PROCESSING
DUPLEX / SUPERDUPLEX

BUTTING

Progress by tradition

BUTTING was founded in 1777 as a coppersmith's, by the ancestors of the current owner, Hermann Butting. In 1945, the family company moved its headquarters to Knesebeck and started producing soldered, and later welded, copper pipes and pipelines. In the late 1950s, stainless steel gradually replaced copper as the main raw material for BUTTING products. The company has been in private ownership for seven generations, and its staff of over 1,400 now handle approx. 40,000 tons of stainless steel of various grades every year.

Versatile Range of Products

The production of high-quality longitudinally welded pipes made from stainless steel – in both standard and special sizes – has long been the focal point of our business since the development of stainless steels. Few companies in Europe can point to such longstanding experience and diversity as BUTTING in the production of stainless steel pipes in sizes ranging from NB 15 to NB 1,800.

The combination of pipes and fittings of proven BUTTING quality into special ready-to-install piping components within

Longitudinally welded Pipes

Pipe Fittings

Clad Pipes

our extensive prefabrication capacity also guarantees you optimum cost-effectiveness and reliability.

Your Material Specialist

Besides austenitic steels, special alloys and titanium, BUTTING has specialized in the fabrication of duplex, superduplex and lean duplex materials.

The family-run company has been supplying pipes and piping components of these materials for worldwide use since 1979. More than 150,000 tons have been processed for various projects all over the world in the petrochemical, paper and oil and gas industries, as well as for waste water treatment, chemical tankers and seawater desalination plants.

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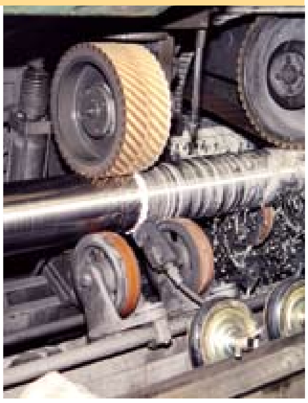
Prefabrication

Vessel Construction

Surface Engineering



Assembly

Close to Customers worldwide

For seven generations, the name BUTTING has stood for quality and flexibility. Pipes and pipework components are now produced in a number of production halls on our site in Knesebeck, which occupies over 395,000 m².
The history of BUTTING is one of continuous healthy growth, with its roots in a far-sighted entrepreneurial spirit. It was this thinking that prompted Dr Hannshermann Butting to establish an affiliated company in Schwedt/Oder following German reunification in 1991. Today, BUTTING Schwedt is our expert unit for vessel and pipework construction and for international assemblies.

Since 2004, BUTTING has been present in China. We have a production facility in Jiading on the outskirts of Shanghai, producing line pipes and customized pieces for the Chinese market. Furthermore our pipe stock for short-term demands of our Chinese customers is established there.

Our aim is to inspire our customers. For some services and/or products this requires geographical proximity to our customers. For the same reason, we decided to establish sales branches in Canada and in Brazil in order to provide our local customers with our many years of experience in processing stainless steels more quickly and directly.

Fig. 2: A team with visions: (L to R) Managing Directors Dr Iris Rommerskirchen, Markus Bartsch, Hermann Butting, Thomas Schüller

Our core Competences

Over the last few years, BUTTING has invested in the latest manufacturing techniques, environmental protection and quality assurance systems, to expand its core competences in the fields of materials, forming and welding technology.

At BUTTING, the use of compatible weld procedures for the materials in question guarantees you problem-free product deployment, based on over 50 years of experience in the welding of stainless steels. The daily work of our welding engineers is to use and optimize familiar weld procedures and tackle new challenges.

Fig. 3: Your partner for longitudinally welded pipes and pipelines

Fig. 1: BUTTING in Knesebeck: "We provide the most up-to-date and sophisticated 12-metre pipe production facilities of the world for pipes made from plate!"

Worldwide Yardstick for Quality

Since BUTTING was founded, reliable quality management has been a prominent pillar of our corporate philosophy. All over the world, the name BUTTING stands for high-quality pipes, fittings and piping components. The high quality and reliability of our products are shown by the variety of applications in which they are used in all branches of industry, such as chemical plants, the aircraft and aerospace industry, power plants, environmental technology and shipbuilding industry.

The constant development of new products and processes and the continuous improvement of the status quo have a long tradition at BUTTING. Combining craftsmanship and engineering knowledge, we have been facing the challenges of tomorrow together with our customers for over 230 years, according to the motto "nothing is impossible".

Duplex Steel

The duplex steel owes its name to its two-phase structure consisting of ferrite and austenite in almost equal proportion. Figure 4 shows a typical duplex structure. The "stainless duplex steel" is a stainless steel with more than 18 % Cr and approx. 5 % Ni.

Since around 1970, a series of stainless duplex steels has been developed, marketed under various names. In the final analysis, it was a nitrogen alloyed version which penetrated the market, generally known as material 1.4462 (X2CrNiMoN 22-5-3) according to the DIN EN / VdTÜV standards (DIN EN 10088-2 / VdTÜV Werkstoffblatt 418), and UNS S31803 or UNS S32205 according to the ASTM / ASME standards (ASTM A240, ASTM A789 / A790, ASTM A928). In material UNS S32205, the minimum chromium, molybdenum and nitrogen contents have been increased compared to material UNS S31803.

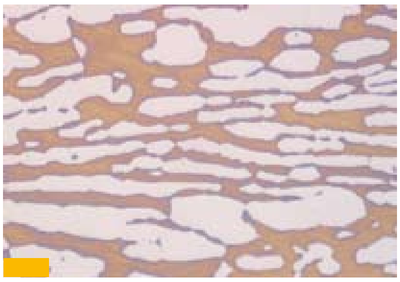


Fig. 4: Duplex structure – light austenite / dark ferrite

Tables 1 to 4 show chemical analyses, mechanical-technological values as well as physical values of these typical representatives of the austenitic-ferritic steels.

Table 1: Chemical analyses of some duplex grades

Grade	Standard	% C	% Cr	% Mo	% Ni	% N
1.4462	DIN EN 10088-2	Max. 0.030	21.0 – 23.0	2.5 – 3.5	4.5 – 6.5	0.10 – 0.22
UNS S31803	ASTM A240	Max. 0.030	21.0 – 23.0	2.5 – 3.5	4.5 – 6.5	0.08 – 0.20
UNS S32205	ASTM A240	Max. 0.030	22.0 – 23.0	3.0 – 3.5	4.5 – 6.5	0.14 – 0.20

Table 2: Mechanical-technological properties of the raw material at ambient temperature

Grade	Standard	$R_{P_{0.2}}$ [MPa]	R_m [MPa]	A_5 [%]	Kv (transverse) [J]	Hardness
1.4462	DIN EN 10088-2	≥ 460	700 – 950	≥ 25	≥ 60	—
UNS S31803	ASTM A240	≥ 450	≥ 620	≥ 25	—	HRC ≤ 31
UNS S32205	ASTM A 240	≥ 450	≥ 655	≥ 25	—	HRC ≤ 31

Table 3: Yield strengths ($R_{P_{0.2}}$) at elevated temperature

Grade	100 °C [MPa]	200 °C [MPa]	250 °C [MPa]	280 °C [MPa]
1.4462	≥ 360	≥ 315	≥ 300	≥ 285
UNS S31803				
UNS S32205				

Table 4: Physical values

Grade	Heat conductivity	Heat expansion	Magnetizability
1.4462	14.9 W/(m · K)	$13.3 \cdot 10^{-6}$ K	Yes
UNS S31803			
UNS S32205			

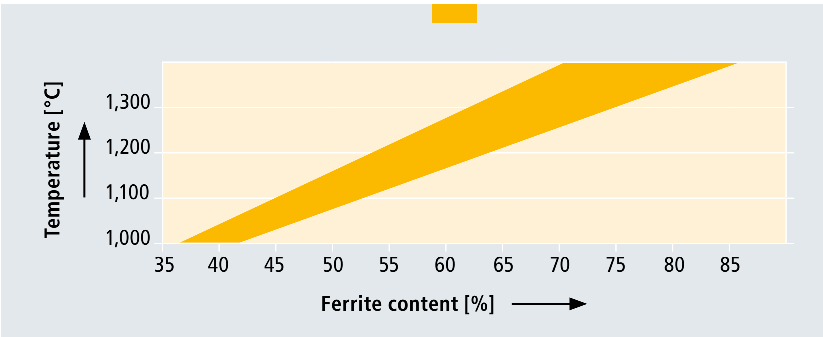
Table 1 – 4: No guarantee for correctness

Optimum Properties

A balanced austenite-ferrite ratio of 50 : 50 is crucial for the high performance of duplex steels.
Compared with normal austenitic steels, duplex steels contain less nickel (approx. 4 – 8 %) which increases its cost-effectiveness considerably.

When working duplex steels, e. g. by welding, the "optimum" austenite-ferrite ratio may be permanently affected. However, heat treatment at approx. 1,040 to 1,100 °C (solution annealing) restores the optimum microstructure.

Diagram 1: Ferrite content depending on the annealing temperature used for the steel



No guarantee for correctness

Fig. 5: Duplex pipes produced according to customer requirements

The steel grade 1.4462 / UNS S31803 / UNS S32205 is noted for its high corrosion resistance, especially to pitting corrosion and stress corrosion cracking and its high strength values (which are twice as high as those of common stainless steels).

According to the VdTÜV-Werkstoffblatt 418 (data sheet) the grade can only be used for temperatures between – 40 °C up to + 280 °C.

Use in many Applications

Varieties of duplex steel are used for two main reasons: the first is their corrosion resistance to various corrosive media that occur in the onshore and offshore environment, such as CO_2, H_2S, chlorides and low pH values. The second is their increased strength. Typical applications are underwater manifolds and flowlines or conduit pipes, along with underwater pipelines and topside processing systems.

Since 1979 BUTTING has supplied more than 125,000 tons of duplex steel pipes and piping components to several projects in Germany and abroad. Typical application areas are:

- Oil and gas industry (onshore / offshore)
- Petrochemical industry
- Process industry using chlorides
- Chemical tankers
- Water treatment plants
- Paper- and pulp industry
- Sea water desalination plants

References can be made available upon request.

Table 5: Chemical analyses of some superduplex grades (DIN EN 10 088-2 and ASTM A240)

Grade	C [%]	Cr [%]	Mo [%]	Ni [%]	N [%]	W [%]	Cu [%]
EN 1.4501	Max. 0.03	24.0 – 26.0	3.0 – 4.0	6.0 – 8.0	0.20 – 0.30	0.5 – 1.0	0.5 – 1.0
EN 1.4507	Max. 0.03	24.0 – 26.0	2.7 – 4.0	5.5 – 7.5	0.15 – 0.30	—	1.5 – 2.5
UNS S32750	Max. 0.03	24.0 – 26.0	3.0 – 5.0	6.0 – 8.0	0.24 – 0.32	—	0.5
UNS S32760	Max. 0.03	24.0 – 26.0	3.0 – 4.0	6.0 – 8.0	0.20 – 0.30	0.5 – 1.0	0.5 – 1.0
UNS S32520	Max. 0.03	24.0 – 26.0	3.0 – 5.0	5.5 – 8.0	0.20 – 0.35	—	0.5 – 3.0
UNS S32550	Max. 0.03	24.0 – 27.0	2.9 – 3.9	4.5 – 6.5	0.10 – 0.25	—	1.5 – 2.5

Table 6: Mechanical-technological properties of the raw material at ambient temperature

Grade	Standard	$R_{p_{0.2}}$ [MPa]	R_m [MPa]	A_5 [%]	Kv (transverse) [J]	Hardness
UNS S32750	ASTM A240	≥ 550	≥ 795	≥ 15	—	HRC ≤ 32
UNS S32760	ASTM A240	≥ 550	≥ 750	≥ 25	—	HBW ≤ 270

Superduplex Steel

The nitrogen alloyed ferritic-austenitic steel 1.4462 / UNS S31803 / UNS S32205 was the basis for the development of a third generation of ferritic-austenitic steels. These higher alloyed duplex steels are called superduplex steels (see tables 5 and 6).

The UNS S32760 normally contains 25 % chromium, 7 % nickel, 4 % molybdenum and 0.25 % nitrogen with an addition of tungsten and / or copper. This group of steels is especially noted for an even higher resistance to pitting corrosion, crevice corrosion and stress corrosion cracking, as well as higher strength properties.

Availability is crucial

The superduplex steels mentioned hereafter represent the currently most commonly used grades which are not only noted for their excellent application properties, but also for their availability in all forms (plate, bar, seamless and welded pipes, piping components, cast). BUTTING has delivered more than 12,000 tons of superduplex steel materials in grades UNS S32760, UNS S32750 (VdTÜV-Werkstoffblatt 508) and UNS S32550 to date, mainly pipes for the oil and gas industry according to the relevant project specifications of for example SHELL, Conoco Phillips, StatoilHydro, PDO, ARCO, BP and other renowned companies.

Fig. 6: Superduplex pipes after heat treatment

Diagram 2: Comparison of critical pitting corrosion temperatures of various steel grades determined during Fe-Cl test acc. to ASTM G48, practice A

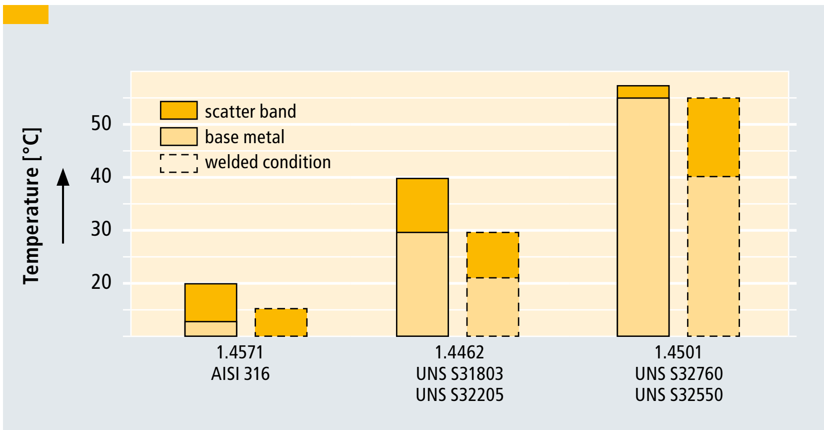


Table 7: Chemical composition of selected lean duplex materials

Grade	C [%]	Mn [%]	Si [%]	P [%]	S [%]	Cr [%]	Ni [%]	Mo [%]	Cu [%]	N [%]
LDX 2101 UNS S32101 1.4162	≤ 0.040	5	≤ 1.0	≤ 0.040	≤ 0.030	21.5	1.5	0.5	0.5	0.22
AL2003 UNS S32003	≤ 0.030	≤ 2.0	≤ 1.0	≤ 0.030	≤ 0.020	21	3.5	1.75	—	0.17
Uranus 35N UNS S32304	≤ 0.030	≤ 2.0	≤ 1.0	≤ 0.030	< 0.002	23	4.4	0.25	0.25	0.11

No guarantee for correctness

Table 8: Mechanical properties of selected lean duplex materials

Grade	$R_{P_{0.2}}$ [MPa]	R_m [MPa]	$A_{50\,mm}$ [%]
LDX 2101 UNS S32101 1.4162	> 450	> 665	30
AL2003 UNS S32003	≥ 450	> 620	25
Uranus 35N UNS S32304	≥ 430	> 620	25

No guarantee for correctness

Lean Duplex

In the last few years, there has been increasing development in the area of low-alloy austenitic-ferritic steels. Austenitic-ferritic steels with a lower alloy content than standard duplex steels are grouped together in the so-called "lean duplex" class of alloys.

Applications of lean duplex steel plates to date include vessel construction for the paper and pulp industry and as structural steel for civil engineering and bridge construction, where the potential weight saving can be exploited. Because of their lower nickel and molybdenum contents compared to standard duplex steels, lean duplex materials are economically attractive for their greater resilience, reliability and ease of working.

Compared to standard steels like 304L and 316L, the lean duplex steels offer the benefit that their elastic limits of 430 – 450 MPa represent nearly double the strength, and hence allow substantial savings in wall thicknesses. Apart from the high strength values, the cost price of these materials at particular relative prices of nickel, chromium and molybdenum may favour the use of lean duplex steels.
The term "lean duplex steels" is not the name of a specific alloy but denotes a group of low-alloy duplex steels that differ widely in their alloy composition. Experience to date relates to plasma / TIG, laser and electron beam welding in the industrial production of longitudinally welded pipes in Uranus 35N, Al 2003 and LDX 2101. These welds have been fully classified according to the applicable Shell and PDO specifications SIEP 97-5763, SP-1095 and SP-1189. All in all, we can conclude that longitudinally welded pipes in lean duplex steels are absolutely suitable for the oil and gas industry – possibly as an alternative to 13 % chromium steels. Typical chemical compositions of lean duplex steels available on the market are listed in table 7. In terms of chromium content, between 21.5 % and 23 %, all lean duplex steels are comparable with the standard duplex type. There are substantial differences between the various lean duplex types when it comes to nickel content (see table 7). LDX 2101 (UNS S32101, 1.4162), with 1.5 % nickel, is at the low-alloy end of the lean duplex scale. Despite the very low nickel content, austenite stability within the two-phase material is maintained by the 5 % manganese element. This increases nitrogen solubility, and 0.22 % nitrogen supports the austenite forming function in addition to the nickel. Clearly, pitting corrosion resistance was not a major factor in developing this alloy, as there is only 0.5 % molybdenum present. AL2003 (UNS S32003) contains 2 % more nickel than LDX 2101 and its 1.75 % molybdenum content brings it much closer to the chemical composition of standard duplex steels.

Uranus 35N (UNS S32304) has still more nickel (4.4 %) than AL2003. While its chromium content of 23 % exceeds even that of the standard duplex steels, the molybdenum content of 0.25 % is rather low.

Fig. 7: Example of a lean duplex pipe with flange

Decisive Advantage: Resistance

The resistance of materials to wear primarily depends on the surface hardness and strength. The steel grade 1.4462 / UNS S31803 / UNS S32205 possesses an extremely favourable combination of hardness and strength and thus a high resistance to abrasion can be expected.

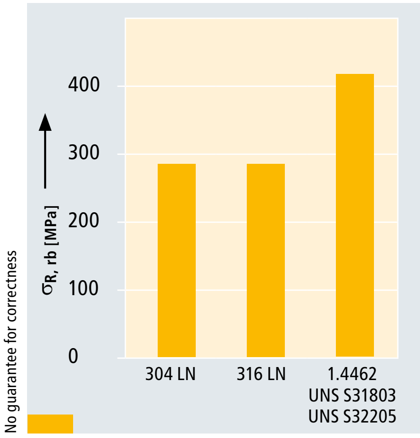


Diagram 3: Corrosion fatigue cracking behaviour of smooth specimens (rotary beam bending test) in a 3 % NaCl-solution, pH value = 7

Fig. 9: Installed duplex pipeline

During comparative tests with unalloyed structural steel, aluminium, stainless austenitic and ferritic steels it could be demonstrated that grade 1.4462 / UNS S31803 / UNS S32205 has indeed far better wear resistance properties. Many years of shop experience with welded pipes and elbows has confirmed these test results.

The special advantage of using duplex steels as wear resisting steels is the fact that it is fully suitable for welding, which is only partly the case with unalloyed wear-proof steels.

By selective heat treatment an even better resistance to wear can be achieved, however this may impair the corrosion resistance and strength properties.

Besides their high strength properties, superduplex steels are also noted for their excellent resistance to abrasion.

Fig. 8: Superduplex pipes, 609.6 × 38.89 mm

Sophisticated Work

The steel 1.4462 / UNS S31803 / UNS S32205 is suitable for cold forming. However, owing to its high strength values it requires higher forming forces than comparable austenitic stainless steels and is noted for its high spring-back properties. Duplex steel can be bent with a bending radius of twice the plate thickness up to 180 ° without showing any cracks.
The duplex steels are also suitable for hot forming. Hot forming should be carried out within a temperature range of 1,000 and 1,100 °C. Rapid cooling after hot forming is recommended, also a post heat treatment may be required.

Note: Due to the high ferrite content of about 50 %, the steel 1.4462 / UNS S31803 / UNS S32205 has a very low creep resistance at temperatures over 800 °C. Therefore, in the case of hot forming or heat treatment above 1,000 °C, the pipes are most likely to lose their shape and will be heavily deformed.

Fig. 10: Undesired sigma phase in the longitudinal weld of a pipe

Also the superduplex steels are suitable for cold forming. It should be taken into account that their strength values (and spring-back properties) are still higher compared with the normal duplex steels.

Temperatures from 1,050 °C up to 1,280 °C must be used during hot forming of superduplex steels. This range is indispensible and must be followed by rapid cooling or, if need be, post heat treatment. The temperature range between 1,000 °C and 700 °C must be passed within 2 minutes in order to avoid any sigma phase.

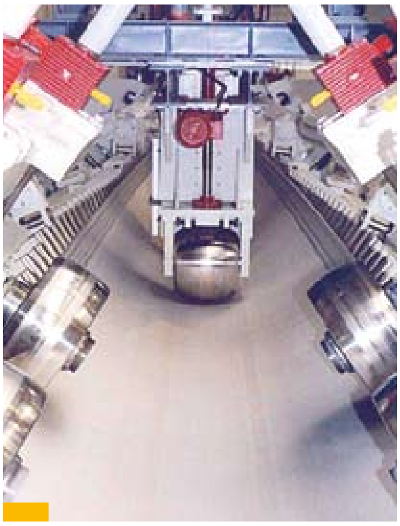


Fig. 11: Continuous forming of a coil in a pipe production line

Fig. 12: Pipe production from plate in 12 metre lengths without circumferential weld

Comprehensive Pipe Production

BUTTING produces duplex steel pipes in the dimensions from OD 21 up to 762 and wall thicknesses of up to 12 mm on different welding lines. The usual production lengths are 6 or 12 metres. Shorter fixed lengths or lengths up to a maximum of 18 metres with numerous dimensions can be produced online and without circumferential weld.

With our latest production equipment and without any outsourced production steps we can produce from single plates longitudinally welded pipes with a max. external diameter of up to 1,219 mm and up to 24 m length.
Pipes having wall thicknesses up to 60 mm in duplex and up to 55 mm in superduplex can be formed and welded. In the case of 6 m lengths, the wall thickness / outside diameter ratio would be approx. 1.2 : 10.

Diagram 4: Duplex pipes are produced in single or double random lengths without circumferential weld. Tolerances and type of construction acc. to international standards (e. g. ASTM A928, DNV-OS-F101, API 5LC) or customers' specifications

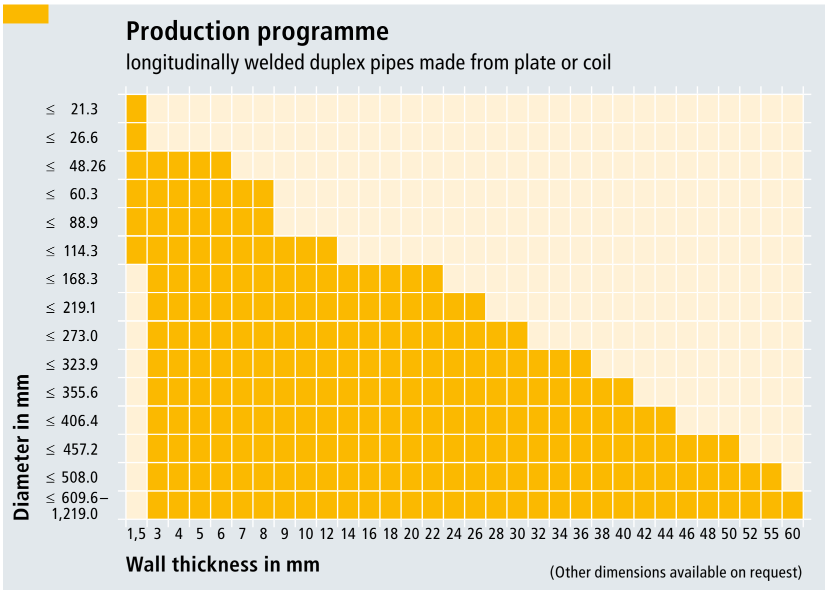


Fig. 13: Welding of superduplex pipes in 12 metre lengths without circumferential weld

Expertise in Welding Technology

Normally duplex steels are weldable using welding procedures generally used for high alloyed steels as mentioned in the following table 9 "Welding processes at BUTTING".

It is important to know that duplex steels reach their most favourable mechanical and corrosion chemical properties if the ferrite-austenite ratio is in the range of 40:60 to 60:40. Generally, the structural condition of the welded joint mainly depends on the three following factors:

1. Chemical composition of the weld metal
2. Cooling rate after welding
3. Post weld heat treatment

Table 9: Welding processes at BUTTING

Welding process	Welding process no. acc. to EN ISO 4063
Manual arc welding	111
Submerged arc welding (SAW)	12
Metal-arc active gas welding (MAG)	135
Tubular-cored metal arc welding with active gas shielding	136
Tungsten inert gas welding (TIG)	141
Plasma arc welding (PAW)	15
Laser beam welding (LBW)	52
Electron beam welding (EBW)	51

The diagram 5 on page 11 gives a typical survey of conditions prevailing during the welding of duplex steel. This diagram shows that the austenite part increases with growing nickel content. However, the use of filler metals with higher nickel content is limited: on the one hand the increase must not be too high so that the ferrite content is lowered too much, i. e. under 30 %, on the other hand this effect is strongly dependent on the dilution ratio. This means that the chemical composition of the weld metal can only be influenced by the welding process to a certain extent.

Fig. 14: Longitudinal weld of a duplex pipe: laser welded (t = 2 mm)

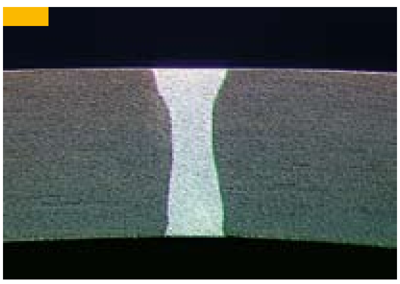


Fig. 15: Longitudinal weld of a duplex pipe: EB-welded (t = 20 mm), final pass and root TIG-welded

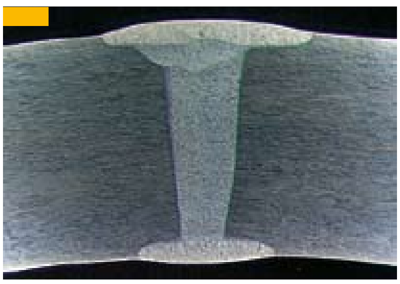


Fig. 16: Welding of BUTTING riser pipes made of superduplex for the oil and gas industry

Welding with the Addition of Filler Metal

It is generally recommended to weld with the addition of filler metal. Nowadays the filler metals are produced in such a way as to counteract ferritizing of the weld (see diagram 5). There is more austenite in the weld than in the parent metal due to a distinctly higher nickel content (up to 9 %) during the cooling down of high temperatures. Table 10 shows typical analyses of duplex and superduplex welding filler metals.

The cooling rate has a considerable impact on the austenite-ferrite ratio developing at ambient temperature. This means that slow cooling causes a higher austenite content than rapid cooling, during which approx. 90 % ferrite is to be expected. In this way it is possible to influence the ferrite-austenite ratio, depending on the weld process and weld geometry. Cooling down slowly from 1,100 °C to 1,000 °C is recommended. Care has to be taken that the temperature range between 950 °C and 700 °C is passed within 2 minutes max.

Table 10: Examples of filler metals

Grade	% C	% Si	% Mn	% Cr	% Ni	% Mo	% N
Duplex / Lean Duplex	< 0.02	0.5	1.6	23.0	9.0	3.2	0.16
Superduplex	< 0.02	0.3	0.4	25.0	9.5	4.0	0.25

Table 11: Recommended heat input and interpass temperatures

Grade	Heat input	Interpass temperature
Duplex / Lean Duplex	0.5 – 2.5 KJ/mm	max. 200 °C
Superduplex	0.2 – 1.5 KJ/mm	max. 150 °C

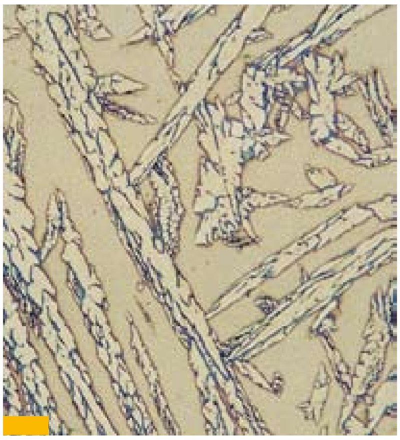
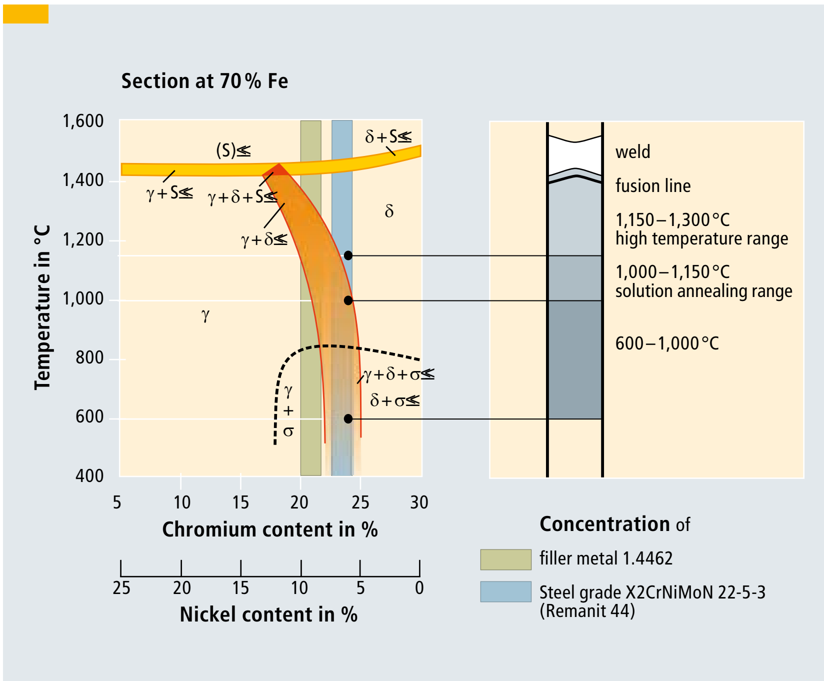


Fig. 17: Structure of weld without heat treatment, approx. 60 % ferrite

Fig. 18: Structure of weld after heat treatment, approx. 40 % ferrite

Diagram 5: Vertical section of the ternary Fe-Cr-Ni system at 70 % iron



No guarantee for correctness

Also the superduplex steels are weldable according to the general welding rules for stainless steel pipes. Extremes of low and high heat input should be avoided depending on the weld geometry, plate thickness and weld procedure. Typical values of heat input and interpass temperatures can be found in table 11.

From these details it can be gathered that the superduplex materials are more susceptible to precipitations and in order to guarantee the required values, control of the interpass temperature and heat input is indispensible.

Welding Technologies for all Requirements

BUTTING has at its disposal the necessary facilities as well as qualified and certified staff to carry out all commonly used welding processes.

Crucial Operation

In order to guarantee a balanced ferrite-austenite ratio of the weld, heat treatment after welding, i. e. solution annealing is recommended. Solution annealing temperature should be approx. 1,080 °C and holding times of around 2 – 3 min / mm wall thickness, followed by a rapid water quench.

In order to avoid the development of a sigma phase, the cooling time from 970 °C down to 700 °C should not be more than 2 minutes.

Fig. 20: Hydraulic calibration of pipes up to 12 metres enabling most stringent tolerances on the entire pipe body

Fig. 19: Heat treated superduplex pipes waiting for calibration

Annealing not only removes hardening of the material which occurred during fabrication, but also provides the most favourable condition to protect against corrosion. If annealing is carried out in an oxidizing atmosphere, then the annealing scale must be removed i. e. by pickling.

Fig. 21: Pipes deformed during heat treatment at calibration

Typical Solution Annealing Temperatures:

For duplex and lean duplex grades:
1,040 – 1,100 °C followed by water quench

For superduplex grades:
1,080 – 1,160 °C followed by water quench

Optimized Material Properties

At BUTTING various heat treatment processes are available to achieve the “heat treated condition”. For pipes made continuously from coil, induction annealing is carried out online or offline in a furnace for pipes made from plate.

Fig. 22: Duplex pipes 12 metre in lengths after heat treatment in the annealing furnace

Safety by high Resistance

The duplex grade 1.4462 / UNS S31803 / UNS S32205 is noted for its high corrosion resistance due to its high PRE (PRE = % Cr + 3.3 × % Mo + 16 × % N) of approx. 34 and its ferritic-austenitic structure. In both neutral and moderately up to mid-sour media it has generally proved superior to the common austenitic steel grades 1.4571 / TP 316L. It is especially resistant to

- pitting corrosion
- stress corrosion cracking
- corrosion fatigue cracking

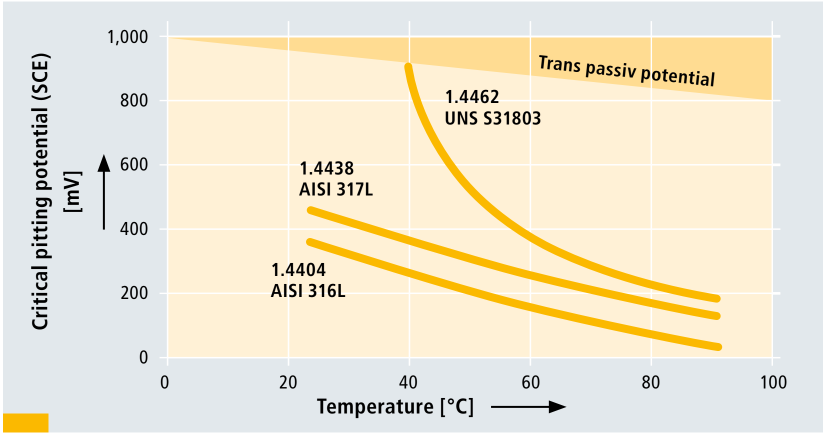


Diagram 7: Critical pitting potential of various steel grades depending on the temperature of a 3 % NaCl-solution

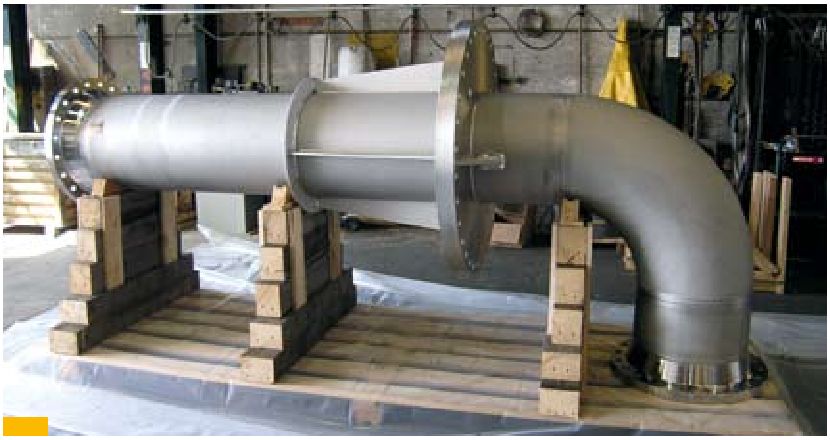


Fig. 23: Corrosion protection is the reason why duplex materials are often used for piping systems prefabricated for drilling and well building techniques

The duplex grade and its welded joints are resistant to intergranular corrosion as tested acc. to DIN EN ISO 3651-2, practice A (formerly DIN 50914), EN 114 / ASTM A262, practice E and according to the more stringent Strauss test. The typical corrosion rates obtained during the Huey test acc. to ASTM A262, practice C are between 0.6 – 1.0 mm / a. The steel is suitable for use in sour gas applications acc. to NACE requirements, however the H_2S partial pressure should not exceed 0.05 bar at 100 °C.

Owing to their PRE (PRE = % Cr + 3.3 × % Mo + 16 × % N) of 40 and higher, the superduplex grades are noted for their very high resistance to pitting corrosion and crevice corrosion. They are also resistant to intergranular corrosion.

Their resistance to stress corrosion cracking was further improved as compared with the normal duplex grades, hence increasing their use in sour gas conditions.

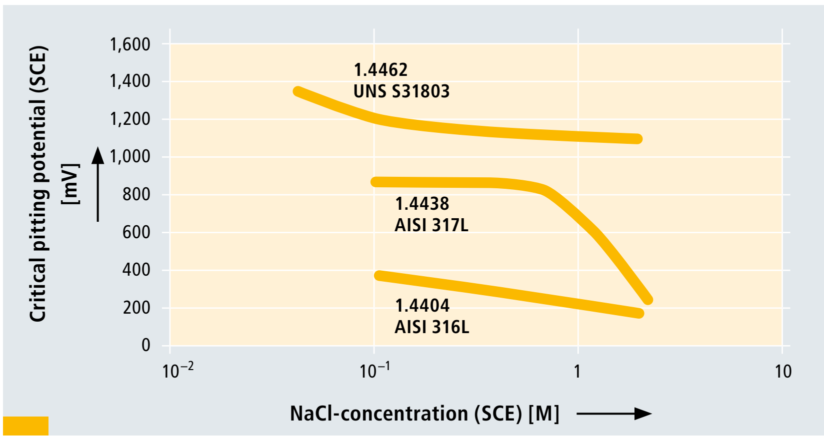
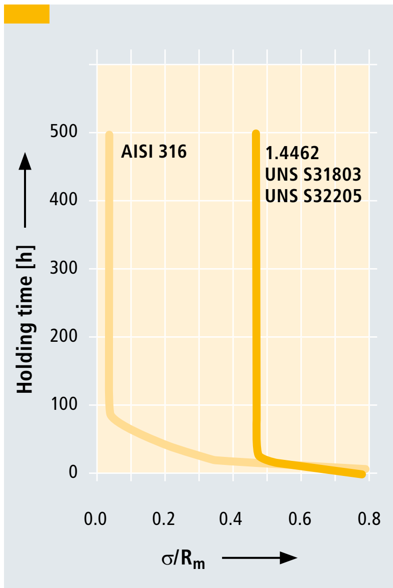


Diagram 6: Critical pitting potential of various steel grades at 20 °C depending on the NaCl concentration

Diagram 8: Stress corrosion cracking behaviour of steel grades AISI 316 and 1.4462 / UNS S31803 / UNS S32205



The Surface Condition is crucial

Chromium-nickel steels provide excellent corrosion resistance in the case of metallic bright surfaces. After further fabrication, this condition must be restored, i. e. oxides, scale and contaminations must be removed. This is possible by a final chemical surface treatment in the form of pickling (full-body pickling or spray pickling).

Fig. 26: Full-body pickling

Fig. 24: Products made of special materials are blasted to reduce pickling times

In order to obtain clean and corrosion resistant surfaces, oxide layers caused by heat may also be removed by grinding, shot peening or brushing. However, corrosion tests have proved that pickling is the most suitable method to achieve the required corrosion resistant surface. In the case of scale firmly settled on the surface, shot peening may be carried out prior to the pickling process.

The type of treatment depends on the service requirements and must be chosen according to the prevailing possibilities.

Optimum Pickling Facilities

BUTTING has at its disposal a combination of peening / blasting and pickling facilities. For the chemical treatment, basins with displaceable partition walls and volumes of up to 60 m^3 are available. The use of hydrofluoric acids, nitric acids and sulphuric acids, hydrogen peroxide or other additions, as well as easy filling, discharging and storing of these chemicals, ensures individual pickling according to the different technical requirements. A wide variety of surface treatments and long-standing experience guarantee an optimum surface condition and thus excellent corrosion resistance.

Fig. 25: Spray pickling of a prefabricated piping component

Fig. 27: Digital X-ray equipment: symbol of quality assurance at highest technical level

Approved worldwide

The Quality Management System of BUTTING is approved by Germanischer Lloyd according to DIN EN ISO 9001. BUTTING also holds numerous approvals from classification companies and third party inspectorates, like Bureau Veritas and BDLI and renowned companies. BUTTING also holds the following approvals:

- Weld procedure qualification acc. to AQUAP
- AREVA NP GmbH-KTA 1401, iAEA 50-C-Q and TÜV-Nord Anlagentechnik AVS D 100/50, KTA 3211.1, KTA 3211.3
- Approval by Germanischer Lloyd for the welding of materials in defence engineering
- TÜV in accordance with the AD Merkblatt W0/HP0 and TRD 100/201
- Extensive verification of suitability acc. to DIN 18 800 part 7
- Approval acc. to HP0 with DIN EN 729-2 and DGRL 97/23/EG
- Approval acc. to the Water Resources Act (WHG) § 19 I

- Statement of Assessment (ASD-EASE EN 9100 without design)
- Environmental Management System acc. to DIN EN ISO 14001
- Work Safety Management System acc. to OHSAS 18001

BUTTING complies with many testing and accreditation requirements:

- § 20 of the rules and regulations of radiation protection
- Accreditation of the laboratory acc. to DIN EN ISO/IEC 17025:2005 etc.

The family business is also certified for projects according to Norsok.

Fig. 28: Burkhard Hirtz at tensile test with microstrain measurement

A great Number of Testing Installations

As regards **non-destructive testing**, the equipment for the following testing methods is available at BUTTING:

- Radiography
- Radioscopy
- Radiology for pipes of up to 18 metres
- Eddy-current testing
- Ultrasonic testing
- Hydrostatic pressure testing
- Endoscope
- X-ray flash device
- Surface roughness measurements
- Dye-penetrant testing and magnetic particle inspection

The following **destructive tests** are performed in the internal laboratory:

- Corrosion tests
- Hardness tests
- Ferrite determination
- Tensile tests with microstrain measurement
- Hot tensile tests
- Bend tests
- Charpy-impact tests, also at low temperatures
- Technological testings
- Metallographic examinations
- Spectroscopic analysis

Fig. 29: Corrosion test

Successful for Decades

BUTTING pipes in duplex and superduplex can be found in many projects all over the world – from Alaska over the African continent to Australia. Since 1979, we have manufactured more than 150,000 tons of pipes in these material grades for various projects with very stringent technical requirements and for renowned customers all over the world, especially in the oil and gas industry, e. g. SHELL, Conoco Phillips, StatoilHydro, ExxonMobil, BP, NAM, Total-FinaELF, GULF, RWE-DEA and ENI.

Fig. 32: Duplex pipeline after laying

Years of Experience

We have supported numerous projects all over the world with our long-standing experience and competence in the production of duplex steels. Since 1987 the Dutch oil company NAM has been one of the established BUTTING customers. Besides the supply of pipes for their offshore plants (e. g. K14, K7 and the Anjum project) and their onshore applications (e. g. Schoonebeek, Waddenzee Development), we also provided replacement pipes for a number of previously installed piping systems in 13 % chromium materials in 2001 / 2002. More than 1,700 tons of duplex pipes from NB 200 up to NB 300 were needed at very short notice and were delivered on schedule.

Fig. 30: Jacketed vessel in duplex for Shell in OD 1,521 × 10 mm

This very successful co-operation between BUTTING and the oil and gas industry led to the placing of an initial order for duplex pipes in 1994 by STATOIL for the "Sleipner Vest" project in Norway. More than 2,300 tons of pipes 508 OD × 14.5 mm thick were produced. Since 1988 we have been an established supplier to various STATOIL projects; from Oseberg to Snøhvit, they all contain duplex pipes from BUTTING.

Worldwide Deliveries

Due to the acknowledged quality of the BUTTING pipes, they were first used for LNG gas flowlines and bulk lines in Oman in 1996. To date we have received orders from PDO Oman for more than 9,500 tons of pipes from 8" OD up to 20" OD. For the Saih Rawl and Barik gas fields in Oman,

Fig. 31: We have been supplying PDO with duplex pipes for many years

more than 130 kilometres of duplex pipes were provided. In October 2003 PDO entrusted us with an order for more than 1,500 tons of duplex pipes for the "SAIH NIHAYDA" project. Apart from the flow and bulk lines, we produced the pipes for the gas cleaning plant in Central Oman. All pipes in UNS S31803 among others in 762 OD × 28 mm were produced according to the very demanding PDO specification. This meant maintaining very tight tolerances, particularly for the external diameter where less than 1 % ovality was allowed.

Fig. 34: Duplex pipes in 18 m lengths are used in the exploitation of Germany's largest natural gas field – Mittelplate

Duplex Pipeline under the Wadden Sea

To transport the largest crude oil deposit in Germany, a pipeline connection was established in 2005 between the Mittelplate platform and the mainland under the Wadden Sea area of the North Sea. Prefabricated pipelines in high-alloy duplex steel were intended to substantially reduce construction times in this protected area. BUTTING was awarded the contract to produce and deliver 8.5 kilometres of duplex pipes 273 OD × 8 mm and 168.3 OD × 11 mm. These were produced in factory lengths of 12 m, some of which were then cut down to 6 m before being welded together into 18 m lengths.

Our affiliated company BUTTING Anlagenbau in Schwedt was also contracted to produce six vessels in duplex with a total length of 7,000 mm and a diameter of 2,900 mm, with a wall thickness of 12 mm.

Special Alloys for special Demands

Since the first supply of pipes in superduplex to Woodside Offshore Petroleum for the "Perseus-over-Goodwyn" project in 1990, this material grade has gained increasing importance in our company. A high point in the production of pipes in this grade was the Scott Seawater and Process System of Amerada Hess which was furnished with pipes 508 OD × 50.01 mm wall.
Our welded superduplex pipes were used for the first time for Shell's "Kingfisher" project, for which they were laid on the sea bed using the reeling method. This order for more than 1,800 tons of pipes 273 OD × 13.75 mm wall represented the biggest challenge with regard to the material grade we had faced to that date.

For an Asian seawater desalination plant, BUTTING processed more than 162 tons of superduplex steel plates. Pipes in various dimensions with large wall thicknesses such as 36" × 23.84 mm had to be

Fig. 35: For seawater desalination plants, pressure exchanger pipes in duplex and superduplex steels with the tightest tolerances are used

supplied, to meet the increased pressure requirements demanded by the operating conditions.
BUTTING was also involved in the construction of the longest gas pipeline in China. For the gas collection station for the Kela 2 project, the increased requirements for corrosion resistance meant that duplex pipes had to be used.

Fig. 33: Prefabrication of distribution pipes made from superduplex for a seawater desalination plant

Fig. 36: For the AFAM project, 12 m lengths of pipe in duplex material were produced

Table 12:
BUTTING stocks duplex plates with wall thicknesses of up to 25 mm, superduplex plates of up to 12,7 mm and duplex pipes in 1.4462 / UNS S31803 / UNS S32205 according to ASTM A928 / DIN EN 10217-7 (DIN 17457)

DN / NB	OD (mm)	t (mm)	1.4462 (kg/m)*
15	21.3	2.00	0.97
25	33.7	2.00	1.59
50	60.3	2.00	2.92
50	60.3	3.05	4.37
80	88.9	2.60	5.62
80	88.9	3.05	6.56
100	114.3	2.60	7.27
100	114.3	3.05	8.50
150	168.3	2.60	10.79
150	168.3	3.40	14.04
200	219.1	3.00	16.23
200	219.1	3.76	20.27
200	219.1	8.18	42.55
250	273.0	3.00	20.28
250	273.0	4.19	28.20
250	273.0	9.27	60.31
300	323.9	4.57	36.54
300	323.9	9.53	73.88

* Indications are guidelines only

No guarantee for correctness

Based on the requested parameters, the project managers chose the duplex steel UNS S32205. Among other things, BUTTING produced more than 4,500 m of pipe 508 OD × 15.9 mm in this material within the required time frame.

Two flowlines for the Miskar field from BG Tunisia Ltd. were equipped by BUTTING with approx. 6,000 m of pipes 273 OD × 14.30 mm in factory lengths of 12 m. Because of the conditions, material UNS S32760 was specified as being the most suitable, and then processed by BUTTING. The order volume also included more than 600 m of risers and various elbows in this material. To transport aggressive raw gas from the Gbaran Ubie field in the Niger delta to the processing plant, BUTTING installed pipes in duplex steel UNS S32205. Saipem had given us the responsibility for producing around 1,200 tons of pipes. These were made in 12 m lengths in our enhanced production facilities, mainly from plates with no circumferential welds.

Diverse Applications

To guarantee corrosion resistance in the aggressive saline seawater encountered in the well building technique, many projects have already had well heads fitted by BUTTING with pipes and prefabricated components in duplex and superduplex materials. For example, we handled the production of 1 ton components sized 508 OD × 9.53 mm for the pipes and 3,155 × 1,000 mm for the complete assembly. This order posed a particular challenge because of the tight tolerances of form and position.

Fig. 37: Filter screens in superduplex for drilling and well building techniques

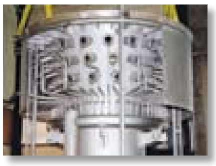
Because of our many years of experience in working duplex steels, BUTTING regularly receives orders to supply pipes, piping components and flanges in 1.4462 for the shipbuilding industry. For example, products in sizes from NB 25 to NB 400 were specified for the construction of eight chemical tankers at the New Stettin Shipyard in Poland.
We will be happy to send you an up-to-date reference list on request.

	**Longitudinally welded pipes**	**Produced continuously from coil in sizes of 15 mm – 762 mm OD and wall thicknesses up to 16 mm**	**From plate: in sizes of 33.7 mm – 3,000 mm OD and wall thicknesses up to 70 mm**	**Pipes in special shapes**	

In random lengths up to 24 m with circumferential welds

	**Clad pipes**	**Mechanically bonded BuBi®-pipes in sizes of 114.3 mm – 660 mm OD**	**Metallurgically clad pipes**		

In random lengths up to 24 m with circumferential welds

	**Vessel construction**	**Up to 6,000 mm OD: complete prefabrication at the mill**	**Above 6,000 mm OD: prefabrication at the mill and assembly on site**		
	**Pre-fabrication**	**Piping components ready for assembly**	**Pipe bends acc. to drawings, piping segments, isometric drawings**		
	**Fittings**	**Tees, reducers, special fittings**	**Pipe bends acc. to DIN 2605**	**Collars acc. to DIN 2642**	**Elbows with long radii**
	**Piping technology**	**Pipes with special tolerances, e.g. furnace rollers, jackets for pumps**	**Pipes with special surface requirements, e.g. for the pharmaceutical industry**	**Further processing of pipes using forming, grinding, laser cutting, e.g. jackets for pumps, valves and lamps**	**Special products, e.g. BUTTING HeRo®** (an uncooled furnace roller)
	**Assemblies**	**Vessels**	**Linepipes**	**Special constructions, equipment**	
	**Surface treatment**	**Pickling** (also on subcontract basis)	**Blasting, peening** (also on subcontract basis)	**Grinding** (also on subcontract basis)	
	**Services**	**Expert technical and metallurgical guidance**	**CAD-facilities, isometric drawings**	**Metallurgical testing and non-destructive testing**	

Material selection

- **Steels containing 10.5 % Cr min,** e.g.
  - ➜ Stainless steels
  - ➜ Heat resisting steels
  - ➜ Creep resisting steels
- **Nickel alloys**
- **Titanium**
- **Aluminium and aluminium alloys**
- **Special alloys**
- **Clad materials**

Approvals

- By TÜV acc. to AD-WO/HPO and TRD 100/201 and DIN EN 729-2
- DGRL (pressure equipment directive)
- Acc. to the Water Resources Act (WHG) § 19 l
- Quality Management System acc. to DIN EN ISO 9001
- Accreditation of the laboratory acc. to DIN EN ISO/IEC 17025:2005
- Statement of Assessment ASD-EASE acc. to EN 9100 (without design)
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