

**WELDING CONSUMABLES  
FOR HYDRO POWER STATIONS**

For almost 80 years, BÖHLER WELDING has been supplying to component fabricators for the power generating industry. Supported by a strong research and development team, BÖHLER WELDING is also a traditional supplier of specially designed high quality filler metals for the construction and the refurbishment of Francis, Kaplan and Pelton hydro turbines made of 13%Cr 4%Ni or 316L stainless steels. Efficient welding solutions are provided with flux and metal cored wires. The complete range of products for SMAW, GTAW, GMAW and SAW using BÖHLER WELDING consumables means safe and trouble-free plant operation. Excellent references can be given for the construction of penstocks for pumped storage hydro power plants.

Penstocks and bifurcators as high tech components call for competent engineering and top class materials. BÖHLER WELDING's

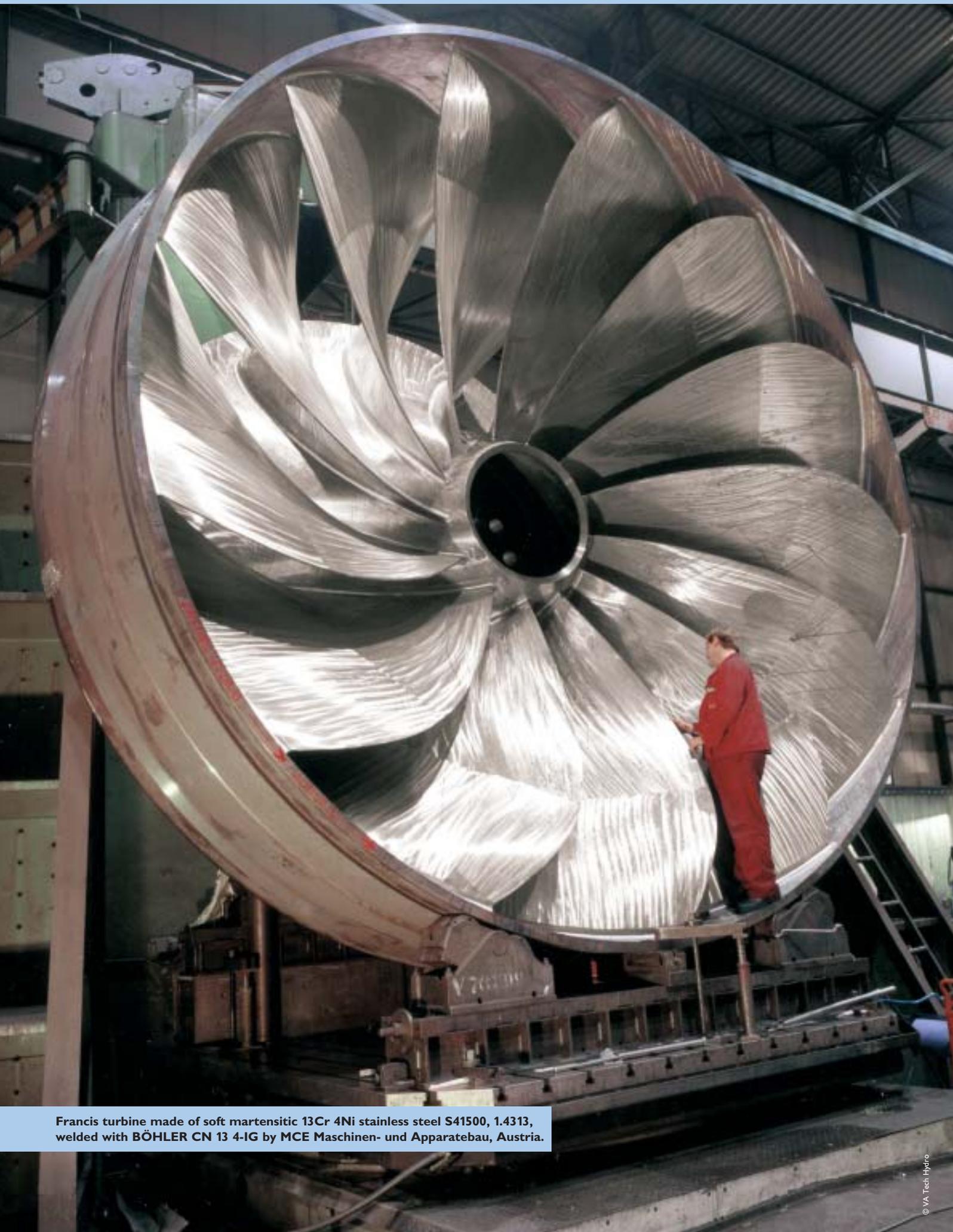
high strength submerged arc wire/flux combinations or the basic coated electrodes for vertical up the so called BÖHLER FOX BVD electrodes for the highly economic vertical down welding meet the most stringent mechanical and safety requirements for both the prefabrication and the in-situ circumferential joint welding. When it comes to the orbital welding technology for the in-situ joint welds of penstocks BÖHLER WELDING supplies also the best suitable GTAW wires.

Experienced engineers provide expert advice to optimize your welding procedures. BÖHLER WELDING's worldwide network of sales partners ensures a reliable delivery service and technical advice in more than 80 countries in every continent. Your nearest sales partner can be found on the Internet at [www.boehler-welding.com](http://www.boehler-welding.com)

**BÖHLER WELDING consumables are available in moisture resistant and hermetically sealed packs.**



## References



Francis turbine made of soft martensitic 13Cr 4Ni stainless steel S41500, 1.4313, welded with BÖHLER CN 13 4-IG by MCE Maschinen- und Apparatebau, Austria.

# Selection guide

	Base metals AISI/UNS/ASTM	Welding processes					Page	
		SMAW	FCAW	GTAW	GMAW	SAW		
<b>API Pipe steels</b>  Re ≤ 450 MPa Re ≤ 555 MPa	X42-X65	FOX BVD 85					5	
	X70, X80	FOX BVD 90					5	
	X80	FOX BVD 100					5	
<b>High strength steels</b>  Re ≤ 500 MPa Re ≤ 600 MPa Re ≤ 690 MPa	A302 Gr.A-D	FOX EV 65			NiMo 1-IG	3NiMo 1-UP+BB 24	5	
	A517 Gr.A-C	FOX EV 75					6	
	USS-T1	FOX EV 85			X 70-IG	3NiCrMo 2.5-UP+BB 24	6	
<b>Stainless steels</b>  Soft martensitic 13Cr 4Ni  16Cr 6Ni Mo  Austenitic 19Cr 9Ni 3Mo L	CA6NM	FOX CN 13/4			CN 13/4-MC		7	
		FOX CN 13/4 SUPRA		CN 13/4-IG	CN 13/4-MC (F)	CN 13/4-UP+BB 203	7	
			FOX CN 16/6 M-HD			CN 13/4-IG		7
							8	
	316L	FOX EAS 4 M FOX EAS 4 M-A	EAS 4 M-FD EAS 4 PW-FD	EAS 4 M-IG	EAS 4 M-IG (Si) EAS 4 M-MC	EAS 4 M-UP+BB 202	8 8	
<b>Special applications</b>  18Cr 8Ni Mn  23Cr 12Ni L  23Cr 12Ni 2Mo L	dissimilar joints, repair and maintenance	FOX A 7	A 7 -FD	A 7 CN-IG	A 7-IG	A 7 CN-UP+BB 203	10	
		FOX A 7-A	A 7 PW-FD		A 7-MC		10	
		FOX CN 23/12-A	CN 23/12-FD	CN 23/12-IG	CN 23/12-IG	CN 23/12-UP+BB 202	11	
			CN 23/12 PW-FD		CN 23/12-MC		12	
		FOX CN 23/12 Mo-A	CN 23/12 Mo-FD				12	
	CN 23/12 Mo PW-FD				12			

# API Pipe steels

BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>FOX BVD 85</b> E 46 5 1Ni B 4 5 H5 E8018-G	SMAW	C 0.04 Si 0.4 Mn 0.9 Ni 0.9	Re 510 N/mm <sup>2</sup> Rm 560 N/mm <sup>2</sup> A5 27% Av 170 J 65 J...-50 °C	3.2 4.0 4.5	TÜV-D, CL, GdF, UDT, SEPROZ	Basic coated electrodes for vertical-down welds of large diameter pipelines e.g. penstocks and for structural work. Suitable for filler and cover pass welding in pipeline construction. Deposit is extremely crack resistant, and features high toughness and a very low hydrogen content (HD < 5ml/100 g).	S235J2G3 - S355J2G3, L290NB - L450NB, L290MB - L450MB, P235GH - P295GH  API Spec. 5 L: A, B, X42, X46, X52, X56, X60, X65
<b>FOX BVD 90</b> E 55 5 Z2Ni B 4 5 H5 E9018-G	SMAW	C 0.04 Si 0.3 Mn 1.2 Ni 2.2	Re 600 N/mm <sup>2</sup> Rm 650 N/mm <sup>2</sup> A5 27% Av 170 J 80 J...-40 °C	3.2 4.0 4.5	TÜV-D, CL, Statoil, UDT, GdF, SEPROZ	The weld deposit of BÖHLER FOX BVD 85 shows an ideal combination between high strength and cryogenic toughness down to -50 °C (-58 °F).  Special design and development work has enabled this electrode to provide exceptional striking characteristics and the avoidance of start porosity on cover (cap) passes. Due to this and the good welding characteristics this special basic electrode offers easy handling even under field conditions.	L485MB, L555MB  API Spec. 5 L: X70, X80
<b>FOX BVD 100</b> E 62 5 Z2Ni B 4 5 H5 E10018-G	SMAW	C 0.07 Si 0.4 Mn 1.2 Ni 2.3	Re 670 N/mm <sup>2</sup> Rm 730 N/mm <sup>2</sup> A5 24% Av 150 J 70 J...-50 °C	4.0 4.5	TÜV-D, UDT, SEPROZ		L555MB  API Spec. 5 L: X80
BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>FOX EV 65</b> E 55 6 1 NiMo B 42 H5 E8018GH4R	SMAW	C 0.06 Si 0.3 Mn 1.2 Ni 0.8 Mo 0.35	Re 600 N/mm <sup>2</sup> Rm 650 N/mm <sup>2</sup> A5 25% Av 180 J 80 J...-60 °C	2.5 3.2 4.0	TÜV-D, UDT, SEPROZ	Basic coated electrode with high ductility and crack resistance, for high-strength fine-grained steels. Ductile down to -60 °C. Resistant to ageing.  Easy to handle in all positions except vertical-down. Preheating and interpass temperature, as well as post weld heat treatment as required by the base metal.  Very low hydrogen content (acc. AWS condition HD < 4 ml/100 g).	Constructional steels, pipe- and vessel steels, cryogenic fine-grained steels and special grades.  E295-E360, P355NL1-P460NL1, P355 NL2-P460NL2, S380N-S500N, S355NH-S460NH, S380NL- S500NL, S380NL1-S500NL1, 15NiCuMoNb5S (WB 36), 20MnMoNi5-5, 17MnMoV6-4 (WB 35), 22NiMoCr4-7  ASTM: A302 Gr.A-D, A225 Gr.C A572 Gr.65
<b>NiMo 1-IG</b> G 55 6 M Mn3Ni1Mo G 55 4 C Mn3Ni1Mo ER90S-G	GMAW	C 0.08 Si 0.6 Mn 1.8 Ni 0.9 Mo 0.3	Re 620 N/mm <sup>2</sup> Rm 700 N/mm <sup>2</sup> A5 23% Av 140 J >47 J...-60 °C (80 % Ar/20 % CO <sub>2</sub> )  Re 590 N/mm <sup>2</sup> Rm 680 N/mm <sup>2</sup> A5 25% Av 120 J >47 J...-40 °C (100 % CO <sub>2</sub> )	1.0 1.2	DB, UZ, ÖBB, GL, UDT, SEPROZ	GMAW wire for high strength, quenched and tempered fine-grained constructional steels.  The wire is suited for joint welding in boiler, pressure vessel, pipeline, and crane construction as well as in structural steel engineering.  Due to the precise addition of micro alloying elements NiMo 1-IG wire features excellent ductility and crack resistance in spite of its high strength. Good cryogenic impact energy down to -60 °C, low hydrogen contents in the deposit, best feedability and low copper contents are other advantages of this wire. Preheating and interpass temperature as required by the base metal.	Pipe steels and fine grained steels, quenched and tempe- red fine-grained steels.  S380N-S500N, S380NL- S500NL, S500NC-S550NC, N-A-XTRA 56-70, BHV70, PAS600, HSM600, 20MnMoNi5-5  ASTM A517 Gr.A,B,C,E,F,H,J,K,M,P A225 Gr.C A633 Gr.E A572 Gr.65
<b>Wire: 3 NiMo 1-UP</b> SZ3Ni1Mo EF3(mod.) <b>Flux: BB 24</b> SA FB 1 65 DC H5	SAW	C 0.08 Si 0.45 Mn 1.55 Ni 0.95 Mo 0.55	Re 580 N/mm <sup>2</sup> Rm 650 N/mm <sup>2</sup> A5 21% Av 180 J 60 J...-40 °C	4.0	TÜV-D, UDT  <b>Wire:</b> TÜV-D	SAW wire/flux combination for joint welding of high strength and low temperature steels. The flux reacts metallurgically Mn-neutral.  The sub-arc wire/flux combination produces very good low temperature impact properties down to -40 °C. Excellent slag detachability, smooth beads, good wetting and low hydrogen contents (≤5 ml/100 g) are further important features. The combination is ideally suited for multi-pass welding of thick plates.	

# High strength steels

<b>BÖHLER</b> Standard EN AWS	<b>Welding process</b>	<b>Typical analysis</b> %	<b>Typical mechanical properties</b>	<b>Sizes</b> mm	<b>Approvals</b>	<b>Characteristics and applications</b>	<b>Base metals</b>
<b>FOX EV 75</b> E 62 6 Mn2NiCrMo B 4 2 H5 E10018-GH4R	SMAW	C 0.05 Si 0.4 Mn 1.6 Cr 0.4 Ni 2.0 Mo 0.4	Re 700 N/mm <sup>2</sup> Rm 750 N/mm <sup>2</sup> A5 23% Av 140 J >47 J...-60 °C	3.2 4.0	UDT, SEPROZ	Basic coated Mn-Mo-Ni-alloyed electrode with high ductility and crack resistance for high-strength, quenched and tempered fine-grained constructional steels. Suitable for service temperatures at -60 °C to +400 °C.  Weld metal recovery approx. 120 %. Easily weldable in all positions except vertical-down. Very low hydrogen content (acc. AWS condition HD < 4 ml/100 g).  Preheat, interpass temperature and post weld heat treatment as required by the base metal.	Quenched and tempered fine-grained steels up to 650 N/mm <sup>2</sup> yield strength, QT-steels up to 730 N/mm <sup>2</sup> tensile strength  UNS: S500N, S460NH, S500NL  ASTM: A225 Gr. C A514 and A517 Gr.A,B,C,E,F,H,J,K,M,P A656 A678 Gr.C
<b>FOX EV 85</b> E 69 6 Mn2NiCrMo B4 H5 E11018-GH4R	SMAW	C 0.05 Si 0.4 Mn 1.7 Cr 0.4 Ni 2.1 Mo 0.5	Re 780 N/mm <sup>2</sup> Rm 840 N/mm <sup>2</sup> A5 20% Av 110 J 60 J...-60 °C	2.5 3.2 4.0 5.0	TÜV-D, DB, UZ, ÖBB, UDT, SEPROZ	Basic coated Mn-Ni-Mo-alloyed electrode with high ductility and crack resistant for high-strength fine-grained constructional steels. Low-temperature ductility at -60 °C and resistant to ageing.  Easily weldable in all positions except vertical-down. Very low hydrogen content (acc. AWS condition HD < 4 ml/100 g).  Preheat, interpass temperature and post weld heat treatment as required by the base metal.	Quenched and tempered fine-grained steels up to 720 N/mm <sup>2</sup> yield strength, QT-steels low-alloyed up to 790 N/mm <sup>2</sup> tensile strength.  S620QL-S690QL, S620QL1, S690QL1  N-AXTRA 56, 63, 70 USS-T1, BH 70 V, HY100  PAS700, HSM700
<b>X 70-IG</b> G 69 5 M Mn3Ni1CrMo ER110S-G	GMAW	C 0.1 Si 0.6 Mn 1.6 Cr 0.25 Ni 1.3 Mo 0.25 V 0.1	Re 800 N/mm <sup>2</sup> Rm 900 N/mm <sup>2</sup> A5 19% Av 190 J >47 J...-50 °C	1.0 1.2	TÜV-D, TÜV-A, DB, UZ, ÖBB, ABS, BV, DNV, GL, LR, RMR, UDT, SEPROZ	GMAW wire for welding of high-strength, heat treated, fine-grained constructional steels with a minimum yield strength of 690 N/mm <sup>2</sup> .  Also suitable for GTAW hot wire welding for e.g. penstocks.  Due to the precise addition of micro-alloying elements X-70-IG wire features excellent ductility and crack resistance in spite of its high strength.  Good cryogenic impact energy down to -50 °C.	ASTM: A514 Gr.F
<b>Wire: 3 NiCrMo 2.5-UP</b> S Z 3Ni2CrMo EM4(mod.)  <b>Flux: BB 24</b> SA FB 1 65 DC H5	SAW	C 0.06 Si 0.3 Mn 1.5 Cr 0.5 Ni 2.2 Mo 0.5	Re 740 N/mm <sup>2</sup> Rm 850 N/mm <sup>2</sup> A5 20% Av 120 J >47 J...-60 °C	3.0 4.0	UDT	SAW wire/flux combination for joint welding of high strength steels with a minimum yield strength of 690 N/mm <sup>2</sup> .  Depending on the annealing temperature yield strength of approx. 470-600 N/mm <sup>2</sup> are achievable.  The flux reacts metallurgically Mn-neutral.  The sub-arc wire/flux combination produces very good low temperature impact properties down to -60 °C. Excellent slag detachability, smooth beads, good wetting and low hydrogen contents (≤ 5 ml/100 g) are further important features. The combination is ideally suited for multi-pass welding of thick plates.	

# Stainless steels – Soft martensitic

BÖHLER Standard EN AWS	Welding process	Typical analysis %	Typical mechanical properties	Sizes mm	Approvals	Characteristics and applications	Base metals
<b>FOX CN 13/4</b> E 13 4 B 62 E410NiMo-25	SMAW	C 0.035 Si 0.3 Mn 0.5 Cr 12.2 Mo 0.5 Ni 4.5	PWHT 600 °C/2 h Re 680 N/mm <sup>2</sup> Rm 910 N/mm <sup>2</sup> A5 17% Av 66 J 50 J...-60 °C	2.5 3.2 4.0 5.0	TÜV-D, UDT, LTSS, SEPROZ	Basic coated low-hydrogen electrode suited for similar soft martensitic and martensitic-ferritic rolled, forged, and cast steels. Mainly used in the construction of hydro turbines, compressors. Resistant to corrosion from water, steam, and sea water atmosphere. Thanks to an optimum balance of alloying components the weld deposit yields very good ductility and toughness & cracking resistance despite of its high strength. Excellent operating characteristics, easy slag removal, and smooth bead appearance. Metal recovery approx. 130 %. Positional weldability is offered up to ø 3.2 mm electrodes. Preheating and interpass temperatures of heavy-wall components 100-160 °C.	1.4317 GX4CrNi13-4, 1.4313 X3CrNiMo13-4, 1.4351 X3CrNi13-4, 1.4414 GX4CrNiMo13-4  AISI: ACI Gr. CA6NM  UNS: S41500
<b>FOX CN 13/4 SUPRA</b> E 13 4 B 42 E410NiMo-15	SMAW	C 0.03 Si 0.3 Mn 0.6 Cr 12.5 Mo 0.5 Ni 4.5	PWHT 600 °C/2 h Re 680 N/mm <sup>2</sup> Rm 930 N/mm <sup>2</sup> A5 18% Av 70 J 55 J...-60 °C	3.2 4.0	TÜV-D, UDT, SEPROZ	Basic coated core wire alloyed electrode for welding of similar alloyed soft martensitic steels. Due to an optimum balanced alloying concept the weld deposit offers very good ductility and cracking resistance despite of its high strength. Out of position weldable except vertical down. Preheating and interpass temperatures of heavy-wall components 100-160 °C. Maximum heat input 15kJ/cm. Post weld heat treatment at 580-620 °C.	
<b>CN 13/4-IG</b> W 13 4 (GTAW) G 13 4 (GMAW) ER410NiMo(mod.)	GTAW  GMAW	C 0.02 Si 0.7 Mn 0.6 Cr 12.3 Mo 0.5 Ni 4.7	PWHT 600 °C/8h Re 750 N/mm <sup>2</sup> Rm 830 N/mm <sup>2</sup> A5 21% Av 150 J >32 J...-60 °C	2.0 2.4	TÜV-D, UDT, SEPROZ	GTAW rod and GMAW wire for welding of similar alloyed soft martensitic steels, with precisely tuned alloying composition for ductile weld metal with best CVN toughness and crack resistance.  The preferred gas for MAG welding is Argon +8-10 % CO <sub>2</sub> .	
<b>CN 13/4-MC</b> T 13 4 MM2 EC410NiMo(mod.)	GMAW	C 0.025 Si 0.7 Mn 0.9 Cr 12.0 Ni 4.6 Mo 0.6	PWHT 580 °C/8h Re 760 N/mm <sup>2</sup> Rm 890 N/mm <sup>2</sup> A5 16% Av 65 J 47 J...-20 °C  Shielding gas: Ar + 2.5 % CO <sub>2</sub>	1.2 1.6	SEPROZ	Metal cored wire for welding of similar alloyed soft martensitic steels and cast steels. CN 13/4-MC offers favourable spray or puls arc characteristics, minimum spatter formation, flat and smooth bead profiles, an excellent wetting behaviour and safe penetration as well as best productivity. Best impact values and extra low hydrogen contents (< 4 ml/100 g acc. to AWS 4.3-93). Recommended preheating and interpass temperatures in case of heavy wall thicknesses are 100-160 °C. Maximum heat input 15 kJ/cm. Tempering at 580-620 °C.	
<b>CN 13/4-MC (F)</b> T 13 4 MM 2 EC410NiMo(mod.)	GMAW	C 0.03 Si 0.7 Mn 0.9 Cr 12.2 Ni 4.6 Mo 0.6	PWHT 580 °C/8h Re 760 N/mm <sup>2</sup> Rm 890 N/mm <sup>2</sup> A5 16% Av 55 J 47 J...-20 °C  Shielding gas: Ar + 2.5 % CO <sub>2</sub>	1.2	-	Metal cored wire for welding of hydro turbine components made of soft martensitic 13 % Cr 4 % Ni alloyed cast steels.  BÖHLER CN 13/4-MC (F) offers favourable spray arc or pulsarc characteristics, minimum spatter formation, flat and smooth bead profiles, excellent wetting behaviour and safe penetration. The hydrogen content is low (maximum 5 ml/100 g acc. to AWS A 4.3-93). Significant gains in productivity can be realized by higher deposition rates and reduced post weld grinding when compared to GMAW using solid wires. Welding with conventional or pulsed power sources (preferably slightly trailing torch position, angel appr. 80 °).  Recommended stick out 18-20 mm and length of arc 3-5 mm.  Recommended preheating and interpass temperatures in case of heavy wall thicknesses are 100-160 °C. Maximum heat input 15 kJ/cm. Tempering at 580-620 °C.	

# Stainless steels – Soft martensitic

BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>Wire: CN 13/4-UP</b> S 13 4 ER410NiMo(mod.) <b>Flux: BB 203</b> SA FB 2 DC	SAW	C 0.025 Si 0.20 Mn 0.6 Cr 12.1 Ni 4.7 Mo 0.5	PWHT 600 °C/2h Re ≥600 N/mm <sup>2</sup> Rm ≥800 N/mm <sup>2</sup> A5 15% Av 50 J	3.0	UDT, SEPROZ	Sub-arc wire/flux combination for welding similar soft-martensitic steels. The weld deposit featuring very good ductility and CVN toughness as well as high crack resistance. BÖHLER BB 203 is a fluoride-basic, agglomerated flux providing good operating characteristics, smooth beads and a low hydrogen weld metal (HD < 5 ml/100 g). Recommended preheating and interpass temperatures in case of heavy wall thicknesses are 100-160 °C. Maximum heat input 15 kJ/cm. Tempering at 580-620 °C.	
<b>FOX CN 16/6 M-HD</b> E Z 16 6 Mo B 6 2 H5 –	SMAW	C 0.03 Si 0.3 Mn 0.6 Cr 15.5 Ni 5.8 Mo 1.1	PWHT 580 °C/4h/air Re 650 N/mm <sup>2</sup> Rm 920 N/mm <sup>2</sup> A5 15% Av 42J HB 340  PWHT 590 °C/8h Re 640 N/mm <sup>2</sup> Rm 920 N/mm <sup>2</sup> A5 16% Av 48 J HB 330	2.5 3.2 4.0 5.0	UDT, SEPROZ	Basic coated, high efficiency electrode for welding of soft martensitic forged and cast steels. The high chromium content enhances the corrosion resistance in water, steam and sea atmosphere. Main applications are found in turbines, pumps- and combustion building. Popular in hydro turbine engineering. The electrode shows very good features in regard to arc stability, weld puddle control, slag detachability and seam cleanliness. Suitable for all positions except vertical down (positional welding up to ø 3.2 mm). Metal recovery approx. 135 %. Low hydrogen (HD < 5 ml/100 g) is an essential and necessary prerequisite of this product. The maximum interpass temperature should not exceed 120 °C.	Soft-martensitic forge steels and cast steels, same-alloyed  1.4505 GX5CrNiMo16-5 1.4418 X4CrNiMo16-5

# Stainless steels – Austenitic

BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>FOX EAS 4 M</b> E 19 12 3 LB 22 E316L-15	SMAW	C 0.03 Si 0.4 Mn 1.2 Cr 18.8 Mo 2.7 Ni 11.5	Re 460 N/mm <sup>2</sup> Rm 600 N/mm <sup>2</sup> A5 38% Av 90 J 32 J...-120 °C >27 J...-196 °C	2.5 3.2 4.0	TÜV-D, TÜV-A, ÖBB, UDT, CL, DNV, Statoil, SEPROZ	Basic coated stainless steel electrode. Designed to produce first class weld deposits. Provides 100 % X-ray safety together with very good root pass and positional welding characteristics. Good gap bridging ability, easy weld pool and slag control. An excellent product for welding on site! Fully alloyed core wire and packed into hermetically sealed tins. Resistant to intergranular corrosion up to +400 °C.	1.4583 X10CrNiMoNb18-12 1.4435 X2CrNiMo18-14-3 1.4436 X3CrNiMo17-13-3 1.4404 X2CrNiMo17-12-2  1.4401 X5CrNiMo17-12-2 1.4571 X6CrNiMoTi17-12-2 1.4580 X6CrNiMoNb17-12-2 1.4409 GX2CrNiMo19-11-2
<b>FOX EAS 4 M-A</b> E 19 12 3 LR 32 E316L-17	SMAW	C 0.03 Si 0.8 Mn 0.8 Cr 18.8 Mo 2.7 Ni 11.7	Re 460 N/mm <sup>2</sup> Rm 600 N/mm <sup>2</sup> A5 36% Av 70 J ≥32 J...-120 °C	1.5 2.0 2.5 3.2 4.0 5.0	TÜV-D, TÜV-A, ÖBB, DB, DNV, GL, ABS, CL, LR, UDT, Statoil, ÜZ, SEPROZ, VUZ	Rutile coated stainless steel electrode. An acknowledged world leader, noted for its superior welding characteristics. Fully alloyed core wire ensures the most reliable corrosion resistance. Other advantages include high current carrying capacity, minimum spatter formation, self releasing slag, smooth and clean weld profile, safety against formation of porosity due to moisture resistant coating and packaging into hermetically sealed tins and VAC-packs. Resistant to intergranular corrosion up to +400 °C.	AISI: 316 Cb 316 L 316 316 Ti  UNS: S31653
<b>EAS 4 M-IG</b> W 19 12 3 L ER316L	GTAW	C 0.02 Si 0.5 Mn 1.7 Cr 18.6 Mo 2.8 Ni 12.3	Re 470 N/mm <sup>2</sup> Rm 650 N/mm <sup>2</sup> A5 38% Av 140 J 32 J...-196 °C	1.6 2.0 2.4 3.0	TÜV-D, TÜV-A, ÜZ, CL, DNV, GL, UDT, DB, ÖBB, SEPROZ	GTAW rod designed to a very precise analysis to create a weld deposit of high purity, superior hot cracking and corrosion resistance. CVN toughness down to -196 °C. Resistant to intergranular corrosion up to +400 °C.	

# Stainless steels – Austenitic

<b>BÖHLER</b> Standard EN AWS	<b>Welding process</b>	<b>Typical analysis</b> %	<b>Typical mechanical properties</b>	<b>Sizes</b> mm	<b>Approvals</b>	<b>Characteristics and applications</b>	<b>Base metals</b>
<b>EAS 4 M-IG (Si)</b> G 19 12 3 L Si ER316LSi	GMAW	C 0.02 Si 0.8 Mn 1.7 Cr 18.4 Mo 2.8 Ni 11.8	Re 450 N/mm <sup>2</sup> Rm 630 N/mm <sup>2</sup> A5 38% Av 120 J 32 J...-196 °C	0.8 1.0 1.2	TÜV-D, TÜV-A, Statoil, ÜZ, GL, DB, CL, ÖBB, DNV, UDT, SEPROZ	GMAW wire designed for first class welding, wetting and feeding characteristics as well as reliable corrosion resistance up to +400 °C and low temperature service down to -196 °C.	
<b>EAS 4 M-MC</b> T 19 12 3 L MM1 EC316L	GMAW	C 0.03 Si 0.8 Mn 1.4 Cr 18.8 Mo 2.7 Ni 12.2	Re 410 N/mm <sup>2</sup> Rm 560 N/mm <sup>2</sup> A5 34% Av 75 J 32 J...-196 °C  Shielding gas: Ar + 2.5 % CO <sub>2</sub>	1.2	TÜV-D	EAS 4 M-MC is an austenitic CrNiMo-metal cored wire for GMAW applicable for same or similar alloyed, stabilized or non stabilized, corrosion resistant CrNiMo-steels. Suitable for service temperatures from -196 °C to +400 °C. This product achieves high productivity and is easy to operate. It provides excellent welding characteristics, smooth almost spatter free weld finish.  The wider arc, in comparison to solid wire, will reduce the risk of lack of fusion and is less sensitive against misalignment of edges and different gap widths.	
<b>EAS 4 M-FD</b> T 19 12 3 L R M(C) 3 E316LT0-4(1) ø 0.9 mm T 19 12 3 L P M (C) 1 E316LT1-4(1)	FCAW	C 0.03 Si 0.7 Mn 1.5 Cr 19.0 Mo 2.7 Ni 12.0	Re 400 N/mm <sup>2</sup> Rm 560 N/mm <sup>2</sup> A5 38% Av 55 J 32 J...-120 °C	0.9 1.2 1.6	TÜV-D, TÜV-A, CL, UDT, GL, DB, CWB, ÜZ, ÖBB, LR, SEPROZ	Rutile flux cored welding wire for downhand welding. This products achieve high productivity and are easy to operate. Self releasing slag, almost no spatter formation and temper discoloration. Smooth weld finish and safe penetration. Suitable for service temperatures from -120 °C to +400 °C.	
<b>EAS 4 PW-FD</b> T 19 12 3 LP M (C) 1 E316LT1-4(1)	FCAW	C 0.03 Si 0.7 Mn 1.5 Cr 19.0 Mo 2.7 Ni 12.0	Re 400 N/mm <sup>2</sup> Rm 560 N/mm <sup>2</sup> A5 38% Av 65 J 32 J...-120 °C	1.2 1.6	TÜV-D, UDT, GL, CWB, SEPROZ, DB, ÖBB, LR	EAS 4 PW-FD is a rutile flux cored welding wire with fast freezing slag providing excellent positional welding characteristics.	
<b>Wire: EAS 4 M-UP</b> S 19 12 3 L ER316L <b>Flux: BB 202</b> SA FB 2 DC	SAW	C ≤0.02 Si 0.6 Mn 1.3 Cr 18.3 Mo 2.7 Ni 12.2	Re 350 N/mm <sup>2</sup> Rm 560 N/mm <sup>2</sup> A5 35% Av 80 J 32 J...-120 °C	3.0	TÜV-D, UDT  <b>Wire:</b> TÜV, KTA 1408.1 DB, ÜZ, ÖBB, TÜV-A, SEPROZ	SAW-wire/flux combination of type 316L for multi-pass welding. Smooth beads, easy slag removal without any slag residues and good welding characteristics are very much appreciated by users.  BB 202 is a basic, agglomerated flux, providing a low flux consumption. Basicity 2.3 acc. to Boniczewski.	

# Special applications

BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>FOX A 7</b> E 18 8 Mn B 22 E307-15(mod.)	SMAW	C 0.1 Si 0.7 Mn 6.5 Cr 18.8 Ni 8.8	Re 460 N/mm <sup>2</sup> Rm 660 N/mm <sup>2</sup> A5 38% Av 90 J ≥32 J...-110 °C	2.5 3.2 4.0 5.0 6.0	TÜV-D, DNV, GL, UDT, LTSS, PRS, VUZ SEPROZ	Basic resp. rutile basic coated stainless steel electrodes. Very popular for numerous applications. The weld deposit offers exceptionally high ductility and elongation together with crack resistance. There is no fear of embrittlement when operating between -110 °C and +850 °C and can be PWHT without any problems. The deposit will work harden and offers good resistance against cavitation. Ductility is good even after high dilution when welding problem steels or when subjected to thermal shock or scaling. An excellent alloy providing cost effective performance.	For fabrication, -repair and maintenance.  Dissimilar joints, tough buffer and intermediate layers prior to hardfacing, 14 % manganese steels, 13 - 17 % Cr heat resistant steels, armour plates, high carbon and quenched & tempered steels, surfacing of gears, valves, turbine blades etc.
<b>FOX A 7-A</b> EZ 18 9 Mn Mo R 32 E307-16(mod.)	SMAW	C 0.1 Si 1.2 Mn 4.2 Cr 19.5 Ni 8.5 Mo 0.7	Re 520 N/mm <sup>2</sup> Rm 720 N/mm <sup>2</sup> A5 35% Av 75 J ≥32 J...-100 °C	2.5 3.2 4.0 5.0	TÜV-D UDT, SEPROZ	BÖHLER FOX A7-A is suitable for both AC and DC.	
<b>A 7 CN-IG</b> W 18 8 Mn ER307(mod.)	GTAW	C 0.08 Si 0.9 Mn 7.0 Cr 19.2 Ni 9.0	Re 460 N/mm <sup>2</sup> Rm 660 N/mm <sup>2</sup> A5 38% Av 120 J ≥32 J...-110 °C	1.6 2.0 2.4 3.0	TÜV-D, DNV, GL, UDT	GTAW rod and GMAW wire. Very popular stainless steel wires for numerous applications. The weld deposit offers exceptionally high ductility and elongation together with crack resistance. There is no fear of embrittlement when operating between -110 °C and +850 °C and can be PWHT without any problems. The deposit will work harden and offers good resistance against cavitation. Ductility is good even after high dilution when welding problem steels or when subjected to thermal shock or scaling. An excellent alloy providing cost effective performance.	
<b>A 7-IG</b> G 18 8 Mn ER307(mod.)	GMAW	C 0.08 Si 0.9 Mn 7.0 Cr 19.2 Ni 9.0	Re 430 N/mm <sup>2</sup> Rm 640 N/mm <sup>2</sup> A5 36% Av 110 J ≥32 J...-110 °C	0.8 1.0 1.2 1.6	TÜV-D, DB, UDT, ÜZ, ÖBB, SEPROZ		
<b>A 7-MC</b> T 18 8 Mn MM1 EC307(mod.)	GMAW	C 0.1 Si 0.6 Mn 6.3 Cr 18.8 Ni 9.2	Re 400 N/mm <sup>2</sup> Rm 600 N/mm <sup>2</sup> A5 42% Av 70 J 30 J...-110 °C  Shielding gas: Ar +2.5 % CO <sub>2</sub>	1.2	-	Metal cored wire of type T 18 8 Mn/ EC307 for numerous applications. The weld metal offers exceptionally high ductility and elongation together with outstanding crack resistance. There is no fear of embrittlement when operating down to service temperatures of -110 °C or above +500 °C. The scaling resistance goes up to +850 °C. When working at service temperatures above +650 °C please contact the supplier. The weld metal can be post weld heat treated without any problems. The deposit will work harden and offers good resistance against cavitation. Ductility is good even after high dilution when welding problem steels or when subjected to thermal shock or scaling. An excellent alloy providing cost effective performance, excellent welding characteristics, smooth almost spatter free weld finish.  The wider arc, in comparison to solid wire, will reduce the risk of lack of fusion and is less sensitive against misalignment of edges and different gap widths.	

# Special applications

BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>A 7-FD</b> T 18 8 MnRM (C) 3 E307T0-G	FCAW	C 0.1 Si 0.8 Mn 6.8 Cr 19.0 Ni 9.0	Re 420 N/mm <sup>2</sup> Rm 630 N/mm <sup>2</sup> A5 39% Av 60 J ≥32 J...-100 °C	1.2 1.6	–	Rutile flux cored welding wire. These products achieve high productivity and are easy to operate achieving excellent welding characteristics, self releasing slag, almost no spatter formation and temper discolouration, smooth weld finish and safe penetration. The weld deposit offers exceptionally high ductility and elongation together with crack resistance. There is no fear of embrittlement when operating between -100 °C and +850 °C and can be PWHT without any problems.	
<b>A 7 PW-FD</b> T 18 8 MnPM (C) 2 E307T1-G	FCAW	C 0.1 Si 0.8 Mn 6.8 Cr 19.0 Ni 9.0	Re 420 N/mm <sup>2</sup> Rm 630 N/mm <sup>2</sup> A5 39% Av 60 J ≥32 J...-100 °C	1.2	–	A7 PW-FD is a rutile flux cored welding wire with fast freezing slag providing positional welding characteristics and fast travel speeds.	
<b>Wire: A 7 CN-UP</b> S 18 8 Mn ER307(mod.) <b>Flux: BB 203</b> SA FB 2 DC	SAW	C 0.08 Si 0.9 Mn 6.8 Cr 18.5 Ni 8.8	Re ≥390 N/mm <sup>2</sup> Rm ≥620 N/mm <sup>2</sup> A5 ≥36% Av ≥95 J ≥40 J...-100 °C	3.0	UDT <b>Wire:</b> TUV-D	SAW wire/flux combination for numerous applications. BÖHLER A 7 CN-UP / BB 203 yields a weld deposit offering exceptionally high ductility and elongation together with outstanding crack resistance. There is no fear of embrittlement when operating down to service temperatures of -100 °C or above 500 °C. The scaling resistance goes up to 850 °C. When working at service temperatures above 650 °C please contact the supplier.  The weld metal can be post weld heat treated without any problems. The deposit will work harden and offers good resistance against cavitation. Ductility is good even after high dilution when welding problem steels or when subjected to thermal shock or scaling. An excellent alloy providing cost effective performance. Preheating and post weld heat treatment as required by the base metal.  BÖHLER BB 203 is a fluoride-basic, agglomerated flux providing good operating characteristics, smooth beads and a low hydrogen weld metal.	
<b>FOX CN 23/12-A</b> E 23 12 L R 32 E309L-17	SMAW	C 0.02 Si 0.7 Mn 0.7 Cr 23.0 Ni 12.5	Re 440 N/mm <sup>2</sup> Rm 570 N/mm <sup>2</sup> A5 40% Av 60 J ≥32 J...-60 °C	2.5 3.2 4.0 5.0	TÜV-D, DB, UDT, ABS, TÜV-A, UZ, GL, DNV, SEPROZ, BV, LR, CL, VUZ, ÖBB	Rutile coated stainless steel electrodes. Superior welding characteristics. Can be used on AC or DC. Other advantages include high current carrying capacity, minimum spatter formation, self releasing slag, smooth and clean weld profile, safety against formation of porosity due to the moisture resistant coating and its packaging into hermetically sealed tins or VAC-packs. Operating temperature up to +300 °C and for weld claddings up to +400 °C.	For fabrication, -repair and maintenance
<b>CN 23/12-IG</b> W 23 12 L (GTAW) G 23 12 L (GMAW) ER309L	GTAW  GMAW	C 0.02 Si 0.5 Mn 1.7 Cr 24.0 Ni 13.2	Re 440 N/mm <sup>2</sup> Rm 590 N/mm <sup>2</sup> A5 34% Av 150 J ≥32 J...-120 °C	1.6 2.0 2.4	TÜV-D, TÜV-A, CL, UDT, GL, SEPROZ	GTAW rod and GMAW wire designed for good welding, wetting and feeding characteristics as well as good safety after dilution when welding dissimilar joints. Suitable for service temperatures between -120 °C (GTAW) and -80 °C, (GMAW) to +300 °C. For GMAW shielding gas Ar + max. 2,5 % CO <sub>2</sub> or Ar + max. 1 % O <sub>2</sub> is recommended.	For welding stainless to mild steel and low alloy steel, for surfacing of mild steel and for root pass welding of clad steel and the first layer of corrosion resistant claddings on mild and low alloyed steels.
		C 0.02 Si 0.5 Mn 1.7 Cr 24.0 Ni 13.2	Re 420 N/mm <sup>2</sup> Rm 570 N/mm <sup>2</sup> A5 32% Av 130 J ≥32 J...-80 °C	0.8 1.0 1.2	TÜV-D, TÜV-A, CL, ÖBB, UDT, UZ, GL, DNV, DB, SEPROZ		

# Special applications

BÖHLER Standard EN AWS	Welding process	Typical analysis  %	Typical mechanical properties	Sizes  mm	Approvals	Characteristics and applications	Base metals
<b>CN 23/12-MC</b> T 23 12 L MM1 EC309L	GMAW	C ≤0.03 Si 0.6 Mn 1.4 Cr 22.77 Ni 12.2	Re 400 N/mm <sup>2</sup> Rm 540 N/mm <sup>2</sup> A5 32% Av 70 J ≥32 J...-120 °C  Shielding gas: Ar + 2.5 % CO <sub>2</sub>	1.2	–	Metal cored wire of type T 23 12 L / ER309L for welding dissimilar joints between high alloyed Cr- and CrNi(Mo)-steels and mild- or low alloyed steels. BÖHLER CN 23/12-MC is designed for very good welding, wetting and feeding characteristics as well as good safety after dilution when welding dissimilar joints. Suitable for service temperatures between -120 °C and +300 °C.  The wider arc, in comparison to solid wire, will reduce the risk of lack of fusion and is less sensitive against misalignment of edges and different gap widths. Preheat and interpass temperature as required by the base metal. Welding with conventional or pulsed power sources (preferably slightly leading torch position, angle appr. 80 °). Recommended stick out 15-20 mm and length of arc 3-5 mm.	
<b>CN 23/12-FD</b> T 23 12 L R M (C) 3 E309LT0-4(1)  ø 0.9 mm T 23 12 L P M (C) 1 E309LT1-4(1)	FCAW	C ≤0.03 Si 0.7 Mn 1.4 Cr 22.8 Ni 12.5	Re 400 N/mm <sup>2</sup> Rm 540 N/mm <sup>2</sup> A5 35% Av 60 J 45 J...-60 °C	0.9 1.2 1.6	TÜV-D, TUV-A, GL, ÜZ, CL, DB, UDT, CWB, ÖBB, LR, SEPROZ	Rutile flux cored welding wires. These products achieve high productivity and are easy to operate achieving excellent welding characteristics, self releasing slag, almost no spatter formation and temper discoloration, smooth weld finish and safe penetration. Increased travel speeds as well as little demand for cleaning and pickling provide considerable savings in time and money. Suitable for service temperatures from -60 °C to +300 °C.	
<b>CN 23/12 PW-FD</b> T 23 12 L P M (C) 1 E309LT1-4(1)	FCAW	C ≤0.03 Si 0.7 Mn 1.4 Cr 22.8 Ni 12.5	Re 400 N/mm <sup>2</sup> Rm 540 N/mm <sup>2</sup> A5 35% Av 65 J 50 J...-60 °C  Shielding gas: Ar + 18 % CO <sub>2</sub>	1.2 1.6	TÜV-D, LR, UDT, ABS, SEPROZ, CWB, CL, DB, ÖBB ÜZ	CN 23/12 PW-FD is a rutile flux cored welding wire with fast freezing slag providing excellent positional welding characteristics and fast travel speeds.	
<b>Wire: CN 23/12-UP</b> S 23 12 L ER309L  <b>Flux: BB 202</b> SA FB 2 DC	SAW	C 0.015 Si 0.65 Mn 1.3 Cr 23.4 Ni 13.1	Re >320 N/mm <sup>2</sup> Rm >520 N/mm <sup>2</sup> A5 >30% Av >70 J	3.0	DNV, UDT  <b>Wire:</b> TUV-D	SAW wire/flux combination for welding dissimilar joints. Steels with poor weldability and weld claddings for multi-pass welding. Smooth beads, easy slag release without any slag residues and good welding characteristics. The average ferrite content is 16 FN. Suitable up to service temperatures of +300 °C. BB 202 is a basic, agglomerated flux, providing a low flux consumption. Basicity 2.3 acc. to Boniczewski.	
<b>FOX CN 23/12 Mo-A</b> E 23 12 2 LR 32 E309MoL-17(mod.)	SMAW	C 0.02 Si 0.7 Mn 0.8 Cr 23.0 Mo 2.7 Ni 12.5	Re 580 N/mm <sup>2</sup> Rm 720 N/mm <sup>2</sup> A5 27% Av 55 J 45 J...-20 °C	2.0 2.5 3.2 4.0 5.0	TÜV-D, TUV-A, CL, UDT, LTSS, DNV, RINA, ABS, VUZ, SEPROZ, LR	Rutile coated stainless steel electrodes. Superior welding characteristics. Can be used on AC or DC. Other advantages include high current carrying capacity, minimum spatter formation, self releasing slag, smooth and clean weld profile, safety against formation of porosity due to the moisture resistant coating and its packaging into hermetically sealed tins or VAC-packs. Operating temperature from -20 °C to +300 °C and for weld claddings (1 <sup>st</sup> layer) up to +400 °C.	
<b>CN 23/12 Mo-FD</b> T 23 12 2 L R M (C) 3 E309LMoT0-4(1)  ø 0.9 mm T 23 12 2 L P M (C) 1 E309LMoT1-4(1)	FCAW	C ≤0.03 Si 0.6 Mn 1.4 Cr 22.7 Mo 2.7 Ni 12.3	Re 500 N/mm <sup>2</sup> Rm 700 N/mm <sup>2</sup> A5 30% Av 55 J 37 J...-60 °C	0.9 1.2 1.6	TÜV-D, TUV-A, CL, ÖBB, DB, UDT, GL, DNV, ÜZ, LR, ABS, RINA, SEPROZ	Rutile flux cored welding wires. These products achieve high productivity and are easy to operate achieving excellent welding characteristics, self releasing slag, almost no spatter formation and temper discoloration, smooth weld finish and safe penetration. Increased travel speeds as well as little demand for cleaning and pickling provide considerable savings in time and money. Suitable for service temperatures from -60 °C to +300 °C. It can also be used for 316L weld cladding of un- or low alloyed base metals with very economic results. CN 23/12 Mo PW-FD is a rutile flux cored welding wire with fast freezing slag providing excellent positional welding characteristics and fast travel speeds.	
<b>CN 23/12 Mo PW-FD</b> T 23 12 2 L P M (C) 1 E309LMoT1-4(1)	FCAW	C ≤0.03 Si 0.7 Mn 1.4 Cr 22.7 Mo 2.7 Ni 12.3	Re 530 N/mm <sup>2</sup> Rm 720 N/mm <sup>2</sup> A5 32% Av 65 J 50 J...-60 °C  Shielding gas: Ar + 18 % CO <sub>2</sub>	1.2	TÜV-D, UDT, SEPROZ BV, LR		

## References



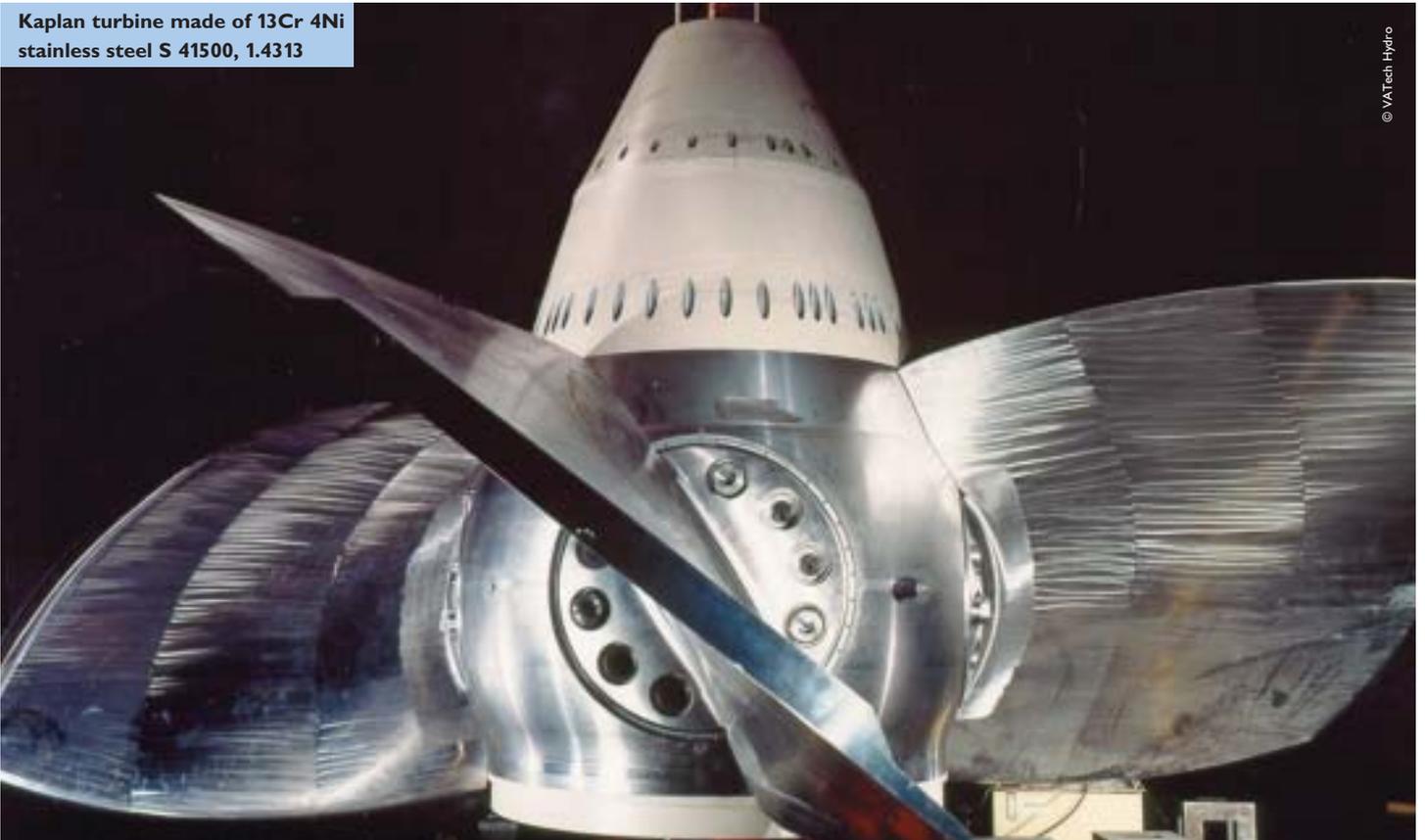
# References

Close up view on a Francis turbine.  
Special jobs need special filler metals!



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Kaplan turbine made of 13Cr 4Ni  
stainless steel S 41500, 1.4313



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# References

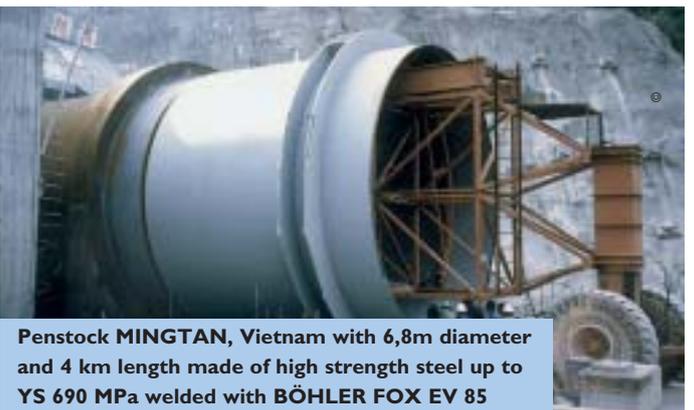
**Spiral case of the hydropower plant Goldisthal, Germany, in the workshops in Ravensburg**



**Penstock Kaprun, Austria. MCE staff control the fully mechanized GTAW hot wire process**



**Prefabrication of the Penstock Kaprun, Austria  
Steel grade S 690 Q, ASTM A514 Gr.F, SAW  
BÖHLER 3NiCrMo2,5UP+BB24**



**Penstock MINGTAN, Vietnam with 6,8m diameter  
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**Böhler Schweißtechnik Austria GmbH**

Böhler-Welding-St. 1

8605 Kapfenberg / AUSTRIA

☎ +43 (0) 3862-301-0

☎ +43 (0) 3862-301-95193

✉ [postmaster.bsga@bsga.at](mailto:postmaster.bsga@bsga.at)

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