.1	–	P H C
		1.4539	N08904	–	904L	0.01	0.06	20	25	4.3	1.5Cu	P H C N B R
		1.4547	S31254	–	254 SMO®	0.01	0.20	20	18	6.1	Cu	P H C N B R
		1.4565	S34565	–	4565	0.02	0.45	24	17	4.5	5.5Mn	P
		1.4652	S32654	–	654 SMO®	0.01	0.50	24	22	7.3	3.5Mn, Cu	On request
HEAT AND CREEP	Austenitic	1.4948	304H	SUS 304	4948	0.05	0.06	18.1	8.3	–	–	P H C B R
		1.4878	321H	SUS 321	4878	0.05	0.01	17.3	9.1	–	Ti	P H C N B R
		1.4818	S30415	–	153 MA™	0.05	0.15	18.5	9.5	–	1.3Si, Ce	P C N B R
		1.4833	309S	SUH 309	4833	0.06	0.08	22.3	12.6	–	–	P H C N B R
		1.4828	–	–	4828	0.04	0.04	20	12	–	2Si	C N B R
		1.4835	S30815	–	253 MA®	0.09	0.17	21	11	–	1.6Si, Ce	P H C N B R
		1.4845	310S	SUH 310	4845	0.05	0.04	25	20	–	–	P H C N B R
		1.4854	S35315	–	353 MA®	0.05	0.17	25	35	–	1.3Si, Ce	P

The grades listed in Tables 1.1–1.6 represent the Outokumpu Stainless steel programme. Other grades are also available. Detailed information can be found in the data sheet “Steel Grades, Properties and Global Standards”.

The Outokumpu steel names are generic and cover corresponding steel numbers/names, which may not have the same chemical composition limits. SAF 2304 and SAF 2507 are trademarks owned by SANDVIK AB.

Product codes
P = Hot rolled plate (Quarto)
H = Hot rolled strip/sheet (CPP)
C = Cold rolled strip/sheet
N = Cold rolled narrow strip
B = Bar
R = Rod

Mechanical properties, room temperature

Table 1.2

Outokumpu steel name	Product	Outokumpu, typical values $R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	A_5 %	EN, min. values No.	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	A_5 %	KV J	ASTM, min. values No.	$R_{p0.2}$ MPa	R_m MPa	$A_{2''}$ %
4016	C	380		520	25	1.4016	260		450	20	–	S43000	205	450	22
4510	C	310		450	30	1.4510	230		420	23	–	S43035	205	415	22
4021	P	–		650	12	1.4021	450		650	12	–	S42010			
4028	P	–		800	10	1.4028	600		800	10	–	S42000			
248 SV	P	730		930	20	1.4418	660		840	14	55	–			
LDX 2101®	P	480		700	38	1.4162						S32101	450	650	30
SAF 2304®	P	450		670	40	1.4362	400		630	25	60	S32304	400	600	25
2205	P	510		750	35	1.4462	460		640	25	60	S32205	450	655	25
SAF 2507®	P	590		830	35	1.4410	530		730	20	60	S32750	550	795	15
4310	N	300	330	800	50	1.4310	250	280	600	40	–	S30100	205	515	40
4318	C					1.4318	350	380	650	40	60	S30153	240	550	45
4372	N	390	420	720	45	1.4372	350	380	750	45	–	S20100	310	655	40
4307	P	280	320	580	55	1.4307	200	240	500	45	60	S30403	170	485	40
4301	P	290	330	600	55	1.4301	210	250	520	45	60	S30400	205	515	40
4311	P	320	360	640	55	1.4311	270	310	550	40	60	S30453	205	515	40
4541	P	250	290	570	55	1.4541	200	240	500	40	60	S32100	205	515	40
4306	P	280	320	580	55	1.4306	200	240	500	45	60	S30403	170	485	40
4303	N	250	280	570	50	1.4303	220	250	500	45	–	S30500	205	515	40
4404	P	280	320	570	55	1.4404	220	260	520	45	60	S31603	170	485	40
4401	P	280	320	570	55	1.4401	220	260	520	45	60	S31600	205	515	40
4406	P	320	360	620	50	1.4406	280	320	580	40	60	S31653	205	515	40
4571	P	270	310	570	50	1.4571	220	260	520	40	60	S31603	205	515	
4432	P	280	320	570	50	1.4432	220	260	520	45	60	S31603	170	485	
4436	P	300	340	590	50	1.4436	220	260	530	40	60	S31600	205	515	40
4435	P	270	310	570	55	1.4435	220	260	520	45	60	S31603	170	485	40
4429	P	350	390	670	45	1.4429	280	320	580	40	60	S31653	205	515	40
4438	P	300	340	610	50	1.4438	220	260	520	40	60	S31703	205	515	40
4439	P	310	350	640	50	1.4439	270	310	580	40	60	S31726	240	550	40
904L	P	260	300	600	50	1.4539	220	260	520	35	60	N08904	215	490	35
254 SMO®	P	340	380	680	50	1.4547	300	340	650	40	60	S31254	310	655	35
4565	P	440	480	825	55	1.4565	420	460	800	30	90	S34565	415	795	35
654 SMO®	P	450	500	830	60	1.4652	430	470	750	40	60	S32654	430	750	40
4948	P	290	330	600	55	1.4948	190	230	510	45	60	S30409	205	515	40
4878	P	250	290	570	55	1.4878	190	230	500	40	–	S32109	205	515	40
153 MA™	P	340	380	660	55	1.4818	290	330	600	40	–	S30415	290	600	40
4833	P	300	340	620	50	1.4833	210	250	500	35	–	S30908	205	515	40
4828	C	270	310	610	55	1.4828	230	270	550	30	–	–			
253 MA®	P	370	410	700	50	1.4835	310	350	650	40	–	S30815	310	600	40
4845	P	270	310	600	50	1.4845	210	250	500	35	–	S31008	205	515	40
353 MA®	H	360	400	720	50	1.4854	300	340	650	40	–	S35315	270	650	40

Mechanical properties, low temperatures

Table 1.3

Outokumpu steel name	EN min. values, MPa and % –196°C No.	$R_{p0.2}$	$R_{p1.0}$	R_m	A_5	–80°C $R_{p0.2}$	$R_{p1.0}$	R_m	A_5	RT $R_{p0.2}$	$R_{p1.0}$	R_m	A_5
4307	1.4307	300	400	1200	30	220	290	830	35	200	240	500	45
4301	1.4301	300	400	1250	30	270	350	860	35	210	250	520	45
4311	1.4311	550	650	1250	35	350	420	850	40	270	310	550	40
4541	1.4541	200	240	1200	30	200	240	855	35	200	240	500	40

From EN 10028-7 Annex F

Mechanical properties, high temperatures

Table 1.4

Outokumpu steel name	EN – min. $R_{p0.2}$ MPa					Max. design stress for pressure equipment σ, MPa								
						EN				ASME VIII-1				
	No.	RT	100	200	400°C	RT	100	200	400°C	No.	RT	100	200	400°C
4016	1.4016	260	220	210	190					S43000	128	126	120	108
4510	1.4510	230	195	185		153	130	123	–	S43035	118	118	118	107
4021	1.4021	–								S42010				
4028	1.4028	–								S42000				
248 SV	1.4418	680	660	620		350	350	350	–	–				
LDX 2101®	1.4162	–								S32101				
SAF 2304®	1.4362	400	330	280		263	220	187	–	S32304	172	164	150	–
2205	1.4462	460	360	315		267	240	210	–	S31803	177	176	165	–
SAF 2507®	1.4410	530	450	400		304	300	267	–	S32750	228	226	208	–
4310	1.4310	250	210	190						S30100				
4318	1.4318	350	265	185		217	177	153		S30153				
4372	1.4372	350	295	230						S20100				
4307	1.4307	200	147	118	89	167	137	120	–	S30403	115	115	109	92
4301	1.4301	210	157	127	98	173	150	131	104	S30400	138	137	127	107
4311	1.4311	270	205	157	125	183	163	143	–	S30453	138	137	127	107
4541	1.4541	200	176	157	125	167	147	130	125	S32100	138	137	129	119
4306	1.4306	200	147	118	89	167	137	120	–	S30403	115	115	109	92
4303	1.4303	220	155	127	98					S30500	138	137	127	107
4404	1.4404	220	166	137	108	173	143	130	113	S31603	115	115	109	91
4401	1.4401	220	177	147	115	173	150	133	–	S31600	138	138	133	111
4406	1.4406	280	211	167	135	193	173	153	–	S31653	138	138	131	105
4571	1.4571	220	185	167	135	173	147	131	125	S31635	138	138	131	105
4432	1.4432	220	166	137	108	173	143	130	113	S31603	115	115	109	91
4436	1.4436	220	177	147	115	177	153	140	–	S31600	138	138	133	111
4435	1.4435	220	165	137	108	173	140	127	–	S31603	115	115	109	91
4429	1.4429	280	211	167	135	193	173	153	–	S31653	186	157	131	104
4438	1.4438	220	172	147	115	173	143	130	–	S31703	138	138	131	109
4439	1.4439	270	225	185	150	193	173	153	–	S31726	157	157	155	–
904L	1.4539	220	205	175	125	173	157	137	–	N08904	140	114	95	–
254 SMO®	1.4547	300	230	190	160	217	205	187	158	S31254	185	184	168	156
4565	1.4565	420	350	270	210					S34565				
654 SMO®	1.4652	430	350	315	295					S32654	214	214	199	178

Steel name	EN – $R_{p1.0}$/100 000h, MPa					EN – R_m/100 000h, MPa				ASME – max. design stress σ, MPa				
	No.	600	700	800	900°C	600	700	800	900°C	No.	600	700	800	900°C
4948	1.4948*	74	22			89	28			S30409*	64	27	11	
4878	1.4878	–				65	22	10		S32109*	59	23	9	
153 MA™	1.4818	80	26	9	3	88	35	14	5	S30415				
4833	1.4833	–				65	16	7	3	S30909*	49	16	6	
4828	1.4828	–				65	16	7	3	–				
253 MA®	1.4835	80	26	11	6	88	35	15	8	S30815*	59	22	10	5
4845	1.4845	–				80	18	7	3	S31009*	49	16	6	
353 MA®	1.4854	52	21	10	5	80	36	18	9	S35315				

* Creep resisting grades for pressure purposes listed in EN 10028-7 and ASME IID.

Physical properties

Table 1.5

Outokumpu steel name	EN	Density, ρ kg/dm³ RT	Modulus of elasticity, E GPa RT	Modulus of elasticity, E GPa 400°C	Thermal expansion, α x 10⁻⁶/°C, (RT→T) 100°C	Thermal expansion, α x 10⁻⁶/°C, (RT→T) 400°C	Thermal conductivity, λ W/m°C RT	Thermal conductivity, λ W/m°C 400°C	Thermal capacity, c J/kg°C RT	Thermal capacity, c J/kg°C 400°C	Electrical resistivity, ρ μΩm RT	Magnetizable RT
Non alloy steel	1.0345	7.8	210	175	12.0	14.0	55	44	460	620	0.18	Y
4016	1.4016	7.7	220	195	10.0	10.5	25	25	460	620	0.60	Y
4510	1.4510	7.7	220	195	10.0	10.5	25	25	460	620	0.60	Y
4021	1.4021	7.7	215	190	10.5	12.0	30	25	460	620	0.55	Y
4028	1.4028	7.7	215	190	10.5	12.0	30	25	460	620	0.65	Y
248 SV	1.4418	7.7	200	170	10.3	11.6	15	25	430	620	0.80	Y
LDX 2101®	1.4162	7.8	200	172	13.0	14.5	15	20	500			Y
SAF 2304®	1.4362	7.8	200	172	13.0	14.5	15	20	500	620	0.80	Y
2205	1.4462	7.8	200	172	13.0	14.5	15	20	500	620	0.80	Y
SAF 2507®	1.4410	7.8	200	172	13.0	14.5	15	20	500	620	0.80	Y
4310	1.4310	7.9	200	172	16.0	18.0	15	20	500	620	0.73	N
4318	1.4318	7.9	200	172	16.0	17.5	15	20	500	620	0.73	N
4372	1.4372	7.8	200	172	16.0	17.5	15	20	500	620	0.70	N
4307	1.4307	7.9	200	172	16.0	18.0	15	20	500	620	0.73	N
4301	1.4301	7.9	200	172	16.0	17.5	15	20	500	620	0.73	N
4311	1.4311	7.9	200	172	16.0	17.5	15	20	500	620	0.73	N*
4541	1.4541	7.9	200	172	16.0	17.5	15	20	500	620	0.73	N
4306	1.4306	7.9	200	172	16.0	17.5	15	20	500	620	0.73	N
4303	1.4303	7.9	200	172	16.0	17.5	15	20	500	620	0.73	N*
4404	1.4404	8.0	200	172	16.0	17.5	15	20	500	620	0.75	N
4401	1.4401	8.0	200	172	16.0	17.5	15	20	500	620	0.75	N
4406	1.4406	8.0	200	172	16.0	17.5	15	20	500	620	0.75	N*
4571	1.4571	8.0	200	172	16.5	18.5	15	20	500	620	0.75	N
4432	1.4432	8.0	200	172	16.0	17.5	15	20	500	620	0.75	N
4436	1.4436	8.0	200	172	16.0	17.5	15	20	500	620	0.75	N
4435	1.4435	8.0	200	172	16.0	17.5	15	20	500	620	0.75	N
4429	1.4429	8.0	200	172	16.0	17.5	14	20	500	620	0.85	N
4438	1.4438	8.0	200	172	16.0	17.5	14	20	500	600	0.85	N
4439	1.4439	8.0	200	172	16.0	17.5	14	20	500	600	0.85	N
904L	1.4539	8.0	195	166	15.8	16.9	12	18	450		1.00	N
254 SMO®	1.4547	8.0	195	166	16.5	18.0	14	18	500		0.85	N
4565	1.4565	8.0	190	165	14.5	16.8	12	18	450		0.92	N
654 SMO®	1.4652	8.0	190	164	15.0	16.2	8.6		500	570	0.78	N
Ni alloy 625	2.4856	8.4	200	180	12.0	13.5	10	16	410	540	1.3	
			500°C	1000°C	500°C	1000°C	500°C	1000°C	500°C	1000°C		
4948	1.4948	7.9	158	120	18.4	20.0	21.9	28.8	530		0.71	N
4878	1.4878	7.9	158		18.4	20.5	21.6	27.5	530		0.74	N
153 MA™	1.4818	7.8	163	120	18.2	19.5	21.2	29.0	580	660	0.84	N
4833	1.4833	7.9	158	120	18.4	20.0	20.5	27.5	530		0.78	N
4828	1.4828	7.9	158	120	18.4	20.0	20.5	27.5	530		0.87	N
253 MA®	1.4835	7.8	163	120	18.2	19.5	21.2	29.0	580	660	0.84	N
4845	1.4845	7.9	158	120	18.4	20.0	19.8	27.1	530		0.96	N
353 MA®	1.4854	7.9	160	130	16.6	18.2	18.5	26.0	580	660	1.00	N

Magnetizable:
Y = Magnetizable ferritic, martensitic, duplex grades;
N = Non-magnetizable austenitic grades with a typical magnetic permeability μ = 1.05 – 1.2.

* Grades suitable for low permeability requirements, i.e. μ max. 1.005.

Fabrication and use characteristics

Table 1.6

Outokumpu steel name	EN	Fabrication				Use		
		Heat treatment temperature[1)] °C	Welding consumables[2)]	Forming[3)] *n/A*$_{hom}$	Machining index[4)]	Pressure purpose[5)]	IGC resistance[6)]	CPT[7)] °C
Non alloy steel	1.0345	N 920 ± 30	P5	0.2/20		EN ASME		
4016	1.4016	A 800 ± 30	308L/MVR or 309L	0.2/20		ASME	A Y/-	< 5
4510	1.4510	A 800 ± 30	308L/MVR or 309L	0.2/20		EN ASME	A Y/Y	< 5
4021	1.4021	T 740 ± 40	739 S					< 5
4028	1.4028	T 690 ± 40	739 S					< 5
248 SV	1.4418	T 610 ± 40	248 SV			EN		< 5
LDX 2101®	1.4162		2205 or matching					
SAF 2304™	1.4362	A 1000 ± 50	2205 or 2304	0.4/20	75/110	EN ASME	A Y/Y	15
2205	1.4462	A 1060 ± 40	2205	0.4/20	65/100	EN ASME	C Y/Y	50
SAF 2507™	1.4410	A 1080 ± 40	2507/P100	0.4/20	45/80	EN ASME	C Y/Y	90
4310	1.4310	A 1050 ± 40	308L/MVR	0.8/35			A N/-	< 5
4318	1.4318	A 1060 ± 40	308L/MVR	0.8/35		EN	A Y/Y	< 5
4372	1.4372	A 1050 ± 50	307 or 309L	0.8/35			A Y/-	< 5
4307	1.4307	A 1050 ± 50	308L/MVR	0.6/40	105/105	EN ASME	A Y/Y	< 5
4301	1.4301	A 1050 ± 50	308L/MVR	0.6/40	105/105	EN ASME	A Y/-*	< 5
4311	1.4311	A 1050 ± 50	308L/MVR	0.6/40	80/70	EN ASME	A Y/Y	< 5
4541	1.4541	A 1050 ± 50	308L/MVR	0.6/40	100/105	EN ASME	A Y/Y	< 5
4306	1.4306	A 1050 ± 50	308L/MVR	0.6/40	105/105	EN ASME	A Y/Y	< 5
4303	1.4303	A 1050 ± 50	308L/MVR	0.6/40	105/105	ASME	A Y/-*	< 5
4404	1.4404	A 1070 ± 40	316L/SKR	0.6/35	100/100	EN ASME	A Y/Y	15
4401	1.4401	A 1070 ± 40	316L/SKR	0.6/35	100/100	EN ASME	A Y/-*	15
4406	1.4406	A 1070 ± 40	316L/SKR	0.6/35	75/70	EN ASME	A Y/Y	20
4571	1.4571	A 1070 ± 40	316L/SKR	0.6/35	95/105	EN ASME	A Y/Y	10
4432	1.4432	A 1070 ± 40	316L/SKR	0.6/35	100/100	EN ASME	A Y/Y	25
4436	1.4436	A 1070 ± 40	316L/SKR	0.6/35	100/100	EN ASME	A Y/-*	25
4435	1.4435	A 1070 ± 40	316L/SKR	0.6/35	100/100	EN ASME	A Y/Y	25
4429	1.4429	A 1070 ± 40	316L/SKR	0.6/35	100/100	EN ASME	A Y/Y	25
4438	1.4438	A 1110 ± 40	317L/SNR	0.6/35	90/100	EN ASME	C Y/Y	35
4439	1.4439	A 1100 ± 40	SLR-NF	0.6/35	70/70	EN ASME	C Y/Y	50
904L	1.4539	A 1100 ± 40	904L or P12	0.6/30	75/95	EN ASME	C Y/Y	60
254 SMO®	1.4547	A 1180 ± 30	P12 or P16	0.6/30	45/70	EN ASME	C Y/Y	90
4565	1.4565	A 1145 ± 25	P16	0.6/30			C Y/Y	
654 SMO®	1.4652	A 1180 ± 30	P16	0.6/30	15/40	ASME	C Y/Y	> 95
Ni alloy 625	2.4856	A 980 ± 30	P12			ASME		> 95
								Scaling temp.[8)] °C
4948	1.4948	A 1080 ± 30	308/308H	0.6/40	105/105	EN ASME	A Y/-	850
4878	1.4878	A 1070 ± 50	347/MVNb	0.6/40	100/105	ASME	A Y/Y	850
153 MA™	1.4818	A 1070 ± 50	253 MA	0.6/40	70/70		A Y/-	1050
4833	1.4833	A 1100 ± 50	309	0.6/35	95/105	ASME	A Y/-	1000
4828	1.4828	A 1100 ± 50	253 MA	0.6/35	95/105		A Y/-	1000
253 MA®	1.4835	A 1070 ± 50	253 MA	0.6/35	70/70	ASME	A Y/-	1150
4845	1.4845	A 1100 ± 50	310	0.6/35	95/105	ASME	A Y/-	1050
353 MA®	1.4854	A 1125 ± 25	353 MA	0.6/35	65/65		A Y/-	1170

1) A = Annealing, T = Tempering, N = Normalising. See data sheet for details.
2) Welding consumables: **Avesta Welding designations.**
3) See data sheet for details.
4) See data sheet for details.
5) See data sheet for details.
6) Y = Yes, N = No for delivery/sensitised conditions. See data sheet for details.
7) See data sheet for details.
8) Scaling temperature in air (°C). See data sheet for details.

* May be multi-certified as Y/Y.

Martensitic and precipitation hardening stainless steels

Microstructure and chemical composition

Sufficient carbon is the key to obtaining a martensitic microstructure (see figure 1.4). With the addition of certain other alloying elements, the strength of martensitic stainless steels can be enhanced through the precipitation of intermetallic phases. In producing these precipitation hardening stainless steels, heat treatment must be carefully controlled.

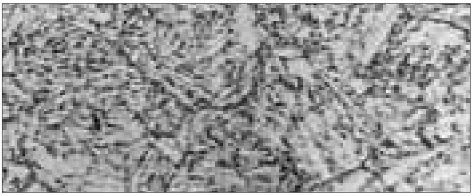


Figure 1.4. The microstructure of a martensitic stainless steel

To give a semi-martensitic structure (martensitic stainless steels are not as easy to alloy as austenitic stainless steels), martensitic stainless steels can also be alloyed with any one or more of the elements nickel, molybdenum and nitrogen. Outokumpu 248 SV is a semi-martensitic stainless steel with, typically, 80% martensite, 15% austenite and 5% ferrite. Combining high strength with good weldability, such steels demonstrate superior toughness after welding.

For use in, amongst other things, oil and gas applications, super martensitic stainless steels have now been introduced. Their combination of high strength, better corrosion resistance and improved weldability give them an advantage over other martensitic stainless steels.

Corrosion resistance

The corrosion resistance of martensitic stainless steels is generally modest, but can be increased by the addition of molybdenum, nickel or nitrogen. Being resistant to carbon dioxide corrosion, 12Cr stainless steels can be used in petroleum refining applications. In such environments, corrosion engendered by carbon dioxide contamination prevents the use of carbon steels.

Mechanical properties

The higher carbon martensitic stainless steels can be produced with very high yield and tensile strengths as well as superior hardness. However, elongation and impact strength suffer.

Weldability

The high hardness and low ductility of fully martensitic, air-hardening, stainless steels make them very susceptible to hydrogen cracking. Weldability can thus be considered poor. Careful preparation (preheating at 75 – 150°C followed by cooling, tempering at 550 – 590°C and, finally, slow cooling in air) is normally necessary.

Figure 1.5. Hydro electric power turbine in 248 SV

The weldability of martensitic-ferritic-austenitic stainless steels (e.g. Outokumpu 248 SV) is much better. The tempered structure, with low carbon martensite and finely dispersed austenite, gives good ductility. Thus, except where thick material and/or restraint conditions are involved, preheating prior to welding and heat treatment after welding are not generally necessary.

To ensure optimal mechanical properties, welding should be performed using matching fillers. Austenitic or duplex fillers can be used in some cases, but the somewhat lower tensile strength of the resulting weld must be borne in mind.

Super martensitic stainless steels are often welded using duplex fillers such as 2205 and 2507.

Applications

Martensitic stainless steels are used in process vessels in the petroleum industry and in water turbines, propellers, shafts and other components for hydropower applications.

Austenitic stainless steels

Microstructure and chemical composition

Austenitic stainless steels are the most common stainless steels. Figure 1.6 shows a fully austenitic structure. The austenitic group covers a wide range of steels with great variations in properties. Corrosion resistance is normally the most important of these. The steels can be divided into the following sub-groups:

- Austenitic without molybdenum (304 and 304L)
- Austenitic with molybdenum (316, 316L, 317L and 904L)
- Stabilised austenitic (321, 321H and 316Ti)
- Fully austenitic with high molybdenum (and often with high nitrogen, e.g. Outokumpu 254 SMO)
- Heat and creep resistant (321H, 253 MA and 310S)

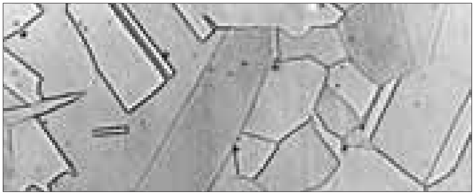


Figure 1.6. The microstructure of an austenitic stainless steel

Austenitic stainless steels with and without molybdenum have an austenitic (α) microstructure with, possibly, a low content of delta-ferrite (δ). The main alloying elements are chromium (17 – 20%) and nickel (8 – 13%). The addition of molybdenum (2 – 3%) increases resistance to pitting corrosion.

Stabilised austenitic stainless steels have an addition of titanium or niobium in proportion to the amount of carbon and nitrogen (typically min. 10 x C). This stabilisation prevents the precipitation of chromium carbides when exposed to temperatures exceeding 400°C. Furthermore, the stabilised steels display good strength and creep resistance up to about 600°C.

Fully austenitic stainless steels are typically highly alloyed with chromium (20 – 25%), nickel (18 – 35%) and nitrogen (up to 0.4%). The austenitic structure is stabilised by the addition of austenite forming elements such as carbon, nickel, manganese, nitrogen and copper.

Corrosion resistance

Austenitic stainless steels are characterised by excellent corrosion resistance. Many austenitic stainless steels have a low carbon content (< 0.030%). This makes them resistant to sensitisation (i.e. predisposition to intergranular corrosion) engendered by the brief thermal exposures associated with cooling after annealing, stress relieving or welding. The effect of carbon content on the times permitted at certain temperatures is shown in figure 1.7.

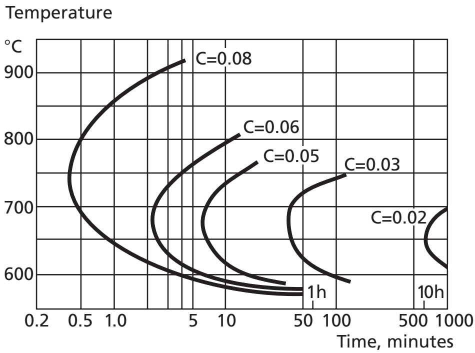


Figure 1.7. Effect of carbon content on sensitisation times

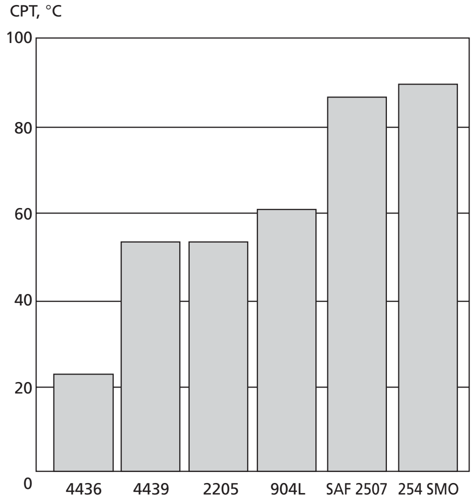


Figure 1.8. Critical pitting temperatures of some austenitic and duplex stainless steels

Chromium and nickel alloyed steels demonstrate good general corrosion resistance in wet environments. Resistance increases generally with increased chromium, nickel, molybdenum and nitrogen content. To obtain good resistance to pitting and crevice corrosion in chloride containing environments, a Cr-Ni-Mo type steel (e.g. 316, or one with an even higher molybdenum content) is necessary. Figure 1.8 shows the pitting corrosion resistance (measured as the CPT value) of some austenitic and duplex stainless steels.

For improved hot cracking resistance and better weldability, austenitic stainless steels (e.g. 316) are normally produced with some ferrite. In certain environments, these steels may demonstrate reduced resistance to selective corrosion. Thus, in applications such as urea production or acetic acid, ferrite free plates and welds are often required.

Steel types 304 and 316 are highly susceptible to stress corrosion cracking. However, resistance to stress corrosion cracking increases with increased nickel and molybdenum content. Highly alloyed austenitic stainless steels such as Outokumpu 254 SMO have very good resistance.

Mechanical properties

Austenitic stainless steels are primarily characterised by their excellent ductility, even at low temperatures. Ferrite-free, fully austenitic stainless steels with a high nitrogen content have very good impact strength and are therefore very suitable for cryogenic applications. Especially for nitrogen alloyed steels, yield and tensile strengths are generally high.

As austenitic stainless steels cannot be hardened by heat treatment, they are normally supplied in quench annealed condition.

Weldability

Austenitic stainless steels are generally easy to weld and do not normally require any preheating or post-weld heat treatment.

With respect to weldability, the filler metals used for welding these steels can be divided into two groups:

- Fillers with min. 3% ferrite (types 308LSi, 316LSi and 347Si)
- Fillers with zero ferrite (type 904L and nickel base fillers such as P12).

The presence of ferrite gives a ferritic solidification mode. In this type of solidification, impurities such as sulphur and phosphorus dissolve into the ferrite. Without ferrite, impurities tend to segregate out to the austenitic grain boundaries. This results in late solidification phases and great susceptibility to hot cracking. A filler metal with a ferrite content of 3 to 10% gives high resistance to cracking.

Fully austenitic stainless steels and welds are somewhat sensitive to hot cracking. Thus, heat input when welding must be carefully controlled and dilution of the parent metal should be kept to a minimum. The interpass temperature must not exceed 100°C.

Fully austenitic stainless steels (e.g. Outokumpu 254 SMO) with high molybdenum and nitrogen contents should be welded using nickel base fillers over-alloyed with molybdenum, e.g. Avesta P12.

Fully austenitic stainless steels may also exhibit grain boundary precipitation in the heat-affected zone. Moderate amounts of precipitation do not usually affect corrosion resistance. However, it is advisable to weld with moderate heat input and the lowest possible dilution of the parent metal.

To offset the segregation that typically occurs during solidification, filler metals are, in most cases, over-alloyed with chromium, nickel and molybdenum.

For niobium or titanium alloyed steels such as 321H, niobium stabilised fillers such as 347 should be used. This is because titanium does not transfer readily across the arc to the weld.

Applications

Austenitic stainless steels are used in a wide range of applications. They are economic where the demands placed on them are moderate, e.g. processing, storing and transporting foodstuffs and beverages. They are also reliably effective in highly corrosive environments, e.g. offshore installations, high-temperature equipment, components in the pulp, paper and chemical industries.

Figure 1.9. High-alloy steels such as 2205 and 254 SMO are widely used in pulp and paper applications

Austenitic-ferritic (duplex) stainless steels

Microstructure and chemical composition

Duplex stainless steels have a two-phase microstructure with approximately 50% austenite and 50% ferrite (see figure 1.10). Chemical composition is typically 22 – 25% chromium, 5 – 7% nickel, 0.10 – 0.25% nitrogen and, if used, 3 – 4 % molybdenum. The most common duplex steel is 2205 (S32205).

Corrosion resistance

Due to the high content of chromium (and, if used, molybdenum and nitrogen), duplex stainless steels are characterised by their high

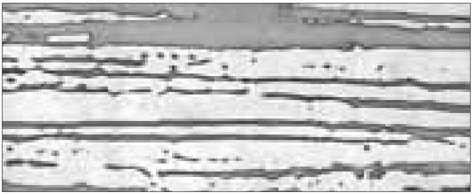


Figure 1.10. The microstructure of a duplex stainless steel

resistance to pitting and crevice corrosion. For example, the pitting resistance of 2205 is significantly higher than that of 316.

Because of their duplex structure, all duplex steels demonstrate superior resistance to stress corrosion cracking.

All modern types of duplex stainless steels are produced with a low carbon content. This makes them resistant to sensitisation to intergranular corrosion.

Mechanical properties

Duplex stainless steels combine many of the properties of ferritic and austenitic steels. Mechanical strength is generally very high and ductility, especially at room temperature, is good.

Weldability

Although somewhat different to ordinary austenitic stainless steels such as 304 and 316, the weldability of duplex stainless steels is generally good. However, the slightly lower penetration into the parent metal and the mildly inferior fluidity of the melt (e.g. compared to 308L or 316L fillers used with austenitic stainless steels) must be borne in mind.

Duplex stainless steels solidify with a fully ferritic structure; there is austenite precipitation and growth during cooling. To stabilise the austenite at higher temperatures, modern duplex stainless steels have a high nitrogen content.

If the cooling rate when welding is very high (e.g. low heat input with thick gauges) there is a risk that post-weld ferrite content will be on the high side (above 65%). This high level of ferrite decreases corrosion resistance and ductility. A too high ferrite content may also result if welding without filler wire or if welding with, for example, pieces cut from the plate.

At the same time, owing to the rapid formation of intermetallic phases, heating in the range 700 – 980°C must be avoided when welding. Even at less than 1%, the presence of these phases has a severely negative impact on corrosion resistance and toughness. Thus, it is important to adopt a procedure that minimises the total time in this critical temperature range. Heat input at welding must be carefully controlled (typically 0.5 to 3.0 kJ/mm).

Matching or over-alloyed filler metals must be used when welding duplex stainless steels. To stabilise and increase the austenitic structure during the rapid cooling following welding, the nickel content of all matching duplex fillers is higher than that of the parent metal.

Applications

The excellent combination of high mechanical strength and good corrosion resistance makes duplex stainless steels highly suitable for: heat exchangers; pressure vessels; pulp digesters; chemical industry equipment; rotors, fans and shafts exposed to corrosion fatigue; and, the huge tanks used for transporting chemicals.

Figure 1.11. Chemical tanker – tanks in 2205 stainless steel

The physical properties of stainless and mild steels

Amongst the physical differences between stainless and mild steels are:

- Thermal expansion
- Thermal conductivity
- Electrical resistivity

Designers and welders must be aware of how these differences affect welding characteristics.

Table 1.5 summarises various physical properties of a number of steel grades.

The **linear thermal expansion** of ferritic and martensitic stainless steels is similar to that of mild steels. It is approximately 50% higher for austenitic stainless steels. As a result, shrinkage stresses are greater and both thick and thin plates of austenitic stainless steel deform relatively easily. Consequently, austenitic stainless steels require more tack welds than ferritic and martensitic stainless steels or carbon-manganese steels. Greater detail is given in chapter 4, "Welding techniques".

The thermal expansion of duplex stainless steels is only slightly higher than that of carbon-manganese steels.

The **thermal conductivity** of ferritic, martensitic and duplex stainless steels is about half that of mild steels. The thermal conductivity of austenitic stainless steels is only one third that of mild steels. Thus, stainless steels conduct heat away from the weld zone more slowly than do carbon-manganese steels. This must be taken into consideration so that distortion control and microstructural stability can be maximised.

The **electrical resistivity** of stainless steels is approximately 4 to 7 times higher than that of mild steels. One of the consequences of this is that stainless steel electrodes reach red heat relatively easily. They are thus usually made shorter to avoid excessive heat build-up. Furthermore, special care is required in dissimilar welds between stainless and mild steels. This is because the arc tends to move towards the latter and compensation has to be made by, for example, directing the arc slightly towards the stainless steel. This is especially important in automatic welding.

The importance of ferrite

Ferrite is known to be very effective in reducing the tendency to hot cracking shown by welds in austenitic stainless steels. Compared to austenite, ferrite is better at dissolving impurities such as sulphur, phosphorous, lead and tin. These elements can segregate out to the grain boundaries of the structure and form low melting secondary phases. The latter can give rise to hot cracking in the weld during cooling (see chapter 5, "Weld imperfections").

Ferrite values can be expressed in several different ways. For example, as per ASTM E562, they can be given as volume fractions (expressed as percentages). Although this is the most accurate method, determination is very time consuming and expensive. For these reasons, a metal's ferrite value is normally given as measured by instruments such as Magne-Gage or Ferritscope, or as calculated from the weld metal composition. In this second case, ferrite content is expressed either as a percentage or as a ferrite number (FN). This latter approach is often preferred. Ferrite numbers are normally calculated using either DeLong (figure 1.12) or WRC-92 diagrams (figure 1.13).

The DeLong constitutional diagram is an excellent tool for predicting the phase balance (e.g. the ferrite content) in a weld.

It should be noted that these diagrams relate to alloys that have been cooled at the high cooling rates associated with welding and not at the relatively low cooling rates that are associated with parent material production.

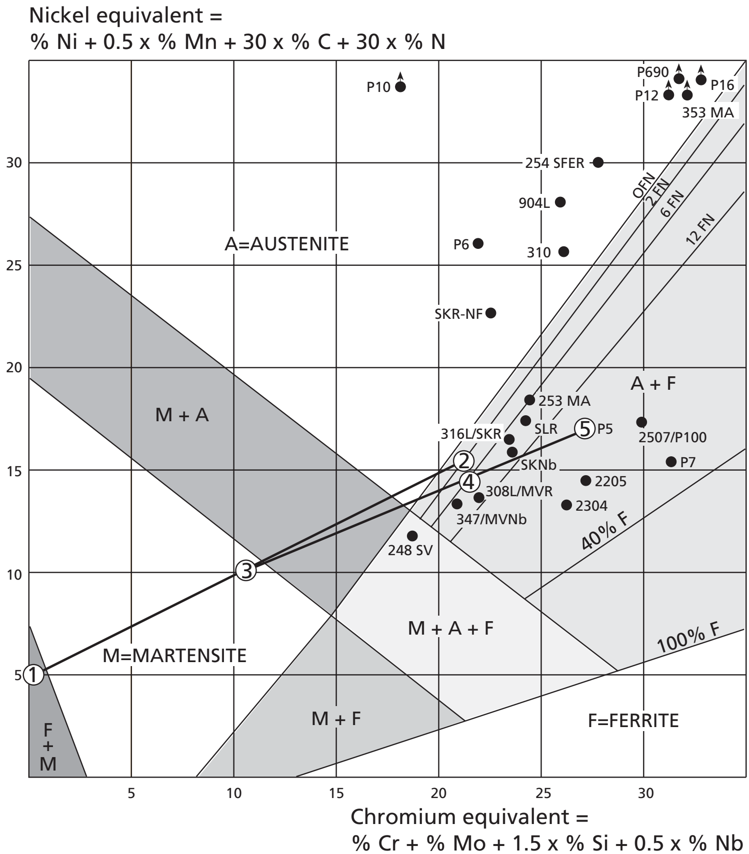


Figure 1.12 DeLong diagram for welding consumables

Example

A mild steel plate ① is welded to a stainless steel plate ② in Outokumpu 4404 (EN 1.4404/ASTM 316L) using P5 electrodes ⑤.

First, a line is drawn between the two metals ① and ②. Assuming that the metals melt equally into the weld, the halfway point ③ is marked on this line. Another line is then drawn between this point and the electrodes ⑤. Knowing that the composition of the weld metal will be approximately 30% parent metals and 70% filler metal, a further point ④ is marked as shown (i.e. the distance between ③ and ④ is 70% of the line's length).

The DeLong diagram predicts a ferrite content of approximately 6 FN for this weld metal. The WRC-92 constitutional diagram can be used in the same way.

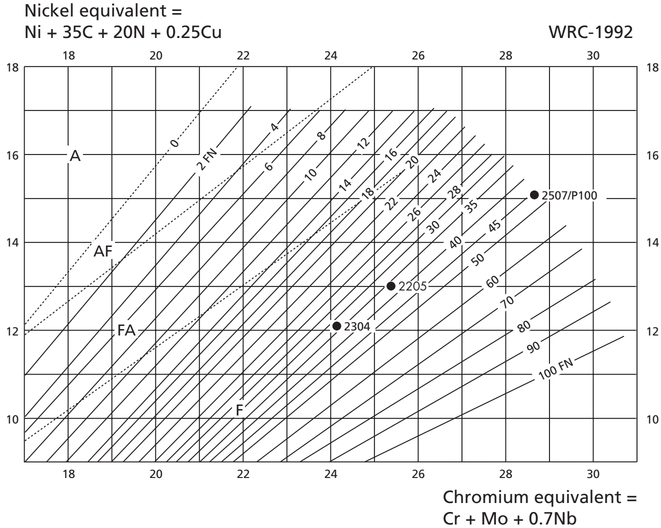


Figure 1.13. WRC-92 diagram for welding consumables

Low ferrite content (0 – 3 FN DeLong) gives a weld that may be slightly sensitive to hot cracking. To avoid this, a filler wire with a relatively high ferrite content must be used. In some demanding environments, e.g. urea plants and certain cryogenic applications, ferrite-free parent metals and welds are stipulated. Welding must then use low ferrite or fully austenitic fillers such as 308L-LF, SKR-NF, P6 and P12. Heat input must be low and controlled. Dilution of the parent metal must be kept to a minimum.

A ferrite content of 3 – 12 FN DeLong gives good resistance to hot cracking. All standard austenitic fillers such as 308L/MVR, 316L/SKR, P5 and 347/MVNb give welds with a ferrite content in this range. Hence, these fillers provide good resistance to hot cracking.

At ferrite contents above 12 FN DeLong, a continuous network of ferrite may be present. In some environments, this may result in selective corrosion. When subjected to heat treatment, the ferrite may, depending on time and temperature, transform totally or partly into sigma phase. This reduces corrosion resistance and toughness.

A duplex stainless steel weld typically has a ferrite content of 25 – 65 FN WRC-92. The increased yield and tensile strengths this gives are highly beneficial.

Figures 1.14 to 1.16 show stainless steel microstructures with, respectively, low, medium and high ferrite contents.

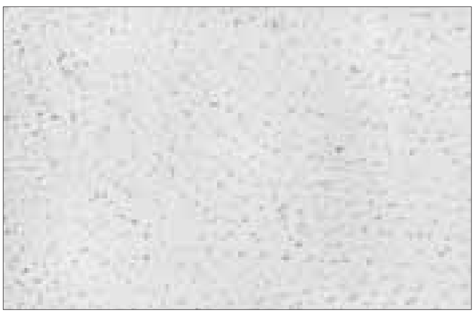


Figure 1.14. Ferrite 3 FN DeLong

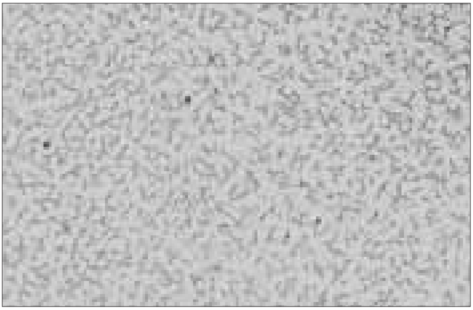


Figure 1.15. Ferrite 12 FN DeLong

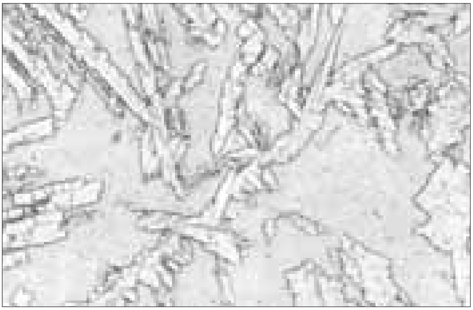


Figure 1.16. Ferrite 50 FN WRC-92

2 Definitions

Welding positions

In principle, four different welding positions are recognised for all types of welded joints. These are: *flat*, *horizontal-vertical*, *overhead* and *vertical-downwards/vertical-upwards.* Figure 2.1 shows the EN and AWS codes for welding positions.

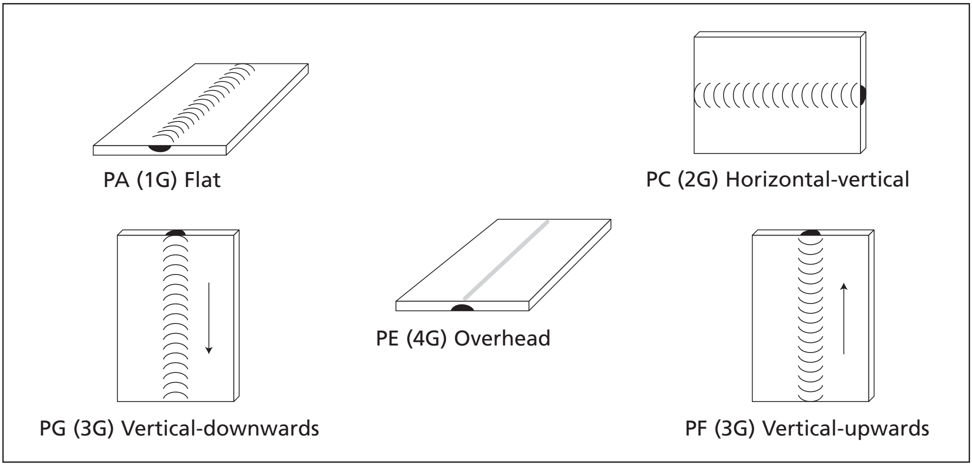


Figure 2.1a. Welding positions for butt welds – EN 287-1 (AWS designations are given in brackets)

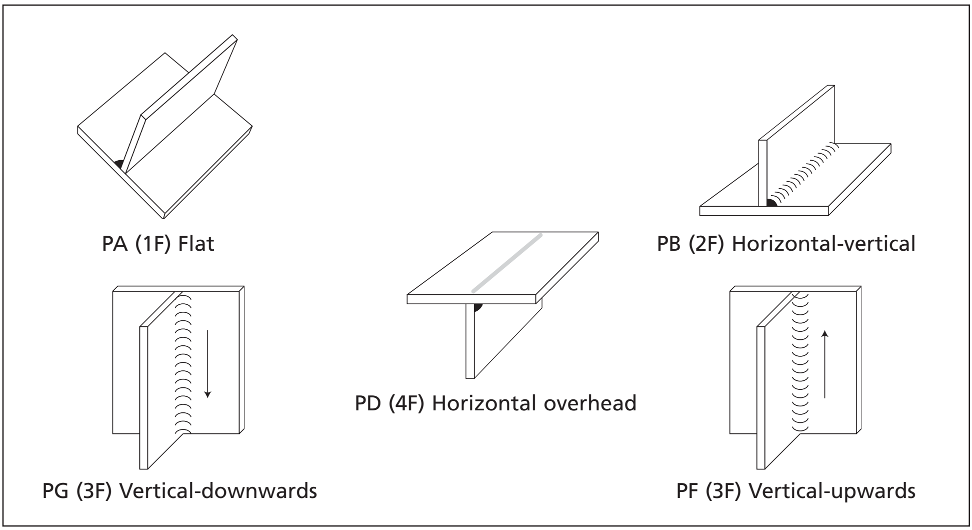


Figure 2.1b. Welding positions for fillet welds – EN 287-1 (AWS designations are given in brackets)

Heat-affected zone

The heat-affected zone (HAZ) is the area around the weld bead that is unavoidably heated during welding (see figure 2.2 for an example). As toughness, corrosion resistance, etc. can all be affected by the welding thermal cycle, HAZ properties may differ from those of the weld and the parent metal. The extent of any difference is determined by the thermal cycle and the stainless steel grades in question.

In general, the thermal cycle is tolerated slightly less well by high-alloy stainless steels than it is by standard grades. Consequently, the welding of high-alloy grades requires closer control. A slightly lower heat input is also probably advisable.

Both ferritic and martensitic steels are mildly prone to grain growth in the HAZ. This can reduce toughness. Hence, low heat input is important when welding these types of steel.

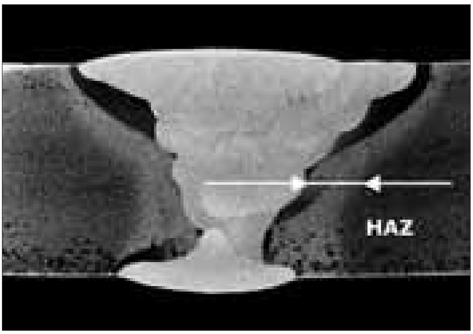


Figure 2.2. Width of the heat-affected zone in 304 steel

Heat input

When welding any metal (stainless steels included therein), heat (energy) input is controlled for a number of reasons. For example, heat input influences distortion, lateral shrinkage and any tendency to form deleterious phases. All of these can affect the serviceability of the welded structure.

The formula below is used to calculate heat input.

$$\text{Heat input [kJ/mm]} = \frac{\text{Current x Voltage}}{\text{Travel speed}} \left[\frac{\text{A x V}}{\text{mm/s x 1,000}}\right]$$

Recommended heat inputs are determined by many factors. One of the most important of these is the thickness of the metal being welded. Below, there are some typical heat input ranges* for a variety of stainless steels.

Austenitic steels	max. 2.0 kJ/mm
Stabilised austenitic steels	max. 1.5 kJ/mm
Fully austenitic steels	max. 1.2 kJ/mm
Duplex steels	0.5 – 2.5 kJ/mm
Super duplex steels	0.2 – 1.5 kJ/mm

* These ranges may have to be adapted to take metal thickness, production factors, etc. into account.

Interpass temperature

Interpass temperature is one of the factors determining the thermal cycle experienced by the weld zone. Amongst the other factors for any given steel are heat (energy) input, thickness and welding process (arc efficiency). The thermal cycle's effect on dilution and microstructure strongly influences the serviceability of the welded joint. Thus, it is advisable to control the interpass temperature in the same way as heat input.

The interpass temperature (T_I) is the temperature at the welding point immediately before the welding arc is restruck in multipass welding.

The interpass temperatures** below are representative for production welding.

Austenitic steels	max. 150°C
Stabilised austenitic steels	max. 150°C
Fully austenitic steels	max. 100°C
Duplex steels	max. 150°C
Super duplex steels	max. 100°C

** These values may have to be adapted to take metal thickness and heat input into account.

Penetration and dilution
Generally, full penetration is essential for the maximum corrosion performance and structural integrity of the weld zone. Single-sided welds can be made with unsupported root beads or by welding onto temporary backing bars (see also chapter 4 ”Welding techniques”). The second side of double-sided welds should be cold cut to bright, sound metal before welding is restarted. The second side cut for a sealing run might typically be 1 – 2 mm deep by 2 – 4 mm wide.

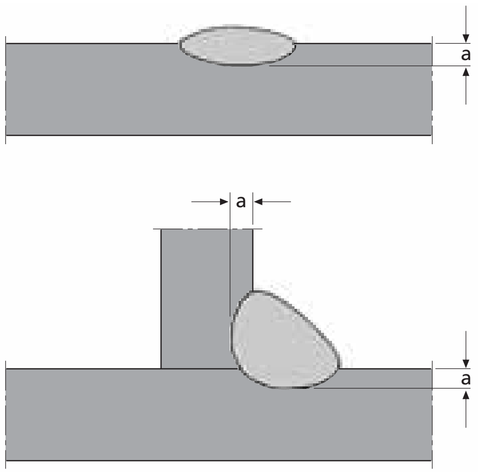


Figure 2.3. Fusion penetration – the depth of fusion is indicated by ”a”

Weld metal dilution is the proportion (by volume) of fused parent metal in the weld. A dilution of 30% means that 30% of the weld comes from the parent metal and 70% from the filler metal. Table 2.1 gives some typical dilution values. Dilution increases with:

- Increased heat input
- The arc directed towards the parent metal rather than the middle of the joint
- Decreased joint angle.

Increased dilution can increase the propensity to hot cracking. This may be a factor for consideration when welding, for example, stainless steel to mild steel, or when welding fully austenitic steels.

Metal deposition rate
The metal deposition rate, often measured as kilogram per hour, is the amount of filler metal that can be deposited during a fixed period of time. As shown in table 2.1. (which also includes typical dilution values), the rate varies between welding methods.

Post-weld heat treatment
Post-weld heat treatment (PWHT) is normally not required for austenitic and duplex stainless steels. In some applications, quench annealing or stress relieving may be

Comparison of deposition rates and dilutions Table 2.1

Welding method	Consumable’s diameter, mm	Deposition rate, kg/h	Typical dilution, %
MMA	3.25	1.5	30
MMA	5.00	3	35
MIG (spray arc)	1.20	2 – 5	30
MIG (spray arc)	1.60	3 – 7	30
TIG	2.40	1 – 2	20
SAW (wire)	3.20	4 – 8	35
SAW (strip)	0.5 x 60	15 – 17	15
Electroslag (strip)	0.5 x 60	20 – 22	10
FCAW	1.20	3 – 6	25

necessary. The best results are obtained by quench annealing at 1,050 – 1,150°C (1,150 – 1,200°C for fully austenitic steels). Cooling must be rapid and in water or air. The absolute temperatures and ranges are grade specific.

In some special cases (e.g. cladding mild steel with stainless steel), stress relieving heat treatment at 600 – 700°C is specified. However, stainless steels are prone to the precipitation of deleterious phases when exposed to temperatures between ~600 and 1,000°C. Notch toughness and corrosion performance can suffer.

To improve toughness and reduce the hardness of the weld, the tempering of martensitic and semi-martensitic stainless steels may be advisable. Semi-martensitic stainless steels (e.g. Outokumpu 248 SV) should be annealed at 500 – 600°C, the exact temperature being determined by the properties that are required.

All heat treatment should be carried out by experienced personnel using qualified procedures and appropriate equipment.

Figure 2.4. 253 MA radiant tubes in a heat treatment furnace. Courtesy of Rolled Alloys.

Effect of high silicon content

MIG/TIG wires from Avesta Welding are available with either a low or a high silicon content (typically 0.04% and 0.9% respectively). A high silicon content improves arc stability and gives better fluidity. This enables higher MIG welding speeds to be used. Porosity and spatter also benefit, the resultant weld surfaces being more attractive.

The above advantages are particularly pronounced when dip transfer MIG welding. Avesta Welding's high-silicon type wires are intended for use with metals that are known to have good resistance to hot cracking.

As most granular fluxes promote silicon alloying, Avesta Welding's SAW wire is produced only in a low-silicon format.

Cast and helix

Wire feeding in MIG welding is influenced by, amongst other things, cast and helix.

Cast is the diameter of a single loop of wire cut from the spool and laid free on a flat surface. Too high or too low a cast can lead to feeding problems in the feeder and/or at the contact tip. Both these have a negative effect on arc stability.

Helix is the vertical distance between the ends of a single loop of wire cut from the spool and laid free on a flat surface. Too large a helix will result in the wire rotating in the feeder and/or at the contact tip. Consequently, the arc will rotate across the plate surface.

In order to maximise MIG feedability and ensure optimum welding characteristics, Avesta Welding controls cast and helix very closely.

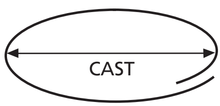


Figure 2.5a

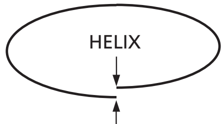


Figure 2.5b

3 Stainless steel welding methods

Introduction

All common arc welding methods can be used with stainless steels. The following are some of the factors affecting the choice of method:

- **Type of parent metal**
- **Thickness**
- **Welding position**
- **Equipment availability**
- **Skill and experience of welders**
- **Welding site (indoors/outdoors)**
- **Productivity (deposition rate)**

This chapter briefly describes the basic characteristics of the most common welding methods.

Welding terminology and abbreviations

European terminology and abbreviations are used throughout this manual. Where appropriate, American equivalents are also given.

European		American	
Manual metal arc	MMA	Shielded metal arc	SMAW
Metal inert gas	MIG	Gas metal arc	GMAW
Tungsten inert gas	TIG	Gas tungsten arc	GTAW
DC electrode positive	DCEP	Reverse polarity	DCRP
DC electrode negative	DCEN	Straight polarity	DCSP
Submerged arc welding	SAW		
Flux cored arc welding	FCAW		
Plasma arc welding	PAW		

This manual follows the common practice of using MIG to refer to both metal inert gas (MIG) welding and metal active gas (MAG) welding.

When deciding which welding method to use, special attention should be paid to the metal deposition rate. Figure 3.1 compares the deposition rates of several welding methods.

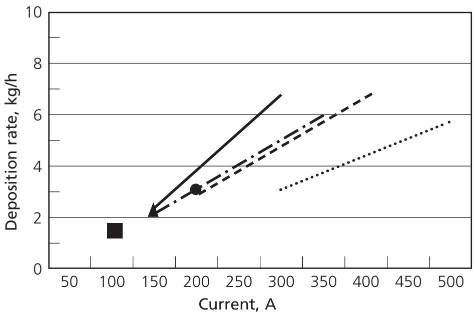


Figure 3.1. A comparison of deposition rates

FCAW (1.20 mm)
MIG (1.20 mm)
MIG (1.60 mm)
SAW (3.20 mm)
MMA (3.25 mm)
MMA (4.00 mm)
MMA (5.00 mm)

MMA – flexible all-position welding

Characteristics

Covered (stick) electrodes are used in this common and flexible welding method. It is suitable for all weldable stainless steels and a broad range of applications. Characterised by great flexibility in all welding positions, MMA is widely employed for primary fabrication, on-site work and repair welding. MMA is manual and is used for material thicknesses of 1 mm and upwards. In principle, there is no upper thickness limit. Figure 3.2 shows the basics of MMA welding.

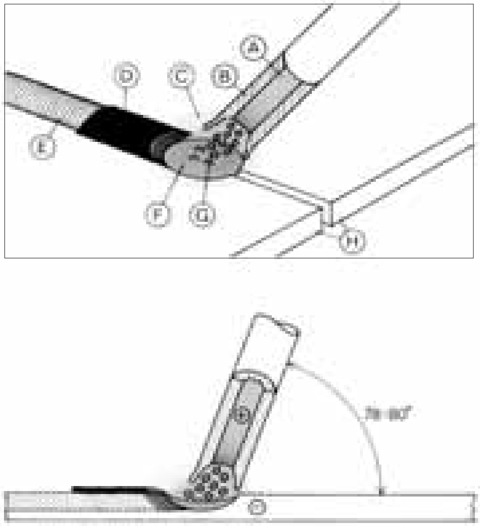


Figure 3.2. MMA welding

A = Core wire (stainless steel)
B = Coating (minerals and metals)
C = Plasma (formed from the coating)
D = Solidified slag
E = Weld metal
F = Weld pool
G = Arc with metal droplets (each droplet is covered by slag)
H = Parent metal

Coatings

Based on usability designations (as given in AWS A5.4 and EN 1600), the coatings of Avesta Welding's electrodes fall into three groups: **rutile-acid electrodes, basic electrodes** and **rutile electrodes**.

- **Rutile-acid electrodes AC/DC** (-17 in AWS A5.4 and R in EN 1600)

The coatings of rutile-acid electrodes (AC/DC) are a modification of rutile electrode coatings. Rutile-acid electrodes are characterised by easy arc ignition and high current capacity. Slag removal is excellent and the electrodes give a smooth, slightly concave weld bead. In order to ensure sufficient penetration, the root gap must be slightly larger than when welding with basic electrodes. DCEP and AC can both be used, however arc stability and weld pool control are normally better with DCEP.

- **Basic electrodes** (-15 in AWS A5.4 and B in EN 1600, all Ni base alloys)

The coatings of basic electrodes have a high CaF_2 content. Compared to rutile and rutile-acid electrodes, they thus have a lower melting point. This gives a weld with a low oxide content and few inclusions. As a result, notch toughness is improved and the risk of hot cracking is reduced. For this reason, many fully austenitic and nickel base electrodes have basic coatings.

In the vertical-up position, weldability is generally very good. Compared with rutile or rutile-acid electrodes, basic electrodes give better penetration into the parent metal. The weld bead is normally slightly convex and not quite as smooth as that obtained with rutile and rutile-acid electrodes. DCEP must be used when welding with basic electrodes.

- **Rutile electrodes** (-16 in AWS A5.4 and R in EN 1600)

The coatings of rutile electrodes have a high TiO_2 (rutile) content. This gives easy arc ignition, very smooth surfaces and simple

MMA parameters Table 3.1

Electrode type	Diameter, mm	Voltage, V	Current, A Horizontal (PA/1G)	Vertical-up (PF/3G)	Overhead (PE/5G)
AC/DC	1.6	26 – 30	30 – 50	30 – 40	35 – 45
	2.0	26 – 30	35 – 60	35 – 50	40 – 50
	2.5	26 – 30	50 – 80	50 – 60	60 – 70
	3.25	26 – 30	80 – 120	80 – 95	95 – 105
	4.0	26 – 30	100 – 160	–	–
	5.0	26 – 30	160 – 220	–	–
Basic*	2.0	24 – 27	35 – 55	35 – 40	35 – 45
	2.5	24 – 27	50 – 75	50 – 60	55 – 65
	3.25	24 – 27	70 – 100	70 – 80	90 – 100
	4.0	24 – 27	100 – 140	100 – 115	125 – 135
	5.0	24 – 27	140 – 190	–	–
Rutile	1.6	22 – 24	30 – 40	30 – 35	30 – 40
	2.0	22 – 24	35 – 55	35 – 40	40 – 50
	2.5	22 – 24	50 – 75	50 – 60	60 – 70
	3.25	22 – 24	70 – 110	70 – 80	95 – 105
	4.0	22 – 24	100 – 150	100 – 120	120 – 135
	5.0	22 – 24	140 – 190	–	–

* For nickel base electrodes (e.g. Avesta P10, P12-R and P16), a slightly lower current must be used.

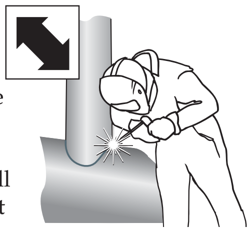
slag removal. The weld's mechanical properties (notch toughness especially) are not quite as good as those obtained when using basic electrodes.

Welding parameters

Typical welding parameters are given in table 3.1.

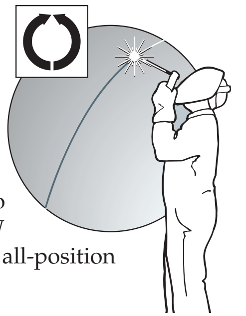
The Vital Arc Concept

AC/DC electrodes are produced with a range of special coatings for different applications. The Vital Arc Concept focuses on optimising efficiency and weld metal quality in each application. The results include maximum fabrication/assembly efficiency and great cost savings. Each grade, size and type of electrode has its own unique formulation to ensure optimum results every time.



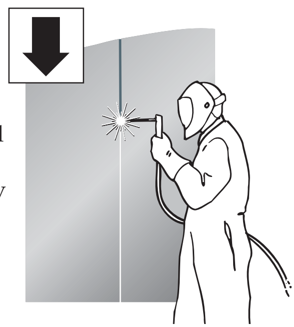
- Standard AC/DC electrodes have a medium thickness flux coating. They are of the fully versatile, “all-round” type, i.e. they can be used in all positions. The current capacity of these electrodes is excellent. For improved welding duty cycle and efficiency, all 4.0 and 5.0 mm diameter electrodes are extra long (450 mm).

- HX designates a high-recovery electrode, i.e. one with a thicker coating than a standard electrode. Metal recovery is up to 150% and, furthermore, the deposition rate is typically 30% higher than with standard electrodes. Altogether, this results in considerable cost savings. The greater weld length also significantly reduces the number of starts/stops. HX electrodes are used primarily in the horizontal position.



- PW electrodes have thinner coatings compared to standard AC/DC electrodes and a low volume, fast freezing slag. Consequently, the slag and the arc are easier to control. This makes PW electrodes excellent for all-position welding.

- PWX electrodes are specifically designed for positional welding. Compared to standard electrodes, they have an extra thin coating and fast freezing slag. The very smooth arc gives an easily controlled weld pool in all positions. Low current settings and excellent fluidity make PWX electrodes admirably suited to, for example, the welding of thin-walled tubes (minimum thickness 2 mm). PWX electrodes are an economic and reliable alternative to TIG.



- VDX electrodes have an extremely thin flux coating and fast freezing slag. They produce a small but readily visible weld pool that is easy to control. Giving good penetration of the parent metal, VDX electrodes are particularly suitable for the vertical-down welding of thin material. They can be used for all types of joint. In some cases, VDX electrodes provide an alternative to TIG welding.

MIG (GMAW) – high productivity with both manual and automatic welding

Characteristics

MIG (i.e. both MIG and MAG) is an economical welding method well suited to continuous welding sequences. The weld metal properties are good. In particular, due to the low oxide content, notch toughness is higher than with MMA and FCAW. The introduction of new inverter and synergic pulsed machines has dramatically improved MIG weldability. Figure 3.3 shows the basics of MIG welding.

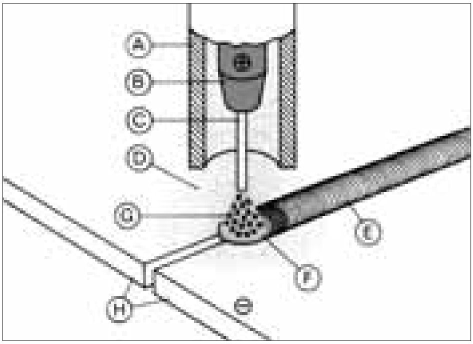


Figure 3.3. MIG welding

A = Gas cup	E = Weld metal
B = Contact tip	F = Weld pool
C = Filler wire	G = Arc (metal transfer)
D = Shielding gas	H = Parent metal

Arc types and metal transfer

DCEP is normally used for MIG. Determined particularly by the welding current/arc voltage balance, there are several different metal transfer modes. Figure 3.4 gives an overview of these. The following metal transfer modes are generally recognised:

- Dip transfer/short arc
- Globular arc
- Spray transfer/open arc
- Pulsed arc
- Rapid arc
- Rapid melt

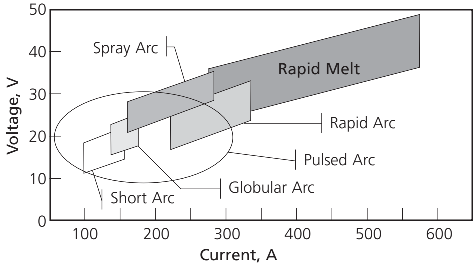


Figure 3.4. Metal transfer for MIG welding; wire diameter 1.20 mm

Dip transfer (short arc)

Dip transfer occurs at low current and voltage settings. The arc is short and melts the wire tip to form "big" droplets that dip into the weld pool. This, in essence, short-circuits and extinguishes the arc. When the arc is extinguished, weld metal is transferred into the weld pool. This allows the arc to re-ignite "explosively". Current, voltage and inductance ("choke") are tuned so that this explosive re-ignition does not generate excessive weld spatter. The short-circuit frequency is typically 50 – 200 Hz.

Dip transfer is a low heat input process suitable for welding thin material and positional welding. The deposition rate is fairly low (1 – 3 kg/h).

Globular metal transfer

A relatively small increase in arc voltage and an increase in welding current will generate larger droplets – typically double or triple the diameter of the wire. The electromagnetic pinch effect detaches the metal droplets from the wire tip. Short-circuiting and/or gravitation then transfer the metal through the arc. As the arc is often comparatively unstable and inconsistent, the risk of spatter is rather high. In the dip transfer mode, spatter particles tend to be fairly fine – typically equal to or less than the diameter of the wire. They tend to be much larger (greater than the wire diameter) in globular transfer. Globular transfer is not normally the first choice metal transfer mode.

Spray transfer (open arc)

Spray transfer occurs with another small rise in arc voltage and an increase in the welding current. In melting, the wire tip forms a sharp cone. Primarily due to electromagnetic effects, the metal detaches in a fine spray and is forced axially across the arc. The arc is stable, open and smooth. Spatter is thus minimal. The deposition rate is typically 4 – 6 kg/h. The higher currents generally result in higher heat inputs, larger weld pools and deeper penetration into the parent metal. For these reasons, the spray arc mode is extremely suitable for the horizontal welding of thicker base material (5 mm and above).

Pulsed arc

In spray transfer, the current is held at a constant level. In pulsed or "synergic" MIG, welding current is supplied as a square wave pulse (see figure 3.5). Metal transfer is controlled by the pulse or peak current. The background current must be sufficient to maintain the arc.

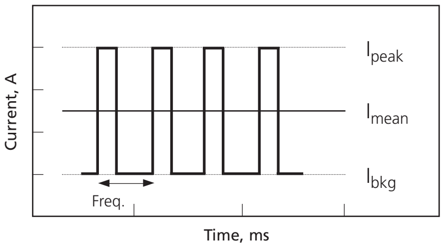


Figure 3.5. The pulsed arc

Besides great flexibility, the low mean current of the pulsed arc also gives excellent arc stability and superior control of metal transfer. As a result, the weld pool is stable and controllable. Compared to both the short arc and spray arc modes, parameter tolerance is consequently much greater (see figure 3.4). Pulsed arc welding is suitable for manual and automatic welding of all thicknesses in all welding positions. With stainless steel or nickel base filler metals, the process is very suitable for welding all standard and high performance grades of stainless steel. The versatility of the process is such that a single wire size, e.g. 1.20 mm diameter, can be used for welding a wide range of plate thicknesses in all welding positions.

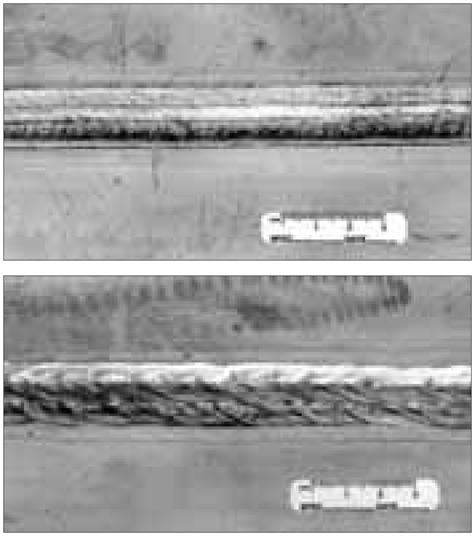


Figure 3.6. Pulsed arc (top) and spray arc (bottom) welding using P12 filler metal

Rapid Arc™ and Rapid Melt™

Higher currents and voltages are used in Rapid Arc and Rapid Melt transfer. Both modes require high wire feed speed and a long electrode stick-out. In Rapid Arc welding, the long stick-out causes both a reduction of the current and increased resistive heating of the wire. The voltage is set relatively low and a forced arc is obtained. Rapid Arc welding gives better parent metal penetration compared to conventional MIG and makes it possible to use a higher travel speed (up to 150 cm/min). A conventional power source can be used.

The even higher current in Rapid Melt welding generates a spray arc. The power source must be capable of running at very

MIG parameters Table 3.2

	Wire diam. mm	Current A	Voltage V	Pulse parameters I_{peak}, A	$I_{background}$, A	Frequency, Hz
Short arc	0.8	90 – 120	19 – 22	–	–	–
	1.0	110 – 140	19 - 22	–	–	–
Spray arc	0.8	150 – 170	24 – 27	–	–	–
	1.0	170 – 200	25 – 28	–	–	–
	1.2	200 – 270	26 – 29	–	–	–
	1.6	250 – 330	27 – 30	–	–	–
Pulsed arc	1.2	75 – 350	24 – 30	300 – 400	35 – 100	50 – 200
Rapid Arc™	1.2	300 – 400	28 – 32	–	–	–
Rapid Melt™	1.2	400 – 500	40 – 50	–	–	–

high voltages and wire feed speeds (up to 50 m/min). Setting the voltage high causes the arc to rotate. This aids fusion. Rapid Melt is primarily used for high productivity welding – the metal deposition rate can be as high as 20 kg/h. Both methods may give rise to slightly increased spatter and radiation. They are mainly used for mechanised welding.

Tandem and twin

Welding productivity may be further improved by using tandem or twin-wire welding.

Tandem welding uses two wires. Each is fed by a separate unit and each is connected to its own power source. The wires can have different potentials, arc modes and parameter settings.

Twin-wire welding has two wires connected to the same power source. However, as this makes it difficult to obtain a stable arc that is free from spatter, the twin wire method is not widely used in MIG welding.

With lower total heat input, both methods give increased welding speed and metal deposition rates.

Welding parameters

Table 3.2 gives typical parameters for MIG welding.

TIG (GTAW) – high quality welds

Characteristics

Tungsten inert gas welding is characterised by high quality weld metal deposits, great precision, superior surfaces and excellent strength. It is widely used in tube and pipe welding (wall thicknesses from 0.3 mm upwards). Root runs for pipes and tubes are one particularly important TIG application. TIG can be either manual or automatic.

Autogenous welding (i.e. without the use of filler metals) can be carried out on certain grades of thin material. However, corrosion resistance and ductility may suffer. Unless solution annealing is possible, suitable filler metals should be used when welding some high-performance/high-alloy stainless steels such as 2205, 904L and 254 SMO. A piece of plate, or the core wire of a covered electrode, must never be used for TIG. Figure 3.7 shows the basics of TIG welding.

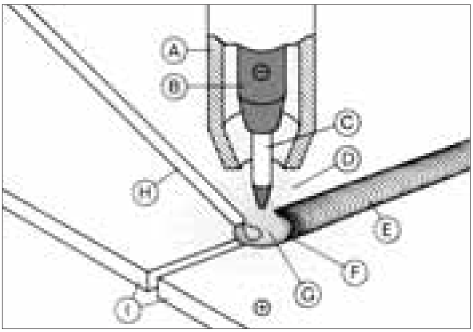


Figure 3.7. TIG welding

A = Gas cup
B = Electrode holder (contact tip)
C = Tungsten electrode (non-consumable)
D = Shielding gas
E = Weld metal
F = Weld pool
G = Arc (struck between electrode and parent metal)
H = Filler wire (fed into the arc from the side)
I = Parent metal

Tungsten electrode

TIG electrodes can be either pure tungsten or, as is more often the case, tungsten alloys (1 – 2% thorium, zirconium or cerium oxides). Electrode diameters range from 1.0 to 4.8 mm. As shown in figure 3.8, the angle of the tungsten electrode has a significant effect on penetration. A narrow angle (15 – 30°) gives a wide arc with low penetration. This is suitable for thin gauges. Wider angles (60 – 75°) give a narrower arc with deeper penetration.

To minimise the risk of tungsten inclusions forming in the weld, the electrode tip (the cone) should be rounded off by grinding.

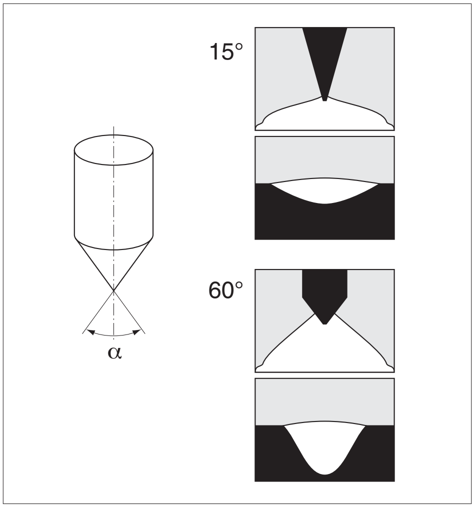


Figure 3.8. Electrode angle (TIG) and examples of effect on penetration.

Welding parameters

Continuous and pulsed DCEN are both used in the TIG welding of stainless steels. Typical welding parameters are given in table 3.3. Pulsed arc is particularly suitable for thin sections and positional welding.

TIG parameters Table 3.3

Tungsten electrode diameter mm	Current A	Voltage V	Typical section thickness mm
1.6	50 – 120	10 – 12	<1.0
2.4	100 – 230	16 – 18	1.0 – 3.0
3.2	170 – 300	17 – 19	>2.0

High frequency (HF) devices are normally used to ignite the arc. Such ignition is generally smooth and reliable. However, the possibility of interference with/from other electronic devices close to the power source must be taken into account. In "lift arc" ignition, raising the electrode from the workpiece initiates electrically controlled ignition. Due to the risk of damaging the electrode and introducing tungsten inclusions into the weld, "scratch start" ignition is seldom used today.

High productivity welding using TIG

Manual TIG gives a high quality weld, but at a fairly low metal deposition rate of around 1 kg/h. In automatic TIG welding (e.g. pipe and tube welding), the deposition rate can be up to ~3 kg/h. Productivity can be increased even further using a hot-wire TIG system.

Narrow gap (NG) welding increases joint completion rate and reduces joint volume. It also has the potential to reduce welding distortion. The joint bevel angle is reduced to around 5° and the weld can be V or U-joint (single or double-sided in both cases) – see chapter 7, "Edge preparation", for further details.

As the joint is very deep and narrow in NG welding, a special welding head is required. When welding thick sections, the NG process is a popular alternative to SAW.

SAW – high productivity welding of thick sections

Characteristics

Submerged arc welding is principally used for thick sections (typically 10 mm and upwards) in the flat (PA/1G) welding position. It is also used for the overlay welding (surfacing or cladding) of both mild and low-alloy steels. The mechanical and corrosion properties of SA welds are of the same high quality as those of other arc welding methods. In SAW, the arc and the weld pool are protected by a flux burden. The flux plays an important part in determining weldability and weld metal properties. During welding, some of the molten flux transfers to the weld metal and some converts into a readily removable slag. Figure 3.9 shows the basics of SAW.

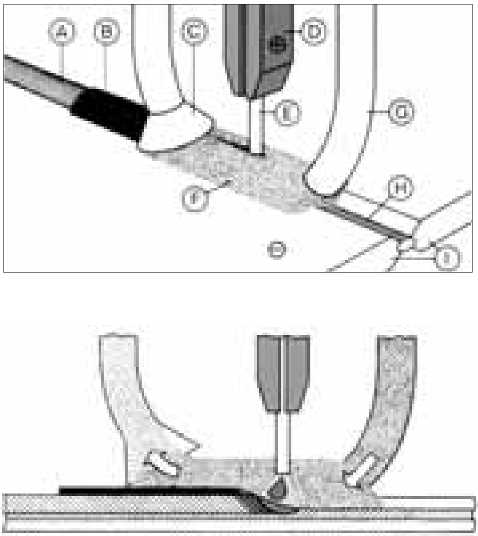


Figure 3.9. SAW

A = Weld metal
B = Slag protecting the arc and weld pool
C = Removal of the flux
D = Contact tip
E = Filler wire
F = Flux
G = Flux supply
H = Root bead
I = Parent metal

Welding parameters

Both DCEP and DCEN are possible with SAW. As it gives the best arc stability and weld bead appearance, DCEP is normally used for joining. For any given current, wire speed is higher with the electrode connected to negative polarity (DCEN). This results in lower dilution and a higher deposition rate. Hence, DCEN is normally only used for cladding.

SAW generally requires higher currents than other arc welding methods. Combined with the higher material thicknesses and protecting slag, this may result in a slower cooling rate than with other processes. Thus, care must be taken where the formation of deleterious phases is a particular problem.

Care must also be taken when welding high-alloy grades of stainless steel to each other, or when welding unalloyed steels to stainless steels. Heat input and dilution with the parent metal should both be kept reasonably low (as per the stipulated welding procedure specification). Joint configuration and welding parameters should be selected so that the width/depth ratio of the weld bead is about 1.5 to 2.0.

Any risk of hot cracking can be reduced by welding the first beads manually using covered electrodes.

SAW parameters Table 3.4

Wire diameter mm	Current A	Voltage V
2.40	200 – 350	27 – 33
3.20	300 – 600	30 – 36
4.00	400 – 700	30 – 36

Travel speed is typically 30 – 60 cm/min.

Flux for SAW

There are two main groups of fluxes – agglomerated and fused. Agglomerated flux, the more modern of the two, has the advantage that it can be alloyed. In obtaining the desired weld metal composition and mechanical properties, choosing the right combination of wire/strip electrode and flux is of the utmost importance. Of course, the optimum welding parameters must also be used.

To compensate for chromium losses in the arc during the welding of Cr-Ni and Cr-Ni-Mo steels, fluxes alloyed with chromium are standard. They are normally neutral to slightly basic. Fluxes used for high-alloy stainless steels are normally more strongly basic. This maximises weld metal cleanness and minimises the risk of microcracking.

Based on the relationship between the basic and acid oxides of which a flux is composed, the basicity index (B.I.) states the chemical/metallurgical balance of fluxes. In this respect, fluxes can be divided into three groups:

- Acid B.I. < 0.9
- Neutral B.I. 0.9 – 1.2
- Basic B.I. > 1.2 – 3.0

Basicity has a great effect on mechanical properties, particularly notch toughness. The more basic the flux, the lower the content of oxides and other inclusions in the weld metal. As a result, notch toughness is higher. This is particularly important for high-alloy grades where particular attention has to be paid to the possibility of microcracking.

Strip welding

SAW can also be used for strip cladding (strip surfacing), i.e. cladding using a strip electrode. For both mild and low-alloy steels, this welding process is widely used to enhance corrosion and/or wear resistance. Deposition rates are considerably higher than in wire cladding, typically 10 – 15 kg/h using a 0.5 x 60 mm strip. Refer to ”Overlay welding” in chapter 4.

FCAW – a high deposition, flexible process for all-position welding

Characteristics

Flux cored arc welding is characterised by high metal deposition rates, great flexibility and good weldability. Weld bead appearance is excellent – the weld is smooth and slightly concave. Due to a higher content of oxides in the weld, notch toughness is lower than in MIG and TIG.

Flux cored wire (FCW) is normally produced from an 18/8 stainless steel tube filled with a granular flux. The flux contains slag forming compounds and alloying elements. Its composition is specifically formulated to ensure the correct chemical composition of the weld, good mechanical properties and optimum welding characteristics in the recommended positions. Figure 3.10 shows the cross-section of a typical flux cored wire.

FCAW is commonly used for welding thicker sections (> 5 mm) in, for example, pressure vessels, chemical tankers, chemical holders, etc. The high deposition rate (typically twice that of solid wire MIG) makes it suitable for the overlay welding of mild and low-alloy steel components.

Due to its combination of a shielding gas and a protective slag, outdoor welding can be carried out far more easily with FCAW than with solid wire MIG and TIG. Nonetheless, steps should be taken to shield against draughts.

Figure 3.10. Cross-section of an Avesta Welding flux cored wire

Welding parameters

The FCAW and solid wire MIG processes are basically the same. The primary difference is that the slag and shielding gas combination in FCAW protects the arc and the weld. FCAW is suitable for positional welding. As it has a greater operating range, the process does not require the same precision as solid wire MIG.

DCEP is always used for FCAW. Table 3.5 gives typical welding parameters.

To obtain a smooth and even weld, free from defects such as slag and porosity, it is important to maintain the proper current to voltage relationship in FCAW. Too high a voltage creates a long arc that leads to heavy

FCAW parameters Table 3.5

Wire	Horizontal (PA/1G)		Vertical-up (PF/3G)		Overhead (PE/5G)	
diameter, mm	Current, A	Voltage, V	Current, A	Voltage, V	Current, A	Voltage, V
0.90	80 – 160	22 – 28	80 – 130	22 – 26	80 – 150	22 – 27
1.20	150 – 280	24 – 32	140 – 170	23 – 28	150 – 200	24 – 29
1.60	200 – 320	26 – 34	–	–	–	–

Welding speed is typically 20 – 60 cm/min for horizontal welding and 10 – 20 cm/min for vertical-up welding.

spatter and a wide weld. There may also be undercutting and a lack of fusion. Too low a voltage, on the other hand, gives a short arc. This could result in a convex weld bead that is prone to porosity and slag inclusions. Thus, for each current level, it is always advisable to use a voltage at the high end of the recommended range. In most applications, a wire stick-out of 15 – 25 mm produces the best results.

A 1.20 mm diameter wire can, in most cases, be used in all positions. However, for thinner sections (2 – 4 mm), and in some welding positions, a 0.90 mm diameter wire may be preferable. The largest diameter wire (1.60 mm) is principally used for thicker sections (>~10 mm) in the horizontal position and the overlay welding of mild steel components.

Single-sided welding against a ceramic backing is common, especially for on-site welding of panels etc. in, for example, chemical tankers (see chapter 4, "Welding techniques"). Figure 3.11 gives the parameter range for FCW 308L and 316L when welding in the horizontal position (PA/1G) using Ar + 25% CO_2 shielding gas.

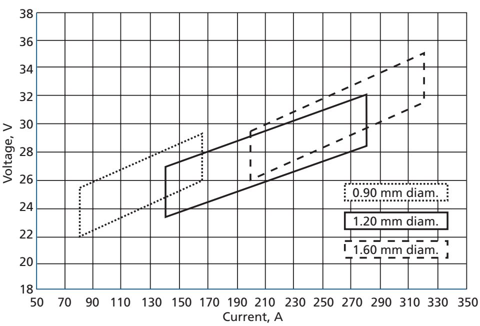


Figure 3.11. FCAW parameters

PAW – a high-energy process for automatic welding

Characteristics

Plasma arc welding is characterised by a high-energy arc which, when welding in the keyhole mode, gives narrow, deep penetration and low distortion of the workpiece. The quality of the weld beads is excellent – the cap and root are low and even and the heat-affected zone (HAZ) is small. Relatively high welding speeds are possible. The method is thus normally used as a mechanised or fully automatic process in, for example, the manufacture of a wide range of containers and the production of tubes and pipes. Material thickness is generally 0.5 – 8 mm.

Welding is usually completed with a square edge closed butt (SECB) weld. However, especially for thicker sections, it may be better to use a bevelled joint that is filled and capped using, for example, TIG, PAW (in "remelt" mode), SAW or MMA.

Edges are normally prepared by shearing, laser cutting or milling. Owing to the narrow arc, joint tolerances are generally tighter for PAW than for other welding methods, e.g. TIG. Figure 3.12 shows the basics of plasma arc welding.

Filler wire for PAW

PAW can be either with or without filler wire. Unless the complete workpiece can be solution annealed to maximise corrosion and mechanical performance, filler wire should be used when welding high-alloy grades such as 2205, 904L and 254 SMO.

The plasma

The parallel-sided plasma arc is formed by constricting the arc through a copper nozzle. This gives arc temperatures in excess of 20,000°C. To protect the arc and weld pool against oxidation, a shielding gas flows through the outer nozzle.

Both the plasma gas and the shielding gas are normally argon (Ar) + 5% hydrogen (H_2).

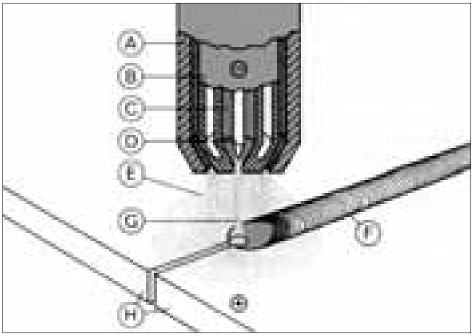


Figure 3.12. PAW

A = Insulating sheath
B = Water-cooled torch
C = Plasma gas forced into the arc
D = Tungsten electrode (non-consumable)
E = Shielding gas
F = Weld metal
G = Plasma jet
H = Parent metal

Keyhole mode welding

The so-called keyhole mode is normally used for full penetration PAW. The arc burns trough the material to form a keyhole. Flowing smoothly behind the arc, the molten metal forms the weld bead. Single pass keyhole mode welding is normally used for material thicknesses of up to 10 mm. Filler metal may or may not be used.

Remelt mode welding

Remelt mode PAW (sometimes referred to as "plasma TIG") is used for filling and, in particular, capping welds. The gas flows are much lower than in keyhole mode.

Penetration depth is generally 2 – 3 mm and filler metal is normally used.

Welding parameters

DCEN is used for PAW. Plate thickness determines the parameter range, i.e. current (refer to table 3.6).

Microplasma arc welding is a development of PAW. It uses extremely low currents (0.3 – 10 A) for welding stainless steels up to around 0.8 mm thick.

PAW (key hole) parameters Table 3.6

Material thickness mm	Current A	Welding speed cm/min	Filler wire diameter mm
2	120 – 130	40 – 60	1.0
4	150 – 160	30 – 40	1.2
6	160 – 180	25 – 30	1.2
8	200 – 250	15 – 20	1.2

Laser welding – high productivity and high quality

Characteristics

Laser welding is a high productivity welding method that is most suitable for thin sections (< 4 mm). However, stainless steels up to 10 mm can also be laser welded. Welding is normally autogenous (i.e. without filler metal), but a solid wire can be used if desired. Unless quench annealing is possible, filler wires should be used for high-alloy and high performance grades of stainless steel, e.g. 2205, 904L and 254 SMO.

In laser welding, the beam of single wavelength, coherent light is focused on a small spot. The two most common types of lasers are YAG and CO_2. Being generally of a lower power, YAG lasers tend to be used on thinner material.

As the beam can be delivered to the weld through fibre optic cables, YAG lasers are particularly suitable for robotic welding.

Laser welding produces a narrow and deep weld with a small heat-affected zone. Consequently, to obtain good results, the tolerances in edge preparation are tight. The root gap must not exceed 0.1 mm. In laser hybrid welding, laser welding is combined with other methods, e.g. MIG, TIG or PAW.

4 Welding techniques

Fit-up and tack welding

When fitting up joints, the requirements of the chosen welding procedure must be respected. The size and the regularity of the root gap are important factors here. Depending on thickness, joint configuration and the working practices that are observed, standard grades can generally be welded either with or without a root gap. Welding without a root gap is not advisable outside the MMA, TIG or submerged arc welding of thin plates/pipes (< 3 mm). In manual welding, a root gap generally makes it easier for root penetration to be consistently achieved.

Unless quench annealing is possible, there should always be a root gap when welding high performance grades of stainless steel. This is because the composition of the filler metal generally differs from that of the parent metal. The difference in composition is to counteract changes in metallurgical microstructure.

Recommended root gaps are shown in table 4.1.

Recommended root gaps Table 4.1

	Plate thickness < 4 mm	Plate thickness* > 4 mm
MMA, basic	0.3 x plate thickness	2.5 mm***
MMA, rutile	0.5 x plate thickness	3.0 mm***
MMA, AC/DC	0.7 x plate thickness	3.2 mm***
MIG	0.7 x plate thickness	2.5 – 3.0 mm
FCAW**	0.7 x plate thickness	2.5 – 3.0 mm
SAW	No root gap	No root gap

* V-joint, X-joint or K-joint welding
** The root gap when welding against a ceramic backing should be 4 – 6 mm.
*** When MMA welding, a useful rule of thumb for thicker gauges is that the root gap should be equal to the diameter of the core wire used in the first run.

Great care should be taken when tack welding sheets. The gap between the sheets must remain uniform along the entire length of the weld. If it is not, there may be inadequate penetration and significant deformation of the sheets.

Tacks should be welded from each end alternately and then in the middle of each space until the operation is complete. If welded from one end only, the plates will tend to pull together at the opposite end (see figure 4.1).

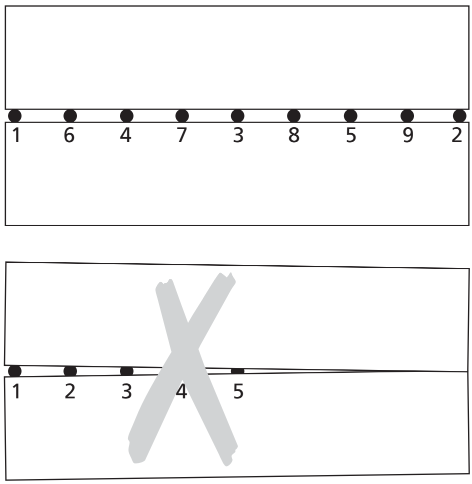


Figure 4.1. To avoid plate movement, tacks should be welded from each end alternately

As regards the spacing between tack welds, this should be considerably shorter for stainless steels than it is for mild steels. This is because, when heated, stainless steels expand more than mild steels (see also "The

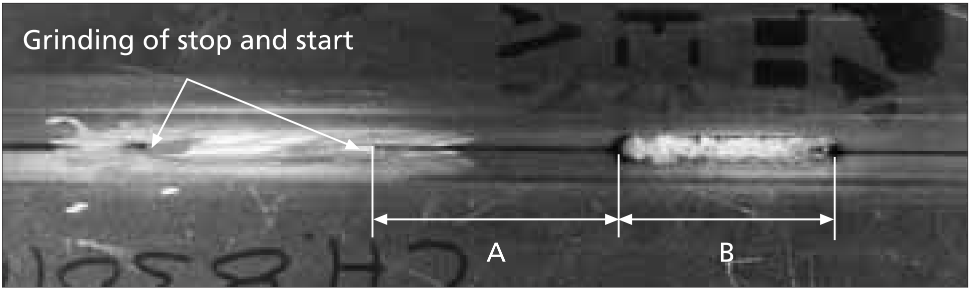


Figure 4.2. Grinding, length of tack welds and recommended distances between tacks for plate thickness > 6 mm (not to scale). A = 150 – 200 mm (NB! Not to scale); B = 20 – 30 mm

Spacing between tack welds — Table 4.2

Plate thickness, mm	Spacing, mm	Tack length, mm
1 – 1.5	30 – 60	5 – 7
2 – 3	70 – 120	5 – 10
4 – 6	120 – 160	10 – 15
> 6	150 – 200	20 – 30

physical properties of stainless and mild steel" in chapter 1 and in this chapter "Welding stainless to mild steel"). Recommended spacings are shown in table 4.2.

Tacks must be carefully ground off before welding. This should be done sequentially, i.e. weld, grind, weld, etc. (see figure 4.2). If welding from one side, the entire tack must be ground away.

Distance pieces, bullets or clamps (sometimes referred to as bridges or horses) can also be used for fitting up (see figure 4.3). This is especially so where plates are thick and the root side cannot be accessed.

Bullets and clamps should be made of stainless steel. All tacking (even temporary) of bullets and clamps should use a filler metal that is compatible with, and appropriate for, the metal being welded. Qualified welding procedures must always be used.

To avoid the risks of crack formation and misalignment, the number of distance pieces or clamps should be held to a minimum for two runs.

When tacking and removing the fit-up support, care should be taken not to contaminate or damage the surface of the stainless steel. Any damage or contamination should be carefully and thoroughly removed.

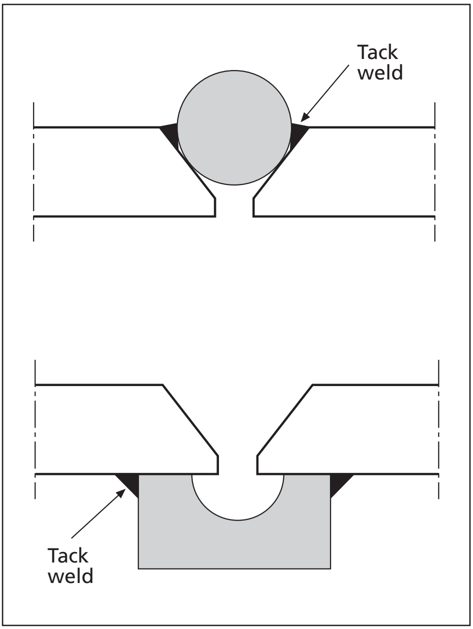


Figure 4.3. Distance piece (top) and bridge to fit up the joint

Planning the welding sequence

Starts and stops (striking and extinguishing the arc)

Every weld (manual, mechanised or automated) has starts and stops. Each start and stop is locally critical as regards corrosion resistance, mechanical properties and structural integrity. For example, stray arcing on the plate surface can have a negative effect on local corrosion performance. Consequently, the arc should be struck at a point in the joint itself. Stray arcing on the plate must be removed by grinding followed by proper repair welding.

When welding small components, or where access is difficult, the arc should be struck/extinguished on run-on/run-off plates.

Rutile and rutile-acid (AC/DC) electrodes are easily struck. Basic electrodes, on the other hand, are slightly more difficult to ignite and re-ignite.

Arcs must always be extinguished carefully. This is done by making a few circular movements over the centre of the weld pool, moving the electrode about 10 mm back through the weld and lifting gently. Removing the electrode quickly from the weld pool entails a great risk of crater cracks (see also chapter 5). Many modern power sources have crater-filling facilities.

To remove end craters, and minimise the risk of inclusions, the start and stop of each weld should be carefully ground before continuing with the next run.

Root runs (single or double sided welds)

Butt welding is easiest when it is double-sided. This makes full penetration on the root side unnecessary. Prior to welding the second side, double-sided welds should be cut back cold to clean, sound metal. Liquid penetrant testing can be used to confirm the soundness of the metal. Punch-through techniques should not be used.

In some cases (e.g. pipes), double-side welding is not possible. Single-sided, unsupported root passes are most commonly deposited using either TIG or MMA welding. MMA may be used where it is possible (or not important) to de-slag the penetration bead. TIG welding is used for weld deposits of the highest quality or where de-slagging access is restricted. Joint preparation for a single-sided root pass has to be particularly precise. The root gap must be perfect.

The following should be borne in mind:

- When welding thin plates or thin-walled tubes (max. 4 mm), the use of an appropriately sized (e.g. 2 mm) grinding disc ensures a consistent root gap. Such a disc is also useful when the root gap has decreased after tacking.
- For best arc and melt control, use small diameter (max. 3.25 mm) covered electrodes.
- PW or PWX type electrodes give best weldability.
- Welding should be performed with a short arc. The longer the arc, the less the penetration.
- For a nicely shaped root bead and minimum oxidation when TIG welding, a backing gas (purging gas) should be used. To ensure good corrosion properties, welds made without a backing gas must be subsequently pickled. See also “Backing gases” in chapter 8.
- For maximum penetration, the electrode should be inclined as little as possible in relation to the workpiece.

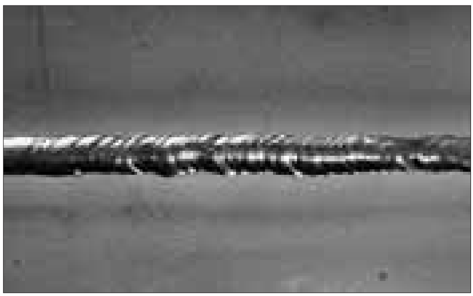


Figure 4.4. Root run on thin plate

Root runs must satisfy three crucial criteria. The welds must be:

- metallurgically sound
- geometrically sound
- deposited cost efficiently.

The run deposited on top of the root run (i.e. run number 2) is called the “cold run”. To avoid any possibility of deleterious phases, the cold run must not excessively reheat the root bead. As regards stainless steels, this is much more of an issue with high performance grades than it is with standard grades.

Root runs against ceramic backing

The use of ceramic backing strips can be advantageous in single-sided welding. Such backings are widely used for on-site FCAW (e.g. in chemical carrier construction). The shape of the backing is determined by joint preparation and welding position. The two most common shapes are flat and round bar (see figure 4.5). To achieve the best possible root surfaces, a backing suitable for stainless steel must be used. It is also very important that there is minimum misfit between plate and backing. The root gap when welding against a ceramic backing is normally 4 – 6 mm.

Fill passes

Fill passes normally use the same filler as the root run. However, other methods with higher deposition rates can, in many cases, be advantageous. Some common choices are:

- TIG root pass – MMA or SAW fill pass
- MMA root pass – SAW or FCAW fill pass
- TIG root pass – MIG fill pass

Fill passes must, most importantly, ensure that the necessary mechanical properties and structural integrity are obtained. Corrosion performance is only an issue on the relatively rare occasions where end grain is exposed.

X or double U-joints (normally recommended for plate thicknesses > 15 mm) can be welded with alternating runs on each side. This minimises plate deformation.

Two requirements determine the heat input for fill passes. The economic production of geometrically sound welds demonstrating the required properties is one of these. The other is the need to maintain both the corrosion performance and the mechanical performance of the root region.

Cap passes

In cap passes, corrosion performance is once again a major consideration. For this reason, heat input must be determined in the same way as it is for root and cold passes (i.e. the right input to achieve the desired balance of corrosion performance, mechanical properties and structural integrity). The correct appearance/shape of the cap pass/passes is critical for good corrosion resistance. Excessive metal, undercuts, unevenness and crevices are all not normally allowed. Aesthetic factors may also have to be taken into consideration.

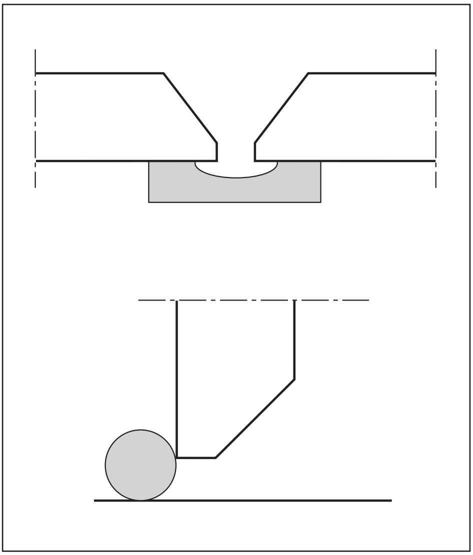


Figure 4.5. Ceramic backings – flat and round

Stringer beads versus weaving

Especially in flat (PA/1G) and horizontal-vertical (PC/2G) positions, stainless steels are normally welded using stringer beads (see figure 4.6).

Weaving can be used in both flat and vertical-up (PF/3G) positions. In the flat position, weave width should not exceed 4 times the diameter of the electrode. This is because of the risk of slag being included each time the electrode changes direction. In the vertical-up position, the width of the weave can be up to 20 mm. Consequently, using a weaving technique rather than stringer beads means that the number of runs can be drastically decreased. For example, with FCAW, a 15 – 18 mm plate can be welded in only three runs, as compared to 8 – 12 runs with stringer beads. This dramatically reduces welding costs.

Using a weaving technique, the travel speed is much lower than with stringer beads. However, the heat input cannot be calculated using the formula given in chapter 2, "Heat input". Furthermore, the solidification direction changes with every weave. Compared to using stringer beads, weaving considerably lowers the risk of hot cracking.

Vertical-up and vertical-down welding

All welding methods, except submerged arc, can be used in the vertical-up position.

MIG welding in the vertical-up position must be with a short or a pulsed arc. It is normally only used for relatively thin plates (less than 3 – 4 mm) and is usually carried out in one run with a very small melt pool. MIG welding in the vertical-down position is also possible. This requires a pulsed arc welding machine and a low parameter set-up.

TIG welding is possible in all positions. The weld pool and weld thickness are once again relatively small.

The slag forming methods, MMA and FCAW, have the advantage that thick plates can be welded easily and with relatively few passes in all positions. The slag freezes, supports the weld pool and prevents it from running. Relatively large weld pools are thus possible. Consequently, compared with other methods, fewer passes are necessary and total welding time is reduced.

A weaving technique is normally used for vertical-up MMA and FCAW. As shown in figure 4.7, the torch or electrode should be held more or less at right angles to the workpiece.

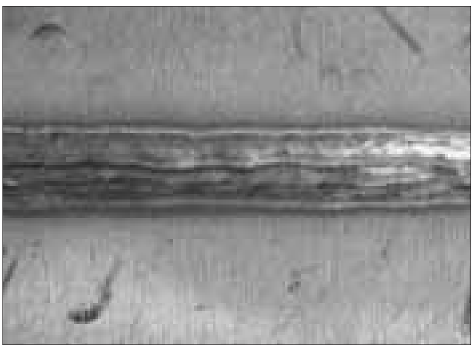


Figure 4.6. Stringer beads in PC position

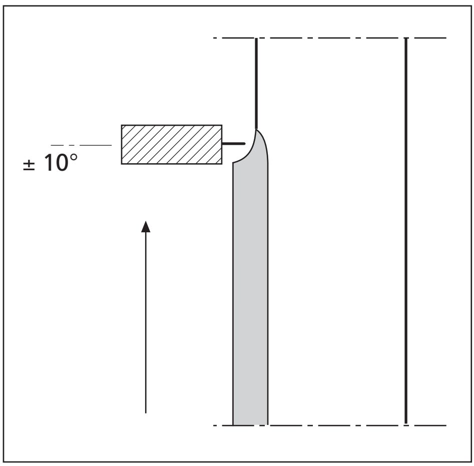


Figure 4.7. Vertical-up welding

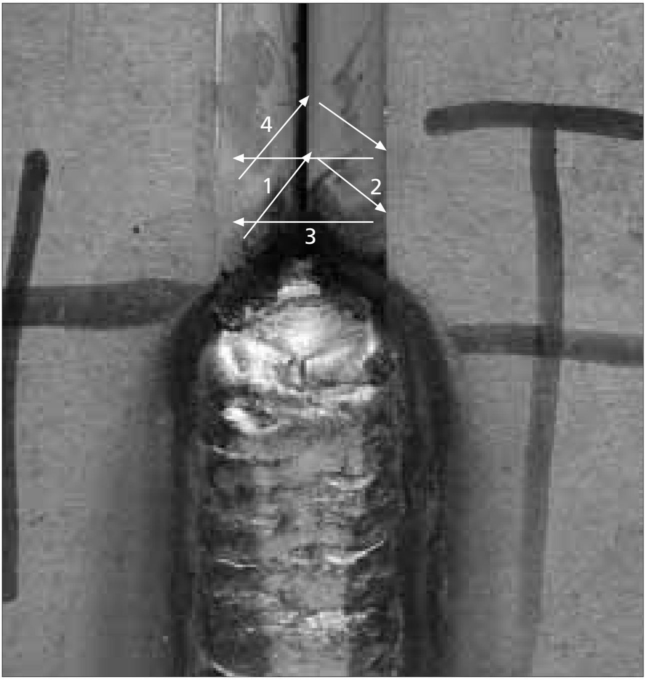


Figure 4.8.
Vertical-up welding using the "in and out" technique

An "in and out" weave, with the torch manipulated in a "side-centre-side" triangle (see figure 4.8), can be used. Care must be taken when changing direction. The slag from the preceding pass must always be remelted when welding in the reverse direction. Failure to do this will commonly result in the formation of slag inclusions.

Compared to horizontal welding, the current in vertical-up welding is typically 40 – 60 A lower for FCAW and 10 – 30 A lower for MMA.

For vertical-down welding, the best option is MMA with VDX type electrodes. The coating of these electrodes is purpose-designed for vertical-down welding. For fillet or overlap welds, vertical-down FCAW is a further possibility. The torch or electrode should be inclined at about 15° to the plate (see figure 4.9).

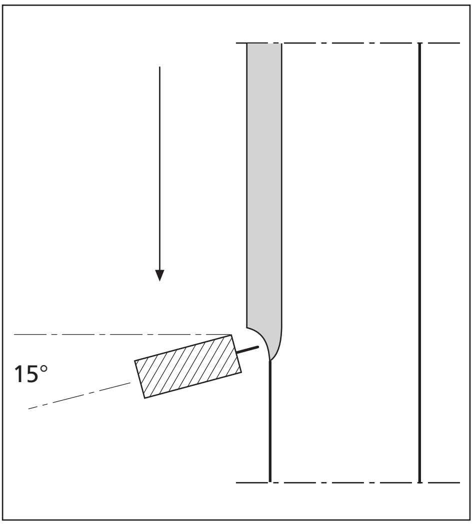


Figure 4.9. Vertical-down welding

Backhand versus forehand welding
Holding the torch at different angles gives different welding results. Backhand (drag angle) and forehand (lead angle) welding are shown in figure 4.10. Table 4.3 summarises the differences between backhand and forehand welding.

The differences are most apparent when MIG welding. Nonetheless, changes in torch angle can also have significant effects in SAW. For best results in FCAW, the torch is generally not angled. For optimum weld pool control in MMA welding, a forehand technique is normally used.

Backhand versus forehand welding Table 4.3

Backhand welding	Forehand welding
+ Increased penetration + Increased arc stability – Increased risk of undercuts – Narrow weld bead – Decreased fluidity	+ Wider and more concave weld bead + Easier and better control of arc and melt pool + Smoother weld surface + Improved gas shield – Decreased penetration

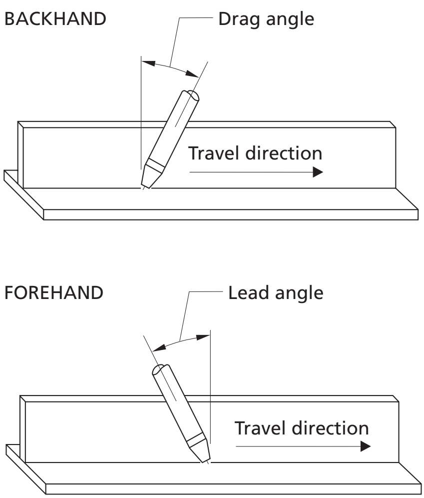


Figure 4.10. Backhand and forehand techniques

Width and depth
Width and depth are two major factors in achieving a good weld. Both are closely related to current, voltage and travel speed. However, other welding parameters such as electrode size, stick-out, torch angle and shielding gas can also influence weld shape.

Figure 4.11 depicts the effects of voltage, current and travel speed on the shape of the weld bead.

Arc current is the parameter having the strongest effect on parent metal penetration. A higher current enhances penetration, but also increases the risk of burn-through and solidification cracking. Too low a current gives low penetration and a great risk of lack of fusion or other root defects.

Arc voltage strongly influences the shape and width of the weld bead. To some extent, it also affects weld depth. High voltage gives a very wide bead with the risk of undercuts and even a concave shape. Too low a current gives a very peaky, erratic and convex weld. In both cases, any slag can be hard to remove.

Travel speed also has an effect on penetration. Increased travel speed normally reduces penetration and gives a narrower weld bead. Decreased speed often improves penetration and results in a wider weld.

With a constant current, an increase in **electrode or wire diameter** reduces current density. This normally reduces penetration and metal deposition rate. Besides these effects, the use of, for example, excessively large diameter consumables in root runs also restricts access, increases the size of the weld pool and makes it more difficult to achieve the desired penetration and profile characteristics.

Electrical stick-out (SAW, MIG and FCAW) is the distance between the contact tip and the workpiece. This distance affects the resistive heating of the electrode tip. A short stick-out

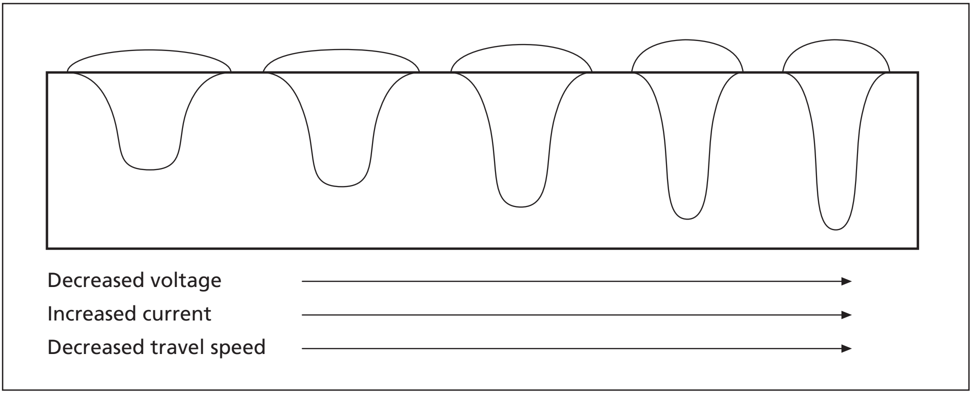


Figure 4.11. The influence of current, voltage and travel speed on bead shape

gives low resistive heating and, consequently, deep penetration. Increasing the stick-out raises resistive heating (i.e. the electrode becomes warmer); the metal deposition rate improves and penetration falls. Particularly in overlay welding, increased stick-out is used to maximise the metal deposition rate.

Distortion

Stainless steel is subject to greater distortion than, for example, C-Mn steel. Below, there are several points and recommendations regarding distortion control.

- Use double-sided welding (X-joint) rather than single-sided (V-joint).
- The transverse shrinkage in butt welds decreases with decreased root gap.
- The transverse shrinkage in butt welds also decreases with decreased bevel angle.
- Transverse shrinkage decreases with increased degree of restraint.
- Presetting the plates (see figure 4.12) can help control angular distortion.
- Distortion is reduced by using balanced welding sequences and techniques. These may incorporate block and back-step welding sequences (see figure 4.13). Intermittent welding can help combat distortion.
- Using clamps, fixtures or a sufficient number of tack welds, combats distortion. To various extents, all these measures increase restraint.
- As excessive welding promotes distortion, it is important to optimise the size of the weld.
- Heat input control may be necessary to minimise distortion.

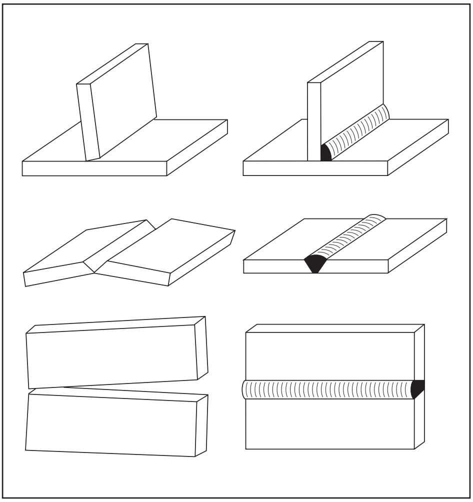


Figure 4.12. Presetting of butt and fillet welds

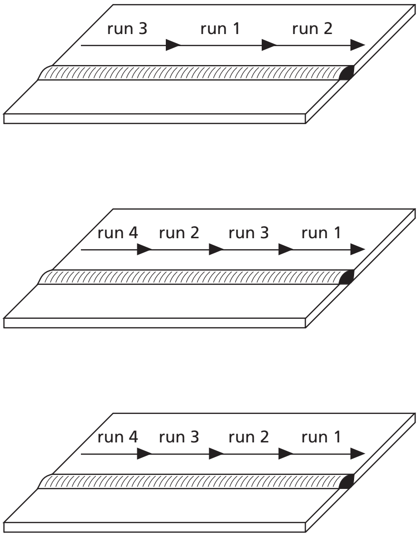


Figure 4.13. Block welding sequences

It is not normally necessary to preheat the mild steel before welding. However, slight preheating (max. 100°C) is advisable:

- when welding cast steel
- if there is a high degree of restraint
- if there are large differences in dimensions.

As there is a significant risk of pore formation, welding to primer-coated sheet should be avoided. The paint should be removed from all surfaces that are likely to be exposed to temperatures above 500°C (i.e. approximately 20 – 30 mm from the weld).

Welding stainless to mild steel

When welding stainless to mild steel, great attention must be paid to cleanliness, dilution and type of filler metal. As detailed in "Dissimilar welding" in chapter 12, an over-alloyed filler should be used. This is to compensate for dilution with the mild steel.

When welding stainless steel to unalloyed or low-alloy steels, it is advisable/necessary to reduce the dilution of the weld as much as possible. Thus, heat input should be limited and an appropriate bevel angle should be used. The arc must not be aimed directly at the mild steel side. In manual welding, it is advisable to angle the torch slightly towards the stainless steel. In SAW, a slight offset of 1 – 2 mm towards the stainless steel is a good idea (see figure 4.14).

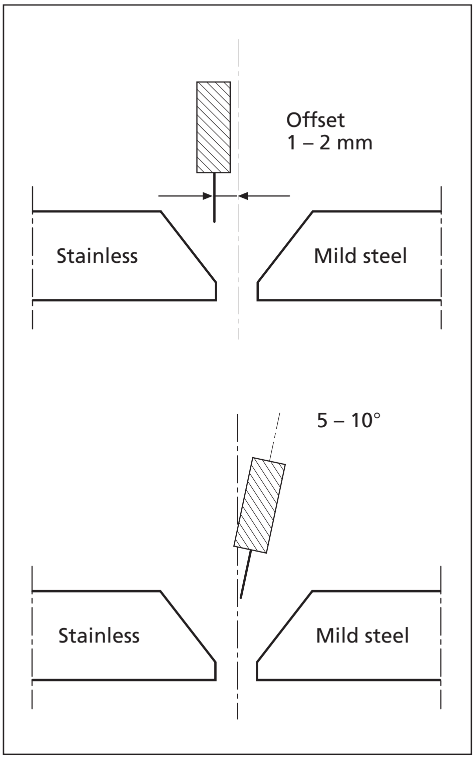


Figure 4.14. Mild steel dilution is minimised by an offset of 1 – 2 mm (SMAW) and by angling the torch towards the stainless steel (MMA, FCW and MIG).

Overlay welding

In applications demanding a corrosion or wear-resistant surface, overlay welding (also called cladding or surfacing) of low-alloy steel is often chosen as an alternative to using clad steel plates or homogenous stainless steel. All types of welding methods can be used for overlay welding. In this case, the main differences between the methods are deposition rate and dilution with the parent metal.

The properties of the weld metal are generally determined by the chemical composition of the deposit. Various combinations of welding methods, consumables, fluxes and welding parameters can be used in overlay welding. Whether overlaying uses one or several layers depends on the welding method used and the stipulated requirements. Type 309L (23 12 L) or P5 (24 12 3 L) consumables are normally used for the first layer.
A consumable with a chemical composition satisfying the stated requirements is used for the final layer(s).

To reduce stress in the component, post-weld heat treatment (PWHT) is often carried out after overlaying. Due to the transformation of ferrite into sigma phase, PWHT reduces the ductility of high-ferrite overlays. Thus, a maximum ferrite content of 8 – 12% is often stipulated. This must be borne in mind when choosing the electrodes, wire or wire/strip and flux combination.

Overlay welding is common in all types of industries where surfacing or repair is required, e.g. the chemical, nuclear, petrochemical and paper industries.

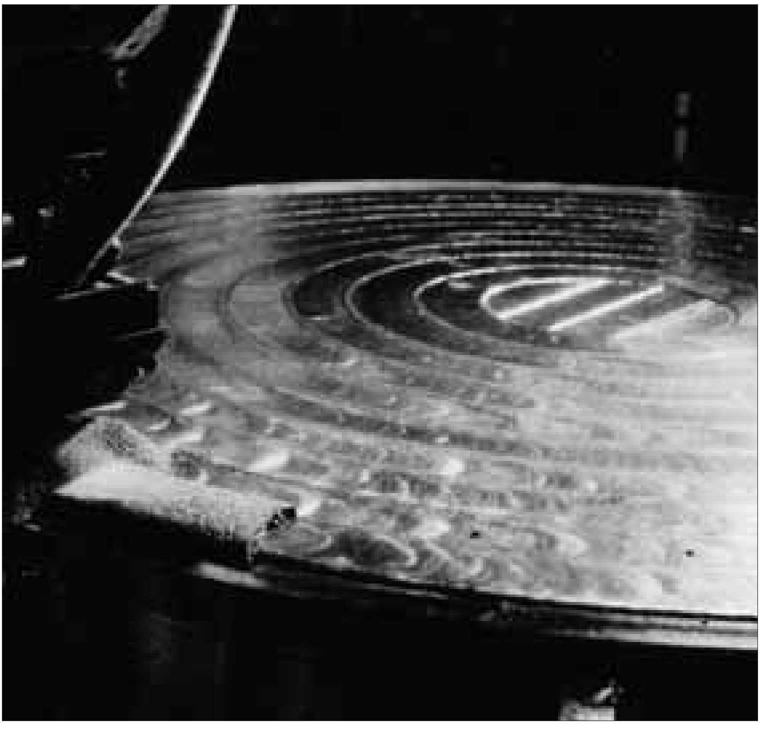


Figure 4.15.
Overlay welding of a heat exchanger end cheek

Carbon content

To minimise the risk of intercrystalline corrosion due to chromium carbide precipitation, carbon content should be held reasonably low (normally less than 0.05%). Using consumables with a maximum carbon content of 0.030% (and observing the recommended welding parameters) this is not usually a problem, even in the first layer. With a two-layer surfacing the carbon content is never higher than 0.03%, which is the maximum allowed for extra low carbon (ELC) steel. Low carbon content also reduces the risk of sensitisation when PWHT is carried out.

Submerged arc strip welding (SAW)

Submerged arc strip welding is the same as conventional SAW except that, instead of wire, strips of various widths are used (30, 60 or 90 mm). The width is determined by the shape of the component to be surfaced. Strip thickness is normally 0.5 mm.

Compared to wire surfacing, strip surfacing is characterised by a high deposition rate and a low and uniform dilution. The cross sections of overlay welds using strip and wire are shown in figure 4.16.

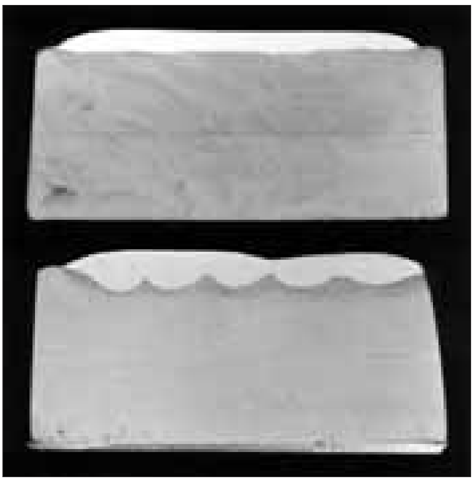


Figure 4.16. Weld bead shape – strip versus wire

The overlay deposit exhibits relatively low dilution (typically 10 – 20%) from the parent metal. Thanks to the good fusion characteristics, a high alloy content is achieved in the first layer. Consequently, a minimum number of layers is required to achieve a particular final deposit composition. Table 4.4 gives examples of some overlay deposits.

Differing only slightly with travel speed, normal penetration is about 1 mm. The surface appearance is superior to that obtained using any other welding technique.

Welding parameters have a great effect on bead thickness and dilution. Figures 4.17 and 4.18 show the effect of travel speed on thickness and dilution respectively. The figures use a constant current (750 A) and voltage (26 V). A suitable thickness for the first layer is 3.5 to 4.5 mm.

To obtain the desired weld metal composition, choosing the right combination of strip electrode and flux, together with the correct welding parameters, is of the utmost importance.

Mainly in terms of current capacity and slag density, the fluxes used for strip surfacing

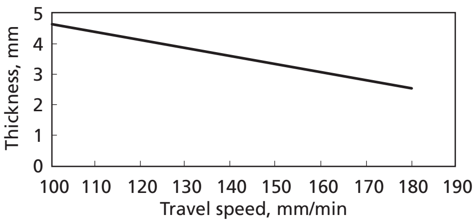


Figure 4.17. Travel speed and thickness

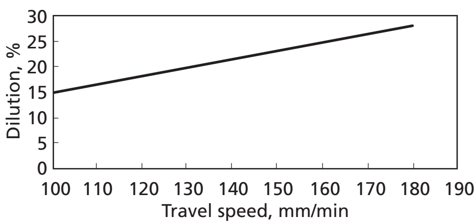


Figure 4.18. Travel speed and dilution

usually differ slightly from wire welding fluxes. Strip surfacing fluxes are normally agglomerated, slightly basic and have a small addition of chromium.

Electroslag welding (ESW)

Electroslag welding is a development of submerged arc strip cladding. The basic difference is that ESW utilises a conductive slag (instead of an electrical arc) to transfer the melted strip. The lower penetration of ESW greatly reduces dilution with the parent metal. For this reason, ESW is normally carried out in a single layer (see table 4.4 for examples of overlay deposits).

The flux used in ESW differs from that used in SAW and cannot be alloyed. The heat input is also generally higher than in SAW. Consequently, the mild steel has to be slightly thicker. The melt pool in ESW is larger than that in SAW. This makes it difficult to clad cylindrical objects that have a diameter of less than 1,000 mm.

Submerged arc wire welding (SAW)

Using wire instead of strip gives a much smaller weld pool. This is a great advantage when surfacing small objects of a complex design. Productivity, on the other hand, is much lower, but can be increased by using two or more wires.

As shown in figures 4.11 and 4.19, welding parameters, torch angle and torch position can have a considerable effect on dilution (see table 4.4 for examples of overlay deposits).

When surfacing cylindrical objects, welding is best performed in a slightly downhill position. The influence of the various welding parameters is detailed in ”Width and depth”. In addition to the measures given there, dilution can also be lowered by switching the polarity to DC-. However, this gives a slightly rougher weld bead surface.

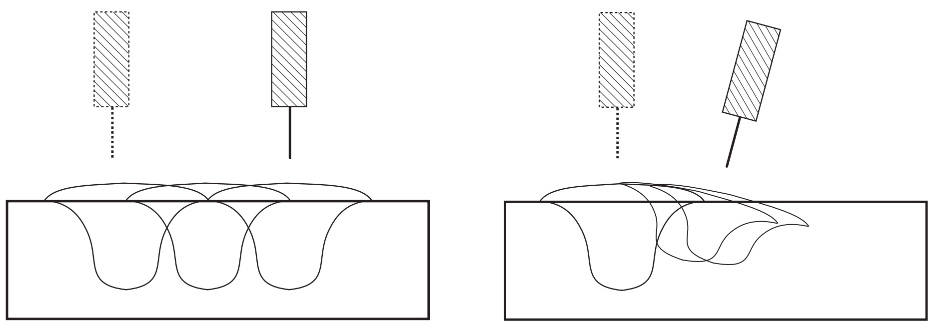
Covered electrodes (MMA)

Covered electrodes are widely used for surfacing small components or when position welding is necessary. As dilution from the parent metal is rather high, more than one layer is normally required (see table 4.4 for examples of overlay deposits).

The effect of torch angle and torch position is depicted in figure 4.19. When surfacing cylindrical objects, welding is best performed in a slightly downhill position.

Compared to other overlaying methods, the use of covered electrodes has the advantage that special coatings (e.g. with a controlled ferrite content) can be purpose-designed for the job in question.

The deposition rate, which is generally rather low, can be improved by using type HX high recovery electrodes.



Vertical torch and little overlap gives high dilution.

Slightly angled torch (10 – 15°) and large overlap gives low dilution.

Figure 4.19. Effect of torch angle and torch position on dilution

Gas metal arc welding (GMAW) and Flux cored arc welding (FCAW)
Due to the development of new welding machines (e.g. synergic pulsed machines), GMAW/FCAW is becoming more widely used for overlaying. The vertical-up overlay welding of digesters in the pulp and paper industry is an example of this. Welding is carried out using a spray or pulsed arc, often in a fully automatic welding machine that has an oscillating torch. Oscillation amplitude and frequency are normally 20 – 50 mm and 40 –- 80 cycles per minute respectively. Compared to stringer beads, oscillation has the advantage that dilution with the parent metal is lower and the resultant surface is more attractive.

Welding is normally performed in two or more layers (see table 4.4 for examples of overlay deposits). The effect of torch angle and torch position is depicted in figure 4.19. When surfacing cylindrical objects, welding is best performed in a slightly downhill position.

Surfacing – examples of chemical composition of overlay deposits Table 4.4

Method	Final layer[1]	Filler	Layer	Flux	Composition of weld metal, weight-%						Ferrite	
					C	Si	Mn	Cr	Ni	Other	FN[2]	%[3]
SAW (strip)	347	309L	1	301	0.03	0.5	1.2	19.0	10.5	–	5	5
		347	2	301	0.02	1.0	1.0	19.7	10.5	Nb 0.30	10	7
	347	309LNb	1	301	0.04	0.5	1.3	19.5	10.5	Nb 0.60	6	5
		347	2	301	0.02	0.5	1.2	19.0	10.5	Nb 0.35	7	5
	308L	309L	1	301	0.03	0.5	1.2	19.0	10.5	–	5	5
		308L	2	301	0.02	1.1	0.6	18.6	10.3	–	10	7
ESW (strip)	347	309LNb	1	ESW-flux	0.03	0.5	1.5	19.6	10.5	Nb 0.65	8	8
SAW (wire)	347	309L	1	805	0.03	0.5	1.4	22.0	13.5	–	7	6
		347/MVNb	2	807	0.04	0.6	0.8	19.0	10.0	Nb 0.70	6	5
	316L	P5	1	805	0.03	0.7	1.4	20.5	14.0	Mo 2.3	5	6
		316L/SKR	2	807	0.02	0.6	1.2	19.5	10.0	Mo 2.5	8	7
MMA	347	309L	1	–	0.03	0.8	1.3	22.5	13.5	–	9	9
		347/MVNb	2	–	0.02	0.8	1.1	19.0	10.0	Nb 0.30	7	6
	904L	904L	1	–	0.04	0.6	0.9	18.0	21.0	Mo 3.5	–	–
		904L	2	–	0.02	0.7	1.2	21.0	24.5	Mo 4.3	–	–
		904L	3	–	0.02	0.7	1.2	21.0	24.7	Mo 4.4	–	–
	P690	P690	1	–	0.05	0.5	1.9	26	45	Nb 1.0	–	–
		P690	2	–	0.03	0.5	2.3	29.5	51	Nb 1.6	–	–
		P690	3	–	0.03	0.5	2.3	30.5	53	Nb 1.6	–	–
FCAW	316L	P5	1	–	0.04	0.5	1.5	21.0	11.5	Mo 2.1	8	6
		316L	2	–	0.03	0.6	1.4	18.5	12.5	Mo 2.8	9	7
	347	309L	1	–	0.04	0.5	1.5	21.5	11.0	–	8	6
		347	2	–	0.03	0.4	1.6	19.0	10.0	Nb 0.60	8	7

1 Composition of final layer as stipulated by AWS
2 Ferrite according to Schaeffler-DeLong
3 Ferrite measured in % using Fischer Feritscope® MP-3

Welding clad steel plates
All methods with shielded arcs can be used for welding clad steel plates. The chemical composition and the thickness of the weld metal in the top layer must correspond to that of the cladding metal.

Edges are normally prepared for V, X or U-joints. The best methods of edge preparation are milling or plasma cutting followed by grinding smooth.

The plates used for V-joints may or may not have pre-milled edges (figures 4.20 and 4.21 respectively). In the latter case 4 – 8 mm of the cladding must be ground away on each side of the groove prior to welding.

Plates over 20 mm thick are best welded using an X or U-joint. Where plates do not have pre-milled edges, 4 – 8 mm of the cladding must be ground away on each side of the groove. Figure 4.22 shows an X-joint.

To minimise welding on the clad side, it is advisable for edges to be prepared asymmetrically. Mild steel electrodes should never be used when welding on the clad steel side.

As far as possible, always start from the mild steel side when welding clad plates. Suitable mild steel consumables should be used. The prime concern is preventing the root bead from penetrating the cladding.

The first bead on the clad side must be deposited using a type 309L or P5 over-alloyed electrode. At least one layer should be welded before capping with a consumable that has a composition matching that of the cladding.

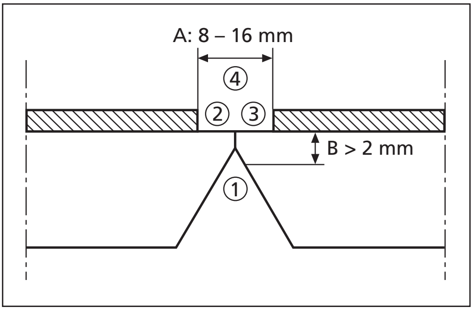


Figure 4.20. V-joint (thickness < 20 mm) – pre-milled plates

Bevel angle:	60 – 70°
Root land:	1.5 – 2.0 mm (+ clad plate)
Root gap:	0 – 3 mm
Pre-milling (A):	8 – 16 mm (4 – 8 mm at each plate edge)

① Welding from mild steel side using mild steel consumables.
② Grinding, or gauging followed by grinding, to at least 2 mm below the cladding (B).
③ Welding from the clad side using type P5 or 309L electrodes (minimum one layer).
④ Welding with consumables that match the cladding (minimum one layer).

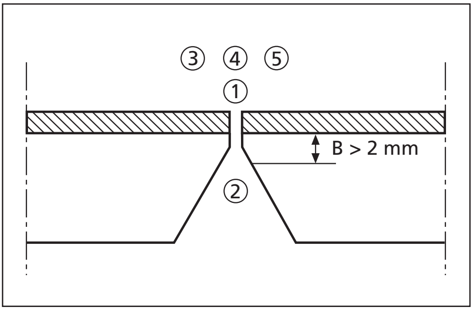


Figure 4.21. V-joint (thickness < 20 mm) – plates not pre-milled

Bevel angle:	60 – 70°
Root land:	1.5 – 2.0 mm (+ clad plate)
Root gap:	0 – 3 mm

① Grinding away of cladding, 4 – 8 mm on each side of the groove.
② Welding from mild steel side using mild steel consumables.
③ Grinding, or gauging followed by grinding, to at least 2 mm below the cladding (B).
④ Welding from the clad side using type P5 or 309L electrodes (minimum one layer).
⑤ Welding with consumables that match the cladding (minimum one layer).

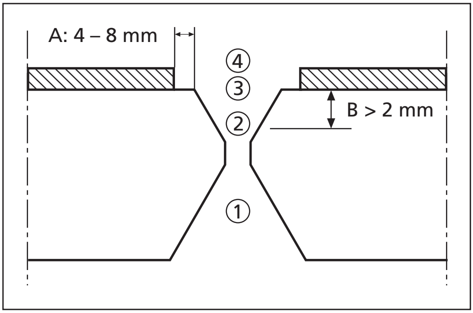


Figure 4.22. X-joint (thickness > 20 mm)

Bevel angle:	60 – 70°
Root land:	1.5 – 2.0 mm (+ clad plate)
Root gap:	0 – 3 mm
Pre-milling (A):	4 – 8 mm

NB! If plates are not pre-milled, 4 – 8 mm of the cladding must be ground away on each side of the groove.

① Welding from mild steel side using mild steel consumables.
② Grinding, or gauging followed by grinding, to at least 2 mm below the cladding (B).
③ Welding from the clad side using type P5 or 309L electrodes (minimum one layer).
④ Welding with consumables that match the cladding (minimum one layer).

Dilution with the mild steel should be kept as low as possible by reducing the current and by directing the arc to the centre of the joint.

In cases where welding can only be performed from one side (e.g. in pipes), all welding should be carried out using stainless steel electrodes of a suitable composition.

All welding, grinding and cutting must be carried out with great care, so that the stainless steel surface is not damaged by spatter, contamination or grinding scars. Cardboard or chalk-paint can be used to protect the surrounding clad surface.

Repair welding

The repair of welding imperfections must, when stipulated, be carried out in a proper manner. Small imperfections such as spatter or scars are normally only ground off using a suitable grinding disc. Note that a grinding disc intended for stainless steels only should be used. The repaired area should then be pickled and passivated in the conventional way. Especially for fully austenitic and duplex steels, TIG remelting (TIG dressing) of imperfections is not recommended. This is because remelting changes the mechanical and corrosion properties of the affected area.

Larger and more severe imperfections require heavier grinding. The ground area must then be filled using a suitable welding consumable.

Where there are internal imperfections in heavy sections, a gauging operation may be required. Air gauging should be used in such cases. Because of the risk of carbon pick-up, gauging with a carbon arc is not recommended for stainless steels. Before repair welding starts, the gauged area should be ground off (1 – 2 mm is normally necessary) to sound metal.

Gauging and repair can be carried out several times without harming the surrounding metal. However, with both gauging and repair, great care must be taken as regards spatter. Use cardboard, chalk-paint or any other suitable protection to shield all surrounding areas.

It is always advisable to establish and follow suitable repair procedures.

5 Weld imperfections

Introduction
Weld imperfections may affect a weld's serviceability. *Imperfection* is a general term for any irregularity or discontinuity in a weld. A *defect* is a type of imperfection that has a negative impact on serviceability and usability. Acceptance levels for the various types of imperfections are set out in, for example, ISO 5817. This standard also has a system of three quality levels – B, C and D. Level B is the most severe and is normally only required where demands are extremely high, e.g. in the welding of pressure vessels.

This chapter examines some of the common imperfections directly associated with the welding process. It also details common causes of imperfections and typical ways of remedying and avoiding imperfections.

The terminology of EN 1792 is used in the section headings giving the names of imperfections. Alternative "shorthand" or "everyday" names are also used in the main text. These would not normally be regarded as the accepted names.

Inspection
To at least the level of visual inspection by the welder, it is good practice to inspect all welds. A range of nondestructive tests can be used for welds in stainless steels (see table 5.1).

Visual and PT are the most common forms of inspection. Visual inspection can be "formal" (undertaken by a qualified quality controller) or "informal" (a welder inspecting his or her own work).

Radiography and UT are used for high integrity work and to inspect for volumetric imperfections.

Formally qualified inspectors should always use qualified inspection procedures. Welders who undertake inspection should be aware of what they are looking for and what is acceptable.

Weld quality should be judged against a set of recognised weld acceptance criteria (WAC) detailing when an indication or imperfection becomes a defect. Design codes, contract technical specifications, etc. normally establish the relevant WAC.

Inspection Table 5.1

Method	Scope	Generic stainless steel Ferritic	Austenitic	Duplex
Visual	Surface breaking	A	A	A
Penetrant (PT)	Surface breaking	A	A	A
Radiography (RT)	Volumetric	A	A	A
Eddy current	Surface breaking and near surface	L	L	L
Ultrasound[1] (UT)	Volumetric	(A)	(A)	(A)
Magnetic Particle Inspection (MPI)	Surface breaking	A	NA	NA

[1] Metal thickness and grain size may limit the efficiency of inspection.

A = Applicable
(A) = Applicable with care
L = Limited applicability
NA = Not applicable

Lack of fusion

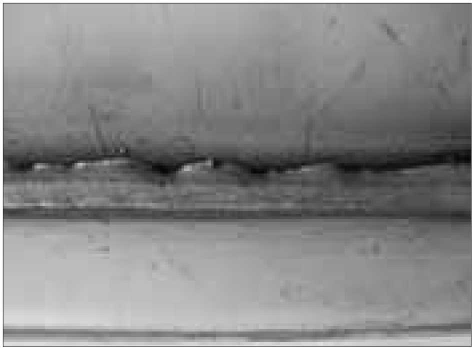


Figure 5.1. Lack of fusion – MIG

Alternative names

- Lack of sidewall fusion
- Lack of inter-run fusion
- Lack of root fusion

Importance

This is normally a serious imperfection that can only be accepted, to a limited extent, at the lowest quality level. It has adverse effects on mechanical and corrosion properties as well as structural integrity.

Incidence

Lack of fusion can occur with all welding methods, but is more common in the MIG welding of heavy gauges and the FCA welding of narrow joints.

Detection

Lack of fusion can be surface breaking or buried. Surface breaking imperfections can be detected visually, though PT (and even RT) is generally used. RT and UT are used to detect buried imperfections.

Common causes

Lack of fusion occurs when the melt pool is too large or when travel speed is so low that the weld pool runs ahead of the arc. Narrow joint angles (less than ~60°) and unfavourable welding positions (e.g.vertical-down) both have a negative impact.

If the melt pool is too cold or too small, non-molten edges may give rise to a lack of fusion.

Typical solutions

- Ensure that the travel speed and the wire speed/current are suitable for each other.
- Avoid welding in narrow/tight joints. If necessary, prior to welding, grind slightly to open the joint.
- In MIG welding, weld bead penetration is wider when CO_2 or He is added to the shielding gas.

Incomplete penetration

Alternative name
- Lack of penetration

Importance
Full penetration is essential for structural integrity and good mechanical and corrosion properties.

Incidence
Care must be taken with all welding methods and with single and double-sided welds. It is more difficult to ensure adequate, consistent penetration with viscous weld pools. Compared to standard 300 series, high-alloy grades present slightly greater problems.

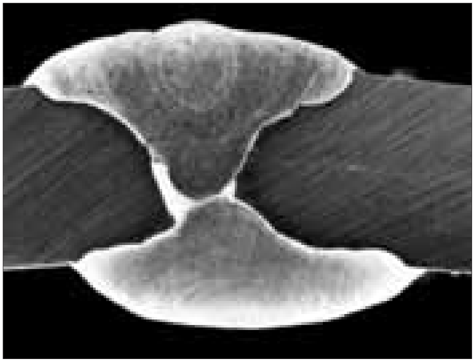


Figure 5.2. Incomplete penetration of a 2205 MIG weld

Detection
Incomplete penetration can be detected by visual inspection, PT, RT or UT.

Common causes
- Root gap too narrow or the bevel angle too small.
- Diameter of the welding consumable too large.
- Incorrect welding parameters, i.e. too low current or too high voltage.

Typical solutions
- Increase the root gap (a common gap is 2 – 3 mm).
- Adjust the welding parameters (e.g. increasing the current while decreasing the travel speed improves penetration).
- The angle of the welding torch is very important. A “leading” angle (torch angled towards the travel direction) increases penetration.
- Grinding followed by a sealing run on the second side is sometimes used to ensure full penetration.

Solidification and liquation cracking

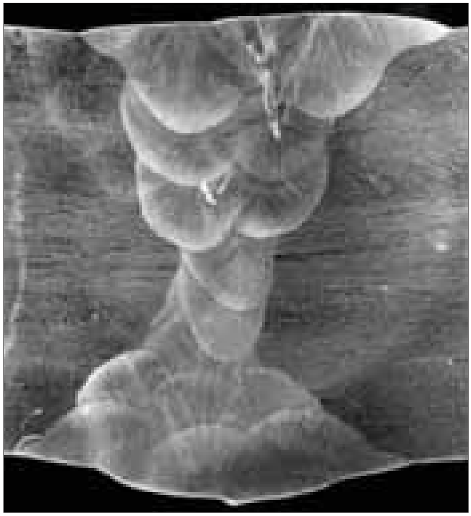


Figure 5.3. Solidification cracking in a SAW weld (t = 20 mm)

Alternative name

- Hot cracking

Importance

Solidification and liquation cracking both have a detrimental effect on corrosion performance and structure. In the worst cases, cracking can result in component failure. A small amount of microfissuring ($h \times l < 1\ mm^2$) may be acceptable under certain codes.

Incidence

Fully austenitic steels are generally more sensitive to hot cracking than steels containing some ferrite. Dissimilar joints between, for example, stainless and mild steels are also more sensitive.

Detection

Solidification cracking, and possibly liquation cracking, may break the weld surface and can thus be detected by visual inspection or PT. Buried cracks can be detected by UT or, in some cases, RT. Examination of weld cross sections, e.g. during welding procedure qualification, can indicate the propensity to solidification and liquation cracking.

Common causes

- Solidification cracking – caused by a combination of high tension, unfavourable solidification directions and segregation of contaminants during solidification of the weld bead. Cracking is generally intergranular.
- Liquation cracking in the weld or HAZ – this is associated with multipass welding (mainly SAW). Repeated welding passes may cause remelting of secondary phases. In combination with high restraint, this may lead to cracking. Crack morphology is generally intergranular.

Typical solutions

- Avoid/reduce restraint.
- Minimise residual stresses by using balanced and double-sided welding techniques.
- Avoid excessive heat input (max. 1.5 kJ/mm for fully austenitic steels).
- Ensure the weld zone is clean.
- Use basic fluxes/coatings – these give fewer inclusions/impurities.
- Use welding methods without any slag formers (e.g. TIG and MIG) – these produce cleaner welds with fewer inclusions/impurities.
- Weld using a filler metal with a ferrite content of 3 – 10 FN.
- Control the weld bead shape to give a width/depth ratio of 1.5 to 2.0.
- Minimise the dilution of mild and low-alloy steels in dissimilar welds.

Crater cracks

Alternative names

–

Importance

Crater cracks can have a detrimental effect on structural integrity and corrosion performance. They may be allowed at the lowest quality level (D) only. The cracks serve to concentrate stresses. This can be detrimental if the component is subjected to static and/or fatigue loads.

Incidence

All welding methods.

Detection

Crater cracks are normally easy to detect by visual inspection, PT (during welding) or (after welding is complete) RT or UT.

Common cause

Incorrect extinction of the electrode.

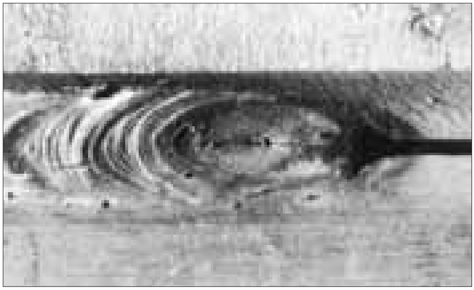


Figure 5.4. Crater cracking in a MMA weld

Typical solutions

- To avoid crater cracks, good stainless steel practice should be followed. Back-step welding from the crater immediately before the arc is extinguished, and use of the current decay/slope out facility built into many modern power sources, are just two examples of this.
- Weld craters should be dressed off or lightly ground to remove any crater cracks. It is extremely unlikely that any subsequent welding pass will melt out crater cracks.

Porosity

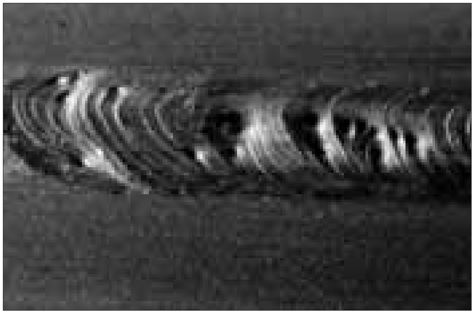


Figure 5.5. Porosity in a MMA fillet weld

Alternative names

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Importance

Particularly if it is surface breaking, porosity can be detrimental to the performance of a weld. In its turn, surface breaking porosity is particularly detrimental to corrosion performance.

The various codes distinguish between "isolated" and "clustered/localised" porosity. Dependent on the thickness being welded, and the quality level in question, considerable levels of porosity may be allowed.

Incidence

Although MMA and FCA welding are slightly more prone, porosity can be engendered by all welding methods. Nitrogen alloyed steels such as 2205 are slightly more sensitive than, for example, 304 and 316 type steels.

Detection

Porosity is normally buried in the weld bead and can be detected using RT or UT. In extreme cases, where porosity breaks the surface, visual or PT inspection is sufficient.

Common causes

- Damp consumables (FCA, MMA and SAW fluxes) and/or moisture on the plate or joint surface.
- Grease or dirt on the plate or joint surface.
- Welding on top of primers or other coatings.
- Inadequate gas protection (TIG, MIG or PAW) due to draughts, too high or too low gas flows or leaking hoses and connections.
- Moisture entrainment in the shielding gas.

Typical solutions

- Store consumables correctly in a climate-controlled room.
- Take positive steps to exclude draughts.
- Take particular care when welding outdoors or in draughty locations.
- Prior to welding, carefully clean all plate and joint surfaces.
- To avoid leakage and moisture entrainment, check all hoses and connections.

Slag inclusions

Figure 5.6. Slag inclusion in a 2205 FCA weld

Alternative name
- Inclusions

Importance
Provided that they are small, spherical and buried, slag inclusions may be accepted at all quality levels. The length of slag inclusions is a further factor in the determination of acceptability.

Incidence
All welding processes, particularly those with slag formers.

Detection
Buried slag inclusions can be detected by RT or UT.

Common causes
- Slag remaining from previous beads – i.e. slag that has not been remelted by subsequent passes over the bead.
- Incorrect FCAW parameters – unfused flux can remain in the weld if the arc is too short (i.e. voltage too low).
- Improper starts/stops when welding with covered electrodes.
- Tack welds that have not been ground away before welding.

Typical solutions
- Between passes, carefully grind tack welds and all starts and stops.
- To obtain and keep the correct arc length, use the right welding technique and welding parameters.
- Avoid too tight/narrow joints – follow the recommendations.
- Seek to form a weld bead with a concave or flat surface.

Spatter

Alternative names
–

Importance
Depending on final application requirements, spatter may be acceptable at all quality levels. However, spatter that has adhered to plate surfaces is a corrosion initiation point and, for optimum corrosion performance, should be removed.

Incidence
Mainly MIG, FCA and MMA welding. Low levels of spatter are almost inevitable with some welding processes and metal transfer modes.

Detection
Visual inspection.

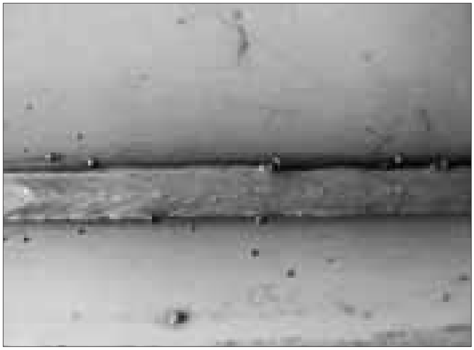

Figure 5.7. Spatter – MIG 316L-Si

Common causes
- Improper shielding gas protection or unsuitable shielding gas.
- Suboptimum welding parameters giving an unstable arc.
- Contamination by dirt, grease or moisture.
- The risk of spatter is, to some extent, connected with alloy content. A high-alloy consumable is generally a little more difficult to weld (without spatter) than a low-alloy consumable.

Typical solutions
- Tune the welding parameters.
- Where feasible, use another shielding gas.
- Ensure the weld zone is clean.
- Never use contaminated or moist electrodes.
- Spatter is more common with dip transfer (MIG welding) or when using older types of welding machines. Spatter from MIG welding is much reduced by using spray arc or pulsed mode.

Undercut

Alternative names

–

Importance

An undercut may serve as a stress concentrator and, consequently, reduce static and fatigue strength. Potentially, it is also a corrosion initiation point.

Incidence

If they are not executed correctly, all welding methods can give undercut. For example, undercutting is strongly related to excessive welding speeds. It is more common in vertical-up (PF/3G), horizontal-vertical (PC/2G) or overhead (PE/4G) welding than in the flat (PA/1G) position.

Detection

Undercut is normally detected by visual inspection.

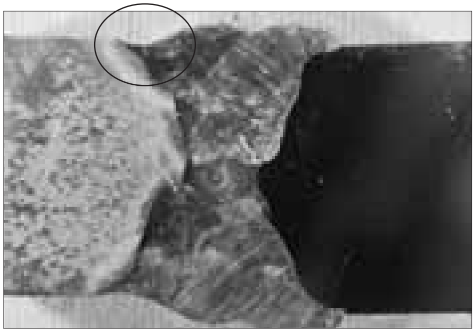

Figure 5.8. Undercut

Common causes

- Forms at weld toes when gravity and surface tension are insufficient for the weld pool to flow adequately into the zone melted by the arc.
- High welding speed or current.
- Excessively large electrodes or wire diameter.
- Improper weaving of the arc.

Typical solutions

- Adjust welding parameters/techniques.
- Undercut should be repaired, as required, by toe grinding and/or additional welding, e.g. TIG or MMA. Autogenous (without filler metal) TIG dressing is only appropriate for 304 and 316 type steels. With high performance grades such as 2205, filler metal must be added when repairing undercut.

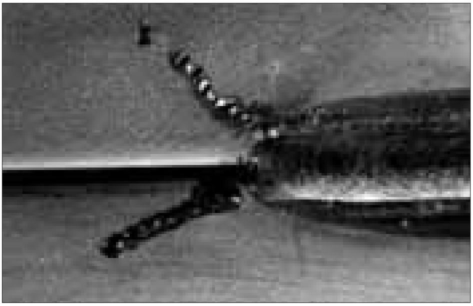

Figure 5.9. Stray arc scars – MMA welding

Stray arcing

Alternative names
- Arc strikes
- Stray flash

Importance
Stray arcing (outside the joint line) can produce scars that act as corrosion initiation points.

Incidence
Mainly MMA, but also other welding methods used for the welding of small components.

Detection
Visual inspection.

Common causes
- Improper manipulation of the electrode or welding torch.
- Because of their reignition characteristics, basic type electrodes are slightly more prone to stray arcing.

Typical solutions
- Ignition must occur at a point in the joint itself.
- Use run-on/run-off plates for ignition/extinction.

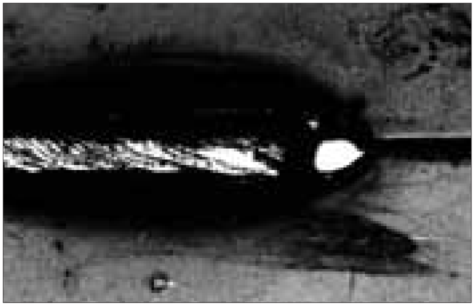

Figure 5.10. Burn-through

Burn-through

Alternative names
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Importance
If not properly repaired, burn-through can impair structural integrity and reduce corrosion resistance.

Incidence
Burn-through occurs primarily in thin sheet welding or when welding unsupported root passes. It arises when the weld pool becomes too large and drops through the weld line. This disturbs the balance between, on the one hand, the welding parameters and, on the other, surface tension, capillary flow within the weld pool round the fusion line and gravitational forces.

Detection
Visual inspection.

Common causes
- Voltage or current too high.
- Excessively large diameter electrodes/ welding wires.
- Welding speed too low or too high.
- Excessive root opening.

Typical solution
- Especially with thin gauges, great care should be taken as regards welding parameters.

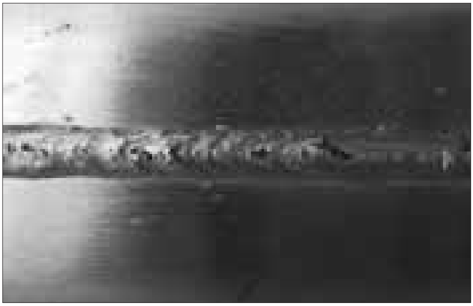


Figure 5.11. Slag islands – MIG 316L-Si

Slag islands

Alternative name
- Surface slag

Importance
Slag islands on the weld bead surface may affect corrosion resistance and structural performance. They should generally be avoided.

Incidence
MIG and TIG welding.

Detection
Visual inspection.

Common cause
- Associated with slag formers in parent metals and consumables.

Typical solution
- Slag islands are difficult to remove by brushing and, unless otherwise specified, may be left on the weld surface. Where removal is specified, light grinding is sufficient.

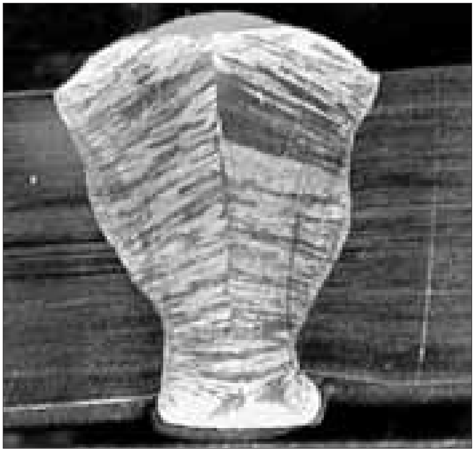


Figure 5.12. Excessive weld metal – MIG 316L-Si

Excessive weld metal

Alternative names
- Excessive penetration
- Excessive reinforcement

Importance
Weld toe notches and the resultant stress concentrations can influence fatigue strength and corrosion performance. Excessive penetration into the bore of a pipe can impede flow and prevent pigging and cleaning operations.

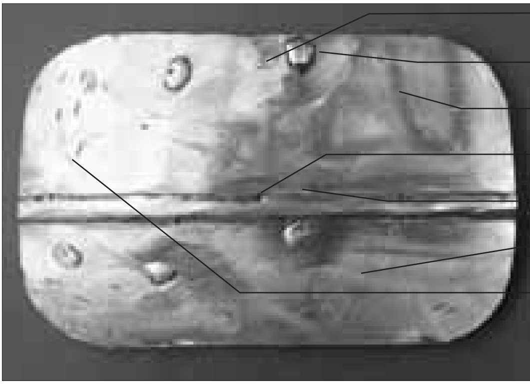
Incidence
All welding methods.

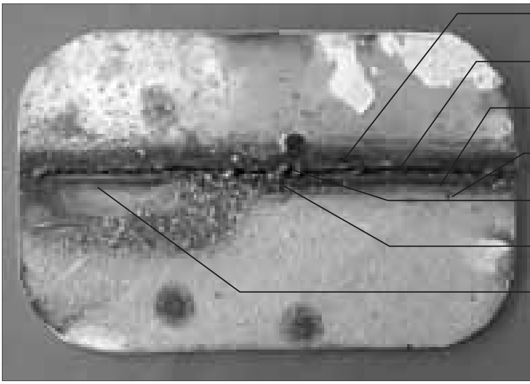
Detection
Visual inspection.

Common causes
Welding parameters (welding speed and current in particular) unsuitable for the joint configuration.

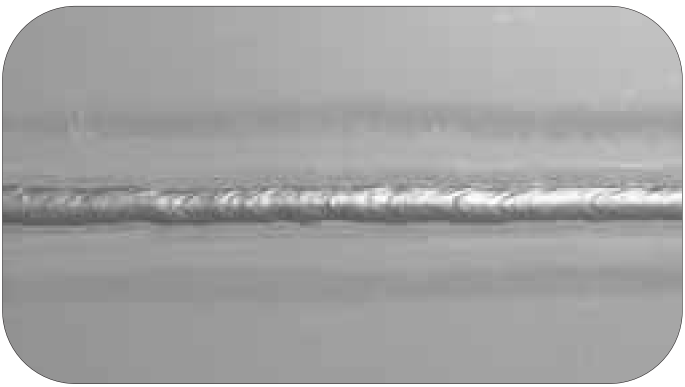
Typical solution
- Rebalance the welding parameters.

Examples of things to avoid...





...and what to aim for!



6 Welding practice – Guidelines for welding different types of stainless steel

Introduction

If good stainless steel practice is followed, it is not normally difficult to weld stainless steels. This is true of all stainless steel grades. However, the importance of the different factors in good practice depends on which grade is being welded.

In presenting the various types of stainless steels, chapter 1 uses the classification in EN 10088. In this chapter, the steels are grouped and discussed as follows:

- Austenitic Cr-Ni and Cr-Ni-Mo stainless steels
- High-alloy austenitic stainless steels
- Duplex stainless steels
- High-temperature stainless steels
- Ferritic, martensitic and precipitation hardening stainless steels

The present chapter gives an outline of good practice and how it applies to different groups of stainless steels.

In all cases, it is of prime importance that appropriate welding procedures are drawn up and implemented. Welding procedures detail the welding parameters (heat input, temperatures, etc.) that have to be used. Cleanliness is also an extremely important factor in achieving good results.

Welding procedure design

When devising and qualifying a welding procedure, many factors have to be considered. Several of these factors are of particular importance for stainless steel.

The procedure must be properly designed. In addition to satisfying the technical requirements of the material being welded, and the quality assurance system in force, a good welding procedure also helps the welder execute the weld. Thus, besides the requirements of the material being welded, and the properties required of the welded joint, the procedure must also take into account the way the welder has to work and the welder's environment.

EN 288 sets out, amongst other things, the process for setting up a welding procedure. There are three main stages in this process:

1. Preliminary welding procedure specification (pWPS)
2. Welding procedure approval record (WPAR)
3. Welding procedure specification (WPS)

Welding parameters

There are no rules governing which welding parameters must be stipulated. The crucial thing is that, in each welding position, the welder must have full control of the arc and the weld pool. Consequently, especially when welding high-alloy fully austenitic steels, upper limits are often set on welding parameters. This is because the parameters have an effect on energy (i.e. heat input).

Heat input

As regards weld serviceability, the single most important determiner is the heat put in via the thermal cycle. Chapter 2 sets out how to calculate heat input.

The heat put into a weld, and the control of this heat input, are both closely linked to steel grade and thickness. There is an optimum heat input for the thickness, joint configuration and grade being welded. This optimum heat establishes a "balance" between the weld pool and metallurgical integrity.

The concept of "balanced heat input" is critical. When welding steels that have a high degree of metallurgical stability (e.g. 304 and

316), the emphasis is on weld pool control. With steels that are relatively metallurgically unstable (e.g. 904L and 254 SMO), the emphasis shifts to metallurgical integrity. In other words, as far as high heat input is concerned, high performance stainless steel grades are more sensitive than their standard counterparts.

The most difficult pass in any weld is the root pass. If the root pass is deposited correctly, all other passes tend to be relatively easy. However, if there are problems with the root pass, it is likely that there will be problems with all the other passes.

The balance of heat inputs from one pass to the next is very important. To maintain good metallurgical integrity, care must be taken to ensure that the root pass is not "overheated" by the second, "cold" pass. Furthermore, the cold pass must be economically deposited and the heat input must be sufficient. Thus, the heat input for the cold pass is directly related to the root pass heat input.

The following model illustrates this relationship. Assuming that the optimum heat input for the root pass of a thick joint is 1.0 kJ/mm, the heat input for the cold pass should be ~0.75 – 1.1 kJ/mm (i.e. between ~75% and 110% of the root pass heat input). The capping pass should be deposited at a heat input of between ~0.8 and 1.5 kJ/mm (i.e. between 80% and 150% of the root pass heat input).

If the cap is to be used in a particularly demanding application, the heat input might be restricted to $\sim 80 < HI_R < 125\%$ (HI_R = root pass heat input). If the root run is backed, or is double-sided, a slightly higher HI_R may be allowed. In this case, the subsequent passes follow the model in the previous paragraph (i.e. the root pass is now regarded as if it were single-sided). The ratios are maintained for all the passes in the joint. In this way, the weld is made cost-efficiently and the risk of metallurgical damage is minimised.

Heat input is relatively easy to control when using mechanised or automated welding systems. To ensure sound welds, travel speed is synchronously adjusted to reflect changes in arc voltage and welding current.

The optimum metal deposition rate is that which correctly balances cost-efficiency with geometric and metallurgical integrity. Clearly enough, it is important to maximise the metal deposition and joint completion rates. However, this must not be at the expense of heat input control.

Preheating

It is not normally necessary to preheat austenitic and duplex stainless steels. Provided, of course, that there is no condensation on the steel, these grades are usually welded from room temperature (i.e. ~20°C). Where there is condensation, the joint and adjacent areas should be heated uniformly and gently (i.e. not so hot that they cannot be touched). Local heating to above 100°C must be avoided as it can give rise to carbon pick-up or metallurgical instability. Both of these have a negative effect on the steels' properties.

Heavy gauges of martensitic grades may require preheating to a minimum of ~100°C. Cooling must be controlled.

Ferritic stainless steels are rarely preheated. However, some heavier gauges may require preheating to ~300°C.

Interpass temperature

When welding stainless steels that have not been preheated (almost certainly austenitic, duplex and precipitation hardening grades), the interpass temperature is regarded as a maximum value. The actual interpass temperature is related primarily to the grade and thickness of the stainless steel in question (see also chapter 2).

As noted in the section on preheating, it may be necessary to preheat martensitic and ferritic grades to certain minimum levels. In these cases, interpass temperatures are also seen as minimum values. They are often the same as the preheating temperatures.

The natural conduction and convection of heat away from the weld line may be sufficient to control interpass temperature. Control can be enhanced by the use of balanced welding sequences/techniques or by working on several welds simultaneously. Distortion control and productivity also benefit from these measures.

During welding, forced air cooling of plate backs and pipe bores is permissible if the weld is ~8 – 10 mm thick. At this thickness (i.e. sufficient for the backing gas to be turned off), there is no risk of accelerated weld pool cooling. For pipes, forced air cooling is particularly effective if the blast forms a vortex down the bore.

Because of the risk of contamination, great care should be taken not to direct blasts of air towards the weld line. Interpass temperature should be measured in the weld zone. Rather than temperature indicating crayons, a contact pyrometer should be used for this.

Post-weld heat treatment

Post-weld heat treatment (PWHT) is not usually necessary for austenitic or duplex stainless steels. These are normally used “as welded”. However, in some situations, full solution annealing may be stipulated for the whole, or parts, of the welded assembly. Particularly for the dimensional stability of, for example, rotating equipment, stress relief heat treatment is also occasionally undertaken.

PWHT is a specialist operation. Qualified procedures and appropriate equipment must be used.

To achieve the required balance of properties (generally strength in relation to toughness and hardness), PWHT may be necessary for fabrication welds in martensitic and ferritic stainless steels.

On the rare occasions that precipitation hardening grades are welded, they generally receive PWHT. This ensures that they retain all their properties.

Cleanliness

Edges and adjacent surfaces are normally cleaned before any welding of stainless steels. Dirt, oil, grinding burs, paint and contamination must be avoided throughout welding. This maximises service performance and minimises post-fabrication cleaning costs.

Prior to welding, the weld zone should be taken back to clean bright metal. This includes not only the bevel and root nose faces, but also surfaces away from the weld line. The surfaces adjacent to the weld line should be cleaned for up to 50 mm from the weld line.

Surfaces should be degreased and then mechanically cleaned. In multipass welding, underlying weld beads should be deslagged and cleaned of excessive welding oxide.

Preferably using cold cutting techniques, cut-backs in double-sided welding should be taken to clean, sound metal. All liquid penetrant inspection fluids and contrast paints must be removed.

Post-weld cleaning

Post-fabrication cleaning is not normally stipulated in welding procedure specifications. This is surprising. Cleaning is clearly good fabrication practice and essential for good results (see chapter 9).

Austenitic Cr-Ni and Cr-Ni-Mo stainless steels

General characteristics

This group includes the most widely used austenitic stainless chromium-nickel and chromium-nickel-molybdenum steels. As noted in ”Austenitic steels” in chapter 1, these grades are used in a very wide range of modest to relatively demanding applications.

The designations of the standard austenitic grades comprising the so-called “300 series” are given in table 6.1 overleaf.

Standard austenitic steels Table 6.1

Grade name		EN designation	UNS designation
4307	304L	1.4307	S30403
4404	316L	1.4404	S31603
4438	317L	1.4438	S31703

Series 300 weldability is generally very good. These grades are normally metallurgically stable.

Filler metals

Welding normally uses a filler metal that has a chemical composition corresponding to that of the steel being welded (see chapter 12). Thin plates (< 3 mm) can, in some cases, be welded without a filler metal.

When welding Cr-Ni or Cr-Ni-Mo stainless steels to mild steel, "over-alloyed" fillers such as, respectively, 309L and P5 (309MoL) should be used.

Welding methods and techniques

All arc welding methods can be used for joining these steels. Resistance welding is a further possibility. The high energy density and, potentially, the solid state joining processes can also be considered.

Edge preparation

See chapter 7.

Heat input

Cr-Ni and Cr-Ni-Mo steels are generally metallurgically stable. A relatively high heat input of up to 2 kJ/mm can thus be used with no negative effects. However, on a case by case basis, it must be borne in mind that increased heat input at welding increases distortion, weld pool size, fume generation and radiation (heat and light).

Steel grades stabilised with titanium or niobium are normally less stable and require a somewhat lower heat input than that which is used when welding with "standard fillers". Low or zero ferrite fillers such as 308L-LF and SNR-NF are also somewhat more sensitive to high heat input. Consequently, heat input should be slightly reduced to a maximum of 1.5 kJ/mm. A maximum heat input of 1.5 kJ/mm should also be used when welding stainless steels to mild steels.

Interpass temperature

The interpass temperature should normally be kept fairly low, i.e. approximately 150°C.

High-alloy austenitic stainless steels (904L, 254 SMO, 20-25-6 and 654 SMO)

General characteristics

High-alloy austenitic stainless steels have such high contents of chromium, nickel, molybdenum and nitrogen that, as regards corrosion resistance and, in some cases, mechanical properties, they differ substantially from more conventional Cr-Ni and Cr-Ni-Mo grades.

High performance austenitic steels Table 6.2

Grade name Outokumpu	EN designation	UNS designation
904L	1.4539	N08904
254 SMO®	1.4547	S31254
20-25-6	1.4529	N08926
654 SMO®	1.4652	S31654

From the point of view of workshop practice (i.e. the manufacturing of components and equipment), these grades are somewhat similar to standard austenitic grades such as 1.4301 and 1.4401. However, welding them still requires specialist know-how.

All four steels in this group are highly suitable for welding. The welding methods used for conventional steels can be used.

Figure 6.1. 254 SMO is widely used in offshore applications

Filler metals

Unless special precautions are implemented and PWHT takes place, filler metal should always be used. Autogenous welding is not recommended.

In choosing filler metals, there is a slight difference between, on the one hand, 904L steel and, on the other, 254 SMO, 20-25-6 and 654 SMO steels. A matching composition filler (i.e. 904L) is used for the former, but nickel base filler metals are normally used for the latter. However, when welding 904L in circumstances where it is necessary to improve the corrosion performance of the weld bead (e.g. in very aggressive, chloride containing environments), P12 filler metal may be considered.

When welding 904L to mild and low-alloy steels, Avesta P5 (309MoL) can generally be used. Filler 904L should only be used where the parent metal is thin and dilution therewith is low.

To minimise the molybdenum segregation associated with iron base filler metals, nickel base fillers should be used when welding 254 SMO, 20-25-6 and 654 SMO. The only exception is where there is a danger of transpassive corrosion. In these circumstances, iron base filler metal (P54) should be used.

Two types of fillers, Avesta P12-R (ENiCrMo-12) and P625 (ENiCrMo-3), can be used in MMA welding. The niobium content of P12-R is lower than that of P625. This has the advantage of reducing interdendritic phases in the weld and, consequently, slightly lowering the risk of hot cracking. In some special situations (e.g. where service temperatures exceed 400°C), P625 is the preferred solution because of its superior structural stability at higher temperatures.

MIG, TIG and SAW can be carried out with either P12 or P12-0^{Nb}. The NORSOK approved P12-0^{Nb} gives a weld metal with almost no secondary phases and extremely good ductility. Furthermore, the tendency towards hot cracking is somewhat reduced. Giving a higher yield and better tensile strength, P12 can be considered the first choice. The corrosion resistance of the two fillers is similar.

When welding 654 SMO, Avesta P16 must be used.

Filler metals for 254 SMO, 20-25-6 and 654 SMO Table 6.3

Welding method	Filler metal Avesta	Cr	Ni	Mo	Fe	Other
MMA	P12-R	21.5	Bal.	9.5	2.0	Nb 2.2
	P625	21.5	Bal.	9.5	1.5	Nb 3.5
	P16	25.0	Bal.	15.0	–	–
	P54	25.5	25.5	5.0	> 35	N 0.35
MIG	P12	22.0	Bal.	9.0	< 1	Nb 3.6
TIG	P12-0^{Nb}	22.0	Bal.	9.0	< 1	Nb < 0.1
SAW	P16	25.0	Bal.	15.0	< 1	Nb < 0.1
	P54	26.0	22.0	5.5	> 35	Mn 5.1

When welding 254 SMO, 20-25-6 and 654 SMO to mild and low-alloy steels, the fillers dictated by the stainless steel should be used. However, Avesta P5 is a more economical alternative and can be used under certain circumstances, e.g. where dilution with the parent metal is low.

Edge preparation

Edge design must facilitate full penetration without the risk of burn through. Bevel angles should be sufficient to ensure good access. A bevel angle of 35 – 40° is generally appropriate for manual welding. A slightly tighter angle (30 – 35°) may be suitable for mechanised or automated welding. With thicker plates (manual, mechanised or automated welding), this angle can be reduced – see joint type 22 in table 7.1, chapter 7, "Edge preparation".

The root gap and root face for single-sided welds should typically be 2 – 3 mm and 1 – 2 mm respectively. The root face in double-sided welding can be slightly increased. Throughout the root pass, the gap is maintained by tack welding and root grinding with slitting discs.

Chapter 7.2 contains several edge preparation examples.

Welding methods and techniques

All arc welding methods are suitable for this group of steels. However, when using SAW, it must be borne in mind that these steels are slightly more sensitive to hot cracking than are the standard austenitic grades.

Where the reverse of the weld is accessible, MIG and MMA (diam. 3.25 mm) can be used for the root pass.

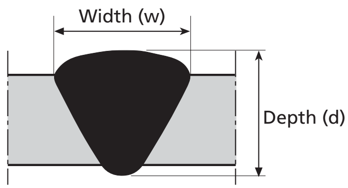
MIG welding is best performed using pure argon or argon with an addition of approximately 30% helium. The addition of helium improves fluidity and gives a somewhat wider bead. The addition of up to 1 – 2% O_2 or 2 – 3% CO_2 helps to sharpen metal transfer. However, weld bead oxidation is slightly heavier. For best arc stability and weld pool control, MIG welding should be carried out using a synergic pulse machine.

TIG is recommended for all single-sided, inaccessible root runs. Pure argon should be used as the shielding gas. The addition of up to 5% helium or hydrogen increases the energy in the arc. Especially with fully automatic welding, this is beneficial as travel speed can be significantly increased. Up to 2% nitrogen can also be added. This slightly improves the weld metal's pitting resistance.

The backing gas, which should be used even at the tacking stage, can be pure argon or, alternatively, nitrogen with a 10% addition of hydrogen.

To control dilution, heat input and bead shape in SAW, the diameter of the filler metal should not exceed 2.40 mm. A basic flux (e.g. Avesta 805) must be used and the heat input must be low and controlled. As an alternative, the first run can be TIG or MMA and the filling passes SAW.

The width of the weld should be 1.5 – 2.0 times the depth. This minimises the risk of hot cracking. The wider and shallower the bead, the greater the susceptibility to interdendritic problems. A deeply penetrating weld bead shifts the susceptible area to the weld centre line. The criterion regulating the shape of the weld bead has obvious implications for welding current and arc voltage. To achieve the correct shape, the voltage must be adjusted to the current (see also ”Width and depth” in chapter 4).



The width/depth ratio of a weld is important. The examples below show how this ratio is stated.

- Width the same as depth ⇒ ratio is 1.
- Width is 20 mm and depth is 10 mm ⇒ ratio is 2.
- Width is 15 mm and depth is 30 mm ⇒ ratio is 0.5.

A width/depth ratio of between 1 and 2 (inclusive) is generally considered optimum. A ratio below 1 or above 2 gives a weld with an unfavourable shape and increased risk of hot cracking.

Figure 6.2. Width/depth ratio

High welding stresses may induce microfissuring. For this reason, it is important to use welding techniques that control, balance and minimise these stresses. Good weld planning is vital. Sequencing is an example of this. The principle of weld sequencing is to weld from “thick to thin” and from “stiff to flimsy”. As far as practical, restraint should be minimised. Bearing in mind the considerations of weld bead access and weld bead geometry, weld volume should be held to a minimum. Especially at thicknesses above ~10 mm, double-sided welding is preferred to single-sided welding. Segmented welding is the preferred technique for the girth welding of pipes.

Close attention should be paid to stopping and starting techniques – craters must be clean and sound. The preferred techniques are stringer bead and weaving. However, the weave must not exceed 2 times the electrode diameter. The current should be set only high enough to obtain a smooth, stable arc and good fusion of weld to parent metal.

The need for great cleanliness is common to the welding of all high-alloy austenitic grades. Weld pool contamination is responsible for changes in surface tension, subtle alterations in bead geometry and microcontamination of grain boundaries. All these factors can promote microfissuring. The weld zone must be kept clean. All the surfaces to be welded (underlying weld beads included) must be bright metal.

Prior to welding, great care must be taken to clean the weld zone of all visible or hydrated oxides and cutting or marking fluids. During welding, any welding oxide or contamination from temperature indication crayons must be removed from the weld zone.

Heat input

High-alloy austenitic grades are generally more sensitive to high heat input than are other stainless steels. The maximum heat input must be adjusted to the joint and the thickness being welded. When welding thick gauges (i.e. those in the 3D cooling regime), the maximum heat input for 904L, 254 SMO and 20-25-6 is 1.5 kJ/mm. For 654 SMO it is 1 kJ/mm. The maximum permitted heat inputs are lower for thin gauges. This minimises the risk of microfissuring and deleterious phase formation.

Excessive heat input during welding is likely to give excessive dilution of the nickel base weld metal. This, in its turn, may lead to reduced corrosion performance and, possibly, weld cracking or microcracking. Joint configuration, heat input and bead placement are important factors in welding procedure design. Controlling these helps to control dilution and thus maximise the performance of the weld.

Interpass temperature

Depending on the thickness being welded and the joint configuration, interpass temperature is generally held in the range 100 – 125°C.

Duplex stainless steels

General characteristics

Duplex stainless steels, also referred to as austenitic-ferritic stainless steels, combine many of the good properties of austenitic and ferritic stainless steels. Due to the high content of chromium and nitrogen (and often also molybdenum), these steels offer good resistance to pitting and general corrosion. The duplex microstructure contributes to high strength and high resistance to stress corrosion cracking. The weldability of duplex steels is good.

When welding duplex stainless steels, the two main concerns are achieving the correct ferrite-austenite phase balance and avoiding deleterious phases (sigma phase in particular). These goals are best reached by good edge preparation and the use of the right filler metal and welding parameters.

All five steels in this group are highly suitable for welding. The welding methods used for conventional stainless steels can be used.

Duplex stainless steels Table 6.4

Grade name Outokumpu	EN designation	UNS designation
LDX 2101®	1.4161	S32101
SAF 2304®	1.4362	S32304
2205	1.4462	S32205/S31803
SAF 2507®	1.4410	S32750
Zeron 100	1.4501	S32760

Figure 6.3. Stainless steel bridge in 2205

Filler metals

To ensure the correct ferrite-austenite phase balance (i.e. avoid high ferrite content), duplex stainless steel filler metals are over-alloyed with nickel. Excessive nickel dilution of the parent metal (e.g. when using a "plate composition" filler or using small or no root gaps) prevents the correct phase balance being achieved in the "as deposited" condition. Unless special precautions are implemented and PWHT takes place, edges must be carefully prepared and filler metal should always be used. Autogenous welding is not recommended.

Duplex stainless steel 2205 is generally welded using 2205 filler. Using 2507/P100 filler metal to weld 2205 maximises the corrosion performance of the weld metal, but slightly reduces high temperature HAZ fracture toughness.

LDX 2101 can be welded using a matching filler or any of the three duplex filler types 2304, 2205 or 2507/P100.

Filler metals for duplex stainless steels Table 6.5

Welding method	Filler metal type Avesta	Cr	Ni	Mo	N
MMA	2304	24.5	9.0	<0.3	0.12
	2205	23.0	9.5	3.0	0.15
	2507/P100	25.5	10.0	3.6	0.23
MIG	2304	23.0	7.0	<0.5	0.14
TIG	2205	23.0	8.5	3.1	0.17
SAW	2507/P100	25.0	9.5	4.0	0.25
FCAW	2205	22.5	9.0	3.2	0.13

When welding duplex to mild and low-alloy steels, a duplex filler can be advantageously used. However, it is important that the edges suit the characteristics of the duplex steel. As an alternative, Avesta P5 (309MoL) or Avesta 309L filler metals can be used.

Edge preparation

Edge design must facilitate full penetration without the risk of burn through. Bevel angles should be sufficient to ensure good access. A bevel angle of 35 – 40° is generally appropriate for manual welding. A slightly tighter angle (30 – 35°) may be suitable for mechanised or automated welding. With thicker plates (manual, mechanised or automated welding), this angle can be broken – see joint type 17 in table 7.1, chapter 7, "Edge preparation".

The root gap and root face for single-sided welds should be typically 2 – 3 mm and 1 – 2 mm respectively. The root face in double-sided welding can be slightly increased.

Provided that welding current and torch angle are optimised to ensure good penetration, the root face in SAW can be up to 8 mm.

Ceramic backing tiles can be used to support the root pass but, as they tend to marginally reduce the cooling rate, care must be taken. Thus, compared to a self-supporting root pass, a slightly lower heat input is appropriate when ceramic backing systems are used.

Chapter 7 contains several edge preparation examples.

Welding methods and techniques

All duplex stainless steels can be welded using standard arc welding methods. However, FCAW should not be used for super duplex grades (SAF 2507 and Zeron 100) because of the generally higher heat inputs and lower weld metal cleanliness (i.e. more slag inclusions).

Where the reverse of the weld is accessible, MIG and MMA (diam. 3.25 mm) can be used for the root pass.

MIG welding is best performed using pure argon with an addition of approximately 30% helium and 1 – 2% CO_2. The addition of helium improves fluidity and gives a somewhat wider bead. Argon with an addition of either 1 – 2% O_2 or 2 – 3% CO_2 can also be used. For best arc stability and weld pool control, MIG welding should be carried out using a synergic pulse machine.

TIG is recommended for all single-sided, inaccessible root runs. Pure argon should be used as the shielding gas. The addition of helium increases the energy in the arc. Especially with fully automatic welding, this is beneficial as travel speed can be significantly increased. Up to 2% nitrogen can also be added. This slightly improves the weld metal's pitting resistance. Due to the increased risk of weld porosity, and the increased wear of the tungsten electrode, a nitrogen addition of more than 3% is not advisable.

TIG welding should be performed using a backing gas of argon or, alternatively, nitrogen with a 10% addition of H_2. The backing gas should be used even at the tacking stage and kept for at least 3 layers.

Duplex SAF 2304 and 2205 are highly suited to SAW. A basic chromium compensated flux (e.g. Avesta 805) should be used. To control dilution, heat input and bead shape when using SAW to weld SAF 2507, the diameter of the filler metal should not exceed 2.40 mm. A basic flux (e.g. Avesta 805) must be used and the heat input must be low and controlled. As an alternative, the first run can be TIG or MMA and the filling passes SAW.

Heat input

Duplex SAF 2304 and 2205 are generally metallurgically stable when subjected to a high heat input. Theoretically, inputs of up to 3 kJ/mm can be used without any negative effects. However, in practice, factors such as distortion, large weld pools, radiation (heat and light) and fume generation set the upper limit. This is especially true for manual welding.

A too low heat input increases the cooling rate and gives little opportunity for the formation of austenite. This results in a high ferrite content that may exceed 65% (normally considered the maximum for duplex 2205).

Super duplex stainless steels are more metallurgically unstable and should be welded using a moderate heat input. A typical maximum is 1.5 kJ/mm. Too high a heat input may result in a high content of deleterious phases (e.g. sigma). This lowers both corrosion resistance and toughness.

Interpass temperatures

The interpass temperature when welding SAF 2304 and 2205 steels should not exceed 150°C. Super duplex grades are somewhat more sensitive to high heat. Consequently, the interpass temperature should not exceed 100°C.

High-temperature (HT) stainless steels

General characteristics

These steels are designed primarily for use at temperatures above approximately 550°C. HT corrosion occurs at these temperatures where, as a rule, creep strength is the dimensioning factor. Although most are austenitic, there are some ferritic HT stainless steels. These ferritic grades should be welded in the same way as the utility ferritic stainless steels (see ”Ferritic and martensitic stainless steels” below).

HT steels and filler metals

To ensure that the weld metal has the same properties (e.g. strength and corrosion resistance) as the parent metal, it is best to use a matching filler metal.

The yield and tensile strength properties of the weld metal are generally equal to, or better than, those of the parent metal. However, the weld metal's creep properties are usually up to 20% lower. Gas shielded welding (MIG and TIG) gives the best creep properties for the welds.

A 309L filler is normally used when welding HT stainless steels to mild and low-alloy steels. However, a nickel base alloy – type P10 (ERNiCr-3) – may be advisable where creep resistance is the dimensioning factor. The nickel acts as a barrier to the carbon, which otherwise tends to segregate from the carbon steel into the stainless steel. Such segregation lowers the creep resistance of the carbon steel.

Austenitic HT steels and recommended filler metals Table 6.6

Grade name Outo-kumpu	EN desig-nation	ASTM/UNS desig-nation	Filler metal Avesta
4948	1.4948	304H	308/308H
4878	1.4878	321H	347/MVNb
153 MA™	1.4818	S30415	253 MA*
4833	1.4833	309S	309/309-Si
4828	1.4828	–	309-Si
253 MA®	1.4835	S30815	253 MA*
4845	1.4845	310S	310
353 MA®	1.4854	S35315	353 MA

*Also available as 253 MA-NF, a non-ferrite filler suitable for cyclic temperatures not exceeding 950°C.

Edge preparation

Edge preparation is the same as for fully austenitic grades. Chapter 7 contains several edge preparation examples.

Welding methods and techniques

When it comes to welding the high-temperature austenitic stainless steels, they should be regarded as being the same as the high performance austenitic grades. The reasons for this are the alloying elements characterising these grades and the generally low, or essentially zero, ferrite content. All arc welding methods are suitable, but fully austenitic HT stainless steels 310S and 353 MA are somewhat more sensitive to hot cracking than are standard austenitic grades. This should be borne in mind, especially with SAW.

Between runs, it is particularly important to remove welding oxide, spatter, etc. Penetration and weld pool fluidity suffer if this is not done. Mechanical cleaning, e.g. grinding or careful brushing, are suitable cleaning methods.

After welding, it is important that final, mechanical cleaning leaves a fine finish. Coarse, rough finishes can generate stress concentrations. These may lead to failure under, for example, differential or cyclic thermal loading.

Heat input

A heat input similar to, or slightly below, that for normal Cr-Ni stainless steels is suitable for low-alloy HT stainless steels such as 1.4948, 1.4878 and 253 MA. A fairly low heat input (max. 1.0 kJ/mm) should be used for high-alloy and fully austenitic HT stainless steels.

Interpass temperature

Depending on the thickness being welded and the joint configuration, interpass temperature is generally held in the range 100 – 125°C.

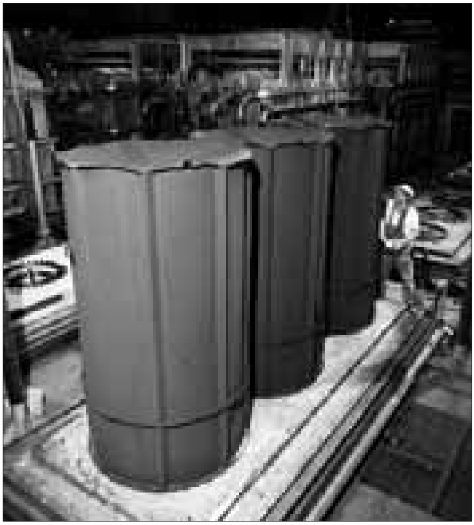


Figure 6.4. Bell furnaces for heat treatment in 253 MA

Ferritic, martensitic and precipitation hardening stainless steels

General characteristics

"Ferritic stainless steel" is a broad, generic expression generally taken to encompass any stainless steel microstructure with large proportions of ferrite. Ferritic and martensitic stainless steels can generally be divided into different groups based on carbon and chromium levels. As set out below, different welding techniques should be used for the different groups.

Ferritic and martensitic steels Table 6.7

EN grade name	EN designation	ASTM designation
X7Cr13	1.4000	410S
X12Cr13	1.4006	410
X20Cr13	1.4021	420
X6Cr17	1.4016	430
X17CrNi16-2	1.4057	431
X2CrMoTi18-2	1.4521	443

Utility ferritic stainless steels

These steels are essentially plain chromium stainless steels with low carbon (max. 0.10%) and, typically, 12 – 16% chromium.

The two main concerns when welding the true ferritic grades are grain coarsening and, in the HAZ, high hardness. The latter is associated with both loss of ductility and notch toughness.

When welding thinner gauges, the preheating temperature is approx. 200°C. For thicker gauges, particularly if the carbon content is rather high (i.e. 0.10%), it is 300°C. Using an austenitic filler, sheets less than around 3 mm thick, and with low carbon content, can be welded without preheating.

Minimum interpass temperatures are at least as high as the preheating temperatures.

To limit grain growth in the HAZ, heat inputs should be "low to medium" relative to the thickness being welded. This is the opposite of the measures taken to avoid hydrogen cracking.

Particularly when using matched ferritic filler metals, thicker gauges should be cooled slowly to ~125°C after welding and held at this temperature for around 1 hour. This is so that martensite transformation can occur. If PWHT is to take place, the weld is taken to 600 – 700°C directly from the transformation temperature. As it leads to severe losses in ductility, low temperature stress relieving in the range 200 – 400°C should be avoided. The effect of PWHT on filler metals should be borne in mind.

This group of steels is most frequently welded with austenitic stainless fillers such as 308/308L and 309/309L. However, 308H and 310 can also be used – especially when the construction will be exposed to temperatures above 550°C.

Low carbon martensitic stainless steels

These steels have 13 – 17% chromium, low carbon (around 0.05%) and low nickel and/or molybdenum.

Thinner gauges of these steels can be welded from room temperature. Thicker gauges, i.e. those where the cooling regime changes from 2D to 3D, should be preheated to approximately 100°C.

Welding is best carried out with either a low or a high interpass temperature. Low interpass should be below the so-called martensite finish (M_F) temperature, i.e. the temperature at which no more martensite forms (normally around 125°C). High interpass should be kept above the martensite start (M_S) temperature, i.e. the temperature where martensite starts to form (typically 250 – 400°C). If a high interpass temperature is used, the welded section must be slowly cooled to just below M_F and held at that temperature whilst martensite transformation takes place.

Particularly when using compositionally matched filler metals, PWHT should be carried out directly from the interpass temperature. Cooling should first be to 800 – 850°C. This is followed by slow cooling to 600°C, then "rapid" cooling to room temperature.

The coarse grain HAZ problem is not as severe as with the ferritic stainless steels, but HAZ properties are still a cause for concern. Heat input should be restricted.

Austenitic stainless fillers such as type 309 can also be used for welding these steels. PWHT is not necessary in these cases.

High carbon martensitic steels

These steels have 12 – 17% chromium, carbon levels of 0.15 to 0.2% and low nickel (< 1.5%). The microstructure comprises ferrite, tempered martensite and some carbides. They are normally considered not to be weldable. If welding is attempted, the use of low hydrogen methods (MIG or TIG) is to be preferred. Any electrodes used must be of the basic type. Thinner gauges are occasionally welded. They must be preheated to temperatures above M_S (typically 250 – 400°C). The interpass temperature should be in the same range.

Martensite start and finish temperatures vary with steel composition and must be checked specifically. Unless the steel contains strong carbide formers, the M_S temperature will be around 300°C. If such formers are present, the M_S temperature is even higher.

Type 309 filler metal is most commonly used for thinner gauges. This avoids the PWHT that is necessary when a compositionally matched filler is used. It may be possible to weld very thin gauges without preheating. Much depends on the steel's composition, the restraints used, etc. When there is no preheating, PWHT is necessary.

Super martensitic stainless steels

These steels have approximately 13% chromium and ultra-low carbon (generally < 0.02%). The composition also includes nickel (~5 – 6%), molybdenum and nitrogen.

Because of the nitrogen content and the low carbon, these steels have reasonable weldability. They generally require little (max. 100°C) or no preheating. The maximum interpass temperature should be low.

To ensure good strength and corrosion performance, 2507/P100 super duplex is the preferred filler metal. Matching fillers may also be used. However, the ductility of the weld metal will then probably be lower than that of the parent metal.

If the HAZ needs to be tempered in order to reduce HAZ hardness, the weld line containing the super duplex filler should be rapidly heated to ~650°C. It should be held there for 2 minutes and then quenched.

Precipitation hardening stainless steels

These steels have a chromium content of ~13 – 17%, nickel, molybdenum and low carbon. They are further alloyed with combinations of aluminium, niobium and copper.

The steels in this group are rarely welded as the heat tends to over-ripen the HAZ precipitates. These provide the strengthening mechanism. If these steels are to be welded, they should be treated as low carbon martensitic grades. The MS temperature is specific to the grade but is generally around 125°C. To limit the over-ripening of the precipitates in the HAZ, the heat input needs to be as low as possible. However, so that precipitation strengthening can take place, it is then normally appropriate to heat treat the full component.

Edge preparation

Chapter 7 contains several edge preparation examples.

Shielding gases

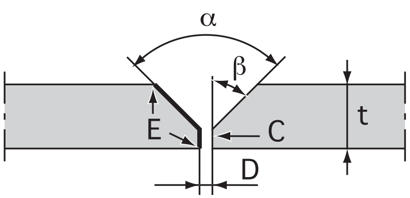
The same shielding gases as for standard austenitic grades may be used. However, because of the risk of hydrogen cracking, hydrogen must not be added to TIG shielding or backing gases.

7 Edge preparation

Choice of joint type

Welding process, welding position and material thickness must all be taken into account when deciding which type of joint to use. The choice is also dependent on whether it is homogenous stainless steel plate or clad plate that is being welded. In the latter case, the joint must be such that the stainless layer is not melted when depositing the root bead on the carbon steel side. See ”Welding clad steel plates” in chapter 4.

Figure 7.1 gives an example of edge preparation and illustrates some key terms.



α = Joint angle
β = Bevel angle
C = Root land (nose)
D = Root gap
E = Joint surface
R = Radius (U-joints only)
t = Plate thickness

Figure 7.1. Edge preparation

The purpose of the welding bevel is to provide good access for the deposition of sound metal. During welding, the root land acts as a support for the arc. Not having any root land would result in a very wide root.

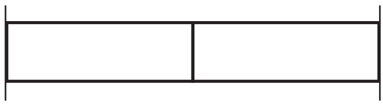
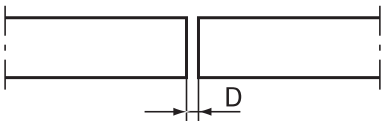
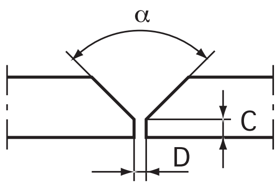
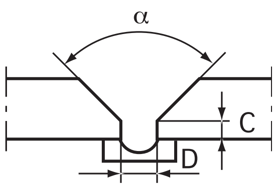
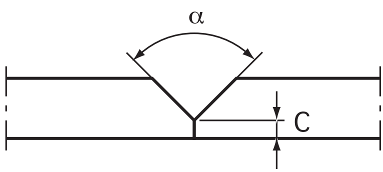
Root faces are either machined (e.g. milled) or cut (e.g. laser, plasma or waterjet). When the faces are cut, it is always advisable to remove any oxidation by lightly grinding the bevel. The bevel and plate surface adjacent to the bevel should be clean and smooth prior to welding.

Table 7.1 gives edge preparation details for a variety of welding methods and plate thicknesses.

Cleaning before welding

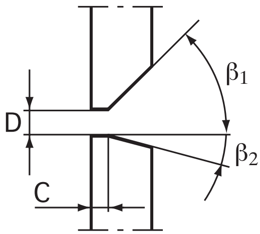
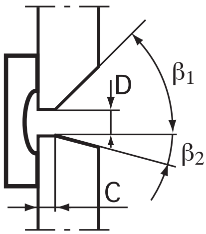
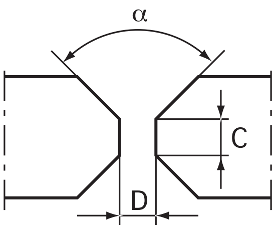
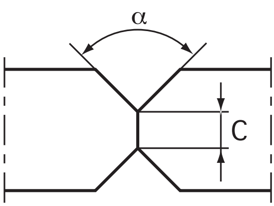
For good welding results, edges must be perfectly clean. Organic contamination (e.g. grease, oil, paint, soil, grit) can give rise to porosity, spatter, lack of fusion or incomplete penetration and must be removed. Avesta cleaning agents or any other degreasing agent (e.g. acetone) can be used for this. Before welding starts, all dirt must be wiped off with a clean cloth.

Joint preparations Table 7.1

No. and joint type		Sides	Method	Thickness
1. I-joint No root gap[1]		One side	TIG	< 2.5 mm
2. I-joint No root gap[2]		Two sides	SAW	6 – 9 mm
3. I-joint		One side	PAW	1 – 8 mm
4. I-joint D = 1.0 – 2.0 mm		One side	MMA MIG TIG	< 2.5 mm
5. I-joint D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG FCW	< 4 mm
6. V-joint α = 60°[3] C = 0.5 – 1.5 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG FCW	4 – 16 mm
7. V-joint α = 60°[3] C = 2.0 – 2.5 mm D = 2.5 – 3.5 mm		Two sides	MMA MIG TIG FCW	4 – 16 mm
8. V-joint α = 60°[3] C = 1.5 – 2.5 mm D = 4.0 – 6.0 mm		One side against backing	FCW	4 – 20 mm
9. V-joint α = 80 – 90° C = 1.5 mm No root gap[1]		Two sides	TIG+ SAW	3 – 16 mm
10. V-joint α = 80 – 90° C = 3.0 – 6.0 mm[4] No root gap		Two sides	SAW	8 – 16 mm
11. V-joint α = 80 – 90° C = 3.0 – 4.0 mm No root gap		Two sides	PAW+ SAW	6 – 16 mm

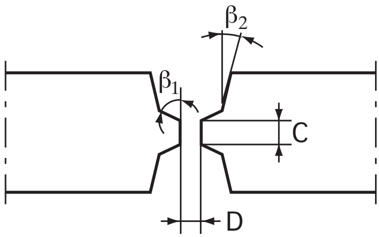
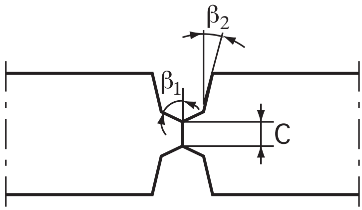
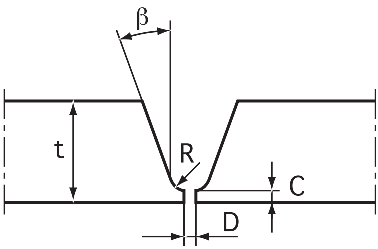
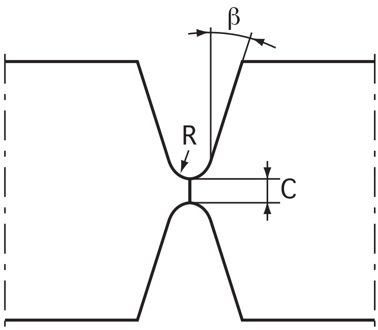
[1] There must be a root gap when welding special grades.
[2] A ground groove, 1 – 2 mm deep and wide.
[3] The joint angle for special grades is 60 – 70°.
[4] A root land of 5 mm and above may require the torch to be angled towards the direction of travel, see "Width and depth" in chapter 4.

Joint preparations Table 7.1

No. and joint type		Sides	Method	Thickness
12. V-joint β_1 = 45° β_2 = 15° C = 1.0 – 2.0 mm D = 2.0 – 3.0 mm		One side	MMA FCW	4 – 16 mm
13. V-joint β_1 = 45° β_2 = 15° C = 2.0 – 2.5 mm D = 2.0 – 2.5 mm		Two sides	MMA FCW	4 – 16 mm
14. V-joint β_1 = 45° β_2 = 15° C = 1.5 – 2.5 mm D = 4.0 – 6.0 mm		One side against backing	FCW	4 – 20 mm
15. X-joint α = 60°[3)] C = 2.0 – 3.0 mm D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG[6)] FCW	14 – 30 mm[8)]
16. X-joint α = 80° C = 3.0 – 8.0 mm[4)] No root gap		Two sides	SAW	14 – 30 mm

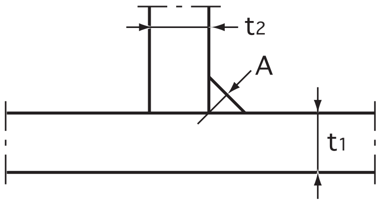
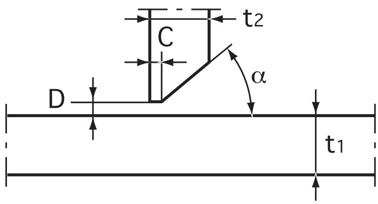
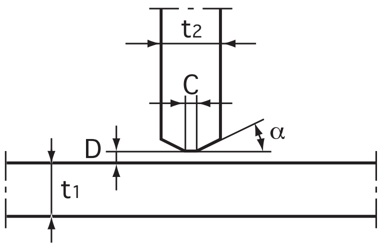
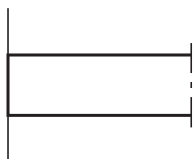
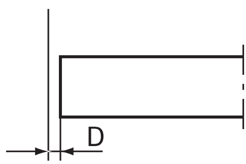
3) The joint angle for special grades is 60 – 70°.
4) A root land of 5 mm and above may require the torch to be angled towards the direction of travel, see "Width and depth" in chapter 4.
6) Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.
8) A thickness above 20 mm can be prepared as an asymmetrical X-joint.

Joint preparations Table 7.1

No. and joint type		Sides	Method	Thickness
17. X-joint β_1 = 45° β_2 = 15° C = 1.5 – 2.5 mm D = 2.5 – 3.0 mm		Two sides	MMA MIG TIG[6] FCW	14 – 30 mm[8]
18. X-joint β_1 = 45° β_2 = 15° C = 3.0 – 8.0 mm[4] No root gap		Two sides	SAW[9]	14 – 30 mm
19. U-joint β = 10° R = 8.0 mm C = 2.0 – 2.5 mm D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG[6] FCW SAW[10]	< 50 mm
20. Double U-joint β = 15° R = 8.0 mm C = 4.0 – 8.0 mm[4]		Two sides	SAW[9]	> 20 mm

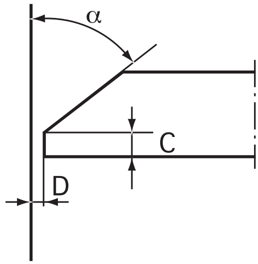
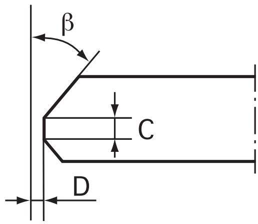
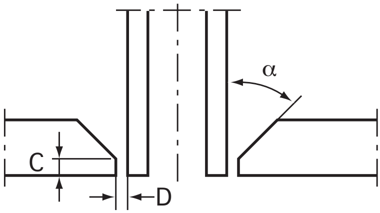
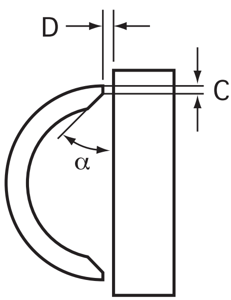
4) A root land of 5 mm and above may require the torch to be angled towards the direction of travel, see "Width and depth" in chapter 4.
6) Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.
8) A thickness above 20 mm can be prepared as an asymmetrical X-joint.
9) TIG or MMA can be used for root runs. Grinding from the back. C = 3.0 mm.
10) SAW can be used for fill and cap passes.

Joint preparations Table 7.1

No. and joint type		Sides	Method	Thickness
21. Fillet weld No root gap A ≈ 0.7 x t		One or two sides	MMA MIG TIG FCW	> 2 mm
22. Half V-joint α = 50° C = 1.0 – 2.0 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG6) FCW	4 – 16 mm
23. Half V-joint α = 50° C = 1.5 – 2.5 mm D = 2.0 – 3.0 mm		Two sides	MMA MIG TIG6) FCW	4 – 16 mm
24. Half X-joint α = 50° C = 1.0 – 1.5 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG6) FCW5)	14 – 30 mm
25. Half X-joint α = 50° C = 1.5 – 2.5 mm D = 2.0 – 3.0 mm		Two sides	MMA MIG TIG6) FCW	14 – 30 mm
26. Fillet weld No root gap		Two sides	MMA MIG TIG FCW	< 2 mm
27. Fillet weld D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG FCW	2 – 4 mm

5) Welding performed against ceramic backing (round type).
6) Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.

Joint preparations Table 7.1

No. and joint type		Sides	Method	Thickness
28. Half V-joint α = 50° C = 1.5 – 2.5 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG[6)] FCW[5)]	4 – 12 mm
29. Half V-joint α = 50° C = 1.5 – 2.5 mm D = 1.5 – 2.5 mm		Two sides	MMA MIG TIG[6)] FCW	4 – 16 mm
30. K-joint β = 50° C = 2.0 – 2.5 mm D = 2.0 – 4.0 mm		Two sides	MMA MIG TIG[6)] FCW	14 – 30 mm[8)]
31. Half V-joint [7)] α = 50° C = 1.0 – 2.0 mm D = 2.0 – 3.0 mm		Two sides	MMA MIG TIG[6)] FCW	4 – 16 mm
32. Half pipe α = 45° C = 1.5 – 2.0 mm D = 1.0 – 2.0 mm		One side	MMA MIG TIG FCW	4 – 16 mm

5) Welding performed against ceramic backing (round type).
6) Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.
7) For openings such as manways, viewports and nozzles.
8) A thickness above 20 mm can be prepared as an asymmetrical X-joint.

8 Shielding and backing gases

Shielding gas function

Shielding gas plays an extremely important role in most arc welding methods. It has two main functions. One of these is to protect the arc and weld pool from the surrounding air. This protection prevents the oxygen in the air oxidising the weld pool and heated metal. Similarly, other elements in the air (e.g. hydrogen and nitrogen) are also prevented from having a negative impact, for example, weld embrittlement, porosity and cracking in the weld. In the heat-affected zone, hydrogen may even embrittle the parent metal.

The second function is the promotion of stable metal transfer through the arc. Besides this, the composition of the shielding gas also influences weld geometry, weld bead appearance, welding speed, the burn-off of alloying elements, corrosion resistance and mechanical properties. Each component of the shielding gas affects weld metal properties in different ways. Thus, different combinations of gases are chosen for different metals and welding methods.

Shielding gas components

Argon

Because it is an inert gas, argon (Ar) does not react in the welding process. Consequently, it does not promote oxidation or affect the chemical composition of the weld metal. For this reason, argon is widely used as the base gas in most of the shielding gases used for stainless steel welding in Europe. The argon arc is very directional with a tendency to give finger-shaped penetration into the workpiece.

Helium

Helium (He) is also an inert gas. Compared to argon, it has a higher ionisation potential and thermal conductivity. This results in a higher energy arc of a different shape. Arc stability is better and penetration is wider and bowl-shaped.

The higher energy arc also enables higher welding speeds. This is particularly beneficial in automatic welding. At the same time, the higher energy also means there is increased heat input. This must be taken into consideration when welding thin gauges or when welding fully austenitic steels that are more prone to precipitation of secondary phases.

In Europe, the helium content in both binary and tertiary shielding gas mixtures is typically 20 – 40%. The positive effect of using a lower content is small. In North America, helium (rather than argon) is widely used as the base gas.

Carbon dioxide and oxygen

Carbon dioxide (CO_2) and oxygen (O_2), both strong oxidising agents, are added to the base gas to stabilise the arc and ensure smooth metal transfer.

The oxidising effect of oxygen is two to three times stronger than that of carbon dioxide. Consequently, it is also responsible for higher losses of alloying elements in the arc. Thus, the oxygen content of argon-based shielding gas mixtures is normally somewhat lower than the carbon dioxide content (i.e. 1 – 2% O_2 as opposed to 2 – 3% CO_2).

The addition of 2 – 3% CO_2 to the argon base gives a slightly wider weld with less penetration.

Strongly dependent on the welding parameters, carbon dioxide can also promote an addition or pick-up of carbon to the weld metal. A carbon pick-up as high as 0.02% can occur when using 3% CO_2 in spray mode MIG welding (see figure 8.1). This factor must be given special consideration when welding extra low carbon (ELC) steels.

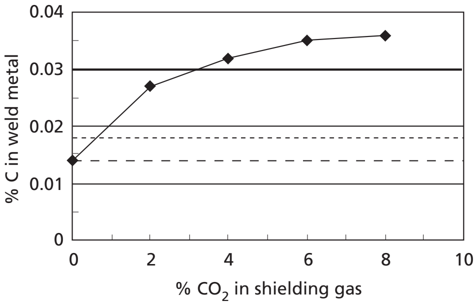


Figure 8.1. Carbon pick-up in austenitic weld metal

Pick-up when using dip transfer or pulsed arc MIG is much less and is normally not a problem.

Nitrogen

Besides improving tensile strength, nitrogen (N_2) also has a beneficial effect on resistance to pitting and crevice corrosion. Nitrogen can be advantageously added when welding nitrogen alloyed steels such as Outokumpu 2205 (S32205), SAF 2507 (S32750) and 254 SMO (S31254).

The addition of up to 2% nitrogen in a binary or tertiary gas mixture will raise the partial pressure of nitrogen above the weld pool. This helps to control the nitrogen content in the weld. The addition of nitrogen also compensates for losses in the arc during the welding of nitrogen alloyed steels.

Hydrogen

With an effect several times greater than that of helium, hydrogen (H_2) increases arc energy and gives a more constricted arc. Penetration and weld pool fluidity are thus improved and travel speed can, as a result, be increased. An addition of up to 5% H_2 can be used in the TIG welding of austenitic steels. A higher content may cause porosity in the weld metal. When welding martensitic and ferritic steels, the addition of hydrogen is not normally recommended – the combination of dissolved hydrogen and high ferrite content can cause hydrogen cracking. This is generally not a problem when welding duplex steels. However, hydrogen must not be added when welding thick gauge duplex steels.

Hydrogen is a strong reducing agent and minimises the amount of oxidation on the weld bead surface.

Nitrogen monoxide

A small addition (0.03%) of nitrogen monoxide (NO) reduces the emission of ozone from the weld zone. This is beneficial for the welder's health and the environment at large. Especially when MIG welding, nitrogen monoxide may also improve arc stability.

Nitrogen monoxide is used in some commercial shielding gases for TIG and MIG welding.

Backing gases

Unless pickling is possible, an inert gas backing must be used when non-fluxing processes are employed for the root runs of single-sided welds. The backing provides protection against oxidation. If no, or inadequate, protection is provided, the penetration bead and surrounding parent metal will, at the very least, be badly oxidised. Further probable consequences are that the penetration bead will not form correctly and that it will be unacceptably porous. The net effect is the serious impairment of the weld zone's corrosion performance and structural stability (see figure 8.2).

Figure 8.2. Single-sided butt weld without backing gas

For reasons of simplicity and practicality, it is most common to use the same gas for both backing and shielding. However, the lowest levels of oxidation are obtained using a backing gas that is a mixture of nitrogen and hydrogen (a so-called Formier gas), e.g. 90% N_2 + 10% H_2. Without any risk of hydrogen pick-up by the weld metal, this gas can also be used as the backing gas when welding duplex steels.

Figure 8.3. A purge insert

When welding pipes, a purge insert (see figure 8.3) is often used to help minimise oxygen levels. Alternatively, the pipe ends are sometimes closed using cardboard or tape. To minimise oxygen content in the enclosure, it should be flushed at least seven times. A volume of purging gas equal to the volume of the enclosure should be used in each flushing. The aim is the minimum possible oxygen content. In all cases, 50 ppm should be seen as a maximum. Preferably, there should be a flow of purging gas throughout the welding sequence. This applies even when welding multiple runs.

There has been much discussion of the acceptance criteria for welds made in the above way. In general, welds with a straw-yellow colour can be accepted. Such a colour can only be achieved when the oxygen content in the purging gas is very low. It has been shown that an oxygen content of 60 – 100 ppm can leave a dark oxide on the weld. The weld is normally rejected in this case.

When argon is used as the purging gas, it must be remembered that the system will purge from the bottom (argon is denser than air). Thus, the purge vent pipe must be at the top. The reverse is true where helium (less dense than air) is used for purging. The vent pipe must then be at the bottom.

Shielding gases for MIG welding

MIG welding is normally carried out using an argon-based shielding gas. To stabilise the arc, there is an addition of 1 – 2% oxygen or 2 – 3% carbon dioxide. Higher contents of these gases will increase oxidation of the weld bead. The addition of carbon dioxide will also increase carbon pick-up. The use of carbon dioxide has a positive effect when position welding with short or pulsed arc transfer.

The addition of up to 30% helium increases arc energy. This improves fluidity and arc stability. It may also enable significantly increased travel speed.

Table 8.1 lists (in order of recommendation) the shielding gases generally used in the MIG welding of most common stainless steels.

Shielding gases for MIG welding Table 8.1

Parent metal	Shielding gas
Ferritic and martensitic	1. Ar + 1 – 2% O_2 *or* Ar + 2 – 3% CO_2
Standard austenitic (304, 316, etc.)	1. Ar + 1 – 2% O_2 *or* Ar + 2 – 3% CO_2 2. Ar + 30% He + 1 – 3% CO_2
Fully austenitic (254 SMO, etc.)	1. Ar + 30% He *or* Ar + 30% He + 1 – 3% CO_2 2. Ar + 30% He + 1 – 2% N_2 3. Ar
Duplex (2205, SAF 2507)	1. Ar + 1 – 2% O_2 *or* Ar + 2 – 3% CO_2 2. Ar + 30% He + 1 – 3% CO_2
Nickel base alloys (625, 800)	1. Ar + 30% He 2. Ar + 30% He + 1 – 3% CO_2 3. Ar

General guidelines:
- The gas flow for manual MIG welding is typically 12 – 16 l/min.
- The gas flow for automatic welding is higher, up to 20 l/min.
- With large diameter nozzles, gas flow should be at the high end of the range.
- Porosity may result if the gas flow is either too low or too high.
- MIG welding is sensitive to draughts. When welding outdoors, suitable draught exclusion must be provided for the weld.

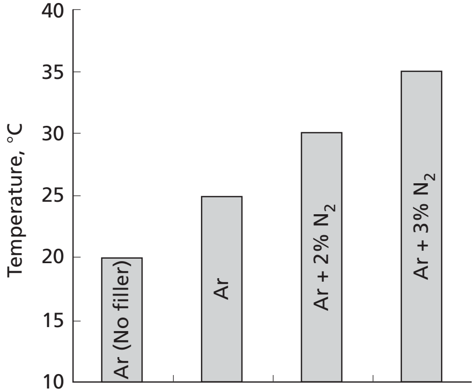


Figure 8.4. Critical pitting temperatures for TIG welded AvestaPolarit 2205

Shielding gases for TIG welding

TIG welding is normally performed using pure argon (minimum 99.99%) as the shielding gas. In special applications where an extremely low content of impurities is essential, the argon may be even purer (99.995%). The addition of helium (up to 30%) or hydrogen (up to 2%) increases arc energy and gives increased penetration as well as a smoother weld bead. Furthermore, welding speed can be increased by up to 50%.

When welding nitrogen alloyed stainless steels such as Outokumpu 2205 or Outokumpu 254 SMO, the addition of up to 2% nitrogen can be advantageous. Compared to welding with a pure argon shielding gas, this improves corrosion resistance (see figure 8.4). A nitrogen content above 2% contributes positively to pitting resistance. However, as it also increases tungsten electrode wear, it is not to be recommended in the majority of cases.

Table 8.2 lists the shielding gases generally used in the TIG welding of most common stainless steels.

Shielding gases for TIG welding Table 8.2

Parent metal	Shielding gas
Ferritic and martensitic	Ar *or* Ar + 30% He
Standard austenitic (304, 316, etc.)	Ar *or* Ar + 30% He *or* Ar + 2% H_2
Fully austenitic (254 SMO, etc.)	Ar *or* Ar + 2% N_2 *or* Ar + 30% He + 2% N_2
Duplex (2205, SAF 2507)	Ar *or* Ar + 2% N_2 *or* Ar + 30% He + 2% N_2
Nickel base alloys (625, 800)	Ar *or* Ar + 30% He

General guidelines:
- The gas flow for manual TIG welding is typically 4 – 8 l/min.
- The gas flow for automatic welding is higher, up to 15 l/min.
- With large diameter nozzles, gas flow should be at the high end of the range.
- Porosity may result if the gas flow is either too low or too high.
- TIG welding is sensitive to draughts. Suitable draught exclusion must be provided when welding in susceptible locations, e.g. on-site or in large, open halls.

Shielding gases for FCAW

The most frequently used shielding gas for flux cored arc welding is argon with an addition of 15 – 25% CO_2 (carbon dioxide). With a minimum of spatter, this gives good arc stability and slag control.

Welding can also be performed using a 100% CO_2 shielding gas. This substantially reduces arc stability. Consequently, there is increased spatter and reduced control of the weld pool.

Due to increased carbon pick-up in the weld, a high carbon dioxide content is not normally suitable for welding stainless steels. However, FCAW provides an exception – each droplet in the arc is covered with slag and is thus protected from the surrounding atmosphere and shielding gas (see figure 8.5).

Table 8.3 lists (in order of recommendation) the shielding gases generally used in the flux cored arc welding of most common stainless steels.

Shielding gases for FCAW Table 8.3

Parent metal	Shielding gas
Ferritic and martensitic	1. Ar + 15 – 25% CO_2 2. 100% CO_2
Standard austenitic (304, 316, etc.)	1. Ar + 15 – 25% CO_2 2. 100% CO_2
Duplex (2205)	1. Ar + 15 – 25% CO_2 2. 100% CO_2

General guidelines:

- The gas flow for FCA welding is typically 20 – 25 l/min.
- Porosity may result if the gas flow is either too low or too high.
- The gas flow should be around, or slightly below, 20 l/min when welding in the vertical-up and overhead positions.
- A somewhat higher voltage (+3V) should be used when welding Outokumpu 2205.
- A somewhat higher voltage (+3V) should be used when the shielding gas is 100% CO_2.

Shielding gases for PAW

The plasma and shielding gases used in plasma arc welding are normally either pure argon or argon with an addition of up to 5% hydrogen. The addition of hydrogen improves weld bead appearance and enables higher welding speeds. An addition of 20 – 30% helium increases arc energy. This improves fluidity and travel speed can thus be increased. For high-alloy steel grades, the addition of 1 – 2% nitrogen improves corrosion resistance.

As in TIG welding, pure argon or a Formier gas (e.g. 90% N_2 + 10% H_2) should be used as the backing gas.

Table 8.4 lists (in order of recommendation) the shielding gases generally used in the plasma arc welding of most common stainless steels.

Shielding gases for PAW Table 8.4

Parent metal	Plasma gas	Shielding gas
Austenitic	1. Ar *or* Ar + 5% H_2 2. Ar + 20 – 30% He 3. Ar + 20 – 30% He + 1 – 2% N_2	Ar *or* the same as the plasma
Duplex	1. Ar 2. Ar + 20 – 30% He 3. Ar + 20 – 30% He + 1 – 2% N_2	Ar *or* the same as the plasma

General guidelines:

- The plasma gas flow for PAW is typically 3 – 7 l/min.
- The shielding gas flow is typically 10 – 15 l/min.

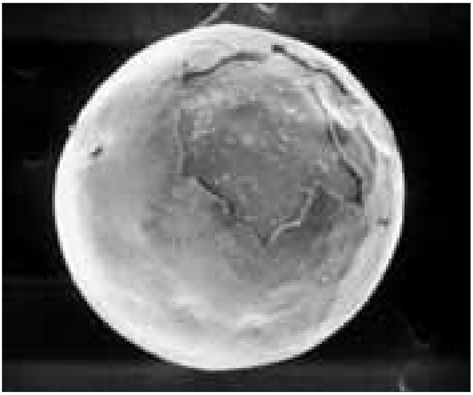


Figure 8.5. Slag protection around the droplet in FCAW

9 Post-weld cleaning of stainless steel

Introduction

A stainless steel surface should appear clean, smooth and faultless. This is obvious when the steel is used for such purposes as façades or in applications with stringent hygienic requirements, but a fine surface finish is also crucial to corrosion resistance.

Stainless steel is protected from corrosion by a thin, impervious, invisible surface layer – the passive layer – that consists mainly of chromium oxide. The oxygen content of the atmosphere or aerated aqueous solutions is normally sufficient to create and maintain this passive layer. Unfortunately, surface defects and imperfections introduced during manufacturing operations may drastically disturb this "self-healing" process and reduce resistance to several types of local corrosion. This means that a final cleaning process will often be required to restore an acceptable surface quality with regard to hygiene and corrosion.

The extent of and methods for post-manufacture treatment will be determined by the corrosivity of the environment, the corrosion resistance of the steel grade, hygienic requirements (e.g. in the pharmaceutical and food industries) or by purely aesthetic considerations. Consideration must also be paid to local environmental requirements. Both chemical and mechanical cleaning methods are available. Good design, planning and methods of manufacture can reduce the need for finishing work and thus reduce costs. The influence of defects, and ultimately their removal, must be considered when manufacturing to specifications that relate to certain surface quality requirements.

Typical defects

Heat tint and oxide scale

High temperature oxidation, caused by processes such as heat treatment or welding, produces an oxide layer with inferior protective properties, compared with those of the original passive layer. A corresponding chromium depletion in the metal immediately below the oxide also occurs. The chromium-depleted zone under normal welding heat tint is very thin and can normally be removed together with the tint. It is, however, necessary to remove this layer in order to completely restore corrosion resistance.

Weld defects

Incomplete penetration, undercut, pores, slag inclusions, weld spatter and arc strikes are typical examples of weld defects.

These defects have negative effects on mechanical properties, resistance to local corrosion and make it difficult to maintain a clean surface. The defects must therefore be removed, normally by grinding, although sometimes repair welding is also necessary.

Iron contamination

Iron particles can originate from machining, cold forming and cutting tools, blasting grits/sand or grinding discs contaminated with lower alloyed material, transport or handling in mixed manufacture, or simply from iron-containing dust. These particles corrode in humid air and damage the passive layer. Larger particles may also cause crevices. Reduced corrosion resistance will result in both cases. This type of corrosion

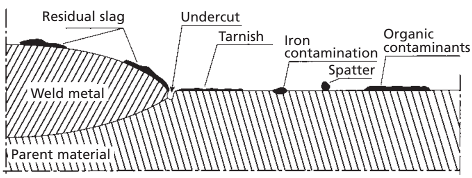


Figure 9.1. Surface defects

produces unsightly discoloration and may also contaminate media used in the equipment in question. Iron contamination can be detected using the ferroxyl test.

Rough surface

Uneven weld beads and grinding or blasting too heavily will result in rough surfaces. A rough surface collects deposits more easily, thereby increasing the risk of both corrosion and product contamination. Heavy grinding also introduces high tensile stresses, which increase the risk of stress corrosion cracking and pitting corrosion. There is a maximum allowed surface roughness (Ra-value) for many applications, and manufacturing methods that result in rough surfaces should generally be avoided.

Organic contamination

Organic contaminants in the form of grease, oil, paint, footprints, glue residues and dirt can cause crevice corrosion in aggressive environments, render surface pickling activities ineffective, and pollute products handled in the equipment. Organic contaminants should be removed using a suitable pre-cleaning/degreasing agent (chlorine-free). In simple cases, a high-pressure water jet can be used.

Cleaning procedures

Different chemical and mechanical methods, and sometimes a combination of both, can be used to remove the defects mentioned. Generally, cleaning based on chemical methods can be expected to produce superior results since most effective mechanical methods tend to produce a rougher surface whilst chemical cleaning methods reduce the risk of surface contamination. Local regulations in respect of environmental and industrial safety as well as waste disposal problems may, however, limit their application.

Mechanical methods

Grinding

Grinding is normally the only method that can be used to remove defects and deep scratches. A grinding disc is usually adequate for treating defects of this type. The grinding methods used should never be rougher than necessary, and a flapper wheel is often sufficient for removing weld tint or surface contamination.

The following points must always be considered:

- Use the correct grinding tools – self-sharpening, iron-free discs should always be used for stainless steel – and never use discs that have previously been used for grinding low-alloy steels.
- Avoid producing a surface that is too rough. Rough grinding with a 40 – 60 grit disc should always be followed by fine grinding using, for example, a higher grit mop or belt to obtain a surface finish corresponding to grit 180 or better. If surface requirements are very exacting, polishing may be necessary.
- Do not overheat the surface. Apply less pressure when grinding in order to avoid creating further heat tint.
- Always check that the entire defect has been removed.

Blasting

Sand and grit blasting (peening) can be used to remove high temperature oxide as well as iron contamination. However, care must be taken to ensure that the sand (preferably of olivine type) or grit is perfectly clean. The blasting material must therefore not have been previously used for carbon steel; nor should the sand or grit be too old, since it becomes increasingly polluted, even if it has only been used for blasting contaminated stainless steel surfaces. The surface roughness is the limiting factor for these methods. Using low pressure and a small angle of approach, a satisfactory result can be achieved for most applications. For the removal of heat tint, shot peening using smooth glass beads produces a good surface finish and introduces compressive stresses which improve stress corrosion cracking resistance and resistance to fatigue.

Brushing

For the removal of heat tint, brushing using stainless steel or nylon brushes usually provides a satisfactory result. These methods do not cause any serious roughening of the surface, but do not guarantee complete removal of the chromium-depleted zone. As regards the other mechanical methods, the risk of contamination is high, and it is therefore important that clean tools that have not been used for processing carbon steels are used.

Summary

A final mechanical cleaning stage following a typical manufacturing programme could be as follows:

- Removal of welding defects by grinding.
- Removal of material affected by high temperatures and, if possible, removal of iron impurities. The surface must not become unacceptably rough.
- Removal of organic contaminants.
- A final acid treatment – passivation/ decontamination – is strongly recommended. A thorough rinsing with fresh water, preferably using a high-pressure water jet must follow the acid treatment. In exceptional cases, however, rinsing by high-pressure water jet only may suffice as the final treatment.

Chemical methods

Chemical methods can remove high temperature oxide and iron contamination without damaging the surface finish. Electropolishing may improve the surface finish. Since they remove the surface layer by controlled corrosion, chemicals will also selectively remove the least corrosion-resistant areas such as the chromium-depleted zones.

After the removal of organic contaminants, the following procedures are commonly used.

Electropolishing

Electropolishing normally produces a surface that guarantees optimal corrosion resistance. The material gains a fine lustre, and, above all, an even micro-profile that meets extremely stringent hygienic requirements.

Pickling

Pickling is the most common chemical procedure used to remove oxides and iron contamination. Thorough rinsing with clean tap water must follow pickling. The water quality requirements, including acceptable chloride content, increase with the surface requirements. Pickling normally involves using an acid mixture containing 8 – 20% (by volume) nitric acid (HNO_3) and 0.5 – 5% (by volume) hydrofluoric acid (HF). Chloride-containing agents such as hydrochloric acid (HCl) should be avoided, since there is an obvious risk of pitting corrosion.

The effectiveness of pickling depends on the following factors:

- **The surface.** This must be free of organic contamination.
- **The temperature.** The effectiveness of the acids increases strongly with temperature. This means, for example, that the pickling rate can be increased considerably by increasing the temperature. There are, however, upper temperature limits that must also be considered.
- **The composition and concentration of the acid mixture.**

Stainless steel grades and their pickleability Table 9.1

Group	International steel number/name EN	ASTM	Outokumpu steel name	Outokumpu chemical composition, typical % C	Cr	Ni	Mo	Others	Pickle-ability*
1	1.4301	304	4301	0.04	18.1	8.3	–	–	1
	1.4401	316	4401	0.04	17.2	10.2	2.1	–	2
	1.4404	316L	4404	0.02	17.2	10.1	2.1	–	2
	1.4571	316Ti	4571	0.04	16.8	10.9	2.1	Ti	2
	1.4436	316	4436	0.04	16.9	10.7	2.6	–	2
2	1.4362	S32304	SAF 2304®	0.02	23	4.8	0.3	–	3
	1.4462	S32205	2205	0.02	22	5.7	3.1	–	3
	1.4439	S31726	4439	0.02	17.8	12.7	4.1	–	3
	1.4539	904L	904L	0.01	20	25	4.3	1.5 Cu	3
3	1.4410	S32750	SAF 2507®	0.02	25	7	4	–	4
	1.4547	S31254	254 SMO®	0.01	20	18	6.1	Cu	4
	1.4652	S32654	654 SMO®	0.01	24	22	7.3	3.5 Mn, Cu	4

* The pickleability of the steel grades ranges from 1 (light) to 4 (heavy).

- **The steel grade.** Highly alloyed grades need a more aggressive acid mixture and/or higher temperature in order to avoid an excessively long pickling time. See table 9.1. The steels have been divided into three groups. The pickleability of these steel grades ranges from 1 (light) to 4 (heavy).
- **The thickness and type of the oxide layer.** This depends largely on the welding procedure used. Welding using an effective shielding gas will produce a minimum of weld oxides. Such a gas should be as free of oxygen as possible. For further information, see chapter 8, "Shielding gases". Mechanical pre-treatment to break or remove the oxide might be advisable, particularly when pickling highly alloyed steel grades.
- **The surface finish.** A rough hot rolled surface may be harder to pickle than a smooth cold rolled one.

A number of different pickling methods can be used:

- **Pickling in a bath** is a convenient method if suitable equipment is available. The composition of the acid mixture and the bath temperature (20 – 65°C) are chosen with regard to the stainless steel grade and the type of heat oxide. Overpickling, resulting in a rough surface, may result when pickling the lowest alloyed stainless grades at excessive temperatures. The effectiveness of pickling is influenced not only by the acid concentration and the temperature, but also by the free metal content (mainly iron) in the bath. An increased iron content requires a higher bath temperature. A rough guideline is that the free iron (Fe) content measured in g/l should not exceed the bath temperature (°C). When metal contents in the bath reach excessive levels (40 – 50 g/l), the bath solution can be partially or totally emptied out and fresh acid added.
- **Pickling with pickling paste.** Pickling paste for stainless steels consists of an acid mixture (normally HF/HNO_3) with added binding agents. It is suitable for pickling limited areas, e.g. weld-affected zones. It is normally applied using an acid-resistant brush. The paste is not effective at low temperatures (5 – 10°C). The risk of overpickling at high temperatures is less than when using bath pickling. A greater risk is that of the paste drying out due to evaporation, resulting in reduced pickling effect and rinsing difficulties. Objects

should therefore not be pickled at temperatures higher than 40°C or in direct sunlight. Rinsing with water should be carried out before the paste dries. Even if, for environmental and practical reasons, neutralisation of the pickling paste is carried out on the metal surface, a thorough rinsing with water is vital.
- **Pickling with pickling solution.** Pickling solutions (or pickling gels in spray form) are normally mixtures of nitric and hydrofluoric acids (phosphoric acid can be used for light pickling), with binding agents and surface-active agents to obtain good thixotropy and the right viscosity. Solutions and gels in spray form are suitable for pickling large surfaces, e.g. when the removal of iron contamination is also desired.

Summary

A final pickling/cleaning operation following a typical manufacturing programme could be:
- Grinding for removal of defects caused by welding. It is important that slag is removed after welding.
- Removal of organic contamination.
- Pickling using a bath, paste or solution, possibly in combination with a careful mechanical treatment to break oxides.
- A thorough rinsing with water, preferably using a high-pressure water jet.

Passivation and decontamination

Traditional passivating solutions are based on nitric acid. From both a handling and an environmental point of view, this has the disadvantage of being hazardous. However, Avesta Finishing Chemicals has developed a new passivating agent that, without sacrificing efficiency, has less impact on the enviroment. Passivating solutions are applied by immersion or spraying. Treatment strengthens the passive layer. It is particularly important after mechanical cleaning and operations involving a risk of iron contamination. This is because the agent also removes iron impurities from the surface. Consequently, the method could also be referred to as decontamination.

Choice of method

The choice of method and the extent of final cleaning required will depend on the need for corrosion resistance, hygienic considerations (pharmaceuticals, foodstuffs) or whether visual appearance is the sole criterion. The routine removal of welding defects, welding oxides, organic substances and iron contaminants is normally a basic requirement and usually allows a comparatively free choice of final treatment. Provided that the surface roughness so permits, both mechanical and chemical methods can be used. However, if an entirely mechanical cleaning method is considered, the manufacturing stage has to be very well planned in order to avoid iron contamination, since decontamination, probably with nitric acid, will otherwise be necessary.

When requirements as to surface finish and corrosion resistance are exacting, the choice of method is more critical. A treatment sequence based on pickling will in such cases provide the best chances of a superior result.

Avesta Finishing Chemicals has now also developed *The Rainbow Concept*, an integrated range of post-weld cleaning products especially for stainless steels. Further details are given on the next page.

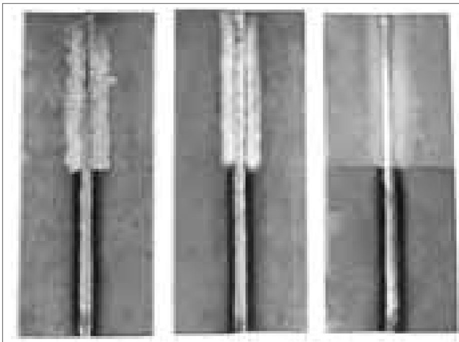


Figure 9.2. Pickling offers better results than alternative surface treatments such as grinding and polishing

The Rainbow Concept

The Rainbow Concept is an integrated range of pickling, cleaning and passivating agents from Avesta Finishing Chemicals. Designed to ensure optimal post-weld cleaning results, the range is colour coded to facilitate choice of the correct product. Colour coding applies not only to labels and caps but also to the pastes, liquids and sprays themselves.

Under the trade name CleanOne, the cleaning and degreasing products in the range are yellow. Identifying the type of pickling for which they are intended, the range's pickling pastes and liquids are green, blue or red. The trade names of the products are GreenOne, BlueOne and RedOne. The passivating and finishing products, trade name FinishOne, are colourless.

Cleaning	Pickling			Finishing
				
CleanOne™ (yellow) for cleaning and degreasing	GreenOne™ for light pickling – minimal environmental impact BlueOne™ for medium pickling – moderate environmental impact RedOne™ for heavy pickling – elevated environmental impact			FinishOne™ (colourless) for passivation and finishing

10 Storage and handling recommendations for covered electrodes, flux-cored wire and fluxes

Moisture pick-up can be harmful for stainless steel covered electrodes, FCW and fluxes. Although consumables from Avesta Welding are supplied in moisture resistant packages, the precautions and measures given below are still recommended.

Storage

Covered electrodes, FCW and fluxes should be stored in their *unopened* and *undamaged* original packaging. Failure to do this may seriously reduce the durability of the consumables.

Storage times should be kept as short as possible. The "first in – first out" principle should be observed.

Neither covered electrodes nor flux should be stored for more than 5 years. Products over 5 years old should be redried before use. Please contact Avesta Welding if unsure of the production year. Avesta Welding rarely ships any consumables over 3 years old. Moisture is carefully checked before supplying such consumables.

Covered electrodes and flux should not be stored in direct contact with floors or outer walls.

Storeroom temperature should be kept as even as possible (+/–5°C variation). It should not fall below 15°C. Relative humidity should not exceed 50%.

Handling of opened packages

Whenever possible, welding should be carried out at room temperature and low relative humidity. Consumables removed from storage should be used as quickly as possible (ideally, never more than one day after removal).

Between shifts, it is advisable to reseal unused electrodes or hold them at 60 – 70°C in a constant temperature, well ventilated oven. Relative humidity should not exceed 50%.

Between shifts, unused welding flux should be removed from the welding machine and kept in an oven at 60 – 70°C. If relative humidity exceeds 55%, FCW should never be left unprotected for more than 24 hours.

Handling of electrodes in the welding area

Electrodes should be kept as dry as possible when they are being used. If the climate so demands, they should be kept warm in a thermo-container or similar. Another solution is to use vacuum sealed, "Extra Dry" packs.

Rebaking of electrodes and fluxes

Electrodes slightly affected by moisture may be rebaked for approx. 3 hours at 250 – 280°C. Heating and cooling should be carried out slowly. Electrodes can be rebaked up to three times with no danger of damaging the coating.

Fluxes slightly affected by moisture may be redried for 2 hours at 250 – 300°C.

FCW that has absorbed moisture **cannot** be redried.

Note

The consequences of moisture pick-up are not as serious for stainless steel electrodes as they are for mild steel electrodes. Hence, any system for handling the latter is also suitable for stainless steel electrodes.

11 Standards and approvals

Introduction

Welding consumable manufacturers normally follow an international standard when classifying their products. In classifying its products, Avesta Welding uses both the AWS (American Welding Society) and EN (European Norm) systems. The latter supersedes the standards systems formerly used in a number of countries, e.g. BS (the United Kingdom), NF (France), DIN (Germany), SS (Sweden). The two standards adopted by Avesta Welding set out the classification of welding consumables in respect of:

- the chemical composition of all-weld metal
- the mechanical properties of all-weld metal
- type of welding current and welding position (MMA and FCAW)
- standard sizes and lengths
- identification and packaging

Many Avesta Welding consumables also have approvals from a number of internationally recognised classification societies.

- CWB (Canadian Welding Bureau)
- DNV (Det Norske Veritas)
- DB (Deutsche Bahn)
- GL (Germanischer Lloyd)
- SK (Svetskommissionen)
- TÜV (Technischer Überwachungs Verein)

Individually, these societies work in different areas of application, e.g. pressure vessels, shipbuilding, pulp and paper.

The approvals for each product are set out in chapter 14, "Product data sheets".

Figure 11.1. Materials testing, here in the presence of a third-party inspector, is continuous

For further details about the standards and approvals referred to in this chapter, please contact Avesta Welding.

EN 1600
Welding consumables – Covered electrodes for manual metal arc welding of stainless and heat resisting steels – Classification

E 19 12 3 L R 3 4

- Welding method (E)
- Chemical composition (19 12 3 L)
- Type of covering (R)
- Metal recovery and type of current (3)
- Welding position (4)

Welding method:
E = covered electrodes

Chemical composition:
As per table 11.1

Type of covering: R = rutile, B = basic

Metal recovery and type of current:

Symbol	Metal recovery,%	Type of current
1	≤ 105	AC and DC
2	≤ 105	DC
3	> 105 ≤ 125	AC and DC
4	> 105 ≤ 125	DC
5	> 125 ≤ 160	AC and DC
6	> 125 ≤ 160	DC
7	> 160	AC and DC
8	> 160	DC

Welding position:
1 = all positions
2 = all positions, except vertical-down
3 = flat butt weld, flat fillet weld, horizontal-vertical fillet weld
4 = flat butt weld, flat fillet weld
5 = vertical-down and as per 3 above

As regards mechanical properties (proof strength, tensile strength and elongation), the all-weld metal has to satisfy the same requirements as the parent metal.

The minimum requirements for each product are shown in the product data sheets in chapter 14.

EN 12073
Welding consumables – Tubular cored electrodes for metal arc welding with or without a gas shield of stainless and heat resisting steels – Classification

T 19 12 3 L R M 4

- Welding method (T)
- Chemical composition (19 12 3 L)
- Type of electrode core (R)
- Shielding gas (M)
- Welding position (4)

Welding method:
T = tubular cored electrode

Chemical composition:
As per table 11.1

Type of electrode core:
R = rutile, slow freezing slag
P = rutile, fast freezing slag
M = metal powder
U = self shielded
Z = other types

Shielding gas:
M = mixed gas (Ar + addition of CO_2)
C = pure CO_2
N = no gas shield

Welding position:
1 = all positions
2 = all positions, except vertical-down
3 = flat butt weld, flat fillet weld, horizontal-vertical fillet weld
4 = flat butt weld, flat fillet weld
5 = vertical-down and as per 3 above

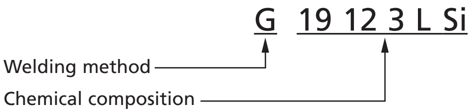
As regards mechanical properties (proof strength, tensile strength and elongation), the all-weld metal has to satisfy the same requirements as the parent metal.

The minimum requirements for each product are shown in the product data sheets in chapter 14.

EN 1600 and EN 12073 (selected fillers only) Table 11.1

	1600	12073	C	Si	Mn	P	S	Cr	Ni	Mo	Other
Austenitic											
19 9	x		0.08	1.2	2.0	0.030	0.025	18.0 – 21.0	9.0 – 11.0	–	–
19 9 L	x	x	0.04	1.2	2.0	0.030	0.025	18.0 – 21.0	9.0 – 11.0	–	–
19 9 Nb	x	x	0.08	1.2	2.0	0.030	0.025	18.0 – 21.0	9.0 – 11.0	–	Nb 8xC – 1.1
19 12 2	x		0.08	1.2	2.0	0.030	0.025	17.0 – 20.0	10.0 – 13.0	2.0 – 3.0	–
19 12 3 L	x	x	0.04	1.2	2.0	0.030	0.025	17.0 – 20.0	10.0 – 13.0	2.5 – 3.0	–
19 12 3 Nb	x	x	0.08	1.2	2.0	0.030	0.025	17.0 – 20.0	10.0 – 13.0	2.5 – 3.0	Nb 8xC – 1.1
19 13 4 L N	x	x	0.04	1.2	1.0 – 5.0	0.030	0.025	17.0 – 20.0	12.0 – 15.0	3.0 – 4.5	N 0.20
Duplex											
22 9 3 N L	x	x	0.04	1.2	2.5	0.030	0.025	21.0 – 24.0	7.5 – 10.5	2.5 – 4.0	N 0.08 – 0.20
25 9 4 N L	x		0.04	1.2	2.5	0.030	0.025	24.0 – 27.0	8.0 – 10.5	2.5 – 4.5	N 0.20 – 0.30, Cu 1.5
Fully austenitic											
18 15 3 L	x		0.04	1.2	1.0 – 4.0	0.030	0.025	16.5 – 19.5	14.0 – 17.0	2.5 – 3.5	–
18 16 5 N L	x	x	0.04	1.2	1.0 – 4.0	0.035	0.025	17.0 – 20.0	15.5 – 19.0	3.5 – 5.0	N 0.20
20 25 5 Cu N L	x		0.04	1.2	1.0 – 4.0	0.030	0.025	19.0 – 22.0	24.0 – 27.0	4.0 – 7.0	Cu 1.0 – 2.0, N 0.25
25 22 2 N L	x		0.04	1.2	1.0 – 5.0	0.030	0.025	24.0 – 27.0	20.0 – 23.0	2.0 – 3.0	N 0.20
27 31 4 Cu L	x		0.04	1.2	2.5	0.030	0.025	26.0 – 29.0	30.0 – 33.0	3.0 – 4.5	Cu 0.6 – 1.5
Special types											
18 8 Mn	x	x	0.20	1.2	4.5 – 7.5	0.035	0.025	17.0 – 20.0	7.0 – 10.0	–	–
23 12 L	x	x	0.04	1.2	2.5	0.030	0.025	22.0 – 25.0	11.0 – 14.0	–	–
23 12 Nb	x		0.10	1.2	2.5	0.030	0.025	22.0 – 25.0	11.0 – 14.0	–	Nb 8xC – 1.1
23 12 2 L	x	x	0.04	1.2	2.5	0.030	0.025	22.0 – 25.0	11.0 – 14.0	2.0 – 3.0	–
29 9	x	x	0.15	1.2	2.5	0.035	0.025	27.0 – 31.0	9.0 – 11.0	–	–
Heat-resisting											
22 12 H	x	x	0.15	1.2	2.5	0.030	0.025	20.0 – 23.0	10.0 – 13.0	–	–
25 20	x		0.06 – 0.20	1.2	1.0 – 5.0	0.030	0.025	23.0 – 27.0	18.0 – 22.0	–	–

EN 12072
Welding consumables – Wire electrodes, wires and rods for arc welding of stainless and heat-resisting steels – Classification



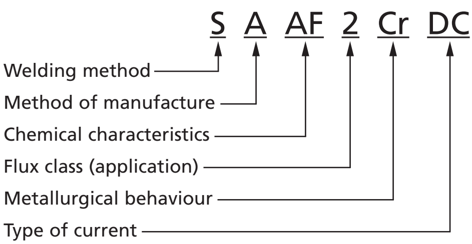
Welding method:
G = gas metal arc welding (MIG)
W = gas tungsten arc welding (TIG)
P = plasma arc welding (PAW)
S = submerged arc welding (SAW)

Chemical composition:
As per table 11.2

As there are exterior factors such as shielding gas and flux, the mechanical properties of the all-weld metal are not part of the standard's classification. However, proof strength, tensile strength and elongation are expected to satisfy the minimum requirements applying to covered electrodes.

The minimum requirements for each product are shown in the product data sheets in chapter 14.

EN 760
Welding consumables – Fluxes for submerged arc welding – Classification



Welding method:
S = submerged arc welding

Method of manufacture:
F = fused flux
A = agglomerated flux
M = mixed flux

Chemical characteristics:
MS = manganese-silicate
CS = calcium-silicate
ZS = zirconium-silicate
RS = rutile-silicate
AR = aluminate-rutile
AB = aluminate-basic
AS = aluminate-silicate
AF = aluminate-fluoride-basic
FB = fluoride-basic
Z = any other composition

Flux class (application):
1 = joint welding and surfacing of unalloyed and low-alloy steels
2 = joint welding and surfacing of stainless and heat-resistant steels and nickel base alloys
3 = surfacing to give a wear-resistant weld metal

Metallurgical behaviour:
Pick-up and/or burn-off of alloying elements (difference between the all-weld metal and the original composition of the filler wire). For flux class 2, the pick-up of alloying elements other than Si and Mn is indicated by giving the chemical symbol (e.g. Cr).

Type of current:
DC = direct current
AC = alternating current

Hydrogen content (H5, H10 and H15), current capacity (maximum acceptable current) and particle size (smallest and largest size of particle) are additional requirements, but do not form part of the flux designation.

EN 12072 (selected fillers only)

Table 11.2

	C	Si	Mn	P	S	Cr	Ni	Mo	Other
Austenitic									
19 9 L Si	0.03	1.2	1.0 – 2.5	0.03	0.02	19.0 – 21.0	9.0 – 11.0	–	–
19 9 Nb Si	0.08	1.2	1.0 – 2.5	0.03	0.02	19.0 – 21.0	9.0 – 11.0	–	Nb 10xC – 1.0
19 12 3 L Si	0.03	1.2	1.0 – 2.5	0.03	0.02	18.0 – 20.0	11.0 – 14.0	2.5 – 3.0	–
19 12 3 Nb Si	0.08	1.2	1.0 – 2.5	0.03	0.02	18.0 – 20.0	11.0 – 14.0	2.5 – 3.0	Nb 10xC – 1.0
Duplex									
22 9 3 N L	0.03	1.0	2.5	0.03	0.02	21.0 – 24.0	7.0 – 10.0	2.5 – 4.0	N 0.10 – 0.20
25 9 4 N L	0.03	1.0	2.5	0.03	0.02	24.0 – 27.0	8.0 – 10.5	2.5 – 4.5	N 0.20 – 0.30, Cu 1.5; W 1.0
Fully austenitic									
18 15 3 L	0.03	1.0	1.0 – 4.0	0.03	0.02	17.0 – 20.0	13.0 – 16.0	2.5 – 4.0	–
18 16 5 N L	0.03	1.0	1.0 – 4.0	0.03	0.02	17.0 – 20.0	16.0 – 19.0	3.5 – 5.0	N 0.10 – 0.20
19 13 4 L	0.03	1.0	1.0 – 5.0	0.03	0.02	17.0 – 20.0	12.0 – 15.0	3.0 – 4.5	
20 25 5 Cu L	0.03	1.0	1.0 – 5.0	0.03	0.02	19.0 – 22.0	24.0 – 27.0	4.0 – 6.0	Cu 1.0 – 2.0
25 22 2 N L	0.03	1.0	3.5 – 6.5	0.03	0.02	24.0 – 27.0	21.0 – 24.0	1.5 – 3.0	N 0.10 – 0.20
27 31 4 Cu L	0.03	1.0	1.0 – 3.0	0.03	0.02	26.0 – 29.0	30.0 – 33.0	3.0 – 4.5	Cu 0.7 – 1.5
Special types									
18 8 Mn Si	0.20	1.2	5.0 – 8.0	0.03	0.03	17.0 – 20.0	7.0 – 10.0	–	–
23 12 L	0.03	0.65	1.0 – 2.5	0.03	0.02	22.0 – 25.0	11.0 – 14.0	–	–
23 12 Nb	0.08	1.0	1.0 – 2.5	0.03	0.02	22.0 – 25.0	11.0 – 14.0	–	Nb 10xC – 1.0
23 12 2 L	0.03	1.0	1.0 – 2.5	0.03	0.02	21.0 – 25.0	11.0 – 15.5	2.0 – 3.5	–
29 9	0.15	1.0	1.0 – 2.5	0.03	0.02	28.0 – 32.0	8.0 – 12.0	–	–
Heat-resisting									
22 12 H	0.04 – 0.15	2.0	1.0 – 2.5	0.03	0.02	21.0 – 24.0	11.0 – 14.0	–	–
25 20	0.08 – 0.15	2.0	1.0 – 2.5	0.03	0.02	24.0 – 27.0	18.0 – 22.0	–	–

AWS A5.4-92
Stainless Steel Electrodes for Shielded Metal Arc Welding

E 308 L - XX

E = covered electrodes
308 = chemical composition
L = low carbon content
XX = usability classification

Chemical composition:
As per table 11.3

Usability classification:
-15 = electrodes usable with DC+ only. Electrodes ≤ 4.00 mm may be used in all positions. The coating is normally of a basic or rutile type.
-16 = electrodes have a rutile coating and are usable with both AC and DC+. Electrodes ≤ 4.00 mm may be used in all positions.
-17 = electrodes have a rutile-acid coating and a slow freezing slag. Welding can be AC or DC+ in all positions.
-25 = slag system similar to -15 designation, but the diameter of the covering is greater. The core wire may be mild steel with all alloying elements in the covering. The electrodes are only suitable for the flat and horizontal positions.
-26 = slag system similar to -16 designation, but the diameter of the covering is greater. The core wire may be mild steel with all alloying elements in the covering. The electrodes are only suitable for the flat and horizontal positions.

AWS A5.4-92 (selected fillers only) Table 11.3

	C	Cr	Ni	Mo	Nb + Ta	Mn	Si	P	S	N	Cu
E307-XX	0.04 – 0.14	18.0 – 21.5	9.0 – 10.7	0.5 – 1.5	–	3.30 – 4.75	0.90	0.04	0.03	–	0.75
E308-XX	0.08	18.0 – 21.0	9.0 – 11.0	0.75	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E308H-XX	0.04 – 0.08	18.0 – 21.0	9.0 – 11.0	0.75	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E308L-XX	0.04	18.0 – 21.0	9.0 – 11.0	0.75	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E309-XX	0.15	22.0 – 25.0	12.0 – 14.0	0.75	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E309L-XX	0.04	22.0 – 25.0	12.0 – 14.0	0.75	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E309Cb-XX	0.12	22.0 – 25.0	12.0 – 14.0	0.75	0.70 – 1.00	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E309MoL-XX	0.04	22.0 – 25.0	12.0 – 14.0	2.0 – 3.0	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E310-XX	0.08 – 0.20	25.0 – 28.0	20.0 – 22.5	0.75	–	1.0 – 2.5	0.75	0.03	0.03	–	0.75
E310Mo-XX	0.12	25.0 – 28.0	20.0 – 22.0	2.0 – 3.0	–	1.0 – 2.5	0.75	0.03	0.03	–	0.75
E312-XX	0.15	28.0 – 32.0	8.0 – 10.5	0.75	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E316-XX	0.08	17.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E316H-XX	0.04 – 0.08	17.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E316L-XX	0.04	17.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E317L-XX	0.04	18.0 – 21.0	12.0 – 14.0	3.0 – 4.0	–	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E318-XX	0.08	17.0 – 20.0	11.0 – 14.0	2.0 – 3.0	6xC – 1.00	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E347-XX	0.08	18.0 – 21.0	9.0 – 11.0	0.75	8xC – 1.00	0.5 – 2.5	0.90	0.04	0.03	–	0.75
E383-XX	0.03	26.5 – 29.0	30.0 – 33.0	3.2 – 4.2	–	0.5 – 2.5	0.90	0.02	0.02	–	0.6 – 1.5
E385-XX	0.03	19.5 – 21.5	24.0 – 26.0	4.2 – 5.2	–	1.0 – 2.5	0.75	0.03	0.02	–	1.2 – 2.0
E2209-XX	0.04	21.5 – 23.5	8.5 – 10.5	2.5 – 3.5	–	0.5 – 2.0	0.90	0.04	0.03	0.08 – 0.20	0.75

AWS A5.9-93
Bare Stainless Steel Welding Electrodes and Rods

This standard classifies consumables for MIG, TIG and SAW (strip and wire).

ER 308 L - Si

ER = solid wire
EQ = strip
308 = chemical composition
L = low carbon content
Si = high silicon content (0.65 – 1.00%)

Chemical composition:
As per table 11.4

AWS A5.9-93 (selected fillers only) Table 11.4

	C	Cr	Ni	Mo	Nb + Ta	Mn	Si	P	S	N	Cu
ER307	0.04 – 0.14	19.5 – 22.0	8.0 – 10.7	0.5 – 1.5	–	3.3 – 4.75	0.30 – 0.65	0.03	0.03	–	0.75
ER308	0.08	19.5 – 22.0	9.0 – 11.0	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER308H	0.04 – 0.08	19.5 – 22.0	9.0 – 11.0	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER308LSi	0.03	19.5 – 22.0	9.0 – 11.0	0.75	–	1.0 – 2.5	0.65 – 1.00	0.03	0.03	–	0.75
ER308L	0.03	19.5 – 22.0	9.0 – 11.0	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER309	0.12	23.0 – 25.0	12.0 – 14.0	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER309L	0.03	23.0 – 25.0	12.0 – 14.0	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER309LMo	0.03	23.0 – 25.0	12.0 – 14.0	2.0 – 3.0	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER309Si	0.12	23.0 – 25.0	12.0 – 14.0	0.75	–	1.0 – 2.5	0.65 – 1.00	0.03	0.03	–	0.75
ER309LSi	0.03	23.0 – 25.0	12.0 – 14.0	0.75	–	1.0 – 2.5	0.65 – 1.00	0.03	0.03	–	0.75
ER310	0.08 – 0.15	25.0 – 28.0	20.0 – 22.5	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER312	0.15	28.0 – 32.0	8.0 – 10.5	0.75	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER316	0.08	18.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER316H	0.04 – 0.08	18.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER316L	0.03	18.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER316LSi	0.03	18.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	1.0 – 2.5	0.65 – 1.00	0.03	0.03	–	0.75
ER317L	0.04	18.5 – 20.5	13.0 – 15.0	3.0 – 4.0	–	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER318	0.08	18.0 – 20.0	11.0 – 14.0	2.0 – 3.0	8xC – 1.00	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER347	0.08	19.0 – 21.5	9.0 – 11.0	0.75	10xC – 1.00	1.0 – 2.5	0.30 – 0.65	0.03	0.03	–	0.75
ER347Si	0.08	19.0 – 21.5	9.0 – 11.0	0.75	10xC – 1.00	1.0 – 2.5	0.65 – 1.00	0.03	0.03	–	0.75
ER383	0.025	26.5 – 28.5	30.0 – 33.0	3.2 – 4.2	–	1.0 – 2.5	0.50	0.02	0.03	–	0.70 – 1.5
ER385	0.03	19.5 – 21.5	24.0 – 26.0	4.2 – 5.2	–	1.0 – 2.5	0.50	0.02	0.03	–	1.2 – 2.0
ER2209	0.03	21.5 – 23.5	7.5 – 9.5	2.5 – 3.5	–	0.5 – 2.0	0.30 – 0.65	0.03	0.03	0.08 – 0.20	0.75

AWS A5.11M-97
Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding

E NiCrMo - 12

E = covered electrodes
NiCrMo = chemical composition
12 = index numbers separating one composition from another within each group

Chemical composition:
As per table 11.5

AWS A5.11M-97 (selected fillers only) — Table 11.5

	C	Mn	Fe	P	S	Si	Cu	Ni	Co	Al	Ti	Cr	Nb + Ta	Mo	V	W	Other
ENiCrFe-3	0.10	5.0 – 9.5	10.0	0.03	0.015	1.0	0.50	>59.0	–	–	1.0	13.0 – 17.0	1.0 – 2.5	–	–	–	0.50
ENiCrFe-7	0.05	5.0	7.0 – 12.0	0.03	0.015	0.75	0.50	Rem	–	0.50	0.50	28.0 – 31.5	1.0 – 2.5	0.5	–	–	0.50
ENiCrMo-3	0.10	1.0	7.0	0.03	0.02	0.75	0.50	>55.0	–	–	–	20.0 – 23.0	3.15 – 4.15	8.0 – 10.0	–	–	0.50
ENiCrMo-4	0.02	1.0	4.0 – 7.0	0.04	0.03	0.2	0.50	Rem	2.5	–	–	14.5 – 16.5	–	15.0 – 17.0	0.35	3.0 – 4.5	0.50
ENiCrMo-12	0.03	2.2	5.0	0.03	0.02	0.7	0.50	Rem	–	–	–	20.5 – 22.5	1.0 – 2.8	8.8 – 10.0	–	–	0.50
ENiCrMo-13	0.02	1.0	5.0	0.02	0.02	0.25	0.50	Rem	–	–	0.25	19.0 – 23.0	–	15.0 – 17.0	–	3.0 – 4.4	0.50

AWS A5.14M-97
Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

This standard classifies consumables for MIG, TIG and SAW (strip and wire).

ER NiCrMo - 3

ER = solid wire
EQ = strip
NiCrMo = chemical composition
3 = index numbers separating one composition from another within each group

Chemical composition:
As per table 11.6

AWS A5.14M-97 (selected fillers only) Table 11.6

	C	Mn	Fe	P	S	Si	Cu	Ni	Co	Al	Ti	Cr	Nb + Ta	Mo	V	W	Other
ERNiCr-3	0.10	2.5 – 3.5	3.0	0.03	0.015	0.50	0.50	>67.0	–	–	0.75	18.0 – 22.0	2.0 – 3.0	–	–	–	0.50
ERNiCrFe-7	0.04	1.0	7.0 – 11.0	0.02	0.015	0.50	0.30	Rem	–	1.10	1.0	28.0 – 31.5	0.10	0.50	–	–	0.50
ERNiCrMo-3	0.10	0.50	5.0	0.02	0.015	0.50	0.50	>58.0	–	0.40	0.40	20.0 – 23.0	3.15 – 4.15	8.0 – 10.0	–	–	0.50
ERNiCrMo-4	0.02	1.0	4.0 – 7.0	0.04	0.03	0.08	0.50	Rem	2.5	–	–	14.5 – 16.5	–	15.0 – 17.0	0.35	3.0 – 4.5	0.50
ERNiCrMo-13	0.010	0.5	1.5	0.015	0.005	0.10	–	Rem	0.3	0.1 – 0.4	–	22.0 – 24.0	–	15.0 – 16.5	–	–	0.50

AWS A5.22-92
Stainless Steel Electrodes for Flux Cored Arc Welding

E 308 L T X - 1

E = welding electrode
308 = chemical composition
L = low carbon content
T = flux cored wire
X = welding position
1 = shielding gas

Chemical composition:
As per table 11.7

Welding position:
0 = flat or horizontal position
1 = all positions

Shielding gas:
1 = CO_2
3 = self-shielded
4 = 75 – 80% argon (remainder = CO_2)
5 = 100% argon

AWS A5.22-92 (selected fillers only)

Table 11.7

	C	Cr	Ni	Mo	Nb + Ta	Mn	Si	P	S	N	Cu
E307TX-X	0.13	18.0 – 20.5	9.0 – 10.5	0.5 – 1.5	–	3.30 – 4.75	1.0	0.04	0.03	–	0.5
E308TX-X	0.08	18.0 – 21.0	9.0 – 11.0	0.5	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E308HTX-X	0.04 – 0.08	18.0 – 21.0	9.0 – 11.0	0.5	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E308LTX-X	0.04	18.0 – 21.0	9.0 – 11.0	0.5	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E309TX-X	0.10	22.0 – 25.0	12.0 – 14.0	0.5	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E309LTX-X	0.04	22.0 – 25.0	12.0 – 14.0	0.5	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E309LCbTX-X	0.04	22.0 – 25.0	12.0 – 14.0	0.5	0.70 – 1.00	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E309LMoTX-X	0.04	22.0 – 25.0	12.0 – 16.0	2.0 – 3.0	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E310TX-X	0.20	25.0 – 28.0	20.0 – 22.5	0.5	–	1.0 – 2.5	1.0	0.03	0.03	–	0.5
E312TX-X	0.15	28.0 – 32.0	8.0 – 10.5	0.5	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E316TX-X	0.08	17.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E316LTX-X	0.04	17.0 – 20.0	11.0 – 14.0	2.0 – 3.0	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E317LTX-X	0.04	18.0 – 21.0	12.0 – 14.0	3.0 – 4.0	–	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E347TX-X	0.08	18.0 – 21.0	9.0 – 11.0	0.5	8xC – 1.00	0.5 – 2.5	1.0	0.04	0.03	–	0.5
E2209TX-X	0.04	21.0 – 24.0	7.5 – 10.0	2.5 – 4.0	–	0.5 – 2.0	1.0	0.04	0.03	0.08 – 0.20	0.5

12 Recommended filler metals

Similar welding

When welding two identical stainless steels to each other, the choice of filler metal is generally determined by the parent metal. To ensure that the weld has the optimum corrosion performance and mechanical properties, the chemical composition of the filler metal must be related to the properties of the steel being welded. Thus, to compensate for losses in the arc, and for segregation of alloying elements in the weld during cooling, the filler metal's content of alloying elements (Cr, Ni, Mo and Mn) is normally higher than that of the workpiece.

There are, however, some exceptions to this latter generalisation. For example, in nitric acid or citric acid environments, the resistance of molybdenum free steels is better than that of molybdenum alloyed steels. Consequently, filler metals may here have a lower alloy content than the workpiece.

Hence, whilst there are standard recommendations, every case must be considered on its merits. Using a filler metal that is more highly alloyed than the parent metal is not normally a problem. However, the higher the alloy content, the higher the price.

Table 12.1 lists the recommended filler metals for use with most common stainless steels. Provided the chemical composition is the same, other consumables (those with PW, HX designations, etc.) can also be used.

In some specific instances, for example cryogenic applications with severe demands as regards toughness at low temperatures, a low/zero ferrite filler might be necessary. Avesta Welding produces many different types of low or non-ferritic consumables such as SMAW 308L-LF and SKR-NF.

For use in very corrosive environments, e.g. urea plants, specially designed consumables can also be requested. Avesta Welding produces a wide range of consumables for specific applications. Examples include P6, 254 SFER and SKR-NF. For details of these, see chapter 14, "Product data sheets".

Dissimilar welding

When welding two different stainless steels to each other, the choice of filler metal is normally determined by the more highly alloyed of the two parent metals. For example, when welding 1.4307/ASTM 304L to 1.4404/ASTM 316L, a 316L type filler should be used. However, as shown in table 12.2, there are exceptions.

To obtain a crack-resistant weld metal when welding stainless steel to mild steel, an over-alloyed and high ferrite electrode, e.g. P5 (309LMo) or 309L, should be used. If the ferrite content is too low (below 3%), the risk of hot cracking increases (see also chapter 1, "Stainless steels; Ferrite and its importance").

When welding stainless steel to unalloyed or low-alloy steels, it is generally advisable to reduce weld dilution as much as possible. Thus, heat input must be limited (max 1.5 kJ/mm) and an appropriate bevel angle has to be selected for the joint. The interpass temperature must not exceed 150°C.

As always, due to the significant risk of pore formation, welding to a C-Mn steel that has a coating of prefabrication primer should be avoided. Where it is unavoidable, the paint must be removed from the surfaces in a radius of up to 20 – 30 mm of any part of the proposed weld.

Table 12.2 lists filler metals for the dissimilar welding of many different combinations of stainless, low-alloy and nickel base steels. If two filler metals are suitable, the upper one should be considered as the first choice. Provided the chemical composition is the same, other consumables (those with PW, HX designations, etc.) can also be used.

Filler metals for similar welding

Table 12.1

Steel designations EN (no.)	EN (name)	ASTM	Outokumpu designations	Old designations SS	BS	DIN	Recommended filler metal, Avesta Welding designations SMAW	MIG	TIG	SAW	FCAW
1.4016	X6Cr17	430	4016	2320	430S17	1.4016	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4510	X3CrTi17	S43035	4510	–	–	1.4510	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4021	X20Cr13	420	4021	2303	420S29	1.4021	739S	–	–	–	–
1.4028	X30Cr13	420	4028	2304	420S45	1.4028	739S	–	–	–	–
1.4418	X4CrNiMo16-5-1	–	248 SV	2387	–	1.4418	248 SV	248 SV	248 SV	248 SV	–
1.4162	–	S32101	LDX 2101®	–	–	–	2205[4]	2205	2205	2205[4]	2205[4]
1.4362	X2CrNiN23-4	S32304	SAF 2304®	2327	–	1.4362	2205[1]	2205	2205	2205[1]	2205
1.4462	X2CrNiMoN22-5-3	S32205	2205	2377	318S13	1.4462	2205	2205	2205	2205	2205
1.4410	X2CrNiMoN25-7-4	S32750	SAF 2507®	2328	–	–	2507/P100	2507/P100	2507/P100	2507/P100	–
1.4310	X10CrNi18-8	301	4310	2331	301S21	1.4310	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4318	X2CrNiN18-7	301LN	4318	–	–	–	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4372	X12CrMnNiN17-7-5	201	4372	–	–	–	307[3]	307-Si[3]	307-Si[3]	–	–
1.4307	X2CrNi18-9	304L	4307	2352	304S11	–	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4301	X5CrNi18-10	304	4301	2333	304S31	1.4301	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4311	X2CrNiN18-10	304LN	4311	2371	304S61	1.4311	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4541	X6CrNiTi18-10	321	4541	2337	321S31	1.4541	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4305	X8CrNiS18-9	303	4305	2346	303S31	1.4305	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4306	X2CrNi19-11	304L	4306	2352	304S11	1.4306	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4303	X4CrNi18-12	305	4303	–	305S19	1.4303	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L
1.4567	X3CrNiCu18-9-4	S30430	4567	–	–	1.4567	308L/MVR	308L-Si/MVR-Si	308L-Si/MVR-Si	308L/MVR	308L

(continued)

1. 2304 may also be used.
2. 2205 may also be used.
3. 309L or 309L-Si may also be used.
4. 2304 or matching filler may also be used.

Filler metals for similar welding (cont.)

Table 12.1

Steel designations EN (no.)	EN (name)	ASTM	Outokumpu designations	Old designations SS	BS	DIN	Recommended filler metal, Avesta Welding designations SMAW	MIG	TIG	SAW	FCAW
1.4404	X2CrNiMo17-12-2	316L	4404	2348	316S11	1.4404	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4401	X5CrNiMo17-12-2	316	4401	2347	316S31	1.4401	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4406	X2CrNiMoN17-12-2	316LN	4406	–	316S61	1.4406	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4571	X6CrNiMoTi17-12-2	316Ti	4571	2350	320S31	1.4571	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4432	X2CrNiMo17-12-3	316L	4432	2353	316S13	–	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4436	X3CrNiMo17-13-3	316	4436	2343	316S33	1.4436	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4435	X2CrNiMo18-14-3	316L	4435	2353	316S13	1.4435	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4429	X2CrNiMoN17-13-3	S31653	4429	2375	316S63	1.4429	316L/SKR	316L-Si/SKR-Si	316L-Si/SKR-Si	316L/SKR	316L
1.4438	X2CrNiMo18-15-4	317L	4438	2367	317S12	1.4438	317L/SNR	317L/SNR	317L/SNR	317L/SNR	317L
1.4439	X2CrNiMoN17-13-5	317LMN	4439	–	–	1.4439	SLR-NF	317L/SNR	317L/SNR	317L/SNR	317L
1.4539	X1NiCrMoCu25-20-5	904L	904L	2562	904S13	1.4539	904L	904L	904L	904L	–
1.4547	X1CrNiMoCuN20-18-7	S31254	254 SMO®	2378	–	–	P12-R[5]	P12	P12	P12	–
1.4565	–	S34565	4565	–	–	–	P16	P16	P16	P16	–
1.4652	X1CrNiMoCuMnN24-22-7	S32654	654 SMO®	–	–	–	P16	P16	P16	P16	–
1.4948	X6CrNi18-8	304H	4948	2333	304S51	1.4948	308/308H	308H	308H	308H	308H
1.4878	–	321H	4878	2337	321S51	1.4878	347/MVNb	347-Si/MVNb-Si	347-Si/MVNb-Si	347/MVNb	347
1.4818	–	S30415	153 MA™	2372	–	–	253 MA	253 MA	253 MA	253 MA	–
1.4833	–	309S	4833	–	309S16	1.4833	309	309-Si	309-Si	–	–
1.4828	–	–	4828	–	–	1.4828	309	309-Si	309-Si	–	–
1.4835	–	S30815	253 MA®	2368	–	–	253 MA	253 MA	253 MA	253 MA	–
1.4845	–	310S	4845	2361	310S16	1.4845	310	310	310	310	–
1.4854	–	S35315	353 MA®	–	–	–	353 MA	353 MA	353 MA	353 MA	–

5. P625 (ENiCrMo-3) may also be used.

Filler metals for dissimilar welding

Table 12.2

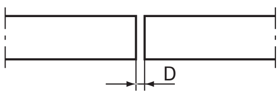
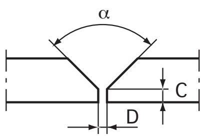
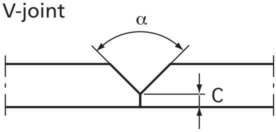
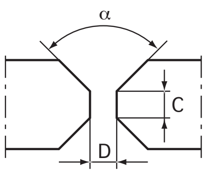
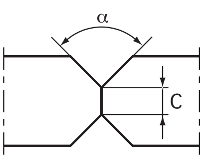
Steel design. EN/ASTM or Outokumpu	1.4016/ 430	248 SV	LDX 2101, SAF 2304	1.4462/ S32205	1.4410/ S32750	1.4310/ 301	1.4301/ 304[1]	1.4401/ 316[2]	1.4571/ 316Ti	1.4438/ 317L	1.4539/ 904L	254 SMO	654 SMO, 4565	1.4948/ 304H	1.4878/ 321H	153 MA, 253 MA	1.4845/ 310S	353 MA	Mild steel	Nickel base
1.4016/430	308L	P5	2205 P5	2205 P5	2507 P5	309L	309L	P5	P5	P5	P5 904L	P12	P16	309L	309L	309L	309L	309L	309L	P10
248 SV	P5	248 SV	2205 P5	2205 P5	P5	P5	P5	P5	P5	P5	P12	P12	P16	P5	P5	P5	P5	P5	P5	P12
LDX 2101, SAF 2304	2205 P5	2205 P5	2205	2205	2507 2205	2205 P5	2205 P5	2205 P5	2205 P5	2205 P5	P21	P12	P16	2205 P5	P5	309L P10	309L P10	P10	2205 P5	P10
1.4462/S32205	2205 P5	2205 P5	2205	2205	2507 2205	2205 P5	2205 P5	2205 P5	2205 P5	2205 P5	P12	P12	P16	2205 P5	P5	309L P10	309L P10	P10	2205 P5	P10
1.4410/S32750	2507 P5	P5	2507 2205	2507 2205	2507	2507 P5	2507 P5	2507 P5	P5	2507 P5	P12	P12	P16	2507 P5	P5	P5	P10	P10	2507 P5	P10
1.4310/301	309L	P5	2205 P5	2205 P5	2507 P5	308L	308L	316L	318	317L P5	904L P5	P12	P16	308L 309L	347 309L	309L	309L	309L	309L	P10
1.4301/304[1]	309L	P5	2205 P5	2205 P5	2507 P5	308L	308L	316L	318	317L P5	904L P5	P12	P16	308H 308L	347	309L	309L	309L	309L	P10
1.4401/316[2]	P5	P5	2205 P5	2205 P5	2507 P5	316L	316L	316L	318 316L	317L P5	904L P5	P12	P16	316L	316L	309L P5	309L	309L	P5	P10
1.4571/316Ti	P5	P5	2205 P5	2205 P5	P5	318	318	318 316L	318	317L P5	904L P5	P12	P16	318	318	309L	309L	309L	P5	P10
1.4438/317L	P5	P5	2205 P5	2205 P5	2507 P5	317L P5	317L P5	317L P5	317L P5	317L	P12	P12	P16	317L	P5	309L	309L	309L	P5	P10
1.4539/904L	P5 904L	P12	P12	P12	P12	904L P5	904L P5	904L P5	904L P5	P12	904L	P12	P16	904L 309L	904 309L	P12 309L	309L	P12 309L	P5 904L	P10 P12
254 SMO	P12	P12	P12	P12	P12	P12	P12	P12	P12	P12	P12	P12	P16	P12	P12	P12	P12	P12 P10	P12	P12
654 SMO, 4565	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16	P16 P10	P16	P16
1.4948/304H	309L	P5	2205 P5	2205 P5	2507 P5	308L 309L	308H 308L	316L	318	317L	904L 309L	P12	P16	308H	347	309L	309L	309L	309L	P10
1.4878/321H	309L	P5	P5	P5	P5	347 309L	347	316L	318	P5	904L 309L	P12	P16	347	347	309L	309L	309L	309L	P10
153 MA, 253 MA	309L	P5	309L P10	309L P10	P5	309L	309L	309L	309L	309L	P12 309L	P12	P16	309L	309L	253 MA	P10	P10	309L	P10
1.4845/310S	309L	P5	309L P10	309L P10	P10	309L	309L	309L	309L	309L	309L	P12	P16	309L	309L	P10	310	P10	309L	P10
353 MA	309L	P5	P10	P10	P10	309L	309L	309L	309L	309L	P12 309L	P12 P10	P16 P10	309L	309L	P10	P10	353 MA	P10	P10
Mild steel	309L	P5	2205 P5	2205 P5	2507 P5	309L	309L	309L	P5	P5	P5 904L	P12	P16	309L	309L	309L	309L	P10	Mild steel	P10
Nickel base	P10	P12	P10	P10	P10	P10	P10	P10	P10	P10	P10 P12	P12	P16	P10	P10	P10	P10	P10	P10	Nickel base

1. All grades with similar composition (1.4303, 1.4305, 1.4306, 1.4307, 1.4567, etc.)
2. All grades with similar composition (1.4404, 1.4406, 1.4432, 1.4435, 1.4436, 1.4429, etc.)

13 Filler metal and flux consumption

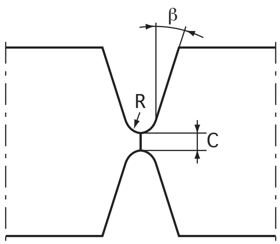
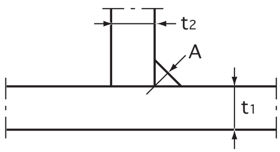
Table 13.1 shows filler metal and flux consumption for various welding methods, joints and plate thicknesses. Consumption is stated as kg per metre of weld.

Filler metal and flux consumption Table 13.1

Joint type	Joint preparation	Thickness mm	Consumption, kg/m* MMA	MIG/TIG	SAW	Flux	FCW
I-joint 	D = 2.0 mm	2	0.07	0.05			0.06
	D = 2.0 mm	3	0.09	0.07			0.08
	D = 2.5 mm	4	0.14	0.10			0.12
V-joint 	α = 60°	4	0.19	0.14			0.16
	C = 1.5 mm	5	0.26	0.19			0.22
	D = 2.5 mm	6	0.34	0.25			0.30
		7	0.43	0.32			0.38
		8	0.54	0.40			0.47
		9	0.66	0.49			0.58
		10	0.80	0.59			0.70
		12	1.10	0.81			0.96
		14	1.46	1.08			1.28
		16	1.87	1.38			1.64
V-joint 	α = 80°	8			0.11	0.09	
	C = 4.0 mm	10			0.25	0.20	
	No root gap	12			0.44	0.35	
		14			0.68	0.54	
		16			0.97	0.77	
X-joint 	α = 60°	14	1.44	1.06			1.26
	C = 1.5 mm	16	1.85	1.36			1.62
	D = 2.5 mm	18	2.31	1.70			2.02
		20	2.82	2.08			2.47
		22	3.38	2.49			2.96
		24	3.99	2.94			3.49
		26	4.66	3.43			4.07
		28	5.37	3.96			4.70
		30	6.14	4.52			5.37
X-joint 	α = 80°	14			1.67	0.54	
	C = 3 – 5 mm	16			0.96	0.77	
	No root gap	18			1.31	1.05	
		20			1.70	1.36	
		22			2.15	1.72	
		24			2.65	2.12	
		26			3.21	2.57	
		28			3.81	3.05	
		30			4.47	3.58	

* Both sides included for double-sided joints.

Filler metal and flux consumption Table 13.1

Joint type	Joint preparation	Thickness mm	Consumption, kg/m * MMA	MIG/TIG	SAW	Flux	FCW
Double U-joint 	β = 15° C = 2.5 mm R = 8 mm No root gap	20	2.72	2.00	1.90	1.52	2.38
		22	3.11	2.29	2.18	1.74	2.73
		24	3.53	2.61	2.48	1.98	3.10
		26	3.98	2.94	2.79	2.23	3.49
		28	4.46	3.28	3.12	2.50	3.90
		30	4.95	3.65	3.47	2.77	4.33
		35	6.29	4.64	4.40	3.52	5.51
		40	7.78	5.73	5.45	4.36	6.81
		45	9.42	6.94	6.60	5.28	8.24
		50	11.21	8.26	7.85	6.28	9.81
Fillet weld 	A ≈ 0.7 x t No root gap	2	0.02	0.02	0.02	0.01	0.02
		3	0.05	0.04	0.03	0.03	0.04
		4	0.09	0.06	0.06	0.05	0.08
		5	0.14	0.10	0.10	0.08	0.12
		6	0.20	0.14	0.14	0.11	0.17
		7	0.27	0.20	0.19	0.15	0.24
		8	0.35	0.26	0.24	0.20	0.31
		9	0.44	0.33	0.31	0.25	0.39
		10	0.55	0.40	0.38	0.31	0.48
		12	0.79	0.58	0.55	0.44	0.69
		14	1.07	0.79	0.75	0.60	0.95
		16	1.40	1.04	0.99	0.79	1.24
		18	1.77	1.32	1.25	1.00	1.57
		20	2.18	1.63	1.55	1.24	1.94

* Both sides included for double-sided joints.

14 Product data sheets

Contents

Introduction
All products manufactured by Avesta Welding are presented on the following pages. The order within each product group is according to EN standard order. More detailed information can be obtained from Avesta Welding, sales offices or representatives and on the web site www.avestawelding.com

Steel grade recommendations
Obsolete national standards, such as BS, NF and SS, remain in the tables covering suitable steel grades. These standards are replaced by EN 10088.

Standard designations
EN and AWS designations are given where applicable; ISO standards are valid for a considerable part of the manufacturing programme.

Approvals
Avesta Welding's products have been approved by various classification bodies and companies as stated under "Approvals". *This information is subject to change without notice*. The following abbreviations are used:

CWB	Canadian Welding Bureau
DB	Deutsche Bahn
DNV	Det Norske Veritas
GL	Germanischer Lloyd
ISCIR*	Inspecţia de Stat pentru Controlul Cazanelor sub Presiune şi Instalaţiilor de Ridicat
SK	Svetskommissionen
TÜV	Technischer Überwachungsverein
UDT	Urzad Dozoru Technicznego

* all products approved

Covered electrodes
Coatings
Standard grade electrodes (e.g. 308L/MVR and 316L/SKR) and some special grade electrodes are produced with different coatings designed for various purposes.

AC/DC	Standard rutile-acid coating
PW	Rutile-acid coating for position welding vertical-up
VDX	Rutile-acid coating for position welding vertical-down
PWX	Rutile-acid coating for tube welding
Basic	For improved mechanical properties and improved weld penetration
Rutile	Predecessor to rutile-acid coating. Gives better weld penetration.

Weld deposit data
In the tables for weld deposit data the following designations are used:

N = kg weld metal per kg electrode
B = number of electrodes per kg weld metal
H = kg weld metal per hour arc time
T = arc time per electrode, seconds

248 SV rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
248 SV	1.4418	–	–	Z6 CND 16-05-01	2387

Standard designations

–

Characteristics

AVESTA 248 SV rutile produces an austenitic-ferritic-martensitic weldment. It is designed for welding and repair of propellers, pumps, valves and shafts in 248 SV, ASTM 420 and similar types of steels and castings. Welding is normally performed without pre-heating unless considerable shrinkage stresses are to be expected.

Welding data

DC+	Diam. mm	Current, A
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data

Metal recovery approx. 105%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.5	3.0	16.0	5.5	1.2	0.12

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	510 N/mm^2	–
Tensile strength R_m	760 N/mm^2	–
Elongation A_5	30 %	–
Impact strength KV		
+20°C	115 J	
Hardness approx.	260 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Annealing for 4 hours at 590°C.

Structure: Approx. 90 – 95% austenite, balanced with ferrite and martensite.

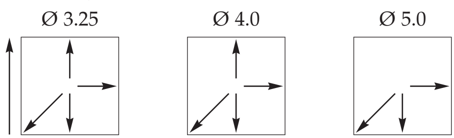
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The resistance to general and pitting corrosion is in level with that of ASTM 304L.

Approvals

–

Welding positions



308L/MVR AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-17

Characteristics

AVESTA 308L/MVR AC/DC is a Cr-Ni electrode for all position welding of ASTM 304 and 304L stainless steels.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	30 – 50
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
1.6	250	0.51	276	0.59	22	109
2.0	300	0.58	144	0.72	35	107
2.5	350	0.57	77	1.08	44	109
3.25	350	0.59	46	1.46	54	109
4.0	450	0.60	23	2.25	70	108
5.0	450	0.66	15	3.06	77	103

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.02	0.8	1.0	20.0	10.5

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	440 N/mm^2	320 N/mm^2
Tensile strength R_m	570 N/mm^2	510 N/mm^2
Elongation A_5	37 %	30 %
Impact strength KV		
+20°C	60 J	
–40°C	55 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

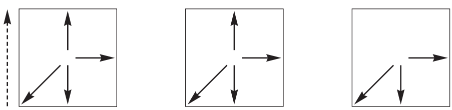
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

- DB
- DNV
- Inspecta
- SK
- TÜV
- UDT

Welding positions

Ø 1.6–3.25 Ø 4.0 Ø 5.0



308L/MVR-HX AC/DC

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-17

Characteristics

AVESTA 308L/MVR-HX is a Cr-Ni high recovery electrode for welding ASTM 304 and 304L stainless steels. The HX type electrode provides a metal recovery of about 150% giving a high deposition rate and an improved productivity in horizontal butt and overlay welding.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	60 – 90
	3.25	80 – 130
	4.0	110 – 170
	5.0	170 – 130

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.5	350					
3.25	350	0.61	33	2.02	53	147
4.0	450	0.64	17	2.96	58	143
5.0	450	0.64	11	4.03	90	141

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.03	0.7	0.9	20.0	10.5

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	395 N/mm^2	320 N/mm^2
Tensile strength R_m	550 N/mm^2	510 N/mm^2
Elongation A_5	41 %	30 %
Impact strength KV		
+20°C	65 J	
–40°C	55 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

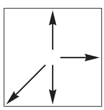
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

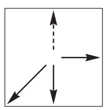
- CWB
- SK
- UDT
- Inspecta
- TÜV

Welding positions

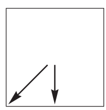
Ø 2.5



Ø 3.25



Ø 4.0–5.0



308L/MVR-PW AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-17

Characteristics

AVESTA 308L/MVR-PW is a Cr-Ni electrode with a coating optimised for vertical-up and overhead position welding of ASTM 304 and 304L stainless steels.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	20 – 45
	2.0	25 – 60
	2.5	35 – 80
	3.25	60 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
1.6	250	0.60	286	0.51	25	106
2.0	250	0.64	181	0.71	28	105
2.5	300	0.65	96	0.94	40	105
3.25	350	0.62	46	1.48	53	107
4.0	350	0.64	23	2.07	56	105
5.0	350					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.02	0.8	1.0	19.0	10.0

Ferrite 5 FN DeLong

Mechanical properties

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	430 N/mm^2	320 N/mm^2
Tensile strength R_m	580 N/mm^2	510 N/mm^2
Elongation A_5	39 %	30 %
Impact strength KV		
+20°C	60 J	
–40°C	50 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

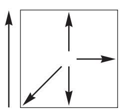
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

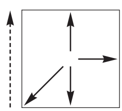
- CWB
- SK
- Inspecta
- UDT

Welding positions

Ø 1.6–3.25



Ø 4.0–5.0



MVR-PWX AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

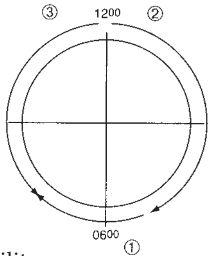
Standard designations

EN 1600 19 9 L R

Characteristics

AVESTA MVR-PWX is a Cr-Ni electrode specially developed for all position welding of thin walled ASTM 304 and 304L stainless tubes and pipes.

Pipe welding can be performed in several different ways. One possibility is to start welding in the overhead position (1), followed by vertical-down on both sides from the 12 o'clock position (2 and 3). Another possibility is to start at the 7 o'clock position and weld vertical-up to the 11 o'clock position on both sides. This requires an inverter power source with a remote control.



Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	18 – 55

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	300	0.67	149	0.73	34	105

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.02	1.1	1.0	19.0	10.5

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	420 N/mm²	320 N/mm²
Tensile strength R_m	520 N/mm²	510 N/mm²
Elongation A_5	35 %	30 %
Impact strength KV +20°C	40 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

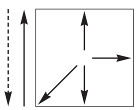
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

–

Welding positions

Ø 2.0



The PWX electrode can be used for welding vertical-down under certain circumstances, such as when welding pipes. However, it does not match the welding properties of the VDX electrode in such conditions.

308L/MVR-VDX AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-17

Characteristics

AVESTA 308L/MVR-VDX is a Cr-Ni electrode specially developed for optimal welding properties when welding thin ASTM 304 and 304L stainless plates in the vertical-down position.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 70
	3.25	95 – 105

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250	0.66	184	0.71	28	104
2.5	300	0.72	96	0.94	40	103
3.25	350	0.73	48	1.45	52	104

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.02	0.7	0.8	19.0	10.0

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	450 N/mm^2	320 N/mm^2
Tensile strength R_m	600 N/mm^2	510 N/mm^2
Elongation A_5	35 %	30 %
Impact strength KV		
+20°C	55 J	
–40°C	40 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

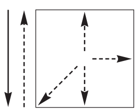
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

• CWB • SK • UDT

Welding positions

Ø 2.0–3.25



308L/MVR basic

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L B
AWS A5.4	E308L-15

Characteristics

AVESTA 308L/MVR basic is a Cr-Ni electrode providing somewhat better ductility than AC/DC type electrodes, especially at lower temperatures. The electrode is intended for welding ASTM 304 and 304L stainless steels.

Welding data

DC+	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 75
	3.25	70 – 100
	4.0	100 – 140
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.0	250					
2.5	300	0.61	100	0.77	47	98
3.25	350	0.67	48	1.23	61	103
4.0	350	0.67	32	1.66	68	102
5.0	350	0.71	20	2.53	71	103

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.03	0.2	1.7	20.0	10.0

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	420 N/mm^2	320 N/mm^2
Tensile strength R_m	560 N/mm^2	510 N/mm^2
Elongation A_5	38 %	30 %
Impact strength KV		
+20°C	70 J	
–40°C	55 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

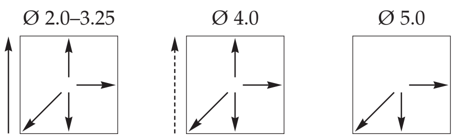
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

- TÜV
- UDT

Welding positions



308L/MVR rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-16

Characteristics

AVESTA 308L/MVR rutile is a Cr-Ni electrode providing improved penetration and smoother bead surface compared to AC/DC type electrodes. The electrode is intended for welding ASTM 304 and 304L stainless steels.

Welding data

DC+	Diam. mm	Current, A
	1.6	25 – 45
	2.0	35 – 55
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
1.6	250					
2.0	250					
2.5	300	0.64	92	0.81	52	106
3.25	350	0.64	50	1.25	61	104
4.0	350	0.65	32	1.70	68	100
5.0	350	0.68	20	1.59	72	103

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.03	0.3	1.5	20.0	10.0

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	430 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	40 %	30 %
Impact strength KV +20°C	60 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

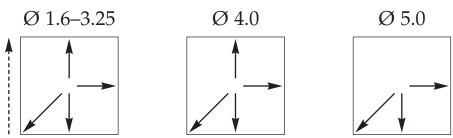
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

• SK • TÜV • UDT

Welding positions



308/308H AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 1600	19 9 R
AWS A5.4	E308H-17

Characteristics

AVESTA 308/308H AC/DC is a high carbon Cr-Ni electrode primarily intended for welding ASTM 304 and 304H type stainless steel exposed to temperatures above 400°C.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	30 – 50
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
1.6	250					
2.0	250					
2.5	300	0.57	87	0.98	42	113
3.25	350	0.59	45	1.52	53	109
4.0	350	0.61	30	2.06	58	107
5.0	350	0.64	20	2.79	64	102

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.06	0.7	1.1	20.0	10.0

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	450 N/mm^2	350 N/mm^2
Tensile strength R_m	605 N/mm^2	550 N/mm^2
Elongation A_5	37 %	30 %
Impact strength KV		
+20°C	55 J	
–40°C	50 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

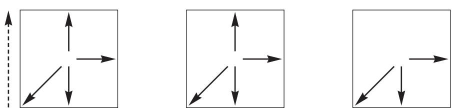
Corrosion resistance: Corresponding to ASTM 304, i.e. good resistance to general corrosion. The enhanced carbon content, compared to 308L, makes it slightly more sensitive to intercrystalline corrosion.

Approvals

- CWB
- TÜV
- UDT

Welding positions

Ø 1.6–3.25 Ø 4.0 Ø 5.0



308L AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-17

Characteristics

AVESTA 308L AC/DC is a Cr-Ni all position electrode for welding ASTM 304 and 304L stainless steels. The length of the electrodes is 350 mm or less as required in AWS A5.4.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	30 – 50
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
1.6	250	0.54	266	0.60	23	113
2.0	250	0.53	170	0.71	30	114
2.5	300	0.57	89	0.99	41	111
3.25	350	0.60	44	1.50	54	111
4.0	350	0.62	30	2.05	59	110
5.0	350	0.65	19	2.97	62	106

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.03	0.8	1.0	20.0	10.5

Ferrite 10 FN DeLong

Mechanical properties

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	450 N/mm²	320 N/mm²
Tensile strength R_m	580 N/mm²	510 N/mm²
Elongation A_5	37 %	30 %
Impact strength KV		
+20°C	60 J	
–40°C	40 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

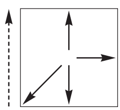
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

- CWB
- UDT

Welding positions

Ø 1.6–3.25



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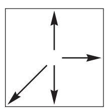
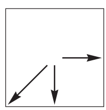


Ø 5.0



308L-LF rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 1600	19 9 L R
AWS A5.4	E308L-15

Characteristics

AVESTA 308L-LF rutile produces a low ferrite weldment (max. 2 FN DeLong) offering particularly good resistance to selective corrosion as well as somewhat better impact strength than 308L type electrodes, especially at low temperatures or after annealing. The electrode is intended for welding ASTM 304 and 304L stainless steels.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.64	92	0.81	52	106
3.25	350	0.64	50	1.25	61	104
4.0	350	0.65	32	1.70	68	100
5.0	350	0.68	20	1.59	72	103

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.03	0.3	1.8	18.5	10.5

Ferrite 1 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	420 N/mm^2	320 N/mm^2
Tensile strength R_m	560 N/mm^2	510 N/mm^2
Elongation A_5	39 %	30 %
Impact strength KV		
+20°C	85 J	
–40°C	30 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 850°C (air).

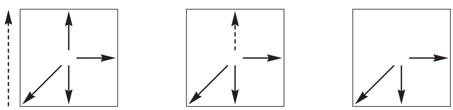
Corrosion resistance: Very good under fairly severe conditions, e.g. in oxidising acids and cold or dilute reducing acids.

Approvals

–

Welding positions

Ø 2.5–3.25 Ø 4.0 Ø 5.0



347/MVNb AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 1600 19 9 Nb R
AWS A5.4 E347-17

Characteristics

AVESTA 347/MVNb AC/DC is a Nb-stabilised Cr-Ni electrode for welding Ti-stabilised steels such as ASTM 321 and 347 exposed to service temperatures exceeding 400°C.

Welding data

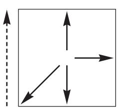
DC+ or AC	Diam. mm	Current, A
	1.6	30 – 50
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
1.6	250					
2.0	250					
2.5	300	0.57	89	0.92	44	109
3.25	350	0.59	45	1.51	53	109
4.0	450	0.62	30	2.07	58	107
5.0	450	0.67	17	3.06	70	106

Welding positions

Ø 1.6–3.25



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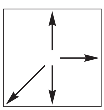
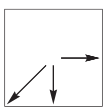


Ø 5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Nb
0.02	0.8	0.8	19.5	10.0	≥10xC

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	470 N/mm^2	350 N/mm^2
Tensile strength R_m	620 N/mm^2	550 N/mm^2
Elongation A_5	35 %	25 %
Impact strength KV		
+20°C	55 J	
–40°C	45 J	
Hardness approx.	225 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none. 347/MVNb can be used for cladding, which normally requires stress relieving at around 590°C. Such a heat treatment will lower the ductility at room temperature. Always consult expertise before performing post-weld heat treatment.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: 347/MVNb is primarily intended for high temperature service or applications that should be heat treated. However, the corrossion resistance corresponds to that of 308H, i.e. good resistance to general corrosion.

Approvals

- CWB
- DNV
- Inspecta
- TÜV
- DB
- GL
- SK
- UDT

347/MVNb basic

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 1600	19 9 Nb B
AWS A5.4	E347-15

Characteristics

AVESTA 347/MVNb basic is a Nb-stabilised Cr-Ni electrode for welding Ti-stabilised steels such as ASTM 321 and 347 exposed to service temperatures exceeding 400°C. 347/MVNb basic provides better impact strength than the AC/DC type electrodes.

Welding data

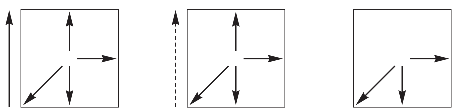
DC+	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 70
	3.25	70 – 100
	4.0	100 – 140
	5.0	140 – 190

Weld deposit data

Metal recovery approx. 100%.

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Nb
0.06	0.2	1.7	19.5	10.0	≥10xC

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	520 N/mm^2	350 N/mm^2
Tensile strength R_m	680 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	80 J	
–40°C	60 J	
Hardness approx.	255 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none. 347/MVNb can be used for cladding, which normally requires stress relieving at around 590°C. Such a heat treatment will lower the ductility at room temperature. Always consult expertise before performing post-weld heat treatment.

Structure: Approx. 90% austenite and 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: 347/MVNb is primarily intended for high temperature service or applications that should be heat treated. However, the corrossion resistance corresponds to that of 308H, i.e. good resistance to general corrosion.

Approvals

- CWB
- DNV
- Inspecta
- TÜV
- DB
- GL
- SK
- UDT

316L/SKR AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600	19 12 3 L R
AWS A5.4	E316L-17

Characteristics

AVESTA 316L/SKR AC/DC is an all position Cr-Ni-Mo electrode for welding ASTM 316 and 316L stainless steels.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	30 – 50
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
1.6	250	0.52	278	0.60	22	109
2.0	300	0.58	143	0.77	32	106
2.5	350	0.57	76	1.06	44	108
3.25	350	0.58	45	1.54	51	107
4.0	450	0.60	23	2.22	71	107
5.0	450	0.64	15	3.28	74	104

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.8	1.1	18.5	12.0	2.8

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	445 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	36 %	25 %
Impact strength KV		
+20°C	55 J	
–40°C	55 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

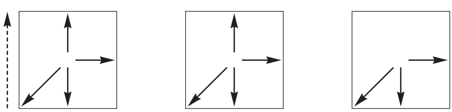
Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- DNV
- Inspecta
- TÜV
- GL
- SK
- UDT

Welding positions

Ø 1.6–3.25 Ø 4.0 Ø 5.0



316L/SKR-HX AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600	19 12 3 L R
AWS A5.4	E316L-17

Characteristics

AVESTA 316L/SKR-HX is a Cr-Ni-Mo high recovery electrode for welding ASTM 316 and 316L stainless steels. The HX type electrode provides a metal recovery of about 150%, giving high deposition rate and an improved productivity in horizontal butt and overlay welding.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	60 – 90
	3.25	80 – 130
	4.0	110 – 170
	5.0	170 – 230

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.60	54	1.47	45	151
3.25	400	0.58	31	2.11	56	136
4.0	450	0.64	17	3.10	69	146
5.0	450	0.63	11	4.18	78	140

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.03	0.8	0.8	18.0	12.0	2.8

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	420 N/mm^2	320 N/mm^2
Tensile strength R_m	575 N/mm^2	510 N/mm^2
Elongation A_5	37 %	25 %
Impact strength KV		
+20°C	55 J	
–40°C	55 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

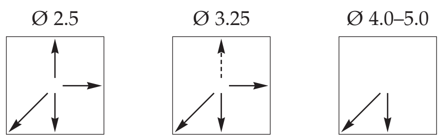
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- CWB
- Inspecta
- TÜV
- DNV
- SK
- UDT

Welding positions



316L/SKR-PW AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600	19 12 3 L R
AWS A5.4	E316L-17

Characteristics

AVESTA 316L/SKR-PW is a Cr-Ni-Mo electrode with a coating optimised for the vertical-up and overhead position welding of ASTM 316 and 316L stainless steels.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	20 – 45
	2.0	25 – 60
	2.5	35 – 80
	3.25	60 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
1.6	250	0.62	274	0.55	24	109
2.0	250	0.63	176	0.69	29	108
2.5	300	0.67	92	0.99	40	107
3.25	350	0.63	45	1.60	50	107
4.0	350	0.64	30	2.17	55	107
5.0	350					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.8	1.0	18.0	12.0	2.8

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	455 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	36 %	25 %
Impact strength KV		
+20°C	60 J	
–40°C	60 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

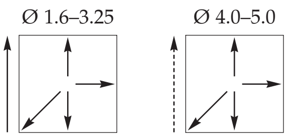
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- CWB
- DB
- DNV
- GL
- Inspecta
- SK
- TÜV
- UDT

Welding positions



SKR-PWX AC/DC

For welding steels such as

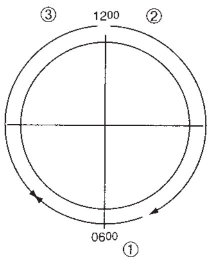
Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600 19 12 3 L R

Characteristics

AVESTA SKR-PWX is a Cr-Ni-Mo electrode specially developed for all position welding of thin walled ASTM 316 and 316L stainless steel tubes and pipes.



Pipe welding can be performed in several different ways. One possibility is to start welding in the overhead position (1), followed by vertical-down on both sides from the 12 o'clock position (2 and 3). Another possibility is to start at the 7 o'clock position and weld vertical-up to the 11 o'clock position on both sides. This requires an inverter power source with a remote control.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	15 – 45
	2.0	18 – 55
	2.5	30 – 80

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
1.6	250	0.61	284	0.52	25	105
2.0	300	0.65	149	0.70	36	103
2.5	300	0.65	96	0.99	38	104

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	1.1	0.7	18.0	12.5	2.7

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	480 N/mm^2	320 N/mm^2
Tensile strength R_m	640 N/mm^2	510 N/mm^2
Elongation A_5	27 %	25 %
Impact strength KV		
+20°C	70 J	
–40°C	50 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

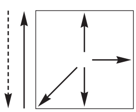
Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- Inspecta
- SK

Welding positions

Ø 1.6–2.5



The PWX electrode can be used for welding vertical-down under certain circumstances, such as when welding pipes. However, it does not match the welding properties of the VDX electrode in such conditions.

316L/SKR-VDX AC/DC

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600 19 12 3 L R
AWS A5.4 E316L-17

Characteristics

AVESTA 316L/SKR-VDX is a Cr-Ni-Mo electrode specially developed for optimal welding properties when welding thin ASTM 316 and 316L stainless steel plates in the vertical-down position.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250	0.66	184	0.71	28	104
2.5	300	0.72	96	0.94	40	103
3.25	350	0.73	48	1.45	52	104

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.7	0.7	18.5	12.5	2.8

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	480 N/mm²	320 N/mm²
Tensile strength R_m	630 N/mm²	510 N/mm²
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	50 J	
–40°C	35 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

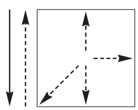
Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- CWB
- Inspecta
- TÜV
- DNV
- SK
- UDT

Welding positions

Ø 2.0–3.25



316L/SKR basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600	19 12 3 L B
AWS A5.4	E316L-15

Characteristics

AVESTA 316L/SKR basic is a Cr-Ni-Mo electrode providing somewhat better ductility than AC/DC type electrodes especially at lower temperatures. The electrode is intended for welding ASTM 316 and 316L stainless steels.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 70
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.63	93	0.86	45	105
3.25	350	0.68	46	1.30	60	108
4.0	350	0.71	30	1.85	64	106
5.0	350	0.73	19	2.66	70	105

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.03	0.2	1.7	18.5	12.0	2.8

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	430 N/mm^2	320 N/mm^2
Tensile strength R_m	565 N/mm^2	510 N/mm^2
Elongation A_5	34 %	25 %
Impact strength KV		
+20°C	70 J	
–40°C	50 J	
–196°C	25 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

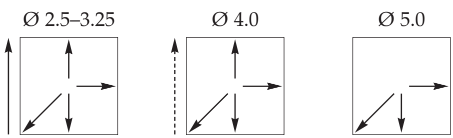
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- Inspecta
- TÜV
- UDT

Welding positions



316L/SKR rutile

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600 19 12 3 L R
AWS A5.4 E316L-16

Characteristics

AVESTA 316L/SKR rutile is a Cr-Ni-Mo electrode providing improved penetration and smoother bead surface compared to AC/DC type electrodes. The electrode is intended for welding ASTM 316 and 316L stainless steels.

Welding data

DC+	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data

Metal recovery approx. 105%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.3	1.4	19.0	12.0	2.8

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	480 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	32 %	25 %
Impact strength KV		
+20°C	75 J	
–40°C	60 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

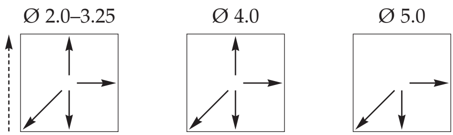
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- Inspecta
- TÜV
- UDT

Welding positions



316/316H AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
4401	1.4401	316	316S16	Z7 CND 17-11-02	2347
4571	1.4571	316Ti	320S17	Z6 CNDT 17-12	2350
–	1.4919	316H	316S51	Z6 CND 17-13	2347

Standard designations

EN 1600	19 12 2 R
AWS A5.4	E316H-17

Characteristics

AVESTA 316/316H AC/DC is a high carbon Cr-Ni-Mo electrode primarily intended for welding ASTM 316 and 316H type stainless steels exposed to temperatures above 400°C.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.55	91	0.99	40	110
3.25	350	0.59	45	1.66	50	108
4.0	350	0.62	30	2.21	58	107
5.0	350	0.65	20	2.99	61	104

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.06	0.8	1.0	19.0	12.0	2.8

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	470 N/mm²	320 N/mm²
Tensile strength R_m	615 N/mm²	550 N/mm²
Elongation A_5	35 %	25 %
Impact strength KV +20°C	50 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Approx. 95% austenite and 5% ferrite.

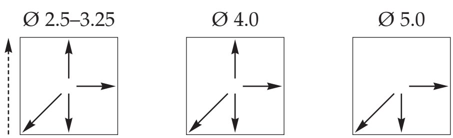
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

- CWB
- TÜV
- UDT

Welding positions



316L AC/DC

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600	19 12 3 L R
AWS A5.4	E316L-17

Characteristics

AVESTA 316L AC/DC is a Cr-Ni-Mo electrode for all position welding of ASTM 316 and 316L stainless steels. The length of the electrodes is 350 mm or less as required in AWS A5.4.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250	0.58	181	0.75	26	107
2.5	300	0.56	92	0.99	40	107
3.25	350	0.58	45	1.58	51	109
4.0	350	0.58	30	2.07	57	107
5.0	350	0.63	19	3.10	60	106

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.8	1.0	18.5	12.0	2.8

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	445 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	36 %	25 %
Impact strength KV		
+20°C	55 J	
–40°C	35 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

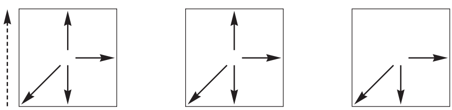
Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe conditions, e.g. in dilute hot acids.

Approvals

• CWB • TÜV • UDT

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



318/SKNb AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600	19 12 3 Nb R
AWS A5.4	E318-17

Characteristics

AVESTA 318/SKNb AC/DC is a Nb-stabilised Cr-Ni-Mo electrode for welding Ti-stabilised steels such as ASTM 316Ti.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	300					
2.5	350	0.58	75	1.05	46	110
3.25	350	0.59	45	1.58	51	109
4.0	450	0.63	26	2.23	63	108
5.0	450					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Nb
0.02	0.8	0.8	18.5	12.0	2.8	≥10xC

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	470 N/mm^2	350 N/mm^2
Tensile strength R_m	605 N/mm^2	550 N/mm^2
Elongation A_5	32 %	25 %
Impact strength KV		
+20°C	50 J	
–40°C	45 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

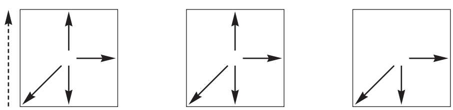
Corrosion resistance: The corrosion resistance corresponds to that of ASTM 316Ti, i.e. good resistance to general, pitting and intercrystalline corrosion.

Approvals

- DB
- GL
- SK
- UDT
- DNV
- Inspecta
- TÜV

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



318/SKNb basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 1600 19 12 3 Nb B
AWS A5.4 E318-15

Characteristics

AVESTA 318/SKNb basic is a Nb-stabilised Cr-Ni-Mo electrode for welding Ti-stabilised steels such as ASTM 316Ti. 318/SKNb basic provides better impact strength compared to the AC/DC type electrodes.

Welding data

DC+	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 70
	3.25	70 – 110
	4.0	100 – 140

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Nb
0.04	0.2	2.1	18.5	12.5	2.7	≥10xC

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	480 N/mm²	350 N/mm²
Tensile strength R_m	620 N/mm²	550 N/mm²
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	75 J	
–40°C	60 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

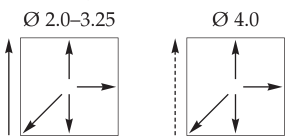
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The corrosion resistance corresponds to that of ASTM 316Ti, i.e. good resistance to general, pitting and intercrystalline corrosion.

Approvals

- TÜV

Welding positions



317L/SNR AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-15-04	2367

Standard designations
AWS A5.4 E317L-17

Characteristics
AVESTA 317L/SNR AC/DC is a high Mo-alloyed electrode corresponding to AWS A5.4 E 317L designed for welding ASTM 317L steel.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data
Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.7	0.9	19.0	13.0	3.7

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values AWS A5.4
Yield strength $R_{p0.2}$	485 N/mm^2	–
Tensile strength R_m	615 N/mm^2	520 N/mm^2
Elongation A_5	31 %	30 %
Impact strength KV +20°C	40 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

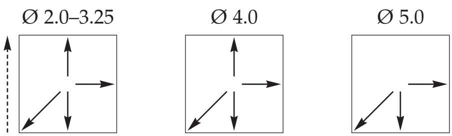
Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Higher resistance than ASTM 316L in acid and chloride containing solutions.

Approvals
- CWB
- Inspecta
- UDT
- DNV
- SK

Welding positions



SLR AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-15-04	2367
4439	1.4439	317LMN	–	Z3 CND 18-14-05 Az	–

Standard designations

EN 1600	19 13 4 N L R
AWS A5.4	E310-17

Characteristics

AVESTA SLR AC/DC is a high Mo-alloyed electrode primarily designed for welding Outokumpu 4438 and 4439. It is also suitable for welding ASTM 317L stainless steel.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.8	1.0	18.0	13.5	4.0

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	490 N/mm^2	350 N/mm^2
Tensile strength R_m	635 N/mm^2	550 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	40 J	
–40°C	30 J	
Hardness approx.	225 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

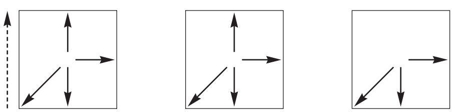
Corrosion resistance: Considerably higher resistance than ASTM 316L and slightly higher than 317L in acid and chloride containing environments.

Approvals

- TÜV
- UDT

Welding positions

Ø 2.5–3.25 Ø 4.0 Ø 5.0



2304 AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2304®	1.4362	S32304	–	–	2327

Standard designations

–

Characteristics

AVESTA 2304 AC/DC is a Cr-Ni alloyed duplex electrode for welding lower-alloyed duplex stainless steels such as SAF 2304. Welding should be carried out as for ordinary austenitic stainless steel. However, the somewhat lower penetration and fluidity of the weld should be considered.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	N
0.02	0.8	0.8	24.5	9.0	0.12

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	640 N/mm^2	–
Tensile strength R_m	780 N/mm^2	–
Elongation A_5	23 %	–
Impact strength KV		
+20°C	40 J	
–40°C	25 J	
Hardness approx.	260 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

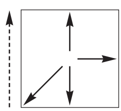
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in nitric acid environments.

Approvals

–

Welding positions

Ø 2.5–3.25



2205 AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 1600	22 9 3 N L R
AWS A5.4	E2209-17

Characteristics

AVESTA 2205 is a Cr-Ni-Mo alloyed duplex electrode for welding duplex steels such as 2205. For light to moderate thickness material, welding should be carried out as for ordinary austenitic stainless steel. However, the somewhat lower penetration and fluidity of the weld should be considered. Very high quench rates and excessive times at red heat or above should be avoided to prevent excessive ferrite or formation of intermetallic phases.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.8	0.7	23.0	9.5	3.0	0.15

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	620 N/mm^2	450 N/mm^2
Tensile strength R_m	810 N/mm^2	550 N/mm^2
Elongation A_5	25 %	20 %
Impact strength KV		
+20°C	45 J	
–40°C	35 J	
Hardness approx.	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

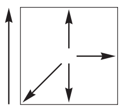
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

• CWB • Inspecta • TÜV

Welding positions

Ø 2.0–3.25



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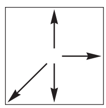
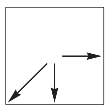


Ø 5.0



2205-HX AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 1600 22 9 3 N L R
AWS A5.4 E2209-17

Characteristics

AVESTA 2205-HX is a high recovery electrode designed for welding duplex steels such as 2205. For light to moderate thickness material, welding should be carried out as for ordinary austenitic stainless steel. However, the somewhat lower penetration and fluidity of the weld should be considered. Very high quench rates and excessive times at red heat or above should be avoided to prevent excessive ferrite or formation of intermetallic phases.

Welding data

DC+ or AC	Diam. mm	Current, A
	4.0	110 – 170
	5.0	170 – 230

Weld deposit data

Metal recovery approx. 140%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.8	0.7	22.5	9.5	3.0	0.15

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	640 N/mm^2	450 N/mm^2
Tensile strength R_m	825 N/mm^2	550 N/mm^2
Elongation A_5	33 %	20 %
Impact strength KV		
+20°C	55 J	
–40°C	40 J	
Hardness approx.	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

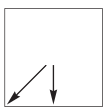
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

–

Welding positions

Ø 4.0–5.0



2205-PW AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 1600 22 9 3 N L R
AWS A5.4 E2209-17

Characteristics

AVESTA 2205-PW is an all-position electrode with special advantages in the vertical-up and overhead positions. The electrode is designed for welding duplex steel of the 2205 type. For light to moderate thickness material, welding should be carried out as for ordinary austenitic stainless steel. However, the somewhat lower penetration and fluidity of the weld should be considered. Very high quench rates and excessive times at red heat or above should be avoided to prevent excessive ferrite or formation of intermetallic phases.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	70 – 110
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250	0.63	182	0.71	28	107
2.5	300	0.66	95	0.99	38	106
3.25	350	0.62	42	1.65	52	115
4.0	350	0.65	28	2.43	52	115
5.0	350	0.67	18	3.30	61	115

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.8	0.8	23.0	9.5	3.0	0.17

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	635 N/mm^2	450 N/mm^2
Tensile strength R_m	830 N/mm^2	550 N/mm^2
Elongation A_5	25 %	20 %
Impact strength KV		
+20°C	55 J	
–40°C	40 J	
Hardness approx.	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

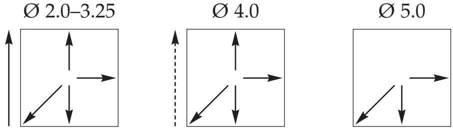
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

- CWB
- Inspecta
- TÜV
- DNV
- SK
- UDT

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



2205-VDX AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 1600	22 9 3 N L R
AWS A5.4	E2209-17

Characteristics

AVESTA 2205-VDX is a specially developed electrode for vertical-down welding of duplex steels such as 2205. Welding is best performed using direct current (DC+). For light to moderate thickness material, welding should be carried out as for ordinary austenitic stainless steel. However, the somewhat lower penetration and fluidity of the weld should be considered. Very high quench rates and excessive times at red heat or above should be avoided to prevent excessive ferrite or formation of intermetallic phases.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 70

Weld deposit data

Metal recovery approx. 105%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.8	0.9	22.8	9.5	3.1	0.15

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	670 N/mm^2	450 N/mm^2
Tensile strength R_m	860 N/mm^2	550 N/mm^2
Elongation A_5	25 %	20 %
Impact strength KV		
+20°C	35 J	
–40°C	25 J	
Hardness approx.	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

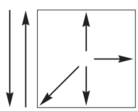
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

–

Welding positions

Ø 2.5



2205 basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 1600 22 9 3 N L B
AWS A5.4 E2209-15

Characteristics

AVESTA 2205 basic provides somewhat better impact properties and position welding properties than the 2205 AC/DC type electrodes. The electrode is designed for welding duplex steel of the 2205 type. For light to moderate thickness material, welding should be carried out as for ordinary austenitic stainless steel. However, the somewhat lower penetration and fluidity of the weld should be considered. Very high quench rates and excessive times at red heat or above should be avoided to prevent excessive ferrite or formation of intermetallic phases.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 70
	3.25	70 – 110
	4.0	100 – 140

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.5	0.8	23.0	9.5	3.0	0.16

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	635 N/mm^2	450 N/mm^2
Tensile strength R_m	820 N/mm^2	550 N/mm^2
Elongation A_5	26 %	20 %
Impact strength KV		
+20°C	80 J	
–40°C	55 J	
Hardness approx.	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

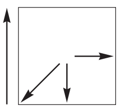
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

–

Welding positions

Ø 2.5–4.0



2507/P100 rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2507®	1.4410	S32750	–	Z3 CND 25-06 Az	2328

Standard designations

EN 1600 25 9 4 N L R

Characteristics

AVESTA 2507/P100 rutile electrodes give a high-alloy, duplex weld metal. They are suitable for super duplex steels such as SAF 2507, ASTM S32750, ASTM S32760 and similar. Heat inputs should be generally lower than those used for 2205. However, the somewhat reduced fluidity and penetration (compared to ordinary austenitic stainless steels) must be taken into consideration. To prevent excessive ferrite, or the formation of intermetallic phases, very high quench rates and excessive times at red heat or above should be avoided.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 70
	3.25	80 – 100
	4.0	100 – 140

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.58	93	0.77	50	107
3.25	350	0.64	46	1.30	59	108
4.0	350	0.68	30	1.88	64	110

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.5	1.3	25.5	10.0	3.6	0.23

Ferrite 30 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	695 N/mm^2	550 N/mm^2
Tensile strength R_m	895 N/mm^2	620 N/mm^2
Elongation A_5	27 %	25 %
Impact strength KV		
+20°C	80 J	
–40°C	55 J	
Hardness approx.	250 Brinell	

Interpass temperature: Max. 100°C.

Heat input: 0.5 – 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with approx. 30% ferrite.

Scaling temperature: Approx. 850°C (air).

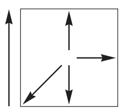
Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments. Pitting resistance in accordance with ASTM G48-A better than 40°C.

Approvals

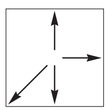
–

Welding positions

Ø 2.5–3.25



Ø 4.0



P6 basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4429	1.4429	316LN	316S63	Z3 CND 17-12 Az	2375
4435	1.4435	316L	316S13	Z3 CND 18-14-03	2353

Standard designations

–

Characteristics

AVESTA P6 basic is a fully austenitic Mn and N-alloyed electrode. The absence of ferrite makes the electrode particularly suitable in low temperature applications, urea industry and constructions requiring a low magnetic permeability (non-magnetic). P6 is approved by Stamicarbon.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 100
	4.0	100 – 140
	5.0	140 – 190

Weld deposit data

Metal recovery approx. 115%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.2	5.5	18.5	17.0	2.7	0.17

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	460 N/mm^2	–
Tensile strength R_m	665 N/mm^2	–
Elongation A_5	31 %	–
Impact strength KV		
+20°C	75 J	
–40°C	65 J	
–196°C	25 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 900°C (air).

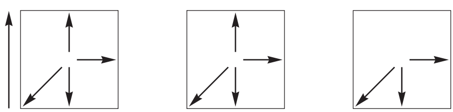
Corrosion resistance: Very resistant to selective corrosion and general corrosion. Approved by the urea industry.

Approvals

• Stamicarbon • TÜV (incl. –196°C) • UDT

Welding positions

Ø 2.5–3.25 Ø 4.0 Ø 5.0



254 SFER rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4466	1.4466	S31050	–	Z2 CND 25-22 Az	–

Standard designations

EN 1600 25 22 2 N L R

Characteristics

AVESTA 254 SFER rutile is a fully austenitic Mn and N-alloyed Cr-Ni-Mo electrode similar to AWS E310MoL. The electrode is designed for welding ASTM S31050 and similar types of high corrosion resistant steels for use in applications producing for example synthetic fertilisers, nitrophosphates, ammonium nitrate and nitric acid.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150

Weld deposit data

Metal recovery approx. 103%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.8	4.5	25.5	22.5	2.4	0.16

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	440 N/mm^2	320 N/mm^2
Tensile strength R_m	660 N/mm^2	510 N/mm^2
Elongation A_5	37 %	25 %
Impact strength KV		
+20°C	60 J	
–196°C	20 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1000°C (air).

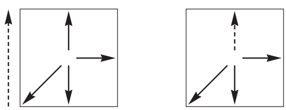
Corrosion resistance: Excellent resistance in strongly oxidising and slightly reducing environments. High resistance to intergranular, selective, pitting and stress corrosion.

Approvals

–

Welding positions

Ø 2.5–3.25 Ø 4.0



SKR-NF rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4435	1.4435	316L	316S13	Z3 CND 18-14-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375

Standard designations
EN 1600 18 15 3 L R

Characteristics
AVESTA SKR-NF rutile is a fully austenitic N-alloyed Cr-Ni-Mo electrode designed for welding ASTM 316LN and similar highly corrosion resistant steels. The absence of ferrite makes the electrode particularly suitable in low temperature applications, urea industry and constructions requiring a low magnetic permeability (non-magnetic).

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.60	91	0.88	49	108
3.25	350	0.62	47	1.30	61	105
4.0	350	0.64	30	1.90	62	105
5.0	350					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.5	2.0	18.5	15.5	2.8	0.18

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	470 N/mm^2	300 N/mm^2
Tensile strength R_m	660 N/mm^2	480 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	75 J	
–196°C	30 J	
Hardness approx.	195 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

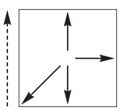
Scaling temperature: Approx. 875°C (air).

Corrosion resistance: Very resistant to selective corrosion and general corrosion.

Approvals
- TÜV (incl. –196°C)
- UDT

Welding positions

Ø 2.5–3.25



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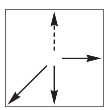

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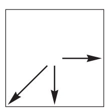


SLR-NF rutile

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-05-04	2367
4439	1.4439	317LMN	–	Z3 CND 18-14-05	–

Standard designations

EN 1600 18 16 5 N L R

Characteristics

AVESTA SLR-NF rutile is a fully austenitic Cr-Ni-Mo-N alloyed electrode primarily designed for welding Outokumpu 4438, 4439 and similar types of steel for use in particularly severe corrosive environments.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.60	82	1.03	43	119
3.25	350	0.63	42	1.59	54	116
4.0	350	0.64	28	2.17	59	107

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.7	1.4	19.0	18.0	4.8	0.13

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	450 N/mm^2	300 N/mm^2
Tensile strength R_m	640 N/mm^2	480 N/mm^2
Elongation A_5	32 %	25 %
Impact strength KV		
+20°C	45 J	
Hardness approx.	225 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 850°C (air).

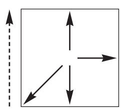
Corrosion resistance: Considerably higher resistance in acid and chloride containing environments than ASTM 317L.

Approvals

- Ciba Geigy
- Inspecta

Welding positions

Ø 2.5–3.25



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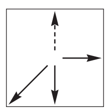


904L AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
904L	1.4539	904L	904S13	Z2 NCDU 25-20	2562

Also for welding similar steels of the 20-25 CrNiMoCu-type.

Standard designations

EN 1600	20 25 5 Cu N L R
AWS A5.4	E385-17

Characteristics

AVESTA 904L AC/DC is a highly alloyed fully austenitic Cr-Ni-Mo-Cu electrode designed for welding ASTM 904L and similar types of stainless steel. 904L filler metal has a fully austenitic structure which makes it somewhat more sensitive to hot cracking than for example 316L AC/DC. Welding should be performed taking great care about low heat input and interpass temperature.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 75
	3.25	80 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	300					
2.5	350	0.69	59	1.09	56	139
3.25	350	0.65	35	1.53	67	139
4.0	400	0.69	20	2.29	80	143
5.0	400	0.69	13	3.37	83	138

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Cu
0.02	0.7	1.2	20.5	25.0	4.5	1.5

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	400 N/mm^2	320 N/mm^2
Tensile strength R_m	565 N/mm^2	510 N/mm^2
Elongation A_5	34 %	25 %
Impact strength KV +20°C	60 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1070 – 1100°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1000°C (air).

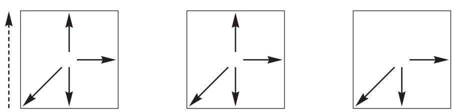
Corrosion resistance: Very good resistance in non-oxidising environments such as sulphuric acid (up to 90% conc.), phosphoric acid and organic acids. Good resistance to pitting and crevice corrosion in chloride containing solutions.

Approvals

- DB
- SK
- TÜV
- UDT
- Inspecta

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



904L-PW AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
904L	1.4539	904L	904S13	Z2 NCDU 25-20	2562

Also for welding similar steels of the 20-25 CrNiMoCu-type.

Standard designations

EN 1600 20 25 5 Cu N L R

Characteristics

AVESTA 904L-PW is a highly alloyed fully austenitic Cr-Ni-Mo-Cu electrode designed for welding ASTM 904L and similar types of stainless steel. The electrode has a coating specially designed for position welding. 904L-PW has a fully austenitic structure which makes it somewhat more sensitive to hot cracking than for example 316L AC/DC. Welding should be performed taking great care about low heat input and interpass temperature.

Welding data

DC+ or AC	Diam. mm	Current, A
	1.6	20 – 45
	2.0	25 – 55
	2.5	35 – 75
	3.25	75 – 110

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Cu
0.02	1.0	1.2	20.0	24.5	4.5	1.5

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	400 N/mm^2	320 N/mm^2
Tensile strength R_m	600 N/mm^2	510 N/mm^2
Elongation A_5	35 %	25 %
Impact strength KV		
+20°C	70 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1000°C (air).

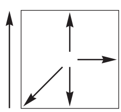
Corrosion resistance: Very good resistance in non-oxidising solutions such as sulphuric acid (up to 90% conc.), phosphoric acid and organic acids. Good resistance to pitting and crevice corrosion in chloride containing solutions.

Approvals

• UDT

Welding positions

Ø 1.6–3.25



383 AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
–	1.4563	N08028	–	–	2584

Standard designations

EN 1600 27 31 4 Cu L R
AWS A5.4 E383-17

Characteristics

AVESTA 383 AC/DC is a highly alloyed fully austenitic electrode with a composition corresponding to AWS E383-17. It is primarily designed for welding ASTM N08028 and similar steels. 383 has a fully austenitic structure which makes it somewhat more sensitive to hot cracking than for example 316L AC/DC. Welding should be performed taking great care about low heat input and interpass temperature.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 75
	3.25	80 – 110
	4.0	100 – 150

Weld deposit data

Metal recovery approx. 120%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Cu
0.02	0.9	0.9	27.0	32.0	3.7	1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	410 N/mm^2	240 N/mm^2
Tensile strength R_m	620 N/mm^2	500 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	55 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1070 – 1100°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 850°C (air).

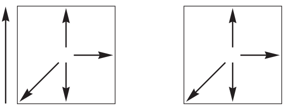
Corrosion resistance: High corrosion resistance in sulphuric and phosphoric acids. Excellent pitting resistance in acidic solutions containing chlorides and fluorides such as seawater.

Approvals

–

Welding positions

Ø 2.5–3.25 Ø 4.0



P12-R basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378

Also for welding nickel base alloys to stainless or unalloyed steels and for surfacing.

Standard designations

EN 14172	Ni Cr 21 Mo Fe Nb
AWS A5.11	ENiCrMo-12

Characteristics

AVESTA P12-R basic is a nickel base electrode intended for 6Mo steels such as 254 SMO. It can also be used for welding nickel base alloys such as Inconel 625 and Incoloy 825. In chloride containing environments, the electrode offers particularly high resistance to pitting, crevice corrosion and stress corrosion cracking. As it has a fully austenitic structure, P12-R is slightly more sensitive to hot cracking than, for example, 316L AC/DC. Consequently, low heat input and careful control of the interpass temperature are essential.

Welding data

DC+	Diam. mm	Current, A
	2.0	25 – 45
	2.5	40 – 70
	3.25	60 – 95
	4.0	90 – 135
	5.0	130 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250	0.61	170	0.59	36	107
2.5	300	0.64	90	0.90	44	104
3.25	350	0.66	44	1.39	59	106
4.0	350	0.70	28	2.14	60	108
5.0	350					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.02	0.4	0.4	21.5	bal.	9.5	2.2	2.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.11
Yield strength $R_{p0.2}$	465 N/mm^2	–
Tensile strength R_m	705 N/mm^2	650 N/mm^2
Elongation A_5	37 %	35 %
Impact strength KV		
+20°C	80 J	
–40°C	80 J	
–196°C	70 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1150 – 1200°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

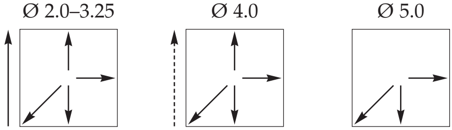
Corrosion resistance: Maximum resistance to pitting and cervice corrosion in chloride containing environments. Good resistance in sulphuric and phosphoric acids contaminated by chlorides.

Approvals

• CWB • TÜV • UDT

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



P625 basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
–	2.4856	N06625	–	–	–

Also for welding nickel base alloys to stainless or unalloyed steels and for surfacing.

Standard designations

EN 14172	Ni Cr 22 Mo 9 Nb
AWS A5.11	ENiCrMo-3

Characteristics

AVESTA P625 basic is a nickel base electrode intended for welding 6Mo and nickel base alloys. Due to its higher niobium content, compared to P12-R, P625 is well suited for welding nickel alloys such as Inconel 625 and Incoloy 825 for use in high temperature applications. P12-R has a fully austenitic structure which makes it somewhat more sensitive to hot cracking than for example 316L AC/DC. Welding should be performed taking great care about low heat input and interpass temperature.

Welding data

DC+	Diam. mm	Current, A
	2.5	40 – 70
	3.25	60 – 95
	4.0	90 – 135
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.64	88	0.99	42	106
3.25	350	0.66	44	1.38	59	105
4.0	350	0.68	29	1.97	63	106
5.0	350	0.72	19	3.20	61	104

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.02	0.5	0.2	21.5	bal.	9.5	3.5	1.5

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.11
Yield strength $R_{p0.2}$	460 N/mm^2	–
Tensile strength R_m	770 N/mm^2	760 N/mm^2
Elongation A_5	30 %	30 %
Impact strength KV		
+20°C	50 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1150 – 1200°C).

Structure: Fully austenitic.

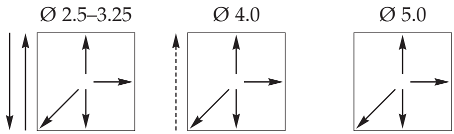
Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Maximum resistance to pitting and cervice corrosion in chloride containing environments. Good resistance in sulphuric and phosphoric acids contaminated by chlorides.

Approvals

–

Welding positions



P16 basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
654 SMO®	1.4652	S32654	–	–	–
–	–	N06059	–	–	–

Standard designations
–

Characteristics
AVESTA P16 basic is a nickel base electrode with a chemical composition similar to Alloy 59. P16 is specially developed for welding Outokumpu 654 SMO and other highly alloyed, fully austenitic steels, providing superior resistance to pitting, crevice and stress corrosion cracking in chloride containing enviroments. P16 has a fully austenitic structure which makes it somewhat more sensitive to hot cracking than, for example, 316L AC/DC. Welding should be performed taking great care about low heat input and interpass temperature.

Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.63	87	0.90	46	109
3.25	350	0.56	45	1.07	74	104
4.0	350	0.62	31	1.60	74	102

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.2	0.3	25.0	bal.	15.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.11
Yield strength $R_{p0.2}$	495 N/mm^2	–
Tensile strength R_m	740 N/mm^2	–
Elongation A_5	35 %	–
Impact strength KV		
+20°C	50 J	
–40°C	40 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1150 – 1200°C).

Structure: Fully austenitic.

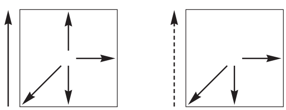
Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Superior resistance to pitting and crevice corrosion (CPT>80°C, ASTM G48-A).

Approvals
–

Welding positions

Ø 2.5–3.25 Ø 4.0



P54 basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
254 SMO®	1.4547	S31254	–	–	–
654 SMO®	1.4652	S32654	–	–	–

Standard designations

–

Characteristics

AVESTA P54 basic is a highly alloyed Cr-Ni-Mo electrode producing a fully austenitic weldment. P54 is specially developed for welding 254 SMO, 654 SMO and other 6 and 7Mo steel for use in highly oxidising environments, e.g. bleach washers in pulp and paper applications, especially those having neutral chloride dioxide conditions.

Welding data

DC+	Diam. mm	Current, A
	3.25	80 – 100

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo	Cu	N
0.02	0.2	2.6	25.7	25.5	4.9	0.8	0.35

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	470 N/mm^2	–
Tensile strength R_m	750 N/mm^2	–
Elongation A_5	22 %	–
Impact strength KV		
+20°C	50 J	
–70°C	30 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

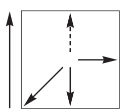
Corrosion resistance: Superior resistance in near neutral chloride dioxide containing environments, such as D-stage bleachers.

Approvals

–

Welding positions

Ø 3.25



307 AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for welding stainless steels to carbon steel, low-alloy steel or Mn-steel.

Standard designations

EN 1600	18 9 Mn Mo R
AWS A5.4	E307-17

Characteristics

AVESTA 307 AC/DC is a Mn-alloyed electrode developed for dissimilar welding between stainless, mild and low-alloy steels as well as Mn-steels. 307 offers a crack resistant weld with good mechanical properties.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.07	0.8	4.0	20.0	10.5	0.8

Ferrite 5 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	465 N/mm^2	350 N/mm^2
Tensile strength R_m	605 N/mm^2	500 N/mm^2
Elongation A_5	35 %	25 %
Impact strength KV		
+20°C	45 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 0 – 5% ferrite.

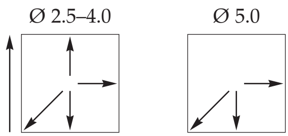
Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Primarily intended for stainless to mild steel connections, however, the corrosion resistance corresponds to ASTM 304.

Approvals

–

Welding positions



309L AC/DC

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for surfacing unalloyed steel, joint welding non-molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.

Standard designations

EN 1600	23 12 L R
AWS A5.4	E309L-17

Characteristics

AVESTA 309L AC/DC is a highly alloyed low carbon electrode designed for dissimilar welding between stainless and mild or low-alloy steels. The electrode is also well suited as a buffer layer when performing overlay welding on mild steels, providing an 18 Cr 8 Ni deposit from the very first layer. It can also be used for welding some high temperature steels such as ASTM 309S.

Welding data

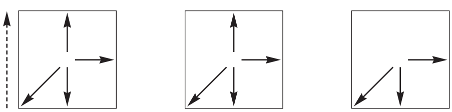
DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250					
2.5	300	0.60	82	1.02	43	119
3.25	350	0.61	43	1.58	52	114
4.0	350	0.63	29	2.07	61	112
5.0	350	0.68	18	3.11	64	112

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.02	0.8	1.0	24.0	13.5

Ferrite 15 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	460 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	50 J	
–40°C	45 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, stress-relieving may be advisable. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 10 – 15% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to 308L. When surfacing mild steel a corrosion resistance equivalent to that of ASTM 304 is obtained already in the first bead.

Approvals

- CWB
- DB
- DNV
- Inspecta
- SK
- TÜV
- UDT

309L basic

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for surfacing unalloyed steel, joint welding non-molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.

Standard designations

EN 1600	23 12 L B
AWS A5.4	E309L-15

Characteristics
AVESTA 309L basic is a highly alloyed low carbon electrode designed for dissimilar welding between stainless and mild or low-alloy steels. The electrode is also well suited as a buffer layer when performing overlay welding on mild steels, providing an 18 Cr 8 Ni deposit from the very first layer.

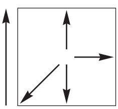
Welding data

DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 100
	4.0	100 – 140
	5.0	140 – 190

Weld deposit data
Metal recovery approx. 105%.

Welding positions

Ø 2.5–3.25



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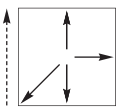

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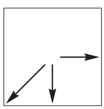


Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.03	0.2	1.9	24.0	13.0

Ferrite 15 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	440 N/mm^2	320 N/mm^2
Tensile strength R_m	570 N/mm^2	510 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	50 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing participation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 10 – 15% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to 308L.
When surfacing mild steel a corrosion resistance equivalent to that of ASTM 304 is obtained already in the first layer.

Approvals
–

P5 AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.

Standard designations

EN 1600	23 12 2 L R
AWS A5.4	E309MoL-17

Characteristics

AVESTA P5 AC/DC is a highly alloyed low carbon electrode corresponding to AWS A5.4 E309MoL-17. The electrode is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding, providing an 18 Cr 8 Ni 2 Mo deposit from the very first layer.

Welding data

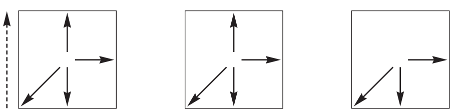
DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	300	0.55	134	0.76	35	115
2.5	350	0.58	74	1.06	46	112
3.25	350	0.59	44	1.59	52	112
4.0	400	0.63	25	2.14	66	109
5.0	400	0.67	16	3.12	70	108

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.8	1.1	22.5	13.5	2.7

Ferrite 20 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	490 N/mm^2	350 N/mm^2
Tensile strength R_m	640 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	30 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to 316L. The corrosion resistance obtained in the first layer when surface welding corresponds to that of ASTM 316.

Approvals

- CWB
- DB
- DNV
- Inspecta
- SK
- TÜV
- UDT

P5-HX AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.

Standard designations

EN 1600	23 12 2 L R
AWS A5.4	E309MoL-17

Characteristics

AVESTA P5-HX is a highly alloyed low carbon electrode corresponding to AWS A5.4 E309MoL-17. The electrode is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding, providing an 18 Cr 8 Ni 2 Mo deposit from the very first layer. P5-HX has an extra thick coating providing a high deposition rate with a metal recovery of about 150%. This electrode is a very cost-effective alternative for overlay welding in horizontal position.

Welding data

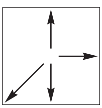
DC+ or AC	Diam. mm	Current, A
	3.25	80 – 130
	4.0	110 – 170
	5.0	170 – 230

Weld deposit data at maximum welding current

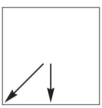
Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
3.25	350					
4.0	450	0.67	16	3.26	69	151
5.0	450	0.65	11	4.08	82	144

Welding positions

Ø 3.25



Ø 4.0–5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.03	0.8	1.0	22.0	13.5	2.7

Ferrite 20 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	450 N/mm^2	350 N/mm^2
Tensile strength R_m	625 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	35 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to 316L. The corrosion resistance obtained in the first layer when surfacing welding corresponds to that of ASTM 316.

Approvals

- UDT

P5-PW AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.					

Standard designations

EN 1600	23 12 2 L R
AWS A5.4	E309MoL-17

Characteristics

AVESTA P5-PW is a highly alloyed low carbon electrode corresponding to AWS A5.4 E309MoL-17. The electrode is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding, providing an 18 Cr 8 Ni 2 Mo type deposit from the very first layer. P5-PW has a coating specially developed for vertical-up and overhead welding.

Welding data

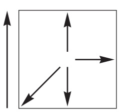
DC+ or AC	Diam. mm	Current, A
	1.6	25 – 45
	2.0	25 – 60
	2.5	35 – 80
	3.25	80 – 120
	4.0	100 – 160

Weld deposit data

Metal recovery approx. 105%.

Welding positions

Ø 1.6–4.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	1.1	1.0	22.5	13.5	2.9

Ferrite 20 FN WRC-92

Mechanical properties	Typical values (IIW)	**Min. values EN 1600**
Yield strength $R_{p0.2}$	525 N/mm^2	350 N/mm^2
Tensile strength R_m	660 N/mm^2	550 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV +20°C	25 J	
Hardness approx.	225 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to 316L. The corrosion resistance obtained in the first layer when surface welding corresponds to that of ASTM 316.

Approvals

–

P5-PWX AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.

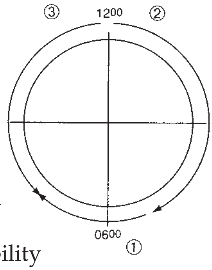
Standard designations

EN 1600 23 12 2 L R

Characteristics

AVESTA P5-PWX is a highly alloyed low carbon electrode. It is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding providing an 18 Cr 8 Ni 2 Mo type deposit from the very first layer. P5-PWX has an extra thin coating providing excellent weldability, in all positions, when butt-welding thin-walled pipes and tubes.

Pipe welding can be performed in several different ways. One possibility is to start welding in the overhead position (1), followed by vertical-down on both sides from the 12 o'clock position (2 and 3). Another possibility is to start at the 7 o'clock position and weld vertical-up to the 11 o'clock position on both sides. This requires an inverter power source with a remote control.



Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	18 – 50

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.0	250	0.64	181	0.71	29	107

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	1.1	1.0	22.5	13.5	2.7

Ferrite 20 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	480 N/mm^2	350 N/mm^2
Tensile strength R_m	635 N/mm^2	550 N/mm^2
Elongation A_5	25 %	25 %
Impact strength KV		
+20°C	30 J	
Hardness approx.	225 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

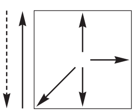
Corrosion resistance: Superior to type 316L. The corrosion resistance obtained on the first layer when surfacing corresponds to that of ASTM 316.

Approvals

–

Welding positions

Ø 2.0



The PWX electrode can be used for welding vertical-down under certain circumstances, such as when welding pipes. However, it does not match the welding properties of the VDX electrode in such conditions.

P5-VDX AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.

Standard designations

EN 1600 23 12 2 L R

Characteristics

AVESTA P5-VDX is a highly alloyed low carbon electrode. It is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding providing an 18 Cr 8 Ni 2 Mo type deposit from the very first layer. P5-VDX has an extra thin coating, providing an excellent weldability when welding thin plates in the vertical-down position, e.g. corner welds.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.02	0.9	0.9	22.5	13.5	2.7

Ferrite 20 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	545 N/mm^2	350 N/mm^2
Tensile strength R_m	685 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	40 J	
Hardness approx.	225 Brinell	

Welding data

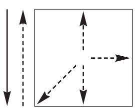
DC+ or AC	Diam. mm	Current, A
	2.5	50 – 70
	3.25	95 – 105

Weld deposit data

Metal recovery approx. 105%.

Welding positions

Ø 2.5–3.25



Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to type 316L. The corrosion resistance obtained on the first layer when surfacing corresponds to that of ASTM 316.

Approvals

- Inspecta
- SK

P5 basic

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.					

Standard designations

EN 1600	23 12 2 L B
AWS A5.4	E309MoL-15

Characteristics

AVESTA P5 basic is a highly alloyed low carbon electrode. It is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding, providing an 18 Cr 8 Ni 2 Mo type deposit from the very first layer. P5 basic provides a somewhat better impact strength than the AC/DC type electrodes.

Welding data

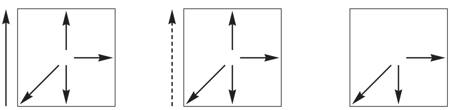
DC+	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 75
	3.25	70 – 100
	4.0	100 – 140
	5.0	130 – 190

Weld deposit data

Metal recovery approx. 105%.

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.03	0.2	2.0	22.5	13.0	2.7

Ferrite 15 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	465 N/mm^2	350 N/mm^2
Tensile strength R_m	615 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	50 J	
–40°C	35 J	
Hardness approx.	230 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing participation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to 316L. The corrosion resistance obtained in the first layer when surface welding corresponds to that of ASTM 316.

Approvals

- Inspecta
- TÜV
- UDT

P5 rutile

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
Overalloyed electrode for surfacing unalloyed steel, joint welding molybdenum-alloyed stainless steel to unalloyed steel and welding clad material.					

Standard designations

EN 1600	23 12 2 L R
AWS A5.4	E309MoL-16

Characteristics

AVESTA P5 rutile is a highly alloyed low carbon electrode. It is designed for dissimilar welding between stainless and mild or low-alloy steels but can also be used for overlay welding, providing an 18 Cr 8 Ni 2 Mo type deposit from the very first layer.

Welding data

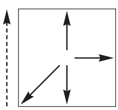
DC+	Diam. mm	Current, A
	2.5	50 – 75
	3.25	70 – 110
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.60	90	0.80	51	108
3.25	350	0.62	49	1.25	52	107
4.0	350	0.64	29	1.71	71	107
5.0	350	0.68	19	2.62	71	107

Welding positions

Ø 2.5–3.25



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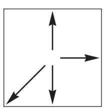
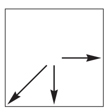


Ø 5.0



Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	Mo
0.03	0.3	1.4	22.5	13.5	2.7

Ferrite 15 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	510 N/mm^2	350 N/mm^2
Tensile strength R_m	620 N/mm^2	500 N/mm^2
Elongation A_5	32 %	25 %
Impact strength KV +20°C	50 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing participation in the temperature range 550 – 950°C.

Structure: Austenite with 15 – 20% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to 316L. The corrosion resistance obtained on the first layer when surface welding corresponds to that of ASTM 316.

Approvals

- TÜV
- UDT

P7 AC/DC

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS

Specially designed for difficult-to-weld steels such as Mn-steels, tool steels and high temperature grades.

Standard designations

EN 1600 29 9 R

Characteristics

AVESTA P7 is a highly alloyed Cr-Ni electrode with approx. 40% ferrite offering high tensile strength and excellent resistance to cracking. The chemical composition corresponds to that of AWS A5.4 E312. The electrode is primarily intended for dissimilar welding between stainless steel, tool steel, spring steel and 14% Mn-steel as well as other difficult-to-weld combinations.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	350	0.59	71	1.00	50	118
3.25	350	0.62	42	1.53	56	117
4.0	400	0.66	24	2.14	70	116
5.0	400					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.09	0.8	0.8	29.0	9.5

Ferrite 40 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	620 N/mm^2	450 N/mm^2
Tensile strength R_m	810 N/mm^2	650 N/mm^2
Elongation A_5	16 %	15 %
Impact strength KV +20°C	25 J	
Hardness approx.	270 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. Alloys of this type are susceptible to precipitation of secondary phases in the temperature range 550 – 950°C.

Structure: Austenite with 30 – 40% ferrite.

Scaling temperature: Approx. 1000°C (air).

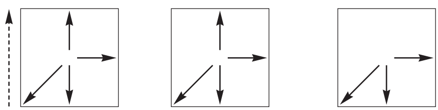
Corrosion resistance: Very good corrosion resistance in wet sulphuric environments, such as in sulphate digesters used by the pulp and paper industry.

Approvals

- SK
- UDT

Welding positions

Ø 2.5–3.25 Ø 4.0 Ø 5.0



P7-PW AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
Specially designed for difficult-to-weld steels such as Mn-steels, tool steels and high temperature grades.					

Standard designations

EN 1600   29 9 R

Characteristics

AVESTA P7-PW is a highly alloyed Cr-Ni electrode with approx. 40% ferrite, offering high tensile strength and excellent resistance to cracking. P7-PW has a coating specially designed for welding in vertical-up and overhead position. The chemical composition corresponds to that of AWS A5.4 E312. The electrode is primarily intended for dissimilar welding between stainless steel, tool steel, spring steel and 14% Mn-steel as well as other difficult-to-weld combinations.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	50 – 80
	3.25	80 – 120

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.10	0.9	1.0	28.5	10.0

Ferrite 40 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	710 N/mm^2	450 N/mm^2
Tensile strength R_m	840 N/mm^2	650 N/mm^2
Elongation A_5	15 %	15 %
Impact strength KV		
+20°C	20 J	
Hardness approx.	260 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. Alloys of this type are susceptible to precipitation of secondary phases in the temperature range 550 – 950°C.

Structure: Austenite with 30 – 40% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Very good corrosion resistance in wet sulphuric environments, such as in sulphate digesters used by the pulp and paper industry.

Approvals

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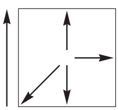
Welding positions

Ø 2.5–3.25



P10 basic

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
All-round electrode suitable for many difficult-to-weld combinations.					

Standard designations

AWS A5.11 ENiCrFe-3

Characteristics

AVESTA P10 basic is a nickel base electrode for welding Inconel 600 and similar nickel alloys. P10 provides high resistance to cracking and is well suited for dissimilar welds between stainless and nickel alloys to mild steel. The P10 electrode can also be used for welding nickel base alloys for use in high temperature applications.

Welding data

DC+	Diam. mm	Current, A
	2.5	45 – 70
	3.25	70 – 110
	4.0	100 – 140
	5.0	130 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.5	300					
3.25	350	0.67	43	1.38	61	110
4.0	350	0.73	28	2.11	62	114
5.0	350	0.75	18	3.14	63	110

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Nb	Fe	Ni
0.02	0.4	6.5	16.0	1.8	5.0	bal.

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.11
Yield strength $R_{p0.2}$	380 N/mm^2	–
Tensile strength R_m	630 N/mm^2	550 N/mm^2
Elongation A_5	39 %	30 %
Impact strength KV		
+20°C	115 J	
–196°C	80 J	
Hardness approx.	180 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

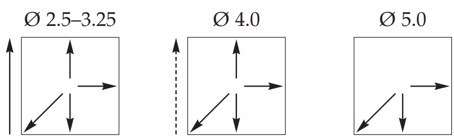
Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Very good resistance to stress corrosion cracking. Also very good resistance to intergranular corrosion due to the low carbon content and absence of sigma phase.

Approvals

- UDT

Welding positions



P690 basic

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS

For welding N06690/2.4642 and for overlay welding of carbon/low-alloy steels. Particularly suited for the conditions in nuclear fabrication.

Standard designations

EN 14172	Ni Cr 30 Fe 9 Nb
AWS A5.11	ENiCrFe-7

Characteristics

AVESTA P690 basic is a nickel base electrode with a basic type coating. P690 is suitable for many welding applications, such as joining nickel base alloys, e.g. Inconel 690 as well as for joining unalloyed or low-alloy steels to stainless steels and nickel base alloys. P690 is also well suited for depositing overlays on carbon steel, especially when there are stringent requirements regarding service at high temperatures, or in the construction of nuclear reactors.

P690 is unsusceptible to sigma phase embrittlement and shows little tendency towards carbon diffusion. It is therefore very well suited for constructions in service at elevated temperatures.

Welding data

DC+	Diam. mm	Current, A
	3.25	70 – 110
	4.0	100 – 145

Weld deposit data

Metal recovery approx. 110%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Nb	Mo	Fe	Ni
0.03	0.4	3.0	30.0	1.5	0.3	9.0	bal.

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 14172
Yield strength $R_{p0.2}$	400 N/mm^2	360 N/mm^2
Tensile strength R_m	640 N/mm^2	550 N/mm^2
Elongation A_5	35 %	30 %
Impact strength KV		
+20°C	110 J	
–196°C	100 J	
Hardness approx.	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

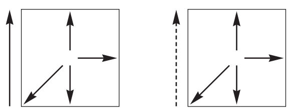
Corrosion resistance: Very good resistance to stress corrosion cracking in oxidising acids and water at high temperatures. Also very good resistance to intergranular corrosion due to the low carbon content and absence of sigma phase.

Approvals

–

Welding positions

Ø 3.25 Ø 4.0



309 AC/DC

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

Overalloyed electrode primarily used for welding high temperature steels such as ASTM 309S, but it may also be used for surfacing unalloyed steel, joint welding stainless steel to unalloyed steel and welding clad material.

Standard designations

AWS A5.4 E309-17

Characteristics

AVESTA 309 AC/DC is a high carbon electrode designed for welding some high temperature steels such as ASTM 309S but it can also be used for dissimilar welding between stainless and mild or low-alloy steels.

Welding data

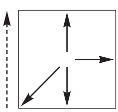
DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 80
	3.25	80 – 120
	4.0	100 – 160
	5.0	160 – 220

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250					
2.5	300	0.60	82	1.02	43	119
3.25	350	0.61	43	1.58	52	114
4.0	350	0.63	29	2.07	61	112
5.0	350	0.68	18	3.11	64	112

Welding positions

Ø 2.0–3.25



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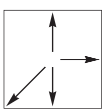

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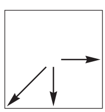


Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.05	0.8	1.0	24.0	13.5

Ferrite 15 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values AWS A5.4
Yield strength $R_{p0.2}$	435 N/mm^2	–
Tensile strength R_m	580 N/mm^2	550 N/mm^2
Elongation A_5	30 %	30 %
Impact strength KV		
+20°C	45 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 10 – 15% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Primarily designed for high temperature applications with service temperatures up to 1000°C. The resistance to intercrystalline corrosion is somewhat limited due to the high carbon content.

Approvals

- CWB
- UDT

310 AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4845	1.4845	310S	310S16	Z8 CN 25-20	2361

Standard designations

EN 1600	25 20 R
AWS A5.4	E310-17

Characteristics

AVESTA 310 AC/DC is a 25Cr-20Ni electrode for welding ASTM 310S and related types of high temperature stainless steels. 310 has a fully austenitic structure, which makes it somewhat more sensitive to hot cracking than, for example, 309L weld filler. Welding should be performed taking great care about low heat input and interpass temperature.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	35 – 60
	2.5	50 – 75
	3.25	70 – 100
	4.0	100 – 150
	5.0	140 – 190

Weld deposit data at maximum welding current

Electrode diam. mm	length mm	N	B	H	T	Metal recov. ~ %
2.0	250					
2.5	300	0.60	82	0.90	49	123
3.25	300	0.62	42	1.31	65	119
4.0	350	0.64	28	1.83	70	114
5.0	350	0.68	19	2.46	78	113

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.10	0.5	2.1	26.0	21.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	430 N/mm^2	350 N/mm^2
Tensile strength R_m	625 N/mm^2	550 N/mm^2
Elongation A_5	35 %	20 %
Impact strength KV		
+20°C	80 J	
–196°C	35 J	
Hardness approx.	190 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1150°C (air).

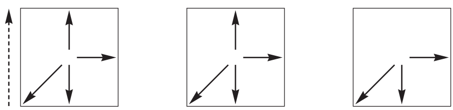
Corrosion resistance: Initially intended for constructions running at high temperatures. Wet corrosion properties are moderate.

Approvals

- CWB
- UDT

Welding positions

Ø 2.0–3.25 Ø 4.0 Ø 5.0



310 basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4845	1.4845	310S	310S16	Z8 CN 25-20	2361

Standard designations

EN 1600	25 20 B
AWS A5.4	E310-15

Characteristics

AVESTA 310 basic is a 25Cr-20Ni electrode for welding ASTM 310S and other similar high temperature steels. 310 has a fully austenitic structure, which makes it somewhat more sensitive to hot cracking than, for example, 309L weld filler. Welding should be performed taking great care about low heat input and interpass temperature. 310 basic provides better impact strength than the AC/DC type electrodes.

Welding data

DC+	Diam. mm	Current, A
	2.0	35 – 55
	2.5	50 – 70
	3.25	70 – 100
	4.0	100 – 140
	5.0	140 – 190

Weld deposit data

Metal recovery approx. 105%.

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.12	0.3	2.4	25.5	21.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	415 N/mm^2	350 N/mm^2
Tensile strength R_m	590 N/mm^2	550 N/mm^2
Elongation A_5	34 %	20 %
Impact strength KV		
+20°C	100 J	
Hardness approx.	190 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1150°C (air).

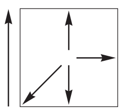
Corrosion resistance: Initially intended for constructions running at high temperatures. Wet corrosion properties are moderate.

Approvals

–

Welding positions

Ø 2.0–3.25



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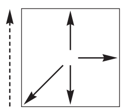

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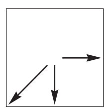


253 MA AC/DC

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
253 MA®	1.4835	S30815	–	–	2368
153 MA™	1.4818	S30415	–	–	2372

Standard designations

–

Characteristics

AVESTA 253 MA AC/DC is primarily designed for welding the high temperature stainless steel Outokumpu 253 MA with excellent resistance to oxidation up to 1100°C. The electrode has a ferrite content of approx. 10%, which gives high resistance to hot cracking.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.0	30 – 50
	2.5	45 – 70
	3.25	70 – 110
	4.0	100 – 140
	5.0	150 – 200

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.0	300					
2.5	350	0.58	78	0.80	58	109
3.25	350	0.58	46	1.18	66	108
4.0	400	0.62	27	1.63	82	105
5.0	400					

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	N
0.08	1.5	0.7	22.0	10.5	0.18

Ferrite 10 FN DeLong

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	535 N/mm^2	–
Tensile strength R_m	725 N/mm^2	–
Elongation A_5	37 %	–
Impact strength KV +20°C	60 J	
Hardness approx.	215 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none.

Structure: Austenite with 3 – 10% ferrite.

Scaling temperature: Approx. 1150°C (air).

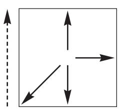
Corrosion resistance: Excellent resistance to high temperature corrosion. Not intended for applications exposed to wet corrosion.

Approvals

–

Welding positions

Ø 2.0–3.25



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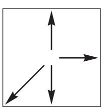

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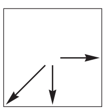


253 MA-NF AC/DC

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
253 MA®	1.4835	S30815	–	–	2368
153 MA™	1.4818	S30415	–	–	2372

Standard designations

–

Characteristics

AVESTA 253 MA-NF AC/DC is a fully austenitic electrode designed for welding Outokumpu 153 MA and 253 MA exposed to medium to high service temperatures (650 – 950°). The absence of ferrite in 253 MA-NF provides high ductility at room temperature, which makes it well suited for applications with a thermal cycle between 20°C and 950°C. However, the fully austenitic solidification structure requires that welding be performed with great care about low heat input and interpass temperature.

Welding data

DC+ or AC	Diam. mm	Current, A
	2.5	45 – 70
	3.25	70 – 110
	4.0	100 – 140

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.5	350	0.58	78	0.80	58	109
3.25	350	0.58	46	1.18	66	108
4.0	400	0.62	27	1.63	82	105

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni	N
0.08	0.7	1.0	19.0	10.0	0.16

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	470 N/mm^2	–
Tensile strength R_m	630 N/mm^2	–
Elongation A_5	35 %	–
Impact strength KV		
+20°C	60 J	
Hardness approx.	210 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1000°C (air).

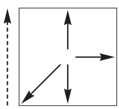
Corrosion resistance: Excellent resistance to high temperature corrosion. Not intended for applications exposed to wet corrosion.

Approvals

–

Welding positions

Ø 2.5–3.25



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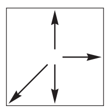


353 MA basic

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
353 MA®	1.4854	S35315	–	–	–

Standard designations

–

Characteristics

AVESTA 353 MA basic is a fully austenitic electrode primarily designed for welding the high temperature steel Outokumpu 353 MA, providing superior properties at temperatures up to 1175°C. The 353 MA filler metal has a fully austenitic structure, which makes it somewhat more sensitive to hot cracking than for example 253 MA filler metal. Welding should therefore be performed taking great care about low heat input and interpass temperature.

Welding data

DC+	Diam. mm	Current, A
	2.5	45 – 70
	3.25	70 – 110
	4.0	100 – 140

Weld deposit data at maximum welding current

Electrode diam. mm	Electrode length mm	N	B	H	T	Metal recov. ~ %
2.5	300	0.59	71	0.85	59	136
3.25	350	0.67	34	1.46	73	147
4.0	350	0.67	24	1.83	83	137

Typical analysis % (All weld metal)

C	Si	Mn	Cr	Ni
0.07	0.7	1.4	27.5	33.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 1600
Yield strength $R_{p0.2}$	385 N/mm^2	–
Tensile strength R_m	565 N/mm^2	–
Elongation A_5	33 %	–
Impact strength KV +20°C	85 J	
Hardness approx.	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1175°C (air).

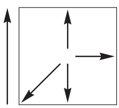
Corrosion resistance: Superior properties for constructions running at service temperatures above 1000°C. Not intended for applications exposed to wet corrosion.

Approvals

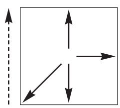
–

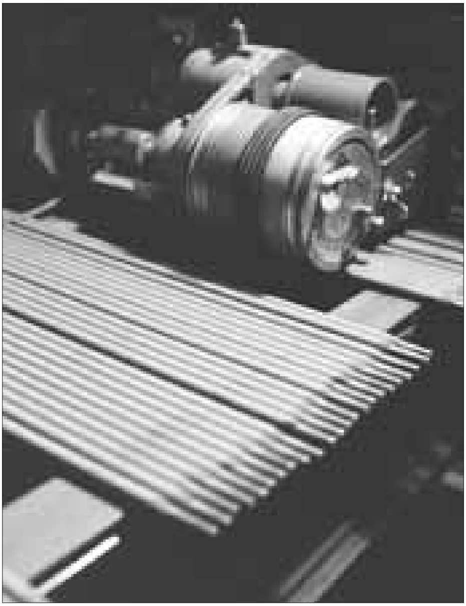
Welding positions

Ø 2.5–3.25



Ø 4.0





248 SV

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
248 SV	1.4418	–	–	Z6 CND 16-05-01	2387

Standard designations

–

Characteristics and welding directions

AVESTA 248 SV is designed for welding Outokumpu 248 SV and steel castings with corresponding composition. Applications include propellers, pumps, valves and shafts.

AVESTA 248 SV has high safety against cracking, superior to many other martensitic consumables. The weld metal properties, on the whole, are similar to those of the steel.

Preheating is normally unnecessary. In cases with heavy wall thicknesses or where considerable shrinkage stresses are to be expected, preheating up to 75 – 150°C is recommended.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	1.00	110 – 140	20 – 22
	1.20	130 – 160	20 – 22
Spray arc	1.00	160 – 220	23 – 27
	1.20	190 – 260	24 – 28

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.35	1.3	16.0	5.5	1.0

Ferrite 10%

Mechanical properties	Typical values (IIW)*	Min. values EN 12072
Yield strength $R_{p0,2}$	460 N/mm^2	–
Tensile strength R_m	840 N/mm^2	–
Elongation A_5	23 %	–
Impact strength KV		
+20°C	80 J	
Hardness	260 Brinell	

* Annealed at 590°C for 4 hours.

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: To stabilise the structure and to minimise the content of brittle martensite an annealing at 590°C for 4 hours followed by air cooling is recommended.

Structure: Austenite balanced with ferrite and martensite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The resistance to general and pitting corrosion is in level with that of ASTM 304.

Approvals

–

308L-Si/MVR-Si

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12072	19 9 L Si
AWS A5.9	ER308LSi

Characteristics and welding directions

AVESTA 308L-Si/MVR-Si is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The wire can also be used for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347-Si/ MVNb-Si is required.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
	1.60	250 – 330	27 – 32
Pulsed arc	1.20	I_{peak} = 340 – 450 A	
		I_{bkg} = 50 – 150 A	
		Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.85	1.8	20.0	10.5

Ferrite	11 FN	DeLong
	9 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	420 N/mm^2	320 N/mm^2
Tensile strength R_m	600 N/mm^2	510 N/mm^2
Elongation A_5	36 %	30 %
Impact strength KV		
+20°C	110 J	
–196°C	60 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as oxidising and cold dilute reducing acids.

Approvals

- DB
- DNV
- SK
- TÜV
- UDT

308L/MVR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12072	19 9 L
AWS A5.9	ER308L

Characteristics and welding directions

AVESTA 308L/MVR is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The wire can also be used for welding titanium and niobium stabilised steels such as ASTM 304Ti and ASTM 304Nb in cases where the construction is to be used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347-Si/MVNb-Si is required.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
	1.60	250 – 330	27 – 32
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.40	1.7	20.0	10.0

Ferrite	8 FN	DeLong
	10 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	390 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	38 %	30 %
Impact strength KV		
+20°C	110 J	
–196°C	50 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as oxidising and cold dilute reducing acids.

Approvals

- DNV
- TÜV
- SK
- UDT

308H

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072 19 9 H
AWS A5.9 ER308H

Characteristics and welding directions

AVESTA 308H is designed for welding austenitic stainless steel type 18 Cr 10 Ni or similar. The consumable has an enhanced carbon content when compared to 308L. This provides improved creep resistance properties, which is advantageous at temperatures above 400°C. 308H type consumables are normally used at temperatures up to 600°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347/MVNb is required.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.05	0.40	1.8	20.0	9.0

Ferrite	10 FN	DeLong
	10 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	400 N/mm^2	350 N/mm^2
Tensile strength R_m	610 N/mm^2	550 N/mm^2
Elongation A_5	37 %	30 %
Impact strength KV		
+20°C	95 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. good resistance to general corrosion. The enhanced carbon content, compared to 308L, makes it slightly more sensitive to intercrystalline corrosion.

Approvals

–

347-Si/MVNb-Si

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072	19 9 Nb Si
AWS A5.9	ER347Si

Characteristics and welding directions

AVESTA 347-Si/MVNb-Si is used for welding titanium and niobium stabilised steels of type 19 Cr 10 Ni Ti or similar, providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 347-Si/MVNb-Si is therefore primarily used for applications where service temperatures exceed 400°C.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb
0.05	0.85	1.2	19.5	10.0	>12xC

Ferrite	10 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	430 N/mm^2	350 N/mm^2
Tensile strength R_m	620 N/mm^2	550 N/mm^2
Elongation A_5	36 %	25 %
Impact strength KV		
+20°C	100 J	
–40°C	90 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. 347 type wire can be used for cladding, which normally requires stress relieving at around 590°C. Such a heat treatment will reduce the ductility at room temperature. Always consult expertise before performing post-weld heat treatment.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: 347-Si/MVNb-Si is primarily intended for high temperature service or constructions that should be heat treated. However, the corrosion resistance corresponds to that of 308H, i.e. good resistance to general corrosion.

Approvals

- DB
- TÜV
- SK
- UDT

316L-Si/SKR-Si

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072	19 12 3 L Si
AWS A5.9	ER316LSi

Characteristics and welding directions

AVESTA 316L-Si/SKR-Si is designed for welding austenitic stainless steel of type 17 Cr 12 Ni 2.5 Mo or similar. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 316Ti in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures, a niobium stabilised consumable such as AVESTA 318-Si/SKNb-Si is required.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
	1.60	250 – 330	29 – 32
Pulsed arc	1.20	I_{peak} = 350 – 450 A	
		I_{bkg} = 50 – 150 A	
		Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.85	1.7	18.5	12.0	2.6

Ferrite	9 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	400 N/mm^2	320 N/mm^2
Tensile strength R_m	600 N/mm^2	510 N/mm^2
Elongation A_5	36 %	25 %
Impact strength KV		
+20°C	110 J	
–196°C	50 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals

- DB
- DNV
- SK
- TÜV
- UDT

316L/SKR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072	19 12 3 L
AWS A5.9	ER316L

Characteristics and welding directions

AVESTA 316L/SKR is designed for welding austenitic stainless steel of type 17 Cr 12 Ni 2.5 Mo or similar. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 316Ti and ASTM 316Nb in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures, a niobium stabilised consumable such as AVESTA 318-Si/SKNb-Si is required.

Avesta Welding also supplies a type 316L wire with high silicon content (316L-Si/SKR-Si). The higher silicon content (0.85%) improves the fluidity of the melt pool with a minimum of spatter and is therefore recommended if the demands on surface quality are high.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 100 – 150 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.40	1.7	18.5	12.0	2.6

Ferrite	8 FN	DeLong
	8 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	390 N/mm^2	320 N/mm^2
Tensile strength R_m	580 N/mm^2	510 N/mm^2
Elongation A_5	37 %	25 %
Impact strength KV		
+20°C	100 J	
–196°C	50 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals

- DNV
- TÜV
- SK
- UDT

318-Si/SKNb-Si

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072 19 12 3 Nb Si

Characteristics and welding directions

AVESTA 318-Si/SKNb-Si is used for welding titanium and niobium stabilised steels of type 17 Cr 11 Ni 2.5 Ti or similar, providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 318-Si/SKNb-Si shows better properties than 316L-Si/SKR-Si at elevated temperatures and is therefore recommended for applications where service temperatures exceed 400°C.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 100 – 150 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb
0.04	0.85	1.3	19.0	12.0	2.6	>12xC

Ferrite 10 FN DeLong
7 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	420 N/mm^2	350 N/mm^2
Tensile strength R_m	600 N/mm^2	550 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	85 J	
–40°C	80 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The corrosion resistance corresponds to that of ASTM 316Ti, i.e. good resistance to general, pitting and intercrystalline corrosion.

Approvals

- DB
- SK
- TÜV
- UDT

317L/SNR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-15-04	2367
4439	1.4439	317LMN	–	Z3 CND 18-14-05 Az	–

Standard designations

EN 12072 19 13 4 L

AWS A5.9 ER317L

Characteristics and welding directions

AVESTA 317L/SNR is designed for welding type 18 Cr 14 Ni 3 Mo austenitic stainless steels and similar. The enhanced content of chromium, nickel and molybdenum compared to 316L gives improved corrosion properties in acid chloride containing environments.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 260	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A	
		I_{bkg} = 50 – 150 A	
		Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.40	1.7	19.0	13.5	3.5

Ferrite	9 FN	DeLong
	9 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	420 N/mm^2	350 N/mm^2
Tensile strength R_m	630 N/mm^2	550 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	85 J	
Hardness	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Better resistance to general, pitting and intercrystalline corrosion in chloride containing environments than ASTM 316L. Intended for severe service conditions, i.e. in dilute hot acids.

Approvals

- SK
- UDT

2205

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 12072 22 9 3 L N
AWS A5.9 ER2209

Characteristics and welding directions

AVESTA 2205 is primarily designed for welding the duplex grade Outokumpu 2205 and similar but it can also be used for SAF 2304 type of steels.

AVESTA 2205 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic stainless steels.

The welding can be performed using short, spray or pulsed arc. Welding using pulsed arc provides good results in both horizontal and vertical-up positions.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	60 – 100	18 – 20
	1.00	90 – 120	19 – 21
Spray arc	1.00	180 – 220	27 – 30
	1.20	200 – 240	28 – 31
Pulsed arc	1.20	I_{peak} = 450 – 550 A I_{bkg} = 150 – 200 A Freq = 120 – 150 Hz	

Shielding gas

As shielding gas argon (Ar) with an addition of 2% O_2 or 2 – 3% CO_2 is normally used, but an addition of 30% He will improve fluidity and penetration.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.50	1.6	23.0	8.5	3.1	0.17

Ferrite 50 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	550 N/mm^2	450 N/mm^2
Tensile strength R_m	770 N/mm^2	550 N/mm^2
Elongation A_5	30 %	20 %
Impact strength KV		
+20°C	150 J	
–40°C	110 J	
Hardness	230 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

- DB
- DNV
- SK
- TÜV

2507/P100

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2507®	1.4410	S32750	–	Z3 CND 25-06 Az	2328

Standard designations
EN 12072 25 9 4 L N

Characteristics and welding directions
AVESTA 2507/P100 is intended for welding super duplex alloys such as SAF 2507, ASTM S32760, S32550 and S31260.

Welding 2507/P100 is preferably done using pulsed arc.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	180 – 220	24 – 28
	1.20	200 – 240	25 – 29
Pulsed arc	1.20	I_{peak} = 450 – 550 A I_{bkg} = 150 – 200 A Freq = 120 – 150 Hz	

Shielding gas
Pure argon or Ar + 30% He + 2.5% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.35	0.4	25.0	9.5	4.0	0.25

Ferrite 50 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	570 N/mm^2	550 N/mm^2
Tensile strength R_m	830 N/mm^2	620 N/mm^2
Elongation A_5	29 %	18 %
Impact strength KV		
+20°C	140 J	
Hardness	280 Brinell	

Interpass temperature: Max. 100°C.

Heat input: 0.5 – 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments. Pitting resistance is in accordance with ASTM G48-A, better than 40°C.

Approvals
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904L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
904L	1.4539	904L	904S13	Z2 NCDU 25-20	2562

Also for welding similar steels of the 20-25 CrNiMoCu-type.

Standard designations

EN 12072	20 25 5 Cu L
AWS A5.9	ER385

Characteristics and welding directions

AVESTA 904L is intended for welding Outokumpu 904L and similar but can also be used for constructions in type ASTM 316 where a ferrite-free weld metal is required, such as cryogenic or non-magnetic applications. The impact strength at low temperature is excellent.

A fully austenitic structure is more prone to hot or solidification cracking than type ASTM 316 welds, so welding should be performed minimising the heat input, interpass temperature and penetration with parent metal.

Welding is best performed using a pulsed arc power source.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	170 – 210	25 – 29
	1.20	180 – 230	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 380 A I_{bkg} = 80 – 120 A Freq = 100 – 120 Hz	

Shielding gas

Welding is best performed using pulsed arc with a shielding gas of pure argon or Ar + 30% He.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Cu
0.01	0.35	1.7	20.0	25.5	4.5	1.5

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	340 N/mm^2	320 N/mm^2
Tensile strength R_m	570 N/mm^2	510 N/mm^2
Elongation A_5	38 %	25 %
Impact strength KV		
+20°C	130 J	
–196°C	100 J	
Hardness	170 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1070 – 1100°C).

Structure: Fully austenitic with extra low content of impurities.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Very good in non-oxidising environments such as sulphuric or phosphoric acids. Very good resistance to pitting and crevice corrosion in chloride containing environments. Excellent resistance to general corrosion and stress corrosion cracking.

Approvals

- DB
- SK
- TÜV
- UDT

P12

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–
Also for welding stainless steels and nickel base alloys to low-alloy and mild steel.					

Standard designations

EN 18274 Ni Cr 22 Mo 9 Nb
AWS A5.14 ERNiCrMo-3

Characteristics and welding directions

AVESTA P12 is a nickel base alloy designed for welding 6Mo-steels such as Outokumpu 254 SMO. The consumable is also suitable for welding nickel base alloys such as Inconel 625 and Incoloy 825 and for dissimilar welds between stainless or nickel base alloys and mild steel.

Welding of fully austenitic and nickel base steels should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	170 – 210	24 – 28
	1.20	180 – 220	25 – 29
Pulsed arc	1.20	I_{peak} = 300 – 380 A	
		I_{bkg} = 90 – 120 A	
		Freq = 90 – 110 Hz	

Shielding gas

Welding is best performed using pulsed arc with a shielding gas of pure argon or Ar + 30% He + 2% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.1	22.0	65.0	9.0	3.6	<1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.14
Yield strength $R_{p0,2}$	480 N/mm^2	–
Tensile strength R_m	750 N/mm^2	760 N/mm^2
Elongation A_5	42 %	30 %
Impact strength KV		
+20°C	170 J	
–40°C	150 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments.

Approvals

- TÜV

P12-0^{Nb}

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA P12-0^{Nb} is a nickel base alloy designed for welding 6Mo-steels such as Outokumpu 254 SMO.

AVESTA P12-0^{Nb} produces a fully austenitic weld metal that due to the absence of niobium is almost free from secondary phases. This gives extremely good ductility with superior impact strength even at low temperatures. The tensile strength is somewhat lower than standard P12.

AVESTA P12-0^{Nb} is specially designed to meet the requirements of NORSOK M-601, 6.3.3.

Welding of fully austenitic and nickel base steels should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00 1.20	170 – 210 180 – 220	24 – 28 25 – 29
Pulsed arc	1.20	I_{peak} = 300 – 380 A I_{bkg} = 90 – 120 A Freq = 90 – 110 Hz	

Shielding gas

Welding is best performed using pulsed arc with a shielding gas of pure argon or Ar + 30% He + 2% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.1	22.0	65.0	9.0	<0.1	<1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.14
Yield strength $R_{p0,2}$	380 N/mm^2	–
Tensile strength R_m	630 N/mm^2	–
Elongation A_5	36 %	–
Impact strength KV		
+20°C	240 J	
–70°C	220 J	
Hardness	210 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic with extra low content of secondary phases.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments which makes the consumable perfect for sea water and offshore applications etc.

Approvals

–

P16

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
654 SMO®	1.4652	S31654	–	–	–
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Also for welding nickel base alloys to stainless steel and mild steel.

Standard designations
EN 18274 Ni Cr 25 Mo 16

Characteristics and welding directions
AVESTA P16 is a nickel base alloy designed for welding 7Mo-steels such as Outokumpu 654 SMO and similar, offering superior resistance to pitting and crevice corrosion. The consumable is also suitable for the welding of nickel base alloys such as Inconel 625 and Incoloy 825 but also for dissimilar welds between stainless and nickel base alloys to mild steel.

The chemical composition corresponds to that of Alloy 59 (ERNiCrMo-13).

Welding of fully austenitic and nickel base steels should be performed taking great care to minimise the risk of hot or solidification cracking. The heat input and dilution with parent metals should be minimised.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	170 – 210	24 – 28
	1.20	180 – 220	25 – 29
Pulsed arc	1.20	I_{peak} = 300 – 380 A I_{bkg} = 90 – 120 A Freq = 90 – 110 Hz	

Shielding gas
Welding is best performed using pulsed arc with a shielding gas of pure argon or Ar + 30% He + 2% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.2	25.0	60.0	15.0	<0.1	<1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 18274
Yield strength $R_{p0,2}$	470 N/mm^2	–
Tensile strength R_m	700 N/mm^2	–
Elongation A_5	33 %	–
Impact strength KV +20°C	120 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1150 – 1200°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Superior resistance to pitting and crevice corrosion (CPT >80°C, ASTM G48-A).

Approvals
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P54

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
254 SMO®	1.4547	S31254	–	–	2378
654 SMO®	1.4652	S32654	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA P54 is an iron-based fully austenitic consumable designed for welding Outokumpu 254 SMO and 654 SMO and other similar 6Mo and 7Mo-steels.

AVESTA P54 is specially developed for applications exposed to highly oxidising chloride containing environments, such as D-stage bleachers in pulp mills, where a nickel base filler will suffer from trans-passive corrosion. The consumable also offers very high resistance to localised corrosion.

AVESTA P54 produces a fully austenitic high alloy weld metal and is therefore somewhat more sensitive to hot cracking than, for example, 304-type steels.

The parameter box when welding P54 is rather narrow and welding is best performed using a synergic pulsed machine.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	170 – 210	24 – 28
	1.20	180 – 220	25 – 29
Pulsed arc	1.20	I_{peak} = 320 – 360 A I_{bkg} = 90 – 120 A Freq = 80 – 100 Hz	

Shielding gas

Pure argon or Ar + 30% He.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N	Cu
0.02	0.20	5.1	26.0	22.0	5.5	0.35	0.9

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	480 N/mm^2	–
Tensile strength R_m	750 N/mm^2	–
Elongation A_5	35 %	–
Impact strength KV		
+20°C	90 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Superior resistance in near neutral chloride dioxide containing environments, such as D-stage bleachers.

Approvals

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307-Si

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 307-Si is primarily used in dissimilar welding between stainless and mild steel or low-alloy steels.					

Standard designations

EN 12072   18 8 Mn Si

Characteristics and welding directions

AVESTA 307-Si is an over-alloyed, fully austenitic consumable for welding stainless steel to mild steel, low-alloy or Mn-steels. It is also suitable for the welding of some 14% Mn-steels and other difficult-to-weld steels.

The high manganese content makes the weld metal, even though it is purely austenitic, very resistant to hot cracking with a good ductility.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	90 – 120	18 – 22
	1.00	110 – 140	19 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 270	26 – 30
	1.60	250 – 330	29 – 32
Pulsed arc	1.20	I_{peak} = 350 – 450 A	
		I_{bkg} = 50 – 150 A	
		Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.09	0.80	7.0	19.0	8.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	470 N/mm^2	350 N/mm^2
Tensile strength R_m	710 N/mm^2	500 N/mm^2
Elongation A_5	42 %	25 %
Impact strength KV		
+20°C	120 J	
–40°C	110 J	
Hardness	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, stress-relieving may be advisable. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Fully austenitic.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Primarily intended for stainless to mild steel connections, however, the corrosion resistance corresponds to ASTM 304.

Approvals

- DB
- TÜV

309L-Si

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA 309L-Si is primarily used when surfacing unalloyed or low-alloy steels and when joining non-molybdenum-alloyed stainless and carbon steels.

Standard designations

EN 12072	23 12 L Si
AWS A5.9	ER309LSi

Characteristics and welding directions

AVESTA 309L-Si is a high-alloy 23 Cr 13 Ni wire primarily intended for surfacing of low-alloy steels and dissimilar welding between mild steel and stainless steels, offering a ductile and crack resistant weldment.

The chemical composition, when surfacing, is equivalent to that of ASTM 304 from the first run. One or two layers of 309L are usually combined with a final layer of 308L, 316L or 347.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.80	1.8	23.5	13.5

Ferrite 13 FN DeLong; 9 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	400 N/mm^2	320 N/mm^2
Tensile strength R_m	600 N/mm^2	510 N/mm^2
Elongation A_5	32 %	25 %
Impact strength KV		
+20°C	110 J	
Hardness	200 Brinell	

Welding data

	Diameter mm	Current A	Voltage V
Short arc	1.00	110 – 140	20 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 260	27 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Approvals

- DB
- TÜV

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to type 308L. When surfacing on mild steel a corrosion resistance equivalent to ASTM 304 is obtained at the first bead.

309L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 309L is primarily used when surfacing unalloyed or low-alloy steels and when joining non-molybdenum-alloyed stainless and carbon steels.					

Standard designations

EN 12072	23 12 L
AWS A5.9	ER309L

Characteristics and welding directions

AVESTA 309L is a high-alloy 23 Cr 13 Ni wire primarily intended for surfacing low-alloy steels and for dissimilar welding between mild steel and stainless steels, offering a ductile and crack resistant weldment.

The chemical composition, when surfacing, is equivalent to that of ASTM 304 from the first run. One or two layers of 309L are usually combined with a final layer of 308L, 316L or 347.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.40	1.8	23.5	14.0

Ferrite 11 FN DeLong; 10 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	380 N/mm^2	320 N/mm^2
Tensile strength R_m	580 N/mm^2	510 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	120 J	
Hardness	200 Brinell	

Welding data

	Diameter mm	Current A	Voltage V
Short arc	1.00	110 – 140	20 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 260	27 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 80 – 120 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Approvals

- DB
- SK
- TÜV
- UDT

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to type 308L. When surfacing on mild steel a corrosion resistance equivalent to ASTM 304 is obtained at the first bead.

P5

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA P5 is primarily used when surfacing unalloyed or low-alloy steels and when joining molybdenum-alloyed stainless and carbon steels.

Standard designations

EN 12072	23 12 2 L
AWS A5.9	(ER309LMo)*

* Cr lower and Ni higher than standard.

Characteristics and welding directions

AVESTA P5 is a molybdenum-alloyed wire of the 309MoL type, which is primarily designed for surfacing low-alloy steels and for dissimilar welding between stainless steels and low-alloy steels, ensuring a high resistance to cracking. When used for surfacing, the composition is more or less equal to that of ASTM 316 from the first run.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	0.80	60 – 120	18 – 22
	1.00	110 – 140	20 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 260	26 – 30
	1.60	250 – 320	29 – 32
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 100 – 150 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.35	1.5	21.5	15.0	2.7

Ferrite	9 FN	DeLong
	8 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	390 N/mm^2	350 N/mm^2
Tensile strength R_m	610 N/mm^2	550 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	75 J	
–40°C	60 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to type 316L. The corrosion resistance obtained on the first layer when surfacing corresponds to that of ASTM 316.

Approvals

- DB
- DNV
- SK
- TÜV

P7

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA P7 is specially designed for difficult-to-weld steels such as Mn-steels, tool steels and high temperature grades.					

Standard designations

EN 12072 29 9
AWS A5.9 ER312

Characteristics and welding directions

AVESTA P7 is a high-alloy consumable designed for welding C/Mn-steels, tool steels, spring steels, high temperature steels and other difficult-to-weld steels. P7 is also suitable for dissimilar welds between stainless and mild steel connections.

AVESTA P7 provides a weldment with high tensile strength and wear resistance as well as an excellent resistance to cracking.

Pre-heating is normally unnecessary, but when working with constricted designs and materials susceptible to hardening, some pre-heating may be required.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	170 – 230	26 – 28
	1.20	200 – 260	27 – 29
Pulsed arc	1.20	I_{peak} = 350 – 380 A I_{bkg} = 50 – 120 A Freq = 70 – 150 Hz	

Shielding gas

Ar + 2% O_2 or Ar + 2 – 3% CO_2 or Ar + 30% He + 2.5% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.11	0.45	1.9	30.0	9.5

Ferrite 60 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	560 N/mm^2	450 N/mm^2
Tensile strength R_m	750 N/mm^2	650 N/mm^2
Elongation A_5	25 %	15 %
Impact strength KV		
+20°C	40 J	
Hardness	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. Alloys of this type are susceptible to precipitation of the secondary phase in the temperature range 550 – 950°C.

Structure: Austenite with 40 – 60% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: AVESTA P7 offers very good corrosion resistance in wet sulphuric environments, such as in sulphate digesters used by the pulp and paper industry.

Approvals

- SK
- UDT

P10

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA P10 is an all-round wire suitable for many difficult-to-weld combinations.

Standard designations

EN 18274	Ni Cr 20 Mn 3 Nb
AWS A5.14	ERNiCr-3

Characteristics and welding directions

AVESTA P10 is a nickel base alloy designed for dissimilar welding of stainless steels, nickel base alloys type Inconel 600 and low-alloy steels as well as some copper alloys. P10 can also be used for welding many high temperature steels and nickel base alloys. The austenitic structure is very stable and the risk of hot or solidification cracking is relatively low.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	180 – 220	24 – 28
	1.20	200 – 240	25 – 29
Pulsed arc	1.20	I_{peak} = 450 – 550 A	
		I_{bkg} = 150 – 200 A	
		Freq = 120 – 150 Hz	

Shielding gas

Welding is preferably done using pulsed arc and with a shielding gas of pure argon or a three-component mixture with Ar + 30% He + 2.5% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb	Fe
0.03	0.10	2.9	20.0	73.0	2.5	<2.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.14
Yield strength $R_{p0,2}$	410 N/mm^2	–
Tensile strength R_m	660 N/mm^2	550 N/mm^2
Elongation A_5	33 %	–
Impact strength KV		
+20°C	–	
Hardness	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: High resistance to stress corrosion cracking but also excellent resistance to intercrystalline corrosion due to the low carbon content and the absence of secondary phases.

Approvals

–

309-Si

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA 309-Si is primarily used for welding high temperature steels such as ASTM 309S, but it may also be used for dissimilar welding between stainless and low-alloy or mild steels.

Standard designations

EN 12072	22 12 H
AWS A5.9	ER309Si

Characteristics and welding directions

AVESTA 309-Si is a high-alloy 23 Cr 13 Ni wire primarily intended for welding high temperature steels such as ASTM 309S but can also be used for dissimilar welding between mild steel and stainless steel, providing a ductile and crack resistant weldment.

Welding data

	Diameter mm	Current A	Voltage V
Short arc	1.00	110 – 140	20 – 22
	1.20	130 – 160	20 – 22
Spray arc	1.00	160 – 220	25 – 29
	1.20	200 – 260	27 – 30
Pulsed arc	1.20	I_{peak} = 350 – 450 A I_{bkg} = 50 – 150 A Freq = 100 – 150 Hz	

Shielding gas

Ar + 2% O_2 or 2 – 3% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.09	0.90	1.8	23.0	13.0

Ferrite	9 FN	DeLong
	4 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	430 N/mm^2	350 N/mm^2
Tensile strength R_m	640 N/mm^2	550 N/mm^2
Elongation A_5	34 %	25 %
Impact strength KV		
+20°C	90 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Primarily designed for high temperature applications with service temperatures up to 1000°C. The resistance to intercrystalline corrosion is somewhat limited due to the high carbon content.

Approvals

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310

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4845	1.4845	310S	310S16	Z8 CN 25-20	2361

Standard designations

EN 12072	25 20
AWS A5.9	ER310

Characteristics and welding directions

AVESTA 310 is designed for welding high temperature steels such as ASTM 310S. The consumable can also be used for welding some ferritic chromium steels, 14%-Mn steels and stainless to mild steel connections.

AVESTA 310 gives a fully austenitic type 26 Cr 21 Ni weld metal and is therefore somewhat more sensitive to hot cracking than 316 type steels. Welding should therefore be performed minimising the heat input, interpass temperature and dilution with parent metal.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	180 – 240	25 – 29
	1.20	190 – 250	26 – 30
Pulsed arc	1.20	I_{peak} = 350 – 380 A I_{bkg} = 100 – 150 A Freq = 100 – 120 Hz	

Shielding gas

Pure argon or Ar + 30% He.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.12	0.35	1.6	25.5	21.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values **EN 12072**
Yield strength $R_{p0,2}$	360 N/mm^2	350 N/mm^2
Tensile strength R_m	570 N/mm^2	550 N/mm^2
Elongation A_5	35 %	20 %
Impact strength KV		
+20°C	120 J	
Hardness	210 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1150°C (air).

Corrosion resistance: Initially intended for constructions running at high temperatures. Wet corrosion properties are moderate.

Approvals

–

253 MA

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
153 MA™	1.4818	S30415	–	–	2372
253 MA®	1.4835	S30815	–	–	2368

Standard designations

–

Characteristics and welding directions

AVESTA 253 MA is designed for welding the high temperature steel Outokumpu 253 MA, used for example in furnaces, combustion chambers, burners etc. Both the steel and the consumable provide excellent properties at temperatures 850 – 1100°C.

MIG welding of 253 MA is best performed using spray arc or pulsed arc. 253 MA has a tendency to give a thick oxide layer during welding and hot rolling. Black plates and previous weld beads should be carefully brushed or ground prior to welding.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	190 – 240	25 – 29
	1.20	210 – 250	26 – 30
Pulsed arc	1.20	I_{peak} = 340 – 380 A I_{bkg} = 100 – 160 A Freq = 100 – 120 Hz	

Shielding gas

Ar + 30% He + 2% CO_2.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	N	Others
0.07	1.60	0.6	21.0	10.0	0.15	REM

Ferrite	9 FN	DeLong
	2 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	440 N/mm^2	–
Tensile strength R_m	680 N/mm^2	–
Elongation A_5	38 %	–
Impact strength KV		
+20°C	130 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none.

Structure: Austenite with 3 – 10% ferrite.

Scaling temperature: Approx. 1150°C (air).

Corrosion resistance: Excellent resistance to high temperature corrosion. Not intended for applications exposed to wet corrosion.

Approvals

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353 MA

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
353 MA®	1.4854	S35315	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA 353 MA is designed for welding Outokumpu 353 MA, offering excellent properties at temperatures above 1000°C. 353 MA has a tendency to give a thick oxide layer during welding and hot rolling. Black plates and previous weld beads should be carefully brushed or ground prior to welding. The weld metal is, due to the fully austenitic structure, somewhat more sensitive to hot cracking than, for example, 253 MA.

Welding data

	Diameter mm	Current A	Voltage V
Spray arc	1.00	190 – 240	25 – 29
	1.20	210 – 250	26 – 30
Pulsed arc	1.20	I_{peak} = 340 – 380 A I_{bkg} = 100 – 160 A Freq = 100 – 120 Hz	

Shielding gas

Welding is best performed using pulsed arc with a pure argon or Ar + 30% He + 2% CO_2 shielding gas.
Gas flow rate 12 – 16 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	N	Others
0.05	0.85	1.6	27.5	35.0	0.15	REM

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	320 N/mm²	–
Tensile strength R_m	590 N/mm²	–
Elongation A_5	43 %	–
Impact strength KV		
+20°C	160 J	
Hardness	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1175°C (air).

Corrosion resistance: Superior properties for constructions running at service temperatures above 1000°C. Not intended for applications exposed to wet corrosion.

Approvals

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248 SV

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
248 SV	1.4418	–	–	Z6 CND 16-05-01	2387

Standard designations

–

Characteristics and welding directions

AVESTA 248 SV is designed for welding Outokumpu 248 SV and steel castings with corresponding composition. Applications include propellers, pumps, valves and shafts.

AVESTA 248 SV has high safety against cracking, superior to many other martensitic consumables. The weld metal properties, on the whole, are similar to those of the steel.

Preheating is normally unnecessary. In cases with heavy wall thicknesses or where considerable shrinkage stresses are to be expected, preheating up to 75 – 150°C is recommended.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.35	1.3	16.0	5.5	1.0

Ferrite 10%

Mechanical properties	Typical values (IIW)*	Min. values EN 12072
Yield strength $R_{p0,2}$	460 N/mm^2	–
Tensile strength R_m	840 N/mm^2	–
Elongation A_5	23 %	–
Impact strength KV		
+20°C	75 J	
Hardness	260 Brinell	

* Annealed at 590°C for 4 hours.

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: To stabilise the structure and to minimise the content of brittle martensite an annealing at 590°C for 4 hours followed by air cooling is recommended.

Structure: Austenite balanced with ferrite and martensite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The resistance to general and pitting corrosion is in level with that of ASTM 304.

Approvals

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308L-Si/MVR-Si

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12072	19 9 L Si
AWS A5.9	ER308LSi

Characteristics and welding directions

AVESTA 308L-Si/MVR-Si is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The wire is also suitable for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347-Si/ MVNb-Si is required.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.85	1.8	20.0	10.5

Ferrite	11 FN	DeLong
	9 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	470 N/mm^2	320 N/mm^2
Tensile strength R_m	640 N/mm^2	510 N/mm^2
Elongation A_5	34 %	30 %
Impact strength KV		
+20°C	140 J	
–196°C	80 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as in oxidising and cold dilute reducing acids.

Approvals

- DB
- DNV
- SK
- TÜV
- UDT

308L/MVR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12072 19 9 L
AWS A5.9 ER308L

Characteristics and welding directions

AVESTA 308L/MVR is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The wire is also suitable for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347-Si/MVNb-Si is required.

AVESTA 308L/MVR is also available with high silicon content (308L-Si/MVR-Si). The higher silicon content will improve fluidity and minimise the spatter, giving a nicer weld bead appearance.

Welding data

Diameter, mm	Current, A	Voltage, V
1.60	80 – 120	10 – 13
3.20	160 – 200	17 – 20

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.40	1.7	20.0	10.0

Ferrite	8 FN	DeLong
	10 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	400 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	35 %	30 %
Impact strength KV		
+20°C	130 J	
–40°C	120 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as in oxidising and cold dilute reducing acids.

Approvals

- DNV
- TÜV
- SK
- UDT

308H

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072	19 9 H
AWS A5.9	ER308H

Characteristics and welding directions

AVESTA 308H is designed for welding austenitic stainless steel type 18 Cr 10 Ni or similar. The consumable has an enhanced carbon content when compared to 308L. This provides improved creep resistance properties, which is advantageous at temperatures above 400°C. 308H type consumables are normally used at temperatures up to 600°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347/MVNb is required.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.05	0.40	1.8	20.0	9.0

Ferrite	10 FN	DeLong
	10 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	450 N/mm^2	350 N/mm^2
Tensile strength R_m	640 N/mm^2	550 N/mm^2
Elongation A_5	38 %	30 %
Impact strength KV		
+20°C	150 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. good resistance to general corrosion. The enhanced carbon content, compared to 308L, makes it slightly more sensitive to intercrystalline corrosion.

Approvals

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347-Si/MVNb-Si

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072 19 9 Nb Si
AWS A5.4 ER347Si

Characteristics and welding directions

AVESTA 347-Si/MVNb-Si is used for welding titanium and niobium stabilised steels of type 19 Cr 10 Ni Ti or similar, providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 347-Si/MVNb-Si is therefore primarily used for applications where service temperatures exceed 400°C.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb
0.05	0.85	1.2	19.5	10.0	>12xC

Ferrite	10 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	520 N/mm^2	350 N/mm^2
Tensile strength R_m	680 N/mm^2	550 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	110 J	
–40°C	100 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. 347 type wire can be used for cladding, which normally requires stress relieving at around 590°C. Such a heat treatment will reduce the ductility of the weld at room temperature. Always consult expertise before performing post-weld heat treatment.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: 347-Si/MVNb-Si is primarily intended for high temperature service or applications that should be heat treated. However, the corrosion resistance corresponds to that of 308H, i.e. good resistance to general corrosion.

Approvals

- DB
- SK
- TÜV
- UDT

347/MVNb

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072 19 9 Nb
AWS A5.4 ER347

Characteristics and welding directions

AVESTA 347/MVNb is used for welding titanium and niobium stabilised steels of type 19 Cr 10 Ni Ti or similar, providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 347/MVNb is therefore primarily used for applications where service temperatures exceed 400°C.

Avesta Welding also supplies a 347 type wire with high silicon content (0.85 %) named 347-Si/MVNb-Si. The higher silicon content will improve the fluidity of the melt pool slightly.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	130 – 160	16 – 18

Shielding gas

Ar (99.95%). Ar with an addition of about 30% helium (He) or 1 – 5% hydrogen (H_2) can also be used.
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb
0.04	0.40	1.3	19.5	9.5	>12xC

Ferrite	6 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	520 N/mm^2	350 N/mm^2
Tensile strength R_m	680 N/mm^2	550 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	110 J	
–40°C	100 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C). 347/MVNb can be used for cladding, which normally requires stress relieving at around 590°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: 347/MVNb is primarily intended for high temperature service or applications that should be heat treated. However, the corrosion resistance corresponds to 308H, i.e. good resistance to general corrosion.

Approvals

• SK • TÜV • UDT

316L-Si/SKR-Si

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072	19 12 3 L Si
AWS A5.9	ER316LSi

Characteristics and welding directions

AVESTA 316L-Si/SKR-Si is designed for welding austenitic stainless steel type 17 Cr 12 Ni 2.5 Mo or similar. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 316Ti in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 318-Si/SKNb-Si is required.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.85	1.7	18.5	12.0	2.6

Ferrite	9 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	480 N/mm^2	320 N/mm^2
Tensile strength R_m	640 N/mm^2	510 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	140 J	
–196°C	80 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals

- DB
- DNV
- SK
- TÜV
- UDT

316L/SKR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072	19 12 3 L
AWS A5.9	ER316L

Characteristics and welding directions

AVESTA 316L/SKR is designed for welding austenitic stainless steel type 17 Cr 12 Ni 2.5 Mo or similar. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 316Ti in cases where the construction is used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 318-Si/SKNb-Si is required.

AVESTA 316L/SKR is also available with high silicon content (316L-Si/SKR-Si). The higher silicon content will improve fluidity and minimse the spatter, giving a nicer weld bead appearance.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.40	1.7	18.5	12.0	2.6

Ferrite	8 FN	DeLong
	8 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	460 N/mm^2	320 N/mm^2
Tensile strength R_m	610 N/mm^2	510 N/mm^2
Elongation A_5	33 %	25 %
Impact strength KV		
+20°C	140 J	
–40°C	130 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals

- DNV
- SK
- TÜV
- UDT

318-Si/SKNb-Si

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations
EN 12072 19 12 3 Nb Si

Characteristics and welding directions
AVESTA 318-Si/SKNb-Si is used for welding titanium and niobium stabilised steels of type 17 Cr 11 Ni 2.5 Ti or similar providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 318-Si/SKNb-Si shows better properties than 316L-Si/SKR-Si at elevated temperatures and is therefore recommended for applications where service temperatures exceed 400°C.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas
Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb
0.04	0.85	1.3	19.0	12.0	2.6	>12xC

Ferrite	10 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	520 N/mm^2	350 N/mm^2
Tensile strength R_m	690 N/mm^2	550 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	110 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The corrosion resistance corresponds to that of ASTM 316Ti, i.e. good resistance to general, pitting and intercrystalline corrosion.

Approvals
- DB
- TÜV
- SK
- UDT

318/SKNb

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072	19 12 3 Nb
AWS A5.9	ER318

Characteristics and welding directions

AVESTA 318/SKNb is used for welding titanium and niobium stabilised steels of type 17 Cr 11 Ni 2.5 Ti or similar, providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 318/SKNb shows better properties than 316L/SKR at elevated temperatures and is therefore recommended for applications where service temperatures exceed 400°C.

Avesta Welding also supplies a 318 type wire with high silicon content (0.85 %) named 318-Si/SKNb-Si. The higher silicon content will improve the fluidity of the melt pool slightly.

Welding data

Diameter, mm	Current, A	Voltage, V
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18

Shielding gas

Ar (99.95%). Ar with an addition of about 30% helium (He) or 1 – 5% hydrogen (H_2) can also be used.
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb
0.04	0.40	1.3	19.0	12.0	2.6	>12xC

Ferrite	8 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	520 N/mm^2	350 N/mm^2
Tensile strength R_m	690 N/mm^2	550 N/mm^2
Elongation A_5	31 %	25 %
Impact strength KV		
+20°C	110 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: The corrosion resistance corresponds to that of ASTM 316Ti, i.e. good resistance to general, pitting and intercrystalline corrosion.

Approvals

- SK
- TÜV
- UDT

317L/SNR

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-15-04	2367
4439	1.4439	317LMN	–	Z3 CND 18-14-05 Az	–

Standard designations

EN 12072	19 13 4 L
AWS A5.9	ER317L

Characteristics and welding directions

AVESTA 317L/SNR is designed for welding type 18 Cr 14 Ni 3 Mo austenitic stainless steels and similar. The enhanced content of chromium, nickel and molybdenum compared to 316L gives improved corrosion properties in acid chloride containing environments.

Welding data

Diameter, mm	Current, A	Voltage, V
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.40	1.7	19.0	13.5	3.5

Ferrite	9 FN	DeLong
	9 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	440 N/mm^2	350 N/mm^2
Tensile strength R_m	630 N/mm^2	550 N/mm^2
Elongation A_5	28 %	25 %
Impact strength KV		
+20°C	100 J	
Hardness	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Better resistance to general, pitting and intercrystalline corrosion in chloride containing environments than ASTM 316L. Intended for severe service conditions, i.e. in dilute hot acids.

Approvals

- SK
- UDT

2304

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2304®	1.4362	S32304	–	Z3 CN 23-04 Az	2327

Standard designations

–

Characteristics and welding directions

AVESTA 2304 is primarily designed for welding the duplex steel SAF 2304 and similar grades.

AVESTA 2304 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic stainless steels.

AVESTA 2304 has a low content of molybdenum, which makes it well suited for nitric acid environments.

Welding without filler metal (i.e. TIG-dressing) is not allowed since the ferrite content will increase drastically and both mechanical and corrosion properties will be negatively affected.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	130 – 180	16 – 19
3.20	160 – 220	17 – 20

Shielding gas

Ar (99.95%). Ar with an addition of up to 2% nitrogen (N_2) is advantageous and will have a positive effect on both mechanical and corrosion properties.
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.40	0.5	23.0	7.0	<0.5	0.14

Ferrite 40 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	460 N/mm^2	–
Tensile strength R_m	640 N/mm^2	–
Elongation A_5	25 %	–
Impact strength KV		
+20°C	160 J	
–20°C	120 J	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 35 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in nitric acid environments.

Approvals

- TÜV

2205

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 12072 22 9 3 L N
AWS A5.9 ER2209

Characteristics and welding directions

AVESTA 2205 is primarily designed for welding the duplex grade Outokumpu 2205 and similar grades but can also be used for welding SAF 2304 type of steels.

AVESTA 2205 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic stainless steels.

Welding without filler metal (i.e. TIG-dressing) is not allowed since the ferrite content will increase drastically and both mechanical and corrosion properties will be negatively affected.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%). Ar with an addition of up to 2% nitrogen (N_2) is advantageous and will have a positive effect on both mechanical and corrosion properties.
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.50	1.6	23.0	8.5	3.1	0.17

Ferrite 50 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	610 N/mm^2	450 N/mm^2
Tensile strength R_m	805 N/mm^2	550 N/mm^2
Elongation A_5	31 %	20 %
Impact strength KV		
+20°C	200 J	
–40°C	170 J	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

- DB
- DNV
- SK

2507/P100

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2507®	1.4410	S32750	–	Z3 CND 25-06 Az	2328

Standard designations
EN 12072 25 9 4 L N

Characteristics and welding directions
AVESTA 2507/P100 is intended for welding super duplex alloys such as SAF 2507, ASTM S32760, S32550 and S31260. It can also be used for welding duplex type 2205 if extra high corrosion resistance is required, e.g. in root runs in tubes.

AVESTA 2507/P100 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic steels.

Welding without filler metal (i.e. TIG-dressing) is not allowed since the ferrite content will increase drastically and both mechanical and corrosion properties will be negatively affected.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18

Shielding gas
Ar (99.95%). Ar with an addition of up to 2% nitrogen (N_2) is advantageous and will have a positive effect on both mechanical and corrosion properties.
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.35	0.4	25.0	9.5	4.0	0.25

Ferrite 50 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	660 N/mm^2	550 N/mm^2
Tensile strength R_m	860 N/mm^2	620 N/mm^2
Elongation A_5	28 %	18 %
Impact strength KV		
+20°C	190 J	
–40°C	170 J	

Interpass temperature: Max. 100°C.

Heat input: 0.5 – 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to pitting and stress corrosion cracking in chloride containing environments. Pitting resistance is in accordance with ASTM G48-A, better than 40°C.

Approvals
- TÜV

904L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
904L	1.4539	904L	904S13	Z2 NCDU 25-20	2562

Also for welding similar steels of the 20-25 CrNiMoCu-type.

Standard designations

EN 12072	20 25 5 Cu L
AWS A5.9	ER385

Characteristics and welding directions

AVESTA 904L is intended for welding Outokumpu 904L and similar but can also be used for constructions in type ASTM 316 where a ferrite-free weld metal is required, such as cryogenic or non-magnetic applications. The impact strength at low temperature is excellent.

A fully austenitic structure is more prone to hot or solidification cracking than type ASTM 316 welds, so welding should be performed minimising the heat input, interpass temperature and penetration with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Cu
0.01	0.35	1.7	20.0	25.5	4.5	1.5

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	410 N/mm^2	320 N/mm^2
Tensile strength R_m	610 N/mm^2	510 N/mm^2
Elongation A_5	35 %	25 %
Impact strength KV		
+20°C	180 J	
–196°C	130 J	
Hardness	170 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1070 – 1100°C).

Structure: Fully austenitic with extra low content of impurities.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Very good in non-oxidising environments such as sulphuric or phosphoric acids. Very good resistance to pitting and crevice corrosion in chloride containing environments. Excellent resistance to general corrosion and stress corrosion cracking.

Approvals

- DB
- TÜV
- SK
- UDT

P12

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Also for welding stainless steels and nickel base alloys to low-alloy and mild steel.

Standard designations

EN 18274 Ni Cr 22 Mo 9 Nb
AWS A5.14 ERNiCrMo-3

Characteristics and welding directions

AVESTA P12 is a nickel base alloy designed for welding 6Mo-steels such as Outokumpu 254 SMO. The wire is also suitable for welding nickel base alloys such as Inconel 625 and Incoloy 825 and for dissimilar welds between stainless and nickel base alloys to mild steel.

Welding of fully austenitic steels and nickel base alloys should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	120 – 150	16 – 18
3.20	140 – 180	17 – 19

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	<0.1	<0.1	22.0	65.0	9.0	3.6	<1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.14
Yield strength $R_{p0,2}$	490 N/mm^2	420 N/mm^2
Tensile strength R_m	740 N/mm^2	700 N/mm^2
Elongation A_5	37 %	25 %
Impact strength KV		
+20°C	130 J	
–40°C	120 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments.

Approvals

- TÜV

P12-0^{Nb}

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA P12-0^{Nb} is a nickel base alloy designed for welding 6Mo-steels such as Outokumpu 254 SMO.

AVESTA P12-0^{Nb} produces a fully austenitic weld metal that due to the absence of niobium is almost free from secondary phases. This gives extremely good ductility with superior impact strength even at low temperatures. The tensile strength is somewhat lower than standard P12.

AVESTA P12-0^{Nb} is specially designed to meet the requirements of NORSOK M-601, 6.3.3.

Welding of fully austenitic steels and nickel base alloys should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.1	22.0	65.0	9.0	<0.1	<1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.14
Yield strength $R_{p0,2}$	440 N/mm^2	–
Tensile strength R_m	670 N/mm^2	–
Elongation A_5	41 %	–
Impact strength KV		
+20°C	220 J	
–70°C	210 J	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic with extra low content of secondary phases.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments which makes the consumable perfect for sea water and offshore applications etc.

Approvals

–

P16

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
654 SMO®	1.4652	S32654	–	–	–
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Also for welding nickel base alloys to stainless steel and mild steel.

Standard designations

EN 18274 Ni Cr 25 Mo 16

Characteristics and welding directions

AVESTA P16 is a nickel base alloy designed for welding 7Mo-steels such as Outokumpu 654 SMO and similar, offering superior resistance to pitting and crevice corrosion. The consumable is also suitable for the welding of nickel base alloys such as Inconel 625 and Incoloy 825 but also for dissimilar welds between stainless and nickel base alloys to mild steel.

The chemical composition corresponds to that of Alloy 59 (ERNiCrMo-13).

Welding of fully austenitic steels and nickel base alloys should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.2	25.0	60.0	15.0	<0.1	<1.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 18274
Yield strength $R_{p0,2}$	510 N/mm^2	–
Tensile strength R_m	760 N/mm^2	–
Elongation A_5	43 %	–
Impact strength KV +20°C	135 J	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1150 – 1200°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Superior resistance to pitting and crevice corrosion (CPT >80°C, ASTM G48-A).

Approvals

–

P54

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
254 SMO®	1.4547	S31254	–	–	2378
654 SMO®	1.4652	S32654	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA P54 is an iron-based fully austenitic consumable designed for welding Outokumpu 254 SMO and 654 SMO or other similar 6Mo and 7Mo-steels.

AVESTA P54 is specially developed for applications exposed to highly oxidising chloride containing environments, such as D-stage bleachers in pulp mills where a nickel base filler will suffer from trans-passive corrosion. The consumable also offers very high resistance to localised corrosion.

Welding of fully austenitic steels and nickel base alloys should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 12
2.40	130 – 160	16 – 18

Shielding gas

Ar (99.95%) or Ar with an addition of 2% nitrogen (N_2).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N	Cu
0.02	0.20	5.1	26.0	22.0	5.5	0.35	0.9

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	450 N/mm²	–
Tensile strength R_m	750 N/mm²	–
Elongation A_5	30 %	–
Impact strength KV +20°C	90 J	
Hardness	220 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: Superior resistance in near neutral chloride dioxide containing environments, e.g. D-stage bleachers.

Approvals

–

307-Si

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 307-Si is primarily used for dissimilar welding between stainless and mild steel or low-alloy steels.					

Standard designations
EN 12072 18 8 Mn Si

Characteristics and welding directions
AVESTA 307-Si is a manganese-alloyed, fully austenitic consumable for welding stainless steel to mild steel, low-alloy or Mn-steels. It is also suitable for the welding of some 14% Mn-steels and other difficult-to-weld steels.

The high manganese content makes the weld metal, even though it is purely austenitic, very resistant to hot cracking, with a good ductility.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas
Ar (99.95%)..
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.09	0.80	7.0	19.0	8.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	470 N/mm^2	350 N/mm^2
Tensile strength R_m	700 N/mm^2	500 N/mm^2
Elongation A_5	40 %	25 %
Hardness	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, stress-relieving may be advisable. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Fully austenitic.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Primarily intended for stainless to mild steel connections, however, the corrosion resistance corresponds to that of ASTM 304.

Approvals
- DB
- DNV
- TÜV

309L-Si

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA 309L-Si is primarily used when surfacing unalloyed or low-alloy steels and when joining non-molybdenum-alloyed stainless and carbon steels.

Standard designations

EN 12072	23 12 L Si
AWS A5.9	ER309LSi

Characteristics and welding directions

AVESTA 309L-Si is a high-alloy 23 Cr 13 Ni wire primarily intended for surfacing of low-alloy steels and dissimilar welding between mild steels and stainless steels, offering a ductile and crack resistant weldment.

The chemical composition, when surfacing, is equivalent to that of ASTM 304 from the first run. One or two layers of 309L are usually combined with a final layer of 308L, 316L or 347.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.80	1.8	23.5	13.5

Ferrite 13 FN DeLong; 9 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	470 N/mm^2	320 N/mm^2
Tensile strength R_m	650 N/mm^2	510 N/mm^2
Elongation A_5	28 %	25 %
Impact strength KV		
+20°C	100 J	
Hardness	200 Brinell	

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2).
Gas flow rate 4 – 8 l/min.

Approvals

- DB
- TÜV

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to 308L.
The corrosion resistance obtained on the first layer when surfacing corresponds to that of ASTM 304.

309L

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 309L is primarily used when surfacing unalloyed or low-alloy steels and when joining non-molybdenum-alloyed stainless and carbon steels.					

Standard designations

EN 12072	23 12 L
AWS A5.9	ER309L

Characteristics and welding directions

AVESTA 309L is a high-alloy 23 Cr 13 Ni wire primarily intended for surfacing low-alloy steels and for dissimilar welding between mild steels and stainless steels, offering a ductile and crack resistant weldment.

The chemical composition, when surfacing, is equivalent to that of ASTM 304 from the first run. One or two layers of 309L are usually combined with a final layer of 308L, 316L or 347.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.40	1.8	23.5	14.0

Ferrite 11 FN DeLong; 10 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	460 N/mm^2	320 N/mm^2
Tensile strength R_m	590 N/mm^2	510 N/mm^2
Elongation A_5	32 %	25 %
Impact strength KV		
+20°C	170 J	
Hardness	200 Brinell	

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2).
Gas flow rate 4 – 8 l/min.

Approvals

- DB
- SK
- TÜV
- UDT

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to 308L.
The corrosion resistance obtained on the first layer when surfacing corresponds to that of ASTM 304.

P5

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA P5 is primarily used when surfacing unalloyed or low-alloy steels and when joining molybdenum-alloyed stainless and carbon steels.					

Standard designations

EN 12072 23 12 2 L
AWS A5.9 (ER309LMo)*

* Cr lower and Ni higher than standard.

Characteristics and welding directions

AVESTA P5 is a molybdenum-alloyed wire of the 309MoL type, which is primarily designed for surfacing low-alloy steels and in dissimilar welding between stainless steels and low-alloy steels ensuring a high resistance against cracking. When used for surfacing, the composition is more or less equal to that of ASTM 316 from the first run.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of 20 – 30% helium (He) or 1 – 5% hydrogen (H_2).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.35	1.5	21.5	15.0	2.7

Ferrite	9 FN	DeLong
	8 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	470 N/mm^2	350 N/mm^2
Tensile strength R_m	640 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	140 J	
–40°C	90 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to 316L.
The corrosion resistance obtained on the first layer when surfacing corresponds to that of ASTM 316.

Approvals

• DB • DNV • SK • TÜV

P7

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA P7 is an all-round wire for difficult-to-weld steels such as Mn-steels, tool steels and high temperature grades.					

Standard designations

EN 12072	29 9
AWS A5.9	ER312

Characteristics and welding directions

AVESTA P7 is a high-alloy consumable designed for welding C/Mn-steels, tool steels, spring steels, high temperature steels and other difficult-to-weld steels. P7 is also suitable for dissimilar welds between stainless and mild steel connections.

AVESTA P7 provides a weldment with high tensile strength and wear resistance and with excellent resistance to cracking.

Pre-heating is normally unnecessary, but when working with constricted designs and materials susceptible to hardening, some pre-heating may be required.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.11	0.45	1.9	30.0	9.5

Ferrite 60 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	650 N/mm^2	450 N/mm^2
Tensile strength R_m	810 N/mm^2	650 N/mm^2
Elongation A_5	26 %	15 %
Impact strength KV		
+20°C	40 J	
Hardness	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. Alloys of this type are susceptible to precipitation of the secondary phase in the temperature range 550 – 950°C.

Structure: Austenite with 40 – 60% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good corrosion resistance in wet sulphuric environments, e.g. in sulphate digesters used by the pulp and paper industry.

Approvals

- SK
- UDT

P10

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA P10 is an all-round wire suitable for many difficult-to-weld combinations.					

Standard designations

EN 18274 Ni Cr 20 Mn 3 Nb
AWS A5.14 ERNiCr-3

Characteristics and welding directions

AVESTA P10 is a nickel base alloy designed for dissimilar welding of stainless steels, nickel base alloys type Inconel 600, low-alloy steels, as well as some copper alloys. P10 can also be used for welding many high temperature steels and nickel base alloys. The austenitic structure is very stable and the risk of hot or solidification cracking is relatively low.

Welding data

Diameter, mm	Current, A	Voltage, V
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb	Fe
0.03	0.10	2.9	20.0	73.0	2.5	<2.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values AWS A5.14
Yield strength $R_{p0,2}$	410 N/mm^2	–
Tensile strength R_m	660 N/mm^2	550 N/mm^2
Elongation A_5	33 %	–

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

Corrosion resistance: High resistance to stress corrosion cracking but also excellent resistance to intercrystalline corrosion due to the low carbon content and the absence of secondary phases.

Approvals

–

309-Si

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 309-Si is primarily used for welding high temperature steels such as ASTM 309S, but it may also be used for dissimilar welding between stainless and low-alloy or mild steels.					

Standard designations

EN 12072	22 12 H
AWS A5.9	ER309Si

Characteristics and welding directions

AVESTA 309-Si is a high-alloy 23 Cr 13 Ni wire primarily intended for welding high temperature steels such as ASTM 309S but can also be used for dissimilar welding between mild steel and stainless steel, providing a ductile and crack resistant weldment.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas

Ar (99.95%) or Ar with an addition of about 30% helium (He) or 1 – 5% hydrogen (H_2). Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.09	0.90	1.8	23.0	13.0

Ferrite	9 FN	DeLong
	4 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	500 N/mm^2	350 N/mm^2
Tensile strength R_m	680 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Primarily designed for high temperature applications with service temperatures up to 1000°C. The resistance to intercrystalline corrosion is somewhat limited due to the high carbon content.

Approvals

–

310

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4845	1.4845	310S	310S16	Z8 CN 25-20	2361

Standard designations

EN 12072 25 20
AWS A5.9 ER310

Characteristics and welding directions

AVESTA 310 is designed for welding high temperature steels such as ASTM 310S and similar. It can also be used for welding some ferritic chromium steels and 14%-Mn steels.

Welding fully austenitic steels and nickel base alloys should be performed taking great care to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	70 – 100	10 – 12
2.40	120 – 150	16 – 18

Shielding gas

Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.12	0.35	1.6	25.5	21.0

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	420 N/mm^2	350 N/mm^2
Tensile strength R_m	610 N/mm^2	550 N/mm^2
Elongation A_5	33 %	20 %

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1150°C (air).

Corrosion resistance: Initially intended for constructions running at high temperatures. Wet corrosion properties are moderate.

Approvals

–

253 MA

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
153 MA™	1.4818	S30415	–	–	2372
253 MA®	1.4835	S30815	–	–	2368

Standard designations
–

Characteristics and welding directions
AVESTA 253 MA is designed for welding the high temperature steel Outokumpu 253 MA, used for example in furnaces, combustion chambers, burners etc. Both the steel and the consumable provide excellent properties at temperatures 850 – 1100°C.

The composition of the consumable is balanced to ensure crack resistant weld metal.

AVESTA 253 MA has a tendency to give a thick oxide layer during welding and hot rolling. Black plates and previous weld beads should be carefully brushed or ground prior to welding.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas
Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	N	Others
0.07	1.60	0.6	21.0	10.0	0.15	REM

Ferrite	9 FN	DeLong
	2 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	520 N/mm^2	–
Tensile strength R_m	720 N/mm^2	–
Elongation A_5	32 %	–
Impact strength KV		
+20°C	140 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none.

Structure: Austenite with 3 – 10% ferrite.

Scaling temperature: Approx. 1150°C (air).

Corrosion resistance: Excellent resistance to high temperature corrosion. Not intended for applications exposed to wet corrosion.

Approvals
–

353 MA

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
353 MA®	1.4854	S35315	–	–	–

Standard designations
–

Characteristics and welding directions
AVESTA 353 MA is designed for welding Outokumpu 353 MA, offering excellent properties at temperatures above 1000°C.

353 MA has a tendency to give a thick oxide layer during welding and hot rolling. Black plates and previous weld beads should be carefully brushed or ground prior to welding.

The weld metal is, due to the fully austenitic structure, somewhat more sensitive to hot cracking than, for example, 253 MA.

Welding data

Diameter, mm	Current, A	Voltage, V
1.20	60 – 80	9 – 11
1.60	80 – 110	10 – 12
2.40	130 – 160	16 – 18
3.20	160 – 200	17 – 19

Shielding gas
Ar (99.95%).
Gas flow rate 4 – 8 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	N	Others
0.05	0.85	1.6	27.5	35.0	0.15	REM

Ferrite 0 FN

Mechanical properties	Typical values (IIW)	Min. values EN 12072
Yield strength $R_{p0,2}$	420 N/mm^2	–
Tensile strength R_m	640 N/mm^2	–
Elongation A_5	37 %	–
Hardness	200 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1175°C (air).

Corrosion resistance: Superior properties for constructions running at service temperatures above 1000°C. Not intended for applications exposed to wet corrosion.

Approvals
–

248 SV

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
248 SV	1.4418	–	–	Z6 CND 16-05-01	2387

Standard designations
–

Characteristics and welding directions
AVESTA 248 SV is designed for welding Outokumpu 248 SV and steel castings with the corresponding composition. Applications include propellers, pumps, valves and shafts.

AVESTA 248 SV offers high safety against cracking, superior to many other martensitic consumables. The weld metal properties on the whole are similar to those of the steel.

Preheating is normally unnecessary. In case of heavy wall thickness or when considerable shrinkage stresses are to be expected, preheating up to 75 – 150°C is recommended.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 and 807.

Corrosion resistance: The resistance to general and pitting corrosion corresponds to that of ASTM 304.

Approvals
–

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.35	1.3	16.0	5.5	1.0

Ferrite 10%

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN
801	0.02	0.9	0.7	16.0	5.0	1.0	–
805	0.02	0.6	0.8	16.5	5.0	1.0	–
807	0.02	0.6	0.8	15.5	5.0	1.0	–

Mechanical properties
Typical values* (IIW) in combination with flux

	801
Yield strength $R_{p0,2}$	520 N/mm^2
Tensile strength R_m	880 N/mm^2
Elongation A_5	16 %
Impact strength KV	
+20°C	30 J

* Annealed at 590°C for 4h.

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: To stabilise the structure and to minimise the content of brittle martensite an annealing at 590°C for 4 hours followed by air cooling is recommended.

Structure: Austenite balanced with ferrite and martensite.

Scaling temperature: Approx. 850°C (air).

308L/MVR

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12072	19 9 L
AWS A5.9	ER308L

Characteristics and welding directions

AVESTA 308L/MVR is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The wire can also be used for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 in cases where the construction will be used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 347/MVNb is required.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 and 807.

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as oxidising and cold dilute reducing acids.

Approvals

In combination with flux

801 • DNV • SK • TÜV • UDT

805 • TÜV

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.40	1.7	20.0	10.0

Ferrite 8 FN DeLong
10 FN WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN[1)]
801	0.02	0.9	1.0	20.0	9.5	13
805	0.02	0.6	1.2	20.5	9.5	14
807	0.02	0.6	1.2	19.5	10.0	8

[1)] According to DeLong.

Mechanical properties

Typical values (IIW) in combination with flux	**801**	**805**
Yield strength $R_{p0,2}$	440 N/mm^2	410 N/mm^2
Tensile strength R_m	590 N/mm^2	580 N/mm^2
Elongation A_5	37 %	36 %
Impact strength KV		
+20°C	65 J	85 J
–196°C	30 J	35 J
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

308H

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072	19 9 H
AWS A5.9	ER308H

Characteristics and welding directions

AVESTA 308H is designed for welding austenitic stainless steel type 18 Cr 10 Ni or similar. The consumable has an enhanced carbon content compared to 308L. This provides improved creep resistance properties, which is advantageous at temperatures above 400°C. 308H type consumables are normally used at temperatures up to 600°C. Above that a niobium stabilised consumable such as AVESTA 347/MVNb is required.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: Corresponding to ASTM 304 i.e. good resistance to general corrosion. The enhanced carbon content, compared to 308L, makes it slightly more sensitive to intercrystalline corrosion.

Approvals

–

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.05	0.40	1.8	20.0	9.0

Ferrite	10 FN	DeLong
	10 FN	WRC-92

Chemical composition, all weld metal (typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN[1)]
801	0.05	0.9	1.1	20.0	9.0	13
805	0.05	0.6	1.3	20.5	9.0	13
807	0.05	0.6	1.3	19.5	9.5	10

1) According to DeLong.

Mechanical properties

Typical values (IIW) in combination with flux	801
Yield strength $R_{p0,2}$	420 N/mm^2
Tensile strength R_m	610 N/mm^2
Elongation A_5	36 %
Impact strength KV	
+20°C	60 J
–40°C	50 J

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 15% ferrite.

Scaling temperature: Approx. 850°C (air).

347/MVNb

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12072 19 9 Nb
AWS A5.4 ER347

Characteristics and welding directions

AVESTA 347/MVNb is used for welding titanium and niobium stabilised steel type 19 Cr 10 Ni Ti or similar, providing improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 347/MVNb is therefore primarily used for applications where service temperatures exceed 400°C.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: 347/MVNb is primarily intended for high temperature service or applications that should be heat treated. However, the corrosion resistance corresponds to 308H, i.e. good resistance to general corrosion.

Approvals

In combination with flux

801 • SK • TÜV • UDT

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Nb
0.04	0.40	1.3	19.5	9.5	>12 x C

Ferrite	6 FN	DeLong
	7 FN	WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Nb	FN[1)]
801	0.04	0.9	0.5	19.5	9.5	0.7	11
805	0.04	0.6	0.8	20.0	9.5	0.7	12
807	0.04	0.6	0.8	19.0	10.0	0.7	6

1) According to DeLong.

Mechanical properties

Typical values (IIW) in combination with flux	801	805
Yield strength $R_{p0,2}$	450 N/mm^2	440 N/mm^2
Tensile strength R_m	640 N/mm^2	640 N/mm^2
Elongation A_5	34 %	35 %
Impact strength KV		
+20°C	60 J	70 J
Hardness	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C). The 347 type wire can be used for cladding, which normally requires stress relieving at around 590°C. Always consult expertise before performing post-weld heat treatment.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

316L/SKR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072	19 12 3 L
AWS A5.9	ER316L

Characteristics and welding directions

AVESTA 316L/SKR is designed for welding austenitic stainless steel type 17 Cr 12 Ni 2.5 Mo or similar where high resistance to general and intercrystalline corrosion is required. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 316Ti in cases where the construction will be used at temperatures not exceeding 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA 318/SKNb is required.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals

In combination with flux

801	• DNV	• SK	• TÜV	• UDT
805	• DNV	• SK	• TÜV	

Chemical composition, wire

(typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.40	1.7	18.5	12.0	2.6

Ferrite	8 FN	DeLong
	8 FN	WRC-92

Chemical composition, all weld metal

(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN[1)]
801	0.02	0.9	1.0	19.0	12.0	2.6	13
805	0.02	0.6	1.2	19.5	12.0	2.6	14
807	0.02	0.6	1.2	18.5	12.0	2.6	8

[1)] According to DeLong.

Mechanical properties

Typical values (IIW) in combination with flux	801	805
Yield strength $R_{p0,2}$	430 N/mm^2	430 N/mm^2
Tensile strength R_m	580 N/mm^2	570 N/mm^2
Elongation A_5	36 %	36 %
Impact strength KV		
+20°C	70 J	80 J
–196°C	–	35 J
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

318/SKNb

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12072 19 12 3 Nb
AWS A5.9 ER318

Characteristics and welding directions

AVESTA 318/SKNb is used for welding titanium and niobium stabilised steel type 17 Cr 11 Ni 2.5 Ti or similar.

A stabilised weld metal possesses improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. 318/SKNb shows somewhat better properties than 316L/SKR at elevated temperatures and is therefore recommended for applications where service temperatures exceed 400°C.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: The corrosion resistance corresponds to that of ASTM 316Ti, i.e. good resistance to general, pitting and intercrystalline corrosion.

Approvals

In combination with flux

801 • SK • TÜV • UDT

Chemical composition, wire

(typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb
0.04	0.40	1.3	19.0	12.0	2.6	>12 x C

Ferrite	8 FN	DeLong
	7 FN	WRC-92

Chemical composition, all weld metal

(typical values in combination with flux, %)

Flux	C	Si	Cr	Ni	Mo	Nb	FN[1)]
801	0.04	0.9	19.0	11.5	2.6	0.6	13
805	0.04	0.6	19.5	11.5	2.6	0.6	14
807	0.04	0.6	18.5	12.0	2.6	0.6	8

[1)] According to DeLong.

Mechanical properties

Typical values (IIW) in combination

with flux	805
Yield strength $R_{p0,2}$	490 N/mm^2
Tensile strength R_m	660 N/mm^2
Elongation A_5	30 %
Impact strength KV	
+20°C	50 J
Hardness	220 Brinell

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

317L/SNR

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-15-04	2367
4439	1.4439	317LMN	–	Z3 CND 18-14-05 Az	–

Standard designations

EN 12072	19 13 4 L
AWS A5.9	ER317L

Characteristics and welding directions

AVESTA 317L/SNR is designed for welding type 18 Cr 14 Ni 3 Mo austenitic stainless steels and similar. The enhanced content of chromium, nickel and molybdenum compared to 316L gives even better corrosion properties, primarily in acid chloride containing environments.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: Better resistance to general, pitting and intercrystalline corrosion than ASTM 316L in chloride containing environments. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals

In combination with flux

801 • SK

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.40	1.7	19.0	13.5	3.5

Ferrite	9 FN	DeLong
	9 FN	WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN[1)]
801	0.02	0.9	1.0	20.0	9.5	13
805	0.02	0.6	1.2	20.5	9.5	14
807	0.02	0.6	1.2	19.5	10.0	8

1) According to DeLong.

Mechanical properties

Typical values (IIW) in combination with flux	**801**	**805**
Yield strength $R_{p0,2}$	440 N/mm^2	410 N/mm^2
Tensile strength R_m	590 N/mm^2	580 N/mm^2
Elongation A_5	37 %	36 %
Impact strength KV		
+20°C	65 J	80 J
–196°C	–	35 J

Interpass temperature: Max. 150°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

2304

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2304®	1.4362	S32304	–	Z3 CN 23-04 Az	2327

Standard designations

–

Characteristics and welding directions

AVESTA 2304 is primarily designed for welding the duplex steel SAF 2304 and similar grades.

AVESTA 2304 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic stainless steels.

AVESTA 2304 has a low content of molybdenum, which makes it well suited for nitric acid environments.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 500	28 – 33
3.20	400 – 600	29 – 34

Welding flux: AVESTA Flux 805.

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in nitric acid environments.

Approvals

In combination with flux

805 • TÜV

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.40	0.5	23.0	7.0	< 0.5	0.14

Ferrite 40 FN WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN[1)]
805	0.02	0.6	0.4	23.5	6.5	< 0.5	40

[1)] According to WRC-92.

Mechanical properties
Typical values (IIW) in combination with flux **805**

	805
Yield strength $R_{p0,2}$	480 N/mm^2
Tensile strength R_m	650 N/mm^2
Elongation A_5	25 %
Impact strength KV +20°C	100 J
Hardness	260 Brinell

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 35 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

2205

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 12072 22 9 3 L N
AWS A5.9 ER2209

Characteristics and welding directions

AVESTA 2205 is primarily designed for welding the duplex grade Outokumpu 2205 and similar steels, but it can also be used for SAF 2304 type of steels.

AVESTA 2205 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic stainless steels.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 500	28 – 33
3.20	400 – 600	29 – 34

Welding flux: AVESTA Flux 805.

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

In combination with flux
805 • DNV • SK • TÜV • UDT

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.50	1.6	23.0	8.5	3.1	0.17

Ferrite 50 FN WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN[1]
805	0.02	0.7	1.0	23.5	8.0	3.1	50

[1] According to WRC-92.

Mechanical properties

Typical values (IIW) in combination with flux **805**

Yield strength $R_{p0,2}$	590 N/mm^2
Tensile strength R_m	800 N/mm^2
Elongation A_5	29 %
Impact strength KV	
+20°C	100 J
–40°C	70 J

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

2507/P100

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
SAF 2507®	1.4410	S32750	–	Z3 CND 25-06 Az	2328

Standard designations
EN 12072 25 9 4 L N

Characteristics and welding directions
AVESTA 2507/P100 is intended for welding super duplex alloys, e.g. SAF 2507, ASTM S32750, S32760, S32550 and S31260.

AVESTA 2507/P100 provides a ferritic-austenitic weldment that combines many of the good properties of both ferritic and austenitic stainless steels.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 805.

Corrosion resistance: Excellent resistance to pitting and stress corrosion cracking in chloride containing environments. Pitting resistance in accordance with ASTM G48-A, better than 40°C.

Approvals
–

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.02	0.35	0.4	25.0	9.5	4.0	0.25

Ferrite 50 FN WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN[1)]
805	0.02	0.6	0.2	25.5	9.0	4.0	50

1) According to WRC-92

Mechanical properties
Typical values (IIW) in combination with flux **805**

Yield strength $R_{p0,2}$	650 N/mm^2
Tensile strength R_m	870 N/mm^2
Elongation A_5	26 %
Impact strength KV	
+20°C	80 J

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

904L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
904L	1.4539	904L	904S13	Z2 NCDU 25-20	2562

Also for welding similar steels of the 20-25 CrNiMoCu-type.

Standard designations

EN 12072	20 25 5 Cu L
AWS A5.9	ER385

Characteristics and welding directions

AVESTA 904L is intended for welding Outokumpu 904L and similar steels but may also be used for ASTM 316 constructions, when a ferrite-free weld metal is required, e.g. in cryogenic or non-magnetic applications. The impact strength at low temperatures is excellent.

A fully austenitic structure is somewhat more prone to hot or solidification cracking than type ASTM 316 welds. Welding should therefore be performed in a way that minimises the heat input, interpass temperature and dilution with the parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 805.

Corrosion resistance: Very good in non-oxidising environments such as sulphuric or phosphoric acids. Very good resistance to pitting and crevice corrosion in chloride containing environments. Excellent resistance to general corrosion and stress corrosion cracking.

Approvals

In combination with flux

805 • TÜV

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	Cu
0.01	0.35	1.7	20.0	25.5	4.5	1.5

Ferrite 0 FN

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN
805	0.01	0.6	1.2	21.0	25.0	4.5	–

Mechanical properties

Typical values (IIW) in combination with flux	805
Yield strength $R_{p0,2}$	350 N/mm^2
Tensile strength R_m	560 N/mm^2
Elongation A_5	36 %
Impact strength KV	
+20°C	100 J
–40°C	90 J

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1070 – 1100°C).

Structure: Fully austenitic with extra low content of impurities.

Scaling temperature: Approx. 1000°C (air).

P12

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–
Also for welding stainless steels and nickel base alloys to low-alloy and mild steels.					

Standard designations

EN 18274 Ni Cr 22 Mo 9 Nb
AWS A5.14 ERNiCrMo-3

Characteristics and welding directions

AVESTA P12 is a nickel base alloy designed for welding 6Mo steels such as Outokumpu 254 SMO. The wire is also suitable for welding nickel base alloys such as Inconel 625 and Incoloy 825 and for dissimilar welds between stainless or nickel base alloys and mild steels.

When welding fully austenitic and nickel base steels, great care should be taken to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33

Welding flux: AVESTA Flux 805.

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments.

Approvals

In combination with flux
805 • UDT

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.1	22.0	65.0	9.0	3.6	<1.0

Ferrite 0 FN

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	Nb	FN
805	0.01	0.3	0.1	22.0	Bal.	9.0	3.6	–

Mechanical properties
Typical values (IIW) in combination

with flux	805
Yield strength $R_{p0,2}$	460 N/mm^2
Tensile strength R_m	730 N/mm^2
Elongation A_5	41 %
Impact strength KV	
+20°C	80 J

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

P12-0^{Nb}

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA P12-0^{Nb} is a nickel base alloy designed for welding 6Mo-steels such as Outokumpu 254 SMO.

AVESTA P12-0^{Nb} produces a fully austenitic weld metal that due to the absence of niobium is almost free from secondary phases. This gives extremely good ductility with superior impact strength even at low temperatures. The tensile strength is somewhat lower than for the standard P12.

AVESTA P12-0^{Nb} is specially designed to meet the requirements set forth by NORSOK M-601, 6.3.3.

When welding fully austenitic and nickel base steels, great care should be taken to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33

Welding flux: AVESTA Flux 805.

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments, which makes the consumable perfect for sea water and offshore applications etc.

Approvals

–

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.1	22.0	65.0	9.0	<0.1	<1.0

Ferrite 0 FN

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	Nb	FN
805	0.01	0.3	0.1	23.0	Bal.	9.0	<0.1	–

Mechanical properties
Typical values (IIW) in combination

with flux	**805**
Yield strength $R_{p0,2}$	400 N/mm^2
Tensile strength R_m	630 N/mm^2
Elongation A_5	36 %
Impact strength KV	
+20°C	120 J
–70°C	110 J

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Fully austenitic with extra low content of secondary phases.

Scaling temperature: Approx. 1100°C (air).

P16

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4565	1.4565	S34565	–	–	–
654 SMO®	1.4652	S31654	–	–	–
254 SMO®	1.4547	S31254	–	–	2378
20-25-6	1.4529	N08926	–	–	–

Also for welding nickel base alloys to stainless steels and mild steel.

Standard designations

EN 18274 Ni Cr 25 Mo 16

Characteristics and welding directions

AVESTA P16 is a nickel base alloy designed for welding 7Mo steels such as Outokumpu 654 SMO and similar, offering superior resistance to pitting and crevice corrosion. The wire is also suitable for welding nickel base alloys such as Inconel 625 and Incoloy 825 and for dissimilar welds between stainless or nickel base alloys and mild steel.

The chemical composition corresponds to that of Alloy 59 (ERNiCrMo-13).

When welding fully austenitic and nickel base steels, great care should be taken to minimise the heat input, interpass temperature and dilution with parent metal.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33

Welding flux: AVESTA Flux 805.

Corrosion resistance: Superior resistance to pitting and crevice corrosion (CPT >80°C, ASTM G48-A).

Approvals

–

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo	Nb	Fe
0.01	0.10	0.2	25.0	60.0	15.0	<0.1	<1.0

Ferrite 0 FN

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN
805	0.01	0.3	0.1	26.0	Bal.	15.0	–

Mechanical properties
Typical values (IIW) in combination with flux

	805
Yield strength $R_{p0,2}$	480 N/mm^2
Tensile strength R_m	720 N/mm^2
Elongation A_5	37 %
Impact strength KV	
+20°C	65 J
–40°C	60 J

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1150 – 1200°C).

Structure: Fully austenitic.

Scaling temperature: Approx. 1100°C (air).

309L

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA 309L is primarily used when joining non-molybdenum-alloyed stainless and carbon steels and for surfacing unalloyed or low-alloy steels.

Standard designations

EN 12072	23 12 L
AWS A5.9	ER309L

Characteristics and welding directions

AVESTA 309L is a high-alloy 24 Cr 14 Ni wire primarily intended for dissimilar welding between stainless and mild steel and for surfacing low-alloy steels.

Thick gauges and joints susceptible to hot cracking should be welded using AVESTA 309L-HF, which has a higher ferrite content than 309L.

The chemical composition obtained when surfacing is from the very first run equivalent to that of ASTM 304. One or two layers of 309L are usually combined with a final layer of 308L, 316L or 347.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: Superior to type 308L filler. When surfacing on mild steel a corrosion resistance equivalent to ASTM 304 is obtained at the very first layer.

Approvals

–

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.40	1.8	23.5	14.0

Ferrite	11 FN	DeLong
	10 FN	WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN[1)]
801	0.02	0.8	1.0	24.0	13.5	15
805	0.02	0.5	1.2	24.5	13.5	14
807	0.02	0.5	1.2	23.5	14.0	11

1) According to DeLong.

Mechanical properties
Typical values (IIW) in combination

with flux	801	805
Yield strength $R_{p0,2}$	410 N/mm^2	400 N/mm^2
Tensile strength R_m	580 N/mm^2	550 N/mm^2
Elongation A_5	36 %	36 %
Impact strength KV		
+20°C	70 J	100 J

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 15% ferrite.

Scaling temperature: Approx. 1000°C (air).

309L-HF

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 309L-HF is primarily used when joining non-molybdenum-alloyed stainless and carbon steels and for surfacing unalloyed or low-alloy steels.					

Standard designations

EN 12072 23 12 L
AWS A5.9 ER309L

Characteristics and welding directions

AVESTA 309L-HF is a high-alloy 24 Cr 13 Ni wire primarily intended for dissimilar welding between stainless and mild steel and for surfacing low-alloy steels.

AVESTA 309L-HF has a composition which under normal welding conditions ensures a crack resistant weld metal with a ferrite content of min. 3%.

AVESTA 309L-HF is also suitable for welding some high temperature steels. Always consult expertise.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: Superior to type 308L filler. When surfacing on mild steel a corrosion resistance equivalent to ASTM 304 is obtained at the very first layer.

Approvals

In combination with flux

801 • DNV • SK • UDT
805 • DNV

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni
0.02	0.35	1.7	24.0	13.0

Ferrite	16 FN	DeLong
	16 FN	WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN[1)]
801	0.02	0.8	1.0	24.0	12.5	20
805	0.02	0.5	1.2	24.5	12.5	20
807	0.02	0.5	1.2	23.5	13.0	16

[1)] According to DeLong.

Mechanical properties

Typical values (IIW) in combination with flux	801	805
Yield strength $R_{p0,2}$	410 N/mm^2	400 N/mm^2
Tensile strength R_m	580 N/mm^2	550 N/mm^2
Elongation A_5	36 %	36 %
Impact strength KV		
+20°C	70 J	100 J
−40°C	60 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 15% ferrite.

Scaling temperature: Approx. 1000°C (air).

P5

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
AVESTA P5 is primarily used when joining molybdenum-alloyed stainless and carbon steels and for surfacing unalloyed or low-alloy steels.					

Standard designations

EN 12072	23 12 2 L
AWS A5.9	(ER309LMo)*

* Cr lower and Ni higher than standard..

Characteristics and welding directions
AVESTA P5 is a molybdenum-alloyed consumable of the 309LMo type, which is primarily designed for joining stainless steels with low-alloy steels (dissimilar joints), ensuring a high resistance to cracking and for surfacing low-alloy steels. When used for surfacing, the composition is more or less equal to that of ASTM 316 from the very first run.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801, 805 or 807.

Corrosion resistance: Superior to type 316L filler. When surfacing on mild steel a corrosion resistance equivalent to ASTM 316 is obtained at the very first layer.

Approvals
In combination with flux

801 • DNV • SK
805 • DNV

Chemical composition, wire
(typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.02	0.35	1.5	21.5	15.0	2.7

Ferrite	9 FN	DeLong
	8 FN	WRC-92

Chemical composition, all weld metal
(typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	Mo	FN[1)]
801	0.02	0.8	0.8	22.0	14.5	2.7	14
805	0.02	0.6	1.0	22.0	15.0	2.7	15
807	0.02	0.6	1.0	21.0	15.5	2.7	11

[1)] According to DeLong.

Mechanical properties
Typical values (IIW) in combination

with flux	801	805
Yield strength $R_{p0,2}$	470 N/mm^2	410 N/mm^2
Tensile strength R_m	620 N/mm^2	600 N/mm^2
Elongation A_5	31 %	35 %
Impact strength KV		
+20°C	50 J	70 J

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints, a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 950°C (air).

P7

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
AVESTA P7 is an all-round wire, specially designed for difficult-to-weld steels such as Mn-steels, tool steels and high temperature grades.					

Standard designations

EN 12072 29 9
AWS A5.9 ER312

Characteristics and welding directions

AVESTA P7 is a high-alloy consumable designed for welding C/Mn-steels, tool steels, spring steels, high temperature steels and other difficult-to-weld steels. P7 is also suitable for dissimilar welds between stainless and mild steel.

AVESTA P7 provides a weldment with high tensile strength and wear resistance as well as an excellent resistance to cracking.

Pre-heating is normally not necessary, but when working with constricted designs and materials susceptible to hardening, some pre-heating may be required.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801 or 805.

Corrosion resistance: Very good corrosion resistance in wet sulphuric enviroments, e.g. in sulphate digesters used by the pulp and paper industry.

Approvals
In combination with flux
801 • DNV • UDT

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.11	0.45	1.9	30.0	9.5

Ferrite 60 FN WRC-92.

Chemical composition, all weld metal (typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN1)
801	0.11	0.9	1.2	30.5	9.0	60
805	0.11	0.6	1.5	31.0	9.0	60

1) According to WRC-92.

Mechanical properties
Typical values (IIW) in combination with flux 805

Yield strength $R_{p0,2}$	640 N/mm^2
Tensile strength R_m	770 N/mm^2
Elongation A_5	22 %
Impact strength KV	
+20°C	35 J

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. Alloys of this type are susceptible to precipitation of secondary phases in the temperature range 550 – 950°C.

Structure: Austenite with 40 – 60% ferrite.

Scaling temperature: Approx. 850°C (air).

253 MA

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
153 MA™	1.4818	S30415	–	–	2372
253 MA®	1.4835	S30815	–	–	2368

Standard designations

–

Characteristics and welding directions

AVESTA 253 MA is designed for welding the high temperature steel Outokumpu 253 MA, used in furnaces, combustion chambers, burners etc. The steel as well as the consumable provides excellent properties at temperatures 850 – 1100°C.

The composition of the consumable is balanced to ensure a crack resistant weld metal.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 500	29 – 33

Welding flux: AVESTA Flux 801 or 805.

Corrosion resistance: Excellent resistance to high temperature corrosion. Not intended for applications exposed to wet corrosion.

Approvals

–

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	N	Others
0.07	1.60	0.6	21.0	10.0	0.15	REM

Ferrite	9 FN	DeLong
	2 FN	WRC-92

Chemical composition, all weld metal (typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN[1)]
801	0.07	2.1	0.2	21.0	9.0	14
805	0.07	1.8	0.2	21.5	9.0	15

1) According to DeLong.

Mechanical properties

Typical values (IIW) in combination

with flux	801
Yield strength $R_{p0,2}$	470 N/mm^2
Tensile strength R_m	690 N/mm^2
Elongation A_5	39 %
Impact strength KV	
+20°C	90 J

Interpass temperature: Max. 150°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none.

Structure: Austenite with 3 – 10% ferrite.

Scaling temperature: Approx. 1150°C (air).

353 MA

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
353 MA®	1.4854	S35315	–	–	–

Standard designations

–

Characteristics and welding directions

AVESTA 353 MA is designed for welding the high temperature steel Outokumpu 353 MA, offering excellent properties at temperatures above 1000°C.

Due to the fully austenitic structure, the weld metal is somewhat more sensitive to hot cracking than for example 253 MA.

Welding data

Diameter, mm	Current, A	Voltage, V
2.40	300 – 400	29 – 33
3.20	350 – 450	29 – 33

Welding flux: AVESTA Flux 805.

Corrosion resistance: Superior properties for constructions running at service temperatures above 1000°C. Not intended for applications exposed to wet corrosion.

Approvals

–

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	N	Others
0.05	0.85	1.6	27.5	35.0	0.15	REM

Ferrite 0 FN DeLong

Chemical composition, all weld metal (typical values in combination with flux, %)

Flux	C	Si	Mn	Cr	Ni	FN
805	0.05	1.0	1.0	28.5	35.0	–

Mechanical properties

–

Interpass temperature: Max. 100°C.

Heat input: Max. 1.0 kJ/mm.

Heat treatment: Generally none.

Structure: Fully austenitic.

Scaling temperature: Approx. 1175°C (air).

FCW 308L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12073	T 19 9 L R M 3
AWS A5.22	E308LT0-4

Characteristics and welding directions

AVESTA FCW 308L is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 in cases where the construction will be operating at temperatures below 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA FCW 347 is required.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
0.90	Horizontal	80 – 160	22 – 28
	Vertical-up	80 – 130	22 – 26
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28
1.60	Horizontal	200 – 320	26 – 34

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.03	0.6	1.6	19.0	10.0

Ferrite	9 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	390 N/mm^2	320 N/mm^2
Tensile strength R_m	540 N/mm^2	510 N/mm^2
Elongation A_5	40 %	30 %
Impact strength KV		
+20°C	55 J	
–40°C	50 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as in oxidising an cold dilute reducing acids.

Approvals

- DB
- DNV
- TÜV
- UDT

FCW 308L-PW

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4307	1.4307	304L	304S11	Z3 CN 18-10	2352
4311	1.4311	304LN	304S61	Z3 CN 18-10 Az	2371
4541	1.4541	321	321S31	Z6 CNT 18-10	2337

Standard designations

EN 12073	T 19 9 L P M 2
AWS A5.22	E308LT1-4

Characteristics and welding directions

AVESTA FCW 308L-PW is designed for welding austenitic stainless steel type 19 Cr 10 Ni or similar. The filler metal is also suitable for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 in cases where the construction will be operating at temperatures below 400°C. For higher temperatures a niobium stabilised consumable such as AVESTA FCW 347 is required.

AVESTA FCW 308L-PW is designed for welding in the vertical-up and overhead positions. Welding in horizontal position can also be performed using FCW 308L.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 240	24 – 32
	Vertical-up	130 – 160	23 – 28
	Overhead	150 – 200	24 – 29

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.03	0.7	1.6	19.0	10.0

Ferrite	6 FN	DeLong
	9 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	390 N/mm^2	320 N/mm^2
Tensile strength R_m	570 N/mm^2	510 N/mm^2
Elongation A_5	39 %	30 %
Impact strength KV		
+20°C	60 J	
Hardness	200 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. fairly good under severe conditions such as in oxidising an cold dilute reducing acids.

Approvals

- UDT

FCW 308H

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
4301	1.4301	304	304S31	Z7 CN 18-09	2333
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations
AWS A5.22 E308HT0-4

Characteristics and welding directions
AVESTA FCW 308H is designed for welding austenitic stainless steel type 18 Cr 10 Ni or similar. It has a higher carbon content, compared to 308L. This provides improved creep resistance properties, which is advantageous at temperatures above 400°C. 308H is also suitable for welding titanium and niobium stabilised steels such as ASTM 321 and ASTM 347 for service temperatures not exceeding 600°C.

AVESTA FCW 308H is primarily designed for horisontal welding but can also be used in the vertical-up position with good result.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.06	0.4	1.5	19.0	9.5

Ferrite	5 FN	DeLong
	5 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values AWS A5.22
Yield strength $R_{p0,2}$	390 N/mm^2	–
Tensile strength R_m	580 N/mm^2	550 N/mm^2
Elongation A_5	41 %	35 %
Impact strength KV		
+20°C	90	
–70°C	50 J	
Hardness	210 Brinell	

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28

Shielding gas
Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 3 – 8% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Corresponding to ASTM 304, i.e. good resistance to general corrosion. The enhanced carbon content, compared to 308L, makes it slightly more sensitive to intercrystalline corrosion.

Approvals
- UDT

FCW 347

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4541	1.4541	321	321S31	Z6 CNT 18-10	2337
–	1.4550	347	347S31	Z6 CNNb 18-10	2338

Standard designations

EN 12073 T 19 9 Nb R M 3
AWS A5.22 E347T0-4

Characteristics and welding directions

AVESTA FCW 347 is used for welding titanium and niobium stabilised steel of type 19 Cr 10 Ni or similar.

A stabilised weldment posses improved high temperature properties, e.g. creep resistance, compared to low-carbon non-stabilised materials. FCW 347 is therefore primarily used for applications where service temperatures exceed 400°C.

AVESTA FCW 347 is primarily designed for horisontal welding, but can also be used in the vertical-up position with good result.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb
0.03	0.4	1.6	19.0	10.5	>8xC

Ferrite	7 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	410 N/mm^2	350 N/mm^2
Tensile strength R_m	580 N/mm^2	550 N/mm^2
Elongation A_5	34 %	30 %
Impact strength KV		
+20°C	70 J	
Hardness	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none. 347 type FCW can be used for cladding, which normally requires stress relieving at around 590°C. Such a heat treatment will reduce the ductility of the weld at room temperature. Always consult expertise before performing post-weld heat treatment.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: FCW 347 is primarily intended for high temperature service or applications that should be heat treated. However, the corrosion resistance corresponds to that of 308H, i.e. good resistance to general corrosion.

Approvals

- UDT

FCW 316L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12073	T 19 12 3 L R M 3
AWS A5.22	E316LT0-4

Characteristics and welding directions

AVESTA FCW 316L is designed for welding austenitic stainless steel type 17 Cr 12 Ni 2.5 Mo, but can also be used for welding titanium and niobium stabilised steels such as ASTM 316Ti in cases where the construction will be operating at temperatures below 400°C.

AVESTA FCW 316L provides excellent weldability in horizantal as well as vertical-up position. Welding overhead etc. is preferably done using AVESTA FCW 316L-PW.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
0.90	Horizontal	80 – 160	22 – 28
	Vertical-up	80 – 130	22 – 26
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28
1.60	Horizontal	200 – 320	26 – 34

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.03	0.6	1.4	18.5	12.5	2.8

Ferrite		
	10 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	390 N/mm^2	320 N/mm^2
Tensile strength R_m	550 N/mm^2	510 N/mm^2
Elongation A_5	38 %	25 %
Impact strength KV		
+20°C	55 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, i.e. in dilute hot acids.

Approvals

- DB
- DNV
- TÜV
- UDT

FCW 316L-PW

For welding steels such as

Outokumpu	EN	ASTM	BS	NF	SS
4436	1.4436	316	316S33	Z7 CND 18-12-03	2343
4432	1.4432	316L	316S13	Z3 CND 17-12-03	2353
4429	1.4429	S31653	316S63	Z3 CND 17-12 Az	2375
4571	1.4571	316Ti	320S31	Z6 CNDT 17-12	2350

Standard designations

EN 12073	T 19 12 3 L P M 2
AWS A5.22	E316LT1-4

Characteristics and welding directions

AVESTA FCW 316L-PW is designed for welding austenitic stainless steel type 17 Cr 12 Ni 2.5 Mo or similar. It is also suitable for welding titanium and niobium stabilised steels such as ASTM 316Ti in cases where the construction will be operating at temperatures below 400°C.

AVESTA FCW 316L-PW is primarily designed for position welding in the vertical-up and overhead positions and offers excellent arc stability, slag control and weld bead appearance.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 240	24 – 32
	Vertical-up	130 – 160	23 – 28
	Overhead	150 – 200	24 – 29

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.03	0.7	1.3	18.0	12.5	3.0

Ferrite	7 FN	DeLong
	6 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	400 N/mm²	320 N/mm²
Tensile strength R_m	560 N/mm²	510 N/mm²
Elongation A_5	37 %	25 %
Impact strength KV		
+20°C	60 J	
–40°C	55 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Excellent resistance to general, pitting and intercrystalline corrosion in chloride containing environments. Intended for severe service conditions, i.e. in dilute hot acids.

Approvals

- DNV
- TÜV
- UDT

FCW 317L

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
4438	1.4438	317L	317S12	Z3 CND 19-15-04	2367
4439	1.4439	317LMN	–	Z3 CND 18-14-05 Az	–

Standard designations
AWS A5.22 E317LT0-4

Characteristics and welding directions
AVESTA FCW 317L is designed for welding type 18 Cr 14 Ni 3 Mo austenitic stainless and similar. The enhanced content of chromium, nickel and molybdenum compared to 316L gives improved corrosion properties in acid chloride containing environments.

AVESTA FCW 317L is primarily designed for horisontal welding but can also be used in the vertical-up position with good result.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28

Shielding gas
Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Nb
0.02	0.6	1.2	18.5	12.5	3.4

Ferrite	10 FN	DeLong
	7 FN	WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	410 N/mm^2	350 N/mm^2
Tensile strength R_m	570 N/mm^2	550 N/mm^2
Elongation A_5	30 %	25 %
Impact strength KV		
+20°C	50 J	
Hardness	210 Brinell	

Interpass temperature: Max. 100°C.

Heat input: Max. 1.5 kJ/mm.

Heat treatment: Generally none (in special cases quench annealing at 1050°C).

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Better resistance to general, pitting and intercrystalline corrosion in chloride containing environments than ASTM 316L. Intended for severe service conditions, e.g. in dilute hot acids.

Approvals
• UDT

FCW 2205

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 12073 T 22 9 3 N L R M 3
AWS A5.22 E2209T0-4

Characteristics and welding directions

AVESTA FCW 2205 is designed for welding ferritic-austenitic (duplex) stainless steels such as Outokumpu 2205 and similar. It is also suitable for welding Cr-Ni duplex steels like SAF 2304.

AVESTA FCW 2205 provides excellent weldability in horizontal as well as vertical-up position. Welding in the overhead position is preferably done using FCW 2205-PW.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.7	0.9	22.5	9.0	3.2	0.13

Ferrite 50 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	590 N/mm^2	450 N/mm^2
Tensile strength R_m	810 N/mm^2	550 N/mm^2
Elongation A_5	29 %	20 %
Impact strength KV		
+20°C	55 J	
–40°C	40 J	
Hardness	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases, quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

- DB
- DNV
- SK
- TÜV
- UDT

FCW 2205-H

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 12073 T 22 9 3 N L R M 3
AWS A5.22 E2209T0-4

Characteristics and welding directions

AVESTA FCW 2205-H is designed for welding ferritic-austenitic (duplex) stainless steels such as Outokumpu 2205 and similar. It is also suitable for welding Cr-Ni duplex steels like SAF 2304.

AVESTA FCW 2205-H is primarily designed for welding against ceramic backing in horizontal as well as vertical-up position. However, it can also be used for two-side butt welding. Welding in the overhead position is preferably done using FCW 2205-PW.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.7	1.0	23.5	9.5	3.4	0.14

Ferrite 50 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	610 N/mm^2	450 N/mm^2
Tensile strength R_m	820 N/mm^2	550 N/mm^2
Elongation A_5	26 %	20 %
Impact strength KV		
+20°C	55 J	
–40°C	40 J	
Hardness	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases, quench annealing at 1100 – 1150°C).

Structure: Austenite with 45 – 55% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

- DNV
- UDT

FCW 2205-PW

For welding steels such as Outokumpu	EN	ASTM	BS	NF	SS
2205	1.4462	S32205	318S13	Z3 CND 22-05 Az	2377

Standard designations

EN 12073 T 22 9 3 N L P M 2
AWS A5.22 E2209T1-4

Characteristics and welding directions

AVESTA FCW 2205-PW is designed for welding ferritic-austenitic (duplex) stainless steels such as Outokumpu 2205 and similar. It is also suitable for welding Cr-Ni duplex steels like SAF 2304.

AVESTA FCW 2205-PW provides excellent weldability in vertical-up and overhead positions. Horizontal welding can also be performed using FCW 2205 or 2205-H.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 240	24 – 32
	Vertical-up	130 – 160	23 – 28
	Overhead	150 – 200	24 – 29

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo	N
0.03	0.6	0.8	23.0	9.5	3.5	0.16

Ferrite 45 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	610 N/mm^2	450 N/mm^2
Tensile strength R_m	840 N/mm^2	550 N/mm^2
Elongation A_5	28 %	20 %
Impact strength KV		
+20°C	60 J	
Hardness	240 Brinell	

Interpass temperature: Max. 150°C.

Heat input: 0.5 – 2.5 kJ/mm.

Heat treatment: Generally none (in special cases, quench annealing at 1100 – 1150°C).

Structure: Austenite with 40 – 50% ferrite.

Scaling temperature: Approx. 850°C (air).

Corrosion resistance: Very good resistance to pitting and stress corrosion cracking in chloride containing environments.

Approvals

- DNV
- UDT

FCW 309L

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA 309L is primarily used when surfacing unalloyed or low-alloy steels and when joining non-molybdenum-alloyed stainless and carbon steels.

Standard designations

EN 12073	T 23 12 L R M 3
AWS A5.22	E309LT0-4

Characteristics and welding directions

AVESTA FCW 309L is a high-alloy 23 Cr 13 Ni wire, primarily intended for surfacing low-alloy steels and for dissimilar welding between mild steel and stainless steels.

AVESTA FCW 309L is primarily designed for welding in the horizontal position. Welding in vertical-up and overhead positions is preferably done using 309L-PW.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28
1.60	Horizontal	200 – 320	26 – 34

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.03	0.6	1.4	23.5	12.5

Ferrite 19 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	400 N/mm^2	320 N/mm^2
Tensile strength R_m	560 N/mm^2	520 N/mm^2
Elongation A_5	34 %	30 %
Impact strength KV		
+20°C	45 J	
–40°C	40 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 500 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Superior to type 308L fillers. When surfacing on mild steel, a corrosion resistance equivalent to that of ASTM 304 is obtained from the first bead.

Approvals

• DB • DNV • TÜV •UDT

FCW 309L-PW

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS
AVESTA 309L-PW is primarily used for surfacing unalloyed or low-alloy steels and when joining non-molybdenum-alloyed stainless and carbon steels.					

Standard designations

EN 12073	T 23 12 L P M 2
AWS A5.22	E309LT1-4

Characteristics and welding directions

AVESTA FCW 309L-PW is a high-alloy 23 Cr 13 Ni wire primarily intended for surfacing on low-alloy steels and for dissimilar welds between mild steel and stainless steels.

AVESTA FCW 309L-PW is designed for welding in vertical-up and overhead positions. Welding in horizontal position can also be performed using FCW 309L.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 240	24 – 32
	Vertical-up	130 – 160	23 – 28
	Overhead	150 – 200	24 – 29

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni
0.03	0.6	1.3	23.5	12.5

Ferrite 20 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	390 N/mm^2	320 N/mm^2
Tensile strength R_m	550 N/mm^2	510 N/mm^2
Elongation A_5	35 %	25 %
Impact strength KV		
+20°C	55 J	
Hardness	210 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 500 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 5 – 10% ferrite.

Scaling temperature: Approx. 1000°C (air).

Corrosion resistance: Corrosion resistance superior to type 308L fillers. When surfacing on mild steel, a corrosion resistance equivalent to ASTM 304 is obtained from the first bead.

Approvals

- DNV
- UDT

FCW P5

For welding steels such as					
Outokumpu	EN	ASTM	BS	NF	SS

AVESTA P5 is primarily used when surfacing unalloyed or low-alloy steels and when joining molybdenum-alloyed stainless and carbon steels.

Standard designations

EN 12073	T 23 12 2 L R M 3
AWS A5.22	E309LMoT0-4

Characteristics and welding directions

AVESTA P5 is a molybdenum alloyed wire of the 309MoL type, primarily designed for welding dissimilar joints between stainless steels and low-alloy steels. It is also widely used for surfacing low-alloy steels offering a composition similar to that of ASTM 316 from the first run.

AVESTA FCW P5 can be used for welding in all positions.

Welding data

Diameter mm	Welding direction	Current A	Voltage V
1.20	Horizontal	150 – 280	24 – 32
	Vertical-up	140 – 170	23 – 28
1.60	Horizontal	200 – 320	28 – 34

Shielding gas

Ar + 15 – 25% CO_2 offers the best weldability, but 100% CO_2 can also be used.
Gas flow rate 20 – 25 l/min.

Chemical composition, wire (typical values, %)

C	Si	Mn	Cr	Ni	Mo
0.03	0.6	1.4	23.0	13.0	2.5

Ferrite 25 FN WRC-92

Mechanical properties	Typical values (IIW)	Min. values EN 12073
Yield strength $R_{p0,2}$	480 N/mm^2	350 N/mm^2
Tensile strength R_m	670 N/mm^2	550 N/mm^2
Elongation A_5	29 %	25 %
Impact strength KV		
+20°C	40 J	
Hardness	220 Brinell	

Interpass temperature: Max. 150°C.

Heat input: Max. 2.0 kJ/mm.

Heat treatment: Generally none.
For constructions that include low-alloy steels in mixed joints a stress-relieving annealing stage may be advisable. However, this type of alloy may be susceptible to embrittlement-inducing precipitation in the temperature range 550 – 950°C. Always consult the supplier of the parent metal or seek other expert advice to ensure that the correct heat treatment process is carried out.

Structure: Austenite with 10 – 15% ferrite.

Scaling temperature: Approx. 950°C (air).

Corrosion resistance: Superior to type 316L. Excellent resistance to pitting and crevice corrosion in chloride containing environments. The corrosion resistance obtained in the first layer, when surfacing, corresponds to that of 316.

Approvals

- DNV
- SK
- TÜV
- UDT

Flux 801

For welding with submerged arc wire such as Avesta Welding
308L/MVR, 347/MVNb, 316L/SKR, 318/SKNb, 309L, 309L-HF and P5

Standard designation

EN 760 SA CS 2 Cr DC

Characteristics

AVESTA Flux 801 is a neutral chromium-compensated agglomerated flux. It is a general-purpose flux designed for both joint welding stainless steel and for cladding onto unalloyed or low-alloyed steel.

Flux 801 can be used in combination with all types of stabilised and non-stabilised Cr-Ni and Cr-Ni-Mo fillers. It provides neat weld surfaces, very good welding properties and easy slag removal.

Flux 801 is chromium-alloyed to compensate for losses in the arc during welding.

- Bulk density: 0.8 kg/dm^3
- Basicity index: 1.0 (Boniszewski)
- Flux consumption: 0.4 kg flux/kg wire (26 V)
  0.7 kg flux/kg wire (34 V)

Welding data

Diameter mm	Current A	Voltage V	Speed cm/min
2.40	300 – 400	29 – 33	40 – 60
3.20	350 – 500	29 – 33	40 – 60
4.00	400 – 600	30 – 36	40 – 60

Flux care

The flux should be stored indoors in a dry place. Moist flux can be redried at 250 – 300°C for 2 hours. Both heating and cooling must be carried out slowly.

Chemical composition, all weld metal (typical values, %)

SA wire	C	Si	Mn	Cr	Ni	Mo	FN
308L/MVR	0.02	0.9	1.0	20.0	9.5	–	13[1)]
316L/SKR	0.02	0.9	1.0	19.0	12.0	2.6	13[1)]

[1)] According to DeLong.

Mechanical properties

Typical values (IIW) in combination with

SAW wire	308L/MVR	316L/SKR
Yield strength $R_{p0,2}$	440 N/mm^2	430 N/mm^2
Tensile strength R_m	590 N/mm^2	580 N/mm^2
Elongation A_5	37 %	36 %
Impact strength KV		
+20°C	65 J	70 J
–196°C	30 J	–
Hardness	200 Brinell	210 Brinell

Approvals

In combination with SAW wire

308L/MVR	• DNV	• TÜV	• UDT
347/MVNb	• TÜV	• UDT	
316L/SKR	• DNV	• TÜV	• UDT
318/SKNb	• TÜV	• UDT	
309L-HF	• DNV	• UDT	
P5	• DNV	• SK	
P7	• DNV	• UDT	

Flux 805

For welding with submerged arc wire such as Avesta Welding
2205, 2507/P100, 904L, P12 and P16, but also with 308L/MVR, 347/MVNb, 316L/SKR, 318/SKNb, 309L, 309L-HF and P5

Standard designation

EN 760 SA AF 2 Cr DC

Characteristics

AVESTA Flux 805 is a basic, slightly chromium-compensated agglomerated flux. It is primarily designed for welding with high-alloyed stainless fillers such as AVESTA P12, 904L and 2205. Standard Cr-Ni and Cr-Ni-Mo fillers can also be welded with excellent results. Flux 805 is especially suitable for applications where high impact strength values are required.

Flux 805 provides neat weld surfaces, very good welding properties and easy slag removal.

- Bulk density: 1.0 kg/dm^3
- Basicity index: 1.7 (Boniszewski)
- Flux consumption: 0.5 kg flux/kg wire (26 V) 0.8 kg flux/kg wire (34 V)

Welding data

Diameter mm	Current A	Voltage V	Speed cm/min
2.40	300 – 400	29 – 33	40 – 60
3.20	350 – 500	29 – 33	40 – 60
4.00	400 – 600	30 – 36	40 – 60

When welding high-alloy grades, such as Avesta P12, current should be kept at the lower range.

Flux care

The flux should be stored indoors in a dry place. Moist flux can be redried at 250 – 300°C for 2 hours. Both heating and cooling must be carried out slowly.

Chemical composition, all weld metal (typical values, %)

SA wire	C	Si	Mn	Cr	Ni	Mo	FN
316L/SKR	0.02	0.6	1.2	19.5	12.0	2.6	14 1)
2205	0.02	0.7	1.0	23.5	8.0	3.1	50 2)
P12	0.01	0.3	0.1	22.0	Bal.	8.5	–

1) According to DeLong.
2) According to WRC-92.

Mechanical properties

Typical values (IIW) in combination with

SAW wire	316L/SKR	2205
Yield strength $R_{p0,2}$	430 N/mm^2	590 N/mm^2
Tensile strength R_m	570 N/mm^2	800 N/mm^2
Elongation A_5	36 %	29 %
Impact strength KV		
+20°C	80 J	100 J
–40°C	–	70 J
–196°C	35 J	–

Approvals

In combination with SAW wire

308L/MVR	• TÜV			
316L/SKR	• DNV	• TÜV		
309L-HF	• DNV			
P5	• DNV			
2304	• TÜV			
2205	• DNV	• SK	• TÜV	• UDT
904L	• TÜV			
P12	• UDT			

Flux 807

For welding with submerged arc wire such as Avesta Welding
308L/MVR, 347/MVNb, 316L/SKR, 318/SKNb, 309L and P5

Standard designation

EN 760 SA AB 2 DC

Characteristics

AVESTA Flux 807 is a basic non-alloyed agglomerated flux. It is a general-purpose flux designed for butt welding with standard Cr-Ni and Cr-Ni-Mo fillers. It can also be used for cladding unalloyed or low-alloy steel.

Flux 807 provides neat weld surfaces, very good welding properties and easy slag removal.

- Bulk density: 1.1 kg/dm^3
- Basicity index: 2.7 (Boniszewski)
- Flux consumption: 0.5 kg flux/kg wire (26 V)
  0.8 kg flux/kg wire (34 V)

Welding data

Diameter mm	Current A	Voltage V	Speed cm/min
2.40	300 – 400	29 – 33	40 – 60
3.20	350 – 500	29 – 33	40 – 60
4.00	400 – 600	30 – 36	40 – 60

Flux care

The flux should be stored indoors in a dry place. Moist flux can be redried at 250 – 300°C for 2 hours. Both heating and cooling must be carried out slowly.

Chemical composition, all weld metal (typical values, %)

SA wire	C	Si	Mn	Cr	Ni	Mo	FN
308L/MVR	0.02	0.6	1.2	19.5	10.0	–	8[1)]
316L/SKR	0.02	0.6	1.2	18.5	12.0	2.6	8[1)]

[1)] According to DeLong.

Mechanical properties

Typical values (IIW) in combination with

SAW wire	308L/MVR	316L/SKR
Yield strength $R_{p0,2}$	380 N/mm^2	380 N/mm^2
Tensile strength R_m	550 N/mm^2	540 N/mm^2
Elongation A_5	40 %	40 %
Impact strength KV		
+20°C	100 J	90 J
–196°C	30 J	30 J

Approvals

–

Flux 301

For submerged arc strip cladding with all types of austenitic stainless steel strip such as
EQ 308L, 347, 316L, 309L and 309LNb.

Standard designation
EN 760 SA Z 2 DC

Characteristics
AVESTA Flux 301 is an agglomerated, slightly basic flux designed for submerged arc strip cladding. It offers excellent welding properties and easy slag removal. Strips of various widths (30, 60 or 90 mm) are used. Flux 301 has a composition that gives a weld metal with a ferrite level exceeding 4 FN (Delong) when welding the first layer with strip EQ 309L.

- Bulk density: 0.8 kg/dm^3
- Basicity index: 1.1 (Boniszewski)
- Flux consumption: 0.7 kg flux/kg strip (750 A, 28 V)

Welding data, 60 mm strip

Strip dim. mm	Current A	Voltage V	Speed mm/min
60 x 0.5	730 – 770	26 – 28	120 – 150

Stick-out: typically 30 mm
Bead thickness: 3 – 5 mm

Heat input
Typically 6 – 30 kJ/mm

Welding directions
Increased current increases the deposition rate, penetration, dilution and weld metal temperature considerably. Normal penetration is about 1 mm, differing slightly with travel speed.

Direct current, positive polarity, gives a smooth overlapping and the best bead appearance. Negative polarity is also possible and gives an increased deposition rate and less penetration.

Since strip surfacing requires high heat input the parent metal must be reasonably thick to ensure dimensional stability during welding. A thickness of 100 mm or more is often required.

Flux care
The flux should be stored indoors in a dry place. Moist flux can be redried at 250 – 300°C for 2 hours.

Approvals
–

Chemical composition, all weld metal, 60 mm strip (typical values, %)

Strip, 60 mm		C	Si	Mn	Cr	Ni	Mo	Nb	Ferrite FN[1)]	Ferrite %[2)]
309L	strip	0.01	0.3	1.8	23.5	13.0	–	–	15	–
	1st layer	0.03	0.5	1.2	19.0	10.5	–	–	5	5
347	strip	0.01	0.2	1.8	19.5	10.5	–	0.5	9	–
	2nd layer	0.02	0.5	1.2	19.0	11.0	–	0.35	7	6
316L	strip	0.01	0.3	1.8	18.5	12.5	2.9	–	6	–
	2nd layer	0.02	0.5	1.2	18.0	12.0	2.3	–	6	5

Welding parameters: 750 A, 28 V, 130 mm/min
Deposition rate: 14 kg/h
Weld overlay thickness: 3.5 – 4.0 mm
Penetration: 1 mm

1) According to DeLong
2) Measured by Fischer Feritescope® MP-3

Pickling paste, pickling gel

Characteristics

Avesta pickling pastes and gels are used to remove welding oxides and the underlying chromium-depleted layer. The paste and the gel also remove micro-slag inclusions and other contaminants that may cause local corrosion.

Avesta pickling paste and pickling gel follow the recommendations of ASTM A-380 A.1 and BS CP-312.

Chemical properties

Composition	Hydrofluoric acid (HF) Nitric acid (HNO_3) Binder
Form	Paste/gel
Density	1.25 – 1.35 kg/l
pH	0
Flammable	No

Products and properties

Name Avesta	Suitable for	Features
Pickling paste 101	All stainless steel grades.	A classic with perfect paste consistency and good adhesion, reducing the risk of splashing.
Pickling gel 122	All stainless steel grades.	More free-flowing than the paste; more heat-stable for use in warmer climates.
GreenOne™ pickling paste 120	Light pickling for easy application.	Non-toxic; pickling of shiny surfaces without dulling.
BlueOne™ pickling paste 130	Medium pickling for standard applications.	Pickling virtually without toxic nitric fumes.
RedOne™ pickling paste 140	Heavy pickling for tough applications.	Fast pickling even at low temperatures.

Spray pickle gel

Characteristics
Avesta spray pickle gels are used to restore larger stainless steel surfaces that have been damaged by working operations such as welding, forming, cutting and blasting. The gel also removes welding oxides, the underlying chromium-depleted layer, micro-slag particles and other contaminants that may cause local corrosion.

Avesta spray pickle gels follow the recommendations of ASTM A-380 A.1 and BS CP-312.

Chemical properties

Composition	Hydrofluoric acid (HF) Nitric acid (HNO_3) Binder
Form	Liquid gel
Density	1.20 – 1.30 kg/l
pH	0
Flammable	No

Products and properties

Name Avesta	Suitable for	Features
Spray pickle gel 204	All stainless steel grades.	A classic, very strong and fast.
GreenOne™ Spray pickle gel 220	Light pickling for easy applications.	Coloured for easy application and rinsing. Pickling of shiny surfaces without dulling.
BlueOne™ Spray pickle gel 230	Medium pickling for standard applications.	Coloured for easy application and rinsing. Overnight pickling (does not dry out).
RedOne™ Spray pickle gel 240	Heavy pickling for tough applications.	Coloured for easy application and rinsing. Overnight pickling (does not dry out).

Pickling bath

Characteristics
Avesta pickling bath is used to restore larger stainless steel surfaces that have been damaged by working operations such as welding, forming, cutting and blasting. The bath also removes welding oxides, the underlying chromium-depleted layer, micro-slag particles and other contaminants that may cause local corrosion.

Avesta Bath Pickling follows the recommendations of ASTM A-380 A.1 and BS CP-312.

Chemical properties

Composition	Hydrofluoric acid (HF) Nitric acid (HNO_3)
Form	Liquid
Density	1.25 – 1.35 kg/l
pH	0
Flammable	No

Products and properties

Name Avesta	Suitable for	Features
Bath Pickling 302	Standard steel grades.	Mix 1 part 302 into 3 parts water.
	High-alloy steels (duplex and austenitic).	Mix 1 part 302 into 2 parts water.
	Super duplex and super austenitic grades.	Mix 1 part 302 into 1 part water.

Pickling related products

Characteristics

The pickling process must often be completed with different treatments to reach the required result and to meet environmental requirements.

Avesta Finishing Chemicals offers surface treatment chemicals for all steps in the pickling process: a cleaner to remove organic contaminants prior to pickling, a passivating agent to accomplish the after-treatment and a neutralising agent to handle the waste water. The product range also includes a first aid spray and a drop test to distinguish different steel grades.

Products and properties

Name Avesta	Intended for	Features
CleanOne™ 401	Cleaning all stainless steel grades.	Removes organic contaminants and improves the surface finish.
CleanOne™ 420	Removing fingerprints and stains.	Quick and easy method; spray on, wipe off. Leaves a clean surface without ”shadows”.
Neutralising agent 502	Handling acetic waste water.	The waste water reaches an adjusted pH-value of 7 to 10. Dissolved metals will be precipitated.

Chemical properties

	401	420	502
Composition	H_3PO_4 Detergent	2-propanol and non-ionic tensides	NaOH
Form	Liquid	Liquid	Liquid
Density	1.1 kg/l	1.0 kg/l	1.4 kg/l
pH	1	12	12
Flammable	No	No	No

Products and properties

Name Avesta	Intended for	Features
Passivating agent 601	Removing contaminants from the steel surface.	Restores the protective chromium oxide layer; removes smut from sensitive surfaces.
FinishOne™ 630	Passivation and removing contaminants from the steel surface.	Non-dangerous – no hazardous waste. Restores the protective oxide layer. Transforms NOx to nitric acid when used as a rinse after pickling.
First Aid spray 910	Absorbing splashes of pickling products.	Suitable for skin and eye treatment.
Moly Drop Test 960	Differentiating grade EN 1.4301 from 1.4401.	Quick and easy method.

Chemical properties

	601	630	910	960
Composition	HNO_3 Corrosion inhibitor	Oxidising agent, complex binder and corrosion inhibitor	Hexafluorine®	HCl
Form	Liquid	Liquid	Liquid	Liquid
Density	1.1 kg/l	1.0 kg/l	1.05 kg/l	1.3 kg/l
pH	0	7	7.4	0
Flammable	No	No	No	No

15 Packaging data

Covered electrodes

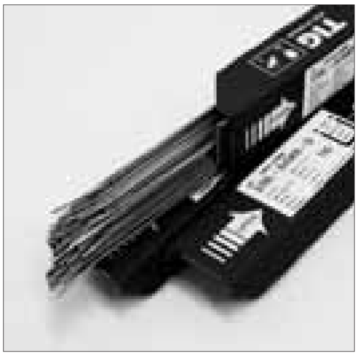
- Moisture-resistant plastic capsules, packed in cardboard boxes.
- Vacuum-packed capsules on request.

Dimensions and lengths Table 15.1

Coating	Diameter and length, mm					
	1.60	2.00	2.50	3.25	4.00	5.00
AC/DC	250	250 – 300	300 – 350	350	350 – 450	350 – 450
HX			350	350 – 400	450	450
PW	250	250	300	350	350	350
VDX, PWX	250	250 – 300	300	350		
Basic		250	300	350	350	350
Rutile	250	250	300	350	350	350

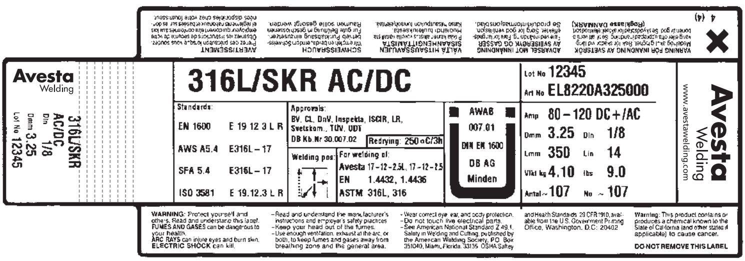
MIG wire

- Precision layer wound on wire basket spool.
  OD 300 mm
  ID 51 mm
  Width 100 mm
  Weight 15 kg
  Also available in drums and on big reels.



TIG wire

- In cardboard box.
  Cut length 1000 mm
  Weight 5 kg



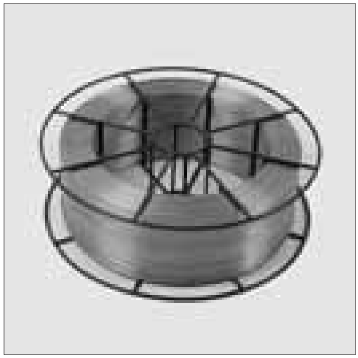
SAW wire

- Precision layer wound on wire basket spool.
  ID 300 mm
  Width 100 mm
  Weight 25 kg

Flux cored wire FCW

- Layer wound on wire basket spools (0.90 mm diam. on plastic spools).
- Moisture resistant packaging.
  OD 300 mm
  ID 51 mm
  Width 100 mm

Weights	0.90 mm	5 kg
	1.20 mm	15 kg
	1.60 mm	17 kg

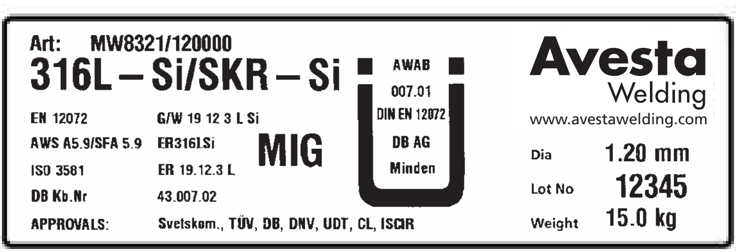


Welding flux

- Plastic lined paper sacks

Weights	Flux 801, 805, 807	25 kg
	Flux 301	20 kg

Other packaging or dimensions are available on request.



Conversion tables – EN units to ASTM, ASME

Packaging (electrodes)

Electrode diameter mm	inch, corresp.	Electrode length mm	inch, corresp.
1.60	1/16″	250	10
2.00	5/64″	300	12
2.50	3/32″	350	14
3.25	1/8″	400	16
4.00	5/32″	450	18
5.00	3/16″		

Weight

1 kg = 2.2046 lbs; 1 lb = 0.4536 kg

Examples (electrode packages):
8.16 kg = 18 lbs
10.89 kg = 24 lbs
12.30 kg = 27 lbs
13.62 kg = 30 lbs
15.90 kg = 35 lbs

Metric conversion factors, useful for welding applications

Property	Preferred unit	Symbol	To convert from...	multiply by...	to get...
Area	millimeter squared	mm^2	in^2	645.16	mm^2
			mm^2	.0016	in^2
Current density	ampere per millimeter squared	A/mm^2	A/in^2	.0016	A/mm^2
			A/mm^2	645.16	A/in^2
Deposition rate	kilogram per hour	kg/h	lb/hr	.45	kg/h
			kg/h	2.2	lb/hr
Energy	joule	J	ft·lbf	1.355	J
			J	.7375	ft·lbf
			kpm	7.233	ft·lbf
			kpm	9.806	J
Heat input	joule per meter	J/m	kJ/in	.0394	MJ/m
	(megajoule per meter)*	(MJ/m)*	J/in	39.37	J/m
			J/m	.0254	J/in
	kilojoule per millimeter	kJ/mm	kJ/mm	25.4	kJ/in
			kJ/in	.0394	kJ/mm
Linear measure	millimeter	mm	in	25.40	mm
			ft	304.8	mm
			mm	.0394	in
			mm	.0033	ft
Tensile strength Yield strength	megapascal	MPa	N/mm^2	145.03	psi
		($1\ N/mm^2 = 1$ MPa)	bar	10^5	Pa
			psi	.0069	MPa
			MPa	145.03	psi
			ksi	6.8947	MPa
			MPa	.1450	ksi
			kg/mm^2	1422.0	psi
			kg/mm^2	9.806	MPa
Travel speed	millimeter per second	mm/s	in/min	.4233	mm/s
			mm/s	2.363	in/min

Temperature

°C = 5/9 x (°F – 32)
°F = 9/5°C + 32

Examples:	1200°C = 2192°F
	1150°C = 2102°F
	1100°C = 2012°F
	1050°C = 1922°F
	1000°C = 1832°F
	950°C = 1742°F
	900°C = 1652°F
	850°C = 1562°F
	590°C = 1094°F
	550°C = 1022°F
	500°C = 932°F
	150°C = 302°F
	100°C = 212°F
	+20°C = +68°F
	– 40°C = –40°F
	–196°C = –321°F

Tensile and yield strength

1 N/mm² = 145.03 psi = 0.1450 ksi
1 ksi = 6.8947 N/mm²
1 N/mm² = 1 MPa

Examples:	350 N/mm² = 51 ksi
	400 N/mm² = 58 ksi
	450 N/mm² = 65 ksi
	500 N/mm² = 73 ksi
	550 N/mm² = 80 ksi
	600 N/mm² = 87 ksi
	650 N/mm² = 94 ksi
	700 N/mm² = 102 ksi
	750 N/mm² = 109 ksi
	800 N/mm² = 116 ksi
	850 N/mm² = 123 ksi

Impact strength

1 J = 0.7375 ft·lbf
1 ft·lbf = 1.355 J

Examples:	20 J = 15 ft·lbf
	30 J = 22 ft·lbf
	40 J = 30 ft·lbf
	50 J = 37 ft·lbf
	60 J = 44 ft·lbf
	70 J = 52 ft·lbf
	80 J = 59 ft·lbf
	90 J = 66 ft·lbf
	100 J = 74 ft·lbf
	110 J = 81 ft·lbf
	120 J = 89 ft·lbf
	130 J = 96 ft·lbf
	140 J = 103 ft·lbf
	150 J = 111 ft·lbf
	160 J = 118 ft·lbf
	170 J = 125 ft·lbf
	180 J = 133 ft·lbf
	190 J = 140 ft·lbf
	220 J = 148 ft·lbf
	210 J = 155 ft·lbf
	220 J = 162 ft·lbf
	250 J = 184 ft·lbf

Heat input

1 kJ/mm = 25.4 kJ/in
1 kJ/in = 0.0394 kJ/mm

Examples:	0.5 kJ/mm = 12.7 kJ/in
	1.0 kJ/mm = 25.4 kJ/in
	1.5 kJ/mm = 38.1 kJ/in
	2.0 kJ/mm = 50.8 kJ/in
	2.5 kJ/mm = 63.5 kJ/in

Abbreviations

In addition to chemical symbols (e.g. Fe = iron), physical units (e.g. MPa = megapascal) and product names (e.g. 254 SMO), this manual uses a number of abbreviations and acronyms. The following list may be useful.

ABS	American Bureau of Shipping
AC	alternating current
AC/DC	standard rutile-acid coating (electrodes)
AISI	American Iron and Steel Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BS	British Standard
BV	Bureau Veritas
CPP	continuously produced plate
CPT	critical pitting temperature
CWB	Canadian Welding Bureau
DB	Deutsche Bahn
DC	direct current
DCEN	DC electrode negative
DCEP	DC electrode positive
DCRP	DC reverse polarity
DCSP	DC straight polarity
DIN	Deutsches Institut für Normung
DNV	Det Norske Veritas
ELC	extra low carbon
EN	European Norm (Europäische Norm)
ESW	electroslag welding
FCAW	flux cored arc welding
FCW	flux cored wire
FN	ferrite number
GL	Germanischer Lloyd
GMAW	gas metal arc welding
GTAW	gas tungsten arc welding
HAZ	heat-affected zone
HF	high frequency
HI_R	root pass heat input
HT	high temperature
HX	high-recovery rutile-acid coating
IGC	intergranular corrosion
IIW	International Institute of Welding
ISO	International Organization for Standardization
JIS	Japanese Industrial Standard
LF	low ferrite (filler)
Lloyd's	Lloyd's Register of Shipping
MAG	metal active gas
M_F	martensite finish
MIG	metal inert gas
MMA	manual metal arc
MPI	magnetic particle inspection
M_S	martensite start
NA	not applicable
NF	non-ferrite (filler)
NF	Norme Française
NG	narrow gap
NORSOK	Norsk Sokkels Konkuranseposisjon
PAW	plasma arc welding
PT	penetrant test
PW	rutile-acid coating for position welding vertical-up
PWHT	post-weld heat treatment
pWPS	preliminary welding procedure specification
PWX	rutile-acid coating for tube welding
RT	radiography test
RT	room temperature
SAW	submerged arc welding
SECB	square edge closed butt

SK	Svetskommissionen
SMAW	shielded metal arc welding
SS	Svensk Standard
T	temperature
t	thickness
TIG	tungsten inert gas
TÜV	Technischer ÜberwachungsVerein
UDT	Urzad Dozoru Technicznego
UNS	Unified Numbering System
UT	ultrasonic test
VDX	rutile-acid coating for position welding vertical-down
WAC	weld acceptance criteria
WPAR	welding procedure approval record
WPS	welding procedure specification
WRC	Welding Research Council

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Bold entries indicate main chapter headings.

Outokumpu is a dynamic metals and technology group
with a clear target to become the number one in stainless steel.
Customers in a wide range of industries use our metal products,
technologies and services worldwide. We are dedicated to
helping our customers gain competitive advantage.
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Avesta Welding AB
P.O. Box 501
SE-774 27 Avesta, Sweden
Tel: +46 (0)226 815 00
Fax: +46 (0)226 815 75
Email: info@avestawelding.com
www.avestawelding.com

Avesta Welding

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