böhler welding
by voestalpine

Welding of Stainless Steels & Duplex

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voestalpine Böhler Application Technology Centre

voestalpine Böhler Welding

www.voestalpine.com/welding

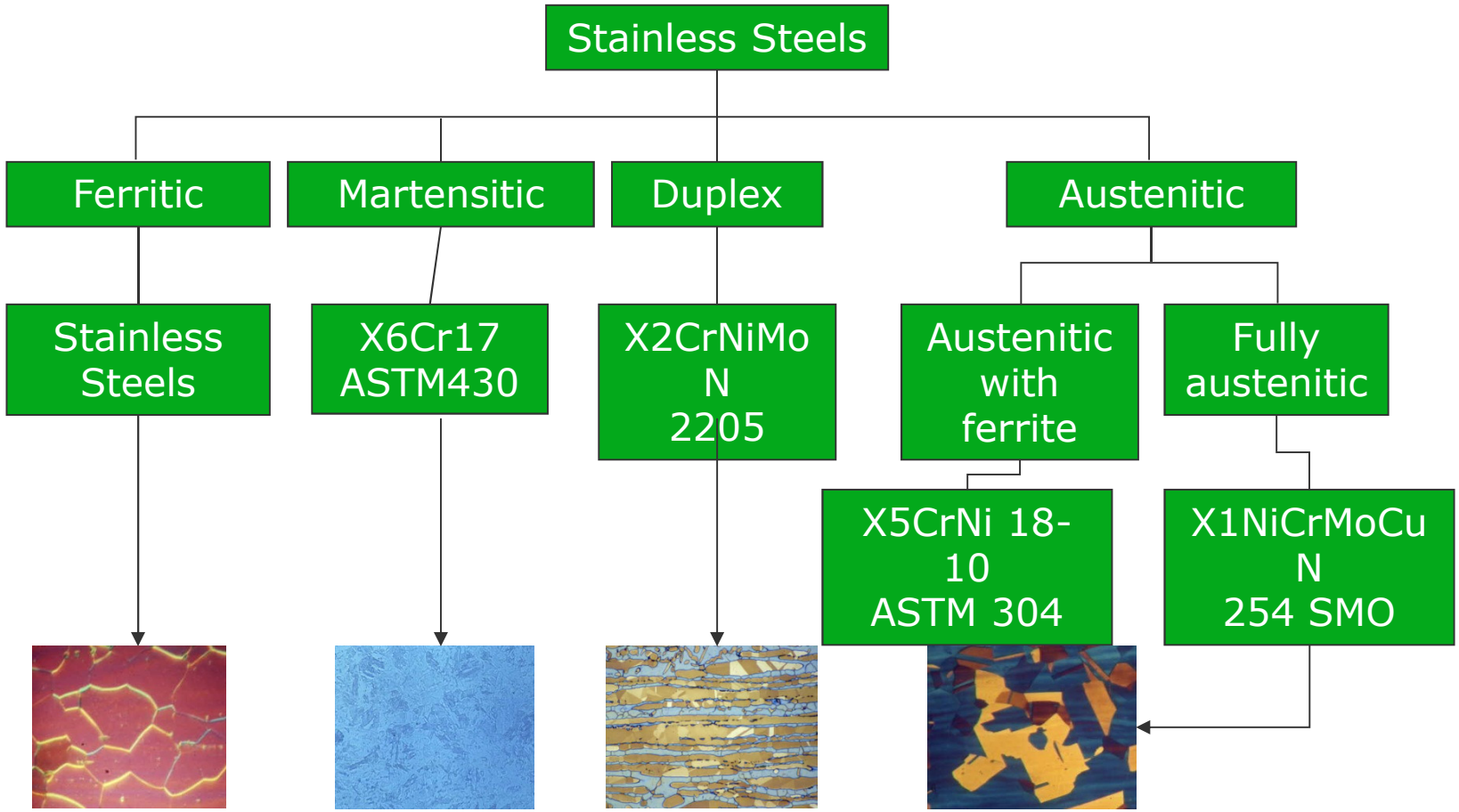
voestalpine
ONE STEP AHEAD.

What is Stainless Steel?

- Iron alloy bearing >11% Chromium and <0.12% Carbon

- Build-up of a self-healing surface layer (passive layer ~ 0,0025 µm) which provides the corrosion resistance

Microstructure



Welding of austenitic stainless steels

Austenitic steels are very well suited for welding, but unsuitable handling can cause problems in the base material and in the weld metal:

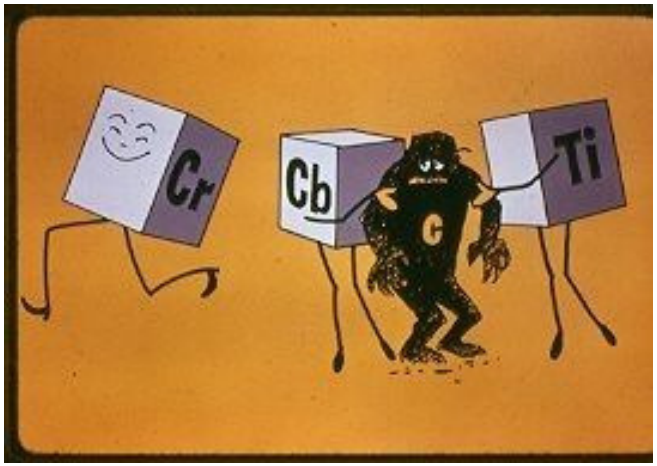
- Sensitisation, i.e. a reduction in the resistance to corrosion due to the formation of chromium carbide
- Hot cracking, i.e. separation of grain boundaries during solidification, or in the highly heated HAZ when rigidly fixed
- Embrittlement, i.e. the precipitation of intermetallic phases such as sigma phase through exposure to high temperatures or annealing

Sensitization

Leads to intergranular corrosion in the HAZ
Chromium Carbide forms and precipitation at grain boundary in HAZ → 427 to 871˚C

High carbon content : Time at the critical mid-range: a few second at 649˚do more damage than several minutes at 454˚C or 788˚C

Control : ELC- Extra low carbon
Stabilized grades: → titanium 321,
niobium (columbium) 347→
stronger affinity for carbon than Chromium



Welding of austenitic stainless steels

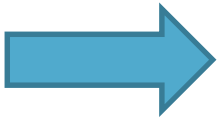
Welding technology:

- Only grades corresponding to the base material and ferrite contents of 5-15 FN should be used. The ferrite content ensures sufficient resistance to hot cracking.
- Preheating is generally not necessary; interpass temperature should not exceed 150 °C.
- Heat treatment after welding should be avoided.
- Chipping hammers and brushes made from stainless steel are necessary

High-alloyed stick electrodes

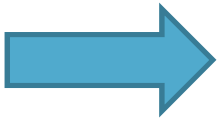
Main difference between un&low-alloyed and high-alloyed electrodes:

- Un&low-alloyed electrodes



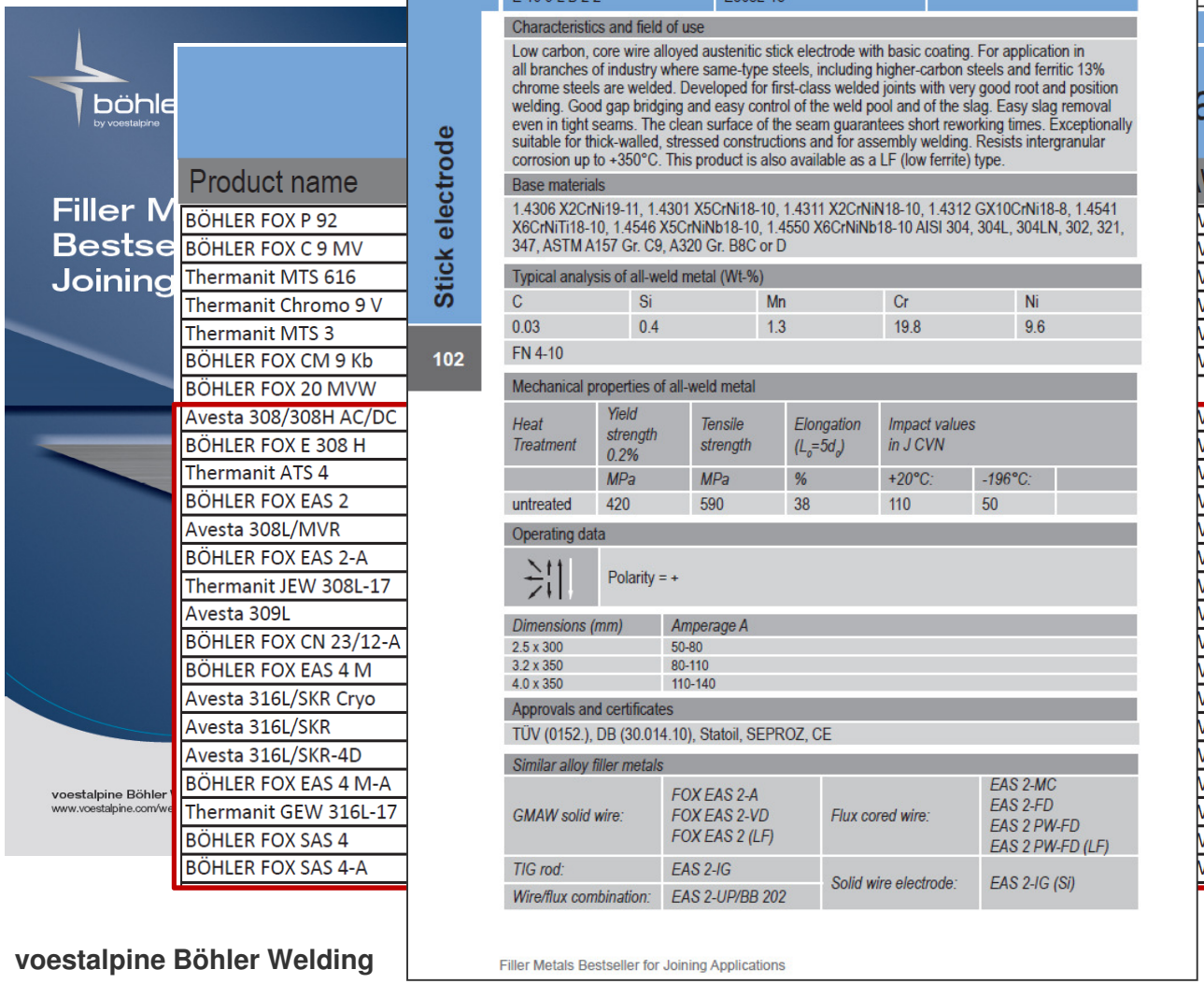
  - Core wire is unalloyed
  - Addition of alloying elements over electrode coating (synthetic electrodes)

- High-alloyed electrodes



  - Core wire is alloyed
  - Electrode coating for arc stabilisation

High-alloyed



Product name
BÖHLER FOX P 92
BÖHLER FOX C 9 MV
Thermanit MTS 616
Thermanit Chromo 9 V
Thermanit MTS 3
BÖHLER FOX CM 9 Kb
BÖHLER FOX 20 MVW
Avesta 308/308H AC/DC
BÖHLER FOX E 308 H
Thermanit ATS 4
BÖHLER FOX EAS 2
Avesta 308L/MVR
BÖHLER FOX EAS 2-A
Thermanit JEW 308L-17
Avesta 309L
BÖHLER FOX CN 23/12-A
BÖHLER FOX EAS 4 M
Avesta 316L/SKR Cryo
Avesta 316L/SKR
Avesta 316L/SKR-4D
BÖHLER FOX EAS 4 M-A
Thermanit GEW 316L-17
BÖHLER FOX SAS 4
BÖHLER FOX SAS 4-A

Stick electrode

102

BÖHLER FOX EAS 2 — Stick electrode

Classifications — high-alloyed

EN ISO 3581-A:	AWS A5.4:	
E 19 9 L B 2 2	E308L-15	

Characteristics and field of use

Low carbon, core wire alloyed austenitic stick electrode with basic coating. For application in all branches of industry where same-type steels, including higher-carbon steels and ferritic 13% chrome steels are welded. Developed for first-class welded joints with very good root and position welding. Good gap bridging and easy control of the weld pool and of the slag. Easy slag removal even in tight seams. The clean surface of the seam guarantees short reworking times. Exceptionally suitable for thick-walled, stressed constructions and for assembly welding. Resists intergranular corrosion up to +350°C. This product is also available as a LF (low ferrite) type.

Base materials

1.4306 X2CrNi19-11, 1.4301 X5CrNi18-10, 1.4311 X2CrNiN18-10, 1.4312 GX10CrNi18-8, 1.4541 X6CrNiTi18-10, 1.4546 X5CrNiNb18-10, 1.4550 X6CrNiNb18-10 AISI 304, 304L, 304LN, 302, 321, 347, ASTM A157 Gr. C9, A320 Gr. B8C or D

Typical analysis of all-weld metal (Wt-%)

C	Si	Mn	Cr	Ni
0.03	0.4	1.3	19.8	9.6

FN 4-10

Mechanical properties of all-weld metal

Heat Treatment	*Yield strength 0.2%*	*Tensile strength*	*Elongation (L_o=5d_o)*	*Impact values in J CVN*	
	MPa	*MPa*	*%*	*+20°C:*	*-196°C:*
untreated	420	590	38	110	50

Operating data

Polarity = +

Dimensions (mm)	*Amperage A*
2.5 x 300	50-80
3.2 x 350	80-110
4.0 x 350	110-140

Approvals and certificates

TÜV (0152.), DB (30.014.10), Statoil, SEPROZ, CE

Similar alloy filler metals

GMAW solid wire:	*FOX EAS 2-A FOX EAS 2-VD FOX EAS 2 (LF)*	*Flux cored wire:*	*EAS 2-MC EAS 2-FD EAS 2 PW-FD EAS 2 PW-FD (LF)*
TIG rod:	*EAS 2-IG*	*Solid wire electrode:*	*EAS 2-IG (Si)*
Wire/flux combination:	*EAS 2-UP/BB 202*		

Filler Metals Bestseller for Joining Applications

alloyed)

AWS		P
VS A5.5	E9015-B9 (mod.)	92
VS A5.5	E9015-B9	93
VS A5.28	E9015-G	94
VS A5.5	E9015-B9	95
VS A5.28	E9015-B9	96
VS A5.5	E8018-B8	97
	-	98
VS A5.4	E308H-17	99
VS A5.4	E308H-16	100
VS A5.4	E308H-15	101
VS A5.4	E308L-15	102
VS A5.4	E308L-17	103
VS A5.4	E308L-17	104
VS A5.4	E308L-17	105
VS A5.4	E309L-17	106
VS A5.4	E309L-17	107
VS A5.4	E316L-15	108
VS A5.4	E316L-16	109
VS A5.4	E316L-17	110
VS A5.4	E316L-17	111
VS A5.4	E316L-17	112
VS A5.4	E316L-17	113
VS A5.4	E318-15	114
VS A5.4	E318-17	115

Designation system
High-alloyed stick electrodes acc. AWS A5.4

Avesta 316L/SKR

E316L-17

Table 1
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]	UNS Number[d]	Weight Percent[a,b] C	Cr	Ni	Mo	Nb (Cb) Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E209-XX	W32210	0.06	20.5–24.0	9.5–12.0	1.5–3.0	—	4.0–7.0	1.00	0.04	0.03	0.10–0.30	0.75	V = 0.10–0.30
E219-XX	W32310	0.06	19.0–21.5	5.5–7.0	0.75	—	8.0–10.0	1.00	0.04	0.03	0.10–0.30	0.75	
E240-XX	W32410	0.06	17.0–19.0	4.0–6.0	0.75	—	10.5–13.5	1.00	0.04	0.03	0.10–0.30	0.75	
E307-XX	W30710	0.04–0.14	18.0–21.5	9.0–10.7	0.5–1.5	—	3.30–4.75	1.00	0.04	0.03	—	0.75	
E308-XX	W30810	0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308H-XX	W30810	0.04–0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308L-XX	W30813	0.04	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	

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Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]	UNS Number[d]	Weight Percent[a,b] C	Cr	Ni	Mo	Nb (Cb) Plus Ta	Mn	Si	P	S	N	Cu	Other[e]
E316L-XX	W31613	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	

E312-XX	W31310	0.15	28.0–32.0	8.0–10.5	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316-XX	W31610	0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316H-XX	W31610	0.04–0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316L-XX	W31613	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316LMn-XX	W31622	0.04	18.0–21.0	15.0–18.0	2.5–3.5	—	5.0–8.0	0.90	0.04	0.03	0.10–0.25	0.75	
E317-XX	W31710	0.08	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E317L-XX	W31713	0.04	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E318-XX	W31910	0.08	17.0–20.0	11.0–14.0	2.0–3.0	6 × C, min	0.5–2.5	1.00	0.04	0.03	—	0.75	

Designation system
High-alloyed stick electrodes acc. AWS A5.4

Avesta 316L/SKR

E316L-17

Table 6
All-Weld-Metal Mechanical Property Requirements

AWS Classification	Tensile Strength, min ksi	Tensile Strength, min MPa	Elongation min. Percent	Heat Treatment
E316-XX	75	520	30	None
E316H-XX	75	520	30	None
E316L-XX	70	490	30	None
E316LMn-XX	80	550	20	None
E317-XX	80	550	30	None

Designation system
High-alloyed stick electrodes acc. AWS A5.4

Avesta 316L/SKR

E316L-17

TABLE 2
TYPE OF WELDING CURRENT AND POSITION OF WELDING

AWS Classification[A]	Welding Current[B]	Welding Position[C]
EXXX(X)-15	dcep	All[D]
EXXX(X)-16	dcep and ac	All[D]
EXXX(X)-17	dcep and ac	All[D]
EXXX(X)-26	dcep and ac	F, H-fillet

A8.3 Usability Designation -15. The electrodes are usable with dcep (electrode positive) only. While use with alternating current is sometimes accomplished, they are not intended to qualify for use with this type of current. Electrode sizes $\frac{5}{32}$ in. [4.0 mm] and smaller may be used in all positions of welding.

A8.4 Usability Designation -16. The covering for these electrodes generally contains readily ionizing elements, such as potassium, in order to stabilize the arc for welding with alternating current. Electrode sizes $\frac{5}{32}$ in. [4.0 mm] and smaller may be used in all positions of welding.

A8.5 Usability Designation -17. The covering of these electrodes is a modification of the -16 covering in that considerable silica replaces some of the titania of the -16 covering. Since both the -16 and the -17 electrode coverings permit ac operation, both covering types were classified as -16 in the past because there was no classification alternative until the 1992 revision of AWS A5.4. However, the operational differences between the two types have become significant enough to warrant a separate classification.

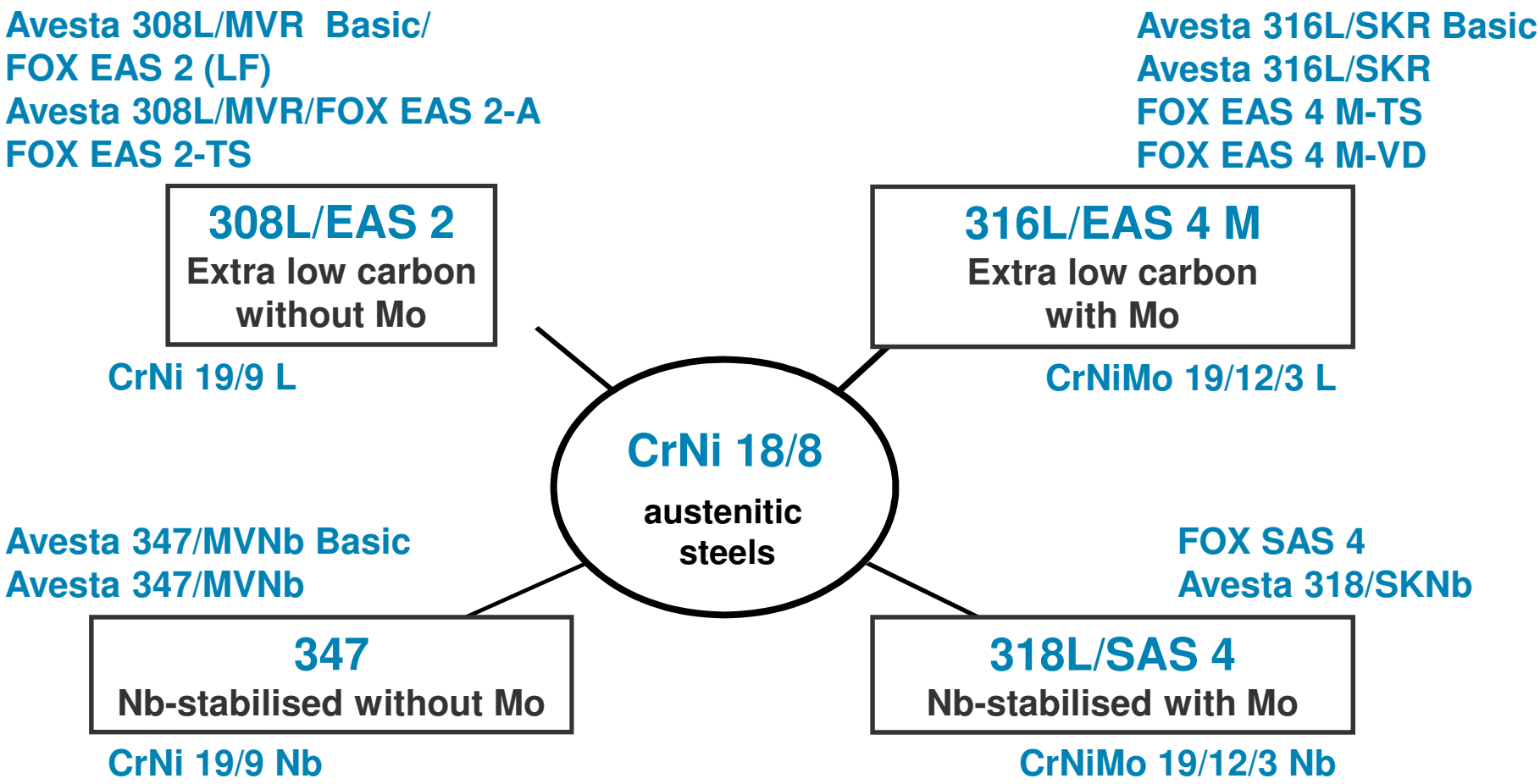
On horizontal fillet welds, electrodes with a -17 covering tend to produce more of a spray arc and a finer rippled weld-bead surface than do those with the -16 coverings. A slower freezing slag of the -17 covering also permits improved handling characteristics when employing a drag technique. The bead shape on horizontal fillets is typically flat to concave with -17 covered electrodes as compared to flat to slightly convex with -16 covered electrodes. When making fillet welds in the vertical position with upward progression, the slower freezing slag of the -17 covered electrodes requires a slight weave technique to produce the proper bead shape. For this reason, the minimum leg-size fillet that can be properly made with a -17 covered electrode is larger than that for a -16 covered electrode. While these electrodes are designed for all-position operation, electrode sizes $\frac{3}{16}$ in. [4.8 mm] and larger are not recommended for vertical or overhead welding.

basic

rutilebasic

rutile

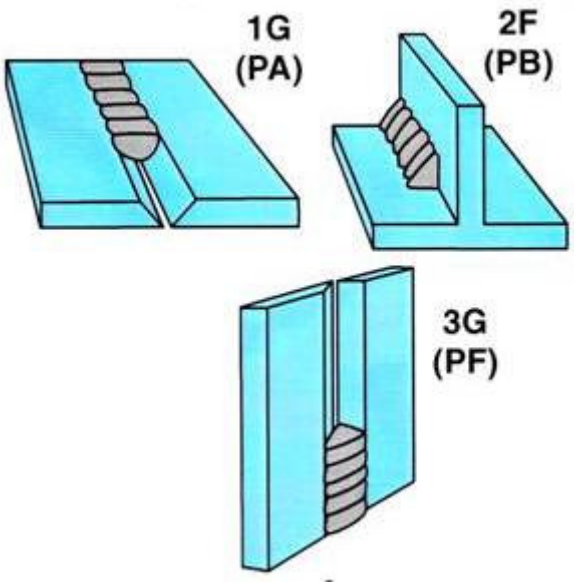
High-alloyed stick electrodes for common austenitic stainless steels



High-alloyed stick electrodes for common austenitic stainless steels

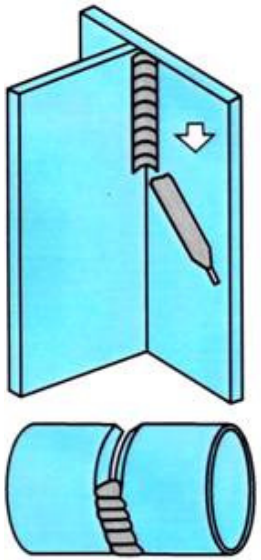
Coated stick electrode
AWS A5.4
EN ISO 3581-A

Prefered Application



E 316 L - 17
E 19 12 3 L R 32
Avesta 316L/SKR
"Beauty Weld type"

E 316L - 15
E 19 12 3 LB 22
Avesta 316L/ SKR basic
"heavy wall"

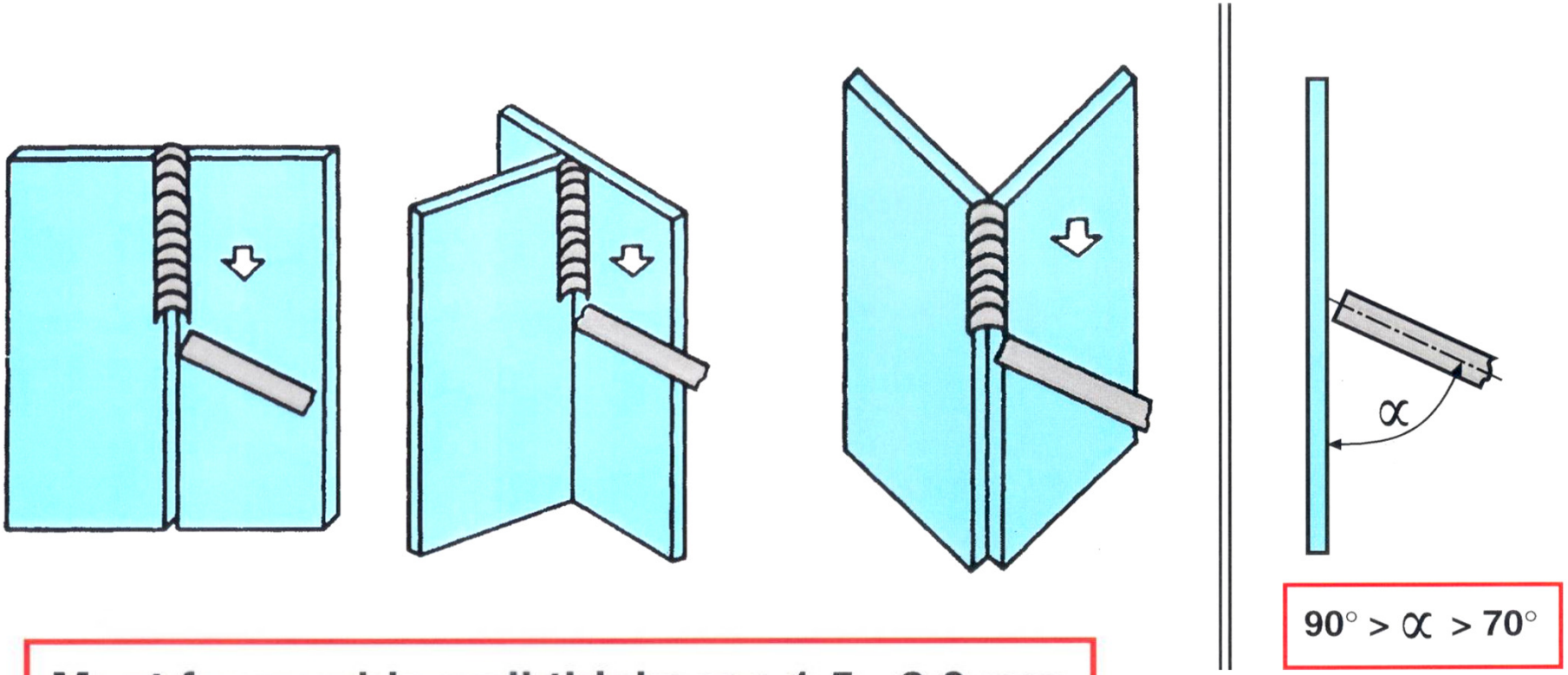


E 316L - 17
E 19 12 3 L R 15
FOX EAS 4M - VD
"Vertical down"

E 316L - 16
E 19 12 3 L R 12
FOX EAS 4M - TS
"Root welds"

High-alloyed stick electrodes for common austenitic stainless steels

Böhler Fox EAS 4 M-VD



Most favourable wall thickness 1,5 - 3,0 mm

308L

Process	Welding Classification	Recommendable Product
	AWS/EN	
SMAW	E 308L-16	Bohler FOX EAS-2 16
SAW	ER 308L	Avesta 308L/MVR with Avesta 805
GTAW	ER 308L	Bohler N ER 308L
GMAW	ER 308L	Avesta 308L
FCAW	E 308LT1-4/1 E 308LT1	Bohler ESA 2 PW-FD

316L

Process	Welding Classification	Recommendable Product
	AWS/EN	
SMAW	E 316L-16	Bohler FOX N EAS 4M-16
SAW	ER 316L	Avesta 316L Flux Avesta 807
GTAW	ER 316L	Bohler N ER 316L
GMAW	ER 316L	Avesta 316L
FCAW	E 316LT1-4/1	Bohler EAS 4M PW FD

309L

Process	Welding Classification	Recommendable Product
	AWS/EN	
SMAW	E 309L	Bohler FOX N CN 23/12-16
SAW	ER 309L	Avesta 309L Flux Avesta 807
GTAW	ER 309L	Bohler N ER 309L
GMAW	ER 309L	Avesta 309L
FCAW	E 309LT1-4/1	Bohler CN 23/12 PW-FD

347

Process	Welding Classification	Recommendable Product
	AWS/EN	
SMAW	E 347-16	Bohler FOX SAS 2-16
SAW	ER 347	Avesta 347/MVNb with Avesta 805
GTAW	ER 347-Si	Avesta 347-Si/MVNb- Si
GMAW	ER 347- SI	Avesta 347-Si/MVNb-Si
FCAW	E 347	Bohler SAS 2 PW-FD

High-alloyed stick electrodes for common austenitic stainless steels

APPLICATION
Agitator vessel

BASE MATERIAL
AISI 316Ti / 1.4571 (vessel) 8 mm
AISI 321Ti / 1.4541 (Limpet coil) 2 mm

USED FILLER MATERIALS
Avesta 316L/SKR
Böhler EAS 4 M-FD
GTAW Avesta 316L

CUSTOMER/COUNTRY
Chemie Linz
Austria

High-alloyed stick electrodes for common austenitic stainless steels

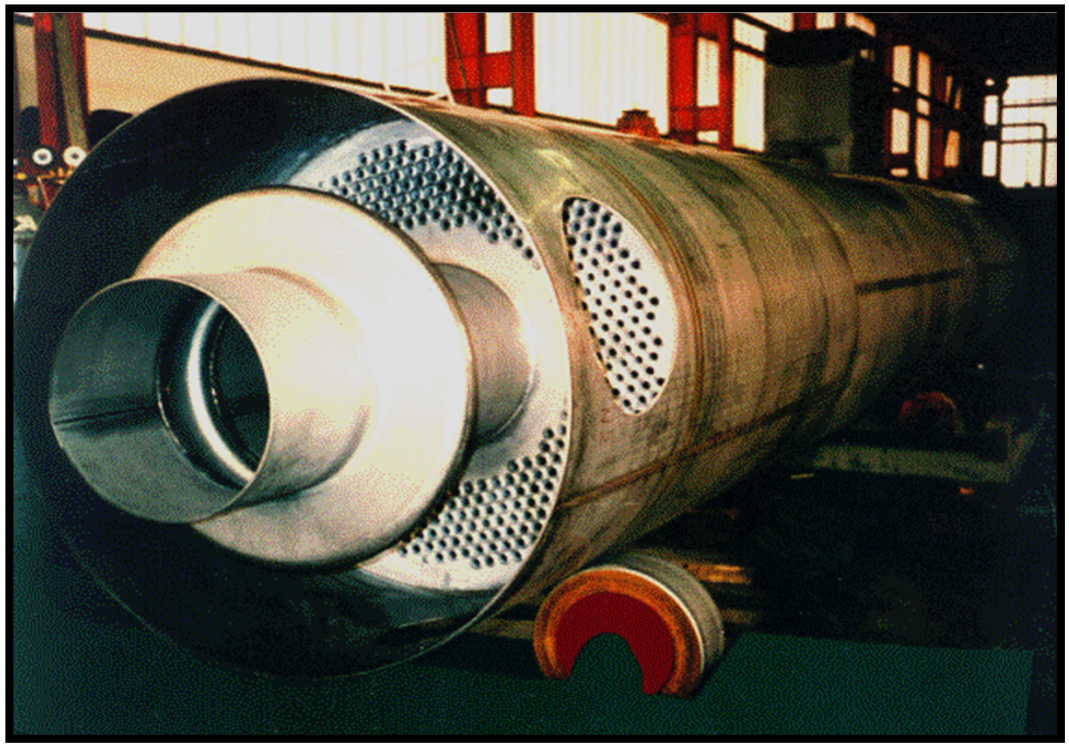
APPLICATION
Casting component for a recycling plant

BASE MATERIAL
AISI 316L / 1.4404 12-20 mm

USED FILLER MATERIALS
Avesta 316L/SKR
Böhler EAS 4 M-FD

CUSTOMER/COUNTRY
M/S Voith
Germany

High-alloyed stick electrodes for common austenitic stainless steels



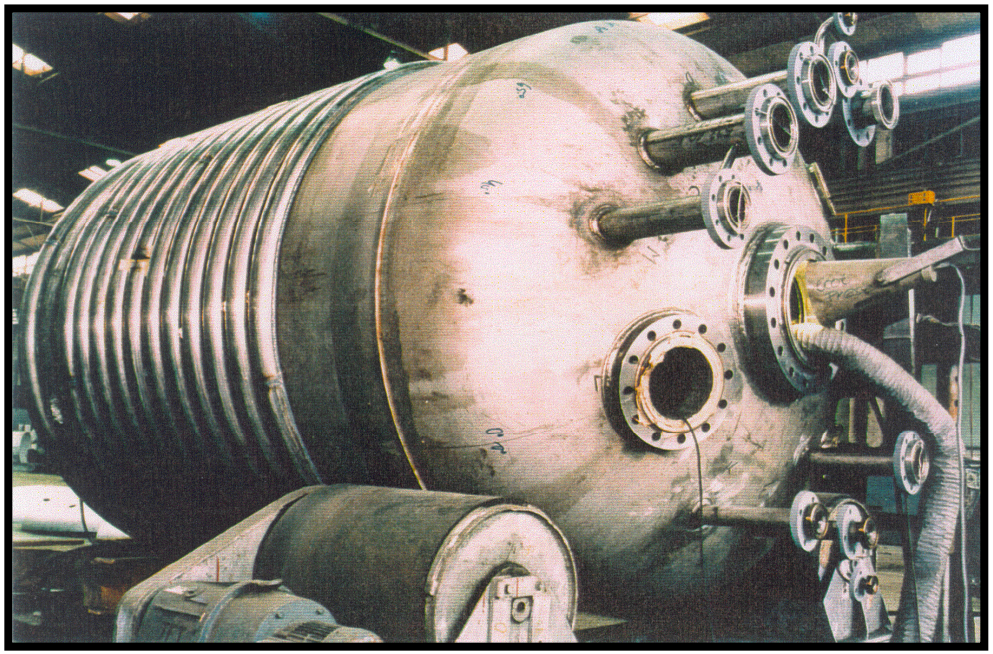
APPLICATION
Heat exchanger

BASE MATERIAL
AISI 308L / 1.4306

USED FILLER MATERIALS
Avesta 308L/MVR
GTAW Avesta 308L/MVR –Si
BÖHLER EAS 2-FD

CUSTOMER/COUNTRY
Apparatebau Kapfenberg
Austria

High-alloyed stick electrodes for common austenitic stainless steels



APPLICATION

Pressure vessel with heating coil

BASE MATERIAL

AISI 316Ti / 1.4571 (Shell and bottom plates)
AISI 321 / 1.4541 (Limpet coil)

USED FILLER MATERIALS

Avesta 318L/ SKNb
GTAW Avesta 318/SKNb
GTAW Avesta 316L/SKR
BÖHLER EAS 4 M-FD

CUSTOMER/COUNTRY

Apparatebau Kapfenberg
Austria

High-alloyed stick electrodes for common austenitic stainless steels

APPLICATION
Refinery-Tank

MEDIUM
Natural oil

BASE MATERIAL
AISI 316 / 1.4436

USED FILLER MATERIALS
Avesta 316L/SKR
GTAW Avesta 316L/SKR
SAW Avesta 316L/SKR Flux Avesta 805

CUSTOMER/COUNTRY
Austrian Energy
Hungary

Special low ferrite products

Especially for low temperature application (down to -196°C) Böhler Welding is able to offer products with limited ferrite content e.g.

Böhler FOX EAS 2 (LF)	FN 3-8
Böhler EAS 2 PW-FD (LF)	FN 3-6
Böhler FOX EAS 4 M (LF)	FN 3-8
Böhler EAS 4 PW-FD (LF)	FN 3-6
Standard FOX EAS 2/4	FN 4-10

Effects of Delta-ferrite

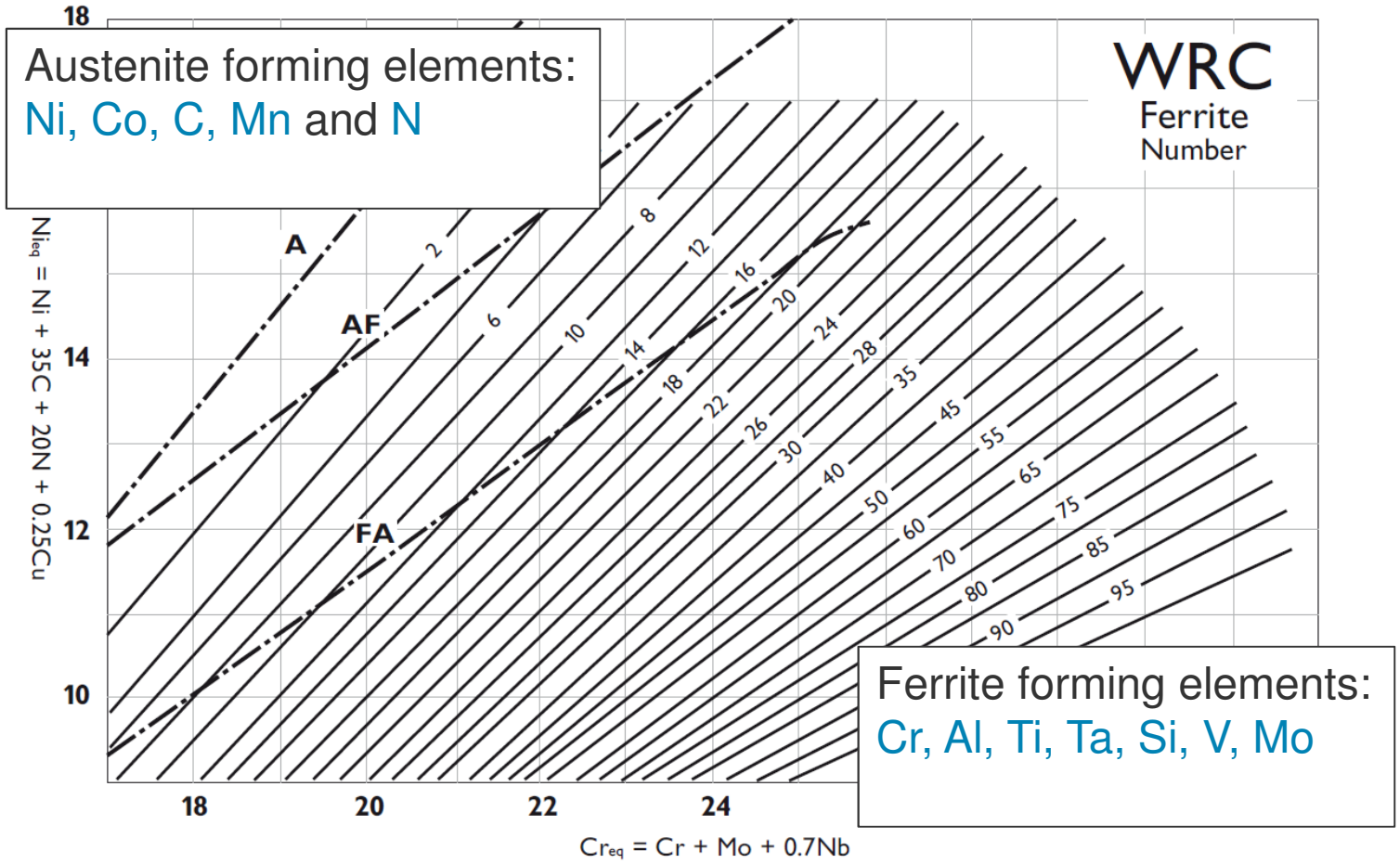
The effect of Delta-ferrite in an austenitic weld metal (basically, also applies to the steel material):

Reasons		Consequences of too much or too little	
Delta-ferrite content is unwanted			
• Requirement for non-magnetic weld metal	FN=0	• Magnetisability	
• Particular corrosion stress	FN<0.5	• Selective corrosion	
• Use at very low temperatures	FN<0.5	• Loss of toughness	
• Use at very high temperatures	FN<0.5	• Phase precipitation	
Low delta-ferrite proportion is advantageous			
• High resistance hot cracking, including thick-walled components	FN=3-15	• Risk of hot cracking	FN<3
• Usage temperatures between -100 and +400 °C		• Loss of toughness	FN>15
		• Phase precipitation	FN>15
• No unusual chemical stress		• Selective corrosion	FN>15
High delta-ferrite content is required			
• Resistance to stress corrosion cracking	FN=30-75	• Reduced resistance to stress corrosion cracking	FN<30
• Increase in strength	FN=30-75	• Reduced toughness	FN<75
		• Reduced strength	FN<30
• Compensation for the dilution when welding dissimilar joints	FN=15-25	• Risk of hot cracking from dilution	FN<15

Determining the ferrite content of the weld metal

Measuring with Feritscope MP30

Determining the ferrite content of the weld metal



Austenite forming elements:
Ni, Co, C, Mn and N

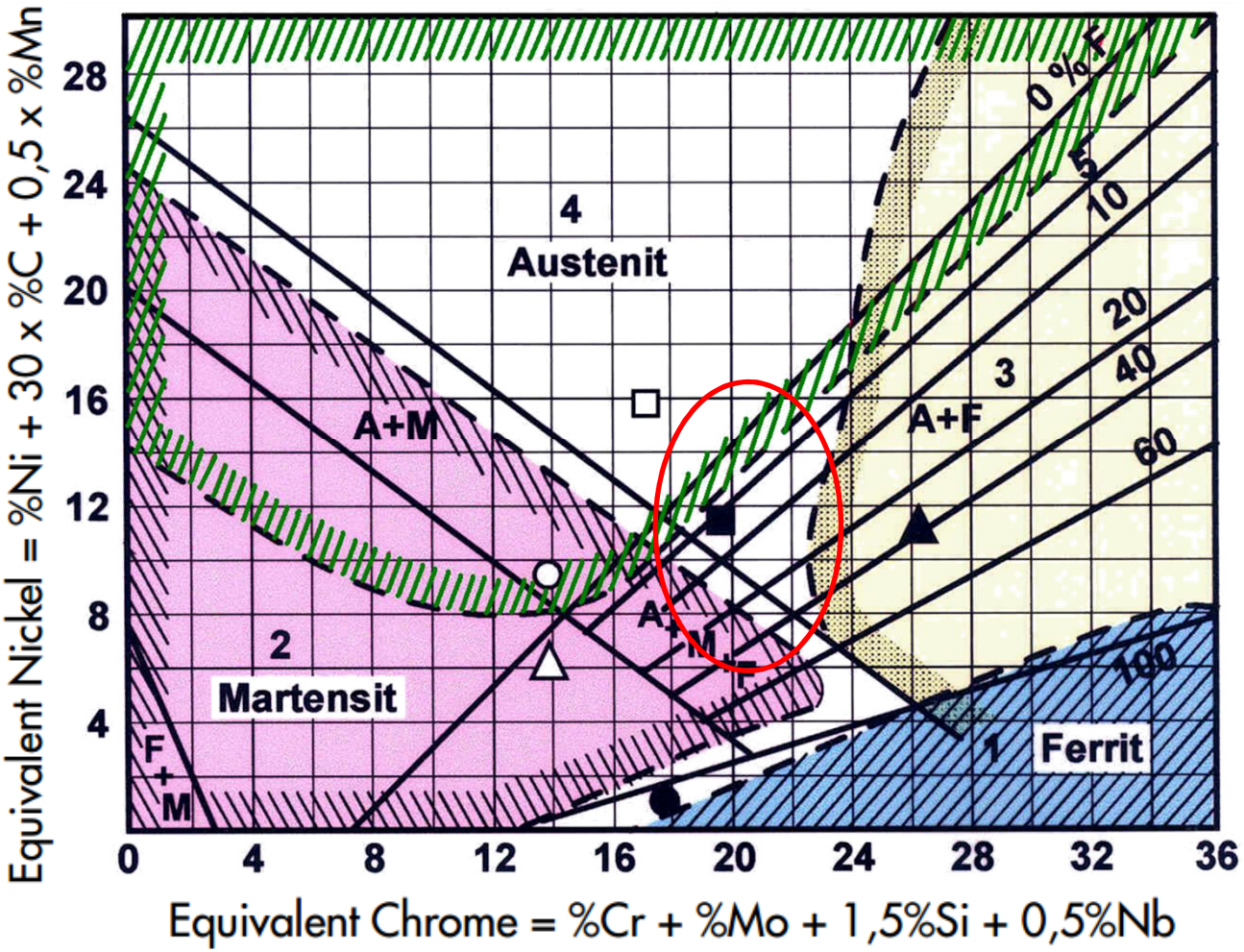
Ferrite forming elements:
Cr, Al, Ti, Ta, Si, V, Mo

Böhler Welding high-alloyed stick electrodes

Stick electrodes for cladding and dissimilar welding:

Product	EN ISO 3581-A	AWS A5.4
Böhler Fox A7	E 18 8 Mn B 2 2	E307-15 (mod.)
Böhler Fox CN 19-9 M	E 20 10 3 R 3 2	E308Mo-17 (mod.)
Avesta 309L	E 23 12 L R 3 2	E309L-17
Avesta P5	E 23 12 2 L R 3 2	E309LMo-17
Böhler Fox CN 24/13 Nb	E 23 12 Nb B 2 2	E309Nb-15 (mod.)
Böhler Fox CN 29/9-A	E 29 9 R 3 2	E312-17

Welding dissimilar joints



Area 1
Grain growth
over 1150 °C

Area 2
Hardening crack
under 400 °C

Area 3
Sigma embrittlement
550 – 900 °C

Area 4
Hot cracks
over 1250 °C

Welding dissimilar joints

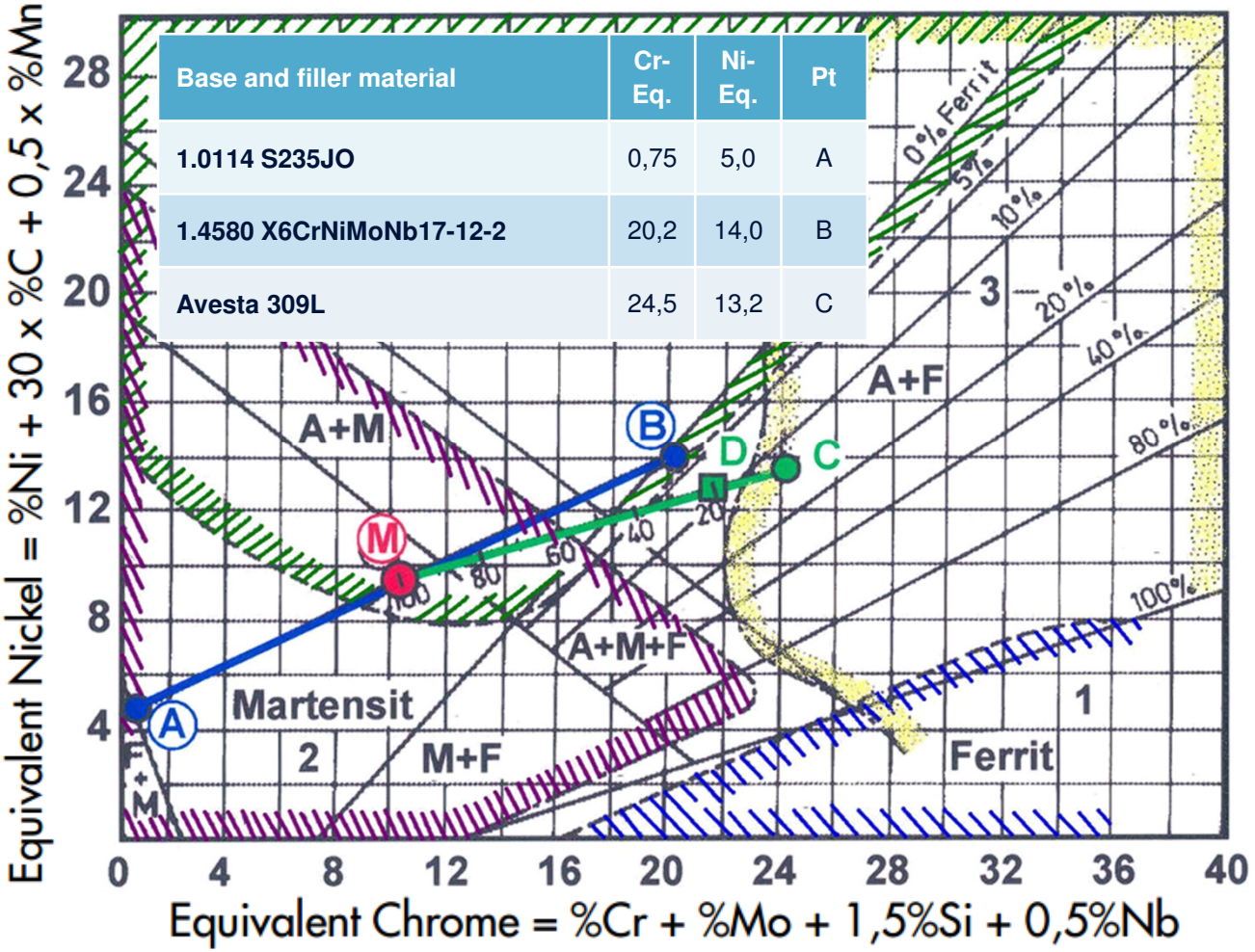
Base and filler material	C	Si	Mn	Cr	Ni	Mo	Nb	Cr-Eq.	Ni-Eq.	Pt
1.0114 S235JO	0,15	0,50	1,0	-	-	-	-	0,75	5,0	A
1.4580 X6CrNiMoNb17-12-2	0,05	0,50	1,2	17,0	11,9	2,2	0,5	20,2	14,0	B
Avesta 309L	0,02	1,0	1,2	23,0	12,0	-	-	24,5	13,2	C

Cr-Equivalent = % Cr + % Mo + 1,5 x % Si + 0,5 x % Nb

Ni-Equivalent = % Ni + 30 x % C + 0,5 x % Mn

Welding dissimilar joints

Base and filler material	Cr-Eq.	Ni-Eq.	Pt
1.0114 S235JO	0,75	5,0	A
1.4580 X6CrNiMoNb17-12-2	20,2	14,0	B
Avesta 309L	24,5	13,2	C



Area 1
Grain growth
over 1150 °C

Area 2
Hardening crack
under 400 °C

Area 3
Sigma embrittlement
550 – 900 °C

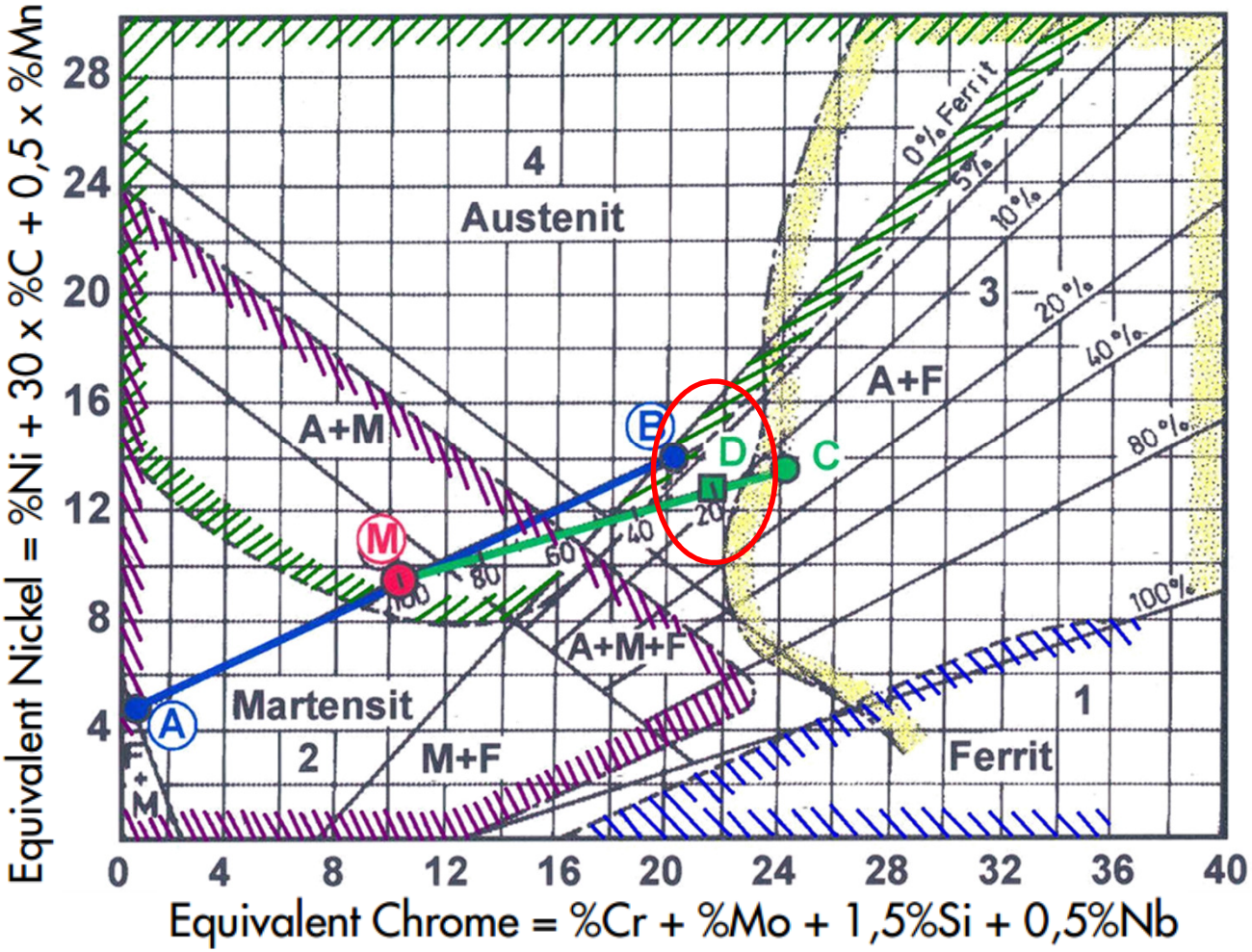
Area 4
Hot cracks
over 1250 °C

Welding dissimilar joints

Dilution:

Welding process	Dilution in vol-%
Rutile stick electrode (SMAW)	15-25
Basic stick electrode (SMAW)	20-30
Solid wire (GMAW)	20-30
Flux-cored wire (FCAW)	15-25
SAW	20-60
GTAW	up to 100 (100 for autogenous)

Welding dissimilar joints



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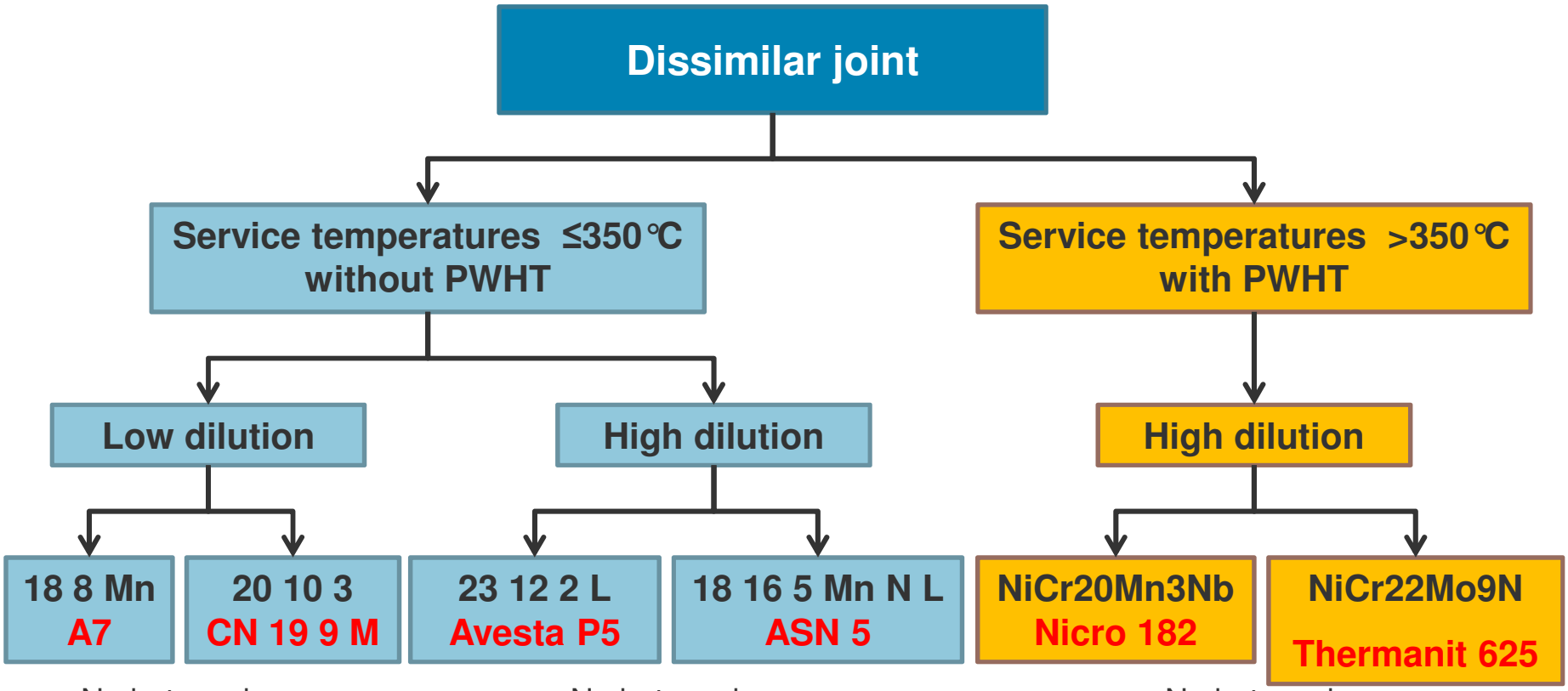
Welding dissimilar joints



No hot cracks
No martensite

No hot cracks
No martensite
Corrosion-resistant

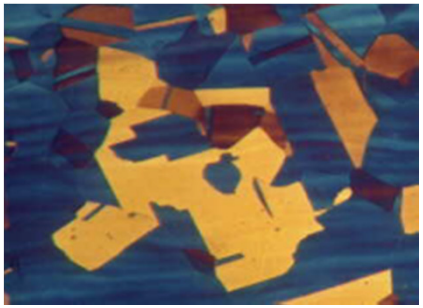
No hot cracks
No martensite
Corrosion-resistant
Heat-resistant

Welding dissimilar joints

Examples:

Dissimilar joint type	Weld metal acc. EN ISO
un&low-alloyed steel with austenitic stainless steel	Avesta 309L Avesta P5 A7
un&low-alloyed steel with full-austenitic CrNiMoN stainless steel	CN 20/25 Thermanit Nicro 82
alloyed Cr steel with austenitic steel	Avesta P5 A7 Thermanit Nicro 82
ferritic creep resistant steel with austenitic steel	Thermanit Nicro 182 Thermanit Nicro 82
ferritic/austenitic steel with nickel-based	Thermanit Nicro 182 Thermanit 625 NIBAS C24

DUPLEX STEELS - Microstructure



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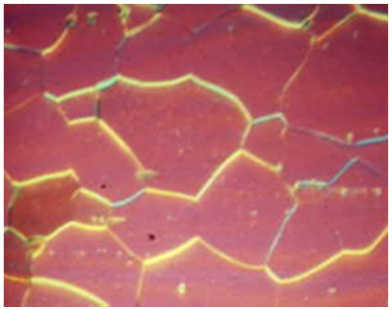

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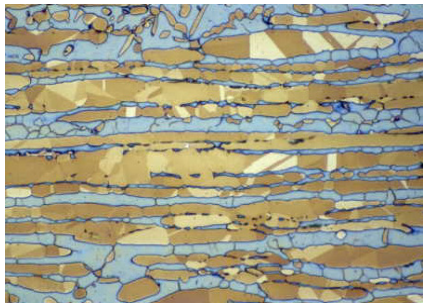


Austenitic	Ferritic	Duplex

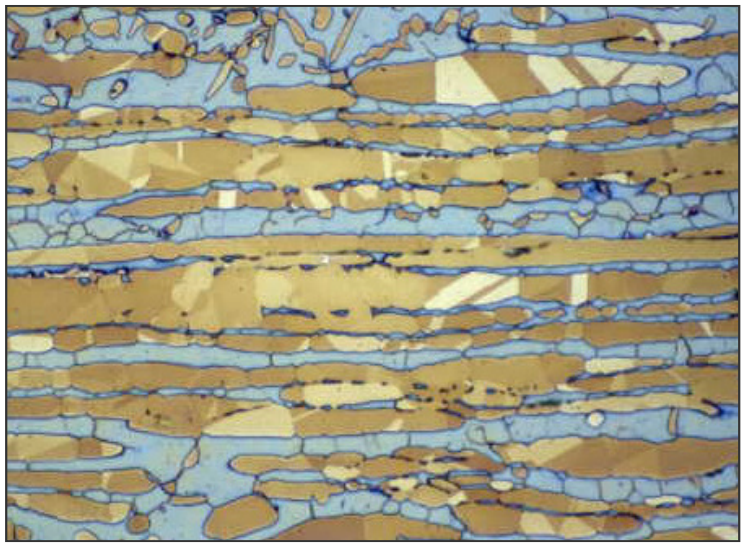
Duplex steels combine the austenitic and ferritic properties

DUPLEX STEELS - Microstructure

BASE MATERIAL

Controlled cooling

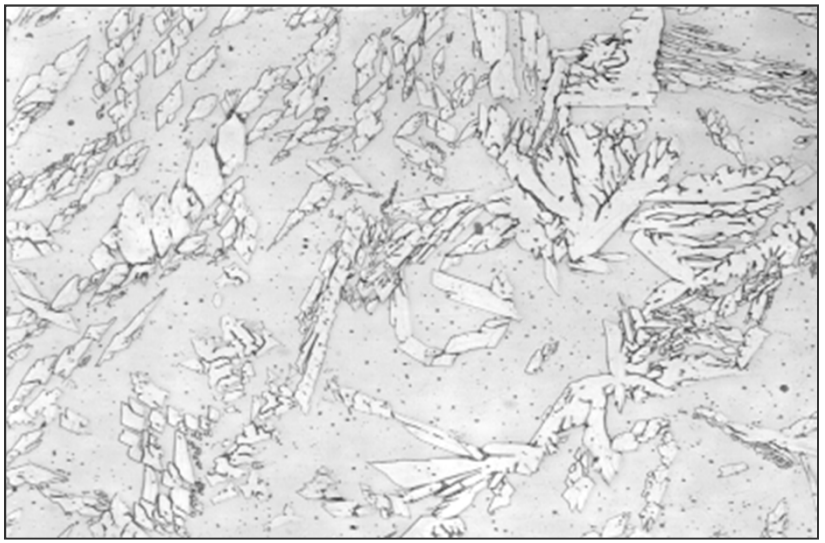
→ Ferrite 50%



WELD METAL

Cooling rate can vary

→ Ferrite 20-70%



DUPLEX STEELS - Chemical composition

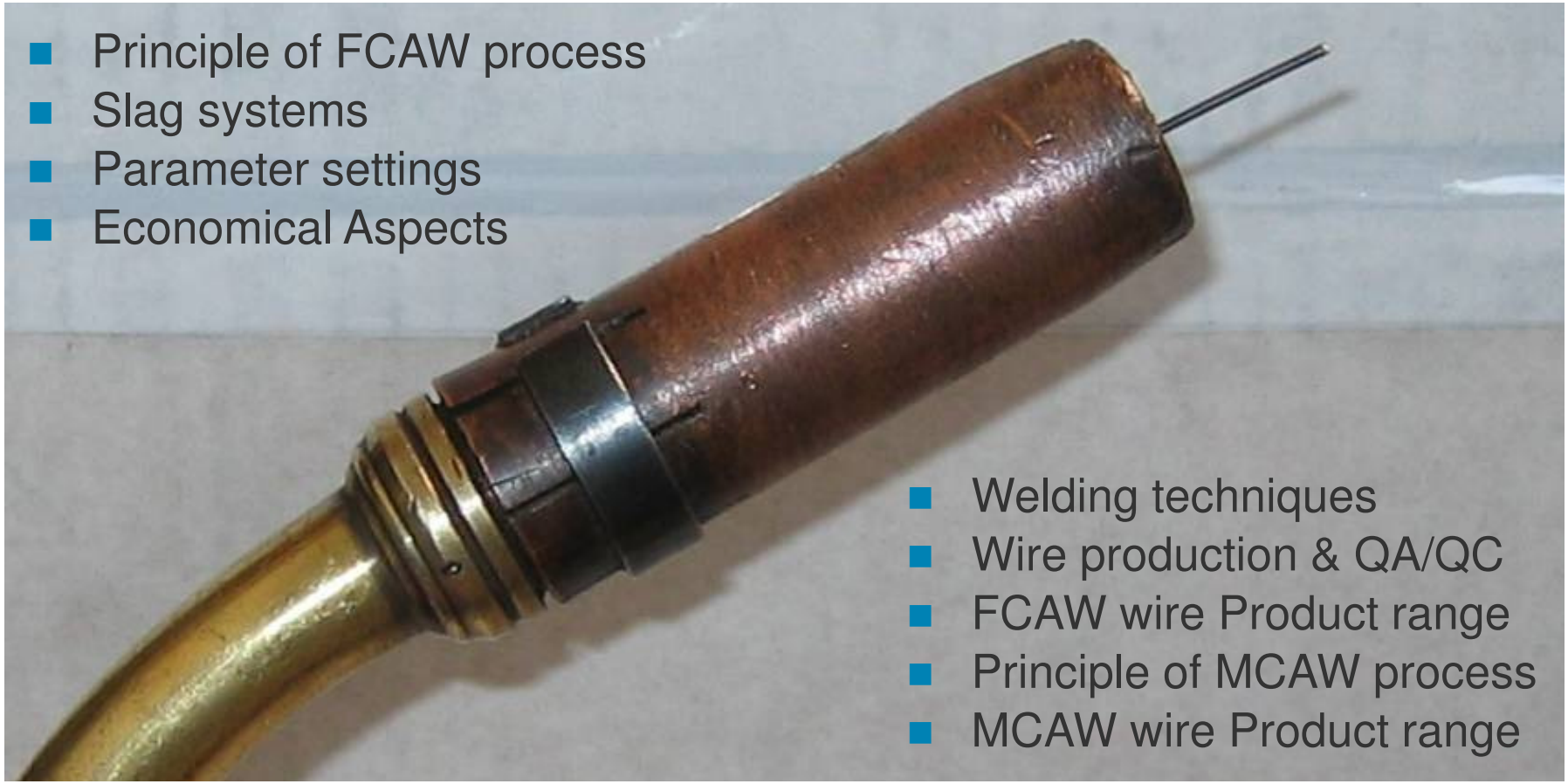
Grade	ASTM	EN	Chemical composition (typical values wt-%)					
			C (max)	N	Cr	Ni	Mo	Mn
LDX 2101®	S32101	1.4162	0.02	0.22	21.5	1.5	0.3	5
Filler LDX	-	(23 7 N L)	0.03	0.16	23.5	7	<0.5	0.8
2304	S32304	1.4362	0.02	0.10	23	5	<0.3	1.5
Filler 2304	-	(23 7 N L)	0.02	0.12	24.5	8	<0.3	0.8
2205	S32205	1.4462	0.02	0.17	22	6	3.1	1.5
Filler 2205	E2209	22 9 3 N L	0.02	0.16	23	9.5	3.2	0.8
2507	S32750	1.4410	0.02	0.27	25	7	4	1.5
Filler 2507	E2594	25 9 4 N L	0.03	0.23	25.5	10	4	1.2

DUPLEX STEELS – Mechanical properties

Grade	ASTM	EN	EN, min. values			ASTM, min. values		
			Rp0,2 [MPa]	Rm [MPa]	A5 [%]	Rp0,2 [MPa/ksi]	Rm [MPa/ksi]	A5 [%]
LDX 2101®	S32101	1.4162	450[1]	650[1]	30[1]	450[2]/65	650[2]/94	30[2]
2304	S32304	1.4362	400	630	25	400/58	600/87	25
2205	S32205	1.4462	460	640	25	450/65	655/95	25
4307	304L	1.4307	200	500	45	170/25	485/70	40
4404	316L	1.4404	220	520	45	170/25	485/70	40

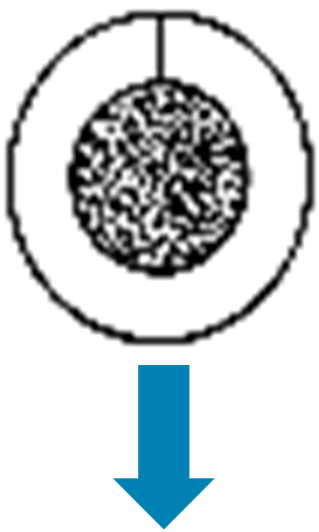
1. Values still not officially, but no deviations from ASTM are expected.
2. According to ASTM A240 for hot rolled plate. For cold rolled sheet, Rp0,2 min. 530 and Rm min. 700 MPa.

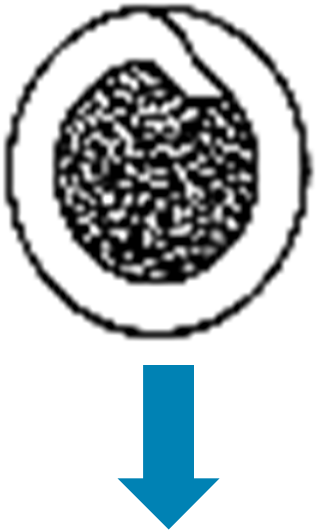
Stainless steel welding by FCAW process



Concepts of flux cored wires

Profiles

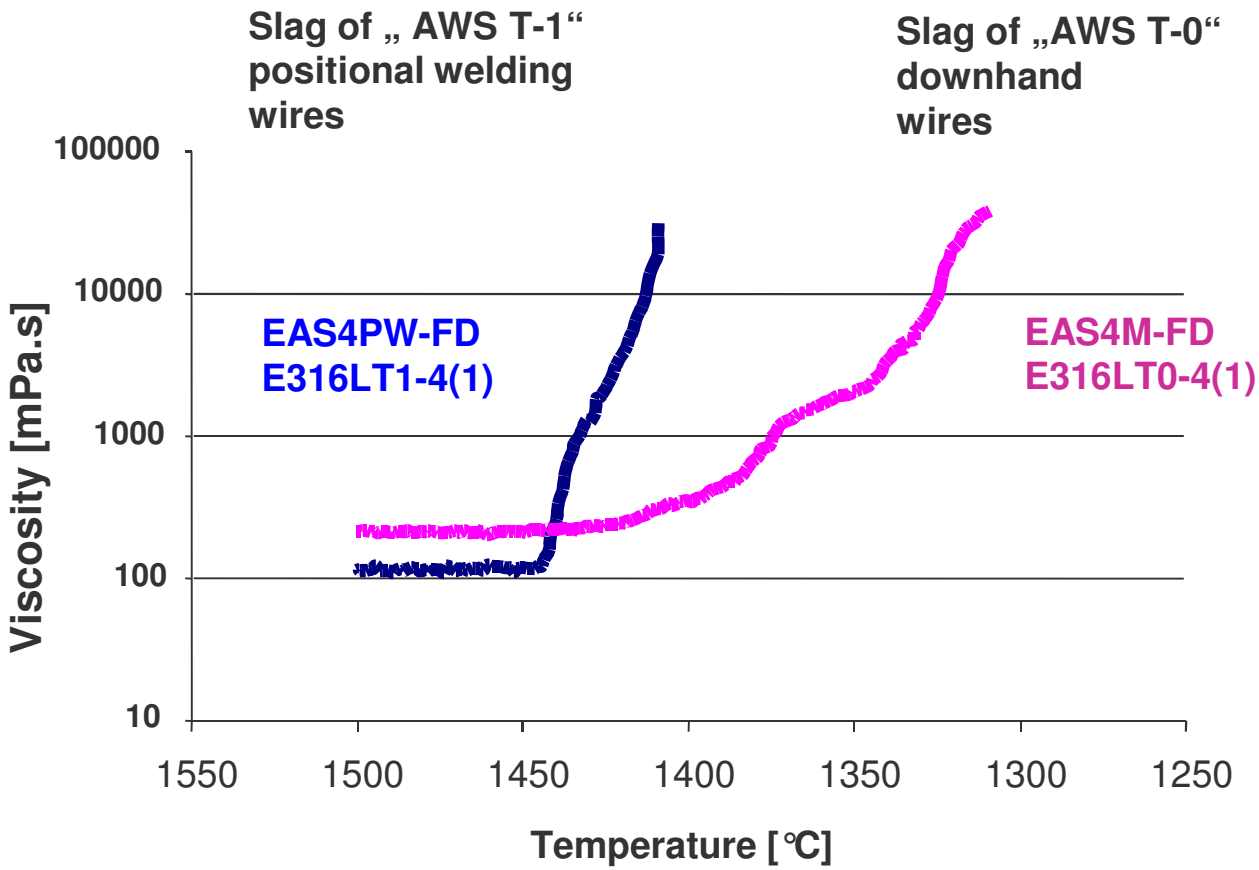




For un- and alloyed MC wires

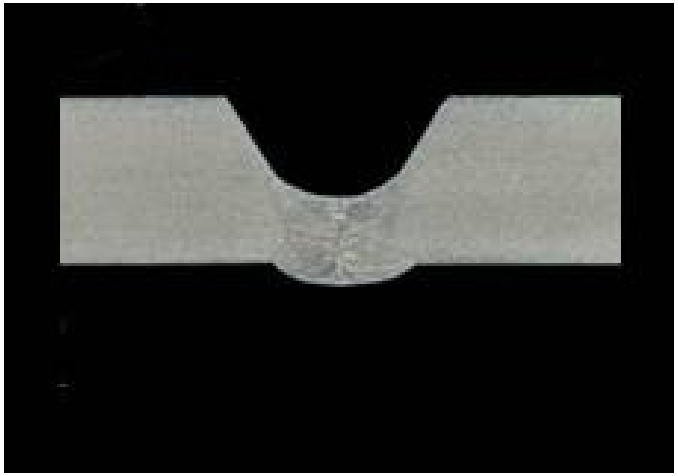
For high alloyed FCAW wires

Slag viscosity of filling systems



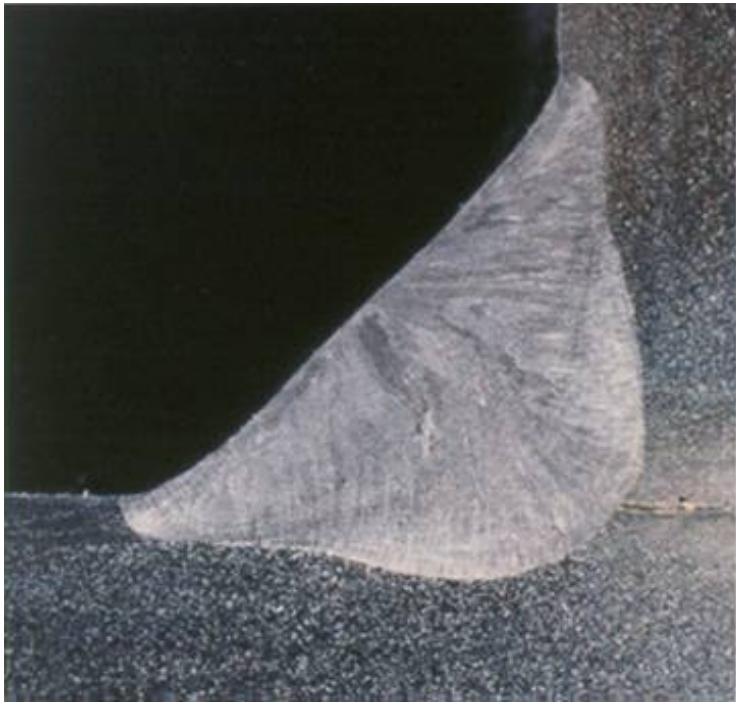
Welding with stainless steel flux cored wire

- Makes the welding process easier
- Increases productivity
- Decreases the total welding costs
- Reduces the risk of weld defects
- Designed to meet highest quality requirements



Penetration compared to solid wire

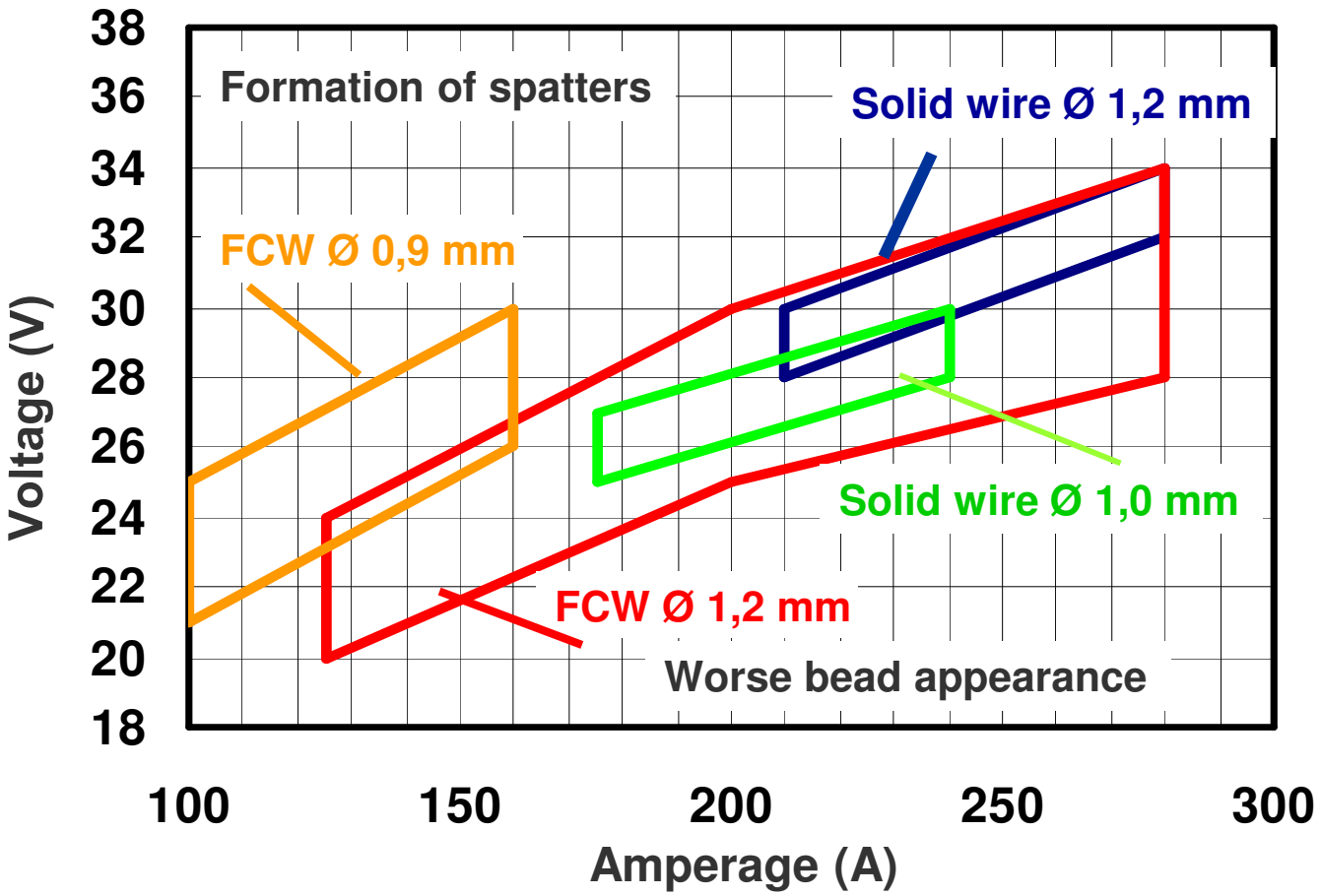
- Flux cored wire have a wider arc
- Operate therefore with a very safe penetration
- The risk of lack of fusion is minimized



Flux cored

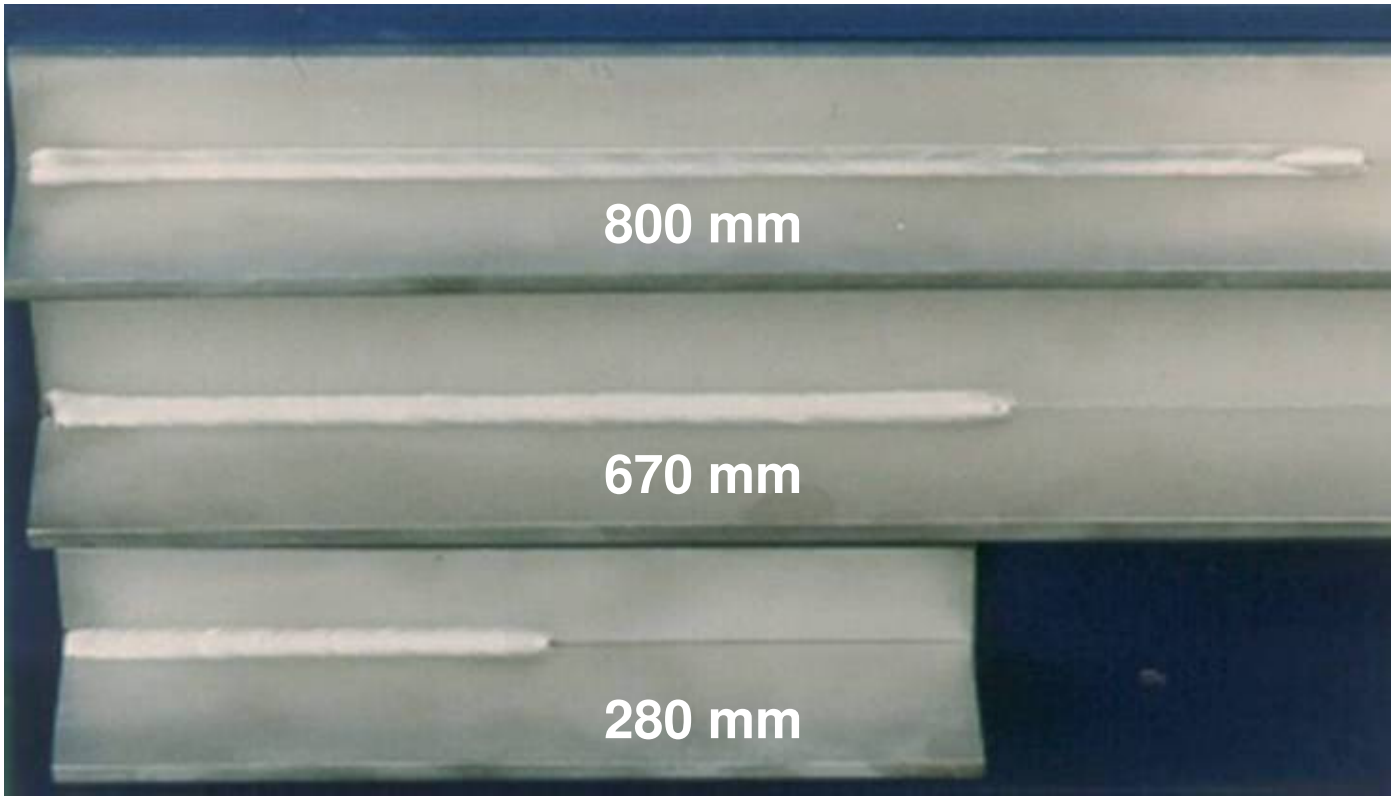
Solid wire

Parameter box for SS flux cored wires



Comparison of weld length

Throat thickness 3 mm, welding time 1 min

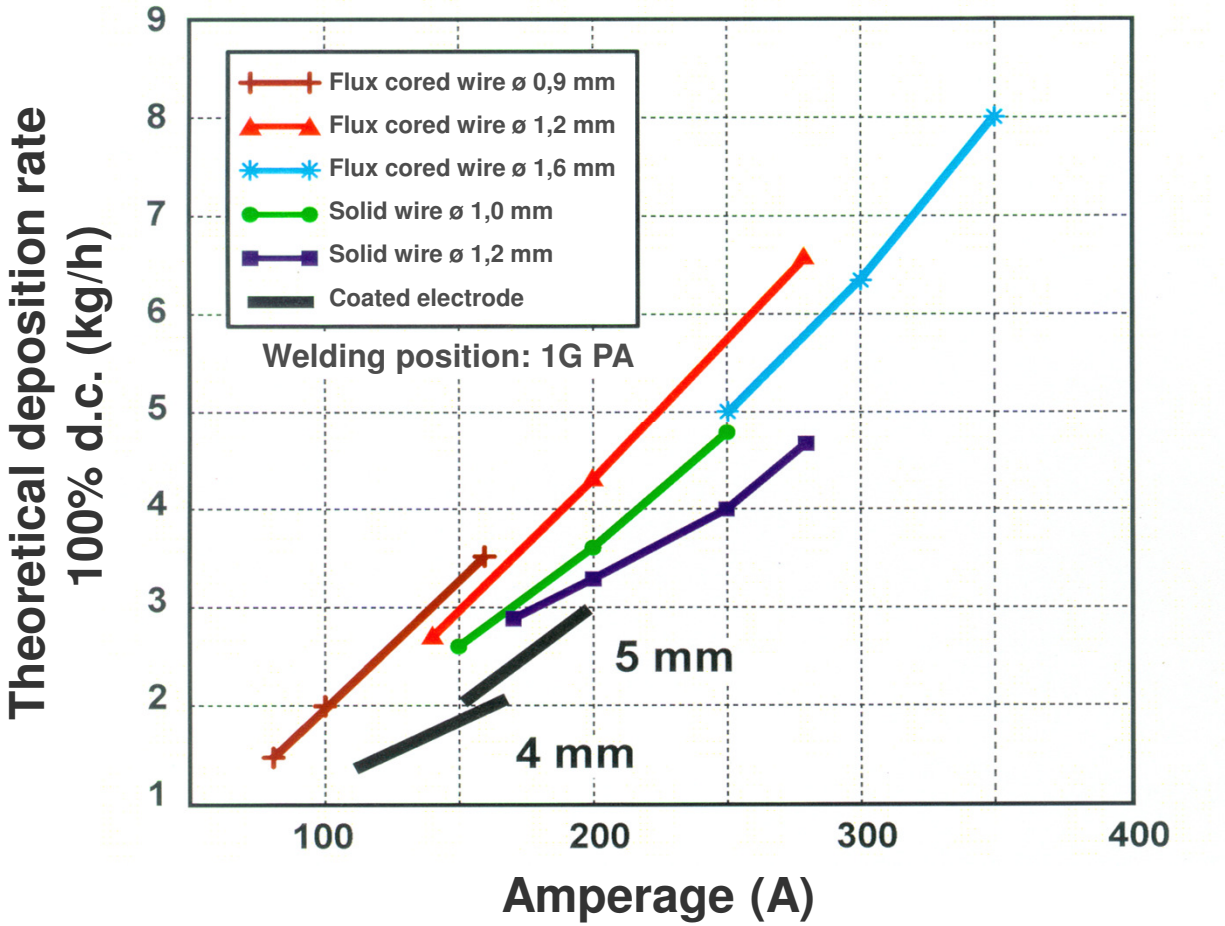


Flux cored wire
Ø 1,2 mm

Solid wire
Ø 1,0 mm

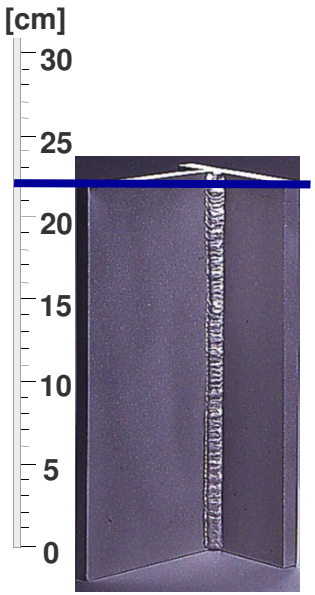
Covered electrode
Ø 3,2 mm

Comparison of deposition rates

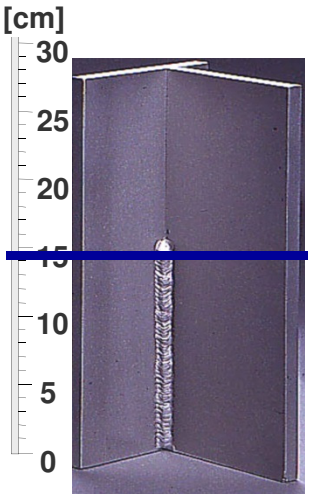


Comparison of weld length

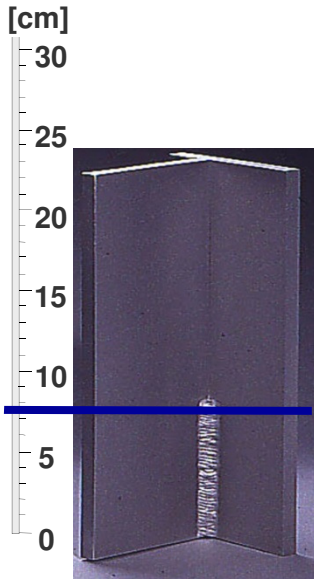
Flux-cored wire
E316LT1-4(1)
EAS 4 PW-FD
Ø 1,2 mm
M 21



Solid wire
ER316L-(Si)
EAS 4 M-IG (Si)
Ø 1,0 mm
M 12



Covered electrode
E316L-17
FOX EAS 4 M-A
Ø 3,2 mm



Flux cored wire
- A = 180
- V= 27,5
- WS = 8,3 m/min
- L = 220 mm/min

Solid wire pulsed
- A = 100
- V = 20
- WS = 5,5 m/min
- L = 145 mm/min

Covered electrode
- A = 90
- V = 26
- L = 75 mm/min

Comparison between FCAW/GMAW

Welding position: vertical up

FCAW Ø 1,2 mm
8,3 m/min, 27,5 V

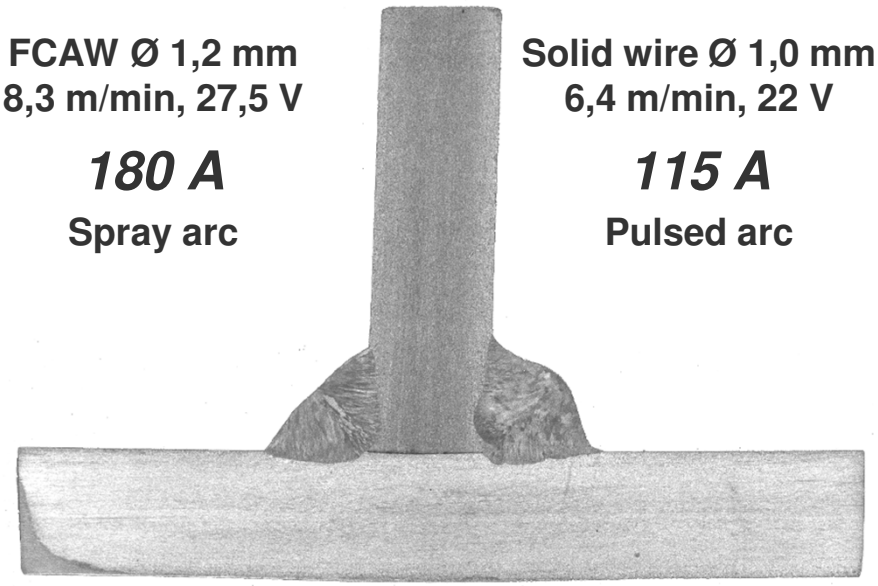
180 A

Spray arc

Solid wire Ø 1,0 mm
6,4 m/min, 22 V

115 A

Pulsed arc



FCAW Ø 1,2 mm
8,3 m/min, 27,5 V

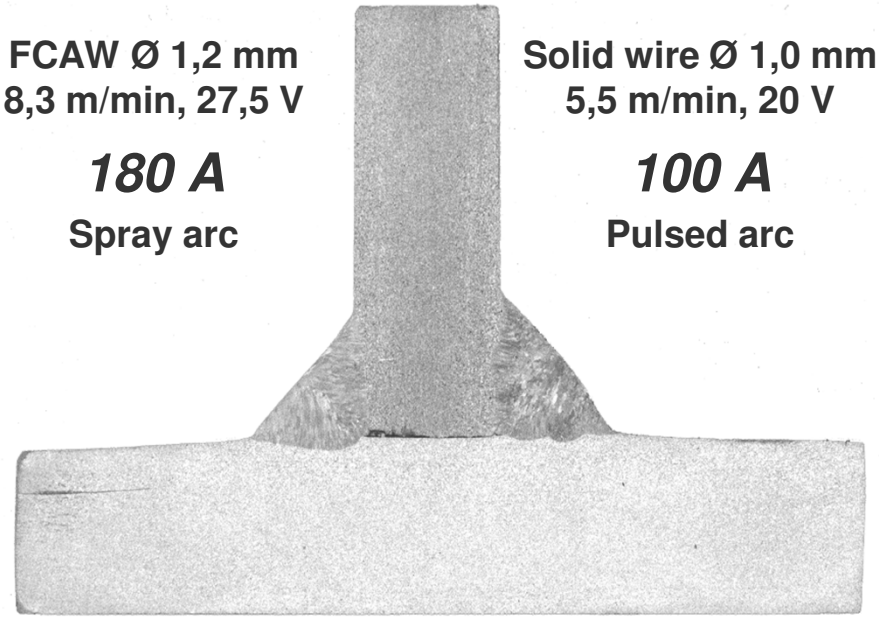
180 A

Spray arc

Solid wire Ø 1,0 mm
5,5 m/min, 20 V

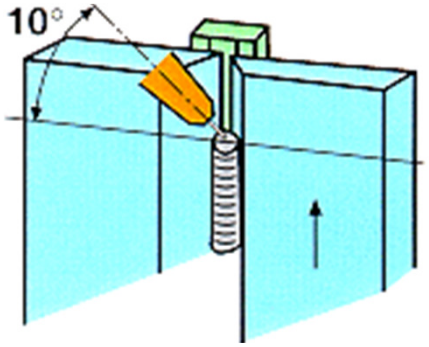
100 A

Pulsed arc

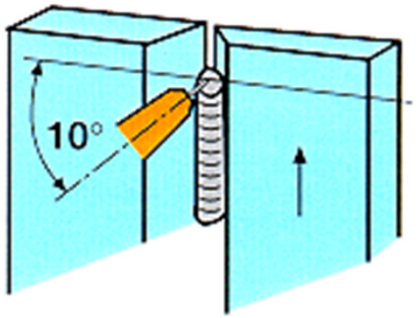


Some practical advise

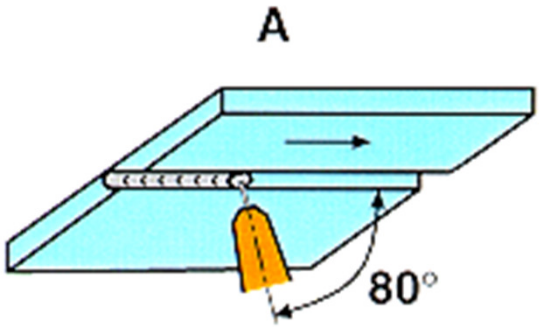
Ceramic backing

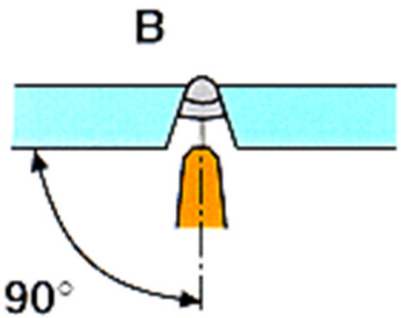


Root



Slight weaving is recommended for all welding positions

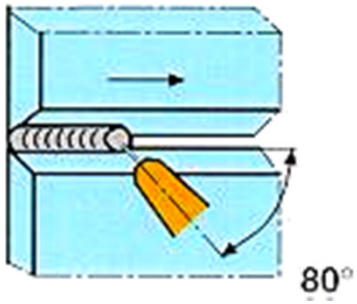


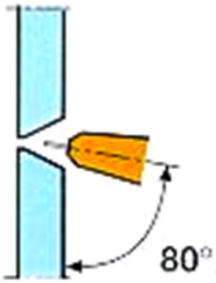


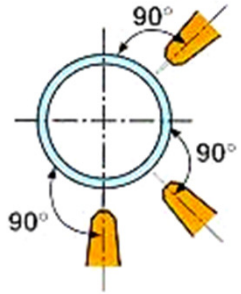
voestalpine
ONE STEP AHEAD.

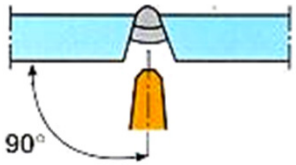
Some practical advise

Butt weld

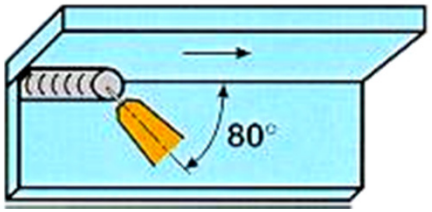


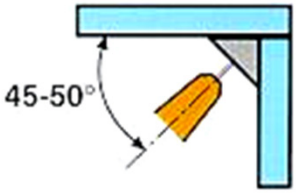




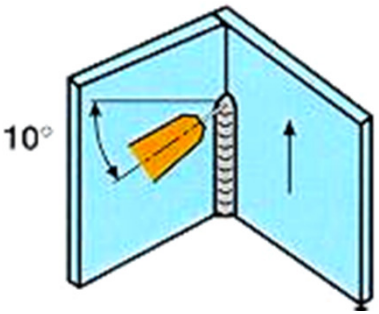


Fillet weld



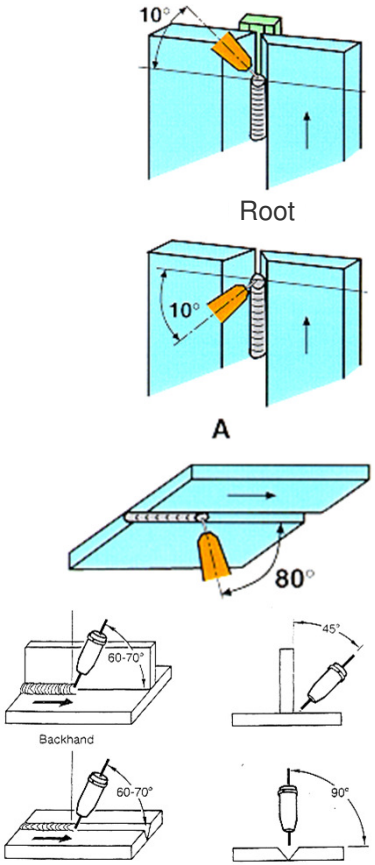


Slight weaving is recommended for all welding positions



voestalpine
ONE STEP AHEAD.

Recommended welding parameters

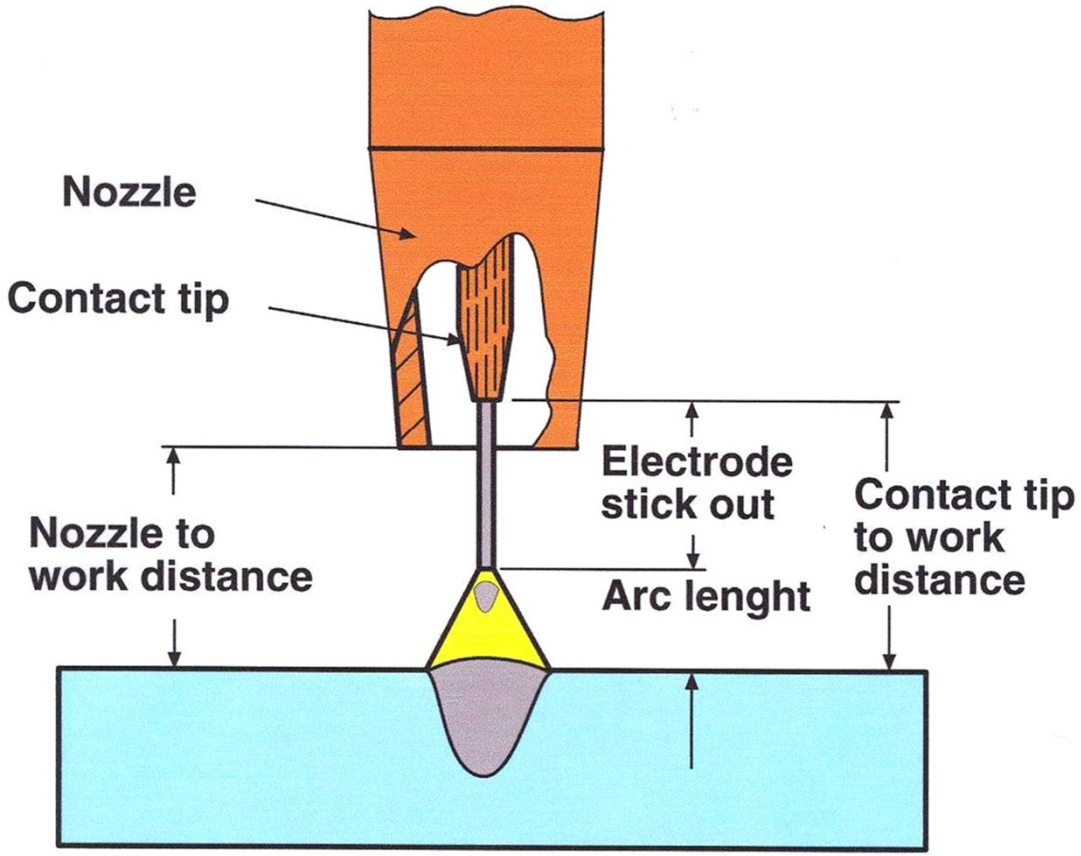


Vertical up
PF/3G, 3F 130-200A 22-30V 6-11cm/min

Overhead
PE/4G, 4F 130-200A 22-30V 6-11cm/min

Horizontal PC/2
flat position PA/1G 130-250A 22-32V 6-13cm/min

Wire stick out (mm)



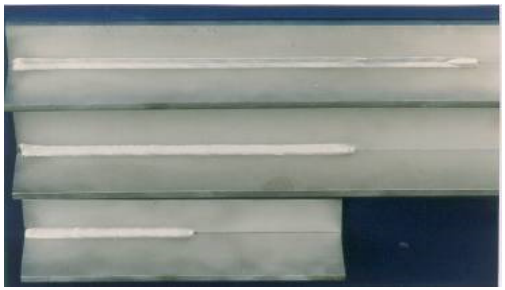
Minimum wall thicknesses for welding with SS-flux cored wires

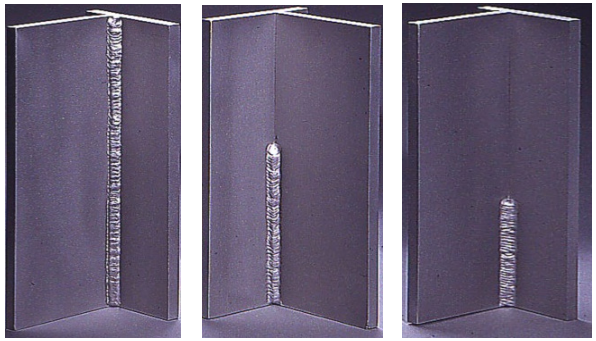
		Min. wall thickness (mm)	
Type of weld	**Welding position**	**Ø 0,9 mm**	**Ø 1,2 mm**
Fillet weld	2F (horizontal)	1,5	3,0
	3F (vertical down)	1,5	3,0
	3F (vertical up)	5,0	5,0
Butt weld	1G (flat)	1,5	3,0
	3G (vertical down)	2,0	3,0
	3G (vertical up)	5,0	5,0

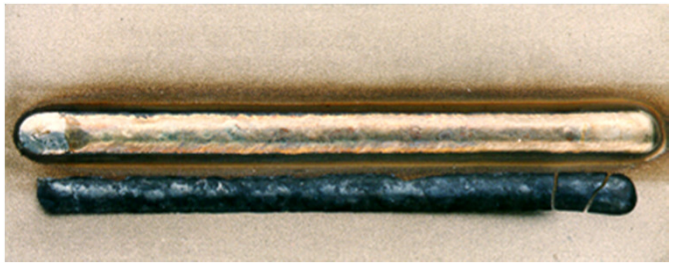
Welding with SS FCAW – Conclusion

In spite of higher costs compared to SMAW & GMAW flux cored wire offers when considering all the production related costs noticeable

- Gain of time
- Increase in productivity
- Post weld savings



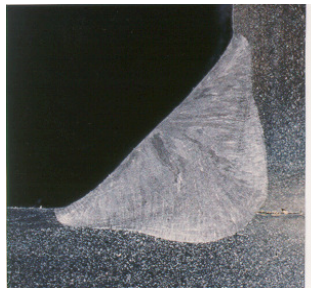
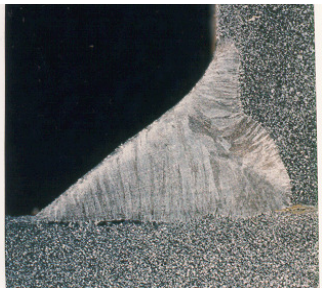
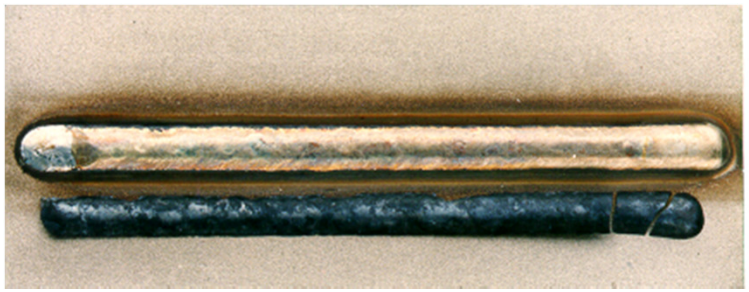




Welding with SS FCAW – Conclusion

Reasons named from end users for their changing towards FCAW

- High deposition rates resp. productivity
- Easy handling
- Smooth bead appearance
- No problems with porosity and lack of fusion
- Low and easy post weld work
- Low shielding gas costs

Product Application

Project Details	
Customer Fabrication shop	■ Bronswerk Heat Transfer BV Nijkerk – the Netherlands
Component description	■ High pressure gas coolers
Base materials	■ Duplex & AISI 321 stainless steels
Filler metal type Quantity	■ Full package of solid wires, fluxcored wires and wire-flux combinations for stainless steel ■ BÖHLER SAS2-FD FCAW ■ BÖHLER CN 22/9N-FD FCAW
Engineering company	■ Vetco Aibel AS, Norway
Owner	■ Petrobras, Brasil
Project name	■ FPSO P53 floating production unit – compression modules

Success story: active support to WPQS, excellent consumables, in time delivery

Product Application

© Bronswerk Heat Transfer, Netherlands

Product Application

Base metal:

- AISI 316Ti/1.4571

Filler metal:

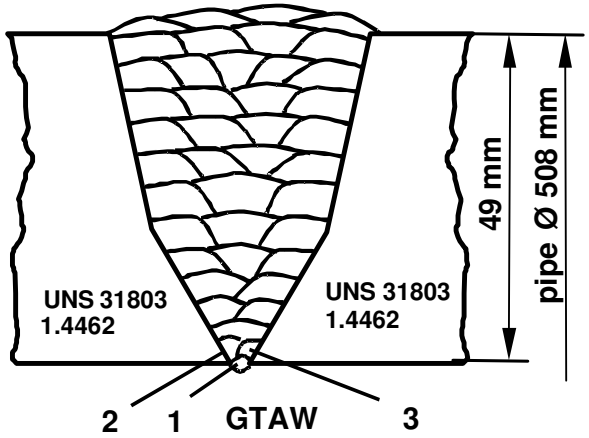
- EAS4M-FD (E316LT0-4(1)

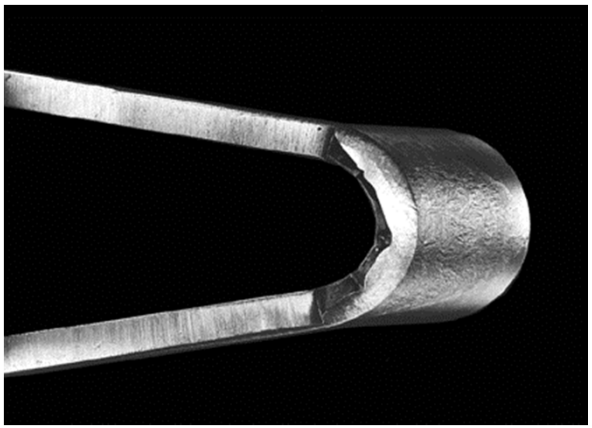
Customer/Country:

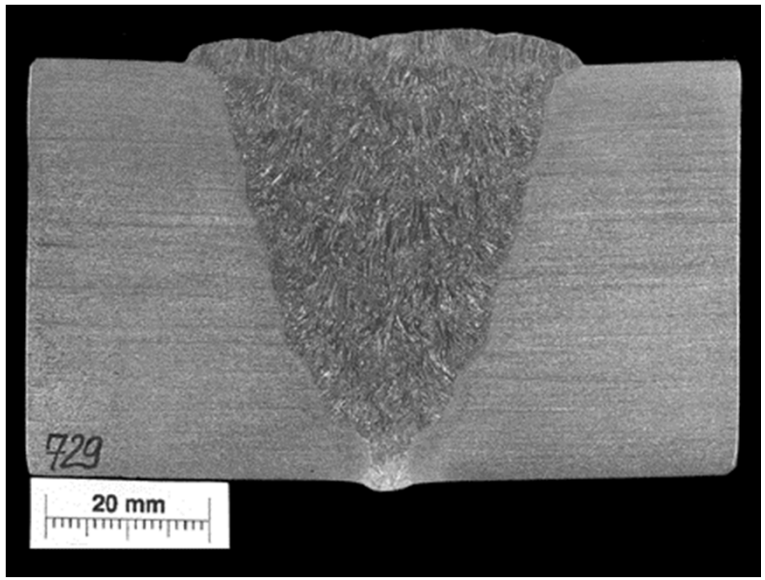
- M/S Andritz AG/A

Worm Shaft

Pipe welded with CN22/9PW-FD Ø1,2 mm







- Shielding gas: **Ar + 20%CO_2**
- IPT: **150°C (300°F)**
- Preheating: **~100°C (~210°F)**
- Welding position: 5G

Product Application

Base metal:

- UNS S 31803/1.4462 15-25mm

Filler metal:

- CN22/9PW-FD (E2209T1-4(1)
- CN22/9N-FD (E2209T0-4(1)

Customer/Country:

- M/S Frank Mohn/Norway

Water injection system for a fire fighting equipment

Product program of SS FCW – Standard Type

For downhand/horizontal position

Designation	EN	AWS	Diameter mm		
Böhler EAS 2-FD	T 19 9 L R M (C) 3	E 308 LT 0-4 (1)	0,9	1,2	1,6
Böhler SAS 2-FD	T 19 9 Nb R M (C) 3	E 347 T 0-4 (1)	-	1,2	1,6
Böhler EAS 4 M-FD	T 19 12 3 L R M (C) 3	E 316 LT 0-4 (1)	0,9	1,2	1,6
Böhler SAS 4-FD	T 19 12 3 Nb R M (C) 3	E 318 T 0-4 (1)	-	1,2	1,6
Böhler E 317L-FD	TZ 19 13 4 L R M (C) 3	E 317 LT 0-4 (1)	-	1,2	-
Böhler CN 22/9 N-FD	T 22 9 3 N L R M (C) 3	E 2209 T 0-4 (1)	-	1,2	-
Böhler CN 23/12-FD	T 23 12 L R M (C) 3	E 309 L T 0-4 (1)	0,9	1,2	1,6
Böhler CN 23/12 Mo-FD	T 23 12 2 L R M (C) 3	E 309 L Mo T 0-4 (1)	0,9	1,2	1,6
Böhler A7-FD	T 18 8 Mn R M (C) 3	E 307 T 0-G	-	1,2	1,6
Böhler E 308 H-FD	TZ 19 9 H R M (C) 3	E 308 HT 0-4 (1)		1,2	-
Böhler NIBAS 70/20-FD	Ni 6082	ENiCr-3TO-4	-	1,2	1,6
Böhler NIBAS 70/20 Mn-FD	**Ni 6082**	**ENiCr-3TO-4 (mod.)**		1,2	-

Product program of SS FCW – “PW” Type

For positional welding

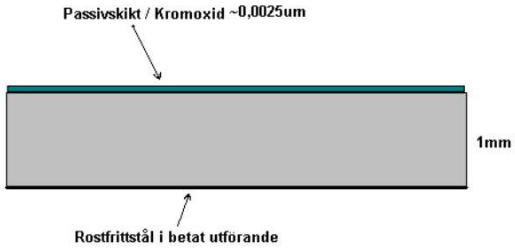
Designation	EN	AWS	Diameter mm	
Böhler EAS 2 PW-FD	T 19 9 L P M (C) 1	E308LT1-4 (1)	1,2	1,6
Böhler EAS 2 PW-FD (LF)	**T 19 9 L P M (C) 1**	**E308LT1-4 (1)**	1,2	1,6
Böhler SAS 2 PW-FD	T 19 9 Nb P M (C) 1	E347T1-4 (1)	1,2	–
Böhler SAS 2 PW-FD (LF)	**T 19 9 Nb P M (C) 1**	**E347T1-4 (1)**	1,2	-
Böhler EAS 4 PW-FD	T 19 12 3 L P M (C) 1	E316LT1-4 (1)	1,2	1,6
Böhler EAS 4 PW-FD (LF)	**T 19 12 3 L P M (C) 1**	**E316LT1-4 (1)**	1,2	1,6
Böhler SAS 4 PW-FD	T 19 12 3 Nb P M (C) 1	E318T1-4 (1)	1,2	–
Böhler CN 22/9 PW-FD	T 22 9 3 N L P M (C) 1	E2209T1-4 (1)	1,2	–
Böhler CN 24/9 LDX PW-FD	T Z 24 9 N L P M (C) 1	E2209 T1-G	1,2	
Böhler CN 25/9 PW-FD	**TZ 25 9 4 N L P M21 2**	**-**	1,2	–
Böhler CN 23/12 PW-FD	T 23 12 L P M (C) 1	E309LT1-4 (1)	1,2	1,6
Böhler CN 23/12 Mo PW-FD	T 23 12 2 L P M (C) 1	E309LMoT1-4 (1)	1,2	–
Böhler E 317L PW-FD	T Z 19 13 4 L P M(C) 1	E317LT1-4 (1)	1,2	–
Böhler A 7 PW-FD (LMn)	T 18 8 Mn P M (C) 2	E307T1-G	1,2	–
Böhler E 308 H PW-FD	T Z 19 9 H P M (C) 1	E308HT1-4 (1)	1,2	–
Böhler NIBAS 625 PW-FD	**Ni 6625**	**ENiCrMo-3T1-4**	1,2	–

Stainless Steel – Passive layer

Is stainless steel always stainless?

- Above 11% Chromium ⇒ Thin invisible surface of chromium oxide = passive layer

- Passive layer ~ 25 Å (0,0025 µm)



- Local break-down of passive layer or disturbance of the self healing process gives ⇒

⇒ CORROSION

Answer: NO!

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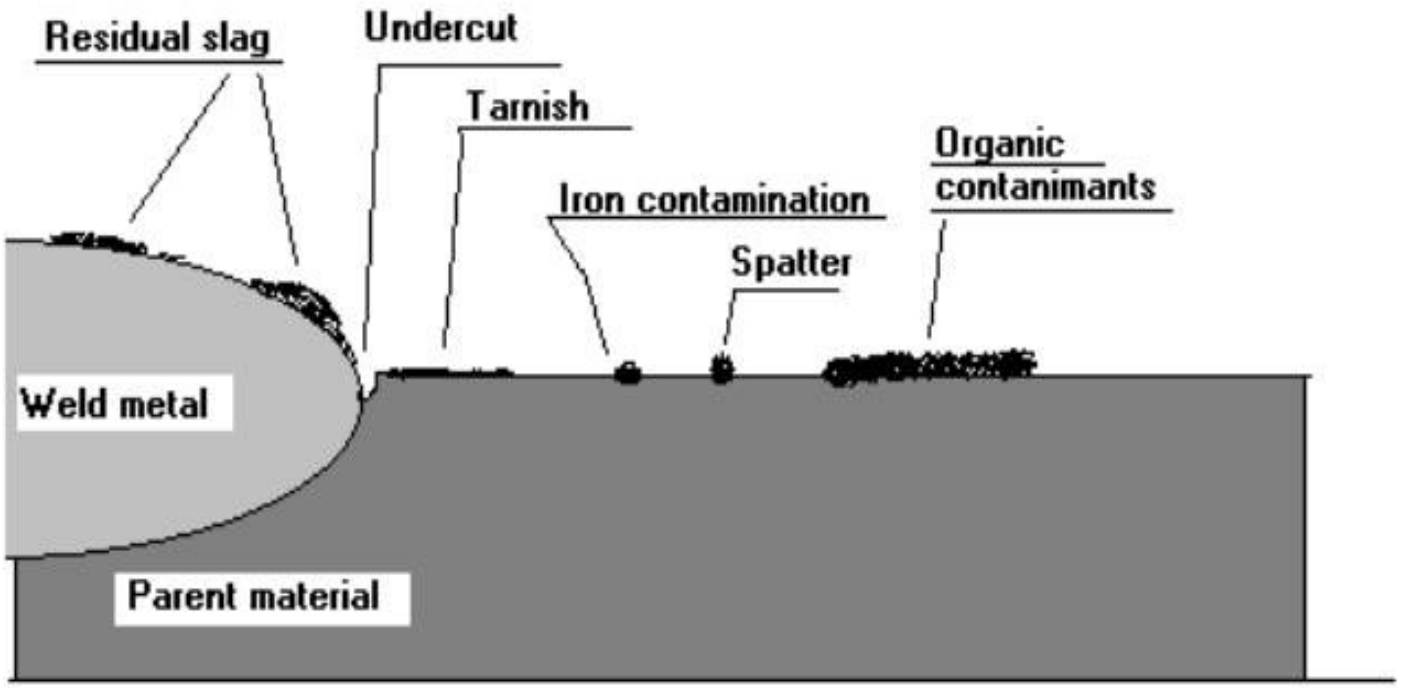
ONE STEP AHEAD.

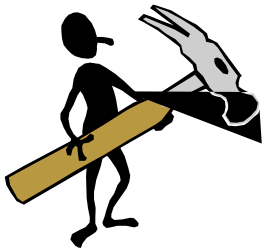
Stainless Steel – Surface defects



Cleaning methods

MECHANICAL

- Grinding
- Blasting
- Brushing



CHEMICAL

- Pickling
- Electropolishing

What to choose?

- Damage
- Contamination
- Quality

Mechanical methods

- Grinding

Removes weld slag, deep scratches, heat oxide and the chromium depleted zone.

The surface quality depends on the roughness achieved through the choice of the grit used. The finer the better! At least 180 grit.

- Blasting

Removes weld slag and heat oxide *but not the chromium depleted zone*.

Surface quality depends on: Blasting material, particle size, pressure.

Gives a uniform appearance but may introduce compressive stresses.

- Brushing

Removes heat oxide and slag. Stainless steel brush / Scotch Brite

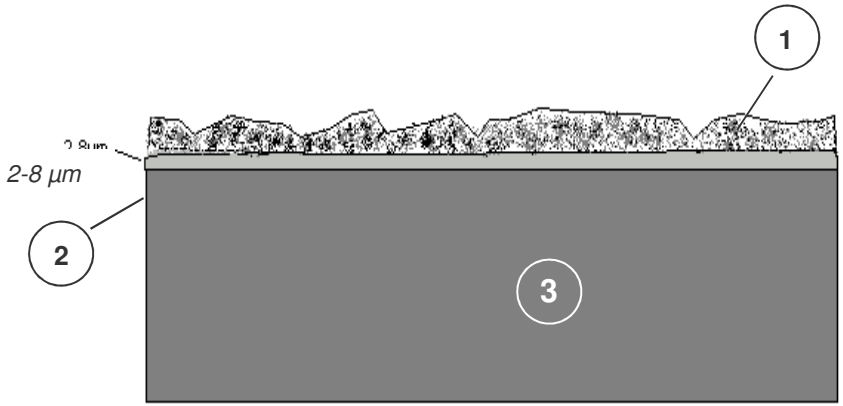
Use the right tool (stainless)!

Finish with a passivation!

Stainless Steel – Chromium depleted zone

Heat treatment or welding disturbs the chromium content of the metal.

1. Heat oxide 50-60 wt % Cr
2. Chromiumdepleted zone <10 wt % Cr
3. Base metal >18 wt % Cr



Layers 1 and 2

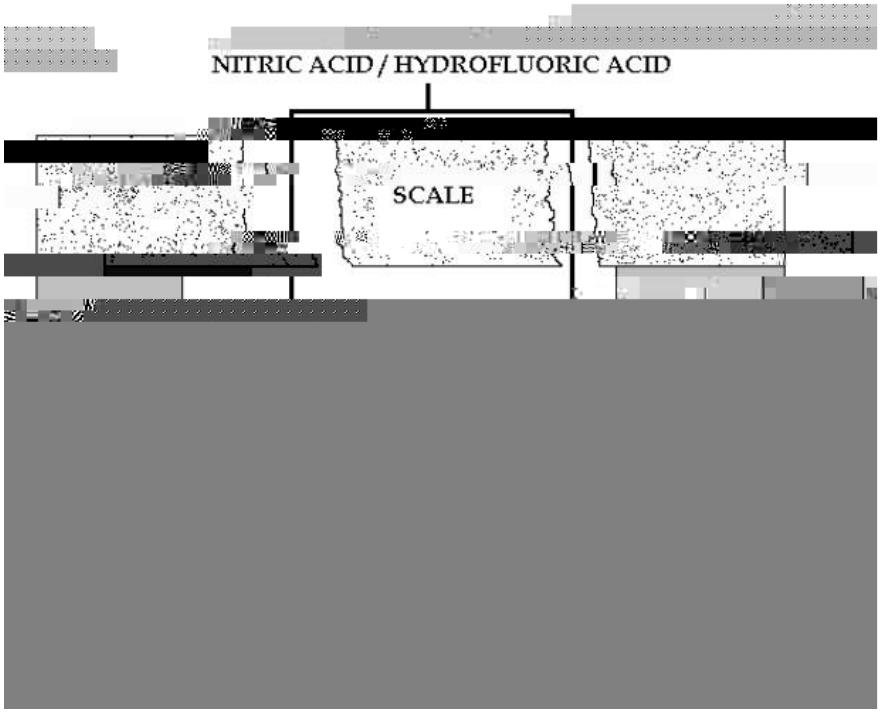
MUST BE REMOVED!

Chemical method: Pickling

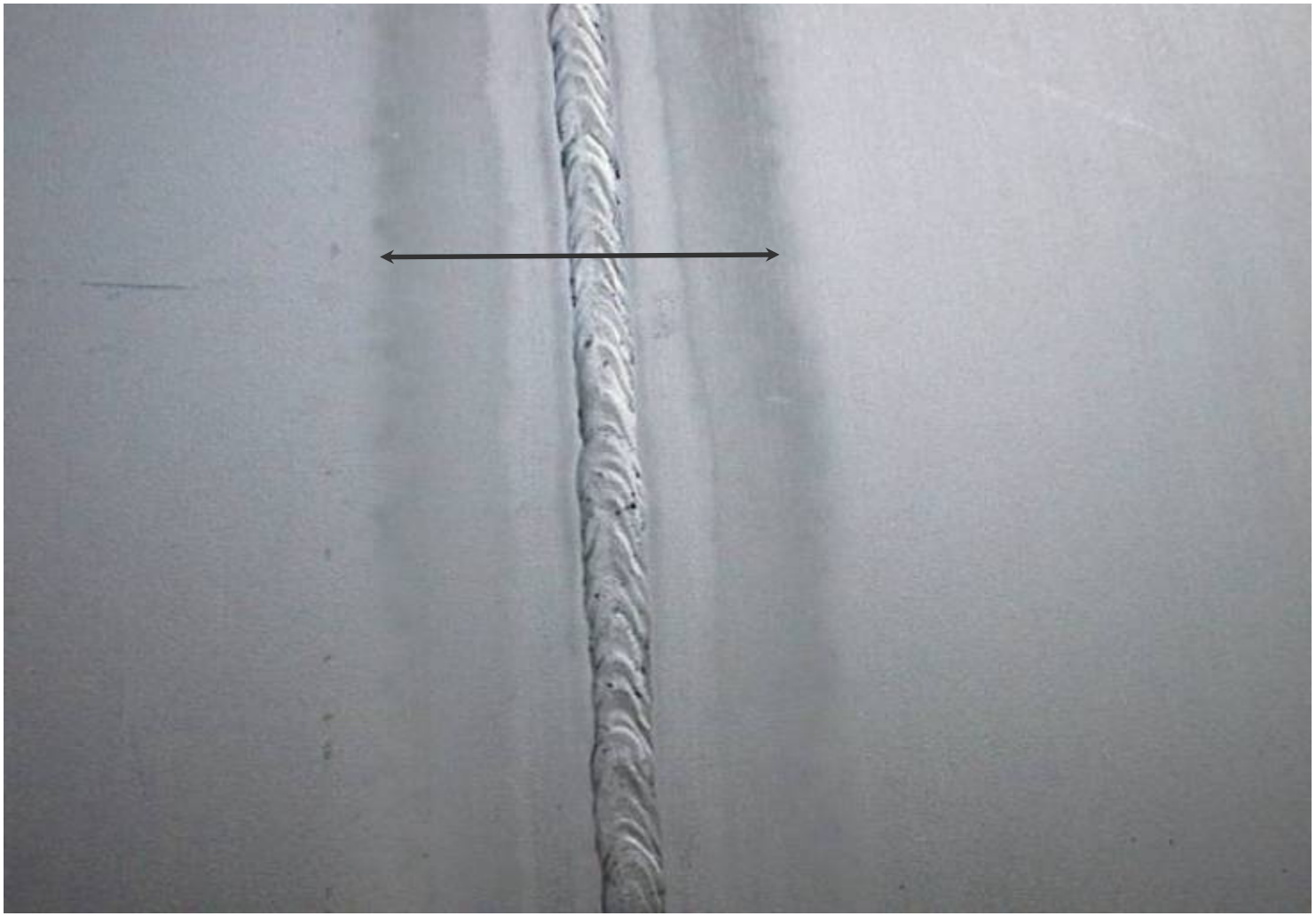
Removes surface defects through a controlled corrosion that selectively removes the least corrosion resistant areas, (the chromium depleted zone).

- Removes heat oxide, Chromium depleted zone and Iron contaminations.
- The acid combination of Hydrofluoric/ Nitric-acid penetrates the heat oxide and dissolves the weak points through corrosion.
- Finally promotes the reformation of the passive layer.

PICKLING DOES NOT DISSOLVE OIL AND GREASE.



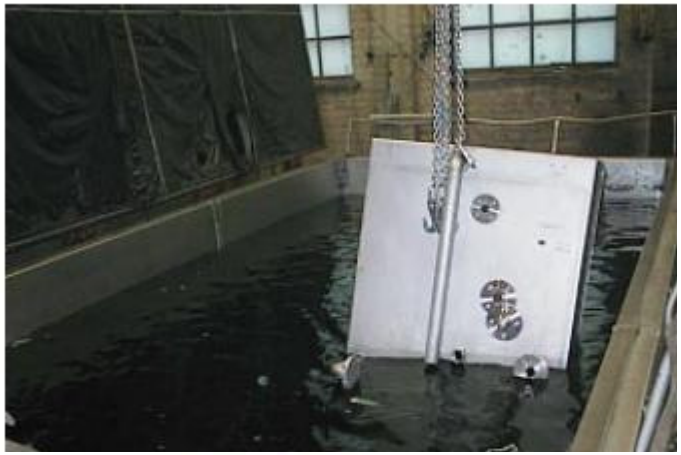
Stainless Steel – Chromium depleted zone



Cleaning methods – Comparison

Pickling produces superior results compared to other surface treatment methods

Pickling - Applications



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ONE STEP AHEAD.

Complete range of products for pickling and cleaning stainless steel

- Paste / Gel
- Solution
- Bath
- Cleaning
- Neutralising
- Passivating
- Accessories

All pickling products conform to international standards:
ASTM A-380, BSI CP-3012, KWU RE-AVS 8, RCCM F-5000-6000

Thank you

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