

Lasting Connections

STAINLESS STEEL AND NICKEL-BASE CORED WIRES TO JOIN STAINLESS STEEL



BÖHLER WELDING

Lasting Connections

As a pioneer in innovative welding consumables, Böhler Welding offers a unique product portfolio for joint welding world-wide. More than 2000 products are adapted continuously to the current industry specifications and customer requirements, certified by well-respected institutes and thus approved for the most demanding welding applications. As a reliable partner for customers, “lasting connections“ are the brand’s philosophy in terms of both welding and people.

Our clients benefit from a partner with

- » the highest expertise in joining, rendering the best application support globally available
- » specialized and best in class product solutions for their local and global challenges
- » an absolute focus on customer needs and their success
- » a worldwide presence through factories, offices and distributors

Flux-cored arc welding – The flexible and productive way to join stainless steel

Böhler Welding flux-cored wires offer a productive and versatile alternative for the welding of stainless steel over SMAW / MMA with stick electrodes or GMAW / MIG with solid wires. The range consists of all-position types with fast-freezing slag enabling superior deposition rates and downhand types with slow-freezing slag optimized for flat and horizontal PA (1G/1F), PB (2F) welding with a high travel speed. They outperform any other manual arc welding process for stainless steel in terms of welding productivity and feature outstanding weldability and superb weld quality. The rutile slag system gives an excellent bead appearance, while the slag is easily removed. The table below summarizes user benefits from Böhler Welding rutile flux-cored wires.



Product characteristics	User benefits
Superior productivity over SMAW / MMA and GMAW / MIG	Substantially lower welding costs Finish work faster
Use of conventional non-pulse power sources	Easy, time-saving parameter setting Lower capital investment in power sources
Use of standard mixed shielding gas or pure CO ₂	Reduced shielding gas costs
Welder-friendly spray arc operation	Lower risk of weld defects Lower repair costs
Reliable weld penetration and side-wall fusion	Lower risk of weld defects Lower repair costs
Superb weld appearance	Reduced cost and time for post weld cleaning
Productive welding of high quality root passes on ceramic backing material	Reduced welding costs Lower repair costs



Stainless Steel Flux-Cored Wires for Flat and Horizontal Welding

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *										
		Typical values										
		C	Si	Mn	Cr	Ni	Mo	N	Fe	Nb	PRE _N	
Flux-cored wires for austenitic stainless steel												
BÖHLER EAS 2-FD	T 19 9 L R M21/C1 3 E308LT0-4/1	0.03	0.7	1.5	19.8	10.5			Bal.			
Avesta FCW-2D 308L/MVR	T 19 9 L R M21/C1 3 E308LT0-4/1	0.03	0.7	1.5	19.5	10.5			Bal.			
BÖHLER SAS 2-FD	T 19 9 Nb R M21/C1 3 E347T0-4/1	0.03	0.6	1.4	19.5	10.6			Bal.	0.37		
BÖHLER EAS 4 M-FD	T 19 12 3 L R M21/C1 3 E316LT0-4/1	0.03	0.7	1.3	18.4	12.1	2.6		Bal.			
Avesta FCW-2D 316L/SKR	T 19 12 3 L R M21/C1 3 E316LT0-4/1	0.03	0.7	1.5	19.0	12.0	2.7		Bal.			
BÖHLER SAS 4-FD	T 19 12 3 Nb R M21/C1 3	0.03	0.6	1.3	18.8	12.2	2.7		Bal.	0.29		
BÖHLER E 317L-FD	T Z 19 13 4 L R M21/C1 3 E317LT0-4 /1	0.03	0.7	1.3	18.8	13.1	3.4		Bal.			
Flux-cored wires for dissimilar joints and buffer layers												
BÖHLER A 7-FD	T 18 8 Mn R M21/C1 3 E307T0-G (mod.)	0.10	0.8	6.8	18.8	9.0			Bal.			
BÖHLER CN 23/12-FD	T 23 12 L R M21/C1 3 E309LT0-4/1	0.03	0.7	1.4	23.0	12.5			Bal.			
Avesta FCW-2D 309L	T 23 12 L R M21/C1 3 E309LT0-4/1	0.03	0.7	1.2	23.1	12.5			Bal.			
BÖHLER CN 23/12 Mo-FD	T 23 12 2 L R M21/C1 3 E309LMoT0-4/1	0.03	0.6	1.4	23.0	12.5	2.7		Bal.			
Flux-cored wires for high temperature applications (bismuth-free)												
BÖHLER E 308 H-FD	T Z 19 9 H R M21/C1 3 E308HT0-4/1	0.05	0.6	1.2	19.4	10.1			Bal.			
BÖHLER E 347L H-FD	T 19 9 Nb R M21/C1 3 E347T0-4/1	0.030	0.6	1.3	18.5	10.5			Bal.	0.45		
BÖHLER E 309L H-FD	T 23 12 L R M21/C1 3 E309LT0-4/1	0.030	0.6	1.3	23.0	12.2			Bal.			

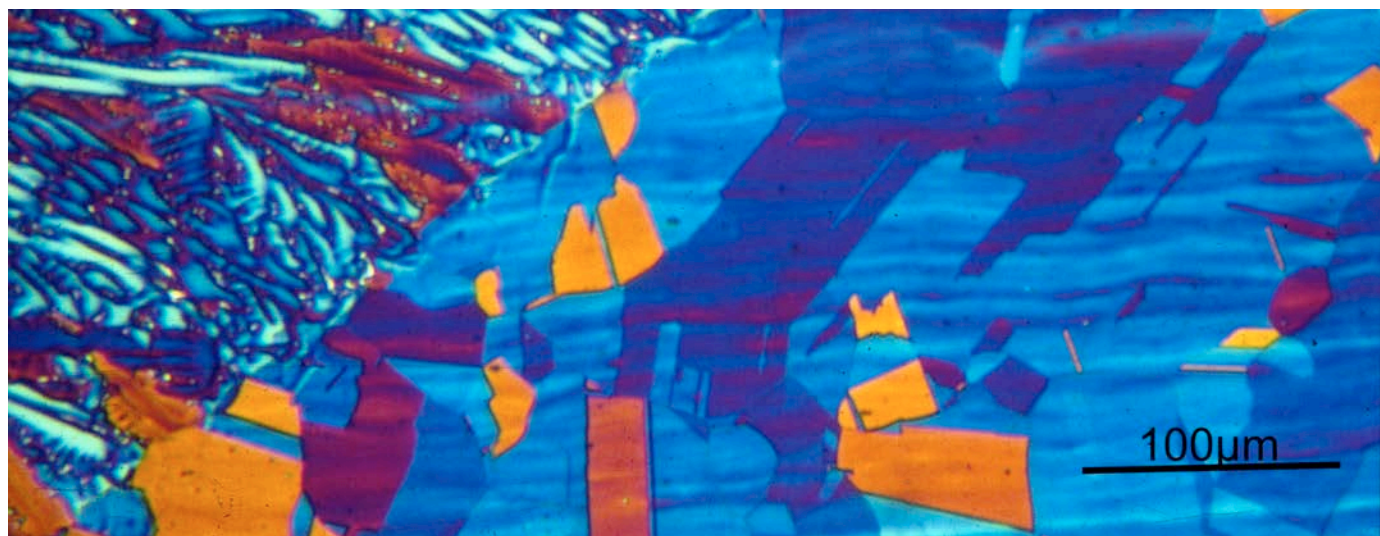
* Typical all-weld metal properties (shielding gas Ar + 18% CO₂), as-welded condition.

	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
					mm		
	360	530	40	35 at -196	1.2 1.6	AISI 304L, 304, 321, 347, 304LN, 302. Ferrite 3–10 FN. Suitable for service temperatures from -196 °C to 350 °C .	TÜV, DB, DNV GL, CE
	380	540	39	37 at -120	1.2 1.6	AISI 304L, 304, 321, 347, 304LN, 302. Ferrite 3–10 FN. Suitable for service temperatures from -196 °C to 350 °C, also with 100% CO ₂ .	TÜV, ABS, CWB, DB, CE
	420	585	40	32 at -196	1.2 1.6	AISI 347, 304, 321, 304L, 304LN, AISI 302. Ferrite 5–13 FN. Suitable for service temperatures from -196 °C to 400 °C.	TÜV, CE
	410	560	34	35 at -120	1.2 1.6	AISI 316L, 316, 316Ti, 316Cb, 316LN. Ferrite 3–10 FN. Suitable for service temperatures from -120 °C to 400 °C.	TÜV, DB, DNV GL, LR, CE
	390	560	39	35 at -120	1.2 1.6	AISI 316L, 316, 316Ti, 316Cb, 316LN. Ferrite 4–12 FN. Suitable for service temperatures from -120 °C to 400 °C, also with 100% CO ₂ .	TÜV, ABS, CWB, DNV GL, CE
	430	570	35	44 at -100	1.2 1.6	AISI 316Cb, 316Ti, 316, 316L. Ferrite 5–13 FN. Suitable for service temperatures from -120 °C to 400 °C.	CE
	420	570	32	45 at -60	1.2	CrNiMo(N) austenitic stainless steels with higher Mo-content or corrosion resistant cladding on mild steel. AISI 317L, 317LN, 316L, 316LN. Ferrite 3–8 FN. Suitable for service temperatures from -60 °C to 300 °C.	CE
	385	605	33	35 at -60 Hardness 200 HB	1.2 1.6	Tough and crack resistant. Cold work hardens up to 400 HB. Surfacing of turbine blades; buffer and intermediate layers prior to hardfacing. Dissimilar joints, 14% Mn steels, 13–17% Cr steels, etc. Ferrite 2–4 FN. Service temperatures from -60 °C to 650 °C.	TÜV, CE
	400	540	33	45 at -60	1.2 1.6	Dissimilar joints between high-alloyed Cr and CrNi steels and unalloyed and low-alloyed steels. Also for weld cladding (buffer layer). Ferrite 14–22 FN. For service temperatures from -60 °C to 300 °C.	TÜV, DB, DNV GL, LR, CE, RINA, BV, CE
	390	560	35	45 at -60	1.2 1.6	Dissimilar joining of high-alloyed Cr and CrNi steels to unalloyed and low-alloyed steels. Also for weld cladding (buffer layer). Ferrite 14–22 FN. For service temperatures from -60 °C to 300 °C, also with 100% CO ₂ .	TÜV, DB, CWB, ABS, DNV GL, LR, RINA, BV, CE
	520	700	28	36 at -60	1.2 1.6	Dissimilar joints between high-alloyed Cr and CrNi(Mo) steels and unalloyed and low-alloyed steels. Also for Mo-containing cladding (buffer layers). Ferrite 27–42 FN. For service temperatures from -60 °C to 300 °C.	TÜV, DB, ABS, DNV GL, LR, RINA, CWB, CE
	370	570	45	85 at RT	1.2 1.6	AISI 304H, 321H, 347H, 304. Creep resistant austenitic CrNi steels for elevated service temperatures. Bismuth-free (Bi ≤ 10 ppm). Ferrite 3–8 FN. Meets API RP582 and AWS A5.22 for high-temperature service or post-weld heat treatment.	TÜV, CE
	420	580	35	37 at -196	1.2	AISI 321, 321H, 347, 347H. Creep resistant austenitic CrNi steels. Bismuth-free (Bi ≤ 10 ppm). Ferrite 5–9 FN. Meets API RP582 and AWS A5.22 for high-temperature service or post-weld heat treatment.	CE
	390	530	45	50 at -60	1.2	Dissimilar joints of high-alloyed Cr and CrNi steels with unalloyed or low-alloyed steels. Cladding (buffer layer) on unalloyed and low-alloyed steels. Suitable for service temperatures down to -60 °C. Bismuth-free (Bi ≤ 10 ppm). Ferrite 12–18 FN. Meets API RP582 and AWS A5.22 for high-temperature service or post-weld heat treatment.	CE

Stainless Steel Flux-Cored Wires for Flat and Horizontal Welding

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *										
		Typical values										
		C	Si	Mn	Cr	Ni	Mo	N	Fe	Nb	PRE _N	
Flux-cored wires for duplex stainless steel												
Avesta FCW-2D LDX 2101	T 23 7 N L R M21/C1 3 E2307T0-4/1	0.025	0.7	1.1	24.6	9.0	0.4	0.14	Bal.		27	
Avesta FCW-2D 2304	T 23 7 N L R M21/C1 3 E2307T0-4/1	0.025	0.7	1.1	24.6	9.0	0.4	0.14	Bal.		27	
BÖHLER CN 22/9 N-FD	T 22 9 3 N L R M21/C1 3 E2209T0-4/1	0.027	0.7	0.9	22.9	9.2	3.2	0.13	Bal.		> 35	
Avesta FCW-2D 2205	T 22 9 3 N L R M21/C1 3 E2209T0-4/1	0.027	0.7	0.9	22.9	9.2	3.2	0.13	Bal.		> 35	
Flux-cored wires for nickel-base alloys												
BÖHLER NIBAS 70/20-FD	EN ISO 12153: T Ni 6082 R M21 3 AWS A5.34 / SFA-5.34: ENiCr3T0-4	0.03	0.40	3.2	19.5	Bal.			≤ 2.0	2.5		
BÖHLER NIBAS 70/20 Mn-FD	EN ISO 12153: T Ni 6083 R M21 3 AWS A5.34 / SFA-5.34: ENiCr3T0-4 (mod.)	0.03	0.3	5.5	19.7	Bal.			≤ 2.0	2.4		

* Typical all-weld metal properties (shielding gas Ar + 18% CO₂), as-welded condition.



317LMN (1.4439 / UNS S31726) base material welded with 317L filler material
Weld metal on the left hand side, base metal to the right.

	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
	570	760	28	41 at -60	1.2	Designed for welding the lean duplex stainless steel LDX 2101®, UNS S32101, S32001, EN 1.4162 and similar alloys. Over-alloyed with nickel to promote austenite formation. Ferrite 27–34 FN. Suitable for service temperatures from -60°C to 250°C.	TÜV, ABS, CE
	570	760	28	41 at -60	1.2	Primarily designed for welding lean duplex stainless steel 2304, UNS S32304, EN 1.4362 and similar alloys. Over-alloyed with nickel to promote weld metal austenite formation. Ferrite 27–34 FN. Suitable for service temperatures from -60°C to 250°C.	TÜV, CE
	620	800	27	45 at -30	1.2	UNS S31803, UNS S32205 and similar alloys. Meets the corrosion test requirements per ASTM A262, ASTM A923-C and ASTM G48-A (24 h) up to 22°C in as-welded condition and 30°C in solution annealed condition. Over-alloyed in nickel to promote austenite formation. Ferrite 39–47 FN. Suitable for service temperatures from -40°C to 250°C.	TÜV, DNV GL, LR, RINA, BV, CE, DB
	620	800	27	45 at -30	1.2 1.6	UNS S31803, UNS S32205, 1.4462 and similar alloys. Meets the corrosion test requirements per ASTM A923 Method C and ASTM G48 Methods A, B and E (22°C); ASTM G36 and NACE TM 0177 Method A. Over-alloyed in nickel to promote austenite formation. Ferrite 39–47 FN. Suitable for service temperatures from -40°C to 250°C.	TÜV, BV, CWB, ABS, DNV GL, LR, RINA, DB, CE
	385	650	39	120 at -196	1.2 1.6	Alloy 600, 600 L, 800 / 800H. Nickel-base wire for the welding of nickel-base alloys, heat resistant and cryogenic steels; dissimilar joints and buffer layers. Suitable for pressure vessel fabrication in the service temperature range -196°C to 550°C, otherwise resistant to scaling up to 1200°C in S-free atmosphere.	TÜV, CE
	380	640	41	115 at -196	1.2	Alloy 600, 600 L, 800 / 800H. Nickel-base wire for the welding of nickel-base alloys, heat resistant and cryogenic steels; dissimilar joints and buffer layers. Higher Mn-content for higher resistance to solidification cracking. Suitable for pressure vessel fabrication in the service temperature range -196°C to 550°C.	CE

Stainless Steel Flux-Cored Wires Wires for All-Position Welding

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *											
		Typical values											
		C	Si	Mn	Cr	Ni	Mo	N	Fe	Nb	PRE _N		
Flux-cored wires for austenitic stainless steel													
BÖHLER EAS 2 PW-FD	T 19 9 L P M21/C1 1 E308LT1-4/1	0.03	0.7	1.5	19.8	10.5			Bal.				
Avesta FCW 308L/MVR-PW	T 19 9 L P M21/C1 1 E308LT1-4/1	0.03	0.7	1.5	19.8	10.5			Bal.				
BÖHLER EAS 2 PW-FD (LF)	T 19 9 L P M21/C1 1 E308LT1-4/1 Also fulfills AWS A5.22 E308LT1-4/1J	0.03	0.6	1.4	19.3	10.9			Bal.				
Avesta FCW 308L/MVR Cryo	T 19 9 L P M21/C1 1 E308LT1-4/1 Also fulfills AWS A5.22 E308LT1-4/1J	0.03	0.6	1.4	19.3	10.9			Bal.				
BÖHLER SAS 2 PW-FD	T 19 9 Nb P M21/C1 1 E347T1-4/1	0.03	0.7	1.4	19.0	10.4			Bal.	0.35			
BÖHLER EAS 4 PW-FD	T 19 12 3 L P M21/C1 1 E316LT1-4/1	0.03	0.7	1.5	19.0	12.0	2.7		Bal.				
BÖHLER EAS 4 PW-FD (LF)	T Z 19 12 3 L P M21/C1 1 E316LT1-4/1 Also fulfills AWS A5.22 E316LT1-4/1J	0.03	0.7	1.4	18.1	12.5	2.1		Bal.				
Avesta FCW 316L/SKR-PW	T 19 12 3 L P M21/C1 1 E316LT1-4/1	0.03	0.7	1.5	19.0	12.0	2.7		Bal.				
BÖHLER SAS 4 PW-FD	T 19 12 3 Nb P M21/C1 1	0.03	0.6	1.3	18.8	12.2	2.7		Bal.	0.46			
BÖHLER E 317L PW-FD	T Z19 13 4 L P M21/C1 1 E317LT1-4/1	0.03	0.7	1.3	18.8	13.1	3.4		Bal.				

* Typical all-weld metal properties (shielding gas Ar + 18% CO₂), as-welded condition.

	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
					mm		
	380	535	39	38 at -196	0.9 1.2 1.6	AISI 304L, 304, 321, 347, 304LN, 302. Ferrite 4–12 FN. Suitable for service temperatures from -196 °C to 350 °C.	TÜV, DB, DNV GL, CE
	380	535	39	38 at -196	0.9 1.2 1.6	AISI 304L, 304, 321, 347, 304LN, 302. Ferrite 4–12 FN. Suitable for service temperatures from -196 °C to 350 °C.	TÜV, ABS, CWB, DB, CE
	390	550	40	42 at -196	1.2 1.6	AISI 304L, 304, 321, 347, 304LN, 302. Good toughness. Lateral expansion at -196 °C ≥ 0.38 mm. Ferrite 3–6 FN. Suitable for LNG applications. Service temperatures from -196 °C to 350 °C.	–
	390	550	40	42 at -196	1.2	AISI 304L, 304, 321, 347, 304LN, 302. High impact toughness as specified for LNG applications. Controlled ferrite 3–6 FN. Suitable for service temperatures from -196 °C to 350 °C. Lateral expansion at -196 °C ≥ 0.38 mm.	–
	420	590	35	40 at -120	1.2	AISI 347, 304, 321, 304L, 304LN, 302. Ferrite 5–13 FN. Suitable for service temperatures from -120 °C to 400 °C.	TÜV, CE
	430	560	34	40 at -120	0.9 1.2 1.6	AISI 316L, 316, 316Ti, 316Cb, 316LN. Ferrite 4–12 FN. Suitable for service temperatures from -120 °C to 400 °C.	TÜV, DB, LR, DNV GL, CE
	400	550	36	35 at -196	1.2	AISI 316L, 316Ti, 316Cb. Particularly for good cryogenic toughness and lateral expansion down to -196 °C as specified for LNG applications. Ferrite 3–6 FN. Suitable for service temperatures from -196 °C to 350 °C.	TÜV, RINA, CE
	430	560	34	40 at -120	0.9 1.2 1.6	AISI 316L, 316, 316Ti, 316Cb, 316LN. Ferrite 4–12 FN. Suitable for service temperatures from -120 °C to 400 °C.	TÜV, ABS, CWB, DB, DNV GL, CE
	480	665	32	40 at -100	1.2	AISI 316Cb, 316Ti, 316L, 316. Stabilized with niobium. Ferrite 5–13 FN Suitable for service temperatures from -120 °C to 400 °C.	–
	430	560	36	50 at -60	1.2	AISI 317L, 317LN, 317LMN, 316L, 316LN. CrNiMo(N) austenitic stainless steels with higher Mo-content or corrosion resistant claddings on mild steels. Ferrite 3–8 FN. Suitable for service temperatures from -60 °C to 300 °C.	BV, CE

Stainless Steel Flux-Cored Wires Wires for All-Position Welding

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *											
		Typical values											
		C	Si	Mn	Cr	Ni	Mo	N	Fe	Nb	PRE _N		
Flux-cored wires for dissimilar joints and buffer layers													
BÖHLER A 7 PW-FD	T 18 8 Mn P M21/C1 2 E307T1-G (mod.)	0.1	0.8	6.8	18.8	9.0			Bal.				
BÖHLER CN 23/12 PW-FD	T 23 12 L P M21/C1 1 E309LT1-4/1	0.03	0.7	1.4	23.0	12.5			Bal.				
Avesta FCW 309L-PW	T 23 12 L P M21/C1 1 E309LT1-4/1	0.03	0.7	1.4	23.0	12.5			Bal.				
BÖHLER CN 23/12 Mo PW-FD	T 23 12 2 L P M21/C1 1 E309LMoT1-4/1	0.03	0.7	1.4	23.0	12.5	2.7		Bal.				
Flux-cored wires for high temperature applications (bismuth-free)													
BÖHLER E 308 H PW-FD	T Z 19 9 H P M21/C1 1 E308HT1-4/1	0.05	0.6	1.2	19.4	10.1			Bal.				
BÖHLER E 347 H PW-FD	T 19 9 Nb P M21/C1 1 E347HT1-4/1	0.045	0.6	1.3	18.5	10.5			Bal.	0.45			
BÖHLER E 309L H PW-FD	T 23 12 L P M21/C1 1 E309LT1-4/1	0.035	0.7	1.3	23.0	12.5			Bal.				
Flux-cored wires for duplex stainless steel													
Avesta FCW LDX 2101-PW	T 23 7 N L P M21/C1 1 E2307T1-4/1	0.03	0.7	1.1	24.6	9.0	0.4	0.14	Bal.		27		
Avesta FCW 2304-PW	T 23 7 N L P M21/C1 1 E2307T1-4/1	0.03	0.7	1.1	24.6	9.0	0.4	0.14	Bal.		27		
Avesta FCW 2205-PW	T 22 9 3 N L P M21/C1 1 E2209T1-4/1	0.029	0.7	1.0	23.0	9.1	3.2	0.13	Bal.		> 35		
BÖHLER CN 22/9 PW-FD	T 22 9 3 N L P M21/C1 1 E2209T1-4/1	0.029	0.7	1.0	23.0	9.1	3.2	0.13	Bal.		> 35		
Avesta FCW LDX 2404-PW	T Z 25 9 4 N L P M21/C1 2 E2594T1-G	0.03	0.7	1.5	25.1	8.80	2.2	0.19	Bal.		36		

* Typical all-weld metal properties (shielding gas Ar + 18% CO₂), as-welded condition.

	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
	mm						
	420	630	39	35 at -100 Hardness 200 HB	1.2	Tough and crack resistant. Cold work hardens up to 400 HB. Surfacing of turbine blades; buffer and intermediate layers prior to hardfacing. Dissimilar joints, 14% Mn steels, 13–17% Cr steels, etc. Ferrite 2–4 FN. Service temperatures from -100 °C to 650 °C.	TÜV, CE
	420	540	36	50 at -60	0.9 1.2 1.6	Dissimilar joints between high-alloyed Cr and CrNi steels and unalloyed and low-alloyed steels. Also for weld cladding (buffer layers). Ferrite 23–36 FN. For service temperatures from -60 °C to 300 °C.	TÜV, DB, LR, DNV GL, BV, RINA, CE
	420	540	36	50 at -60	0.9 1.2 1.6	Dissimilar joints between high-alloyed Cr and CrNi steels and unalloyed and low-alloyed steels. Also for weld cladding (buffer layers). Ferrite 14–22 FN. For service temperatures from -60 °C to 300 °C.	TÜV, ABS, CWB, DB, DNV GL, CE
	540	705	28	44 at -60	0.9 1.2	Dissimilar joints between high-alloyed Cr and CrNi(Mo) steels and unalloyed and low-alloyed steels. Also for Mo containing weld cladding. Ferrite 15–23 FN. For service temperatures from -60 °C to 300 °C.	TÜV, BV, LR, CWB, DNV GL, CE
	370	560	45	90 at +20	1.2	AISI 304H, 321H, 347H, 304. Creep resistant austenitic CrNi steels for elevated service temperatures. Bismuth-free (Bi ≤ 10 ppm). Ferrite 3–8 FN. Meets API RP582 and AWS A5.22 for high-temperature service or post-weld heat treatment.	TÜV, CE
	370	560	45	38 at -196	1.2	AISI 321, 321H, 347, 347H. Creep resistant austenitic CrNi steels for elevated service temperatures. Bismuth-free (Bi ≤ 10 ppm). Ferrite 4–8 FN. Meet API RP582 and AWS A5.22 for high-temperature service or post-weld heat treatment. Also fulfills AWS A5.22 E347T1/4/1.	–
	390	530	35	60 at -60	1.2	Dissimilar joints of high-alloyed Cr and CrNi steels with unalloyed or low-alloyed steels, as well as cladding (buffer layer) on unalloyed and low-alloyed steels. Suitable for service temperatures down to -60 °C. Bismuth-free (Bi ≤ 10 ppm). Ferrite 10–23 FN. Meets API RP582 and AWS A5.22 for high-temperature service or post-weld heat treatment.	–
	580	750	31	54 at -30	1.2	Lean duplex stainless steel LDX 2101®, UNS S32101, S32001 and similar alloys. PREN ≥ 27. Over-alloyed with nickel to promote austenite formation. Ferrite ≥ 30 FN. Suitable for service temperatures from -50 °C to 250 °C.	ABS, CE
	580	750	31	54 at -30	1.2	Designed for welding lean duplex stainless steel 2304, UNS S32304, EN 1.4362 and similar alloys. PREN ≥ 27. Over-alloyed with nickel to promote austenite formation. Ferrite ≥ 30 FN. Suitable for service temperatures from -50 °C to 250 °C.	–
	600	800	27	45 at -40	1.2 1.6	UNS S31803, UNS S32205, S32304, S32101. Meets corrosion test requirements per ASTM G48 (25 °C). Over-alloyed in nickel to promote austenite formation. PREN > 35. Ferrite 35–41 FN. Suitable for service temperatures from -50 °C to 250 °C.	TÜV, BV, ABS, CWB, DNV GL, LR, RINA, CE
	600	800	27	45 at -40	1.2	UNS S31803, UNS S32205, UNS S32304, S32101; Meets the corrosion test requirements per ASTM G48 at 25 °C and ASTM A923 Method C at 22 °C. Over-alloyed in nickel to promote austenite formation. Ferrite 35–41 FN. Suitable for service temperatures from -46 °C to 250 °C.	TÜV, DNV GL, LR, RINA, BV, CE
	630	830	30	46 at -40	1.2	Designed for welding lean duplex stainless steel LDX 2404®, EN 1.4662, UNS S82441. PREN ≥ 35. Over-alloyed with nickel to promote austenite formation. Ferrite 45–65 FN. Suitable for service temperatures from -40 °C to 250 °C.	–

Stainless Steel Flux-Cored Wires Wires for All-Position Welding

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *										
		Typical values										
		C	Si	Mn	Cr	Ni	Mo	N	Fe	Nb	PRE _N	
Avesta FCW 2507/P100-PW	T 25 9 4 N L P M21/C1 2 E2594T1-4/1	0.03	0.7	0.9	25.3	9.8	3.7	0.23	Bal.		> 41	
Avesta FCW 2507/P100-PW NOR	T 25 9 4 N L P M21/C1 2 E2594T1-4/1	0.03	0.7	0.9	25.3	9.8	3.7	0.23	Bal.		> 41	
Flux-cored wires for nickel-base alloys												
BÖHLER NIBAS 625 PW-FD	EN ISO 12153: T Ni 6625 P M21 2 AWS A5.34 / SFA-5.34: ENiCrMo3T1-4	0.05	0.4	0.4	21.0	Bal.	8.5		< 1.0	3.3		
Flux-cored wires for soft-martensitic stainless steel												
BÖHLER CN 13/4 PW-FD	T 13 4 P M21/C1 1 (H5) E410NiMoT1-4/1 (H4)	0.023	0.7	0.9	12.0	5.0	0.5		Bal.			

* Typical all-weld metal properties (shielding gas Ar + 18% CO₂), as-welded condition.



	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
	690	890	27	38 at -40	1.2	25% Cr superduplex stainless steel and castings such as UNS S32570 and UNS S32760. PREN ≥ 41. Can be used for joints between superduplex grades and austenitic stainless steels or carbon steels. Ferrite 45–55 FN. Operating temperature range -40°C to 220°C.	–
	640	880	28	41 at -50	1.2	25% Cr superduplex stainless steel and castings such as UNS S32570 and UNS S32760. Developed to satisfy severe requirements specified in NORSOK M-601 and similar standards. Ferrite 40–45 FN. Operating temperature range -50°C to 220°C.	–
	460 ** PWHT: 580 °C / 8 h – 1076 °F / 8 h	740	40	80 at -196	1.2	Alloy 600, 600L, 625, 800 / 800H, 825, UNS, N07080, N0810, N08367, N08926, S31254. For high Mo-containing nickel-base alloys and dissimilar joints; creep resistant, heat resistant and 9% Ni steels for cryogenic applications (e.g. LNG). Suitable for service temperatures from -196°C. Scaling resistance up to 1200°C in S-free atmosphere.	TÜV, CE
	790**	920	17	40 at -50	1.2 1.6	Fabrication and repair welding of soft-martensitic 13Cr-4Ni hydro turbine components (UNS S41500). Very good impact toughness after heat treatment. Extra low diffusible hydrogen content of 1–3 ml / 100 g.	–

Böhler weldCare offers a full range of agents for the pickling and passivation of stainless steel. Pickling of stainless steel is the technically superior method to create a superior stainless steel surface and obtain the best corrosion resistance.

Stainless Steel Metal-Cored Wires

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *											
		Typical values											
		C	Si	Mn	Cr	Ni	Mo	N	Ti	Nb	PRE _N		
Metal-cored wires for austenitic stainless steel													
BÖHLER EAS 2-MC	T 19 9 L M M12 2 EC308L	0.025	0.6	1.4	19.8	10.5							
BÖHLER EAS 4 M-MC	T 19 12 3 L M M12 2 EC316L	0.025	0.6	1.4	18.8	12.2	2.7						
Metal-cored wires for dissimilar joints and buffer layers													
BÖHLER A 7-MC	T 18 8 Mn M M12 1 EC307 (mod.)	0.10	0.6	6.3	18.8	9.2							
BÖHLER CN 23/12-MC	T 23 12 L M M12 2 EC309L	0.025	0.6	1.4	23.0	12.5							
Metal-cored wires for high temperature applications / austenitic stainless steel													
BÖHLER FF-MC	T 22 12 H M M13 1 EC309H (mod.)	0.07	0.6	0.6	20.2	10.6							
Metal-cored wires for high temperature applications / ferritic stainless steel													
BÖHLER CAT 439L Ti-MC	T Z 17 Ti L M M12/M13 1 EC439	0.02	0.5	0.7	18.5				0.85				
BÖHLER CAT 430L Cb-MC	T Z 17 Nb M M12/M13 1 EC439Nb	0.02	0.5	0.7	18.5				0.12	0.65			
BÖHLER CAT 430L CbTi-MC	T Z 17 Nb Ti L M M12/M13 1 EC430 (mod.), EC439Nb	0.02	0.5	0.7	18.5				0.35	0.55			

* Typical all-weld metal properties (Ar + 2.5% CO₂), as-welded condition.

	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
					mm		
	420	560	36	40 at -196	1.2	AISI 304, 304L, 321, 347, 304LN. Stabilized or non-stabilized, austenitic stainless CrNi steels. Ferrite 4–12 FN. Suitable for service temperatures from -196 °C to 350 °C.	TÜV, CWB, CE
	420	560	34	38 at -120	1.2	AISI 316L, 316Ti, 316Cb. Stabilized or non-stabilized, austenitic stainless CrNi(Mo) steels. Ferrite 4–12 FN. Suitable for service temperatures from -196 °C to 400 °C.	TÜV, CWB, CE
	408	608	40	40 at -60	1.2 1.6	Tough and crack resistant. Surfacing of turbine blades; buffer and intermediate layers. Dissimilar joints, 14% Mn steels, 13–17% Cr steels, etc. Ferrite 2–4 FN. Service temperatures -90 °C up to 650 °C. Scaling resistant up to 850 °C.	TÜV,DB, CE
	400	550	32	51 at -120	1.2	Dissimilar joints between high-alloyed Cr and CrNi steels and unalloyed and low-alloyed steels. Also for weld cladding (buffer layer). Ferrite 13–22 FN. For service temperatures from -120 °C to 300 °C.	CWB, CE
	380	560	55	74 at RT	1.2	Ferritic (1.4713, 1.4724, 1.4742, 1.4740) and austenitic (AISI 305; 1.4828, 1.4833 and 1.4826). Ferrite 5–10 FN. For robotic welding of exhaust systems. More resistant to hot cracking than when using solid wire. Resistant to scaling up to 1000 °C.	–
				Hardness 180 HB	1.2	Ferritic stainless AISI 430, 439; UNS S43000, S43035. For robotic welding of exhaust systems. Stabilized (Ti). Low carbon content. Resistant to scaling up to 850 °C	–
				Hardness 180 HB	1.2	Ferritic stainless AISI 430; UNS S43000. For robotic welding of exhaust systems. Stabilized. Low carbon content. Resistant to scaling up to 900 °C.	–
				Hardness 180 HB	1.2	Ferritic stainless AISI 430, 441; UNS S43000, S43940. For robotic welding of exhaust systems. Double-stabilized (Nb + Ti). Low carbon content with reduced tendency for grain coarsening. Resistant to scaling up to 900 °C.	–

Stainless Steel Metal-Cored Wires

Böhler Welding product name	Classification EN ISO 17633-A AWS A5.22 / SFA-5.22	Chemical composition (%) *											
		Typical values											
		C	Si	Mn	Cr	Ni	Mo	N	Fe	Nb	PRE _N		
Metal-cored wires for soft-martensitic stainless steel													
BÖHLER CN 13/4-MC	T 13 4 M M12 2 EC410NiMo (mod.)	0.022	0.7	0.9	12.0	4.6	0.6		Bal.				
BÖHLER CN 13/4-MC HI	T 13 4 M M12 2 EC410NiMo (mod.)	0.014	0.3	0.6	12.0	4.7	0.5		Bal.				
BÖHLER CN 13/4-MC (F)	T 13 4 M M12 2 EC410NiMo (mod.)	0.023	0.7	0.9	12.2	4.6	0.6		Bal.				

* Typical all-weld metal properties (Ar + 2.5% CO₂), as-welded condition.

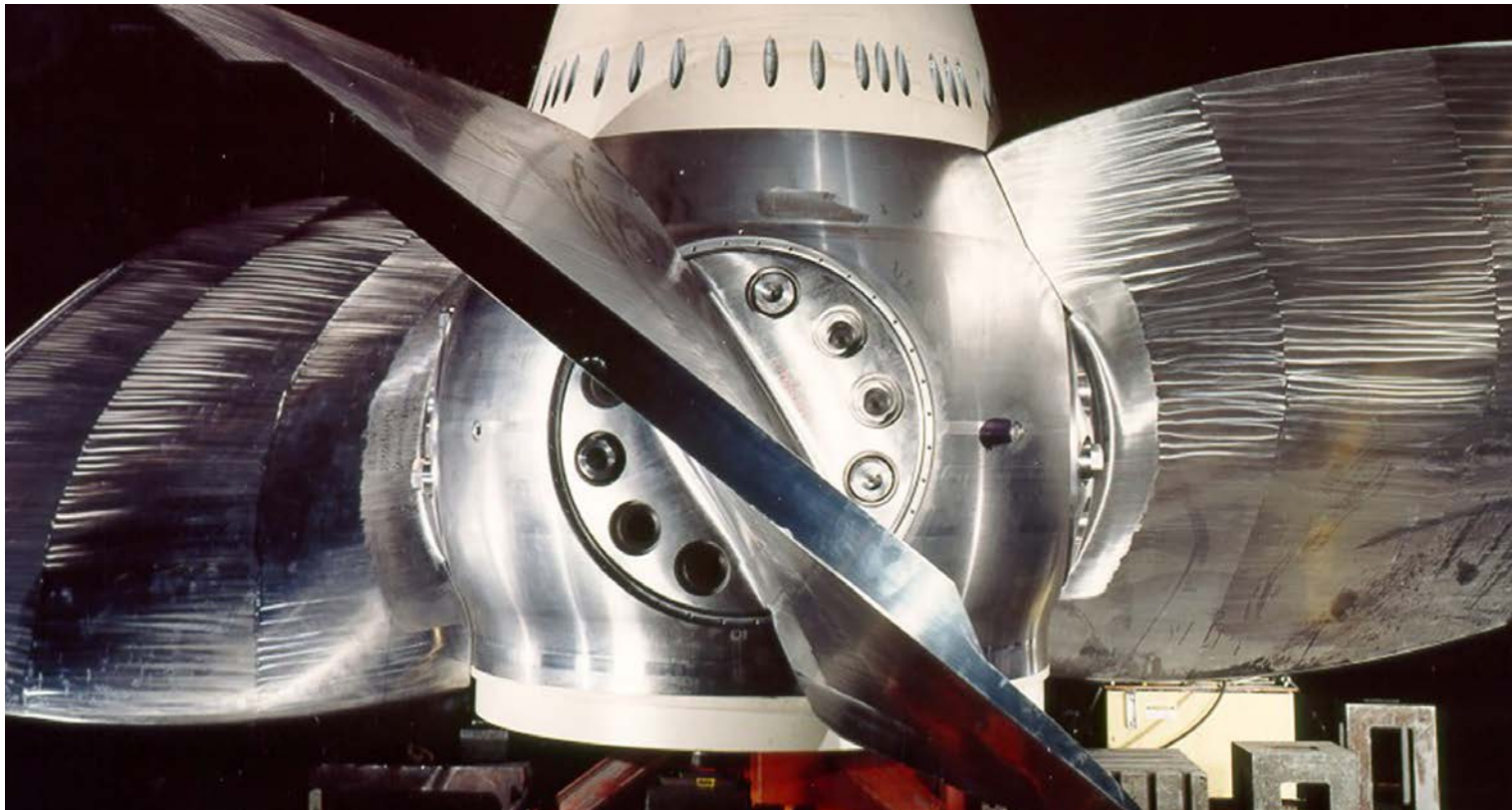
Summary of companies already benefiting from cored wires from Böhler Welding



	Mechanical properties *				Dia- meter	Characteristics and applications	Approvals
	Typical values						
	R _{p0.2}	R _m	A (L ₀ =5d ₀)	CVN			
	MPa	MPa	%	J at °C			
					mm		
	730 **	860	17	62 at -20	1.2 1.6	Fabrication and repair welding of soft-martensitic 13Cr-4Ni hydro turbine components (UNS S41500). Very good impact toughness after heat treatment. Extra low diffusible hydrogen content max. 4 ml / 100 g.	TÜV, LR, CE
	685 **	770	21	75 at -20	1.2	Fabrication and repair welding of soft-martensitic 13Cr-4Ni hydro turbine components (UNS S41500). Extra high impact values for heat treated weld metal. Extra low diffusible hydrogen content max. 4 ml / 100 g.	TÜV, LR, CE
	715 ***	840	18	50 at -20	1.2 1.6	Fabrication and repair welding of cast soft-martensitic 13Cr-4Ni hydro turbine components (EN 1.4407). Highest fluidity for repair welding in foundries. Extra low diffusible hydrogen content max. 4 ml / 100 g.	–

** PWHT: 580 °C / 8 h – 1076 °F / 8 h

*** PWHT: 580 °C / 12 h – 1076 °F / 12 h



OPTIMIZED PERFORMANCE FROM FLUX-CORED WIRES

Flux-cored arc welding (FCAW) resembles the gas metal arc welding (GMAW) process, but handling is considerably easier and results are mostly better. FCAW offers optimized performance and flexibility in the choice of welding position. Flux-cored wires may be somewhat more expensive than solid wires, but this is amply compensated by significant cost savings when all related welding expenses are taken into account. An example is minimized post-weld labor due to a lower risk of lack of fusion and other defects such as porosity. Also cleaning of the welds takes less time, because of the superb bead appearance from flux-cored cored wires.



In FCAW, the weld pool is protected by both slag and shielding gas. The slag covers the surface of the weld bead as well as the reversed side of the root, making the process very suited for one-sided welding, outdoors on-site. The rutile slag system is most common and two slag types are applied; fast freezing and slow freezing.

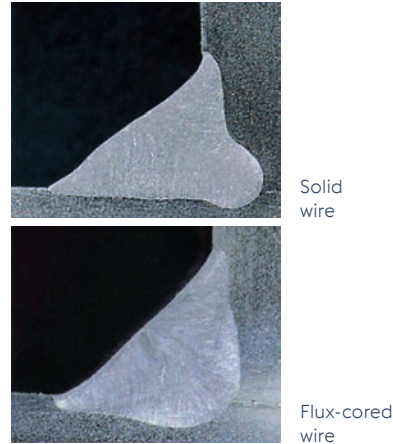
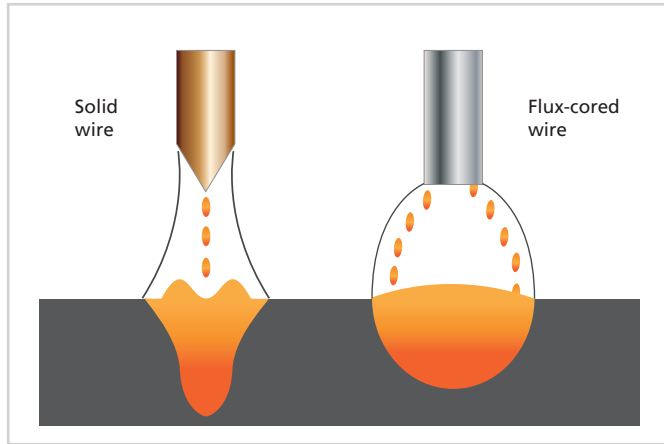
A fast freezing rutile slag is applied for all-position rutile flux-cored wires. The slag supports the weld pool when welding out of position and can accommodate much more fluid weld metal than possible with solid wire. Subsequently, applicable deposition rates in vertical-up position are 2–3 times higher than with stick electrodes or GMAW with solid wires, which is a major productivity advantage. These cored wire types are most universally applied and referred to as T1 types according to AWS.

A slow-freezing rutile slag is applied for downhand rutile cored wires. The slag is designed to follow the arc and protects the weld when applying high travel speed in flat and horizontal position (PA / 1G, PB / 2F). They give the nicest bead appearance with a finely rippled surface, smooth wetting and hardly any temper colors. They are the number one choice when a cosmetic weld appearance matters. Obtainable travel speeds are again significantly higher than possible with solid wire. They are not suited for welding in vertical-up and overhead positions. These flux-cored wire types are referred to as T0 types according to AWS.

The T1 slag concept generally results in the highest impact toughness and makes the weld metal more resistant to solidification cracking. The all-position wires are, for this reason, also preferred in flat and horizontal positions when welding thicker materials (≥ 25 mm).

Arc type & characteristics

Due to their design, flux-cored wires have a more bell-shaped arc than solid wires. This characteristic results in a uniform and safe weld penetration profile with good side-wall fusion, which significantly reduces the risk of lack of fusion weld defects as compared to GMAW. There is also less repair work due to radiographically sound weld deposits, free from porosity.

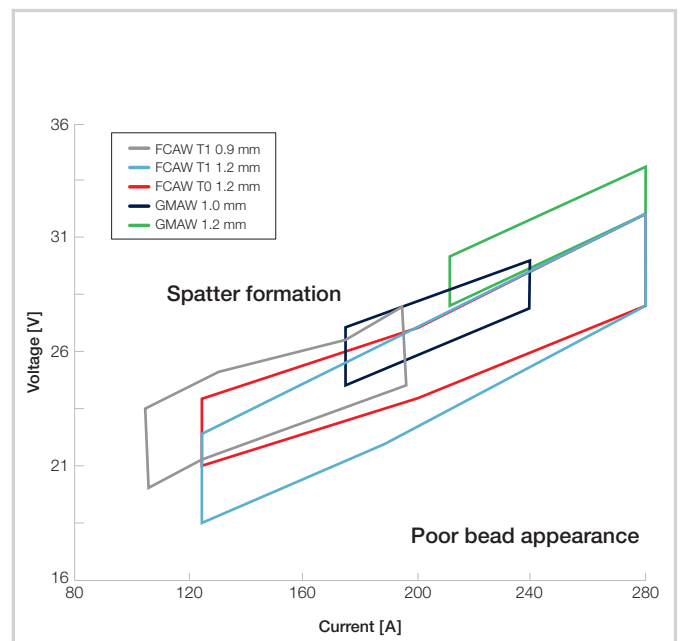


Characteristic differences in arc type. Flux-cored wires give a more uniform weld penetration profile than with solid wire and this decreases the risk of lack of fusion defects.

Wider window of applicable welding parameters

Another characteristic feature of flux-cored wires is favorable spray arc operation over the full (and wider) window of applicable welding parameters, brought about by its typical design and the action of the rutile slag system. They can be welded with conventional non-pulse power sources. When welding with solid wires, pulsed spray arc is preferred. Especially high-alloyed stainless steel benefits from pulsing, resulting in smoother welds. Also the risk of lack of fusion defects is higher without pulsing. Short arc, on the other hand, may lead to spatter formation. Controlled pulsing requires a higher investment in welding equipment.

Welder comfort is higher with rutile flux-cored wires. The larger operating window makes it easier for the welder to find the correct welding parameters and the excellent wetting behavior reduces the need to manipulate the gun. The backhand (drag) technique used with flux-cored wires is less demanding than the forehand (push) technique used with solid wires where the welder's hand constantly moves over the hot weld pool. In addition, FCAW uses a longer stick-out than GMAW and therefore gives better access to confined joints, e.g. in single-bevel T-butt welds. Faster travel speeds equal shorter arc time, which helps reduce welder fatigue. The FCAW process is ideal for stitch and tack welds. Ease of handling and trouble-free processing make training and re-testing of welders easier while, at the same time, maintaining and improving quality assurance aspects.




T0 and T1 type flux-cored wires have larger windows of applicable welding parameters than same diameter solid wires.

Deposition rate


One of the most appealing features of flux-cored wires is their superior deposition rate, brought along by the flux-cored wire product design. When compared with solid wire of the same diameter, the current conducting cross-section of cored wires is smaller and, therefore, resistance heating in the sheath (I^2R effect) is higher at the same welding current. This translates into a higher wire melt-off rate. In the case of rutile flux-cored wires, the slag system is designed

to accommodate the higher melt-off rate and convert it into a higher deposition rate (all-position types) or a higher fillet welding travel speed (downhand types). The productivity gains are astonishing. Productivity gains of 20–50% can be achieved compared to GMAW with solid wire and even more compared with SMAW and GTAW,

Improved productivity in vertical-up position (3G / PF)				Method	Weld length	Deposition rate
	GTAW					
	Ø 2.4 mm	41 mm	1.0 kg/h			
	SMAW					
	Ø 3.2 mm	68 mm	1.8 kg/h			
	GMAW (pulse)					
	Ø 1.2 mm	105 mm	3.1 kg/h			
	FCAW					
	Ø 1.2 mm	210 mm	4.3 kg/h			
GTAW	SMAW	GMAW	FCAW			

Stainless steel welding processes.

Comparison of weld length for fillet welds in vertical-up position (PF / 3G), throat thickness 3 mm, welding time 1 min.

Improved productivity in horizontal (PB / 2F) position		Method	Weld length	Deposition rate
		FCAW		
		Ø 1.2 mm	800 mm	3.4 kg/h
		GMAW (pulse)		
		Ø 1.0 mm	570 mm	2.9 kg/h
		SMAW		
		Ø 3.2 mm	280 mm	1.2 kg/h

Stainless steel welding processes.

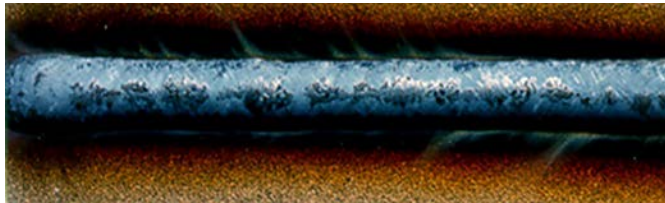
Comparison of weld length for fillet welds in flat position (PB / 2F), throat thickness 3 mm, welding time 1 min.

Weld discoloration

Rutile flux-cored wires furthermore feature the general characteristics of rutile welding consumables; smooth and flat welds without spatter and – unlike solid wires – absence of difficult to remove so called embedded slag remainders on the weld surface. Also there is less weld discoloration as with solid wires, due to the protection of the slag when the

weld is hot. Altogether, this substantially shortens the time for post-weld cleaning – as it is easier to hand brush the surface – and pickling time needed to restore corrosion resistance is shorter. (voestalpine Böhler weldCare offers a full range of pickling and passivation chemicals).

FCAW shows less discoloration compared with GMAW with solid wire.



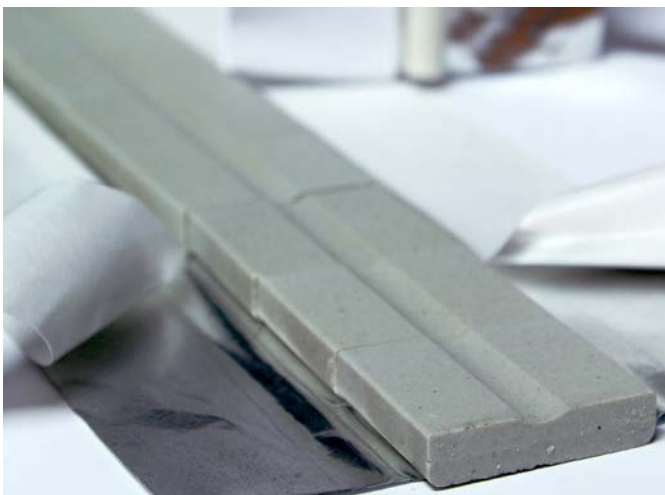
GMAW



FCAW

Shielding gases

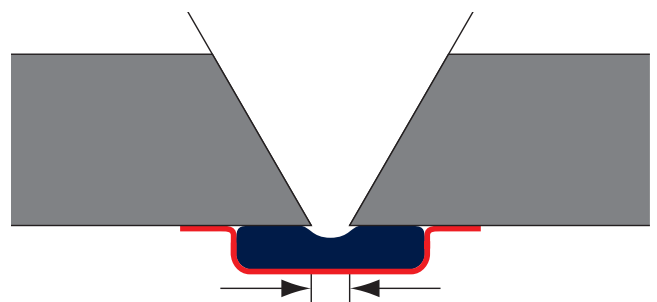
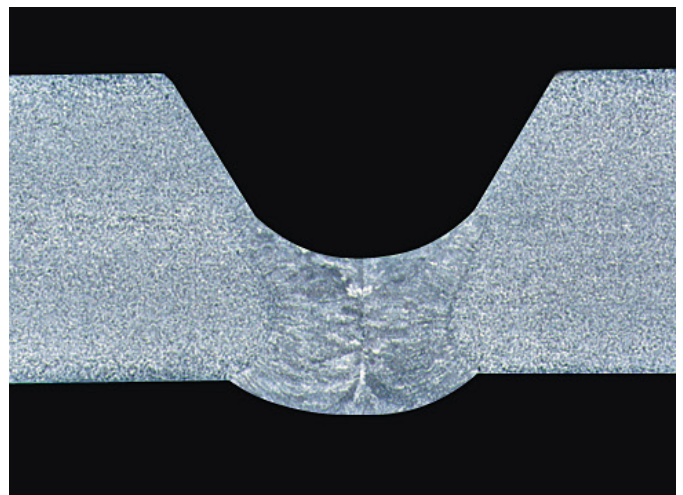
Stainless steel flux-cored wires are welded using the commercially available shielding gases Ar + 15–25% CO₂ or 100% CO₂. Solid wires are usually welded with Ar + 2% CO₂. The cost benefits for the user result from lower gas costs as well as from lower gas consumption due to shorter welding time. The potential cost savings are even higher when welding duplex stainless steel, as Ar + 30% He + 2% CO₂ is preferred for the GMAW process to improve the fluidity of the melt.



Root pass welding on ceramic backing material – a very economic method to deposit high quality root passes. Single-sided welding possible. Root pass performed with Ø 1.2 mm wire.

Ceramic backing material

By using ceramic weld metal support for the welding of root passes with the FCAW process, it is possible to weld the full joint – from root to cap – from only one side. It is a very productive way of depositing high quality root passes with excellent penetration and wetting, while eliminating time-consuming gouging / grinding from the opposite side.



BÖHLER WELDING FLUX-CORED WIRES

Böhler Welding offers stable, reliable and consistently high-quality flux-cored wires. The precise alloy and slag concept ensures welds with excellent corrosion resistance and mechanical properties. During manufacturing, an automatic system constantly monitors production ensuring that the flux fill is uniformly distributed throughout the entire length of the wire.

Böhler Welding high-alloyed flux-cored wires are produced in Europe in accordance with the EN ISO 9001 quality system. All wires fulfill both the EN ISO and AWS codes choosing the most stringent requirements. As an example, the AWS A5.22 code allows 2.0–3.0 wt.% Mo in 316L wires, while the EN ISO 17633-A code is stricter with 2.5–3.0 wt.% Mo. Molybdenum is an expensive alloying element, but it also increases the corrosion resistance of the weld metal. Böhler Welding, for this reason, only offers 316L wires with 2.5–3.0 wt.% Mo.

Rutile flux-cored wires for flat and horizontal welding

The wires are easy to handle with a wide parameter range. High deposition rates result in high productivity with outstanding welding performance and very low spatter formation. Excellent arc stability is produced by the very small droplet size, which gives the welder full control of the weld pool and slag. The wide arc ensures good wetting with even penetration and side-wall fusion to prevent lack of fusion. Welders report a very clean weld pool, which leads to a lower risk of weld defects and less rework.

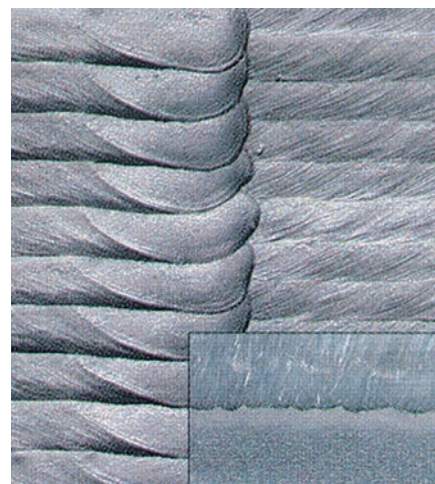


Fillet weld in flat position (PB / 2F). The base material is AISI 304L and the filler Avesta FCW-2D 308L/MVR (E308LT0-4/1). Ø 1.2 mm.



Welding on-site of stainless steel tanks – a typical application of Böhler Welding rutile all-position flux-cored wires. Tanks are in UNS S32101 and welded with Avesta FCW LDX 2101-PW (E2307T1-4/1).

Böhler Welding wires for flat and horizontal positions (T0 types) have smooth welding characteristics and run well, even at higher currents, which significantly increases the deposition rate. The T0 wires produce a smooth weld profile with a finely rippled surface pattern. The slag is self-releasing and leaves an even, beautiful weld finish. T0 type wires are also very suited for the cladding of corrosion resistant overlay onto unalloyed or low-alloyed steel.



Cladding with BÖHLER CN 23/12 Mo-FD (E309MoT0-4/1) for the 1st and BÖHLER EAS 4 M-FD (E316LT0-4/1) for the 2nd layer. Results in very uniform ferrite levels.

All-position rutile flux-cored wires

Böhler Welding manufactures all-position stainless flux-cored arc wires with a thicker sheath than comparable wires in the market, which makes them operate with 2 m/min higher wire feed speed and 1–2 more volts. This increases the deposition rate, welding speed and productivity. Customers have been able to reduce the amount of filling weld passes, as these wires allow higher wire feed speeds and fill the joint more efficiently. At higher travel speeds, it is possible to keep the heat input down and minimize distortion. The thicker sheath also provides for less flux filling and lower fume emission compared to competitive products.

Böhler Welding all-position wires are known to form a thin slag, which safely protects the entire weld surface from beginning to end. The slag detachability is very good and the resulting bead surface smooth. Deposition rate and deposition efficiency (recovery) of these wires are superior.

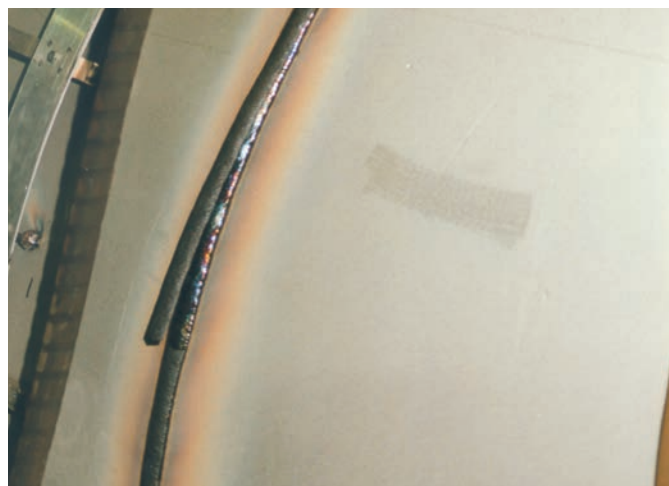


Cladding using Avesta FCW 309L-PW (E309T1-4/1) for high surface quality, also when welding out of position.

Böhler Welding all-position wires are genuine T1 types. This means that the welder can use these wires for welding overhead without being afraid of losing control of the weld pool. The all-positional T1 wires have a wide parameter range and ensure smooth transitions between different welding positions so that there is no need for changing the parameter settings. It is possible to weld pipe vertical-up from 6 to 12 o'clock (fixed position PF / 5G) with only one parameter setting. It means that the welder can weld longer, before having to change from physical position, and does not have to change any parameters to continue welding. In addition, these wires are reported by users to be more resistant to crater cracks and require less grinding between

The slag system does not only give the best possible recovery rate – with less slag chipped onto the floor – but also excellent impact toughness and corrosion resistance. The high arc intensity gives improved side-wall fusion and very low risk of lack of fusion in all positions. Welds produced with these wires show excellent radiographic results with regards to porosity and slag inclusions.

Increased travel speeds as well as self-releasing slag with little need for cleaning and pickling provide considerable savings in time and money. There is no need to clean spatter outside the weld. By using Böhler Welding cored wires, it is possible to reduce welding downtime by avoiding expensive subsequent work such as grinding, slag and spatter removal.



BÖHLER EAS 4 PW-FD (E316LT1-4/1) with self-releasing slag.

the passes, so the welder can almost immediately resume welding after removing the slag.

The FCAW process is also very popular for the repair welding of cast defects in foundries, because of the considerably higher productivity than SMAW and GMAW. With all-positional wires, it is possible to weld in different positions without having to turn large pieces. For example, superduplex flux-cored wires have largely replaced solid wires for the repair of cast superduplex alloys, which is also motivated by the higher susceptibility to porosity of the GMAW process.



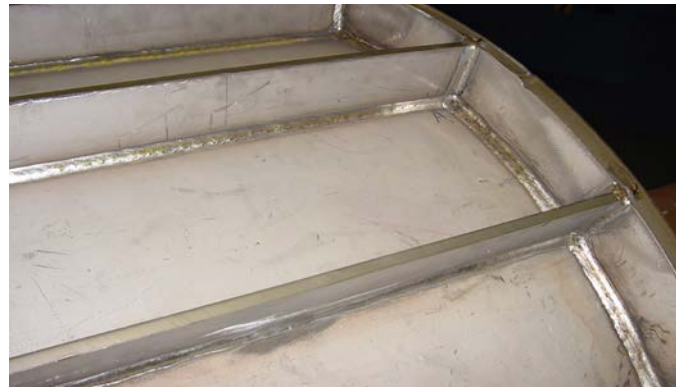
Worm shaft for the pulp and paper industry made of AISI 316Ti and welded with Ø 1.2 mm BÖHLER EAS 4 M-FD (E316LT0-4/1). Courtesy Andritz AG, Austria.



Welding of superduplex UNS S32750 pipe, using Avesta FCW 2507/P100-PW NOR (E2594T1-4/1).



Cargo tanks in a chemical tanker made of UNS S32205 and welded using 100% CO₂ shielding gas. Welds in the flat and horizontal positions made with Avesta FCW-2D 2205 (E2209T0-4/1) using ceramic backing for the root pass. Avesta FCW 2205-PW (E2209T1-4/1) is used for welding out-of-position. Avesta FCW-2D 309L (E309T0-4/1) and Avesta FCW 309L-PW (E309T1-4/1) are applied for dissimilar welds.



Smooth and shiny fillet welds. The application is a shaft for a disk filter in a pulp and paper mill. The base metal was AISI 316Ti and the wire BÖHLER EAS 4 M-FD (E316LT0-4/1).

Welding technique affects final result

While the GMAW process is welded with the pushing (fore-hand) technique to avoid cold laps in the flat and horizontal positions, FCAW shall be welded with the backhand technique. All flux-cored wire manufacturers are sometimes confronted with customers failing X-ray inspections due to slag inclusions and slag pockets / lack of fusion. The rule of thumb is “with slag you drag”. The trailing torch permits good weld pool control and – at the same time – promotes defect-free side-wall fusion, while maintaining high deposition rates. Welding with the backhand technique also improves slag detachability, minimizes spatter formation and gives a deeper penetration.

The FCAW process can be used for welding in all positions, although vertical-up (PF, 3G / 3F) is preferred over

vertical-down (PG, 3G / 3F). When using flux-cored wire for welding vertical-down, the penetration profile is shallow, hence the risk of slag inclusions and lack of fusion defects increases. The slag also becomes thinner, which can have a negative effect on the slag removal.

The optimum parameter setting depends on the characteristics of the power source. The voltage used for welding should be adjusted to result in an arc length of 3–4 mm. A longer arc tends to become soft and the weld wider, while a shorter arc length improves penetration. This can be achieved by reducing the voltage. The wire stick-out should be 15–20 mm when welding with 1.2–1.6 mm wires and 12–20 mm with 0.9 mm wires.

Flux-cored wire	Shielding gas	Wire stick-out
Ø 0.9 mm	Ar + 18–25% CO ₂	10–15 mm
Ø 1.2 / 1.6 mm	Ar + 18–25% CO ₂	15–20 mm
Solid wire	Ar + 2% CO ₂	12 mm

When welding stainless steel with flux-cored wires, Ar + 18–25% CO₂ is the shielding gas that produces the best results and the greatest slag control. Mixed gas has a very positive influence on arc stability, producing a fine, spatter-free droplet transfer. A typical gas flow for most applications and when welding outdoors is 20–25 l/min. In the vertical-up and overhead positions, a somewhat lower gas flow of 15–20 l/min (32–38 CFH) may be advantageous. It is also possible to use 100% CO₂, but the voltage needs to be increased by 2–3 V to achieve the correct arc length. The main advantage with pure CO₂ is that it provides deep

weld penetration, which is useful when welding thick material. The process runs hotter, which can be a benefit, but at the same time makes it more challenging to weld thin plates or when welding out-of-position. Moreover, it produces more welding fumes and the surface becomes more oxidized and some alloy elements may burn-off. The latter can affect the mechanical properties and the corrosion resistance. In applications where the ferrite content is of importance, one needs to take into account that the use of pure CO₂ shielding gas may lead to an increased austenite content in the weld.

More applications in duplex stainless steel



Welding of UNS S32205 in vertical-up and overhead position, using Avesta FCW 2205-PW (E2209T1-4/1).



Water injection risers in PUQ jackets. Superduplex welded with Avesta FCW 2507/P100-PW NOR (E2594T1-4/1).



Avesta FCW 2507/P100-PW NOR (E2594T1-4/1) used for the repair welding of cast superduplex stainless steel.



Seawater pump in UNS S32205 duplex stainless steel welded with Avesta FCW 2507/P100-PW (E2594T1-4/1) for highest possible corrosion resistance.

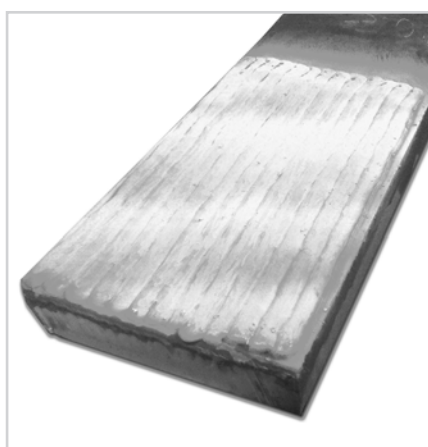
Bismuth-free wires for applications at elevated temperatures

The American Petroleum Institute (API) has incorporated a limit of 20 ppm bismuth for austenitic stainless steel FCAW deposits in the standard API RP 582 “Welding Guidelines for the Chemical, Oil, and Gas Industries”, valid when these weld metals are exposed to temperatures above 538 °C during fabrication and / or during service. AWS A5.22:2012 states that stainless steel electrodes containing bismuth additions should not be used for high temperature services or post-weld heat treatment (PWHT) above about 500 °C.

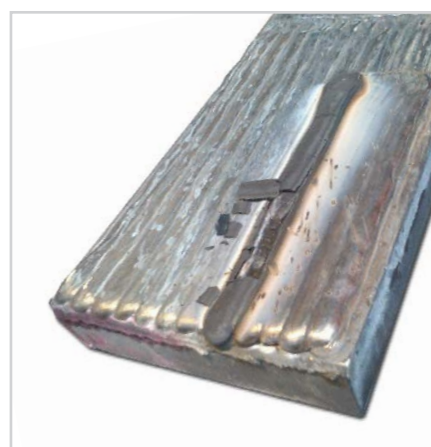
For this reason, bismuth-free stainless steel flux-cored wires providing no more than 20 ppm (0.002 wt.%) bismuth in the weld metal should be specified. Critical process equipment is typically operated at temperatures below 500 °C, but depending on the alloy grade and requirements on mechanical properties, a final PWHT is performed at 600-710 °C. Bismuth-free flux-cored wires show improved resistance to embrittlement after PWHT at 700 °C and the impact toughness and lateral expansion values are higher than for wires containing bismuth. The example below shows that bismuth-free flux-cored wires are also suitable for cladding.



First layer cladding with BÖHLER E 309L H-FD (E309LT0-4/1) with good slag detachability.



Dye-penetrant test after first layer with BÖHLER E 309L H-FD (E309LT0-4/1). No indication of cracks or porosity.



The second BÖHLER E 347L H-FD (E347T0-4/1) layer shows slag removal similar to that of the first layer.

The first layer with BÖHLER E 309L H-FD (E309LT0-4/1) shows good slag detachability and no cracks or irregularities were reported. Slag detachability from the second layer – welded with BÖHLER E 347L H-FD (E347T0-4/1) – was similar to that of BÖHLER E 309L H-FD. Both wires provide very good weld appearance with uniform solidification lines on the surface. The bead appearance is comparable to that of standard bismuth-alloyed wires and there was no spatter formation.

Measured composition of the first and second layer performed with T0 wires, wt.%.

Filler	Layer	C	Si	Mn	Cr	Ni	Mo	Nb	Ferrite*
BÖHLER E 309L H-FD	1	0.048	0.529	1.30	19.80	10.33	0.148	< 0.004	8.9 FN
BÖHLER E 347L H-FD	2	0.034	0.593	1.49	19.28	10.21	0.083	0.39	6.5–7.5 FN

Measured composition of the first and second layer performed with T1 wires, wt.%.

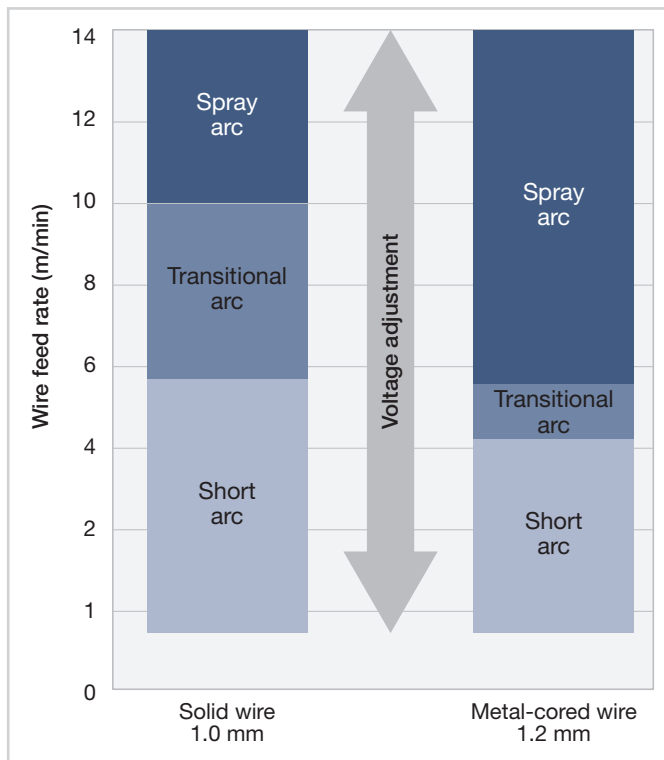
Filler	Layer	C	Si	Mn	Cr	Ni	Mo	Nb	Ferrite*
BÖHLER E 309L H PW-FD	1	0.042	0.743	1.21	23.56	12.48	0.034	< 0.004	9.3 FN
BÖHLER E 347 H PW-FD	2	0.044	0.712	1.46	18.52	10.55	0.082	0.424	6.1 FN

*Ferrite measured with Fischer FeritScope MP30.

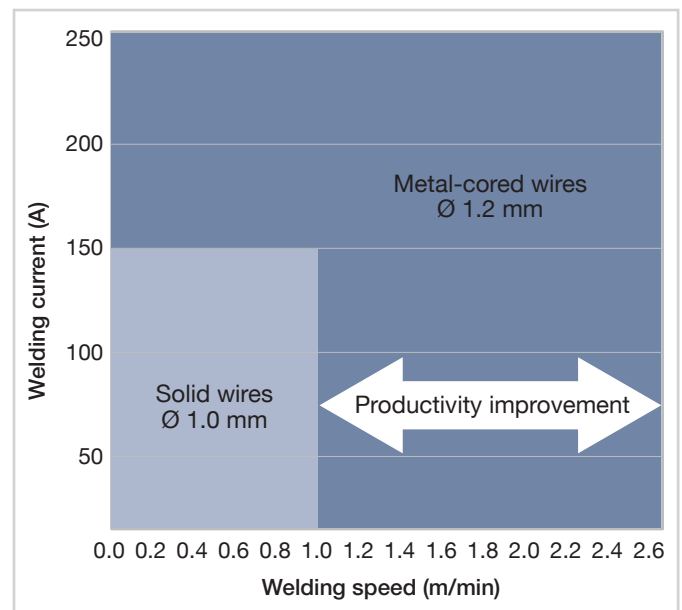
METAL-CORED WIRES – ADVANTAGES OVER GMAW

In comparison with flux-cored wires, metal-cored wires are not filled with flux, but contain metal powder in their core. They are welded using GMAW power sources with Ar + 2–3% CO₂ or Ar + 1–2% O₂ (M12 or M13) shielding gas. Just as for solid wire, the process can be optimized by using (synergic) pulse welding.

Comparing metal-cored wire to solid wire, the parameter range for metal-cored wires almost covers the range of Ø 1.0 mm and Ø 1.2 mm solid wires in both spray and short arc mode.



Parameter range for solid wire compared with metal-cored wire.



The metal-cored wires have a higher current density and spray arc is obtained at lower current settings. Metal-cored wires enter the favorable spray arc droplet transfer mode at a much lower wire feed rate than solid wire. This makes it easier to find suitable welding parameters.

Significantly higher deposition rate and welding speed can be achieved compared to solid wires of the same diameter. As travel speeds of up to 2.6 m/min can be reached, these wires are the best choice for high productivity welding in mechanized applications.

Spray arc is used for high productivity welding in flat position and – for thicker plates – also in the horizontal position. Welding in horizontal-vertical and vertical-up position is possible with short arc, but productivity will be similar to that of solid wire.

Compared with solid wires, metal-cored wires feature a wider arc that ensures uniform and safe side-wall fusion. This results in improved resistance to lack of fusion defects and makes metal-cored wires less sensitive to edge misalignment and variation in gap width. This method is excellent for small, single pass fillet welds at high welding speed. It is possible to weld thinner material than with solid wire, down to 0.6 mm.



0.6 mm exhaust manifold welded with Ø 1.2 mm BÖHLER EAS 2-MC (EC308L). With 2.6 m/min wire feeding, 80–85 A and 20 V, the travel speed was 85 cm/min. It was not possible to use solid wire for this sheet metal application.



Welding of limpet coils with Ø 1.2 mm using BÖHLER EAS 4 M-MC (EC316L).
Courtesy: Neuman Anlagentechnik, Germany

Other advantages from metal-cored wires are excellent wetting and a smooth surface with less oxidation and residual slag. The arc is extremely stable resulting in a minimal amount of spatter.



Metal-cored wire



Solid wire

Metal-cored wires applied in the automotive industry

Metal-cored wires are proven to be very efficient for cost reductions and quality improvement, within the automotive industry. Stainless steel metal-cored wires from Böhler Welding are, for instance, used for robotic welding of exhaust systems. Ferritic and austenitic types are available for welding the various grades used for different components. The wires are optimized for high speed welding of thin sheets. They show good arc stability, weld penetration and gap bridging properties along different arc types.

Cost savings reported are shorter cycle times, higher production output and increased weld quality. The wider penetration profile is beneficial to avoid lack of fusion defects and associated rejects and repairs. A manufacturer of catalytic converters reported a scrap rate of 1% due to burn-through with solid wire and a rework rate of 10%. With Böhler Welding metal-cored wire applied with a robotic system with precise parameter control over the entire weld length, the scrap rate was 0% and the rework rate 0.3%. Time and cost savings were substantial.

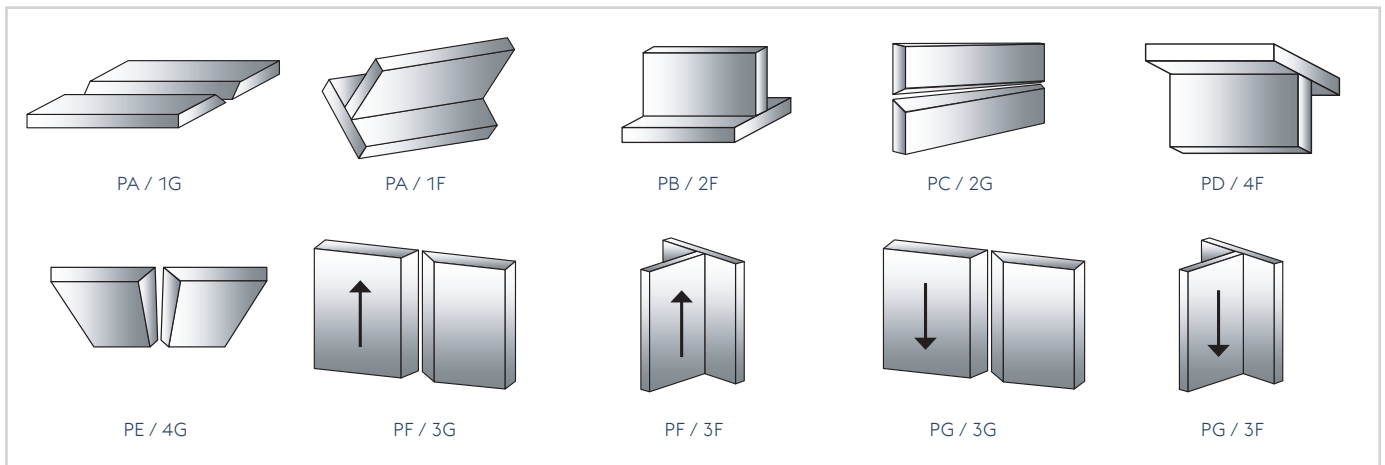
Typical welding parameters for metal-cored wires.

Ø	Stick-out	Arc length	Wire feed speed	Current	Voltage
mm	mm	mm	m / min	A	V
1.2	15	~3	3.5–13	100–280	10–27
1.6	20	~3	1.5–8	110–380	10–27



WELDING PARAMETERS FOR DIFFERENT POSITIONS

EN and AWS welding positions / butt & fillet welds



Below typical welding parameters are listed for different alloys and wire types. The actual welding parameters further depend on welding position, joint type and shielding gas. Here typical values are given for Ar + 18% CO₂. With 100% CO₂ as shielding gas, the voltage is normally 2–3 V higher. The arc voltage is highly power source dependent so different values may be needed with different equipment.

Typical welding parameter range for T0 and T1 types for different alloys.

Ø	Wire feed speed	Arc length	Current	Voltage
mm	m/min	mm	A	V
Austenitic T0 wires				
1.2	5.0–15.0	~ 3	130–280	22–30
1.6	4.5–9.5	~ 3	200–350	25–30
Austenitic T1 wires				
0.9	8.0–15.0	~ 3	100–160	22–27
1.2	6.0–13.0	~ 3	150–280	22–30
1.6	4.5–9.5	~ 3	200–360	23–28
Duplex T0 wires				
1.2	6.5–15.5	~ 3	150–280	24–30
1.6	5.0 – 9.5	~ 3	200–350	26–30
Duplex T1 wires				
1.2	5.5–11.5	~ 3	130–230	23–30
1.6	5.0–9.0	~ 3	200–320	25–30
Nickel-base T0 wires				
1.2	5.0–15.0	Max. 3	130–280	22–30
1.6	4.5–9.5	Max. 3	200–350	25–30
Nickel-base T1 wires				
1.2	6.0–12.0	Max. 3	130–230	23–27

Downhand PA / 1G, 1F typical parameter range for 1.2 mm T0 wire with Ar + 18% CO₂.

	Stick-out	Current	Voltage	Wire feed	Run
	mm	A	V	m/min	
	15	140 - 190	22.0 - 26.5	6.5 - 9.0	Root (ceramic backing)
	15	165 - 220	24.5 - 28.0	8.5 - 11.5	Fill
	15	165 - 250	24.5 - 29.0	9.0 - 13.5	Cap

Flat fillet PB / 2F typical parameter range for 1.2 mm T0 wire with Ar + 18% CO₂.

	Stick-out	Current	Voltage	Wire feed	Run
	mm	A	V	m/min	
	15	160 - 260	25.0 - 29.0	8.5 - 15.0	Fill (10 mm material thickness)
	15	135 - 215	22.5 - 27.5	6.5 - 11.0	Fill (5 mm material thickness)

Horizontal-vertical PC / 2G typical parameter range for 1.2 mm T1 wire with Ar + 18% CO₂.

	Stick-out	Current	Voltage	Wire feed	Run
	mm	A	V	m/min	
	15	130 - 170	21.0 - 23.5	6.0 - 8.0	Root (ceramic backing)
	15	155 - 235	22.5 - 24.0	7.0 - 10.5	Fill
	15	160 - 235	22.5 - 24.0	7.0 - 10.5	Cap

Vertical-up PF / 3G, 3F typical parameter range for 1.2 mm T1 wire with Ar + 18% CO₂.

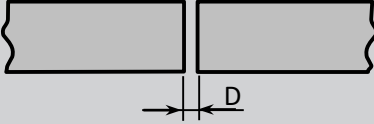
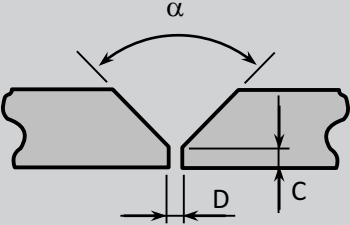
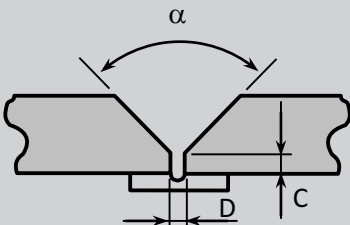
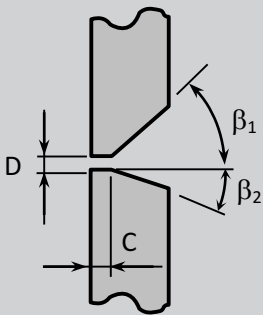
	Joint type	Stick-out	Current	Voltage	Wire feed	Run
		mm	A	V	m/min	
	Butt	15	140 - 175	20.5 - 23.5	6.0 - 8.5	Root (ceramic backing)
	Butt	15	145 - 230	22.5 - 26.5	6.0 - 12.5	Fill
	Fillet	15	130 - 280	21.0 - 26.5	5.5 - 13.5	Fill

Overhead PD, PE / 4G, 4F typical parameter range for 1.2 mm T1 wire with Ar + 18% CO₂.

	Joint type	Stick-out	Current	Voltage	Wire feed	Run
		mm	A	V	m/min	
	PE Butt	15	160 - 200	21.0 - 22.5	6.5 - 8.5	Root (ceramic backing)
	PE Butt	15	165 - 220	22.0 - 24.0	7.0 - 12.0	Fill
	PD Fillet	15	170 - 250	22.0 - 24.0	7.0 - 11.5	Fill

DIFFERENT JOINT TYPES

When the type of joint to be used for a certain weld needs to be selected, several factors have to be weighed. The welding process, welding position, type of material and material thickness must all be taken into account.

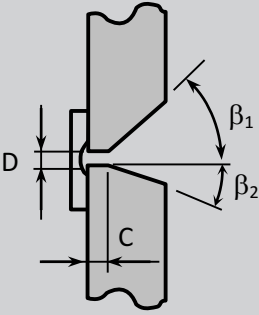
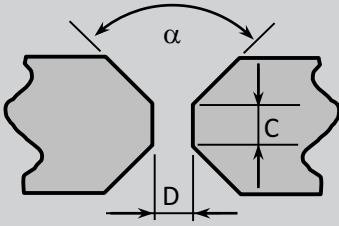
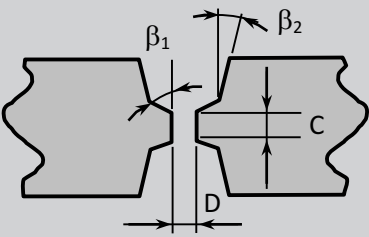
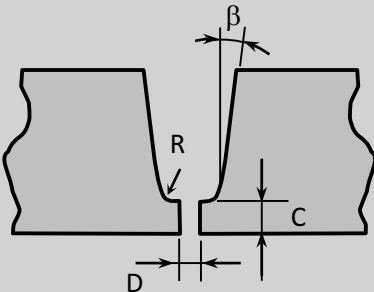
Joint type	Geometry	Thickness	Welding sides
I-joint; root gap $D = 1.0\text{--}2.0\text{ mm}$		$< 2.5\text{ mm}$	One
I-joint; root gap $D = 2.0\text{--}2.5\text{ mm}$		$< 4\text{ mm}$	Two
V-joint; root gap $\alpha = 60^\circ$ $C = .5\text{--}1.5\text{ mm}$ $D = 2.0\text{--}4.0\text{ mm}$		4–16 mm	One
V-joint; root gap $\alpha = 60^\circ$ ¹ $C = 2.0\text{--}2.5\text{ mm}$ $D = 2.5\text{--}3.5\text{ mm}$		4–16 mm	Two
V-joint; root gap $\alpha = 60^\circ$ ¹ $C = 1.5\text{--}2.5\text{ mm}$ $D = 4.0\text{--}6.0\text{ mm}$		4–20 mm	One-sided on ceramic backing
V-joint; root gap $\beta_1 = 45^\circ$ $\beta_2 = 15^\circ$ $C = 1.0\text{--}2.0\text{ mm}$ $D = 2.0\text{--}3.0\text{ mm}$		4–16 mm	One
V-joint; root gap $\beta_1 = 45^\circ$ $\beta_2 = 15^\circ$ $C = 2.0\text{--}2.5\text{ mm}$ $D = 2.0\text{--}2.5\text{ mm}$		4–16 mm	Two

¹⁾ The joint angle for special grades is $60\text{--}70^\circ$.

²⁾ Welding performed on ceramic backing (round type).

³⁾ For openings, such as manholes, view-ports, nozzles, etc.

Joint or edge preparation can be performed in several ways; by machining, cutting, or by grinding.

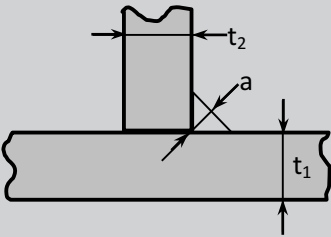
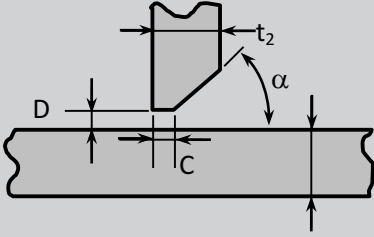
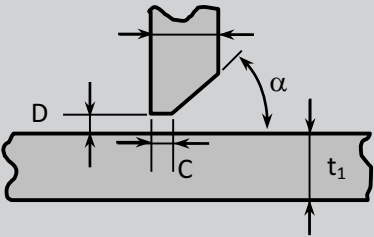
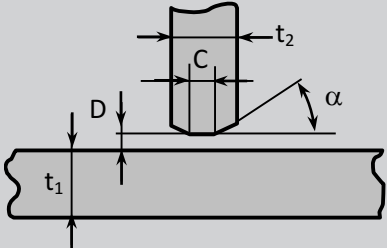
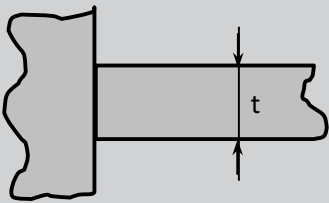
Joint type	Geometry	Thickness	Welding sides
V-joint; root gap $\beta_1 = 45^\circ$ $\beta_2 = 15^\circ$ $C = 2.0\text{--}2.5\text{ mm}$ $D = 2.0\text{--}2.5\text{ mm}$		4–20 mm	One side against backing
X-joint; root gap $\alpha = 60^\circ$ ¹⁾ $C = 2.0\text{--}3.0\text{ mm}$ $D = 2.0\text{--}2.5\text{ mm}$		14–305 mm	Two
X-joint; root gap $\beta_1 = 45^\circ$ $\beta_2 = 15^\circ$ $C = 1.5\text{--}2.5\text{ mm}$ $D = 2.5\text{--}3.0\text{ mm}$		14–30 mm	Two
U-joint $\beta = 10^\circ$ $R = 8\text{ mm}$ $C = 2.0\text{--}2.5\text{ mm}$ $D = 2.0\text{--}2.5\text{ mm}$		< 50 mm	Two

¹⁾ The joint angle for special grades is 60–70°.

²⁾ Welding performed on ceramic backing (round type).

³⁾ For openings, such as manholes, view-ports, nozzles, etc.

Joint or edge preparation can be performed in several ways; by machining, cutting, or by grinding.

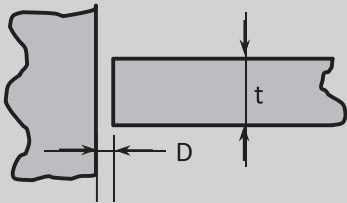
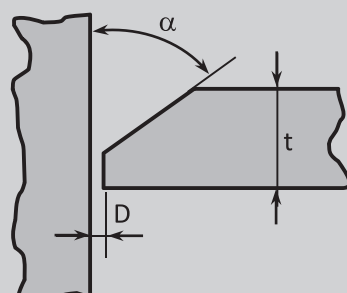
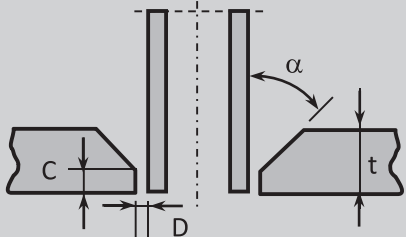
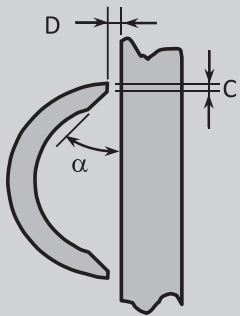
Joint type	Geometry	Thickness	Welding sides
Fillet weld; no root gap $a \approx 0.7 \times t$ a = weld throat		> 2 mm	One/Two
Half V-joint; root gap $\alpha = 50^\circ$ $C = 1.0\text{--}2.0$ mm $D = 2.0\text{--}4.0$ mm		4–16 mm	One
Half V-joint; root gap $\alpha = 50^\circ$ $C = 1.5\text{--}2.5$ mm $D = 2.0\text{--}3.0$ mm		4–16 mm	Two
Half X-joint; root gap $\alpha = 50^\circ$ $C = 1.5\text{--}2.5$ mm $D = 2.0\text{--}4.0$ mm		14–30 mm	Two ²
Fillet weld; no root gap		< 2 mm	Two

¹⁾ The joint angle for special grades is 60–70°.

²⁾ Welding performed on ceramic backing (round type).

³⁾ For openings, such as manholes, view-ports, nozzles, etc.

Joint or edge preparation can be performed in several ways; by machining, cutting, or by grinding.

Joint type	Geometry	Thickness	Welding sides
Fillet weld; root gap $D = 2.0\text{--}2.5\text{ mm}$		2–4 mm	Two
Half V-joint; root gap $\alpha = 50^\circ$ $C = 1.5\text{--}2.5\text{ mm}$ $D = 2.0\text{--}4.0\text{ mm}$		4–16 mm	One ²
Half V-joint; root gap $\alpha = 50^\circ$ $C = 1.5\text{--}2.5\text{ mm}$ $D = 1.5\text{--}2.5\text{ mm}$		14–30 mm	Two
Half V-joint ³ ; root gap $\alpha = 50^\circ$ $C = 1.0\text{--}2.0\text{ mm}$ $D = 2.0\text{--}3.0\text{ mm}$		4–16 mm	Two
Half pipe $\alpha = 60^\circ$ $C = 3.0\text{--}4.0\text{ mm}$ $D = 2.0\text{--}3.0\text{ mm}$		4–16 mm	One

¹⁾ The joint angle for special grades is $60\text{--}70^\circ$.

²⁾ Welding performed on ceramic backing (round type).

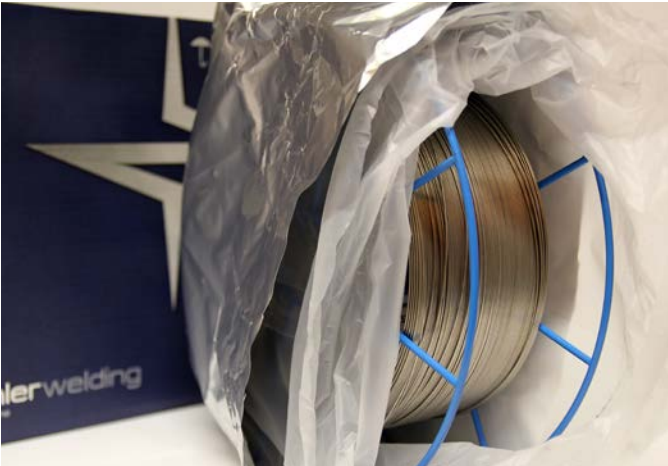
³⁾ For openings, such as manholes, view-ports, nozzles, etc.

Joint or edge preparation can be performed in several ways; by machining, cutting, or by grinding.

Packaging

Böhler Welding cored wires are available on wire basket and plastic spools. They are precision layer wound and have excellent feeding characteristics. All stainless steel flux-cored wires are vacuum-packed in moisture resistant aluminized bags for maximum protection. Inside, the spool is contained by a plastic bag. This makes protection of the wire easier when not used. Storage in opened packaging can considerably shorten the service life of the product. It

is recommended to put wires back in their original packaging when they are not being used. It is beneficial to use a room with controlled humidity. The storage temperature should be as constant as possible and kept above 15 °C. The wires may be stored at a lower temperature, but must then be taken into a warmer area to warm up and avoid condensation on the wire surface.



Spools delivered in plastic and aluminized bags for best storage safety.

The standard weights and packaging are given below. For fully automated applications, smaller spool packaging is offered 5 kg. For details, please contact your voestalpine Böhler Welding representative.

Flux-cored wires

Ø Wire diameter	Weight
0.9 mm	12.5 kg
1.2 mm	15 kg
1.6 mm	15 kg

Metal-cored wires

Ø Wire diameter	Weight
1.2 mm	16 kg
1.6 mm	16 kg

Dimensions

	<table> <tr> <th colspan="2">Blue wire basket BS300 Precision layer wound</th></tr> <tr> <td>Ø external</td><td>300 mm</td></tr> <tr> <td>Ø inner</td><td>52 mm</td></tr> <tr> <td>Width</td><td>95 mm</td></tr> </table>	Blue wire basket BS300 Precision layer wound		Ø external	300 mm	Ø inner	52 mm	Width	95 mm
Blue wire basket BS300 Precision layer wound									
Ø external	300 mm								
Ø inner	52 mm								
Width	95 mm								
	<table> <tr> <th colspan="2">Blue plastic spool S300 Precision layer wound</th></tr> <tr> <td>Ø external</td><td>300 mm</td></tr> <tr> <td>Ø inner</td><td>52 mm</td></tr> <tr> <td>Width</td><td>110 mm</td></tr> </table>	Blue plastic spool S300 Precision layer wound		Ø external	300 mm	Ø inner	52 mm	Width	110 mm
Blue plastic spool S300 Precision layer wound									
Ø external	300 mm								
Ø inner	52 mm								
Width	110 mm								
	<table> <tr> <th colspan="2">5 kg (10 lbs.) Plastic spool S200 Precision layer wound</th></tr> <tr> <td>Ø external</td><td>200 mm</td></tr> <tr> <td>Ø inner</td><td>52 mm</td></tr> <tr> <td>Width</td><td>47 mm</td></tr> </table>	5 kg (10 lbs.) Plastic spool S200 Precision layer wound		Ø external	200 mm	Ø inner	52 mm	Width	47 mm
5 kg (10 lbs.) Plastic spool S200 Precision layer wound									
Ø external	200 mm								
Ø inner	52 mm								
Width	47 mm								
	<table> <tr> <th colspan="2">Octagonal drum</th></tr> <tr> <td>Height</td><td>865 mm</td></tr> <tr> <td>Ø</td><td>580 mm</td></tr> </table> <p>Wire volume drum system for additional savings, especially in mechanized and robotic operations. It drastically reduces the downtime for spool exchange and increases the arc time. No spools get empty during welding and there are no partly welded objects to repair or scrap. The octagonal drums weigh 120–200 kg and can be folded after use to save storage space.</p>	Octagonal drum		Height	865 mm	Ø	580 mm		
Octagonal drum									
Height	865 mm								
Ø	580 mm								
<p>Octagonal drums are foldable after use for space saving storage.</p>									

Ø 0.9 mm and Ø 1.6 mm, 5 kg plastic spools and drum packaging are not available for all products; please contact your voestalpine Böhler Welding sales representative for detailed information.



JOIN! voestalpine Böhler Welding

With over 100 years of experience, voestalpine Böhler Welding is the global top address for the daily challenges in the areas of joint welding, repair, hardfacing and cladding as well as brazing. Customer proximity is guaranteed by more than 43 subsidiaries in 25 countries, with the support of 2,300 employees, and through more than 2,000 distribution partners worldwide. With individual consultation by our application technicians and welding engineers, we make sure that our customers master the most demanding welding challenges. voestalpine Böhler Welding offers three specialized and dedicated brands to cater our customers' and partners' requirements.



Lasting Connections – As a pioneer in innovative welding consumables, Böhler Welding offers a unique product portfolio for joint welding worldwide. More than 2000 products are adapted continuously to the current industry specifications and customer requirements, certified by well-respected institutes and thus approved for the most demanding welding applications. As a reliable partner for customers, "lasting connections" are the brand's philosophy in terms of both welding and people.



Tailor-Made Protectivity™ – UTP Maintenance ensures an optimum combination of protection and productivity with innovative and tailor-made solutions. Everything revolves around the customer and their individual requirements. That is expressed in the central performance promise: Tailor-Made Protectivity™.



In-Depth Know-How – As a leading brand of soldering and brazing consumables, Fontargen Brazing offers proven solutions based on 50 years of industrial experience, tried and tested processes and methods. This In-Depth Know-How has made Fontargen Brazing an internationally preferred partner for every soldering and brazing task.

The Management System of voestalpine Böhler Welding Group GmbH, Peter-Mueller-Strasse 14-14a, 40469 Duesseldorf, Germany has been approved by Lloyd's Register Quality Assurance to: ISO 9001:2015, ISO 14001:2015, OHSAS 18001:2007, applicable to: Development, Manufacturing and Supply of Welding and Brazing Consumables. More information: www.voestalpine.com/welding



