böhler welding
by voestalpine

Lasting Connections

WELDING SOLUTIONS FOR THE NUCLEAR INDUSTRY

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

WELDING SOLUTIONS FOR DEMANDING INDUSTRIES

We focus on industries with high technological standards and deliver products tailored to industry-specific requirements. In the development and optimization of filler materials, we collaborate closely with customers, manufacturers, and research institutes.

Whether destined for use in challenging scenarios or in standard applications – our high quality filler materials are ideally suited for all applications in the following industry sectors:

- Oil & Gas
- Pipeline
- Chemical
- Power Generation
- Transportation & Automotive
- Maintenance & Repair
- Brazing Industries


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NUCLEAR INDUSTRY AND BÖHLER WELDING

Nuclear power is with 15% of the global electrical power generation regarded as one of the major ways of producing electrical power with low CO_2-emission. It is a fact that in the last decade a rise in the number of nuclear power-plants has been made, especially in the Asian countries. Böhler Welding is an industry leader who supplies the nuclear industry with uncompromised quality products combined with expertise and technical support.

New reactors under construction in 2013 globally:

PWR	Pressurized Water Reactor	38
VVER	Russian PWR	14
BWR	Boiling Water Reactor	4
PHWR	Pressurized Heavy Water Reactor	5

Böhler welding is known as a global leader in the supply of welding-consumables to the nuclear Industry with a 50 year impeccable track record. Böhler Welding has a proven track record in the supply of high quality and innovative welding consumables to the nuclear industry, where it is known that welding itself is the most critical operation within the construction of a nuclear power plant. Therefore, special attention must be paid to the welding procedure as well as the production and delivery of welding consumables. We have offered high quality solutions using the widest range of technical expertise with a consistent QA/QC standard. Trusted deliveries have been made to the world's leading nuclear equipment manufacturers, for use in both new reactors and plant modernizations all over the world.

Replacements in nuclear power plants are principally done for reactor-vessel-heads, pressurizers and steam-generators, with as a main goal to improve safety, energetic performance and plant life extension.

Serving different nuclear technologies

Core and secondary parts of most reactor types in service today such, as Pressurized Water Reactor (PWR)/VVER, Boiling Water Reactor (BWR), Pressurized Heavy Water Reactor (PHWR), are built with our welding consumables, as are reprocessing plants and research reactors. Our products meet the needs from the nuclear industry in terms of tight chemical compositions and product cleanliness, as well as strength and corrosion resistance. Nuclear projects have a higher standard of product safety and reliability, requiring partners with strong experience.

Product selection advice and technical support

Teaming up with Böhler Welding also means gaining access to industry-leading service and support. This covers everything from product selection and own testing facilities. We understand the industry's requirements and our plants have the relevant qualifications, approvals and streamlined processes to obtain them.

Materials testing, Application Engineering and R&D

To help you choose the best solution among alternatives, we offer the option to test and finally qualify candidate products. We have built up industry knowledge through many years of cooperation with major reactor technology providers, engineering companies and design institutes. Today, we have more than 30 dedicated nuclear specialists and welding engineers who can support you in technical questions and recommendations regarding welding and metallurgy related to your nuclear project. Our technicians our supported by our certified in-house laboratories, which are also at your disposal.

Certified products, quality control and documentation

Our products are known for their outstanding quality and hence comply with the strictest quality standards. We are well acquainted with leading trade standards and regulations such as ASME NQA-1, NCA-3800,RCC-M, RCC-MR, KTA 1408.2, 10 CFR 50 as specific project specifications. This ensures not only that we produce products with industry leading tolerance accuracies, but also that our grades for the nuclear industry meet the relevant industry standards with certified material and quality documents in detail.
A further proof for the international appreciation of the high quality of our welding consumables is the Quality System Certificate (Materials), ASME sec. III-NCA 3800, which has been awarded by ASME to the following production sites:

- Hamm and Bad Krozingen in Germany
- Seneffe in Belgium
- Kapfenberg in Austria

Each nuclear process sets its own special demands on the materials used and therefore it is of importance that these materials are chosen with care. We provide on the next pages some examples to illustrate the choice for key nuclear industry applications in a Pressurized Water Reactor. For more specific information, also concerning welding consumable choice for other type of nuclear reactors or for future Generation IV reactors, we invite you to get in touch with our local specialists or specialists in our factories. Modifications on the products are possible in case of sufficient quantities.

Our productions facilities for nuclear products are certified according to ASME III-NCA 3800

voestalpine Böhler Welding: top-AREVA-supplier

PRESSURIZED WATER REACTOR (PWR)

On a global scale the Pressurized Water Reactor is the most common type of reactor.

The reactor itself in the nuclear plant is constructed inside the containment vessel, which is an overarching structure with layers of thick concrete and steel.

The PWR-nuclear plant can be divided into 3 circuits:

The Primary Circuit which holds:

- The Reactor Pressure Vessel (RPV): this is a coolant (also called primary water) filled vessel where the nuclear fuel and control rods are located. Movement of the control rods regulates the rate of the nuclear reaction (and the heat generated). Submerging the control rods shuts down the plant completely
- Stainless Steel Piping is used to transport the cold coolant to the reactor vessel and hot coolant to the Steam Generator. In order to keep the coolant flowing the transport is supported by pumps
- The Pressurizer (PRZ): The basic design of the pressurized water reactor includes a requirement that the coolant (water) in the reactor coolant system must not boil. The coolant must remain in the liquid state at all times, especially in the reactor vessel. To achieve this, the coolant in the reactor coolant system is maintained at a pressure sufficiently high that boiling does not occur at the coolant temperatures experienced while the plant is operating. To pressurize the coolant system to a higher pressure than the boiling point of the coolant at operating temperatures, a separate pressurizing system is required.
- In the Steam-Generator (SG) the hot coolant is transported through large bundles of small nickel-alloy tubes with a total length of 140 km, which heats a secondary flow of water; and steam is generated. The collected steam is sent to the turbine by way of a steam line into the Secondary Circuit. These separate circuits have an important safety role because they constitute one of the primary barriers between the radioactive and non-radioactive sides of the plant as the primary coolant becomes radioactive from its exposure to the core.

Depending on the design of the PWR the number of Steam-Generators can be different, also called loops

- The EPR designed by Areva is a 4 loop-reactor
- The AP1000 designed by Westinghouse is a 2 loop reactor
- The VVER-1800 designed by Rosatom is a 3 loop-reactor

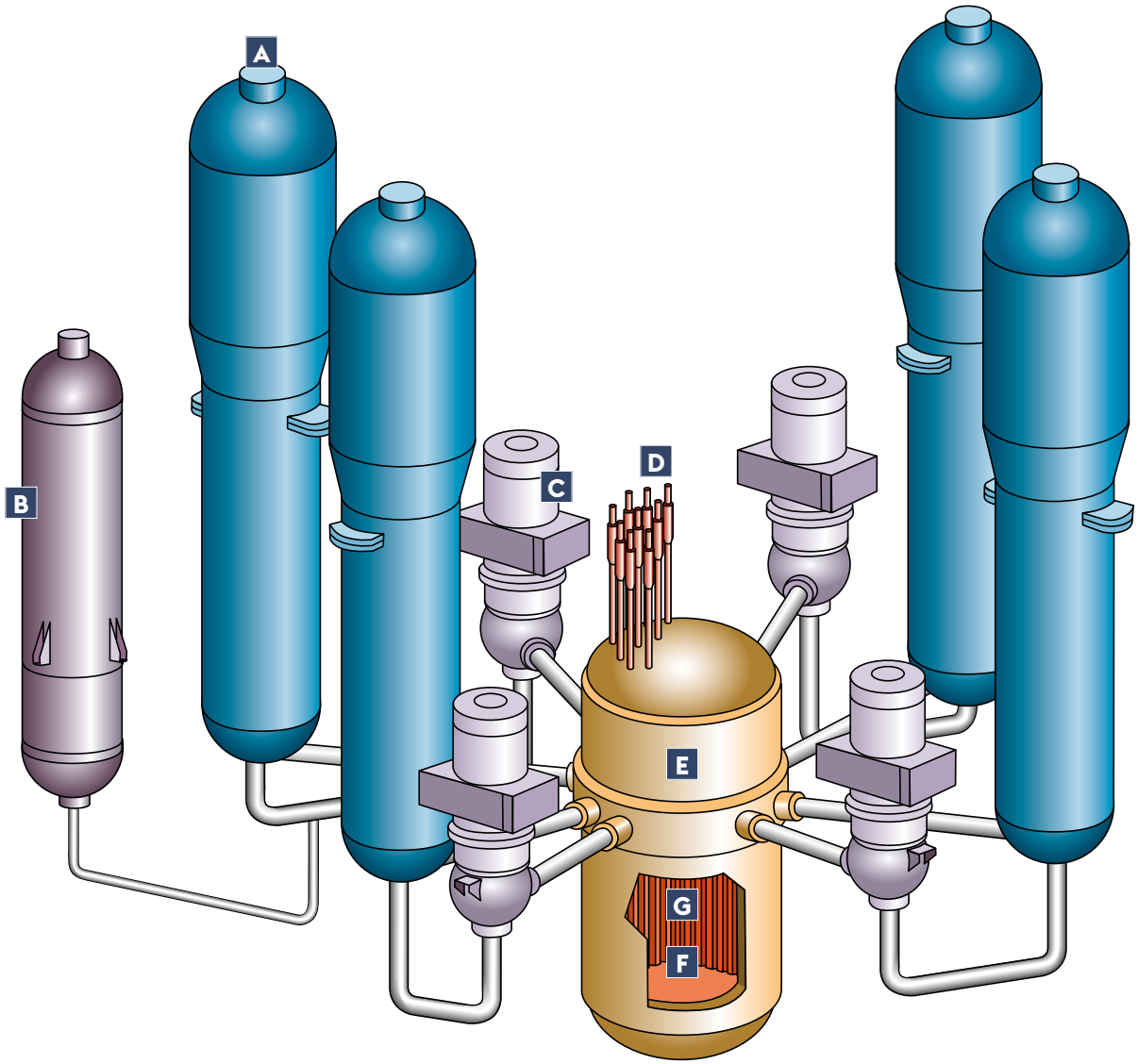
The Secondary Circuit:

- The turbine generates electrical power. The steam which passes through the turbine is transported through a cooling water condenser.
- The condenser will send the newly cooled liquid back to the steam generator to maintain indirectly the core temperature to an required level and will also send coolant to the coolant tower into the tertiary circuit.

The tertiary circuit:

- The coolant tower decreases the temperature of the liquid moving through it, and transported back to the condenser. The vapor that rises from the cooling tower is ordinary water.

The secondary and tertiary circuit can also be found in thermal-power plants, and will not be referred to in this brochure. Although it must be mentioned that Böhler Welding has a wide choice of welding consumables for the use of the construction and maintenance of parts for the secondary and tertiary circuit.



A	Steam Generators
B	Pressurizer
C	Reactor Coolant Pump
D	Control Rod Drive Mechanism
E	Reactor Vessel
F	In-core Instrumentation
G	Internal Equipment

Scheme of the primary circuit of a PWR, showing RPV, SG, PRZ, Pumps, piping

MATERIALS CHOICE AND WELDING CONSUMABLES RECOMMENDATIONS IN THE PRIMARY CIRCUIT OF A PWR

Nuclear Pressure Vessel Codes: Each country defines its own regulations for their nuclear Industry. The most widely adopted are the French nuclear standard RCC-M and the ASME codes of the American Society of mechanical Engineering (ASME Sec. III Div 1 and ASME Sec. XI). These codes specify the requirements in terms of design, fabrication, testing, inspection and quality assurance. A nuclear power plant consists of different parts for which we go in deeper detail below.

When a nuclear power plant is constructed welding consumables must be selected with care and be in compliance with the applied code. The welding consumables must be of reliable high quality, meet to the mechanical (strength/toughness at different temperatures) and chemical requirements (e.g. high resistance to neutron irradiation brittleness) and have good weldability.

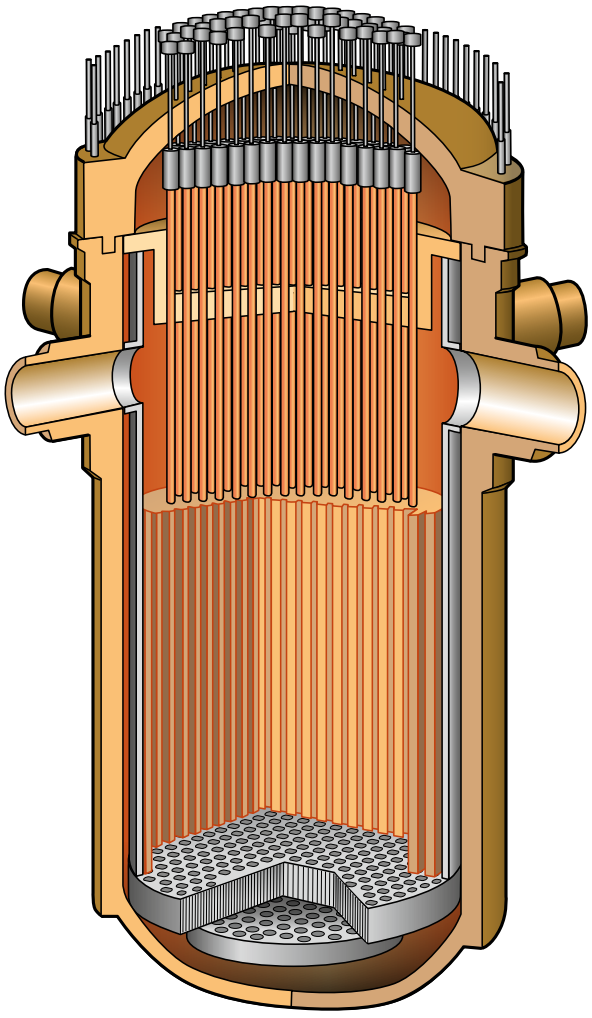
Reactor Pressure Vessel (RPV)

The Reactor Pressure Vessel consists of a thick-walled cylindrical steel vessel enclosing the reactor core in a nuclear power plant. The vessel is made of special fine-grained low alloy ferritic steel, well suited for welding and with a high toughness. The inside is lined with austenitic steel cladding to protect against corrosion. For a 1,300 MWe pressurized water reactor, the pressure vessel is about 12 m high, the inner diameter is 5 m, and the wall of the cylindrical shell is about 250 mm thick. The overall weight amounts to approx. 530 t without internals. The vessel is designed for a pressure of 175 bar and a process-temperature of 350 °C, materials and welding which correspond to this pressure and temperature must be used.

Reactor Pressure Vessel Body: The reactor vessel body is the largest component and is designed to contain the fuel assembly, coolant, and fittings to support coolant flow and support structures. It is usually cylindrical in shape and is open at the top to allow the fuel to be loaded. The inner surface constitutes a severe corrosive environment due to the circulating coolant contaminated with radioactive elements. The inner surface in direct contact with the coolant is cladded with stainless steel or nickel-base welding consumables, in order to protect the vessel from corrosion. The most economical way to clad such a large surface is by means of cladding with a strip with the submerged or electroslag process (higher production-efficiency compared to SAW-strip cladding). For smaller surfaces and not-easily accessible surfaces GTAW or SMAW welding process can be used.

Reactor Pressure Vessel Head: This structure is attached to the top of the reactor vessel body. It contains penetrations to allow the control rod driving mechanism to attach to the control rods in the fuel assembly. The coolant level measurement probe also enters the vessel through the reactor vessel head. The head provides access for the replacement of spent fuel, and Alloy 600 penetration nozzles for control rod drive mechanisms and instrumentation. The closure head is typically made of low alloy steel and clad with stainless steel like the rest of the reactor vessel. Recently, many reactor closure heads in existing PWR systems have experienced corrosion damage and are being replaced.

Fuel Assembly: The fuel assembly of nuclear fuel usually consisting of uranium or uranium/plutonium mixes. The fuel assembly is usually a rectangular block of gridded fuel rods.



Reactor Pressure Vessel
(RPV)

Steam Generator (SG)

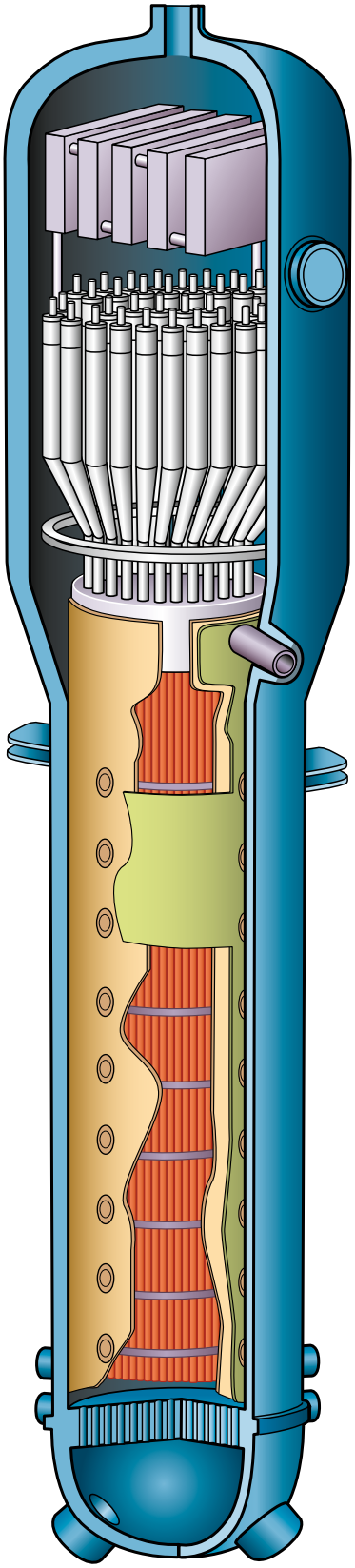
In commercial power plants steam generators can measure up to 21 m in height and weigh as much as 800 tons. Each steam generator can contain anywhere from 3,000 to 16,000 tubes. The principal materials being used are low alloyed high strength – high-toughness materials. The inside of the vessel is also submitted to the same corrosive environment as the RPV, an internal stainless clad is also required. The internal tubing is submitted to the primary coolant where Primary Water Stress Corrosion Cracking is the main problem, to overcome this problem alloy 690 has been chosen as the solution in new and replacement Steam Generators.

Pressurizer (PRZ)

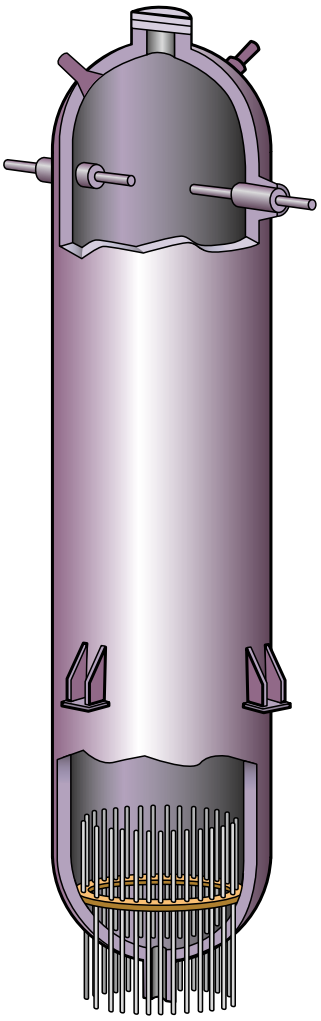
The materials applied and the welding processes applied in a pressurizer is basically the same as in the steam-generator This unit is a tall, cylindrical tank typically connected at the bottom to a reactor coolant loop hot leg through surge line piping. Spray is introduced near the top of the pressurizer through a nozzle and line from a cold leg. Heater bundles are installed over the lower portion of the pressurizer. Pressure relief devices are mounted at the top of the unit.

Nuclear Piping

The reliable operation and integrity of nuclear pressure equipment are of great importance for the safety of nuclear facilities. The requirements apply to the design, manufacturing, inspection, testing and installation of nuclear piping as well as piping supports. Stainless steel type 304L and 316L is primarily used for the piping and elbows in the primary circuit.



Steam Generator (SG)



Pressurizer (PRZ)

Consumable selection for SG, PRZ and Piping

	Base Metal	Weld / Cladding	Welding Process	Welding consumable standard	Welding Consumable Selection according to Construction Code	
				ASME II-C	RCC-M	ASME
Pressure retaining parts base metal Tube sheet base metal	**18MND5** **SA-508 Gr. 3 Cl. 2**	**SG and PRZ:** Shell to shell welds **SG:** Channel head to tubes-sheet Bundle wrapper to Lower shell weld Feed-water nozzle to conical shell **PRZ:** Man-way, safety valve, venting nozzle Surge nozzle Shell to shell welds	SAW	EG (EF3-mod)	Union S 3 NiMo 1 / UV 420 TTR BÖHLER 3 NiMo 1-UP / BÖHLER BB 24 SC	Union S 3 NiMo 1 / UV 420 TTR BÖHLER 3 NiMo 1-UP / BÖHLER BB 24 SC
				EG (EF6-mod)	–	Union S 3 NiMoCr / UV 418 TT
				EM2	–	Union S 3 NiMoCr-M2 / UV 418 TT-M2
			GATW	ER90S-D2	Union I MoMn	Union I MoMn
				ER100S-1	Union I NiMoCr-M2	Union I NiMoCr-M2
			SMAW	E8018-G	BÖHLER FOX EV 65 R	BÖHLER FOX EV 65 R
				E9018-G	BÖHLER FOX EV 65 R+	BÖHLER FOX EV 65 R +
					Phoenix SH Schwarz 3 K Ni	Phoenix SH Schwarz 3 K Ni 2
					Comet J 66 ELH Q5	Phoenix SH Schwarz 3 K Ni
					–	Phoenix SH Schwarz 3 K Ni Mn
						BÖHLER FOX EV 70 R
				E9018-M	–	Phoenix SH Schwarz 3 K Ni M
		SG and PRZ: First layer cladding: » Pressure boundary » Nozzles **SG:** Tube sheet cylindrical shell	SAW Strip	EQ309L	SOUDOTAPE 309 L Q5 / RECORD INT 101 Q5	SOUDOTAPE 309 L Q5 / RECORD INT 101 Q5
			GTAW	ER309L	Thermanit 25/14 E-309L	Thermanit 25/14 E-309L
					BÖHLER CN 23/12 IG	BÖHLER CN 23/12 IG
			SMAW	E309L-16	SOUDOCROM L 309 Q5	BÖHLER FOX CN 24/13-AR
		SG and PRZ: Subsequent layer cladding: » Pressure boundary » Nozzles **SG:** Tube sheet cylindrical shell	SAW Strip	EQ308L	SOUDOTAPE 308 L Q5/ RECORD INT 101 Q5	SOUDOTAPE 308 L Q5 / RECORD INT 120 Q5
			GTAW	ER308L	Thermanit JE-308L	Thermanit JE-308L
					BÖHLER EAS 2-IG	BÖHLER EAS 2-IG
			SMAW	E308L-16	Thermanit JEW 308L-16	Thermanit JEW 308L-16
					BÖHLER FOX EAS 2-AR	BÖHLER FOX EAS 2-AR
		SG: Tube-sheet cladding	SAW strip	EQNiCrFe-14	SOUDOTAPE 690 Q5 / RECORD NFT 690 Q5	SOUDOTAPE 690 Q5 / RECORD NFT 690 Q5
				EQNiCrFe-7	SOUDOTAPE NiCrFe-7 Q5 / RECORD NFT NiCrFe-7 Q5	SOUDOTAPE NiCrFe-7 Q5 / RECORD NFT NiCrFe-7 Q5
			ES-strip	EQNiCrFe-14	SOUDOTAPE 690 Q5 / RECORD EST 690 Q5	SOUDOTAPE 690 Q5 / RECORD EST 690 Q5
				EQNiCrFe-7	SOUDOTAPE NiCrFe-7 Q5 / RECORD EST NiCrFe-7 Q5	SOUDOTAPE NiCrFe-7 Q5 / RECORD EST NiCrFe-7 Q5
			GTAW	ERNiCrFe-7	Thermanit 690	Thermanit 690
			SMAW	ENiCrFe-7	Thermanit 690	Thermanit 690

Consumable selection for SG, PRZ and Piping

	Base Metal	Weld / Cladding	Welding Process	Welding consumable standard	Welding Consumable Selection according to Construction Code	
				ASME II-C	RCC-M	ASME
SG: Tubes, clad-ded tube-sheet, partition plate, channel head	**Alloy 690**	**SG:** Homogenous welds between: » tubes » tube-sheet » partition plate » channel head	GTAW	ERNiCrFe-7	Thermanit 690	Thermanit 690
			SMAW	ENiCrFe-7	Thermanit 690	Thermanit 690
SG: Safe end, par-titionplate, welded tube-sheet, primary nozzle weld, chan-nel head. PRZ: Safe end welds	**Alloy 690 to low alloy**	**SG:** Dissimilar welds: » artition plate to tube-sheet » Safe end to primary nozzle **PRZ:** Safe end to nozzles	GTAW	ERNiCrFe-7	Thermanit 690	Thermanit 690
			SMAW	ENiCrFe-7	Thermanit 690	Thermanit 690
PRZ surgeline Piping, fittings	**Z2CND 18-12 AISI 316 L**	**PRZ:** Branch connections, safe ends, heater ele-ments, connection parts Piping: Weld joining surge line with main coolant line	GTAW	ER316L	Thermanit GE 316L	Thermanit GE 316L
					BÖHLER EAS 4 M-IG	BÖHLER EAS4 M-IG
			SMAW	E316L-16	Thermanit GE Spezial	Thermanit GE Spezial
					BÖHLER FOX EAS 4 M R	BÖHLER FOX EAS 4 M R
Main cool-ant line	**Z2CN 19-10 AISI 304L**	Pipes, elbows	GTAW	ER308L	Thermanit JE-308L	Thermanit JE-308L
					BÖHLER EAS 2-IG	BÖHLER EAS 2-IG
			SMAW	E308L-16	Thermanit JEW 308L-16	Thermanit JEW 308L-16
					BÖHLER FOX EAS 2-AR	BÖHLER FOX EAS 2-AR

Consumable selection for Reactor Pressure Vessel

	Base Metal	Weld / Cladding	Welding Process	Welding consumable standard	Welding Consumable Selection according to Construction Code	
				ASME II-C	RCC-M	ASME
Pressure boundary base materials	**16MND5** **SA-508 Gr. 3 Cl. 1** **20MnMoNi5-5**	Homogeneous ferritic welds of pressure boundary	SAW	EG	Union S 3 NiMo 2 / UV 420 TTR	–
				EF2	Union S 3 NiMo 0.8 / UV 420 TTR	Union S 3 NiMo 0.8 / UV 420 TTR
			GTAW	ER90S-D2	Union I MoMn	Union I MoMn
			SMAW	E8018-G	BÖHLER FOX EV 65 R	BÖHLER FOX EV 65 R
				E9018-G	Phoenix SH Schwarz 3 K Ni 2	Phoenix SH Schwarz 3 K Ni 2
		First layer cladding of pressure boundary	SAW Strip	EQ309L	SOUDOTAPE 309 L Q5 / RECORD INT 101 Q5	SOUDOTAPE 309L Q5 / RECORD INT101 Q5
			GTAW	ER309L	Thermanit 25/14 E-309L	Thermanit 25/14 E-309L
					BÖHLER CN 23/12-IG	BÖHLER CN 23/12 -IG
			SMAW	E309L-16	SOUDOCROM L 309 L Q5	BÖHLER FOX CN 24/13-AR
		Subsequent layers cladding of pressure boundary	SAW Strip	EQ308L	SOUDOTAPE 308 L Q5 / RECORD INT 101 Q5	SOUDOTAPE 308 L Q5 / RECORD INT 120 Q5
			GTAW	ER308L	Thermanit JE-308L	Thermanit JE-308L
					BÖHLER EAS 2-IG	BÖHLER EAS 2-IG
			SMAW	E308L-16	Thermanit JEW 308L-16	Thermanit JEW 308L-16
					BÖHLER Fox EAS 2-AR	BÖHLER FOX EAS 2-AR
		Dissimilar safe end to nozzle welds	GTAW	ERNiCrFe-7	Thermanit 690	Thermanit 690
Closure head penetrations base metals (Ni Base to ferric)	**Alloy 690**	Dissimilar closure head penetrations	SMAW for buttering	ENiCrFe-7	Thermanit 690	Thermanit 690
					UTP 6229 Mn	
			GTAW for weld	ERNiCrFe-7	Thermanit 690	Thermanit 690
		Dissimilar closure head penetration to flange welds	GTAW	ERNiCrFe-7	Thermanit 690	Thermanit 690
Internals base metals	**Z2CN19-10 AISI 304L**	Welding consumables for reactor internals	GTAW	ER308L	Thermanit JE-308L	Thermanit JE-308L
					BÖHLER EAS 2-IG	BÖHLER EAS 2-IG
			SMAW	E308L-15	Thermanit JE Spezial	Thermanit JE Spezial
					BÖHLER FOX EAS 2 R	BÖHLER FOX EAS 2 R
	Z2CND 18-12 AISI 316L		GTAW	ER316L	Thermanit GE 316L	Thermanit GE 316L
					BÖHLER EAS4 M-IG	BÖHLER EAS4 M-IG
			SMAW	E316L-15	Thermanit GE Spezial	Thermanit GE Spezial
					BÖHLER FOX EAS 4 M R	BÖHLER FOX EAS 4 M R

NUCLEAR DECOMMISSIONING INDUSTRY

The nuclear decommissioning and nuclear-spent-fuel storage industry is also a prime user of high quality stainless and low alloy steels for different types of transport or storage canisters and boxes for low- to high level nuclear-spent-fuel.

Nuclear-spent-fuel canisters are designed to safely store bundles of nuclear spent fuel at plant sites, and some designs allow transport to long-term storage sites and nuclear fuel reprocessing plants. The design of the canisters and internal structures serves as the containment boundary to confine radioactive spent fuel and provide a leak-tight, inert atmosphere to ensure that the integrity of the fuel cladding is maintained. For that purpose high toughness materials are used such as 2.5Ni and 3.5Ni-alloys, voestalpine Böhler Welding has a wide selection of welding consumables for the different welding processes available. Also corrosion is a main issue in the storage canister, a stainless-steel clad might be needed when necessary; different solutions exist and are applied from voestalpine Böhler Welding.

REFERENCES

Böhler Welding, with its worldwide production implementations, is one of the most successful producers of welding consumables globally. The production range of SAW fluxes, wires, coated electrodes, which are intended for critical nuclear applications, where the highest quality is required, are widely applied and appreciated by our customers. The production of our welding consumables is carried out under a stringent Quality Assurance System and audited by inspection bodies and customers in order to assure the high quality required by our customers. Our factories have been audited according to ASME and RCC-M by many of our customers who are using our products for their critical nuclear welding-applications.
Longer service life requirements and new designs of nuclear power plants often mean higher demands on the installation and hence higher requirements for the materials to be used:

- Improved mechanical properties/toughness
- Higher restrictions in the chemistry of the weld-deposit: e.g. Co, V, B, Cu, P, ferrite content
- Wider range of application: welding parameters, welding process, service temperature

In these situations the existing welding-consumables' chemical and mechanical properties can often still be used, in the contrary case our R&D-departments are ready for the challenge to improve or develop a welding consumable which meet the new critical requirements for the project. Many customers in the list below have called upon our expertise to make their nuclear project to a success in the last 50 years. Together we make everything possible as partners in the nuclear industry!

Consumables from voestalpine Böhler Welding are used in installations in:												
Argentina:	2	China:	30	Germany:	26	South Korea:	7	Switzerland:	5	Other:	12
Brazil:	3	France:	30	Slovakia:	2	Spain:	4	USA:	7		

Consumables from voestalpine Böhler Welding are used in below recent designs							
EPR	France / China / Finland	CAP 1400	China	ACPR 1000	China	VVER	Slovakia / Czech Republic
AP 1000	China/USA	CPR 1000	China	APR 1000	South Korea	ITER	France

Customer references:	
Areva	Doosan Heavy Industries and Construction Co.
Babcock and Wilcox	ENSA
China First Heavy Industries	Harbin Electric Corporation (QHD) Heavy Equipment Co
China Nuclear Industry 23 Construction Co.	Mangiarotti Nuclear S.p.A.
China Nuclear Industry Fifth Construction Co	SENPEC
China Second Heavy Industries (CNEG)	Westinghouse
Dong Fang (Guangzhou) Heavy Machinery	and many more

Joining 1/4

	Alloy Group	Welding Process	Product Name	Classification AWS/EN
Unalloyed Steels	C-Mn R_m > 510 Mpa $R_{p0,2}$ > 420 Mpa	SMAW	BÖHLER FOX EV 47	AWS A5.1-04 E7016-1H4R EN ISO 2560-A E 38 4 B 42 H5
			Phoenix 120 K	AWS A5.1-04 E7018-1 EN ISO 2560-A: E 42 5 B 32 H5 RCC-M S2810
			BÖHLER FOX EV 50 R	AWS A5.1-04 E7018-1 H4R EN ISO 2560-A E 42 5 B 42 H5 RCC-M: S2810
		SAW Wire	Union S 2 Si / BÖHLER EMS 2	AWS A5.17 EM12K EN 756 S2Si
		SAW Flux	UV 418 TT / BÖHLER BB 24	- EN ISO 14174 SA FB 1 55 AC H5
		SAW Wire+Flux	Union S 2 Si + UV 418 TT / BÖHLER EMS 2 + BÖHLER BB 24	AWS A5.17-SFA 5.17 F7A6-EM12K RCC-M: S2860
		SAW Wire	Union S 3 Si	AWS A5.17 EH12K EN 756 S3Si
		SAW Flux	UV 418 TT	- EN ISO 14174 SA FB 1 55 AC H5
		SAW Wire+Flux	Union S 3 Si + UV 418 TT	AWS A5.17-SFA 5.17 F7A8-EH12K
		GTAW	BÖHLER EMK 6 / Union I 52	AWS A5.18 ER70S-6 EN ISO 636-A W 42 5 W3Si1 RCC-M S 2840
			BÖHLER EML 5	AWS A5.18 ER70S-3 EN ISO 636-A W 46 5 W2Si RCC-M S2870
		GMAW	BÖHLER EMK 6	AWS A5.18 ER70S-6 EN ISO 14341-A G3Si1 RCC-M S 2840
		FCAW	BÖHLER Ti 52-FD	AWS A5.20 E71T-1MJH8 EN ISO 17632-A T 46 4 P M 1 H10
Low-alloyed Pressure Vessel Steels	C-1/4 Mo R_m > 560 Mpa $R_{p0,2}$ > 480 MPa	SMAW	BÖHLER FOX EV 50 Mo R	AWS A5.1-04 E7018-1 EN ISO 2560-A:2010 E 42 5 B 42 H5 RCC-M S2810
			Phoenix SH Schwarz 3 MK	AWS A5.5-E 7018-G EN ISO 2560-A: E 50 4 Mo B 42
	C- 1/2 Mo R_m > 550 Mpa $R_{p0,2}$ > 470 Mpa	SMAW	BÖHLER FOX DMO Kb	AWS A5.5 E7018-A1H4R EN ISO 2560-A E Mo B 42 H5
		SAW Wire	Union S 2 Mo / BÖHLER EMS 2 Mo	AWS A5.23: EA2 EN 756: S2Mo
		SAW Flux	UV 420 TTR / BÖHLER BB 24 SC	- EN ISO 14174: SA FB 1 65 AC H5
		SAW Wire+Flux	Union S 2 Mo + UV 420 TTR BÖHLER EMS 2 Mo + BÖHLER BB 24 SC	AWS A5.17-SFA 5.17: F8A4-EA2-A2 -
		GTAW	Union I MoMn	AWS A5.28: ER90S-D2 EN ISO 636-B: W 4 M31
			BÖHLER DMO-IG	AWS A5.28: ER70S-A1 (ER80S-G) EN ISO 21952-A: W Mo Si
	1 ¼ Cr ½ Mo 1 Cr ½ Mo	SMAW	Phoenix Chromo 1 / BÖHLER DCMS Kb	AWS A5.5 E8018-B2 EN ISO 3580-A ECrMo1 B 4 2 H5
		GTAW	Union ER 80S-B2	AWS A5.28 ER80S-B2
	2 ¼ Cr 1 Mo	SMAW	Phoenix SH Chromo 2 KS	AWS A5.5 E9015-B3 EN ISO 3580-A ECrMo2 B 4 2 H5 | EN ISO 3580-B E 6215-2C1M
			BÖHLER FOX CM 2 Kb	AWS A 5.5 E9018-B3H4R EN 1599 E CrMo2 B 4 2 H5

Joining 2/4

	Alloy Group	Welding Process	Product Name	Classification AWS/EN
Low-alloyed Pressure Vessel Steels		GTAW	BÖHLER CM 2-IG	AWS A5.28 ER90S-G EN ISO 21952-A W CrMo2Si | EN ISO 21952-B W 62 2C1M3
			Union ER 90S-B3	AWS A5.28 ER90S-B3
	0,8 Ni 1/2 Mo R_m > 550 Mpa $R_{p0,2}$ > 345 Mpa	SMAW	Phoenix SH Schwarz 3 K Ni 2	AWS A5.5: E9018-G EN ISO 2560-A - E 50 4 1NiMo B 42 H5
			BÖHLER FOX EV 65 R	AWS A5.5 E8018-G EN ISO 2560-A - E 55 6 1NiMo B 42 H5 RCC-M S2820B
		SAW Wire	Union S 3 Ni Mo 0,8	AWS A5.23 EG (EF2 Mod) EN 756: S 50 4 FB S3Ni1Mo
		SAW Flux	UV 420 TTR	- EN ISO 14174 SA FB 1 65 DC
		SAW Wire+Flux	Union S 3 Ni Mo 0,8 + UV 420 TTR	AWS A5.23 F9P4-EG-F2 N -
		GTAW	Union I Ni Mo 0,8	AWS A 5.28 ER90S-G EN 12534 W Z
	1 Ni 1/2 Mo R_m > 620 Mpa $R_{p0,2}$ > 540 Mpa	SMAW	Phoenix SH Schwarz 3 K Ni	AWS A5.5: E9018-G EN ISO 2560-A E50 4 1 NiMo B 42 H5
			BÖHLER FOX EV 65 R+	AWS A5.5 E9018-G EN 757 E 55 6 1 NiMo B 42 H5 RCC-M S 2820B
			Comet J66 ELH Q5	AWS A5.5: E9018-G EN 757:E 55 2Mn1 NiMo B 12 H5
			Phoenix SH Schwarz 3 K Ni Mn	AWS A5.5: E9018-G
		SAW Wire	Union S 3 NiMo 1 / BÖHLER S 3 NiMo 1-UP	AWS A5.23 EG (EF3 Mod.) EN 756 S3Ni1Mo
		SAW Flux	UV 420 TTR / BÖHLER BB 24 SC	- EN ISO 14174 SA FB 1 65 DC
		SAW Wire+Flux	Union S 3 NiMo 1 + UV 420 TTR / BÖHLER S 3 NiMo 1-UP + BÖHLER BB 24 SC	AWS A5.23 F9P8-EG-F3 N EN 756: S 50 4 FB S3Ni1Mo RCC-M S 2830A
		GTAW	Union I NiMo 1	AWS A5.28 ER90S-G EN 12534: W Z
	1½ Ni 0,5 Mo R_m > 620 Mpa $R_{p0,2}$ > 540 Mpa	SMAW	Phoenix SH Schwarz 3 K Ni M	AWS A5.5: E9018-M EN ISO 2560-A E 50 4 1,5NiMo B 42 H5
		SAW Wire	Union S 3 NiMoCr-M2	AWS A5.23 EM2 EN ISO 26304-A SZ 3Ni2,5CrMo
		SAW Flux	UV 418 TT-M2	- EN ISO 14174 SA FB 1 65 AC H4
		SAW Wire+Flux	Union S 3 NiMoCr-M2 + UV 418 TT-M2	AWS: F9P4 EM2-M2 EN ISO 26304-A S 55 2 FB SZNi2,5CrMo
		GTAW	Union I NiMoCr-M2	AWS A 5.28 ER 100 S-1
Low alloyed Ni Steel	2.5% Ni	SMAW	BÖHLER FOX 2.5 Ni	AWS A5.5 E8018-C1H4R
			Phoenix SH Ni 2 K 70	EN ISO 2560-A E 46 8 2Ni B 42 H5
		SAW Wire	Union S 2 Ni 2,5	AWS A5.23 ENi2 EN 756 S2Ni2
		SAW Flux	UV 418 TT	- EN ISO 14174 SA FB 1 55 AC H5
		SAW Wire+Flux	Union S 2 Ni 2,5 + UV 418 TT	AWS A5.17-SFA 5.17 F8A10-ENi2-Ni2 -
		GTAW	BÖHLER 2.5 Ni-IG	AWS A5.28 ER80S-Ni2 EN ISO 636-A W2Ni2
		GMAW	BÖHLER 2.5 Ni-IG	AWS A5.28 ER80S-Ni2 EN ISO 14341-A G2Ni2

Joining 3/4

	Alloy Group	Welding Process	Product Name	Classification AWS/EN
Low alloyed Ni Steel	3.5% Ni	SMAW	Phoenix SH Ni 2 K 80	AWS A5.5 E7018-C2L EN ISO 2560-A E 46 8 2Ni B 42 H5
		SAW Wire	Union S 2 Ni 3,5	AWS A5.23 ENi3 EN 756 S2Ni3
		SAW Flux	UV 418 TT	- EN ISO 14174 SA FB 1 55 AC H5
		SAW Wire+Flux	Union S 2 Ni 3,5 + UV 418 TT	AWS A5.17-SFA 5.17 F8A15-ENi3-Ni3 -
		GTAW	Union I 3,5 Ni	AWS A 5.28 ER80S-Ni 3 EN ISO 636-A W2Ni3
Stainless Steel	Austenitic S.S 309L Weld overlay Buffer Dissimilar	SMAW	BÖHLER FOX CN 24/13 R	AWS A 5.4 E309L-15 EN 1600 E 23 12 B 2 2
			BÖHLER FOX CN 24/13 AR	AWS A 5.4 E309L-16 EN 1600 E 23 12 L R 3 2
			Soudocrom L 309 L Q5	AWS A 5.4 E309L-16 EN 1600 E 23 12 L R 1 2 RCC-M S 2930
			BÖHLER FOX CN 23/12 AR	AWS A 5.4 E309L-17 EN 1600 E 23 12 L R 3 2
			Thermanit 25/14 EW 309L-17	AWS A 5.4 E309L-17 EN 1600 E 23 12 L R 1 2
		SAW Wire	Thermanit 25/14 E309L / BÖHLER CN 23/12-UP	AWS A 5.9 ER309L EN 12072 S 23 12 L
		SAW Flux	Marathon 431 / BÖHLER BB 202	EN 760 SA FB 2 DC -
		SAW Wire+Flux	Thermanit 25/14 E309L+ Marathon 431 BÖHLER CN 23/12-UP + BÖHLER	RCC-M S 2950 -
		GTAW	BÖHLER CN 23/12-IG / Thermanit 25/14 E 309L	AWS A 5.9 ER 309L EN 12072 W 23.12 L
		GMAW	Thermanit 25/14 E309L Si	AWS A 5.9 ER 309L Si EN ISO 14343-A G 23 12 L Si
		FCAW	BÖHLER CN 23/12-FD	AWS A 5.22: E309LT0-4 EN ISO 17633 A T 23 12 L R M (C) 3
	S.S. 308 L	SMAW	BÖHLER FOX EAS 2 R / Thermanit JE Spezial	AWS A 5.4 E308L-15 EN 1600 E 19 9 L B 2 2
			BÖHLER FOX EAS 2-AR / Thermanit JEW 308L-16	AWS A 5.4 E308L-16 EN 1600 E 19 9L R 3 2 RCC-M S 2920
			BÖHLER FOX EAS 2-A / Thermanit JEW 308L-17	AWS A 5.4 E308L-17 EN 1600 E 19 9 L R 3 2
		SAW Wire	Thermanit JE 308L / BÖHLER EAS 2-UP	AWS A 5.9 ER308L EN 12072 S 19 9 L
		SAW Flux	Marathon 431 / BÖHLER BB 202 / BÖHLER BB 203 / RECORD IND 24	EN 760 SA FB 2 DC - - -
			RECORD IND 27	EN 760 SA FB 2 Cr DC
		SAW Wire+Flux	Thermanit JE 308L + Marathon 431 / BÖHLER EAS 2 -UP + BÖHLER	RCC-M S2940 -
		GTAW	BÖHLER EAS 2-IG / Thermanit JE 308L	AWS A 5.9 ER308L EN 12072 W 19 9 L RCC-M S2910
		FCAW	BÖHLER EAS 2-FD	AWS A 5.22: E308LT0-4 EN ISO 17633 A T 19 9 L R M (C) 3
	S.S. 316 L	SMAW	BÖHLER FOX EAS 4 M R / Thermanit GE Spezial	AWS A 5.4 E316L-15 EN 1600 E 19 12 3 L B 2 2

Joining 4/4

	Alloy Group	Welding Process	Product Name	Classification AWS/EN
Stainless Steel			BÖHLER FOX EAS 4 M-AR / Thermanit GEW 316L-16	AWS A 5.4 E316L-16 EN 1600 E 19 12 3L R 3 2 RCC-M S 2925
			BÖHLER FOX EAS 4 M-A / Thermanit GEW 316L-17	AWS A 5.4 E316L-17 EN 1600 E 19 12 3 L R 3 2
		SAW Wire	Thermanit GE 316L / BÖHLER EAS 4 M-UP	AWS A 5.9 ER316L EN 12072 S 19 12 3 L
		SAW Flux	Marathon 431 / BÖHLER BB 202 / BÖHLER BB 203 / RECORD IND 24	EN 760 SA FB 2 DC - - -
		SAW Wire+Flux	Thermanit GE 316L + Marathon 431 / BÖHLER EAS 4 M-UP + BÖHLER	RCC-M S 2945 -
		GTAW	BÖHLER EAS 4 M-IG / Thermanit GE 316L	AWS A 5.9 ER316L EN 12072 W 19 12 3 L RCC-M S 2915
		FCAW	BÖHLER EAS 4 M-FD	AWS A 5.22: E316LT0-4 EN ISO 17633 A T 19 12 3 L R M (C) 3
	Austenitic Nb Stabilized S.S 321/347	SMAW	BÖHLER FOX SAS 2 R	AWS A 5.4 E347-15 EN 1600 E19 9 Nb B 2 2
			BÖHLER FOX SAS 2-A R	AWS A5.4 E347-16 EN 1600 E 19 9 Nb R 3 2
		SAW Wire	Thermanit H-347 / BÖHLER SAS 2-UP R	AWS A 5.9 ER347 EN 12072 S 19 9 Nb
		SAW Flux	Marathon 431 / BÖHLER BB 202 / BÖHLER BB 203 /	EN 760 SA FB 2 DC - -
		GTAW	BÖHLER SAS 2-IG R / Thermanit H-347	AWS A 5.9 ER347 EN 12072 W 19 9 Nb
Nickel-Base	Alloy 600 UNSN06600	SMAW	UTP 068 HH / BÖHLER FOX NIBAS 70/20 / Thermanit Nicro 82	AWS 5.11 ENiCrFe-3 (mod.) EN ISO 14172 ENi6082 -
			UTP 7015 / BÖHLER FOX NIBAS 70/15 / Thermanit Nicro 182	AWS 5.11 ENiCrFe-3 EN ISO 14173 ENi6182 -
		GTAW	UTP A 068 HH / BÖHLER NIBAS 70/20-IG / Thermanit Nicro 82	AWS A 5.14 ERNiCr-3 EN ISO 148274 S Ni 6082 RCC-M S 2985
		GMAW	UTP A 068 HH / BÖHLER NIBAS 70/20-IG / Thermanit Nicro 82	AWS A 5.14 ERNiCr-3 EN ISO 148274 S Ni 6082 -
	Alloy 625 UNS06625	SMAW	UTP 6222Mo / Thermanit 625	AWS A5.11 ENiCrMo-3 EN ISO 14172 ENi6625
		GTAW	UTP A 6222 Mo / Thermanit 625	AWS A5.14 ERNiCrMo-3 EN ISO 18274 S NI 6625
		GMAW	UTP A 6222 Mo / Thermanit 625	AWS A5.14 ERNiCrMo-3 EN ISO 18274 S NI 6625
	Alloy 690 UNS06690	SMAW	UTP 6229Mn / Thermanit 690	AWS A5.11 ENiCRFe-7 EN ISO 14172 ENi6152 RCC-M S 2986
		GTAW	Thermanit 690	AWS A5,14 ERNiCrFe-7 EN ISO 18274 S Ni 6052 RCC-M S 2981
		GMAW	Thermanit 690	AWS A5,14 ERNiCrFe-7 EN ISO 18274 S Ni6052

Strip Cladding

	Deposited Alloy	Welding Process	Layer	Strip	Flux
Stainless Steel	S.S 308L	SAW	1st Layer	SOUDOTAPE 309 L Q5	RECORD INT 101 Q5
			2nd Layer	SOUDOTAPE 308 L Q5	RECORD INT 101 Q5
			3rd Layer	SOUDOTAPE 308 L Q5	RECORD INT 101 Q5
		SAW	1st Layer	SOUDOTAPE 309 L Q5	RECORD 9V308T1 Q5
			2nd Layer	SOUDOTAPE 308 L Q5	RECORD 8B308T2 Q5
			3rd Layer	SOUDOTAPE 308 L Q5	RECORD 8B308T2 Q5
		SAW tensile strength >520 Mpa	1st Layer	SOUDOTAPE 309 L Q5	RECORD INT 101 Q5
			2nd Layer	SOUDOTAPE 308 L Q5	RECORD INT 120 Q5
			3rd Layer	SOUDOTAPE 308 L Q5	RECORD INT 120 Q5
		ESW	1st Layer	SOUDOTAPE 309 L Q5	RECORD EST 122 Q5
			2nd Layer	SOUDOTAPE 308 L Q5	RECORD EST 122 Q5
		ESW High Speed	1st Layer	SOUDOTAPE 309 L Q5	RECORD EST 136 Q5
			2nd Layer	SOUDOTAPE 308 L Q5	RECORD EST 136 CR Q5
	S.S 347	SAW	1st Layer	SOUDOTAPE 309 L Q5	RECORD INT 109 Q5
			2nd Layer	SOUDOTAPE 347 Q5	RECORD INT 109 Q5
Nickel-Base	Alloy 600	SAW	1st Layer	SOUDOTAPE NiCr3 Q5	RECORD NiCr 3T Q5
			2nd Layer	SOUDOTAPE NiCr3 Q5	RECORD NiCr 3T Q5
			3nd Layer	SOUDOTAPE NiCr3 Q5	RECORD NiCr 3T Q5
		ESW	1st Layer	SOUDOTAPE NiCr3 Q5	RECORD EST 201 Q5
			2nd Layer	SOUDOTAPE NiCr3 Q5	RECORD EST 201 Q5
			3rd Layer	SOUDOTAPE NiCr3 Q5	RECORD EST 201 Q5
	Alloy 690 with strip EQNiCrFe-14	SAW	1st Layer	SOUDOTAPE 690 Q5	RECORD NFT 690 Q5
			2nd Layer	SOUDOTAPE 690 Q5	RECORD NFT 690 Q5
			3rd Layer	SOUDOTAPE 690 Q5	RECORD NFT 690 Q5
		ESW	1st Layer	SOUDOTAPE 690 Q5	RECORD EST 690 Q5
			2nd Layer	SOUDOTAPE 690 Q5	RECORD EST 690 Q5
	Alloy 690 with strip EQNiCrFe-7	SAW	1st Layer	SOUDOTAPE NiCrFe-7 Q5	RECORD NFT NiCrFe-7 Q5
			2nd Layer	SOUDOTAPE NiCrFe-7 Q5	RECORD NFT NiCrFe-7 Q5
			3rd Layer	SOUDOTAPE NiCrFe-7 Q5	RECORD NFT NiCrFe-7 Q5
		ESW	1st Layer	SOUDOTAPE NiCrFe-7 Q5	RECORD EST NiCrFe-7 Q5
			2nd Layer	SOUDOTAPE NiCrFe-7 Q5	RECORD EST NiCrFe-7 Q5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