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Stainless
welding products

SANDVIK

Sandvik Materials Technology serves the world of welding

For over 70 years Sandvik Materials Technology has been one of the world's major manufacturers of stainless welding products. The knowledge and experience which we have gained is invested in active and ongoing development of products for automated welding.

We control our own metallurgy to complement our wire and strip production. This means that we control the whole production chain from steel melt to finished product, using the latest, most reliable technology.

You benefit from our R&D

Sandvik's leading metallurgy, inclusion and trace-element technology enable us to produce welding products with optimum and consistent properties. We can produce materials, which meet the requirements of the most demanding standards and applications.

Experienced technicians in our welding laboratories undertake continuous development of welding products and processes so that our customers can achieve the best welding results and the highest productivity.

A programme for every job

Sandvik can offer welding products in the form of wire, strip and covered electrodes for all common welding methods. You will find welding products in our range for most stainless materials, including duplex and superduplex stainless steels and nickel-base alloys. Fluxes, pickling and neutralisation pastes and accessories for mechanised welding are also available to complement the product package.

Make use of our know-how

Our welding expertise and the practical know-how of our sales force are at your disposal to solve your welding problems and improve your productivity.

We are where you are

We manufacture in Sweden, Brazil and the USA. So, with production facilities on three continents, our own sales units in 130 countries, supported by agents and distributors, you are never far away from products, service and support.

Our logistical network can provide you with all necessary order processing and progress details.
And, we can share technical and commercial information with you using the latest web techniques. We invite you to visit us on our web site:
www.smt.sandvik.com

Sandvik Group

The Sandvik Group is a global high technology enterprise with 39,000 employees in 130 countries. Sandvik's operations are concentrated on its three core businesses of Sandvik Tooling, Sandvik Mining and Construction, and Sandvik Materials Technology – areas in which the group holds leading global positions in selected niches.

Sandvik Materials Technology

Sandvik Materials Technology is a world-leading manufacturer of high value-added products in advanced stainless steels, special alloys, metallic and ceramic resistance materials, as well as process plants and sorting systems.

Quality Assurance

Sandvik Materials Technology has Quality Management Systems approved by internationally recognised organisations. We hold for example: the ASME Quality System Certificate as a Materials Organisation; approval to ISO 9001, QS 9000 and PED 97/23/EC, as well as approvals from LRQA, JIS, TüV and others as a materials manufacturer.

Environment

Environmental awareness is an integral part of our business and is at the forefront of all activities within our operation. We hold approval to ISO 14001.

Index

Choice of welding consumables

The choice of welding consumable is crucial to the result of the welding operation. It must give the required weld properties and ensure a crack-free weld. The key factor in the choice is, of course, the parent metal, but welding method can also influence the selection of filler metal. For surfacing, the welding parameters have to be considered as well.

Balanced composition

The composition of the welding consumable normally corresponds to that of the parent metal. For example, parent metal 304L (18% Cr, 8% Ni) is welded with a 308L filler metal (19% Cr, 9% Ni). In general, the contents of the main alloying elements – Cr, Ni and Mo – are higher in the welding consumable than in the parent metal in order to compensate for segregation in the weld metal.

Impurity levels, however, are lower in the consumable than in the parent metal in order to reduce the risk of hot cracking, and to obtain the best arc stability, fluidity and wetting properties. In standard austenitic welding consumables – 308L, 316L, 347 and 317L – hot cracking can in practice be eliminated by a chemical composition, which gives a ferritic solidification. A ferrite content in the consumable of about 10% (10 FN) is usually sufficient, unless dilution from the parent metal is excessive.

Fully austenitic stainless steels and nickel-base alloys have the most stringent requirements regarding impurity content in order to deal with the hot-cracking problem. The prevention of hot cracking may be further strengthened by increased Mn and decreased Si contents. Ferrite is not present in these consumables, because it would destroy the corrosion resistance of the weld metal.

Variants of one and the same consumable

For most standard grades there are two versions available: one with normal and one with high silicon content. The chemical compositions have been adapted to suit the welding method.

MIG welding

The high silicon versions are recommended for MIG welding, because they give the best arc stability and smooth welds.

TIG and plasma-arc welding

In TIG and plasma-arc welding, the high silicon filler metals are not as advantageous as in MIG welding. Nonetheless, they are still preferred by many users. To satisfy most preferences, standard grade

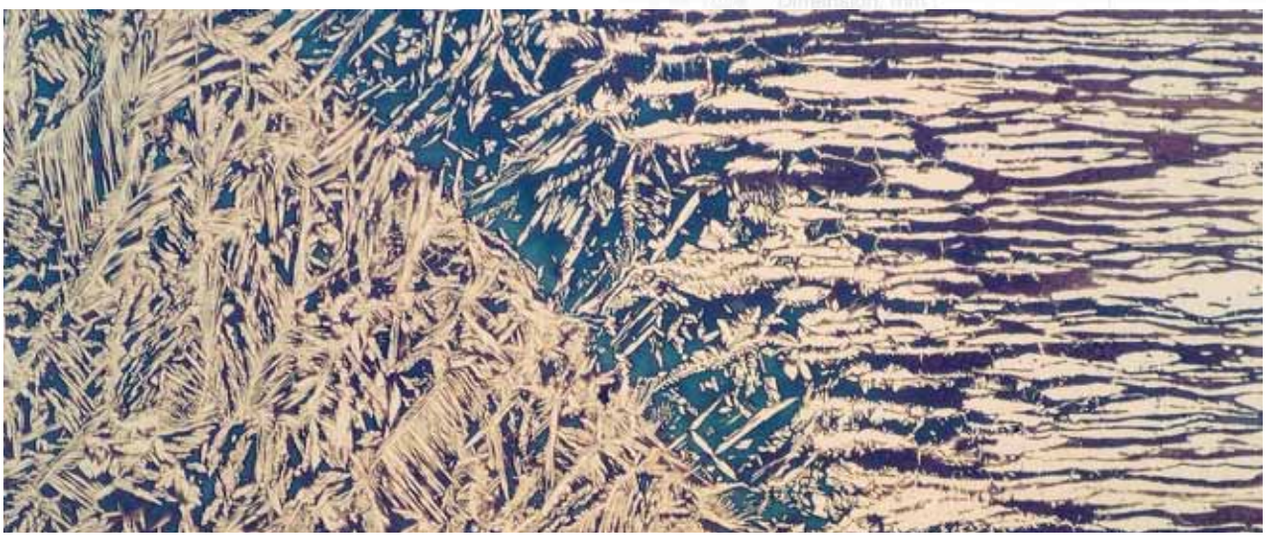
TIG rods are therefore made in both variants. The main reason for high silicon electrodes for plasma-arc welding is their greater availability.

Submerged-arc welding

The normal-silicon content version is required for submerged-arc welding. High silicon versions are not suitable because the silicon pick-up from the flux would result in too high silicon content in the deposit.

Simplified stock holding

For stock holding reasons, many fabricators use one consumable grade to weld several different parent metals. Molybdenum has been shown to give only positive effects, except in highly concentrated, hot nitric acid environments. Therefore, 316L consumables can normally be used for both 316/316L and 304/304L parent metals. The simpler stock holding and the elimination of the risk of mixed material fully compensates for the potentially higher price for 316L consumables compared to 308L.



Recommended selection of welding consumables

The tables below give typical selections of welding consumables and basic designations for wire electrodes and filler wire/rods. They do not indicate the Si-alloyed variants used for MIG welding or the variants of covered electrodes or wire-flux combinations for submerged-arc welding. For exact designations, please refer to the tables with chemical compositions in the various sections of this brochure.

To address the welding job in question a number of factors have to be considered. The weld geometry and dilution, requirements for heat treatment in association with the welding process, service conditions and temperature, etc. These factors may dictate the choice of consumable beyond those recommended here. This is particularly relevant with the welding of high-nickel steels and nickel alloys, such as Alloy 800 and Alloy 600, which require thorough evaluation of the materials used as well as service conditions and temperature.

For guidance on other steels or combination of steels not covered in these tables, please contact Sandvik.

Joining of similar materials				
Parent metal			Sandvik welding consumable	
AISI/UNS/ Common name	EN	Sandvik	Normal choice [a]	Over-alloyed choice [a]
304L [b]	1.4306 [b]	3R12 [b]	19.9.L (19.9.Nb)	19.12.3.L (19.12.3.Nb)
321 / 347 [b]	1.4541 / 1.4550 [b]	6R35 / 8R40 [b]	19.9.Nb (19.9.L)	19.12.3.Nb (19.12.3.L)
316L [b]	1.4435 [b]	3R60 [b]	19.12.3.L (19.12.3.Nb)	25.22.2.LMn
"316Ti" [b, c] / 318 [b]	1.4571 [b] / –	5R75 [b] / –	19.12.3.Nb (19.12.3.L)	(20.25.5.LCu)
317L	1.4438	3R64	19.13.4.L	20.25.5.LCu
310	1.4845 [b]	7RE10 [b]	25.20.C	–
S30815	1.4835	253MA	22.12.HT	–
S35315	1.4854	353MA	28.34.HT	–
"310L" [c]	1.4335	2RE10	25.20.L	(25.22.2.LMn)
S31050	1.4466	2RE69	25.22.2.LMn	–
S31500	1.4417	3RE60	22.8.3.L	–
S31803	1.4462	SAF 2205	22.8.3.L	25.10.4.L
S32304	1.4362	SAF 2304	22.8.3.L	–
S32750	1.4410	SAF 2507	25.10.4.L [d]	–
S32906	–	SAF 2906	29.8.2.L	–
N08028	1.4563	Sanicro 28	27.31.4.LCu	–
N08904	1.4539	2RK65	20.25.5.LCu	27.31.4.LCu
S31254	1.4547	254 SMO	Sanicro 60	–
Alloy 600	–	Sanicro 70	Sanicro 72HP	–
Alloy 625	–	–	Sanicro 60	–
Alloy 800	1.4876	Sanicro 31HT	Sanicro 72HP	–
Alloy 825	–	Sanicro 41	27.31.4.LCu	–

[a] Alternative selection within brackets.
[b] Also other grades with similar chemical compositions (minor variations mainly the C and/or N contents). Stabilising element, if any, can be either Ti or Nb.
[c] Not standard designation. For information only.
[d] 25.10.4.L can also be used for the welding of other similar superduplex steels as well as for a group of 25% Cr duplex steels with PRE values between 37 and 40 – S31803 has PRE 35 and S32750 PRE >41.

Joining of dissimilar materials

Parent metal 1[a] Type AISI/UNS EN Sandvik	Parent metal 2 [b] AISI/UNS/ Common name	EN	Sandvik Welding consumable
Carbon and low-alloyed steel	304L	1.4306	18.8.Mn/24.13.LHF/22.15.3.L
	321/347	1. 4541/1. 4550	18.8.Mn/24.13.LHF/22.15.3.L
	316L	1.4435	18.8.Mn/24.13.LHF/22.15.3.L
	"316Ti"/318	1.4571/–	18.8.Mn/24.13.LHF/22.15.3.L
	S30815	1.4835	22.12.HT
	S35315	1.4854	28.34.HT
	S31803	1.4462	22.8.3.L
	S32304	1.4362	22.8.3.L
	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/ Sanicro 60
18/8 304L 1.4306 3R12	321/347	1.4541/1.4550	19.9.L/19.9.Nb
	316L	1.4435	19.12.3.L
	"316Ti"/318	1.4571/–	19.12.3.L/19.12.3.Nb
	S30815	1.4835	22.12.HT
	S35315	1.4854	28.34.HT
	S31803	1.4462	22.8.3.L
	S32304	1.4362	22.8.3.L
	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/ Sanicro 60
18/8/Ti or Nb 321/347 1.4541/1.4550 6R35/8R40	316L	1.4435	19.12.3.L
	"316Ti"/318	1.4571/–	19.12.3.L/19.12.3.Nb
	S30815	1.4835	22.12.HT
	S35315	1.4854	28.34.HT
	S31803	1.4462	22.8.3.L
	S32304	1.4362	22.8.3.L
	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/Sanicro 60
18/12/Mo 316L 1.4435 3R60	"316Ti"/318	1.4571/–	19.12.3.L/19.12.3.Nb
	S30815	1.4835	22.12.HT
	S35315	1.4854	28.34.HT
	S31803	1.4462	22.8.3.L
	S32304	1.4362	22.8.3.L
	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/Sanicro 60
18/12/Mo/Ti or Nb "316Ti"/318 1.4571/– 5R75	S30815	1.4835	22.12.HT
	S35315	1.4854	28.34.HT
	S31803	1.4462	22.8.3.L
	S32304	1.4362	22.8.3.L
	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/Sanicro 60

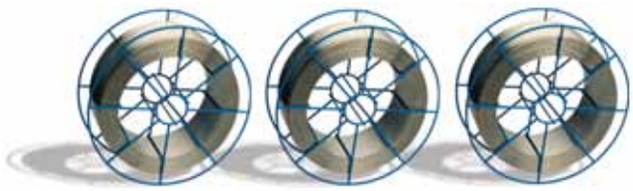
Parent metal 1[a] Type AISI/UNS EN Sandvik	Parent metal 2 [b] AISI/UNS/ Common name	EN	Sandvik Welding consumable
Duplex S31803 1.4462 SAF 2205	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/Sanicro 60
Duplex S32304 1.4362 SAF 2304	S32750	1.4410	25.10.4.L
	S32906	–	29.8.2.L
	N08028	1.4563	27.31.4.LCu
	N08904	1.4539	20.25.5.LCu
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 72HP/Sanicro 60
Superduplex S32750 1.4410 SAF 2507	N08028	1.4563	Sanicro 60
	N08904	1.4539	Sanicro 60
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 60
Superduplex S32906 – SAF 2906	N08028	1.4563	Sanicro 60
	N08904	1.4539	Sanicro 60
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 60
20/25/5 N08904 1.4539 2RK65	N08028	1.4563	Sanicro 60
	S31254	1.4547	Sanicro 60
	Alloy 600 [c]	–	Sanicro 60
20/18/6 S31254 1.4547 254 SMO	N08028	1.4563	Sanicro 60
	Alloy 600 [c]	–	Sanicro 60
27/31/4 N08028 1.4563 Sanicro 28	Alloy 600 [c]	–	Sanicro 60

[a] Each group of stainless steels is also valid for other grades with similar compositions.

[b] Also other steels with similar compositions.

[c] Represents a whole group of Ni/Cr and Ni/Cr/Mo alloys, such as Alloy 625, Alloy 800 and Alloy 825.

Wire electrodes and filler wire/rods



A demand for better productivity and lower production costs drives a trend within the welding industry towards the increased use of mechanised welding methods. This calls for automatic welding wire of higher quality, especially concerning feeding and welding properties. However, the development must not lead to impaired weld deposit corrosion resistance or strength.

Achieving this delicate balance has been the challenge for our experts in steel melting, wire production and R&D. By mastering the micro-metallurgy and the wire drawing techniques we can produce material with excellent and consistent properties from delivery to delivery – a pre-requisite for improved productivity. All properties are thoroughly tested in our own welding laboratories.

A full product programme

Our programme contains filler metals in standard and special stainless steels and alloys suitable for MIG, TIG, plasma-arc and submerged-arc welding.

For most standard grades there are variants with both normal and high silicon content to suit different welding methods. All grades have a well controlled, low impurity level to reduce the risk of hot cracking. Please refer to "Choice of welding consumables" on page 4 for more details.

We pay attention to the delivery form

Wire for MIG, mechanised TIG and submerged-arc welding is delivered as standard on environmentally friendly basket spools. Empty spools can be treated as metal scrap. There are two types, one for MIG and mechanised TIG welding (15 kg) and one for submerged-arc welding (28 kg). The MIG and mechanised TIG spool has been developed by Sandvik and is the adopted European standard type BS 300, in accordance with EN 759.

We also have other spools, holding different weights, designed to meet customer needs.

TIG rods are supplied in cartons and in straightened lengths of normally 1000 mm. Subject to agreement other lengths can be supplied.

Pay-off system for automatic welding

For robotic and mechanised MIG welding we offer a special pay-off system – Sanpac – containing 150 or 300 kg of filler wire.

The advantages are:

- Increased productivity with less down time compared with standard spools.
- Less wear on welding-machine parts – no-twist pay-off system.
- Clean conditions – no contamination from the shop environment.
- Low space requirements – the drum diameter is only 510 mm.
- Short set-up time – adapts quickly and easily to any conventional feeder.

More information

Comprehensive data sheets and material safety data sheets (MSDS) can be ordered from our sales offices or, through our web site: www.smt.sandvik.com

Delivery forms

Sanpac ▲
Wire diameter 0.8, 1.0, 1.2, 1.6 mm. Outside diameter of the drum 510 mm. Height of drum 450 or 820 mm. Wire weight approx. 150 or 300 kg.

Basket rim, B 450 ▼
Wire diameter 2.0, 2.4, 3.2, 4.0, 5.0 mm. Wire weight 28 kg. Precision layer wound. Highly environmentally compatible. Empty rims can be treated as metal scrap.

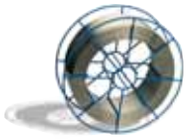
◀ ***Basket spool, BS 300***
Wire diameter 0.8, 1.0, 1.2, 1.6 mm. Wire weight 15 kg. Precision layer wound. Highly environmentally compatible. Empty spools can be treated as metal scrap.

Rods ▶
Wire diameter 1.0, 1.2, 1.6, 2.0, 2.4, 3.2, 4.0, 5.0 mm. Length 1000 mm. Weight of rods 5 kg. Each rod marked for identity. Paper carton.

Plastic spool, S 100 ▲
Wire diameter max 1.0 mm. Wire weight 1 kg. Precision layer wound.

Plastic spool, S 200 ▶
Wire diameter max 1.0 mm. Wire weight 5 kg. Normal wound.

Chemical composition

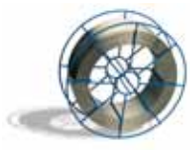


Sandvik	Corresponds to		Chemical composition (nominal), %						
	AWS [a]	EN 12072							
	ER	G/W/P/S [b]	C	Si	Mn	Cr	Ni	Mo	Others
Austenitic stainless steels									
19.9.L	308L	19 9 L	≤0.025	0.4	1.8	20	10	–	–
19.9.LSi	308LSi	19 9 L Si	≤0.025	0.9	1.8	20	10.5	–	–
19.9.Nb	347	19 9 Nb	0.03	0.4	1.3	19.5	9.5	–	Nb≥12xC
19.9.NbSi	347Si	19 9 Nb Si	0.04	0.9	1.2	19.5	10	–	Nb≥12xC
19.12.3.L	316L	19 12 3 L	≤0.020	0.4	1.8	18.5	12.5	2.6	–
19.12.3.LSi	316LSi	19 12 3 L Si	≤0.025	0.9	1.8	18.5	12.5	2.6	–
19.13.4.L	317L	19 13 4 L	≤0.020	0.4	1.5	19	14	3.7	–
19.12.3.Nb	318	19 12 3 Nb	0.04	0.4	1.5	18.5	11.5	2.6	Nb≥12xC
19.12.3.NbSi	"318Si"	19 12 3 Nb Si	0.04	0.9	1.2	18.5	12.5	2.6	Nb≥12xC
18.8.Mn	(307)	18 8 Mn Si	0.08	0.9	7.0	18	8	–	–
18.8.CMn	"307C"	18 8 Mn	0.15	0.4	7.0	18	8	–	–
24.13.L	309L	23 12 L	≤0.020	0.4	1.8	23.5	13.5	–	–
24.13.LSi	309LSi	23 12 L Si	≤0.025	0.9	1.8	23.5	13.5	–	–
24.13.LHF	309L	23 12 L	≤0.015	0.3	1.8	24	13	–	–
24.13.Si	309Si	22 12 H	0.09	0.9	1.8	23.5	13	–	–
24.13.LNb	“309LNb”	23 12 Nb	≤0.020	0.3	2.1	24	12.5	–	Nb=0.8
22.15.3.L	(309LMo)	23 12 2 L	≤0.025	0.4	1.5	21.5	15	2.7	–
24.16.3.L	(309LMo)	(23 12 2 L)	≤0.020	0.4	1.5	24.5	17	2.8	–
25.20.C	310	25 20	0.12	0.3	1.8	26	21	–	–
29.9	312	29 9	0.10	0.4	1.8	30.5	9	–	–
Special purpose grades									
22.8.3.L	2209	22 9 3 N L	≤0.020	0.5	1.6	23	9	3.2	N=0.16
22.8.3.LSi	2209	22 9 3 N L	≤0.020	0.8	1.8	23	9	3.2	N=0.16
25.10.4.L	2594	25 9 4 N L	≤0.020	0.3	0.4	25	9.5	4.0	N=0.25
29.8.2.L	–	–	≤0.020	0.3	1.0	29	7	2.2	N=0.35
22.12.HT	–	–	≤0.10	1.7	0.5	21	10	–	N=0.17
28.34.HT	–	–	0.04	0.7	1.8	27.5	35	–	N=0.15
25.20.L	–	–	≤0.020	0.2	1.8	24.5	20.5	≤0.30	–
25.22.2.LMn	(310LMo)	25 22 2 N L	≤0.020	≤0.2	4.5	25	22	2.1	N=0.13
20.25.5.LCu	385	20 25 5 Cu L	≤0.020	0.4	1.8	20	25	4.5	Cu=1.5
27.31.4.LCu	383	27 31 4 Cu L	≤0.020	≤0.2	1.8	27	31	3.5	Cu=1.0
Sanicro 60	NiCrMo-3	–	≤0.030	0.2	0.2	22	>60	9.0	Nb=3.5 Fe≤1.0
Sanicro 68HP	NiCrFe-7	–	≤0.030	0.2	0.5	29	>58	–	Fe=10
Sanicro 72HP	NiCr-3	–	≤0.030	0.1	3.0	20	72.5	–	Nb=2.6 Fe≤1.0

[a] (xxx) = nearest equivalent; "xxx" = constructed classification, denotes the type.
[b] G = MIG welding; W = TIG welding; P = Plasma-arc welding; S = Submerged-arc welding.

Approvals
Most welding-wire/rod grades are approved by inspection authorities and/or shipping societies such as TÜV, DB, Controlas, UDT, DNV. Please contact your nearest Sandvik office for our latest list of approvals.

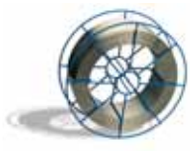
Properties and applications



Sandvik AWS ER EN 12072 [a]	Suitable welding methods [b]	Mechanical properties typical values at 20°C		Applications	Corrosion resistance
19.9.L 308L 19 9 L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	390 MPa 600 MPa 34% 135 J	Joining of stainless Cr-Ni steels, stabilised or non-stabilised, e.g. 304, 304L, 321 and 347, for service temperatures up to 350°C. Also for stainless Cr steels with max 19% Cr. Cryogenic applications down to -269°C, depending on welding process.	Good resistance to general and, owing to the low C content, intergranular corrosion.
19.9.LSi 308LSi 19 9 L Si	MIG TIG PAW	$R_{p0.2}$ R_m A KV	390 MPa 600 MPa 42% 120 J	Joining of stainless Cr-Ni steels, stabilised or non-stabilised, e.g. 304, 304L, 321 and 347, for service temperatures up to 350°C. Also for stainless Cr steels with max 19% Cr. Cryogenic applications down to -269°C, depending on welding process.	Good resistance to general and, owing to the low C content, intergranular corrosion.
19.9.Nb 347 19 9 Nb	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	400 MPa 610 MPa 42% 150 J	Joining of stainless, stabilised Cr-Ni steels, e.g. 321 and 347. Due to the strengthening effect of Nb, 19.9.Nb is recommended for weld metals subjected to temperatures above 400°C. Particularly suitable for use in the nuclear industry owing to the low cobalt and impurity levels. Also for overlay welding of pressure vessels for the petrochemical industry.	Good resistance to general and, owing to the Nb content, intergranular corrosion.
19.9.NbSi 347Si 19 9 Nb Si	MIG TIG PAW	$R_{p0.2}$ R_m A KV	400 MPa 610 MPa 35% 110 J	Joining of stainless, stabilised Cr-Ni steels, e.g. 321 and 347. Due to the strengthening effect of Nb, 19.9.NbSi is recommended for weld metals subjected to temperatures above 400°C.	Good resistance to general and, owing to the Nb content, intergranular corrosion.
19.12.3.L 316L 19 12 3 L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	410 MPa 610 MPa 35% 110 J	Joining of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C. Also for stainless Cr steels with max 19% Cr.	Good resistance to general and, owing to the low C content, intergranular corrosion. The Mo content gives good resistance also to pitting.
19.12.3.LSi 316LSi 19 12 3 L Si	MIG TIG PAW	$R_{p0.2}$ R_m A KV	400 MPa 610 MPa 37% 130 J	Joining of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C. Also for stainless Cr steels with max 19% Cr.	Good resistance to general and, owing to the low C content, intergranular corrosion. The Mo content gives good resistance also to pitting.
19.13.4.L 317L 19 13 4 L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	380 MPa 600 MPa 47% 140 J	Joining of stainless Cr-Ni-Mo ELC steels, e.g. 316L and 317L, for use in more severe corrosion conditions, e.g. in the petrochemical and pulp and paper industries.	Good corrosion resistance in most inorganic and organic acids owing to the high Mo content. Better resistance to pitting in chloride-bearing solutions than 19.12.3.L because of the higher Mo content. The good resistance to intergranular corrosion is due to the low C content.
19.12.3.Nb 318 19 12 3 Nb	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	400 MPa 610 MPa 36% 135 J	Joining of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C.	Good resistance to general and, owing to the Nb content, intergranular corrosion. The Mo content gives good resistance also to pitting.
19.12.3.NbSi "318Si" 19 12 3 Nb Si	MIG TIG PAW	$R_{p0.2}$ R_m A KV	400 MPa 610 MPa 35% 110 J	Joining of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C.	Good resistance to general and, owing to the Nb content, intergranular corrosion. The Mo content gives good resistance also to pitting.
18.8.Mn (307) 18 8 Mn Si	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	460 MPa 650 MPa 41% 140 J	Joining of work-hardenable steels, armour plates, stainless austenitic Mn steels and free-machining steels, e.g. 303. Also for stainless Cr steels with max. 18% Cr, e.g. in the automotive industry. Overlay welding of carbon and low-alloyed steels.	The corrosion resistance is similar to that of the respective parent metal.

[a] Prefix G/W/P/S according to EN 12072, where G = MIG welding; W = TIG welding; P = Plasma-arc welding; S = Submerged-arc welding.
[b] MIG = Metal Inert Gas welding, TIG = Tungsten Inert Gas welding, PAW = Plasma-arc Welding, SAW = Submerged-arc Welding.

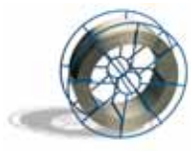
Properties and applications



Sandvik AWS ER EN 12072 [a]	Suitable welding methods [b]	Mechanical properties typical values at 20°C		Applications	Corrosion resistance
18.8.CMn "307C" 18 8 Mn	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	460 MPa 650 MPa 42% 150 J	Joining of work-hardenable steels, armour plates, stainless austenitic Mn steels and free-machining steels, e.g. 303. Also for stainless Cr steels with max.18% Cr. Overlay welding of carbon and low-alloyed steels.	The corrosion resistance is similar to that of the respective parent metal.
24.13.L 309L 23 12 L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	400 MPa 600 MPa 40% 140 J	Joining of stainless Cr-Ni steels of the 309 type, wrought or cast. Also for stainless Cr steels. Dissimilar steels, e.g. austenitic stainless steel to carbon or low-alloyed steels for service up to 320°C. First-layer overlay welding of carbon or low-alloyed steels to give a 304L deposit.	The corrosion resistance is similar to that of the respective parent metal.
24.13.LSi 309LSi 23 12 L Si	MIG TIG PAW	$R_{p0.2}$ R_m A KV	400 MPa 600 MPa 35% 140 J	Joining of stainless Cr-Ni steels of the 309 type, wrought or cast. Also for stainless Cr steels, e.g. in the automotive industry.	The corrosion resistance is similar to that of the respective parent metal.
24.13.LHF 309L 23 12 L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	410 MPa 600 MPa 40% 140 J	Joining of dissimilar steels, e.g. austenitic stainless steel to carbon or low-alloyed steel for service temperatures up to 300°C. Stainless Cr-Ni steels of the 309 type, wrought or cast. Problem solver when center-line cracking occurs with 24.13.L. Overlay welding of carbon or low-alloyed steels.	The corrosion resistance is similar to that of the respective parent metal.
24.13.Si 309Si 22 12 H	MIG TIG PAW	$R_{p0.2}$ R_m A KV	400 MPa 640 MPa 35% 115 J	Joining of stainless Cr-Ni steels of the 304 and 309 types, wrought or cast. Heat-resistant, similar steels. Dissimilar steels, e.g. austenitic stainless steel to carbon or low-alloyed steel. Also for stainless Cr steels, e.g. in the automotive industry.	The corrosion resistance is similar to that of the respective parent metal. Good oxidation resistance in air up to 950°C.
22.15.3.L (309LMo) 23 12 2 L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	400 MPa 600 MPa 40% 140 J	Joining of stainless Cr-Ni or Cr-Ni-Mo steels 304, 309 or 316 to ensure corrosion resistance in e.g. the pulp & paper industry. For dissimilar joints when alloying with Mo is essential. Overlay applications where higher Mo content is desired in the second and third layers.	The corrosion resistance is similar to that of the respective parent metal.
25.20.C 310 25 20	MIG TIG PAW	$R_{p0.2}$ R_m A KV	390 MPa 590 MPa 43% 175 J	Joining of heat-resistant stainless Cr-Ni steels of the 310 type.	Good oxidation resistance in air up to 1100°C.
29.9 312 29 9	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	520 MPa 730 MPa 25% 100 J	Joining of stainless steels where high strength or wear resistance is essential. Problem solver when joining similar or dissimilar steels with limited weldability. Overlay welding of carbon and low-alloyed steels.	High oxidation resistance in air up to 1100°C. Work-hardenable and hot-cracking resistant.
22.8.3.L 2209 22 9 3 N L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	600 MPa 750 MPa 25% 160 J	Joining of duplex stainless steels Sandvik 3RE60, SAF 2205 and SAF 2304 or other similar duplex steels.	Very good resistance to intergranular corrosion and pitting. Good resistance to stress corrosion cracking, especially in environments containing H_2S and chlorides.
25.10.4.L – 25 9 4 N L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	650 MPa 850 MPa 25 % 160 J	Joining of superduplex stainless steel Sandvik SAF 2507 or other similar superduplex steels. Can also be used to join SAF 2205 and other duplex steels of the 25% Cr type when the highest possible corrosion resistance is desired.	Better resistance to intergranular corrosion, pitting and stress corrosion cracking than 22.8.3.L.

[a] Prefix G/W/P/S according to EN 12072, where G = MIG welding; W = TIG welding; P = Plasma-arc welding; S = Submerged-arc welding.
[b] MIG = Metal Inert Gas welding, TIG = Tungsten Inert Gas welding, PAW = Plasma-arc Welding, SAW = Submerged-arc Welding.

Properties and applications



Sandvik AWS ER EN 12072 [a]	Suitable welding methods [b]	Mechanical properties typical values at 20°C		Applications	Corrosion resistance
29.8.2.L – –	TIG PAW SAW	$R_{p0.2}$ R_m A KV	700 MPa 870 MPa 25% 180 J	Joining of superduplex stainless steel Sandvik SAF 2906 or other similar steels.	Better resistance to intergranular corrosion, pitting and stress corrosion cracking than 22.8.3.L.
22.12.HT – –	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	400 MPa 580 MPa 35% 120 J	Joining of stainless Cr-Ni steel Sandvik 253MA or other similar high-temperature steels.	High oxidation resistance in air up to 1150°C.
28.34.HT – –	MIG TIG PAW	$R_{p0.2}$ R_m A KV	410 MPa 600 MPa 30% 120 J	Joining of stainless Cr-Ni steel Sandvik 353MA or other similar high-temperature steels.	Excellent oxidation resistance in air up to 1200°C.
25.20.L – –	MIG TIG PAW	$R_{p0.2}$ R_m A KV	380 MPa 590 MPa 37% 120 J	Joining of stainless Cr-Ni steel Sandvik 2RE10 or other similar steels exposed to heavily oxidising media, e.g. nitric acid.	Especially suitable for use in oxidising media, e.g. nitric acid. Good resistance to intergranular corrosion and stress corrosion cracking owing to the high Cr and Ni contents.
25.22.2.LMn (310LMo) 25 22 2 N L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	335 MPa 575 MPa 42% 120 J	Joining of stainless Cr-Ni-Mo steels used in the urea industry, e.g. Sandvik 2RE69 or other similar steels as well as modified type 316L. Stainless Cr-Ni and Cr-Ni-Mo steels, 304L, 304LN and 316L, 316LN, for cryogenic applications down to -269°C and/or applications demanding low magnetic permeability.	High resistance to pitting and intergranular corrosion. More resistant to stress corrosion cracking than 19.12.3.L. Especially suitable for use in the urea industry.
20.25.5.LCu 385 20 25 5 Cu L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	400 MPa 540 MPa 35% 120 J	Joining of stainless high-alloyed Ni-Cr-Mo-Cu grade 904L or other similar materials.	Good resistance to stress corrosion cracking and intergranular corrosion as well as in non-oxidising acids, e.g. sulphuric, phosphoric and acetic. Better resistance to pitting than 19.13.4.L.
27.31.4.LCu 383 27 31 4 Cu L	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	360 MPa 540 MPa 35% 165 J	Joining of stainless superaustenitic grades, e.g. Sandvik Sanicro 28, Alloy 825 or other similar materials.	High resistance to general corrosion, particularly in contaminated phosphoric acid. Better resistance to intergranular corrosion, pitting and stress corrosion cracking than 20.25.5.LCu.
Sanicro 60 NiCrMo-3 –	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	430 MPa 670 MPa 42% 150 J	Joining of Alloy 625, Alloy 825 and other similar materials. Dissimilar materials, e.g. austenitic stainless steels to Ni-Cr-Mo grades. Steels of the 9% Ni type for cryogenic service. 254 SMO and similar 6% MoN stainless steels. Overlay welding of carbon and low-alloyed steels.	Good resistance to pitting corrosion. Very resistant to stress corrosion cracking in chloride-containing environments. Good resistance to oxidation in air up to 1100°C.
Sanicro 68HP NiCrFe-7 –	TIG PAW	$R_{p0.2}$ R_m A KV	420 MPa 650 MPa 38% 180 J	Joining of Alloy 690 and Alloy 600. Overlay welding in the nuclear industry.	Better resistance to stress corrosion cracking as well as general and intergranular corrosion than Sanicro 72HP.
Sanicro 72HP NiCr-3 –	MIG TIG PAW SAW	$R_{p0.2}$ R_m A KV	390 MPa 660 MPa 45% 245 J	Joining of Alloy 800, Alloy 800H, Alloy 600 and other similar materials. Steels of 9% Ni type used for cryogenic service. Dissimilar steels, e.g. austenitic stainless steels to carbon steels for high-temperature service, Ni-Cu alloys to carbon steels, and Ni-Cu alloys to nickel-base alloys.	Good resistance to stress corrosion cracking and, owing to the low C and high Cr contents, good resistance to general and intergranular corrosion. Good oxidation resistance in air up to 1175°C.

[a] Prefix G/W/P/S according to EN 12072, where G = MIG welding; W = TIG welding; P = Plasma-arc welding; S = Submerged-arc welding.
[b] MIG = Metal Inert Gas welding, TIG = Tungsten Inert Gas welding, PAW = Plasma-arc Welding, SAW = Submerged-arc Welding.

Shielding the weld

The primary tasks of a shielding gas are to protect the molten pool from the influence of the atmosphere, i.e. from oxidation and nitrogen absorption, and to stabilise the electric arc. The choice of gas can also influence the characteristics of the arc.

In submerged-arc welding the shield is achieved by a flux, completely covering the consumable, the arc and the molten pool. The flux also stabilises the electric arc. We have a range of fluxes to suit different applications.

Shielding gases

MIG welding

Besides the development of welding machines, the use of shielding gases contributes to increased efficiency in the MIG method. This has led to greater usage of MIG welding.

The basic gas for MIG welding is inert – argon (Ar) or helium (He), or a mixture of both. However, small additions of oxygen (O_2) or carbon dioxide (CO_2) can further stabilise the arc, improve the fluidity and also improve the quality of the weld deposit. For stainless steels there are also gases available containing small amounts of hydrogen (H_2).

The table below indicates the appropriate choice of gas for MIG welding, taking account of different types of stainless steel and arc types.

TIG and plasma-arc welding

The normal gas for TIG welding is argon or helium, or a mixture. In some cases nitrogen (N_2) and/or hydrogen (H_2) is added in order to achieve special properties. For instance, an addition of hydrogen can be used for many conventional stainless steels to increase productivity. Alternatively, if nitrogen is added, the weld deposit properties can be improved. Oxidising additions are not used because they destroy the tungsten electrode.

Gas	Parent metal Austenitic	Duplex	Ferritic	High-alloy austenitic	Super-duplex	Nickel alloys
MIG welding						
Ar	(●)	(●)	(●)	●	● [a]	●
He	(●)	(●)	(●)	●	● [a]	●
Ar + He	(●)	(●)	(●)	●	● [a]	●
Ar + (1-3)% O_2	● [b]	● [b]	● [b]	● [c]	● [b]	
Ar + (1-3)% CO_2 [d]	● [e]	● [e]	● [e]	● [c]	● [e]	
Ar + 30% He + (1-3)% O_2	● [f]	● [f]	● [f]	● [c]	● [f]	
Ar + 30% He + (1-3)% CO_2 [d]	● [f]	● [f]	● [f]	● [c]	● [f]	
Ar + 30% He + (1-2)% N_2				● [g]	●	
TIG welding						
Ar	●	●	●	●	●	
He	●	●	●	●	●	●
Ar + He	●	●	●	●	●	● [h]
Ar + (2-5)% H_2	● [i]			● [i]		● [i]
Ar + (1-2)% N_2		●			●	
Ar + 30% He + (1-2)% N_2		●			●	

a Ar preferably in pulsed MIG welding
b Higher fluidity of the molten pool than with Ar
c Except for 22.12.HT and 27.31.4.LCu where Ar is preferred
d Not to be used in spray-arc welding where extra low carbon is required
e Higher fluidity of the molten pool than with Ar. Better short-arc welding properties than with Ar + (1-3)% O_2
f Higher fluidity of the molten pool than with Ar. Better short-arc welding properties than with Ar + (1-3)% CO_2
g For nitrogen alloyed grades
h Ar + 30% He improves flow compared with Ar
i Preferably for automatic welding. High welding speed. Risk of porosity in multi-run welds.

Recommendations for shielding gases used in TIG welding of different stainless steels are given in the table above. For plasma-arc welding, the gas types with hydrogen additions in the table are mostly used as plasma gas, and pure argon as shielding gas.

Root protection

A perfect welding result, without impairment of corrosion resistance and mechanical properties, can only be obtained when using a backing gas with very low oxygen content. For best results, a maximum 20 ppm O_2 at the root side can be tolerated.

This can be achieved with a purging set-up and can be controlled with a modern oxygen meter.

Pure argon is by far the most common gas for root protection of stainless steels. Formiergas (90% N_2 + 10% H_2) is an excellent alternative for conventional austenitic steels. The gas contains an active component, H_2, which brings down the oxygen level in the weld area. Nitrogen can be used for duplex steels in order to avoid nitrogen loss in the weld metal.

In certain cases root flux can be an alternative to gas purging. Please refer to page 24 for further information.

Fluxes

Information about fluxes for submerged-arc welding is given in the section "Complementary products", page 24.

Covered electrodes

Manual metal arc welding with covered electrodes, MMA, is an all-round welding method. Although it is comparatively slow, it is an important complement to modern welding production. MMA is for instance often the best suited method for assembly and repair work and it is the only one that can be used outdoors without special measures.

We have developed a range of covered electrodes, which are adapted to the parent metals. The easy-to-weld electrodes ensure that the required weld-metal properties are met. Over the years we have gathered extensive know-how that is available to our customers and our product development engineers are always prepared to find solutions to difficult welding problems.

Our large programme of rutile and basic electrodes covers most standard and special stainless steels and alloys. We can also offer electrodes for high deposition and vertical-down welding.

Rutile electrodes

The rutile types (-16 and -17) are by far the most common where stainless steels are concerned. They can be used for all types of steels except high-alloyed austenitics, which require clean welds to meet the demands for corrosion resistance and the prevention of hot cracking. Rutile electrodes should not be selected when good impact strength is needed at low temperature.

Rutile electrodes weld with a smooth and stable arc. They are easy to strike and restrike. The amount of spatter is low and slag removal is easy. The weld bead is smooth with an even transition to the parent metal. The -17 type gives spray metal transfer with a stable arc, whereas the -16 type has globular metal transfer. The penetration is moderate for type -16 and shallow for type -17.

We can also offer rutile-basic electrodes intended for fully austenitic parent metals with high molybdenum content, e.g. UNS N08028 and N08904. Because these grades are so reliable in resisting hot cracking, all the above benefits can be obtained when welding is performed with this special type of rutile electrode.

Basic electrodes

The basic type (-15) has globular metal transfer. In comparison with the rutile electrodes, the basic electrodes are harder to strike and restrike, and slag removal is not as easy. They give a slightly convex bead with deeper penetration than rutile electrodes.

The main advantage of the basic electrodes is that they give cleaner weld deposits – less non-metallic inclusions and impurities. They are therefore recommended for parent metals of fully austenitic steels, e.g. type 25/22/2, and nickel-base alloys in order to avoid problems with hot cracking. The basic type is also used in cryogenic applications which require good impact properties.

High-deposition electrodes

These electrodes are of the rutile -17 type. They are used when high productivity is required, but mainly in the flat position. Applications, for example, are large fillet welds and joints in heavy gauge plate, which cannot be performed with mechanised welding.

Electrodes for vertical welding

Special electrodes, of the rutile -16 type, can be used for welding in the vertical-down position. They can cope with large variations in gap widths and thin material. This has made these electrodes very suitable for maintenance work especially within the pulp and paper industry.

Re-drying of covered electrodes

When electrodes leave the factory, the humidity level has been checked. If, however, the electrode has picked up humidity, it can easily be reconditioned. Temperature and holding time depend on the type of electrode – recommendations are given on each pack. Please note, that the specified time begins when the electrodes have reached the furnace temperature. For best drying results no more than four layers of electrodes at a time should be dried.

More information

Comprehensive data sheets including packaging data and material safety data sheets (MSDS) can be ordered from our sales offices or, through our web site: www.smt.sandvik.com

Chemical composition

Sandvik	Corresponds to		Chemical composition for all-weld metal (nominal), %						
	AWS [a]	EN 1600							
	E	E	C	Si	Mn	Cr	Ni	Mo	Others
Austenitic stainless steels									
19.9.LR	308L-17	19 9 L R	≤0.03	0.7	1.0	19	10	–	–
19.9.LB	308L-15	19 9 L B	≤0.04	0.6	1.0	19	10	–	–
19.9.NbR	347-17	19 9 Nb R	≤0.03	0.7	1.0	20	10	–	Nb=0.4
19.12.3.LR	316L-17	19 12 3 L R	≤0.03	0.7	1.0	18	12	2.8	–
19.12.3.LRHD	316L-17	19 12 3 L R	≤0.03	0.7	0.7	18.5	12	2.8	–
19.12.3.LRV	316L-16	19 12 3 L R	≤0.03	0.7	0.7	18	12	2.8	–
18.8.MnR	(307-16)	18 8 Mn R	≤0.10	0.7	6.0	18	8	–	–
23.12.2.LR	309LMo-17	23 12 2 L R	≤0.03	0.8	1.0	23	13	2.7	–
24.13.LR	309L-17	23 12 L R	0.03	0.8	0.8	24	13	–	–
29.9.R	312-16	29 9 R	0.10	0.8	1.5	28.5	10	–	–
Special purpose grades									
22.9.3.LR	2209-17	22 9 3 N L R	≤0.030	0.8	0.8	22	9	3.0	N=0.13
25.10.4.LR	–	25 9 4 N L R	≤0.03	0.5	0.7	25	9.5	4.0	N=0.25
29.8.2.LR	–	–	≤0.03	0.5	0.9	28.5	8.5	2.0	N=0.30
22.12.HTR	–	–	0.06	1.5	0.8	22	10.5	–	N=0.18
28.34.HTB	–	–	0.07	0.7	1.3	28	35	–	N=0.04
25.20.LR	–	–	≤0.030	0.4	1.5	25	20	–	–
25.22.2.LMnB	(310LMo-15)	25 22 2 N L B	≤0.04	0.4	4.5	25	22	2.1	N=0.15
20.25.5.LCuR	385-16	20 25 5 Cu N L R	≤0.03	0.5	1.0	20	25	5.0	Cu=1.5
27.31.4.LCuR	(383-16)	27 31 4 Cu L R	≤0.025	0.8	1.0	27	31	3.5	Cu=1.0
Sanicro 60	NiCrMo-3	–	≤0.05	0.3	0.1	21	>60	9.0	Nb=3.5 Fe≤6.0
Sanicro 69	NiCrFe-7	–	≤0.03	0.4	1	29.5	57	–	Nb=2 Fe=10
Sanicro 71	(NiCrFe-3)	–	≤0.05	≤0.5	5.0	20	>67	≤2.0	Nb=2.2 Fe≤4.0

[a] (xxx) = nearest equivalent.

Approvals

Most grades for covered electrodes are approved by inspection authorities and/or shipping societies such as TÜV, DB, Controlas, UDT, DNV. Please contact your nearest Sandvik office for our latest list of approvals.

Properties and applications

Sandvik AWS E EN 1600	Mechanical properties, typical values at 20°C		Applications	Corrosion resistance
19.9.LR 308L-17 19 9 L R	$R_{p0.2}$ R_m A KV	390 MPa 600 MPa 34% 70 J	Rutile-basic all-round electrode for joining of stainless Cr-Ni steels, stabilised or non-stabilised, e.g. 304, 304L, 321 and 347, for service temperatures up to 350°C. Also for stainless Cr steels with max 19% Cr.	Good resistance to general and, owing to the low C content, intergranular corrosion.
19.9.LB 308L-15 19 9 L B	$R_{p0.2}$ R_m A KV	390 MPa 600 MPa 42% 100 J	Basic electrode with good impact and position-welding properties for joining of stainless Cr-Ni steels, stabilised or non-stabilised, e.g. 304, 304L, 321 and 347, for service temperatures up to 350°C. Also for stainless Cr steels with max 19% Cr. Cryogenic applications down to -196°C.	Good resistance to general and, owing to the low C content, intergranular corrosion.
19.9.NbR 347-17 19 9 Nb R	$R_{p0.2}$ R_m A KV	450 MPa 610 MPa 35% 55 J	Rutile-basic all-round electrode for joining of stainless, stabilised Cr-Ni steels, e.g. 321 and 347. Due to the strengthening effect of Nb, 19.9.Nb is recommended for weld metals subjected to temperatures above 400°C.	Good resistance to general and, owing to the Nb content, intergranular corrosion.
19.12.3.LR 316L-17 19 12 3 L R	$R_{p0.2}$ R_m A KV	410 MPa 580 MPa 35% 60 J	Rutile-basic all-round electrode for joining of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C. Also for stainless Cr steels with max 19% Cr.	Good resistance to general and, owing to the low C content, intergranular corrosion. The Mo content gives good resistance also to pitting.
19.12.3.LRHD 316L-17 19 12 3 L R	$R_{p0.2}$ R_m A KV	410 MPa 580 MPa 40% 60 J	Rutile-basic high-deposition electrode for joining of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C. Also for stainless Cr steels with max 19% Cr.	Good resistance to general and, owing to the low C content, intergranular corrosion. The Mo content gives good resistance also to pitting.
19.12.3.LRV 316L-16 19 12 3 L R	$R_{p0.2}$ R_m A KV	410 MPa 600 MPa 40% 65 J	Rutile-basic electrode for joining, especially in the vertical-down position, of stainless Cr-Ni-Mo and Cr-Ni steels, stabilised or non-stabilised, e.g. 316, 316L and 316Ti as well as 304, 304L, 321 and 347, for service temperatures up to 400°C. Also for stainless Cr steels with max 19% Cr.	Good resistance to general and, owing to the low C content, intergranular corrosion. The Mo content gives good resistance also to pitting.
18.8.MnR (307-16) 18 8 Mn R	$R_{p0.2}$ R_m A KV	430 MPa 620 MPa 40% 60 J	Rutile-basic all-round electrode for joining of work-hardenable steels, armour plates, stainless austenitic Mn steels and free-machining steels, e.g. 303. Also for stainless Cr steels with max. 18% Cr, e.g. in the automotive industry. Welding of carbon and low-alloyed steels.	The corrosion resistance is similar to that of the respective parent metal.
24.13.LR 309L-17 23 12 L R	$R_{p0.2}$ R_m A KV	450 MPa 590 MPa 40% 50 J	Rutile-basic all-round electrode for joining of stainless Cr-Ni steels of the 304 type, where corrosion conditions are more severe. Stainless steels of the 309 type, wrought or cast. Also for stainless Cr steels. Dissimilar steels, e.g. austenitic stainless steel to carbon or low-alloyed steels for service up to 300°C. First-layer overlay welding of carbon or low-alloyed steels to give a 304L deposit.	The corrosion resistance is similar to that of the respective parent metal.
23.12.2.LR 309LMo-17 23 12 2 L R	$R_{p0.2}$ R_m A KV	450 MPa 600 MPa 35% 60 J	Rutile-basic all-round electrode for joining of stainless Cr-Ni and Cr-Ni-Mo steels 304, 309 or 316 to ensure corrosion resistance in e.g. the pulp and paper industry. Dissimilar steels when alloying with Mo is essential. Overlay applications where higher Mo content is desired in the second and third layers.	The corrosion resistance is similar to that of the respective parent metal.
29.9.R 312-16 29 9 R	$R_{p0.2}$ R_m A KV	600 MPa 750 MPa 25% 50 J	Rutile-basic, work-hardenable and hot-cracking resistant electrode for joining of stainless steels where high strength or wear resistance is essential. Problem solver when joining similar or dissimilar steels with limited weldability. Overlay welding of carbon and low-alloyed steels.	High oxidation resistance in air up to 1100°C.

Properties and applications

Sandvik AWS E EN 1600	Mechanical properties, typical values at 20°C		Applications	Corrosion resistance
22.9.3.LR 2209-17 22 9 3 N L R	$R_{p0.2}$ R_m A KV	600 MPa 750 MPa 25% 50 J	Rutile-basic electrode for joining of duplex stainless steels Sandvik 3RE60, SAF 2205 and SAF 2304 or other similar duplex steels.	Very good resistance to intergranular corrosion and pitting. Good resistance to stress corrosion cracking, especially in environments containing H_2S and chlorides.
25.10.4.LR – 25 9 4 N L R	$R_{p0.2}$ R_m A KV	650 MPa 850 MPa 25 % 50 J	Rutile-basic electrode for joining of superduplex stainless steel Sandvik SAF 2507 or other similar superduplex steels. Can also be used to join SAF 2205 and other duplex steels of the 25% Cr type when the highest possible corrosion resistance is desired.	Better resistance to intergranular corrosion, pitting and stress corrosion cracking than 22.9.3.LR.
29.8.2.LR – –	$R_{p0.2}$ R_m A KV	700 MPa 870 MPa 25% 45 J	Rutile-basic electrode for joining of superduplex stainless steel Sandvik SAF 2906 or other similar superduplex steels.	Better resistance to intergranular corrosion, pitting and stress corrosion cracking than 22.9.3.LR.
22.12.HTR – –	$R_{p0.2}$ R_m A KV	500 MPa 650 MPa 35% 60 J	Rutile-basic electrode for joining of stainless Cr-Ni steel Sandvik 253MA or other similar high-temperature steels.	High oxidation resistance in air up to 1150°C.
28.34.HTB – –	$R_{p0.2}$ R_m A KV	380 MPa 590 MPa 30% 85 J	Basic electrode for joining of stainless Cr-Ni steel Sandvik 353MA or other similar high-temperature steels.	Excellent oxidation resistance in air up to 1200°C.
25.20.LR – –	$R_{p0.2}$ R_m A KV	300 MPa 590 MPa 30% 50 J	Rutile-basic electrode for joining of stainless Cr-Ni steel Sandvik 2RE10 or other similar steels exposed to heavily oxidising media, e.g. nitric acid.	Especially suitable for use in oxidising media, e.g. nitric acid. Good resistance to intergranular corrosion and stress corrosion cracking owing to the high Cr and Ni contents.
25.22.2.LMnB 310LMo-15 25 22 2 N L B	$R_{p0.2}$ R_m A KV	380 MPa 600 MPa 40% 80 J	Basic electrode for joining of stainless Cr-Ni-Mo steels used in the urea industry, e.g. Sandvik 2RE69 or other similar steels as well as modified type 316L. Stainless Cr-Ni and Cr-Ni-Mo steels, 304L, 304LN and 316L, 316LN, for cryogenic applications down to -196°C and/or applications demanding low magnetic permeability.	High resistance to pitting and intergranular corrosion. More resistant to stress corrosion cracking than 19.12.3.LR. Especially suitable for use in the urea industry.
20.25.5.LCuR 385-16 20 25 5 Cu L R	$R_{p0.2}$ R_m A KV	400 MPa 540 MPa 35% 80 J	Rutile-basic electrode for joining of stainless high-alloyed Ni-Cr-Mo-Cu grade 904L or other similar materials.	Good resistance to stress corrosion cracking and intergranular corrosion as well as in non-oxidising acids, e.g. sulphuric, phosphoric and acetic. Better resistance to pitting than 19.13.4.LR.
27.31.4.LCuR (383-16) 27 31 4 Cu L R	$R_{p0.2}$ R_m A KV	400 MPa 580 MPa 35% 80 J	Rutile-basic electrode for joining of stainless superaustenitic grades, e.g. Sandvik Sanicro 28, Alloy 825 or other similar materials.	High resistance to general corrosion, particularly in contaminated phosphoric acid. Better resistance to intergranular corrosion, pitting and stress corrosion cracking than 20.25.5.LCuR.
Sanicro 60 NiCrMo-3 –	$R_{p0.2}$ R_m A KV	430 MPa 670 MPa 35% 65 J	Basic electrode for joining of Alloy 625, Alloy 825 and other similar materials. Dissimilar materials, e.g. austenitic stainless steels to Ni-Cr-Mo grades. Steels of the 9% Ni type for cryogenic service. 254 SMO and similar 6% MoN stainless steels. Overlay welding of carbon and low-alloyed steels.	Good resistance to pitting corrosion. Very resistant to stress corrosion cracking in chloride-containing environments. Good resistance to oxidation in air up to 1100°C.
Sanicro 69 NiCrFe-7 –	$R_{p0.2}$ R_m A KV	400 MPa 620 MPa 35% 100 J	Basic electrode for joining of Alloy 690 and Alloy 600. Overlay welding in the nuclear industry.	Better resistance to stress corrosion cracking as well as general and intergranular corrosion than Sanicro 71.
Sanicro 71 NiCrFe-3 –	$R_{p0.2}$ R_m A KV	390 MPa 620 MPa 35% 80 J	Basic electrode for joining of Alloy 800, Alloy 800H, Alloy 600 and other similar materials. Steels of 9% Ni type used for cryogenic service. Dissimilar materials, e.g. austenitic stainlless steels to carbon steels for high-temperature service, as well as Ni-Cu alloys to nickel-base alloys.	Good resistance to stress corrosion cracking and, owing to the low C and high Cr contents, good resistance to general and intergranular corrosion. Good oxidation resistance in air up to 1175°C.

Strip electrodes

Sandvik Materials Technology is the world leader in stainless welding consumables for surfacing of carbon and low-alloyed steels. We supply strip electrodes and suitable fluxes for the most demanding applications, for example in the chemical, petrochemical and nuclear industries.

We have a wide choice of strip electrodes suitable for both submerged-arc welding (SAW) and electroslag welding (ESW). The many over-alloyed variants make it possible to obtain the required weld deposit with a single layer or, for example, a 308 deposit using different speeds and fluxes.

Sandvik's programme also includes strip in duplex, superduplex and fully austenitic grades. Our wide experience in the corresponding tube materials and in demanding applications has helped us to find the best combination of strip composition and flux.

Controlled ferrite content

A well-controlled, sufficiently high ferrite content in deposits of standard austenitic steels is necessary to ensure a ferritic solidification and thereby crack-free welds. The ferrite content is expressed as an FN number in the table on the following page. Our strip electrodes show a maximum scatter from heat to heat of ±2 FN.

Low impurity level

Very low impurity levels are a must for fully austenitic and nickel-base alloy surfacing materials in order to avoid microcracking, even though solidification is austenitic. Our sophisticated metallurgy is a guarantee that this requirement will be fulfilled. We can also meet the demand for low contents of cobalt and copper in strip electrodes intended for the nuclear industry.

Low carbon content

Surfacing is undertaken mostly in order to place a corrosion resistant layer on mild steel. This calls for a carbon content in the deposit of 0.03% max. (ELC), taking into account the dilution from a parent metal with a relatively high carbon content. Therefore, the strip electrode must have a very low carbon content. Most of our electrodes have carbon contents below 0.020%, and several of those intended for first-layer deposits below 0.015%. In many cases the low carbon content allows single-layer ELC deposits to be achieved with the ESW process.

Strip electrodes for high productivity

Our electrodes have both low carbon contents and high amounts of alloying elements. It is therefore possible to reach the required properties in the deposit even when the dilution from the parent metal is high. The electrodes can tolerate, therefore, the high speeds, which are a prerequisite of high productivity.

However, high productivity cannot be obtained unless surfacing can continue uninterrupted, i.e. as few coil changes as possible. To this end we produce large coils containing up to 700 kg.

Our ongoing development of consumables and welding processes will ensure that you have the highest productivity and the optimal deposit properties for each application.

More information

Comprehensive data sheets and material safety data sheets (MSDS) can be ordered from our sales offices or, through our web site: www.smt.sandvik.com

Chemical composition

Sandvik	Corresponds to AWS EQ	DIN W.-Nr.	Chemical composition (nominal), % C	Si	Mn	Cr	Ni	Mo	Others	Ferrite content FN [a]	FN [b]
Austenitic stainless steels											
19.9.L	308L	1.4316	≤0.015	0.3	1.8	20	10.5	–	–	10	12
19.9.LNb	347	1.4551	≤0.020	0.4	1.8	19.5	10.5	–	Nb=0.5	9	11
19.12.3.L	316L	1.4430	≤0.020	0.4	1.8	18.5	13	2.9	–	7	8
19.13.4.L	317L	(1.4438)	≤0.020	0.5	1.5	19	14	3.7	–	9	7
24.13.L	309L	1.4332	≤0.015	0.4	1.8	23.5	13.5	–	–	15	13
23.12.L	(309L)	(1.4332)	≤0.015	0.3	1.7	23	11.5	–	–	22	20
22.11.L	(309L)	(1.4332)	≤0.015	0.2	1.8	21	11.5	–	–	11	12
24.13.LNb	"309LNb"	1.4556	≤0.020	0.3	2.1	24	12.5	–	Nb=0.8	20	22
23.11.LNb	"309LNb"	1.4556	≤0.015	0.2	2.1	23	12	–	Nb=0.8	17	20
21.11.LNb	"309LNb"	(1.4556)	≤0.015	0.2	1.8	21	11	–	Nb=0.6	12	15
21.13.3.L	(309LMo)	(1.4459)	≤0.015	0.2	1.8	20.5	13.5	2.9	–	11	13
Special purpose grades											
22.6.3.L	(2209)	1.4462	≤0.025	0.5	0.9	22	5	3.2	N=0.18	–	>80
22.8.3.L	2209	(1.4462)	≤0.020	0.5	1.6	23	9	3.2	N=0.16	–	50
29.8.2.L	–	–	≤0.020	0.3	1.0	29	7	2.2	N=0.35	–	–
25.22.2.LMn	"310LMo"	1.4466	≤0.020	0.2	4.5	25	22	2.1	N=0.13	0	0
20.25.5.LCu	385	(1.4519)	≤0.020	0.4	1.8	20	25	4.5	Cu=1.5	0	0
24.29.5.LCu	(385)	(1.4519)	≤0.020	0.4	2.0	23.5	28.5	5.4	Cu=1.8	0	0
Sanicro 60	NiCrMo-3	–	≤0.05	0.3	0.2	21	≥60	9.0	Nb=3.5 Fe≤5.0	0	0
Sanicro 69HP	(NiCrFe-7)	–	≤0.015	0.1	1.3	30	56	–	Nb=1.8 Fe=9	0	0
Sanicro 72HP	NiCr-3	2.4806	≤0.030	0.1	3.0	20	72.5	–	Nb=2.6 Fe≤1.0	0	0

[a] According to DeLong.
[b] According to WRC.

Approvals
Please contact your nearest Sandvik office for our latest list of approvals.

Delivery forms

Strip electrodes are supplied in coils with inner diameter 305 mm in the cold rolled condition with a dry, bright surface and with deburred edges.
Standard sizes are
0.5 x 30, 60, 90, 120 mm
0.4 x 50, 75, 150 mm

Maximum coil weights for the thickness 0.5 mm are:

30 mm	170 kg
60 mm	350 kg
90 mm	525 kg
120 mm	700 kg

Properties and applications

Type AISI/UNS EN	Typical procedures [a]	Applications	Properties
18/8 304 1.4301	1 layer 24.13.L + SAW Cr comp. flux 1 layer 23.12.L + ESW flux, high speed 1 layer 24.13.L + ESW flux, high speed	General purpose austenitic weld overlay for mildly corrosive media. Low cost overlay as only one layer is necessary. Usually not post-weld heat-treated (PWHT) as C content is >0.03%.	Good resistance to general corrosion, limited resistance to pitting. Resistance to intergranular corrosion (IGC) in Strauss testing good if not PWHT.
18/8/ELC 304L 1.4306	2 layers 24.13.L/19.9.L + SAW Cr comp. flux 1 layer 22.11.L + ESW flux 1 layer 23.12.L + ESW flux, moderate speed	General purpose austenitic weld overlay for mildly corrosive media. In principle same applications as 18/8. The most common weld metal. Required properties can be reached in one layer with ESW.	Same resistance to general and pitting corrosion as 18/8. Good resistance to IGC, even after PWHT (Strauss/Huey). Ferrite content for SAW can be controlled by the choice of flux.
18/8/Nb 347 1.4550	1 layer 24.13.LNb + SAW Cr comp. flux 2 layers 24.13.L/19.9.LNb + SAW Cr comp. flux 1 layer 21.11.LNb + ESW flux 1 layer 23.11.LNb + ESW flux, moderate speed 1 layer 24.13.LNb + ESW flux, high speed	General purpose austenitic weld overlay for mildly corrosive media, also at elevated temperatures. Often the preferred choice if service temperature is above 400ºC. Very common in petrochemical applications.	Same resistance to general and pitting corrosion as 18/8/ELC. Very good resistance to IGC, even after PWHT up to 690ºC.
19/12/3/ELC 316L 1.4435	2 layers 21.13.3.L/19.12.3.L + SAW Cr comp. flux 2 layers 24.13.L/19.12.3.L + SAW Cr comp. flux 1 layer 21.13.3.L + ESW flux	Used where better resistance to corrosion in acids or pitting is required. Common choice for heat exchangers, e.g. in the petrochemical industry or offshore. The Mo content, which is important for corrosion resistance, varies with the procedure. For higher corrosion resistance requirements use 20/25/5/Cu/ELC.	Better resistance to pitting than the 18/8 types and better resistance to all acids, except nitric acid. Almost equal resistance to IGC as 18/8/Nb after PWHT.
25/22/2/ELC S31050 1.4466	2 layers 25.22.2.LMn + SAW flux 31S 2 layers 25.22.2.LMn + ESW flux 37S	One of the most commonly used weld overlays in urea plants, where fully austenitic overlays are required.	Very good resistance in ammonium carbamate and nitric acid. Huey testing is commonly used for qualification. The overlay will pass max. 1 µm/48 hours and max. 70 µm selective attack. Fully austenitic.
20/25/5/Cu/ELC 904L 1.4539	2-3 layers 20.25.5.LCu + SAW Cr comp. flux 2-3 layers 20.25.5.LCu + ESW flux	Used in the chemical, petrochemical, pulp and paper and metallurgical industries, often in connection with sea-water cooling. This grade is used where fully austenitic overlays are required.	Very good resistance to pitting and acidic corrosion. Good resistance to stress corrosion cracking due to the high Ni content. Strauss testing satisfactory after PWHT up to 5 hours at 600ºC. CPT is 30ºC.
22/8/3/ELC N31803 1.4462	2-3 layers 22.8.3.L + SAW Cr comp. flux 2-3 layers 22.8.3.L + ESW flux	Used in the process industry to solve problems of stress corrosion cracking and pitting. Its high strength makes it very resistant to erosion and therefore suitable, for example, for valve seats, especially in seawater. Cost effective alternative to fully austenitic overlays.	Good resistance to IGC. CPT is 25ºC. Good resistance to stress corrosion owing to its ferritic-austenitic microstructure.
20/70/Nb/ELC N06600 –	2-3 layers Sanicro 72HP + SAW flux 50SW 2-3 layers Sanicro 72HP + ESW flux	High nickel alloy mostly used in the nuclear industry, e.g. for tube sheets and outlets. For higher corrosion resistance requirements use 30/60/Nb/ELC.	Good resistance to IGC also after PWHT. Good resistance to stress corrosion cracking.
30/60/Nb/ELC N06690 –	2-3 layers Sanicro 69HP + SAW flux 50SW 2-3 layers Sanicro 69HP + ESW flux	High nickel alloy for nuclear steam generators, e.g. for tube sheets and outlets.	Better resistance to IGC than N06600. Good resistance to stress corrosion cracking.

[a] SAW = submerged-arc welding; ESW = electroslag welding.

Complementary products

In addition to welding consumables, Sandvik offers a range of complementary products:

- *Fluxes*
- *Root flux*
- *Pickling and neutralisation pastes*
- *Accessories to Sanpac*
- *Sanbab, a device for improved feeding from Sanpac.*

Fluxes

We have a selection of fluxes for:

- submerged-arc welding (SAW) and electroslag welding (ESW)
- surfacing with strip or wire electrodes
- joining of plates with wire electrodes
- standard and special stainless steels and nickel-base alloys.

When choosing a flux for a given combination of strip/wire electrode and

Flux	Characteristics [a, b]	Application
Submerged-arc welding, SAW		
10S	Slightly Cr compensated Basicity 1.0	General purpose flux for both strip and wire electrodes of Cr-Ni and Cr-Ni-Mo steels, stabilised or non-stabilised. Good slag removal. Gives about 2% lower ferrite content than 10SW.
10SW	Cr compensated Basicity 1.0	General purpose flux for both strip and wire electrodes of Cr-Ni and Cr-Ni-Mo steels, stabilised or non-stabilised. Good slag removal. Gives about 2% higher ferrite content than 10S.
15W	Non-Cr compensated Basicity 1.7	Special purpose flux for wire electrodes of Cr-Ni and Cr-Ni-Mo steels, stabilised or non-stabilised as well as duplex, superduplex and fully austenitic grades, e.g. 20.25.5.LCu. Good slag removal. Gives good impact properties. The Nb burn-off is very small when using stabilised electrodes, such as 19.9.Nb.
31S	Non-Cr compensated Basicity 1.1	Single purpose flux for both strip and wire electrodes of 25.22.2.LMn, intended for urea applications. Good slag removal.
50SW	Non-Cr compensated Basicity 2.4	General flux for strip and wire electrodes of nickel-base alloys. Good slag removal.
52W	Non-Cr compensated Basicity 1.4	Flux for wire electrodes of nickel-base alloys as well as fully austenitic Cr-Ni, e.g. 25.20.C, or Cr-Ni-Mo grades, e.g. 27.31.4.LCu. Good slag removal.
Electroslag welding, ESW		
37S	Non-Cr compensated Basicity 3.8	General purpose flux for strip electrodes of Cr-Ni and Cr-Ni-Mo steels, stabilised or non-stabilised, duplex and fully austenitic grades, e.g. 25.22.2.LMn. Excellent slag removal and bead appearance.
47S	Non-Cr compensated Basicity 4.0	General purpose flux for strip electrodes of Cr-Ni and Cr-Ni-Mo steels, stabilised or non-stabilised as well as duplex and fully austenitic Cr-Ni-Mo grades, e.g. 20.25.5.LCu. Excellent slag removal and bead appearance. Low Si pick up.
48S	Non-Cr compensated Ni alloying. Basicity 4.0	Special nickel alloying flux for strip electrodes of mainly superduplex type.
49S	Non-Cr compensated Basicity 4.4	High speed flux for strip electrodes of Cr-Ni and Cr-Ni-Mo steels, stabilised or non-stabilised. Excellent slag removal and bead appearance.
59S	Non-Cr compensated Basicity 5.0	Flux for strip electrodes of nickel-base alloys. Excellent slag removal and bead appearance. Gives good safety against micro cracking.

[a] Basicity according to Boniszewski.
[b] All fluxes are agglomerated.

parent metal, the welding parameters also have to be considered in order to obtain the desired composition of the weld metal.

Characteristics and applications are given in the table below.

Root flux

Sandvik supplies a root flux for joining tubes and pipes which can be an alternative root protection in cases where access is limited or it is impractical to use a shielding gas (see page 14). However, the root flux does not give the same degree of protection. It can, therefore, only be used when the parent metal has enough margin of corrosion resistance for the actual application. The use of root flux reduces the risk of porosity, surface oxides and burn through and is, of course, always better than no root protection.

Root flux is a powder, which is mixed with water or methanol to form a paste. It is brushed on to the root side, about 20 mm on each side of the joint. During welding the paste reacts with the heat of welding, forming a thin protective slag. The slag is washed away by the process medium when the pipe is taken into service.

The root flux, which can be used for root passes made by the MMA, TIG or MIG welding methods, is available in plastic bottles containing 0.5 kg, sufficient for about 50 m of root weld.

Pickling and neutralisation pastes

A perfect weld having the required corrosion resistance is not obtained until the naturally occurring oxide layer on the weld is removed together with the chromium depleted layer under the oxide. Sandvik markets a pickling paste for fast and efficient cleaning of the weld.

The thixotropic consistency makes the paste easy to apply without splashes – particularly important because of its aggressiveness. The paste has excellent adhesion and can be applied therefore to vertical and overhead welds without the risk of dripping.

1 kg of pickling paste is enough for approximately 120 m of weld bead or a surface of approximately 6 m^2.

After pickling there is always some residual paste containing acid on the weld. This can be effectively neutralised with our thixotropic neutralisation paste, thereby ensuring the best possible environmental protection. The neutralisation paste does not contain any harmful components. It is as easy to apply as the pickling paste and can be flushed with water into any drain.

There are instructions for use and safety precautions on each pack.

Accessories to Sanpac

To be able to use Sanpac, our MIG wire pay-off system, a set of accessories is required – a conical plastic dome, an adapter and a hose. These accessories are re-usable on each Sanpac drum.

Sanbab

Sanpac can be equipped – in a single operation – with a special device called Sanbab, developed by Sandvik. The aim is to stabilise feeding and neutralise the wire stresses, which can occur during long welding sequences. Sanbab is an excellent choice not only for mechanised welding but also for intermittent robotic welding, since it offers extra reliability in service. In special feeding cases, for example extra long wire conduits or complicated robotic movements, Sanbab increases the assurance of trouble free pay-off.

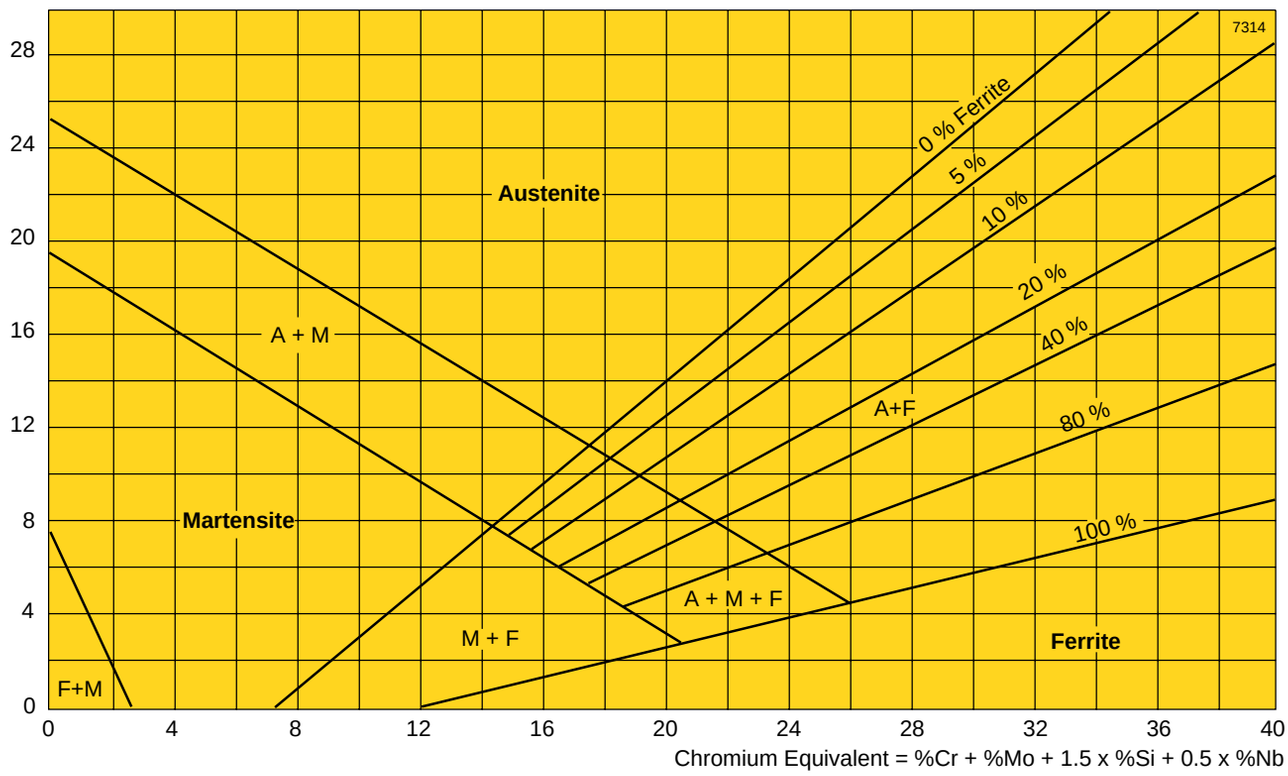
More information

Comprehensive data sheets and safety data sheets can be ordered from our sales offices or, through our web site: www.smt.sandvik.com

Ferrite content
diagrams

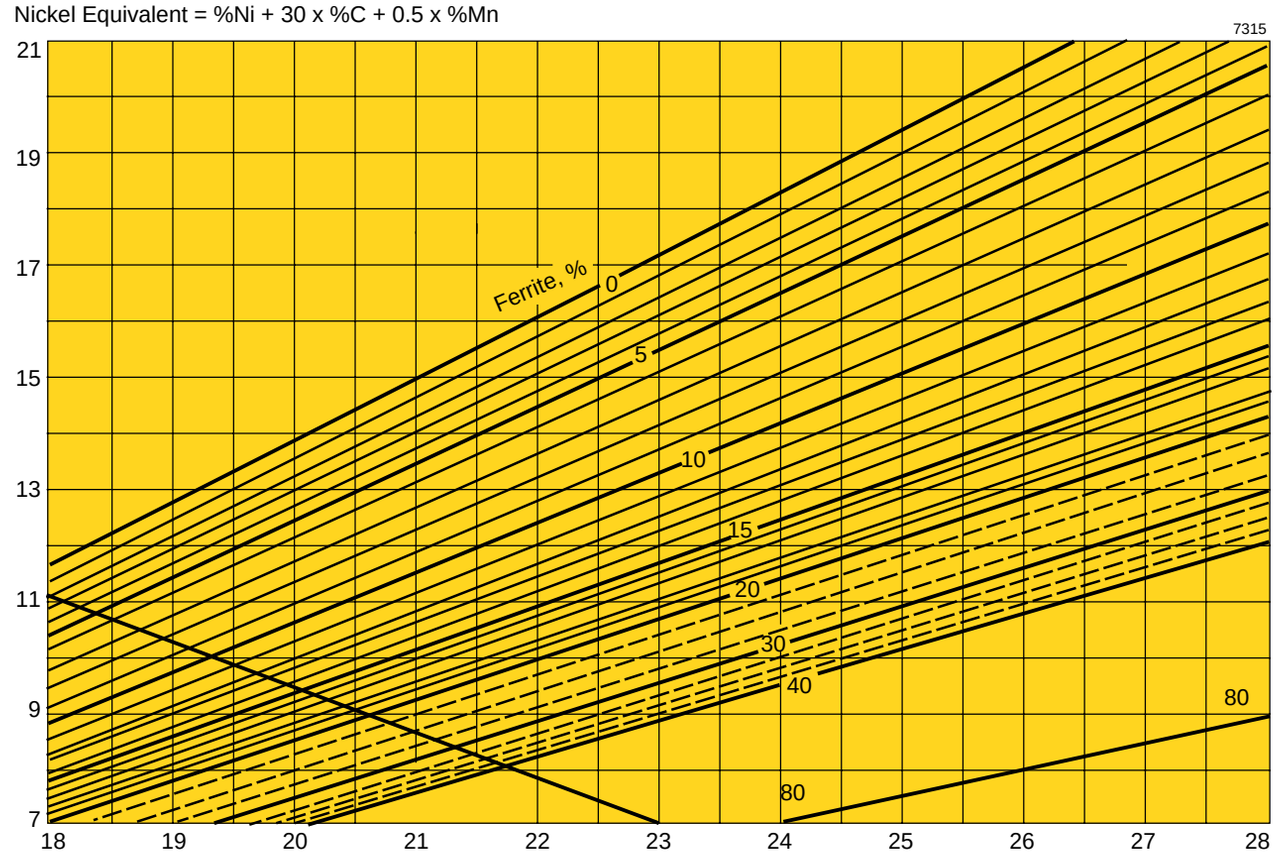
Schaeffler diagrams

Nickel Equivalent = %Ni + 30 x %C + 0.5 x %Mn



Chromium Equivalent = %Cr + %Mo + 1.5 x %Si + 0.5 x %Nb

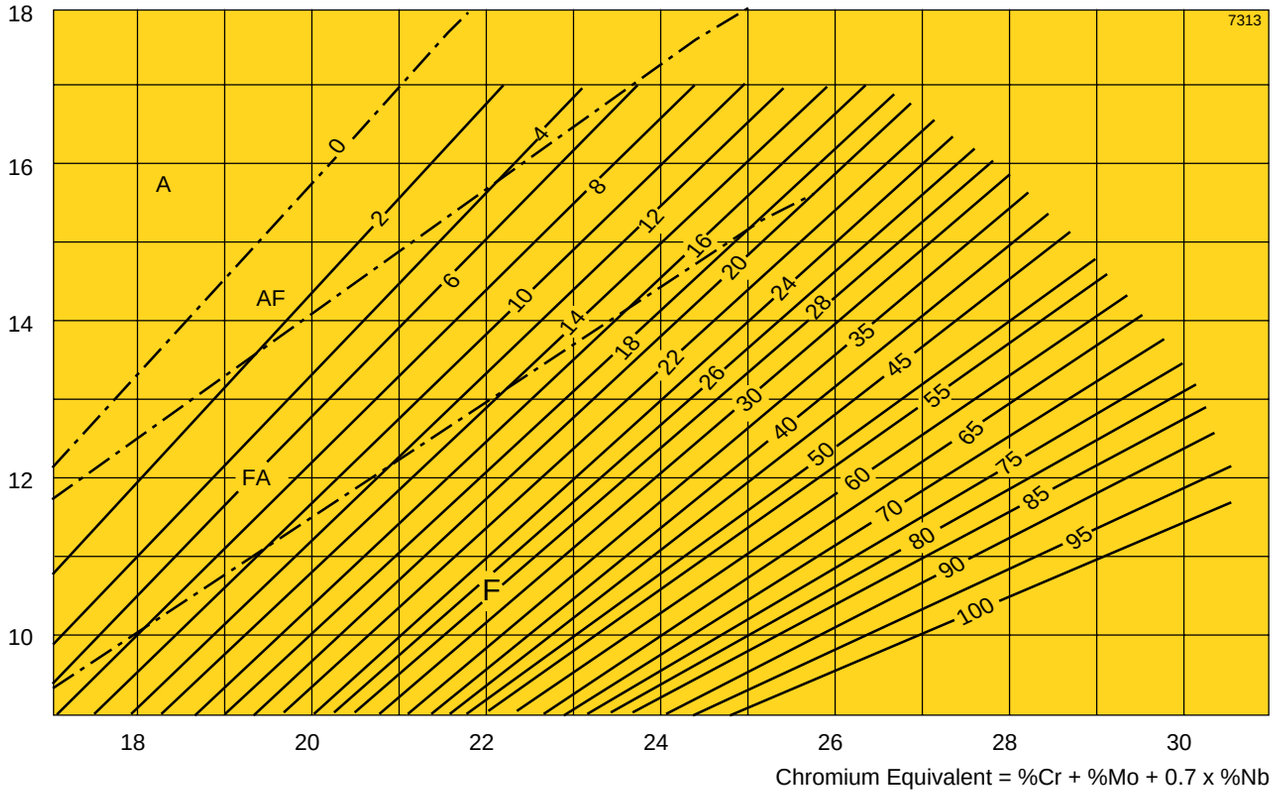
Nickel Equivalent = %Ni + 30 x %C + 0.5 x %Mn



Chromium Equivalent = %Cr + %Mo + 1.5 x %Si + 0.5 x %Nb

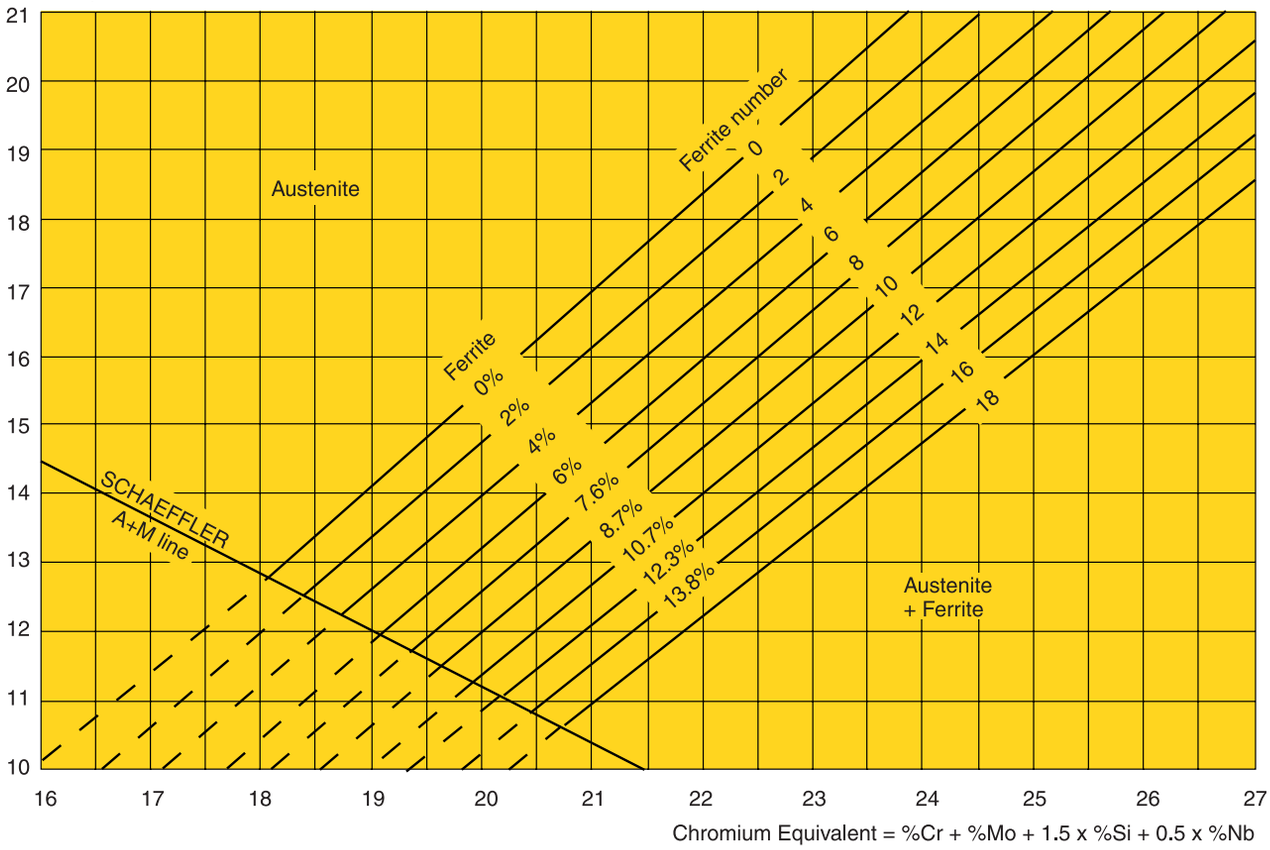
WRC diagram

Nickel Equivalent = %Ni + 35 x %C + 20 x %N + 0.25 x %Cu



DeLong diagram

Nickel Equivalent = %Ni + 30 x %C + 30 x %N + 0.5 x %Mn



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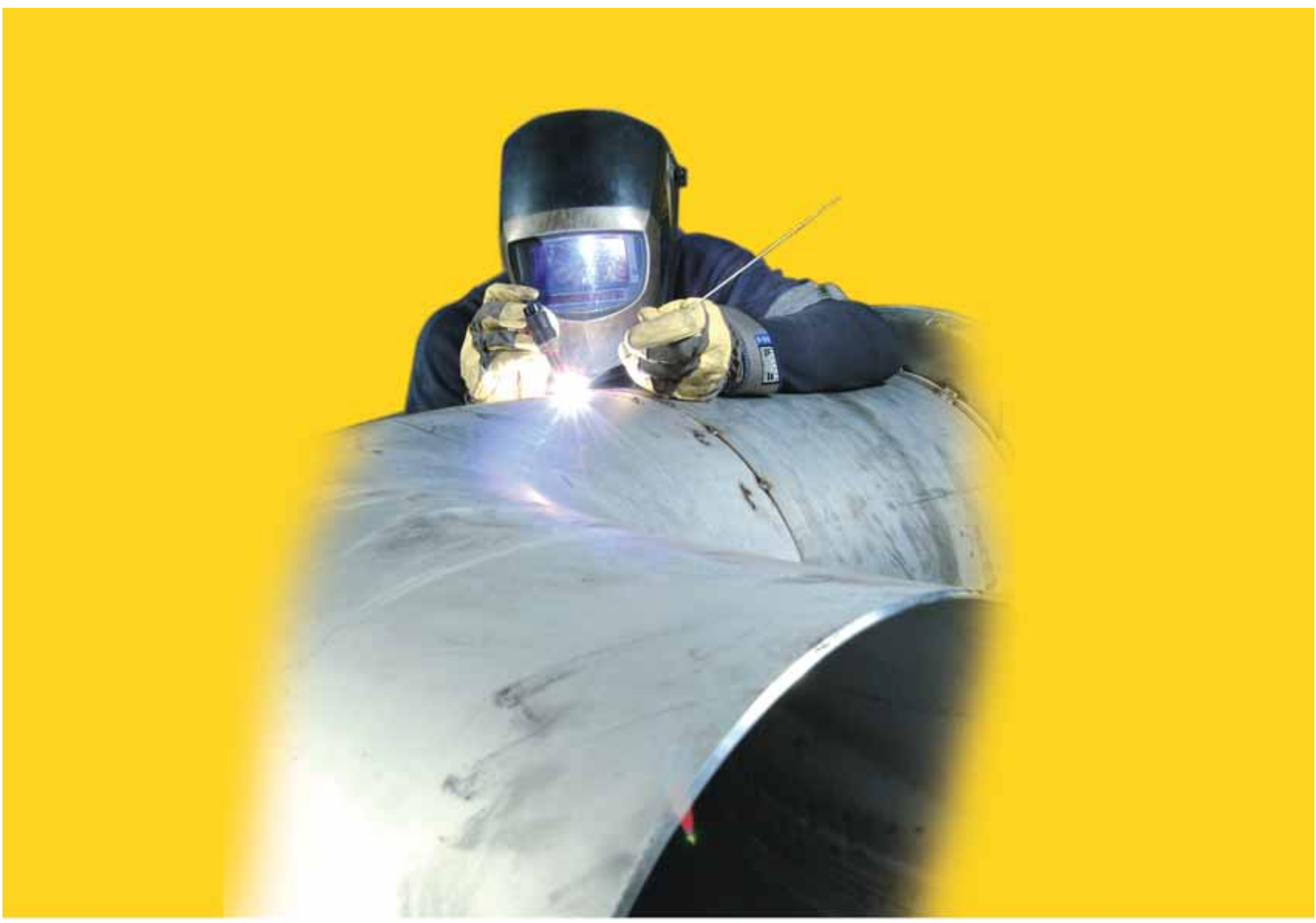

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