Lasting Connections

WELDING SOLUTIONS FOR OIL & GAS DOWNSTREAM

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.

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

SPECIALIZED WELDING CONSUMABLES FOR THE OIL & GAS DOWNSTREAM INDUSTRY

Böhler Welding has more than 30 years of experience in the production of welding consumables for critical process equipment (CPE) and furnace tubes for demanding applications. Amongst others, we provide best-in-class CrMo and CrMoV welding consumables, fulfilling and often exceeding the requirements of relevant API recommended practices, the applicable codes, as well as the specifications used in the industry. They feature excellent toughness at low temperature, high resistance to temper embrittlement, creep resistance and all the needed mechanical properties.

We supply weld overlay solutions for a wide number of alloys, including innovative single layer and high speed strip cladding, with proven corrosion resistance and disbonding properties. Last but not least we provide well referenced solutions for centrifugal casting tubes, with filler metals matching the base material grades.

Oil and gas play an important role in the future global energy supply model. However, the emergence of new and unconventional sources of oil and gas will change the landscape with regard to extraction and processing in many significant ways. Upstream Oil & Gas refers to the search for crude oil and natural gas, followed by their recovery and production. This segment is also referred to as the Exploration and Production (E&P) sector; it includes the search for potential underground or sub-sea oil and gas fields, the drilling of exploratory wells, and the subsequent drilling and operation of the wells that recover and bring the crude oil and/or raw natural gas to the surface. Downstream Oil & Gas refers to the refining and processing of the extracted oil and gas from both conventional and unconventional resources. This segment is also referred to as hydrocarbon processing and includes refineries, natural gas processing plants, Olefins and Aromatics as well as Methanol plants.

voestalpine Böhler Welding provides solutions driven by its high-quality welding consumables for safe, efficient, and cost-effective operation of upstream, midstream, and downstream facilities and equipment to these segments worldwide. These products are supplied by regional manufacturing, development, sales, and support units under a range of products that are recognized worldwide.

OIL & GAS DOWNSTREAM – WALKING ON THE EDGE OF STEEL LIMITS

Global demand for fuel products is increasing. The quality of petroleum compounds, such as crude oil or natural gas that is extracted in different geographical locations varies, and extra-heavy oil is playing a more significant role than in the past. More sources of unconventional oil and gas from oil sands and shale have been recently explored, and they have been receiving a great deal of attention. Today, environmental regulations with regard to fuels and petrochemical products have become more stringent.

All these variables put together a complicated function in front of the oil and gas “super-majors” to make top-quality products especially from extra-heavy feedstock, and still achieve a healthy margin. As shown in this road map derived from the key drivers, the main challenge in setting defined objectives and developing solutions is to maintain the integrity of the process component while dealing with a wide range of damage mechanisms.

These additional damage mechanisms are either related to the unconventional feedstock or enhanced service conditions. In recent years, steel manufacturers have been developing better steel grades to withstand such service conditions. One must take into consideration that steel products need to be welded or cladded by weldoverlay; it is at this point that customers face the main welding challenges.

A good example is development of vanadium-enhanced Cr-Mo steels, which require special weld fabrication expertise. Welding consumables may seem to be a very small part of this industry, but almost all oil and gas downstream experts confirm that welding and welding technologies are the main drivers in the development of optimized process reactors and furnaces. The requirements for welding consumables in the downstream segment are generally considered to be more stringent than the conventional standard requirements for the same grades in other fields.

In the following, we will summarize the most important damage mechanisms in each of the three main plants. We will also be providing information about two of the major challenges: fabrication of hydroprocessing reactors (Page 8) and reforming / cracking furnaces (Page 13).

Key Drivers	Objectives	Process Solutions
Environmental Regulations	» Cleaner Fuel » Lower CO_2 Emission » Lower Sulfur	» Hydrotreating » Refinery Upgrade
Refining Market Pressure	» Flexibility on Feedstock » Increase the Yield » High Yield from Heavy Crude	» Conversion Units » High Nelson Complexity
Unconventional Oil/Gas	» Shale Gas in the Value chain » Reasonable Yield from Oil Sands » Utilize Extra Sour Gas » Gas to Liquid Fuel	» Conversion Units » Gas Processing » GTL
Operational Costs	» Optimizing Energy Consumption » Maximize Component Lifetime » Minimize M&R Costs	» Wider use of CRA » Wider use Cladding

Damage Mechanism

OIL REFINERIES

Hydrocarbon molecules come in many different sizes and shapes that generally depend on the quality of the crude oil. In an oil refinery, five different process categories are utilized to achieve both a higher yield and cleaner fuel.

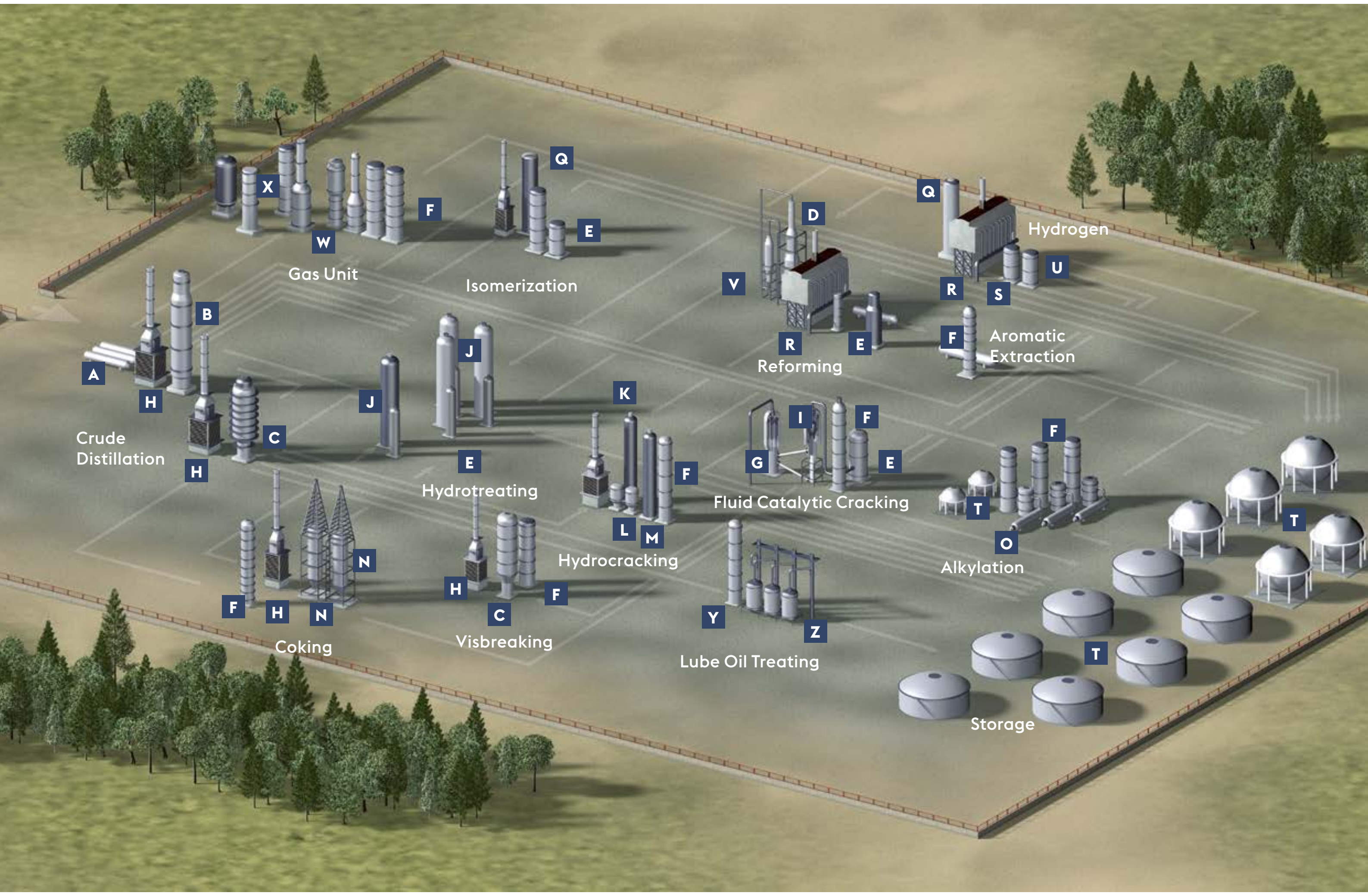


Table A: Alloy choices for major refinery components

Components		Joining Alloy Choices																			Weld-Overlay Deposit Choices											
		C-Mn	C- ½ Mo	1 ¼ Cr ½ Mo	2 ¼ Cr 1 Mo	2 ¼ Cr 1 Mo ¼ V	5 Cr ½ Mo	9 Cr 1 Mo	S.S 304H	S.S 310	Alloy 800 / 800H	Alloy HP / HP Nb	S.S 347	Alloy 600	Alloy 625	Alloy 825	Alloy 617	1% Ni	2.5% Ni	3% Ni	S.S 410S	S.S 308L	S.S 308H	S.S 316L	S.S 317L	S.S 347	Alloy 254 SMo	Alloy 276	Alloy 825	Alloy 625	Alloy 400	Alloy 200
A	Desalter	•																				•					•		•	•		
B	Atmospheric Distillation Tower	•																			•			•	•							
C	Vacuum Distillation Tower	•																														
D	Naphtha Reformer Reactor			•																												
E	Feed/Effluent Heat Exchanger		•	•	•	•																•		•		•					•	•
F	Fractionator	•		•																	•	•		•							•	•
G	FCC Regenerator	•	•																				•									
H	Fired Heater								•	•																						
I	FCC Reactor				•	•															•											
J	HDS Reactor	•			•	•																				•						
K	Hydrocracking Reactor				•	•																				•						
L	Hot Separator				•																					•						
M	Cold Separator	•																						•								
N	Coke Drum			•																	•									•		
O	Alkylation Reactor	•																											•	•	•	•
P	Post Heater/Furnace Piping						•	•	•	•			•																			
Q	Hydrogenation Reactor			•	•												•									•						
R	Steam Reformer Furnace										•	•																				
S	Low Temp. Shift Convertor	•																														
T	Storage Tanks	•																•	•	•												
U	High Temp. Shift Convertor			•																												
V	CCR Regenerator		•								•	•																				
W	Sulfur Recovery Piping													•	•	•																
X	Sour Water Stripper	•																										•				
Y	Extraction Tower	•																			•			•	•							
Z	Evaporator	•							•	•																						

- Fractionating hydrocarbon molecules by size, e.g., in a crude distillation unit
- Cracking larger molecules into smaller ones, e.g., in a fluid catalytic cracking unit or a hydrocracking unit
- Combining smaller hydrocarbon molecules into larger molecules, e.g., in an alkylation unit
- Changing the molecule shapes, e.g., in a catalytic reforming unit
- Hydrotreating units are also needed to reduce sulfur, aromatics, nitrogen, oxygen, and metals while enhancing the combustion quality, density, and smoke point of fuels

Depending on the process, its feedstock and operating conditions, various damage mechanisms can pose a threat to the life cycle of a refinery, to equipment integrity, and to plant safety. Many of these damage mechanisms can directly or indirectly relate the quality of welding consumables and welding condition. Some of the major damage mechanisms are listed in this text.

The choices regarding the base material used for critical process equipment in a refinery as well as for weld-overlay cladding are limited. Some of these choices are listed in Table A, which refers directly to the relevant product for the target grade.

Table B: Damage mechanisms

Unit	Damage Mechanisms
Crude Distillation Unit	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Creep / Stress Rupture
	Polythionic Acid Stress Corrosion
	Naphetanic Acid Corrosion
	Ammonium Chloride Corrosion
	HCl Corrosion
	Caustic Corrosion / Cracking
	Erosion / Erosion-Corrosion
	Aqueous Organic Acid Corrosion
	Fuel Ash Corrosion

Unit	Damage Mechanisms
Gas Unit	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Ammonium Bisulfid Corrosion
	Chloride SCC
	Flue Gas Dew Point Corrosion
	Amine Corrosion / Cracking
	Titanium Hybriding
	Sulfuric Acid Corrosion
Isomerization Unit	High Temperature Hydrogen Attack (HTHA)
	HCl Corrosion
	Caustic Corrosion / Cracking

Unit	Damage Mechanisms
Crude Distillation Unit	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Creep / Stress Rupture
	Polythionic Acid Stress Corrosion
	Naphetanic Acid Corrosion
	Ammonium Chloride Corrosion
	HCl Corrosion
	Caustic Corrosion / Cracking
	Erosion / Erosion-Corrosion
	Aqueous Organic Acid Corrosion
	Fuel Ash Corrosion
Gas Unit	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Ammonium Bisulfid Corrosion
	Chloride SCC
	Flue Gas Dew Point Corrosion
	Amine Corrosion / Cracking
	Titanium Hybriding
	Sulfuric Acid Corrosion
Isomerization Unit	High Temperature Hydrogen Attack (HTHA)
	HCl Corrosion
	Caustic Corrosion / Cracking
Delayed Coking	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Creep / Stress Rupture
	Naphetanic Acid Corrosion
	Ammonium Chloride Corrosion
	Ammonium Bisulfide Corrosion
	Thermal Fatigue
	Carburizaion
	Dealloying
	Carbonate SCC
Hydrotreating & Hydrocracking Unit	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	High Temperature Hydrogen Attack
	High Temperature H2/H2S Corrosion
	Polythionic Acid Stress Corrosion
	Naphetanic Acid Corrosion
	Creep / Stress Rupture
	Temper Embrittlement
	Ammonium Chloride Corrosion
	Ammonium Bisulfide Corrosion
	Amine Corrosion / Cracking
	Hydrogen Embrittlement
	Chloride Stress Corrosion Cracking
	Brittle Fracture
	Reheat Cracking

Unit	Damage Mechanisms
Visbreaking	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Polythionic Acid Corrosion
	Naphetanic Acid Corrosion
	Ammonium
	Ammonium Chloride Corrosion
	Ammonium Bisulfide Corrosion
	Carburization
	Chloride SCC
	Creep / Stress Rupture
	Sour Water Corrosion
FCCU	Sulfidation
	Wet H2S Damage (Blistering/HIC/SOHIC/SCC)
	Creep / Stress Rupture
	Polythionic Acid Stress Corrosion
	Naphetanic Acid Corrosion
	Ammonium Chloride Corrosion
	Thermal Fatigue
	Graphitization
	Temper Embrittlment
	Decarburization
	Carburization
	Reheat Cracking
Catalytic Reforming	High Temperature Hydrogen Attack
	HCl Corrosion
	Creep / Stress Rupture
	Temper Embrittlment
	Carburization
	Hydrogen Embrittlement
	Ammonia SCC
	Mechanical Fatigue
	Metal Dusting
Lube Oil	Phenol (Cabolic Acid) Corrosion
Alkylation	Caustic Corrosion / Cracking
	HF Acid Corrosion
	Erosion / Erosion-Corrosion
	Hydrogen Stress Corrosion HF
	Galvanic Corrosion
	Dissimilar Weld Metal (DMW) Cracking
Hydrogen Unit	High Temperature Hydrogen Attack (HTHA)
	Thermal Fatigue
	Temper Embrittlement
	Carbonate SCC
	Amine Corrosion / Cracking
	Chloride SCC
	Thermal shock
	Reheat Cracking
	CO_2 Corrosion
	Metal Dusting

HYDROPROCESSING REACTORS

Production of cleaner fuels in accordance with current standards requires a refinery to use hydrotreating units to reduce sulfur, aromatics, nitrogen, oxygen, and metals while improving the combustion quality and smoke point of naphtha, diesel, and kerosene.

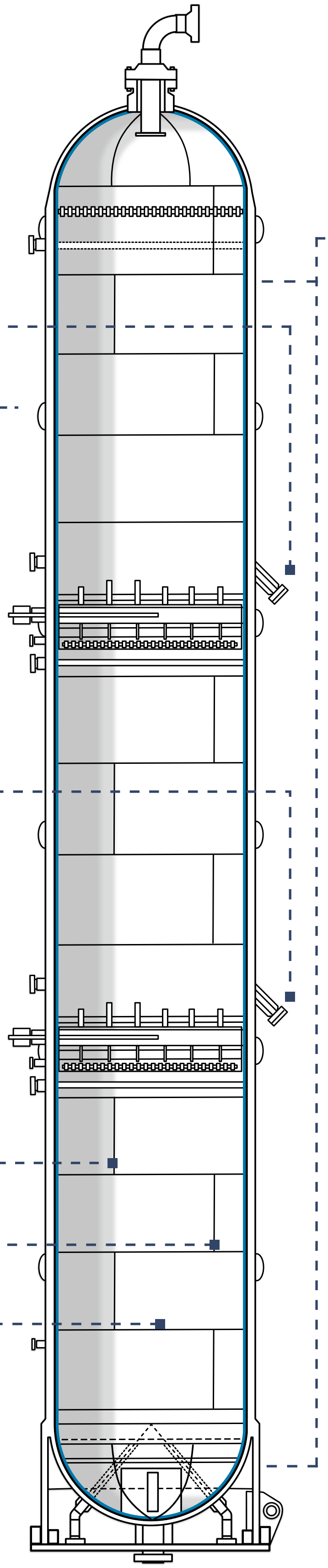
Hydrotreating / hydrodesulphurization (HDS) reactors are critical equipment in a hydrotreating unit.

In order to increase the refinery's yield rate, however, conversion units are needed to crack the vacuum gas oil (VGO) and the atmospheric gas oil (AGO) as well as the gas oil from the coker and the visbreaker units. This method enables the refinery to process the residual oil ("the bottom-of-the-barrel"). For example, hydrocracking is a catalytic cracking process that is assisted by the presence of hydrogen. In this case, hydrocracking reactors are the critical equipment.

The common element among hydroprocessing reactors of this type is the use of advanced 2.25Cr-1Mo-0.25V material, which has numerous merits over conventional grade material, including greater tensile strength at elevated temperatures, enabling the industry to use reactors with lower wall thickness and weight (about 25% less weight). Additionally, it makes reactors less susceptible to damage mechanisms, such as temper embrittlement and high temperature hydrogen attack (HTHA) and last but not least, it provides stronger resistance to weld overlay disbonding induced by hot hydrogen.

Despite all these advantages, weld fabrication of reactors made of this grade of material ultimately becomes challenging due to various material sensitivities. e.g., weld cracking and re-heat cracking. Furthermore, intermediate and post-weld heat treatment as well as non-destructive examination (NDE) requires a different – and very precise – process compared to conventional 2.25Cr-1Mo grades. An example is the Time Of Flight Diffraction (TOFD) ultrasonic test.

Let's take a brief look at the welding of a hydroprocessing reactor:



B Nozzle welds

Piping nozzles, instrumentation nozzles, as well as the hand holes are critical areas as they are the only openings of the reactor and must thereby withstand conditions within the reactor. The conventional method represents the use of the SMAW process for the nozzle welds, but experienced fabricators currently use single-wire SAW. Due to the especially restrained condition of the joint, ISR (intermediate stress relieving) is of paramount importance.

D Weld overlay

The usual overlay deposit for such reactors is S.S 347. Depending on the accessibility and the cladding area, different processes are chosen:

Inside reactor: Strip cladding SAW, ESW 2 layer, ESW single layer, ESW high speed
Inside nozzles, fittings and restoration: FCAW, SMAW, GTAW
Weld-overlay build-up of the internal "supports": SMAW, GTAW. CrMo-22V FCAW 347

An important point to Cr-Mo 22V build up overlay is the necessity of ISR (intermediate stress relieving) due to restrained condition.

A Fabrication of the reactor shell

Depending on the design requirements and the wall thickness, shell material can be fabricated from plate or forged rings. If plates are used, they must be re-rolled and longitudinally welded to form a ring. A combination of both plate rings and forged rings is also possible, for example, forged rings for the quench zone and support skirt and plate rings for the rest of the shell arrangement. Narrow gap submerged arc welding (SAW), either with tandem or single wire, is the process of choice. With our wire/flux combination and the corresponding parameter setting, it is feasible to have the smallest possible opening, which significantly reduces the consumption of filler metals and welding time. A smaller amount of GTAW rod and SMAW electrode is also deposited.

Longitudinal Joints: ASME SA542 Gr. D CL 4a. ASME SA832 Gr. 22V

Circumferential Joints:
Forged rings: ASME SA336 Gr. F22V
Plate-fabricated rings: ASME SA832 Gr. 22V or ASME SA542 Gr. D, CL 4a

C **Shell to dished end / dished end to support welds**

Heads are either single-piece or multi-piece welded. Precise joint alignment is also needed as the dished end has a lower wall thickness compared to the shell. If forged profiles are used, skirt to bottom is sometimes a single forged piece.

E **Heat treatment**

DHT: Dehydrogenation heat treatment of 350° C for 4 hours is essential to minimize the susceptibility to cold cracking due to residual hydrogen in the weld.
ISR: Intermediate stress relieving is necessary, especially for highly restrained joints such as nozzle welds. The recommended temperature for ISR is 650 – 670° C for 4 hours to ensure a partial elimination of the residual stresses in the weld.
PWHT: Post weld heat treatment for CrMo-22V has a very narrow tolerance in comparison to conventional steel grades. The recommended PWHT is 705° C for 8 hours.
Max PWHT: Several heat treatments are applied during fabrication, including DHT, ISR, and final PWHT. Sometimes, repairs are undertaken during fabrication. An additional cycle should be planned for any necessary repairs after installation. A maximum PWHT condition, which has an equal effect of all previously cited PWHT cycles, must be simulated. To that end, and to define one PWHT condition that covers all cycles, the Hollomon parameter (HP) of all the PWHTs should be calculated and then for any given time a PWHT temperature can be calculated vice versa.

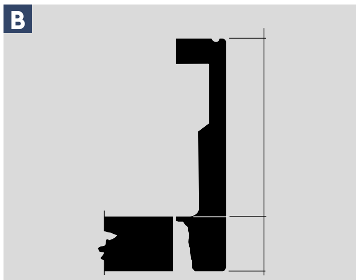
$HP = (273°C + T) \times (20 + \log10(t/60))\ 10\text{-}3$
$T = 103\ HP/(20 + \log10(t/60))\text{-}273°C$
$t = 60 \times 10(1000\ HP/(273°C + T)\text{-}20)$
Step cooling: is done to simulate an accelerated embrittlement for evaluation of potential temper embrittlement.

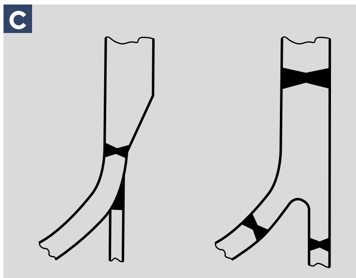
F **Reheat cracking and tramp elements**

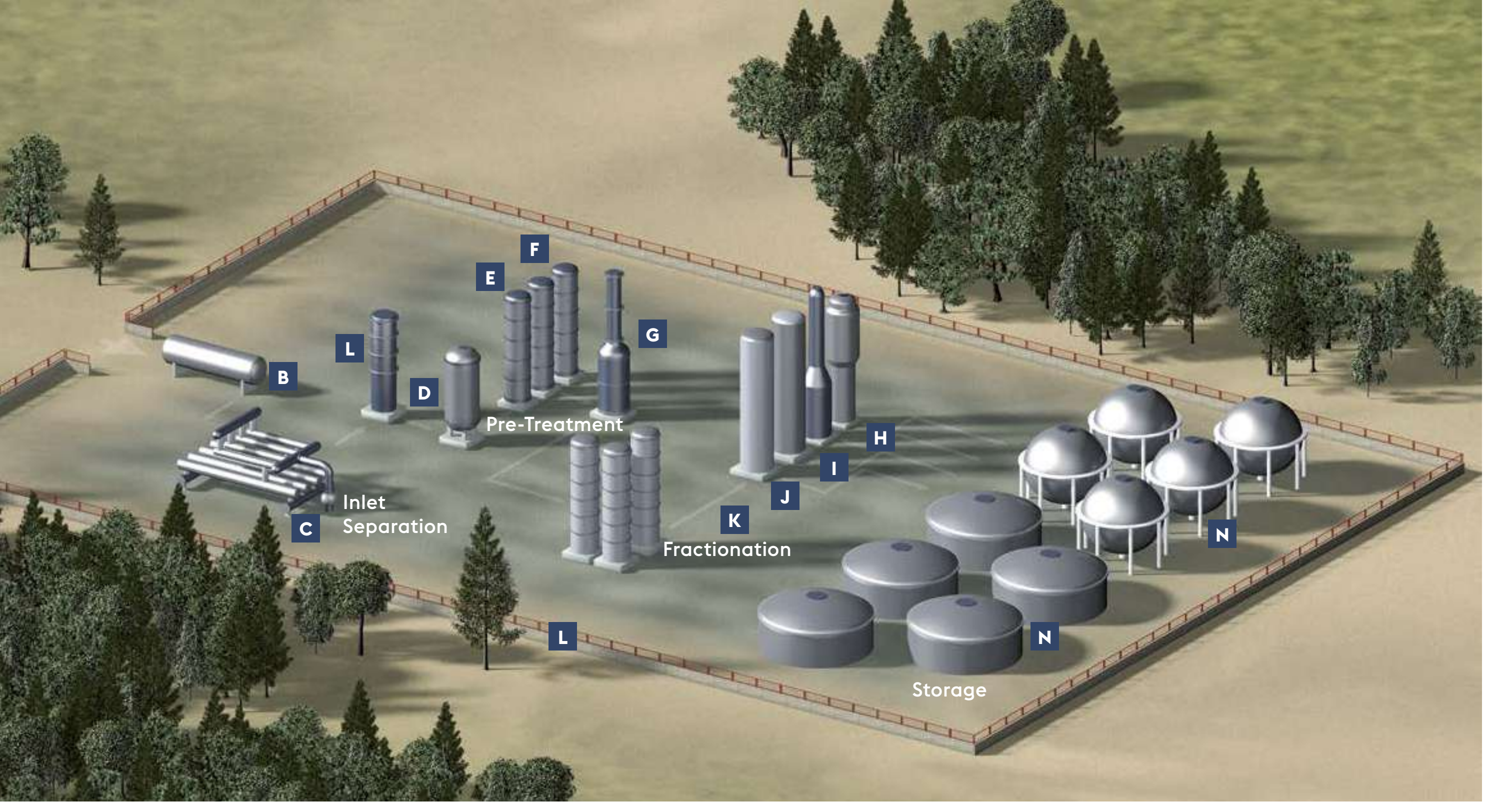
Since introduction of this material, the industry has encountered many difficulties due to reheat cracking after PWHT. With precisely controlled amount of the tramp elements (Typical X factor: 8 and typical K factor: 0.7), the reheat cracking problem is under control.

G **Standard codes; recommended practices**

ASME BPVC Section VIII Division 2, API RP 934A, API RP582, ASTM G146-01







GAS PROCESSING

In the form it is extracted, natural gas cannot be used as fuel or feedstock. It needs to be treated in gas processing plants. Irrespective of whether a gas processing plant is constructed for a specific gas field or inside a refinery to process refinery gases, it generally contains:

The global gas resource landscape has changed significantly within the past decade. Unconventional gas, so called either due to its quality (sour and ultra-sour gas) or its source (shale gas, coal gas), has begun to play an important role. As such, there is a need for different solid or weld overlaid corrosion resistance alloys in different separators and fractionators. Examples are the injection lines, inlet separators, and slug catcher manifold / drums in which – depending on the sourness of the gas – S.S 316L, Alloy 825, or Alloy 625 weld overlay is applied.

Selection of the base material can also vary depending on the operating pressure or job site temperature. Use of carbon steel as well as low alloy / chrome-molly alloys is possible depending on the operating conditions.

Inlet facilities: To separate natural gas from water and impurities. These facilities can also include slug catcher manifold/drum
Pre-treatment: To remove sulfur, H2O, Hg, and CO_2 from natural gas
Fractionation: To fractionate different gaseous and NGL hydrocarbons

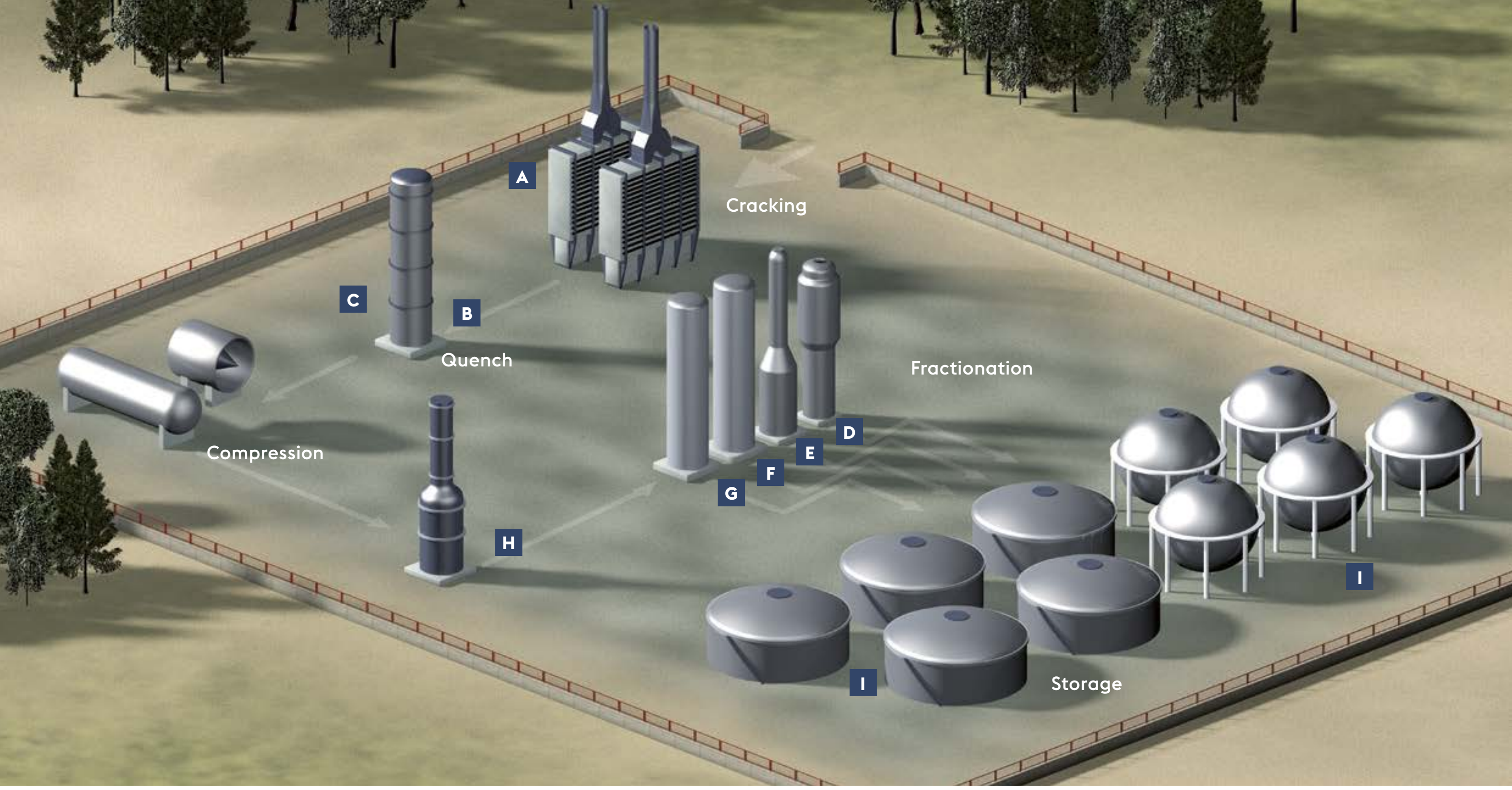
Table D: Alloy choices for main gas processing components

Components		Joining Alloy Choices									Weld-Overlay Deposit Choices							
		C-Mn	1 ¼ Cr ½ Mo	2¼ Cr 1Mo	S.S 316L	Alloy 625	1% Ni	2.5% Ni	3% Ni	Alloy 22	S.S 308L	S.S 316L	S.S 317L	Alloy 254 SMo	Alloy 276	Alloy 825	Alloy 625	Alloy 22
A	Sour Gas Injection Pipes			•														
B	Slug Catcher Drum	•										•		•			•	
C	Slug Catcher Manifold	•										•		•			•	
D	Inlet Separator	•										•		•		•	•	
E	Sour Water Stripper	•																
F	Dehydrator	•																
G	Amine Regenerator	•										•					•	
H	De-Methanizer	•			•							•					•	
I	De-Ethanizer	•			•							•						
J	De-Propanizer	•																
K	De-Butanizer	•																
L	Fractionator	•									•							
M	Sulfur Recovery Line	•			•	•										•	•	
N	Storage Tanks	•					•	•	•									
O	Flue Gas Desulphurization									•								•

In Table D, we have listed some of the critical process equipment in a gas processing plant. A number of the major damage mechanisms in a typical gas processing plant are listed in Table C. Some of these damage mechanisms can be controlled by selecting high-quality base material and welding consumables.

Table C: Damage mechanisms

Unit	Damage Mechanism
Inlet Facilities	Wet H2S Blistering
	Wet H2S HIC
	Wet H2S SOHIC
	Wet H2S SCC
	Slugging
	Amine Degradation Corrosion
Pre-Treatment	Sulfidation
	Wet H2S damage (Blistering/HIC/SOHIC/SCC)
	Ammonium Bisulfide
	Alkaline SCC
	Erosion / Erosion-Corrosion
	Amine Cracking
	Amine Corrosion
	CO_2 Corrosion
	Chloride Stress Corrosion Cracking
	Titanium Hybriding
	Sulfuric Acid
	Mercury Attack Corrosion
	Flue Gas Dew Point Corrosion



OLEFINS AND AROMATICS

Olefins (such as Ethylene and Propylene) and Aromatics (Benzene, Toluene, and Xylene) are key products in the petrochemical industry. Naphtha from the oil refinery enters the cracking furnace and is cracked by being heated to 1,150°C. The cracked hydrocarbon enters the quench oil / water columns. The gases are then compressed and liquefied in different temperatures down to -150°C.

A cracker furnace represents the heart of a plant (a description follows on the next page). voestalpine Böhler Welding draws upon many years of experience in the production of filler metals for welding the cracker furnace tubes. A plant has both high-temperature parts and low-temperature areas. Various hydocarbons have very low boiling temperatures and therefore, low-temperature steels grades are needed for transport and storage of these materials within the plant. Some cryogenic products are listed in the products table of this brochure. However, all the LPG- and LNG-related products are separately described in our LNG/ LPG brochure.

In Table F, we have listed some of the critical process equipment in an Olefin / Aromatic plant. A number of the major damage mechanisms from typical olefins/aromatics are listed in Table G. Some of these damage mechanisms can be controlled by selecting high-quality base material and welding consumables.

Table F: Alloy choices for main olefin/aromatic plant components

Components		Joining Alloy Choices											Weld-Overlay Deposit Choices		
		C-Mn	Alloy 35 / 45 Nb	5Cr ½Mo	9Cr 1Mo	S.S 316L	S.S 347	S.S 310	S.S304H	1% Ni	2.5% Ni	3% Ni	S.S 308L	S.S 316L	Alloy 625
A	Cracking Furnace		•												
B	Post Furnace Piping			•	•		•	•	•						
C	Quench Column	•											•	•	
D	De-Methanizer	•				•								•	•
E	De-Ethanizer	•				•								•	•
F	De-Propanizer	•													
G	De-Butanizer	•													
H	Ethylene Oxide Reactor	•													
I	Storage Tanks									•	•	•			

Table E: Steel choices for cryogenic application

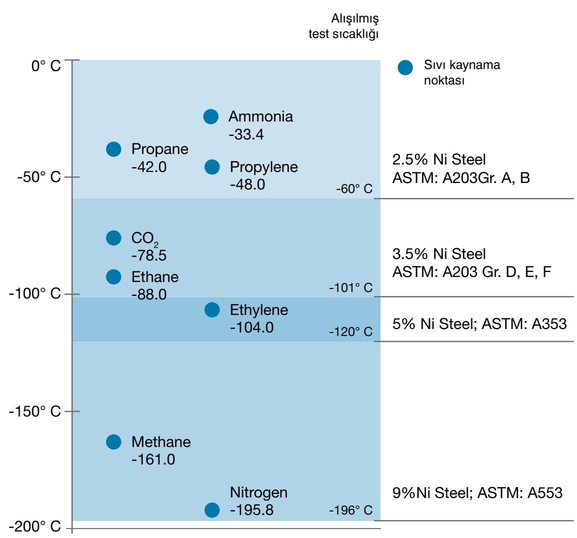


Table G: Damage mechanisms

Unit	Damage Mechanism
Cracking	Creep / Stress Rupture
	Carburization
	Temper Embrittlement
	Thermal Shock
	Graphitization
	Thermal Fatigue
	Caustic Corrosion
	Caustic Crack
Quench	Caustic Corrosion
Fractionation	Caustic Crack
	Low Temperature Embrittlement

WELDING OF REFORMER AND CRACKER TUBES

In petroleum refining, there is the demand for a steam / catalytic reforming process that reforms the hydrocarbon molecule to a desired shape. This process is also used for hydrogen production in the hydrogen unit of large-scale refineries, where very large amounts of process hydrogen are needed. The operating temperature can exceed 900°C.

In petrochemical plants, e.g., in Olefin and Aromatic plants, naphtha from the refinery first enters into a cracker, the heart of the plant. The temperature in the cracker furnace can exceed 1,150°C. The cracking process leaves coke on the tube walls, which results in higher temperatures that can reach the operational limits.

In both of the above-mentioned applications, centrifugally cast tubes represent the main element of the process. The tubes and the respective welded joints must be able to withstand numerous damage mechanisms, including but not limited to creep / stress rupture, carburization, and fatigue. Being able to balance increased strength, higher creep resistance, and greater toughness has been a challenge for the industry.

Over decades, the industry has benefited from the introduction of new alloys with various Cr and Ni content and the addition of alloying elements, such as Si, Ti, Zr, Nb, Mo, Co, etc. to create the ability to withstand higher operating temperatures and, at the same time, to reach reasonable creep strength and carburization resistance.

Over-alloyed welding consumables have always been available in our portfolio, but similar or matching consumables for every new tube grade have been what we offer in order to minimize the difference between the thermal expansion coefficient in the weld joint and the tube; this enables a longer life cycle of the welded tubing.

A list of the main products for the welding of furnace tubes is provided in the product section of this brochure.

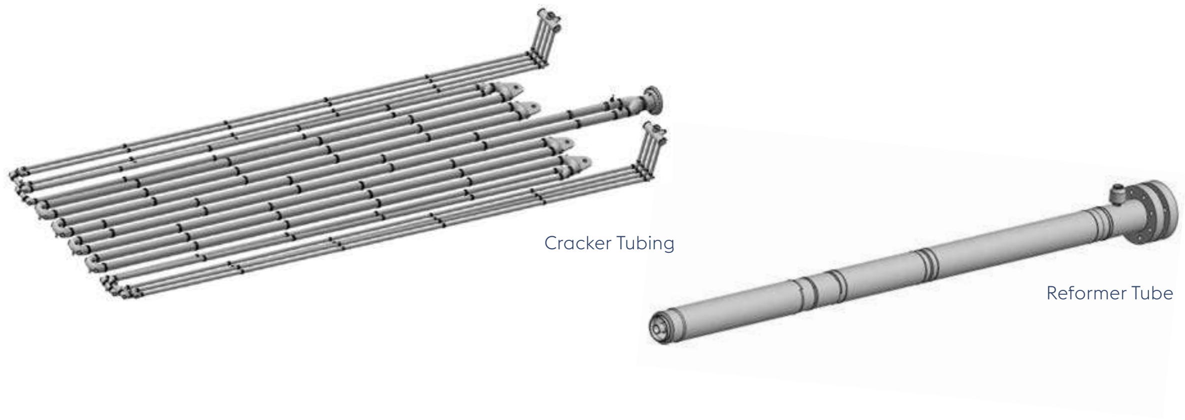
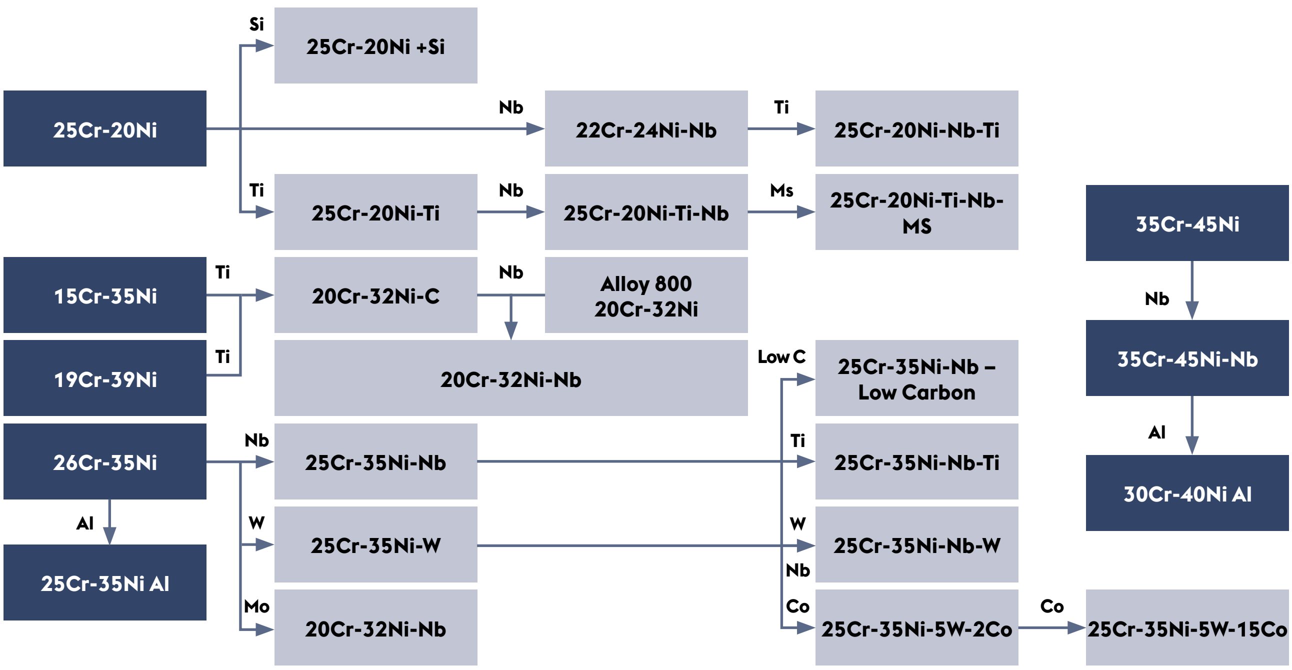


Table H: Cast tube alloy evolution



REFERENCES

HELPE Refinery Greece

Fabricator name: Larsen and Toubro
Component: Hydrocracking Reactor (970 MT)
Base material: CrMo-22V (292mm)
Joining products: SMAW: Phoenix Chromo 2V
GTAW: Union I CrMo 2V
SAW wire: Union S1 CrMo 2V
SAW Flux: UV 430 TTR-W

Burgas Refinery Bulgaria

Fabricator name: Belleli Energy CPE S.r.L
Component: Hydroprocessing Reactors
Base material: CrMo-22V + S.S 347 (240 + 3mm)
Joining products: SMAW: Phoenix Chromo 2V
GTAW: Union I CrMo 2V
SAW wire: Union S1 CrMo 2V
SAW Flux: UV 430 TTR-W
Cladding Products: Strip: Soudotape 21.11 LNb,
Flux: Record EST 122

Mina Abduallah and Mina Al-Ahmadi Refinery Kuwait

Fabricator name: Larsen and Toubro
Component: 22 Hydroprocessing Reactors
Base material: CrMo 22, CrMo-22V
Joining products: SMAW: Phoenix SH Chromo 2 KS, Phoenix Chromo 2V
GTAW: Union I CrMo 910 Spezial, Union I CrMo 2V
SAW wire: Union S1 CrMo 2, Union S1 CrMo 2V
SAW Flux: UV 420 TTR-W, UV 430 TTR-W

This is a short list of some of our partners:

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Joining 1/6

	Alloy Group	Base Material Examples	Welding Process	Product Name	Classification AWS/EN
Unalloyed Steels	C-Mn	Plate: ASME SA516 GR. 55 Plate: ASME SA516 GR. 60	SMAW	BÖHLER FOX EV 47	AWS A5.1: E7016-1H4R EN ISO 2560-A: E 38 4 B 42 H5
		Plate: ASME SA516 GR. 65 Plate: ASME SA516 GR. 70		BÖHLER FOX EV 50	EN ISO 2560-A: E 42 5 B 42 H5 AWS A5.1: E7018-1H4R
		Forged: ASME SA181 Gr. F1 Pipe: ASME SA105 Gr. A, B, C	SAW Wire	Union S 2 Si	AWS A5.17 EM12K EN ISO 14171 S2Si
		Pipe: ASME SA106 Gr. A, B, C Tube: ASME SA210 Gr. A, B, C	SAW Flux	UV 418 TT	EN ISO 14174 SA FB 1 55 AC H5
			SAW Wire+Flux	Union S 2 Si + UV 418 TT	AWS A5.17-SFA 5.17 F7A6-EM12K EN ISO 14171-S 42 5 FB S2Si
			SAW Wire	Union S 3 Si + UV 418 TT	AWS A5.17 EH12K EN ISO 14171 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 EN ISO 14171-S 46 6 FB S3Si
			GTAW	BÖHLER EMK 6	AWS A5.18: ER70S-6 EN ISO 636-A: W 42 5 W3Si1
				BÖHLER EML 5	AWS A5.18 ER70S-3 EN ISO 636-A: W 46 5 W2Si
			GMAW	BÖHLER EMK 6	AWS A5.18: ER70S-6 EN ISO 14341-A: G3Si1 (wire)/ G 42 4 M21 3Si1
			FCAW	BÖHLER Ti 52-FD	AWS A5.36: E71T-1M21A4-CS1-H8 E71T-1-C1A2-CS1-H4 EN ISO 17632-A: T 46 4 P M 1 H10 EN ISO 17632-A T 42 2 P C 1 H5
Low-alloyed Pressure Vessel Steels	C- ½ Mo	Plate: ASME SA571 Gr. J Fitting: ASME SA 234 WP1, WP1	SMAW	BÖHLER FOX DMO Kb	AWS A5.5: E7018-A1H4R EN ISO 2560-A: E Mo B B 42 H5
		Forging: ASME SA336 Gr. F1 Forged Fitting: ASME SA 182 Gr. F1	SAW Wire	Union S 2 Mo	AWS A5.23 EA2 EN ISO 14171 S2Mo / EN ISO 24598-A S S Mo
		Pipe: ASME SA 335 Gr. P1 Tube: ASME SA 250 Gr. T1a, T1b	SAW Flux	UV 418 TT	- EN ISO 14174 SA FB 1 55 AC H5
		Tube: ASME SA209 Gr. T1 Tube: EN10216-2: 16Mo3	SAW Wire+Flux	Union S 2 Mo + UV 418 TT	AWS A5.23-SFA 5.23 F8A6-EA2-A2 EN ISO 14171 S46 4 FB S2Mo
			GTAW	BÖHLER DMO-IG	AWS A5.28: ER70S-A1 (ER80S-G) EN ISO 21952-A: W Mo Si
			GMAW	BÖHLER DMO-IG	AWS A5.28: ER70S-A1 (ER80S-G) EN ISO 21952-A: G Mo Si

Joining 2/6

	Alloy Group	Base Material Examples	Welding Process	Product Name	Classification AWS/EN
Low-alloyed Pressure Vessel Steels			FCAW	BÖHLER DMO TI-FD	AWS A5.36: E81T1-M21PY-A1H8 EN ISO 17634-A: T MoL P M 1 H10
	1 ¼ Cr ½ Mo 1 Cr ½ Mo	Plate: ASME SA387 Gr. 11 Gr. 12 Fitting: ASME SA 234 WP11, WP12	SMAW	Phoenix Chromo 1	AWS A5.5 E8018-B2 EN ISO 3580-A ECrMo1 B 4 2 H5
		Forging: ASME SA336 Gr. F11 Forged Fitting: ASME SA 182 Gr. F11, F12	SAW Wire	Union S 2 CrMo	AWS A5.23 EB2R EN ISO 24598-A S S CrMo1
		Pipe: ASME SA 335, P11, P12 Tube: ASME SA 213 T11, T12	SAW Flux	UV 420 TTR	- EN ISO 14174 SA FB 1 65 DC
				UV 420 TTR-W	- EN ISO 14174 SA FB 1 65 AC
			SAW Wire+Flux	Union S 2 CrMo + UV 420 TTR(-W)	AWS A5.23-SFA 5.23 F8P2-EB2R-B2 EN ISO 24598-A S S CrMo1 FB
			GTAW	Union I CrMo	AWS A5.28 ER80S-G [ER80S-B2 (mod.)] EN ISO 21952-A W CrMo1Si | EN ISO 21952-B W 55 1CM3
				Union ER 80S-B2	AWS A5.28 ER80S-B2 EN ISO 21952-B W 1CM
Low-alloyed Pressure Vessel Steels	2 ¼ Cr 1 Mo	Plate: ASME SA387 Gr. 22 Fitting: ASME SA 234 WP22	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
		Forging: ASME SA336 Gr. F22 Forged Fitting: ASME SA 182 Gr. F22	SAW Wire	Union S 1 CrMo 2	AWS A5.23 EB3R EN ISO 24598-A S S CrMo2
		Pipe: ASME SA 335, P22 Tube: ASME SA213 Gr. T22	SAW Flux	UV 420 TTR	- EN ISO 14174 SA FB 1 65 DC
				UV 420 TTR-W	- EN ISO 14174 SA FB 1 65 AC
			SAW Wire+Flux	Union S1 CrMo 2 + UV 420 TTR(-W)	AWS A5.23-SFA 5.23 F9P2-EB3R-B3R
			GTAW	Union I CrMo 910 Spezial	AWS A5.28 ER90S-G
				Union ER 90S-B3	AWS A5.28 ER90S-B3 EN ISO 21952-B W 2C1M
	2 ¼ Cr 1 Mo ¼ V	Plate: ASME SA542 Type D, CL 4a Plate: ASME SA832 Gr. 22V	SMAW	Phoenix Chromo 2V	AWS A5.5 E9015-G EN ISO 3580-A E ZCrMoV2 B 4 2 H5
		Forging: ASME SA336 Gr. F22V, SA541 Gr. 22V Forged Fitting: ASME SA 182 Gr. F22V	SAW Wire	Union S 1 CrMo 2V	AWS A5.23 EG EN ISO 24598-A S S Z CrMoV2

Joining 3/6

	Alloy Group	Base Material Examples	Welding Process	Product Name	Classification AWS/EN
Medium-alloyed High Temperature Steels			SAW Flux	UV 430 TTR-W	- EN ISO 14174 SA FB 1 57 AC
			SAW Wire+Flux	Union S1 CrMo 2V + UV 430 TTR-W	AWS A5.23 F9PZ-EG-G EN ISO 24598-A S S Z CrMo 2V FB
			GTAW	Union I CrMo 2V	AWS A5.28 ER90S-G
	5 Cr ½ Mo	Plate: ASME SA387 Gr. 5 CL. Fitting: ASME SA 234 WP5 Forging: ASME SA336 Gr. F5 Forged Fitting: ASME SA 182 Gr. F5 Pipe: ASME SA335 Gr. P5 Tube: ASME SA213 Gr. T5	SMAW	BÖHLER FOX CM 5 Kb	AWS A5.5: E8018-B6H4R EN ISO 3580-A: ECrMo5 B 4 2 H5
			SAW Wire	Union S1 CrMo 5	AWS A5.23 EB6 EN ISO 24598-A S S CrMo5
			SAW Flux	UV 420 TT	- EN ISO 14174 SA FB 1 65 AC
			GTAW	BÖHLER CM 5-IG	AWS A5.28: ER80S-B6 EN ISO 21952-A: W CrMo5Si
			GMAW	BÖHLER CM 5-IG	AWS A5.28: ER80S-B6 EN ISO 21952-A: G CrMo5Si
	9 Cr 1 Mo	Plate: ASME SA387 Gr. 9 Fitting: ASME SA234 WP9 Forging: ASME SA336 Gr. F9 Forged Fitting: ASME SA 182 Gr. F9	SMAW	BÖHLER FOX CM 9 Kb	AWS A5.5: E8018-B8 EN ISO 3580-A: ECrMo9 B 4 2 H5
		Pipe: ASME SA335 Gr. P9 Tube: ASME SA213 Gr. T9	GTAW	BÖHLER CM 9-IG	AWS A5.28 ER80S-B8 EN ISO 21952-A G CrMo9Si
Heat Resistant Stainless Steels	S.S 304H	UNS30409	SMAW	Thermanit ATS 4	AWS A5.4 E308H-15 EN ISO 3581-A E 19 9 H B 2 2
			SAW Wire	Thermanit ATS 4	AWS A5.9 ER19-10H EN ISO 14343 S 19 9 H
			SAW Flux	Marathon 104	EN ISO 14174 SA FB 2 55 AC H5
			SAW Wire+Flux	Thermanit ATS 4 + Marathon 104	AWS A5.9 ER19-10H EN ISO 14343 S 19 9 H
			GTAW	Thermanit ATS 4	AWS A5.9 ER19-10H EN ISO 14343-A W 19 9 H / EN ISO 14343-B SS19-10H
			GMAW	Thermanit ATS 4	AWS A5.9 ER19-10 H EN ISO 14343-A G 19 9 H / EN ISO 14343-B SS19-10H

Joining 4/6

	Alloy Group	Base Material Examples	Welding Process	Product Name	Classification AWS/EN
Heat Resistant Stainless Steels	S.S 304H	UNS30409	FCAW	BÖHLER E 308 H PW-FD Bi-Free	AWS A5.22: E308HT1-1/4 EN 17633-A: T Z 19 9 H P C1/M21 1
	S.S 310	UNS31000	SMAW	Thermanit C	AWS A5.4 E310-15 (mod.) EN ISO 3581-A E25 20 B 2 2
			GTAW	Thermanit C Si	AWS A5.9 ER310 (mod.) EN ISO 14343-A W 25 20 Mn / EN ISO 14343-B SSZ31
			GMAW	Thermanit C Si	AWS A5.9 ER310 (mod.) EN ISO 14343-A G 25 20 Mn
High Temperature High-alloyed	Wrought: Alloy 800 Alloy 800H Alloy 800HT	 UNS8800 UNS8810 UNS8811	SMAW	UTP 2133 Mn	- EN ISO 3581-A: EZ 21 33 B 4 2
			GTAW	UTP A 2133 Mn	- EN ISO 14343: WZ 21 33 Mn Nb
			GMAW	UTP A 2133 Mn	- EN ISO 14343: GZ 21 33 Mn Nb
	Cast Tubes: Alloy HK Alloy HP Alloy HP Nb Alloy HP M.A		SMAW	UTP 2535 Nb	- EN 1600: EZ 25 35 Nb B 6 2
			GTAW	UTP A 2535 Nb	- EN ISO 14343-A: WZ 25 35 Zr
			GMAW	UTP A 2535 Nb	- EN ISO 14343-A: GZ 25 35 Zr
	Cast Tubes Alloy 35/45 Alloy 35/45 M.A	GX45NiCrNbSiTi 45-35	SMAW	UTP 3545 Nb	- EN 1600: EZ 35 45 Nb B 6 2
			GTAW	UTP A 3545 Nb	- EN ISO 14343-A: WZ 35 45 Nb
			GMAW	UTP A 3545 Nb	- EN ISO 14343-A: GZ 35 45 Nb
Stainless Steel	Austenitic	S.S 309L Only Weld-Overlay Buffer	SMAW	BÖHLER FOX CN 23/12	AWS A5.4: E309L-17 EN ISO 3581-A: E 23 12 L R 3 2
			SAW Wire	Thermanit 25/14 E309L	AWS A5.9 ER309L EN ISO 14343 S 23 12 L
			SAW Flux	Marathon 431	EN ISO 14174 SA FB 2 64 DC
			GTAW	BÖHLER CN 23/12-IG	AWS A5.9: ER309L EN ISO 13343-A: G 23 12 L
			GMAW	Thermanit 25/14 E309L Si	AWS A5.9 ER 309 L Si EN ISO 14343-A G 23 12 L Si

Joining 5/6

	Alloy Group	Base Material Examples	Welding Process	Product Name	Classification AWS/EN
Stainless Steel			FCAW	BÖHLER CN 23/12-FD	AWS A5.22: E309LT0-4/1 EN 17633-A: T 23 12 L R M21 (C1) 3
	Austenitic Nb Stabilized	S.S 321/347	SMAW	BÖHLER FOX SAS 2	AWS A5.4: E347-15 EN ISO 3581-A: E 19 9 Nb B 2 2
			SAW Wire	Thermanit H-347	AWS A5.9 ER347 EN ISO 14343 S 19 9 Nb
			SAW Flux	Marathon 431	 EN ISO 14174 SA FB 2 64 DC
			GTAW	BÖHLER SAS 2-IG	AWS A5.9: ER347 EN ISO 13343-A: W 19 9 Nb
			GMAW	Thermanit H-347	AWS A5.9 ER 347 EN ISO 14343-A G 19 9 Nb / EN ISO 14343-B SS347
				Thermanit H Si	AWS A5.9 ER 347Si EN ISO 14343-A G 19 9 Nb Si / EN ISO 14343-B SS347Si
			FCAW	BÖHLER SAS 2-FD	EN ISO 17633-A: T 19 9 Nb R M21/C1 3 AWS A5.22: E347T0-4/1
Nickel-base	Alloy 600	UNSN06600	SMAW	UTP 068 HH	AWS A5.11 : E NiCrFe-3 (mod.) EN ISO 14172 : E Ni 6082 (NiCr20Mn3Nb)
			GTAW	UTP A 068 HH	AWS A5.14 : ER NiCr-3 EN ISO 18274 : S Ni 6082 (NiCr20Mn3Nb)
			GMAW	UTP A 068 HH	AWS A5.14 : ER NiCr-4 EN ISO 18274 : S Ni 6082 (NiCr20Mn3Nb)
	Alloy 625 Alloy 825	UNS06625 UNS08825	SMAW	UTP 6222 Mo	AWS A5.11 : E NiCrMo-3 EN ISO 14172 : E Ni 6625 (NiCr22Mo9Nb)
			GTAW	UTP A 6222 Mo	AWS A5.14 : ER NiCrMo-3 EN ISO 18274 : S Ni 6625 (NiCr22Mo9Nb)
			GMAW	UTP A 6222 Mo	AWS A5.14 : ER NiCrMo-4 EN ISO 18274 : S Ni 6625 (NiCr22Mo9Nb)
	Alloy 617	UNS06617	SMAW	UTP 6170 Co	AWS A5.11 : ~ ENiCrCoMo-1 (mod.) EN ISO 14172 : ~ E Ni 6117~ (NiCr22Co12Mo)
			GTAW	UTP A 6170 Co	AWS A5.14 : ER NiCrCoMo-1 EN ISO 18274 : S Ni 6617 (NiCr22Co12Mo9)
			GMAW	UTP A 6170 Co	AWS A5.14 : ER NiCrCoMo-2 EN ISO 18274 : S Ni 6617 (NiCr22Co12Mo9)

Joining 6/6

	Alloy Group	Base Material Examples	Welding Process	Product Name	Classification AWS/EN
Low-temperature Steels	1% Ni	ASME SA572 Gr. 65 ASME SA573	SMAW	BÖHLER FOX EV 60	AWS A5.5 E8018-C3H4R EN ISO 2560-A E 46 6 1Ni B 42 H5
			SAW Wire	Union S 3 NiMo 1	AWS A5.23 EF3 EN ISO 14171 S3NiMo1
			SAW Flux	UV 420 TT(R)	- EN ISO 14174 SA FB 1 65 DC
			GTAW	BÖHLER Ni1-IG	AWS A5.28 ER80S-Ni1 (mod.) EN ISO 636-A W3Ni
			GMAW	BÖHLER NiMo1-IG	AWS A5.28 ER90S-G EN ISO 16834-A G Mn3Ni1Mo (wire) / G 55 6 M21 Mn3Ni1Mo
	2-2.5% Ni	ASME SA203 Gr. A & B ASME SA572 Gr. 65	SMAW	BÖHLER FOX 2,5 Ni	AWS A5.5 E8018-C1H4R EN ISO 2560-A E 46 8 2Ni B 42 H5
			SAW Wire	Union S 2 Ni 2,5	AWS A5.23 ENi2 EN ISO 14171 S2Ni2
			SAW Flux	UV 418 TT, UV 421 TT	- EN ISO 14174 SA FB 1 55 AC H5
			SAW Wire+Flux	Union S 2 Ni 2,5 + UV 418 TT	AWS A5.23-SFA 5.23 F8A10-ENi2-Ni2 EN ISO 14171 S 46 8 FB S2Ni2
			GTAW	BÖHLER 2,5 Ni-IG	AWS A5.28 ER80S-Ni2 EN ISO 636-A W2Ni2 / W 46 8 W2Ni2
			GMAW	BÖHLER 2,5 Ni-IG	AWS A5.28 ER80S-Ni2 (wire) / G 46 8 M/C G2Ni2 EN ISO 14341-A G2Ni2
	3.5% Ni	ASME SA203 Gr. D, E, F	SMAW	Phoenix SH Ni 2 K 80	AWS A5.5 E7018-C2L EN ISO 2560-A E 42 6 3Ni B 3 2 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 A5.23-SFA 5.23 F8A15-ENi3-Ni3 EN ISO 14171 S 46 8 FB S2Ni3
			GTAW	Union I 3,5 Ni	AWS A 5.23 ER80S-Ni3 (mod.) EN 1668 W Z42 10 W2Ni3

Strip Cladding

	Deposited Alloy	Welding Process	Layer	Strip	Flux
Steinless Steel	S.S 410S	SAW	1st Layer	SOUDOTAPE 430	RECORD INT 101
		ESW	1st Layer	SOUDOTAPE 430	RECORD EST 122
	S.S 308L	SAW	1st Layer	SOUDOTAPE 309 L	RECORD INT 109
			2nd Layer	SOUDOTAPE 308 L	RECORD INT 109
		ESW	1st Layer	SOUDOTAPE 309 L	RECORD EST 122
			2nd Layer	SOUDOTAPE 308 L	RECORD EST 122
		ESW Single layer	Single Layer	SOUDOTAPE 308 L	RECORD EST 308-1
		ESW High Speed	1st Layer	SOUDOTAPE 309 L	RECORD EST 136
	S.S 308H	SAW	1st Layer	SOUDOTAPE 309 L	RECORD INT 101
			2nd Layer	SOUDOTAPE 308 L	RECORD EST 136
	S.S 316L	SAW	1st Layer	SOUDOTAPE 309 L	RECORD INT 109
			2nd Layer	SOUDOTAPE 316 L	RECORD INT 109
		ESW	1st Layer	SOUDOTAPE 309 L	RECORD EST 122
			2nd Layer	SOUDOTAPE 316 L	RECORD EST 122
		ESW Single layer	Single Layer	SOUDOTAPE 21.13.3 L	RECORD EST 122
		ESW High Speed	1st Layer	SOUDOTAPE 309 L	RECORD EST 136
			2nd Layer	SOUDOTAPE 316 L	RECORD ESt 136
	S.S 317L	SAW	1st Layer	SOUDOTAPE 21.13.3 L	RECORD INT 101 Mo
			2nd Layer	SOUDOTAPE 316 L	RECORD INT 101 Mo
		ESW	1st Layer	SOUDOTAPE 316 L	RECORD EST 317-2
			2nd Layer	SOUDOTAPE 316 L	RECORD EST 317-2
		ESW Single layer	Single Layer	SOUDOTAPE 21.13.3 L	RECORD EST 317-1
	S.S 347	SAW	1st Layer	SOUDOTAPE 309 L	RECORD INT 109
			2nd Layer	SOUDOTAPE 347	RECORD INT 109
		ESW	1st Layer	SOUDOTAPE 309 L	RECORD EST 122
			2nd Layer	SOUDOTAPE 347	RECORD EST 122
		ESW Single layer	Single Layer	SOUDOTAPE 21.11 LNb	RECORD EST 122
		ESW High Speed	Single Layer	SOUDOTAPE 24.12 LNb	RECORD EST 136
		ESW High Speed	1st Layer	SOUDOTAPE 309 L	RECORD EST 136
			2nd Layer	SOUDOTAPE 347	RECORD EST 136
	Alloy 254 SMO	ESW	1st Layer	SOUDOTAPE 254SMo	RECORD EST 122
			2nd Layer	SOUDOTAPE 254SMo	RECORD EST 122
		ESW	1st Layer	SOUDOTAPE 309L	RECORD EST 122

Strip Cladding

	Deposited Alloy	Welding Process	Layer	Strip	Flux
Nickel-Base	Alloy 276	ESW	1st Layer	SOUDOTAPE NiCrMo59	RECORD EST 259
			2nd Layer	SOUDOTAPE NiCrMo4	RECORD EST 259
	Alloy 59	ESW	1st Layer	SOUDOTAPE NiCrMo59	RECORD EST 259
			2nd Layer	SOUDOTAPE NiCrMo59	RECORD EST 259
	Alloy 825	ESW	1st Layer	SOUDOTAPE 825	RECORD EST 201
			2nd Layer	SOUDOTAPE 825	RECORD EST 201
		ESW Single layer	Single Layer	SOUDOTAPE 825	RECORD EST 138
	Alloy 625	SAW	1st Layer	SOUDOTAPE 625	RECORD NFT 201
			2nd Layer	SOUDOTAPE 625	RECORD NFT 201
		ESW	1st Layer	SOUDOTAPE 625	RECORD EST 201
			2nd Layer	SOUDOTAPE 625	RECORD EST 201
		ESW Single layer	Single Layer	SOUDOTAPE 625	RECORD EST 625-1
		ESW High Speed	1st Layer	SOUDOTAPE 625	RECORD EST 236
			2nd Layer	SOUDOTAPE 625	RECORD EST 236
	Alloy 400	SAW	1st Layer	SOUDOTAPE NiCu7	RECORD NiCuT
			2nd Layer	SOUDOTAPE NiCu7	RECORD NiCuT
			3rd Layer	SOUDOTAPE NiCu7	RECORD NiCuT
		ESW	1st Layer	SOUDOTAPE NiCu7	RECORD EST 400
			2nd Layer	SOUDOTAPE NiCu7	RECORD EST 400
	Alloy 200	SAW	1st Layer	SOUDOTAPE NiTi	RECORD NiT
			2nd Layer	SOUDOTAPE NiTi	RECORD NiT
			3rd Layer	SOUDOTAPE NiTi	RECORD NiT
		ESW	1st Layer	SOUDOTAPE NiTi	RECORD EST 200
			2nd Layer	SOUDOTAPE NiTi	RECORD EST 200
			3rd Layer	SOUDOTAPE NiTi	RECORD EST 200
	Alloy 22	ESW	1st Layer	SOUDOTAPE NiCrMo22	RECORD EST 259
			2nd Layer	SOUDOTAPE NiCrMo22	RECORD EST 259

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