böhler welding
by voestalpine

Lasting Connections

WELDING SOLUTIONS FOR THERMAL POWER GENERATION

voestalpine Böhler Welding
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ONE STEP AHEAD.

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.

Our customers 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

HIGH CLASS WELDING CONSUMABLES FOR THE THERMAL POWER INDUSTRY

Welding consumables for Thermal Power plants are a core competence of Böhler Welding. With decades of experience, a product range to fulfill the most specific requirements and a worldwide distribution network Böhler Welding is your partner.

The development and production of welding consumables for heat and creep resistant steels for power plant applications are a focus of Böhler Welding. Additionally we support fabricators with our deep experience in the processing of creep resistant steels.

Our products are used especially for:

- Boiler Tubes and Pipes
- Castings
- Super- / Reheater Tubing
- Dissimilar Welds
- Water Wall


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COAL FIRED POWER PLANT

In coal fired power plants the chemical energy stored in fossil fuels such as coal (hard or lignite coal) and oxygen of the air is converted successively into thermal energy, mechanical energy and, finally, electrical energy.

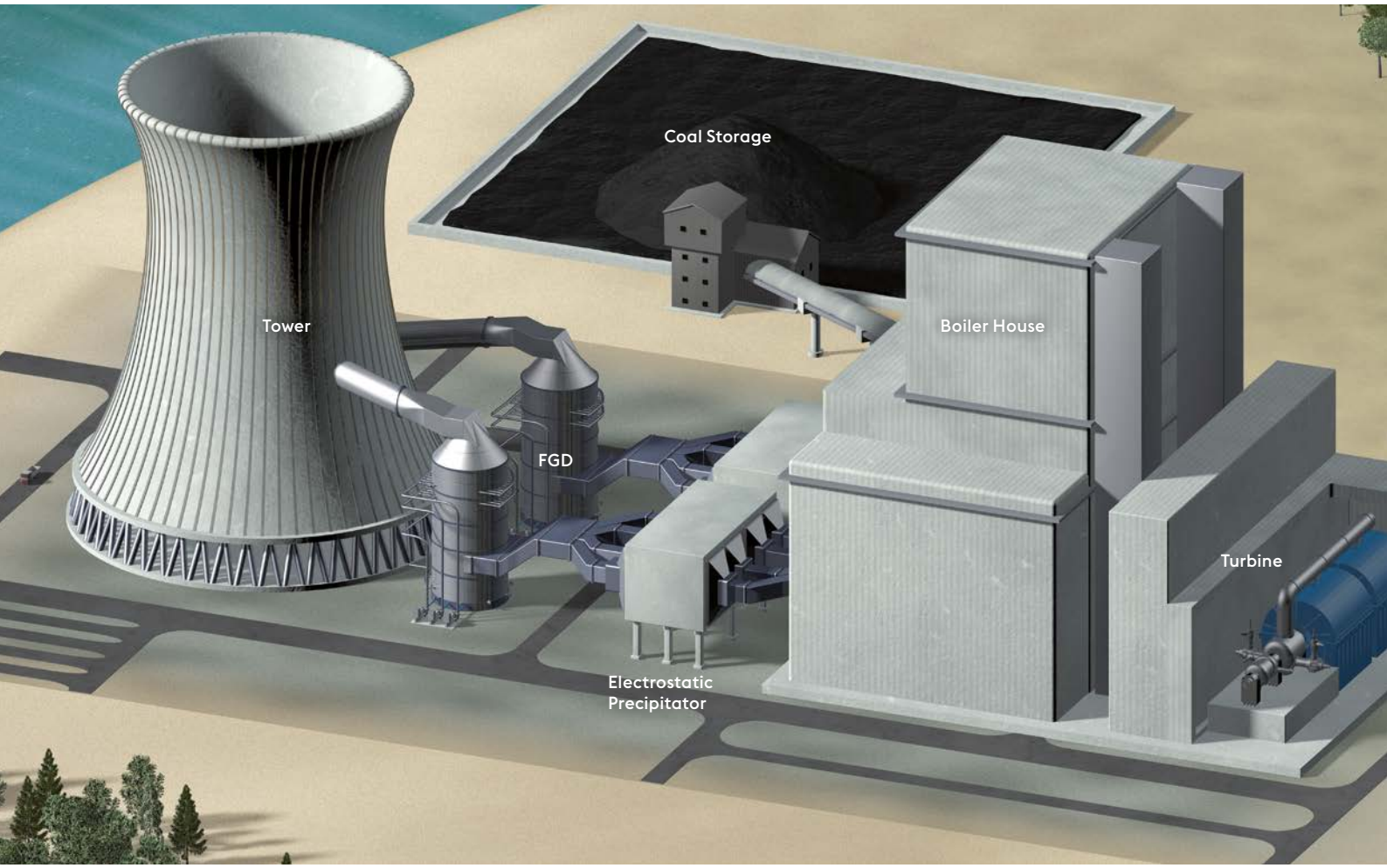
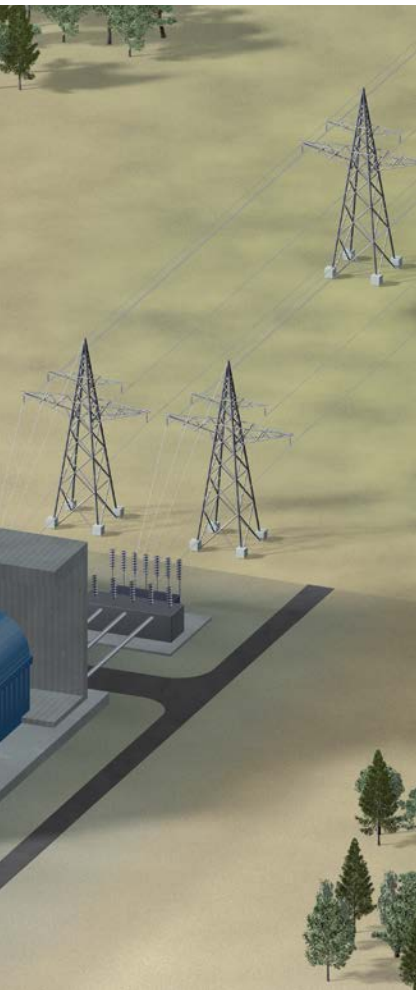


Figure 1 shows an overview of a modern coal fired power plant.

Each coal fired power plant is a complex, custom – designed system. Chunks of coal are crushed into fine pulver and are fed into a combustion unit where it is burned. Heat from the burning coal is used to generate steam that is used to rotate one or more turbines to generate electricity.

The thermal efficiency of old power plants is around 33%. Raising the furnace temperature improves the efficiency but complicates the design with loss of profitability, primarily by the selection of materials used for construction, making the power plant more expensive. However there are worldwide a lot of efforts to reduce the specific fuel-energy consumption per kilowatt-hour. The key to this must be a further increase in the efficiency of new power plants. New design and process solutions represent only part of the whole spectrum of possibilities. The main factors influencing a rise in efficiency are the steam parameters, i.e. pressure and temperature.

Newest power plants realize thermal efficiency of 46%. But this can only be realized with modern steels like T/P92, VM12-SHC, 304H Cu which enable steam temperature up to 625°C. Beside these modern martensitic and austenitic steels new bainitic steels for the water walls are necessary like T23 and T24.



	Alloy Group	Base Material Examples ASTM/EN
Bainitic Steels	0,5 Mo	T/P1 / 16Mo3
	1 1/4 Cr; 0,5 Mo	T/P12 / 13CrMo4-5
	1 Cr; 1 Mo; V	-- / 15CrMoV5-10
	0,5 Cr; 1 Mo; V	-- / 14MoV6-3
	1 Ni; 0,5 Cu; 0,5 Mo; Nb	-- / 15NiCuMoNb5 (WB36)
	2 1/4 Cr; 1 Mo	T/P22 / 10CrMo9-10
	2 1/4 Cr; 0,5 Mo; 1,5 W; V; Nb; B	T/P23 / 7CrWVMoNb9-6
	2 1/4 Cr; 1 Mo; V; Ti; B	T/P24 / 7CrMoVTiB10-10
Martensitic Steels	9 Cr; 1 Mo; V; Nb	T/P91 / X10CrMoVNb9-1
	9 Cr; 0,5 Mo; 1,5 W; V, Nb	T/P92 / X10CrWMoVNb9-2
	9 Cr; 1 Mo; 1 W; V; Nb	T/P911 / X11CrMoWVNb9-1-1
	11 Cr; 0,5 Mo; 1,5 W; 1 Co; V; Nb	VM12-SHC / X12CrCoWVNb11-2-2
	10 Cr; 1 Mo; V	-- / X20CrMoV11-1
	9 Cr; 1,5 Mo; 1 Co; V; Nb	CB2 (GX13CrMoCoVNb9-2-1)
Austenitic Steels	18 Cr; 9 Ni; 3 Cu; Nb	304HCu
	25 Cr; 21 Ni; Nb	310N (HR3C)
	18 Cr; 10 Ni; Nb	347H FG
Ni-Base Alloys	22 Cr; 9 Mo; 12 Co; 0,3 Ti; 1 Al; Ni balance	Alloy 617
	20 Cr; 6 Mo; 20 Co; 2 Ti; 0,5 Al; Ni-base	Alloy 263
		Dissimilar welds

Table 1 enables heat and creep resistant steels and alloys which are used for modern power plants and for refurbishments.

The development and production of welding consumables for heat and creep resistant steels for power plant application have been a focus point at voestalpine Böhler Welding since decades. Consequently, there are numerous references available in processing the wide range of creep resistant steels.

voestalpine Böhler Welding is producing suitable tried and tested TUV-approved welding consumables for the mentioned base metals in Table 1. The selection of welding filler metals for these steels is partially aligned with the long-term properties, especially in the case of tubes and pipes that are subjected to temperature above 450°C. The latest developments can always be related to state-of-the-art base metals like grades T/P23, T/P24,T/P91, T/P92, VM12 – SHC and 304H. All the matching filler metals for these creep resistant steels and alloys are tested under creep conditions at elevated temperature and above. Creep tests have been done on all weld metal and real welds. There are creep data available for more than 50,000 hours.

STEAM GENERATOR / BOILER

The heart of every coal-fired power plant is the utility steam generator (boiler). This is where the pulverized coal is combusted at above 1,200 °C and evaporates water which flows through planar super heater tube bundles in the furnace and in the wall of the steam generator. There, the fully desalinated and demineralized water (feed water) evaporates to make so-called main steam. It leaves the steam generator at a temperature of up to 620 °C and pressure of up to 300 bar (temperature and pressure depends on design, capacity and material selection). Thus charged with energy, it flows into a turbine.

A Water walls (or membrane walls)

Water walls (or membrane walls) build the gastight chamber of a boiler. Many kilometers of tubes and fins are welded together and form the outside wall of the boiler. Depending on the design of the boiler, the capacity, the temperature and pressure different tube and fin material is used. Table B informs about different steels which are used nowadays for water walls. As higher the steam temperature and pressure as higher alloyed the tubes for the water walls. Due to different temperature ranges in a boiler different tube steels are used. A boiler for modern power plants with a capacity of 1,000 MW can reach a height of more than 100 meter (depends on design). In such a boiler more than 30,000 tube to tube welds are necessary (GTA welded).

B Headers

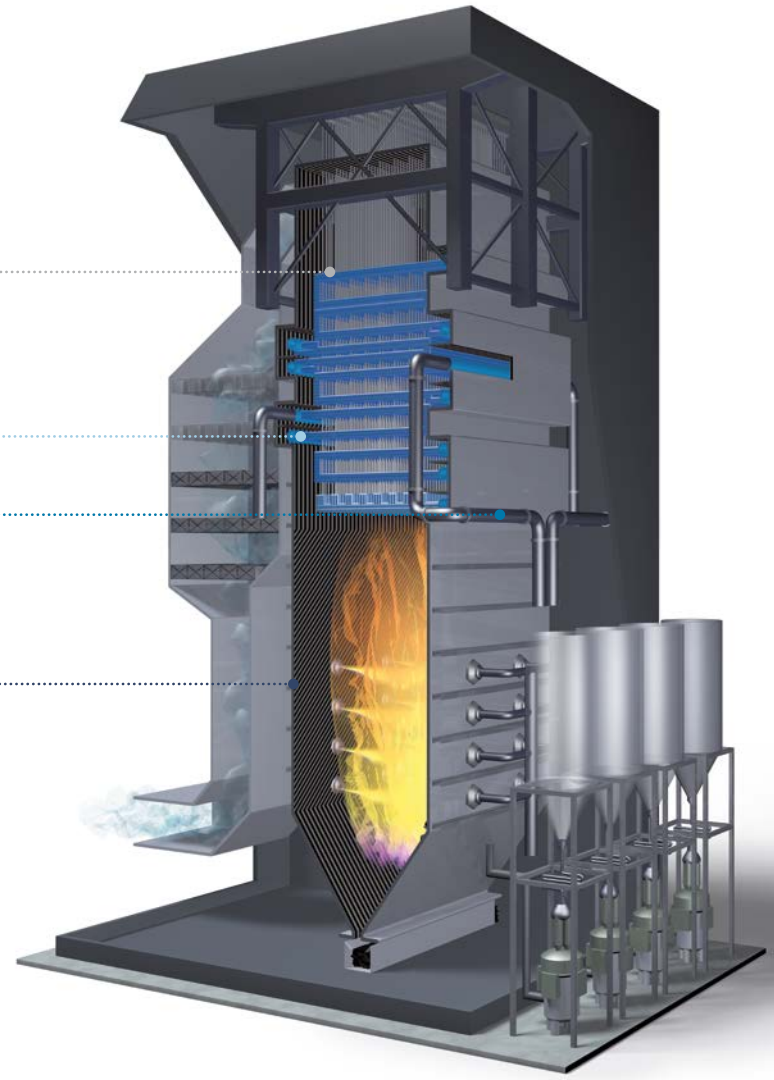
Headers are thick-walled extruded pipes in which the fluids carried by the tubes are mixed and homogenized. They serve either as receptacles (Inlet header) or dischargers (Outlet header). Below a thick wall-pipe penetrated by a number of tubes is shown. These heavy-section components have to meet creep strength requirements. Table B informs about different pipe steels used for headers. With the pipe steel P92 feed water temperature up 620°C can be realized.

C Superheater / Reheater

Superheater and reheater tubes are necessary to convert wet, saturated steam into dry steam. These tube bundles are located within the combustion chamber of the boiler. According to the design of the power plant and steam parameter (temperature and pressure) different tube steels and alloys are used. Table B informs about common steels for these applications.

D Main steam / hot reheat piping

The main steam and hot reheat piping are thick walled seamless pipes which transport the dry steam from the headers to the turbine. Wall thickness of these pipes up to 100 mm are used. Due to the high temperature (up to 620°C) and pressure (up to 350 bar) the requirements for the pipe material, filler metal and for manufacturer of pipe construction are highly demanding. Table B shows suitable pipe steels.



	16M03, T/P1	13CrMo4-5; T/P12	15CrMoV5-10	14MoV6-3	15NiCuMoNb5, (WB36)	10CrMo9-10; T/P22	7CrWVMoNb9-6; T/P23	7CrMoVTiB10-10; T/P24	X10CrMoVNb9-1; T/P91	X10CrWMoVNb9-2; T/P92	X11CrMoVNb9-1-1; T/P911	X12CrCoWVNb11-2-2; VM12-SHC	X20CrMoV11-1	304H Cu	310N, HR3C	347H FG	Sanicro 25	Alloy 263	Alloy 617B	Alloy 740H
Economizer	•				•	•	•													
Water Wall	•	•					•	•	•	•		•							•	
Supporting Tubes							•	•												
Feedwater Pipe					•															
Superheater Tubing		•				•	•	•	•	•		•		•	•	•	•	•	•	•
Reheater Tubing	•	•				•			•	•			•	•	•	•	•	•	•	•
Header	•	•	•	•	•	•			•	•	•		•						•	
Main Steam Pipe									•	•	•		•					•	•	•
Reheater Steam Pipe									•	•	•		•					•	•	•
Separator									•	•										

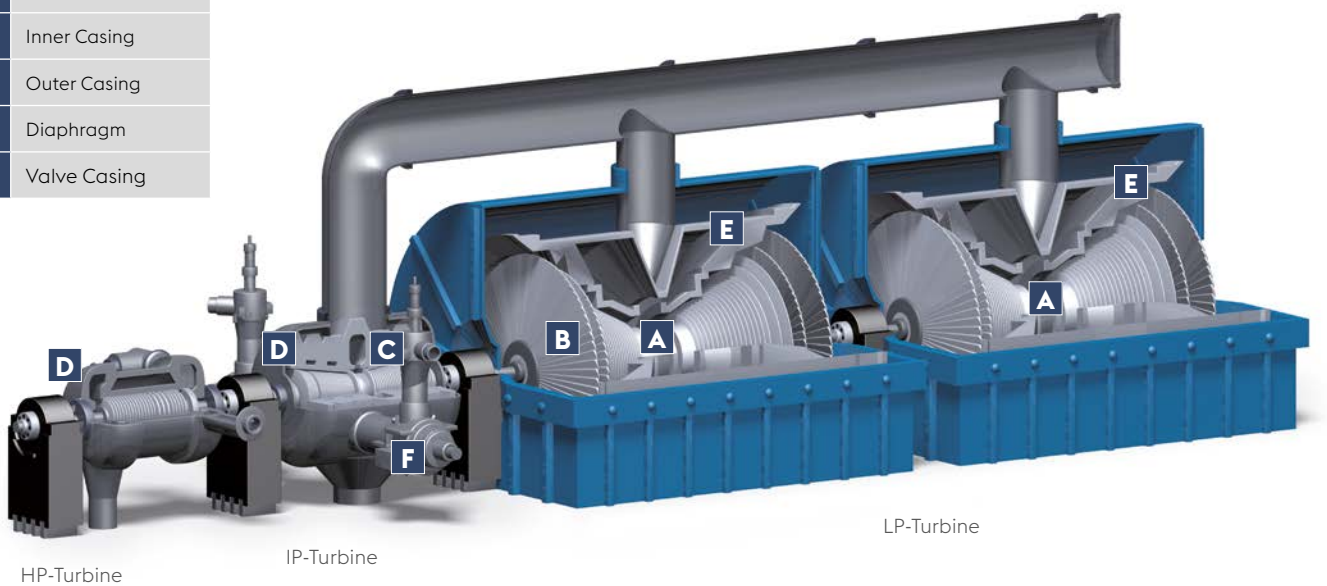
Table B gives an overview about the allocation of base metals to different components of power plant components.

• Candidates for 700 °C - technology (A-USC)

TURBINE

The high pressure steam produced in the steam generator enters the high pressure section of the steam turbine and initiates the mechanical operation, while expending and cooling. The turbine is linked to a generator via a shared shaft, the generator converts its rotary motion into electricity according to the dynamo principle.

A	Rotors
B	Blades
C	Inner Casing
D	Outer Casing
E	Diaphragm
F	Valve Casing



HP-Turbine IP-Turbine LP-Turbine

For high stressed components such as valves, turbine housing and rotors, special steels are required. Heavy steel castings and rotor forgings, made of creep resistant steels, play a key role in fossil fuel fired power plants for highly loaded components in the high and intermediate pressure sections of a turbine casting.

Table C illustrates an overview about casting steels and recommended filler metals for different applications. As welding is an important cycle in the manufacturing process of steel castings, the development of high integrity welding consumables is a critical issue for the foundries.

In general the PWHT temperature of welds in cast steels is very often lower than that used for forged steel, however the holding time is longer and sometimes two or more PWHT cycles are necessary. All our filler metals fulfill the requirements of the foundries.

Turbine and generator rotors withstand high stresses and from a safety aspect are the most significant components of a turbine generator system. Depending on the appropriate operating temperatures, the shafts can be fabricated out of low/high alloy heat/creep resistance material or of low alloyed, highly toughened material for low pressure application.

Table D illustrates all steels available to use with the customary permissible operating temperatures. There is no commercial forging alloy which meets all the necessary material requisitions, therefore combinations of different steels are used for welded rotors. By contrast the welding of low pressure shafts require matching filler metals. Combined intermediate-low pressure shafts and combined high-low pressure shafts are welded using different steels. These dissimilar welded joints are designed to be located in low stress shaft areas. For this reason, the strength requirements for these welded joints are lower than for the high alloyed base material. On the other hand, impact energy values of the weldments are even higher than minimum base material values. For the LP end of the rotor, creep is not a problem but high yield strength, high ductility and low Fracture Appearance Transition Temperature (FATT) behavior is required. We offer tailormade solutions for specific customer requirements regarding different steel combinations. A general recommendation for the right filler metal selection can be found in Table D. Each turbine manufacturer has its own individual specification and requirements and will specify different welding processes. Our technical application departments will support you by finding the best welding solutions.

Table C: Casting materials for Steam Turbine Components

Steel	Application-temperature	Filler Metal	Remarks
EN-GJS-400-18U-RT (GGG40.3)	≤450 °C	Thermanit FeNi	Outer casing (LP)
G20Mn5 0,2 C; 1 Mn; max. 0,8 Ni	≤450 °C	Böhler FOX EV 50 Phoenix 120 K	Pressure parts
G20Mo5 0,2 C; 0,7 Mn; 0,5 Mo	≤500 °C	Böhler FOX DMo Phoenix SH Schwarz 3 K	Pressure parts, casings, valves
G17CrMo9-10 0,17 C; 2,25 Cr; 1 Mo	≤550 °C	Böhler FOX CM 2 Kb Phoenix SH Chromo 2 KS	Inner Casing, Valve casing, blade carrier
G17CrMo5-5 0,17 C; 1,25 Cr; 0,5 Mo	≤530 °C	Böhler FOX DCMS Phoenix Chromo 1	Inner casing, outer casing, diffusor, nozzle, steam chests, blade carrier
G17CrMoV5-10 0,17 C; 1,3 Cr; 1 Mo; 0,25V	≤560 °C	Böhler FOX DCMV Union I CrMo Phoenix SH Kupfer 3 KC	Inner casing, valve casing, inlet carrier, steam chests, elbows
GX23CrMoV12-1 0,23 C; 12 Cr; 0,9 Ni; 1 Mo; 0,3V	≤600 °C	Böhler FOX 20 MVW Thermanit MTS 4	Valve casing, seal ring, outer shells
G-X12CrMoVNb9-1 0,12 C; 9 Cr; 1 Mo; 0,2 V; 0,06 Nb; N	<600 °C	Böhler FOX C 9 MV Thermanit Chromo 9 V	Valve casing, flanges, nozzle boxes, inlet piping
GX12CrMoWVNbN10-1-1 0,12 C; 10 Cr; 1 Mo; 1 W, 0,2 V, 0,06 Nb; N	<625 °C	Böhler FOX C 9 MVW Thermanit MTS 911	Valve casing, connecting pipes, bonnets
G-X13CrMoCoVNbNB9-2-1 (CB2) / 0,13 C; 9 Cr; 1,5 Mo; 1 Co; 0,2 V, 0,06 Nb; N; 100ppm B	<625 °C	Böhler CB 2 Ti-FD Thermanit MTS 5 Co 1	Valve casing
GX5CrNiMo13-4 0,04 C; 13 Cr; 4 Ni	<350° C	Böhler FOX 13/4 CN13/4-IG, CN13/4-MC	Blade carriers
Alloy 625 0,06 C; 21 Cr; Ni-base; 9 Mo; 3,5 Nb	≤720 °C	Böhler Nibas 625 Thermanit 625	Inner casing, valve body, nozzles
Alloy 617 0,05 C; 23 Cr; Ni -base, 9 Mo; 12 Co; 1,2 Al; 0,5 Ti	≤750 ° C	Böhler Nibas 617 Thermanit 617	Inner casing, nozzle, valves

This List is not exhaustive; includes the most engaged casting material.

Table D: Forging materials for Steam Turbine – and Generator Rotor Turbine – and Generator Rotor

Steel	Application-temperature	Filler Metal	Remarks
27NiCrMoV11-6 / 3 Ni; 1,5 Cr; V	≤350 °C	NiCrMo2,5	LP; Gen.
27NiCrMoV15-6 / 3,5 Ni; 1,5 Cr; 0,4 Mo; V	≤350 °C	NiCrMo2,5	LP disk; Gen.
22CrNiMo9-9 / 2,2 Cr; 2,2 Ni; 0,7 Mo	≤350 °C	3NiCrMo2,5	LP shaft
22Cr2Ni3MoV / 0,8 Cr; 0,5 Mo; 3 Ni; V	≤350 °C	3NiCrMo2,5	LP; Gen.
21CrMoNiV5-9 / 1,2 Cr; 0,9 Mo; 0,6 Ni; V	≤560 °C		HP; IP
28CrMoNiV4-9 / Cr; 1 Mo; Ni; V	≤560 °C		HP; IP
25CrMoV3-8 / 0,8 Cr; 0,8 Mo; 0,6 Ni; V	≤560 °C		HP; IP
23CrNiMo7-4-7 / 1,8 Cr; 0,7 Mo; 1 Ni	≤530 °C	NiCrMo1	HP; LP
22CrMoNiWV8-8 / 2 Cr; 0,8 Mo; 0,7 Ni; 0,7 W	≤530 °C		HP-LP; Rotor
X12CrMoWVNbN10-1-1 / 10 Cr; 1 Mo; 1 W; V, NB (E911)	≤600 °C	Böhler C 9 MVW Thermanit MTS 911	HP; IP; Steam turbine rotor
FB2 / 9 Cr; 1,5 Mo; 1 Co; V; Nb	≤630 °C	Böhler C 9 MVW Thermanit MTS 911	HP; IP

Gen = Generatorwelle; HD = Hochdruck; MD = Mitteldruck; ND = Niederdruck

FLUE GAS DESULPHURISATION (FGD)

The steam generators are equipped with pulverized – hard or lignite coal burners which should be operated with low excess air and optimized airflow. This reduces the emergence of nitrogen oxides. In addition, nitrogen oxides can be reduced in a downstream flue-gas denoxing plant. There, the nitrogen oxides react with ammonia using a catalyst to become water and pure nitrogen. The flue gases flow through electrostatic precipitators. Dust is separated by electrostatically charging via discharge electrodes and drawing it to oppositely charged surfaces. Hereafter the sulphur dioxide has to be removed.

A variety of FGD processes are available. The most widely used processes are the limestone gypsum processes. In this wet scrubbing process the flue gas is treated with limestone slurry, in order to remove the S02 and neutralize it. The final product is calcium sulphate dehydrate (gypsum). The scrubbed flue gases are discharged via the cooling tower or a separate stack.

This is the most common FGD process worldwide over 40 years.FGD-Plants require high corrosion resistant steels and Ni-alloys, depending on the application for tanks, piping, absorber etc. The selection criteria for the steels and alloys depend on the chloride and pH concentration. In general the flue of lignite coal fired power plants are more aggressive than of hard coal fired power plants. Therefore the FGD's of lignite coal fired power plant needs in general high corrosion-resistant Ni-base alloys with increased CPT-values.

A basic requirement is that the weld seam must at least show the same corrosion resistance as the base material. This can be achieved often by using welding consumables which are higher alloyed than the base material. The only exception is when so called C-alloys like alloy 59, C 2000 and 686 are used.

A	Flue gas inlet (ductwork)
B	Slurry agitator (for stirring slurry to prevent settling)
C	Oxidation zone
D	Oxidation header
E	Oxidation air supply
F	Recirculation pumps
G	Gas distribution trays
H	Interspartial spray level with slurry spray nozzle/pipe
I	Moisture separator
J	Clean gas outlet (ductwork)

Austenitic and Ni-base alloys which are used in FGD plants.

Alloy Common Name	UNS Designation	Material No	Alloy Group	Filler Metal (GTAW)
316L	S31603	1.4435	18 Cr / 14Ni / 3Mo	BÖHLER ASN5-IG / Thermanit 18/17E Mn
316LN	S31653	1.4429	17 Cr / 13 Ni / 3 Mo	BÖHLER ASN5-IG / Thermanit 18/17E Mn
317LMN	S31726		18 Cr / 15 Ni / 4 Mo / N	BÖHLER CN 20/25 M-IG / Thermanit 20/25 Cu
904L	N08904	1.4539	20 Cr / 25 Ni / 4 Mo / 1,5 Cu	BÖHLER CN 20/25 M-IG or NIBAS 625-IG Thermanit 20/25 Cu or 625
Alloy G	N06007		22 Cr / Ni Bal / 7 Mo / 2 Cu / 1,5 Co / 2 Nb	BÖHLER NIBAS 625-IG / Thermanit 625
1925hMo	N08926	1.4529	20 Cr / 25 Ni / 6 Mo / 1 Cu / 0,2 N	BÖHLER NIBAS 625-IG / Thermanit 625
6XN	N08367		21 Cr / 24 Ni / 6,2 Mo / 0,2 N / 0,2 Cu	BÖHLER NIBAS 625-IG / Thermanit 625
254 SMO	S31254	1.4547	20 Cr / 18 Ni / 6 Mo / N / Cu	BÖHLER NIBAS 625-IG / Thermanit 625
Alloy 31	N0831	1.4562	27 Cr / 31 Ni / 6,5 Mo / / 1,2 Cu / N	BÖHLER NIBAS C 24-IG / Thermanit Nimo C 24
Alloy 625	N06625	2.4856	21 Cr / Ni Bal / 9 Mo / 3,5 Nb	BÖHLER NIBAS 625-IG / Thermanit 625
654 SMO	S32654		24 Cr / 22 Ni / 7 Mo / 3,5 Mn / Cu	BÖHLER NIBAS C 24-IG / Thermanit Nimo C 24
Alloy C-22	N06022	2.4602	22 Cr / Ni Bal / 13 Mo / 3 W / 2,5 Co	Thermanit 22
Alloy C-276	N10276	2.4819	16 Cr / Ni Bal / 16 Mo / 4 W	BÖHLER NIBAS C 24-IG / Thermanit Nimo C 24
Alloy 59	N06059	2.4605	23 Cr / Ni Bal / 16 Mo / Al	BÖHLER NIBAS C 24-IG / Thermanit Nimo C 24
AlloyC-2000	N06200		23 Cr / Ni Bal / 16 Mo / 1,6 Cu	
Alloy 686	N06686		21 Cr / Ni Bal / 16 Mo / 4 W	Thermanit 686
255	S32550	1.4507	26 Cr / 6,3 Ni / 3,5 Mo / 1,7 Cu / 0,2 N	BÖHLER CN 25/9 CuT-IG / Thermanit 25/09 CuT
2705	S32750	1.4410	25 Cr / 7 Ni / 4 Mo / 0,27 N	BÖHLER CN 25/9 CuT-IG / Thermanit 25/09 CuT
Zeron 100	S39276	1.4501	25 Cr / 7 Ni / 3,5 Mo / 0,7 Cu / 0,7 W / 0,25 N	BÖHLER CN 25/9 CuT-IG / Thermanit 25/09 CuT

REFERENCES

Böhler Welding provides welding solutions for thermal power stations since 1926. Whenever high temperature and creep resistance properties are essential, Böhler Welding is the competent partner and supplier. Therefore it was not surprising back in 1990 that our filler metals were chosen for the first application of P91 in the thermal power industry.

Today with even more experience of researching these filler metal types to meet and exceed the industries ever more demanding applications, Böhler Welding has moved forward in line with the principle material manufacturers to introduce new filler metals for alternative pipe and tube. Grades like T/P 92, VM12-SHC, T/P23, T/P24 Super 304H – all these materials have confidently been joined and are in service at principle power plants since the beginning of the individual industrial application – all using Böhler Welding filler metals. In addition the high integrity welds produced using our filler metals are supported by many thousands of hours, proofed creep properties of all weld metal and real welds. Therefore, we are not surprised but delighted that our reputation for high quality filler metals has resulted in our products being used for numerous newly built power plants worldwide.

We would like to acknowledge and thank the following companies for referencing Böhler Welding filler metals for power plant component fabrication and construction (this list is not completed).

Ansaldo Energia
Alstom
Babcock + Wilcox
Bharat Heavy Electricals Ltd.
Bilfinger Berger
Bilfinger Power System
DEE Development
Dongfang
Doosan Heavy Industries
Energomontaz
Forster Wheeler
Harbin Boiler
Hitachi Power (Europe)
IHI
Kraftanlagen München
Mitsubishi Heavy Industry
Larsen and Toubro Piping
Larsen and Toubro MHI
Rafako
Remak
Sefako
SES TImace
Shanghai Boiler Works
Shanghai Electric
Siemens
Skoda

Böhler Welding filler metals have been used for new ultra super critical power plant projects. A choice of projects in Europe and South Africa is listed:

Germany:	
Neurath	2x1100 MW
Walsum	750 MW
Boxberg	670 MW
Datteln	1100 MW
RDK8 Kralsruhe	900 MW
Westfalen D+E	2x800 MW
Wilhelmshaven (EBL1)	800 MW
Staudinger	1100 MW
Moorburg A+B	2x800 MW
GKM Mannheim	911 MW

Netherlands:	
Rotterdam (EBL2)	800 MW
Maasvlakte	1100 MW
Eemshaven	2x800 MW

Czech Republic:	
Ledvice S.C	660 MW

Italy:	
Torrevalduliga Nord	3x660 MW

Poland:	
Lagiza S.C. (C.F.B)	460 MW
Belchatow, S.C.	833 MW

Slovenia:	
Sostary 6	600 MW

Estonia:	
Tartu	234 MW

South Africa:	
Kusile	3x800 MW
Medupi	6x800 MW

There are numerous thermal power plant projects all over the world today, in particular in China, India and the United States of America. We are proud that our customers rely on quality assured products. voestalpine Böhler Welding filler metals are engineered to produce high integrity joints. They have been developed from years of careful formulation backed by factual technical research and testing to enable our customer to enjoy the confidence that our products can offer during many years in plant service.

Joining 1/4

	Alloy Group	Base Material Examples ASTM / EN	Welding Process	Product Name	Classification AWS	Classification EN ISO
Bainitic Steels	0,5 Mo	T/P1 / 16Mo3	SMAW	Phoenix SH Schwarz 3 K	A5.5: E7015-G	3580-A: E Mo B 4 2 H5
				BÖHLER FOX DMO Ti	A5.5: E7015-G	3580-A: E Mo R 1 2
				BÖHLER FOX DMO Kb	A5.5: E7018-A1H4R	3580-A: E Mo B 4 2 H5
			GTAW	Union I Mo	A5.28: ER70S-A1	21952-A: W MoSi
				BÖHLER DMO-IG	A5.28: ER70S-A1 (ER80S-G (A1))	21952-A: W MoSi
			GMAW	Union I Mo	A5.28: ER70S-A1	21952-A: G MoSi
				BÖHLER DMO-IG	A5.28: ER70S-A1 (ER80S-G (A1))	21952-A: G MoSi
			FCAW	Union MV Mo	A5.28: E 80 C-G H4	17632-A: T Mo M M 2 H5
				BÖHLER DMO Ti-FD	A5.29: E 81 T1-A1M	17634-A: T Mo L P M 1
			SAW wire	Union S 2 Mo	A5.23: EA2	14171: S2Mo
				BÖHLER EMS 2 Mo	A5.23: EA2	14171: S2Mo
			SAW flux	UV 420 TT		14174: SA FB 1 65 DC
				UV 305		14174: SA AR 1 76 AC H5
				BÖHLER BB 24		14174: SA FB 1 65 DC H5
	1 1/4 Cr; 0,5 Mo	T/P12 / 13CrMo4-5	SMAW	Phoenix Chromo 1	A5.5: E8018-B2	3580-A: E CrMo 1 B 4 2 H5
				BÖHLER FOX DCMS Ti	A5.5: E8013-B2 (mod.)	3580-A: E CrMo 1 R 1 2
				BÖHLER FOX DCMS Kb	A5.5: E8018-B2 H4R	3580-A: E CrMo 1 B 4 2 H5
			GTAW	Union I CrMo	A5.28: ER80S-G	21952-A: W CrMo 1 Si
				Union ER 80S-B2	A5.28: ER80S-B2	
				BÖHLER DCMS-IG B2	A5.28: ER80S-B2	
				BÖHLER DCMS-IG	A5.28: ER80S-G	21952-A: W CrMo 1 Si
			GMAW	Union I CrMo	A5.28: ER80S-G	21952-A: G CrMo 1 Si
				BÖHLER DCMS-IG	A5.28: ER80S-G	21952-A: G CrMo 1 Si
			FCAW	Union MV CrMo	A5.28: E 80 C-B2 H4	17634-A: T CrMo 1 M M 2 H5
				BÖHLER DCMS Ti-FD	A5.29: E 81 T1-B2M	17634-A: (T CrMo 1 P M 1)
			SAW wire	Union S 2 CrMo	A5.23 EB2R	24598-A: S CrMo1
				BÖHLER EMS 2 CrMo	A5.23: EB2	24598-A: S CrMo1
			SAW flux	UV 420 TT		14174: SA FB 1 65 H5
				UV 305		14174: SA AR 1 76 AC H5
				BÖHLER BB 24		14174: SA FB 1 65 DC H5
	1 Cr; 1 Mo; V	-- / 15CrMoV5-10	SMAW	Phoenix SH Kupfer 3 K	A5.5: E9018-G	3580-A: E Z CrMoV1 B 4 2 H5
				BÖHLER FOX DCMV	A5.5: E9018-G	3580-A: E Z CrMoV1 B 4 2 H5
	0,5 Cr; 1 Mo; V	-- / 14MoV6-3	SMAW	BÖHLER FOX DMV 83 Kb	A5.5: E9018-G	3580-A: E Mo V B 4 2 H5
			GTAW	BÖHLER DMV 83-IG	A5.28: ER80S-G	21952-A: W MoVSi
			GMAW	BÖHLER DMV 83-IG	A5.28: ER80S-G	21952-A: G MoVSi
	1 Ni; 0,5 Cu; 0,5 Mo; Nb	-- / 15NiCuMoNb5 (WB36)	SMAW	Phoenix SH Schwarz 3 K Ni	A5.5: E9018-G	2560-A: E 50 4 1 NiMo B 4 2 H5
				BÖHLER FOX DMO Kb	A5.5: E7018-A1H4R	3580-A: E Mo B 4 2 H5
			GTAW	Union I Mo	A5.28: ER70S-A1	21952-A: W MoSi
				BÖHLER DMO-IG	A5.28: ER70S-A1 (ER80S-G (A1))	21952-A: W MoSi
			GMAW	Union MoNi	A5.28: ER90S-G	16834-A: G 62 5 M Mn3Ni1Mo
				BÖHLER DMO-IG	A5.28: ER70S-A1 (ER80S-G (A1))	21952-A: G MoSi
			SAW wire	Union S 3 NiMo 1	A5.23: EF3	14171-A: S3Ni1Mo / 26304-A: S3Ni1Mo
				BÖHLER 3 NiMo 1-UP	A5.23: EF3	26304: S 3Ni1Mo
			SAW flux	UV 420 TT(R)		14174: SA FB 1 65 DC
				BÖHLER BB 24		14174: SA FB 1 65 DC H5

Joining 2/4

	Alloy Group	Base Material Examples ASTM / EN	Welding Process	Product Name	Classification AWS	Classification EN ISO
Bainitic Steels	2 1/4 Cr; 1 Mo	T/P22 / 10CrMo9-10	SAW wire	Union S 1 CrMo 2	A5.23: EB3R	24598: S CrMo2
				BÖHLER CM 2-UP	A5.23: EB3	24598: S CrMo2
			SAW flux	UV 420 TTR		14174: SA FB 1 65 DC
				UV 305		14174: SA AR 1 76 AC H5
				BÖHLER BB 24		14174: SA FB 1 65 DC H5
	2 1/4 Cr; 0,5 Mo; 1,5 W; V; Nb; B	T/P23 / 7CrWVMoNb9-6	SMAW	Thermanit P 23	A5.5: E9015-G	3580-A: E ZCrWV 2 1,5 B 4 2 H5
				BÖHLER FOX P 23	A5.5: E9015-G	3580-A: E ZCrWV 2 1,5 B 4 2 H5
			GTAW	Union I P23	A5.28: ER90S-G	21952-A: W ZCrWV 2 1,5
				BÖHLER P 23-IG	A5.28: ER90S-G	21952-A: W ZCrWV 2 1,5
			SAW wire	Union S P23	A5.23: EG	24598-A: S Z CrWV 2 1,5
				BÖHLER P 23-UP	A5.23: EG	24598-A: S Z CrWV 2 1,5
			SAW flux	UV P23		14174: SA FB 1 55 AC
				UV 305 (only single layer)		14174: SA AR 1 76 AC H5
				BÖHLER BB 430		14174: SA FB 1 55 AC
				BÖHLER BB 305 (only single layer)		14174: SA AR 1 76 AC H5
	2 1/4 Cr; 1 Mo; V; Ti; B	T/P24 / 7CrMoVTiB10-10	SMAW	Thermanit P 24	A5.5: E9015-G	3580-A: E ZCrMo2WVNb B 4 2 H5
				BÖHLER FOX P 24	A5.5: E9015-G	3580-A: E ZCrMo2VNb B 4 2 H5
			GTAW	Union I P24	A5.28: ER90S-G	21952-A: W ZCrMo2VTi/Nb
				BÖHLER P 24-IG	A5.28: ER90S-G	21952-A: W ZCrMo2VTi/Nb
			SAW wire	Union S P24	A5.23: EG	24598-A: S ZCrMo2VNb
				BÖHLER P 24-UP	A5.23: EG	24598-A: S ZCrMo2VNb
			SAW flux	UV P 24		14174: SA FB 1 55 AC
				UV 305		14174: SA AR 1 76 AC H5
				BÖHLER BB 430		14174: SA FB 1 55 AC
				BÖHLER BB 305 (only single layer)		14174: SA AR 1 76 AC H5
Martensitic Steels	9 Cr; 1 Mo; V; Nb	T/P91 / X10CrMoVNb9-1	SMAW	Thermanit Chromo 9 V	A5.5: E9015-B9	3580-A: E CrMo9 1 B 4 2 H5
				Thermanit Chromo T 91 (root)	A5.5: E9018-B9	3580-A: E CrMo9 1 B 4 2 H5
				BÖHLER FOX C 9 MV	A5.5: E9015-B9	3580-A: E CrMo9 1 B 4 2 H5
			GTAW	Thermanit MTS 3	A5.28: ER90S-B9	21952-A: W CrMo 9 1
				BÖHLER C 9 MV-IG	A5.28: ER90S-B9	21952-A: W CrMo 9 1
			GMAW	Thermanit MTS 3	A5.28: ER90S-B9	21952-A: G CrMo 9 1
				BÖHLER C 9 MV-IG	A5.28: ER90S-B9	21952-A: G CrMo 9 1
			FCAW	Thermanit MTS 3-PW	A5.29: E91T1-B9M	17634-B: T 69 T1-1M-9C1MV
				BÖHLER C 9 MV Ti-FD	A5.28: E91T1-B9M	17634-B: T 69 T1-1M-9C1MV
			SAW wire	Thermanit MTS 3	A5.23: EB9	24598-A: S CrMo9 1
				BÖHLER C 9 MV-UP	A5.23: EB9	24598-A: S CrMo9 1
			SAW flux	Marathon 543		14174: SA FB 2 55 DC H5
				BÖHLER BB 910		14174: SA FB 2 55 DC H5
	9 Cr; 0,5 Mo; 1,5 W; V, Nb	T/P92 / X10CrWMoVNb9-2	SMAW	Thermanit MTS 616	A5.5: (E9015-B9 mod.)	3580-A: E ZCrMoWVNb 9 0,5 2 B 4 2 H5
				BÖHLER FOX P 92	A5.5: (E9015-B9 mod.)	3580-A: E ZCrMoWVNb 9 0,5 2 B 4 2 H5
			GTAW	Thermanit MTS 616	A5.28: (ER90S-B9 mod.)	21952-A: W ZCrMoWVNb 9 0,5 1,5
				BÖHLER P 92-IG	A5.28: (ER90S-B9 mod.)	21952-A: W ZCrMoWVNb 9 0,5 1,5
			GMAW	Thermanit MTS 616	A5.28: (ER90S-B9 mod.)	21952-A: G ZCrMoWVNb 9 0,5 1,5
				BÖHLER P 92-IG	A5.28: (ER90S-B9 mod.)	21952-A: G ZCrMoWVNb 9 0,5 1,5
			FCAW	Thermanit MTS 616-PW	A5.29: E91T1-GM	17634-A: T ZCrWMo9VNb P M 1
				BÖHLER P 92 Ti-FD	A5.29: E91T1-GM	17634-A: T ZCrWMo9VNb P M 1
			SAW wire	Thermanit MTS 616	A5.23: EB9 (mod.)	24598-A: S ZCrMoWVNb 9 0,5 1,5
				BÖHLER P 92-UP	A5.23: EB9 (mod.)	24598-A: S ZCrMoWVNb 9 0,5 1,5
			SAW flux	Marathon 543		14174: SA FB 2 55 DC H5
				BÖHLER BB 910		14174: SA FB 2 55 DC H5

Joining 3/4

	Alloy Group	Base Material Examples ASTM / EN	Welding Process	Product Name	Classification AWS	Classification EN ISO
Bainitic Steels	2 1/4 Cr; 1 Mo	T/P22 / 10CrMo9-10	SMAW	Phoenix SH Chromo 2 KS	A5.5: E9015-B3	3580-A: E CrMo 2 B 4 2 H5
				BÖHLER FOX CM 2 Kb	A5.5: E9018-B3 H4R	3580-A: E CrMo 2 B 4 2 H5
			GTAW	Union I CrMo 910	A5.28: ER90S-G	21952-A: W CrMo 2 Si
				Union ER 90S-B3	A5.28: ER90S-B3	
				BÖHLER CM2-IG B3	A5.28: ER90S-B3	
				BÖHLER CM 2-IG	A5.28: ER90S-G	21952-A: W CrMo 2 Si
			GMAW	Union I CrMo 910	A5.28: ER90S-G	21952-A: G CrMo 2 Si
				BÖHLER CM 2-IG	A5.28: ER90S-G	21952-A: G CrMo 2 Si
			FCAW	Union MV CrMo 910	A5.28: E91 T1-B3M	17634-A: T CrMo 2 M M 2 H5
				BÖHLER CM 2 Ti-FD	A5.29: E91T1-B3M	17634-A: T ZCrMo2 P M 1
Martensitic Steels	9 Cr; 1 Mo; 1 W; V; Nb	T/P911 / X11CrMoWVNb9-1-1	SMAW	Thermanit MTS 911	A5.5: E9015-B9 (mod.)	3580-A: E ZCrMoWVNb 9 1 1 B 4 2 H5
				BÖHLER FOX C 9 MVW	A5.5: E9015-B9 (mod.)	3580-A: E ZCrMoWVNb 9 1 1 B 4 2 H5
			GTAW	Thermanit MTS 911	A5.28: ER90S-B9 (mod.)	21952-A: W ZCrMoWVNb 9 1 1
				BÖHLER C 9 MVW-IG	A5.28: ER90S-B9 (mod.)	21952-A: W ZCrMoWVNb 9 1 1
			GMAW	Thermanit MTS 911	A5.28: ER90S-B9 (mod.)	21952-A: G ZCrMoWVNb 9 1 1
				BÖHLER C 9 MVW-IG	A5.28: ER90S-B9 (mod.)	21952-A: G ZCrMoWVNb 9 1 1
			SAW wire	Thermanit MTS 911	A5.23: EB9 (mod.)	24598-A: S ZCrMoWVNb 9 1 1
				BÖHLER C 9 MVW-UP	A5.23: EB9 (mod.)	24598-A: S ZCrMoWVNb 9 1 1
			SAW flux	Marathon 543		14174: SA FB 2 55 DC H5
				BÖHLER BB 910		14174: SA FB 2 55 DC H5
	11 Cr; 0,5 Mo; 1,5 W; 1 Co; V; Nb	VM12-SHC / X12CrCoWVNb11-2-2	SMAW	Thermanit MTS 5 CoT	A5.5: E9015-B9 (mod.)	3580-A: E ZCrCoW11 2
				BÖHLER FOX C12 CoW	A5.5: E9015-B9 (mod.)	3580-A: E ZCrCoW11 2
			GTAW	Thermanit MTS 5 CoT	A5.28: ER110S-G	21952-A: W ZCrCoW 11 2 2
				BÖHLER C12 CoW-IG	A5.28: ER110S-G	21952-A: W ZCrCoW 11 2 2
	10 Cr; 1 Mo; V	-- / X20CrMoV11-1	SMAW	Thermanit MTS 4		3580-A: E CrMoWV 12 B 4 2 H5
				BÖHLER FOX 20 MVW		3580-A: E CrMoWV 12 B 4 2 H5
			GTAW	Thermanit MTS 4 Si		21952-A: W CrMoWV 12 Si
				BÖHLER 20 MVW-IG		21952-A: W CrMoWV 12 Si
			GMAW	Thermanit MTS 4 Si		21952-A: G CrMoWV 12 Si
				BÖHLER 20 MVW-IG		21952-A: G CrMoWV 12 Si
			SAW wire	Thermanit MTS 4		24598-A: S CrMoWV 12
				BÖHLER 20 MVW-UP		24598-A: S CrMoWV 12
			SAW flux	Marathon 543		14174: SA FB 2 55 DC H5
				UV 420 TT		14174: SA FB 1 65 DC H5
				BÖHLER BB 24		14174: SA FB 1 65 DC H5
	9 Cr; 1,5 Mo; 1 Co; V; Nb	CB2 (GX13CrMo-CoVNb9-2-1)	SMAW	Thermanit MTS 5 Co 1	A5.5: E9015-G	3580-A: E Z CrCoMoV 10 1 1 B 42 H5
			FCAW	BÖHLER CB 2 Ti-FD	A5.29: E91T1-GM	17634-A: T ZCrMoCo9VNbNB P M 1
Austenitic Steels	18 Cr; 9 Ni; 3 Cu; Nb	304HCu	SMAW	Thermanit 304 H Cu	A5.4: E308H-15 (mod.)	3581-A: EZ1816 Cu H B22
				BÖHLER FOX E 304 H Cu	A5.4: E308H-15 (mod.)	3581-A: E Z 18 16 1 Cu H B 2 2
			GTAW	Thermanit 304 H Cu		14343-A: W Z 18 16 1 Cu H
				BÖHLER ER 304 H Cu-IG	A5.9: ER308H (mod.)	14343-A: W Z 18 16 1 Cu H
	25 Cr; 21 Ni; Nb	310N (HR3C)	SMAW	(Thermanit 310N)* or Thermanit 617		14172: E Ni 6117
				BÖHLER FOX NIBAS 617	A5.11: E NiCrCoMo-1 (mod.)	14172: E Ni 6117
			GTAW	(Thermanit 310N)* or Thermanit 617		18274: S Ni 6617
				BÖHLER NIBAS 617-IG	A5.14: ER NiCrCoMo-1	18274: S Ni 6117
	18 Cr; 10 Ni; Nb	347H FG	SMAW	(Thermanit 310N)* or Thermanit 617		18274: S Ni 6617
				BÖHLER FOX NIBAS 617	A5.11: E NiCrCoMo-1 (mod.)	14172: E Ni 6117
			GTAW	(Thermanit 310N)* or Thermanit 617		18274: S Ni 6617
				BÖHLER NIBAS 617-IG	A5.14: ER NiCrCoMo-1	18274: S Ni 6617

Joining 4/4

	Alloy Group	Base Material Examples ASTM / EN	Welding Process	Product Name	Classification AWS	Classification EN ISO
Ni-Base Alloys	22 Cr; 9 Mo; 12 Co; 0,3 Ti; 1 Al; Ni balance	Alloy 617	SMAW	Thermanit 617	A5.11: E NiCrCoMo-1 (mod.)	14172: E Ni 6117
				BÖHLER FOX NIBAS 617	A5.11: E NiCrCoMo-1 (mod.)	14172: E Ni 6117
			GTAW	Thermanit 617	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
				BÖHLER NIBAS 617-IG	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
			GMAW	Thermanit 617	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
				BÖHLER NIBAS 617-IG	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
			SAW wire	Thermanit 617	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
				BÖHLER NIBAS 617-UP	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
			SAW flux	Marathon 444		14174: SA FB 2 AC
				BÖHLER BB 444		14174: SA FB 2 AC
Ni-Base Alloys	20 Cr; 6 Mo; 20 Co; 2 Ti; 0,5 Al; Ni-base	Alloy 263	SMAW	Thermanit 263*		
			GTAW	Thermanit 263		
		Dissimilar welds	SMAW	Thermanit Nicro 82	A5.11: E NiCrFe-3 (mod.)	14172: E Ni 6082
				BÖHLER FOX NiCr 70 Nb	A5.11: E NiCrFe-3 (mod.)	14172: E Ni 6082
				Thermanit Nicro 182	A5.11: E NiCrFe-3	14172: E Ni 6182
				BÖHLER FOX NiCr 70/15	A5.11: E NiCrFe-3	14172: E Ni 6182
				Thermanit 617	A5.11: E NiCrCoMo-1 (mod.)	14172: E Ni 6117
				BÖHLER FOX NIBAS 617	A5.11: E NiCrCoMo-1 (mod.)	14172: E Ni 6117
			GTAW	Thermanit Nicro 82	A5.14: ER NiCr-3	18274: S Ni 6082
				BÖHLER NiCr 70 Nb-IG	A5.14: ER NiCr-3	18274: S Ni 6082
				Thermanit 617	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
				BÖHLER NIBAS 617-IG	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
			GMAW	Thermanit Nicro 82	A5.14: ER NiCr-3	18274: S Ni 6082
				BÖHLER NiCr 70 Nb-IG	A5.14: ER NiCr-3	18274: S Ni 6082
				Thermanit 617	A5.14: ER NiCrCoMo-1	18274: S Ni 6617
				BÖHLER NIBAS 617-IG	A5.14: ER NiCrCoMo-1	18274: S Ni 6617

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