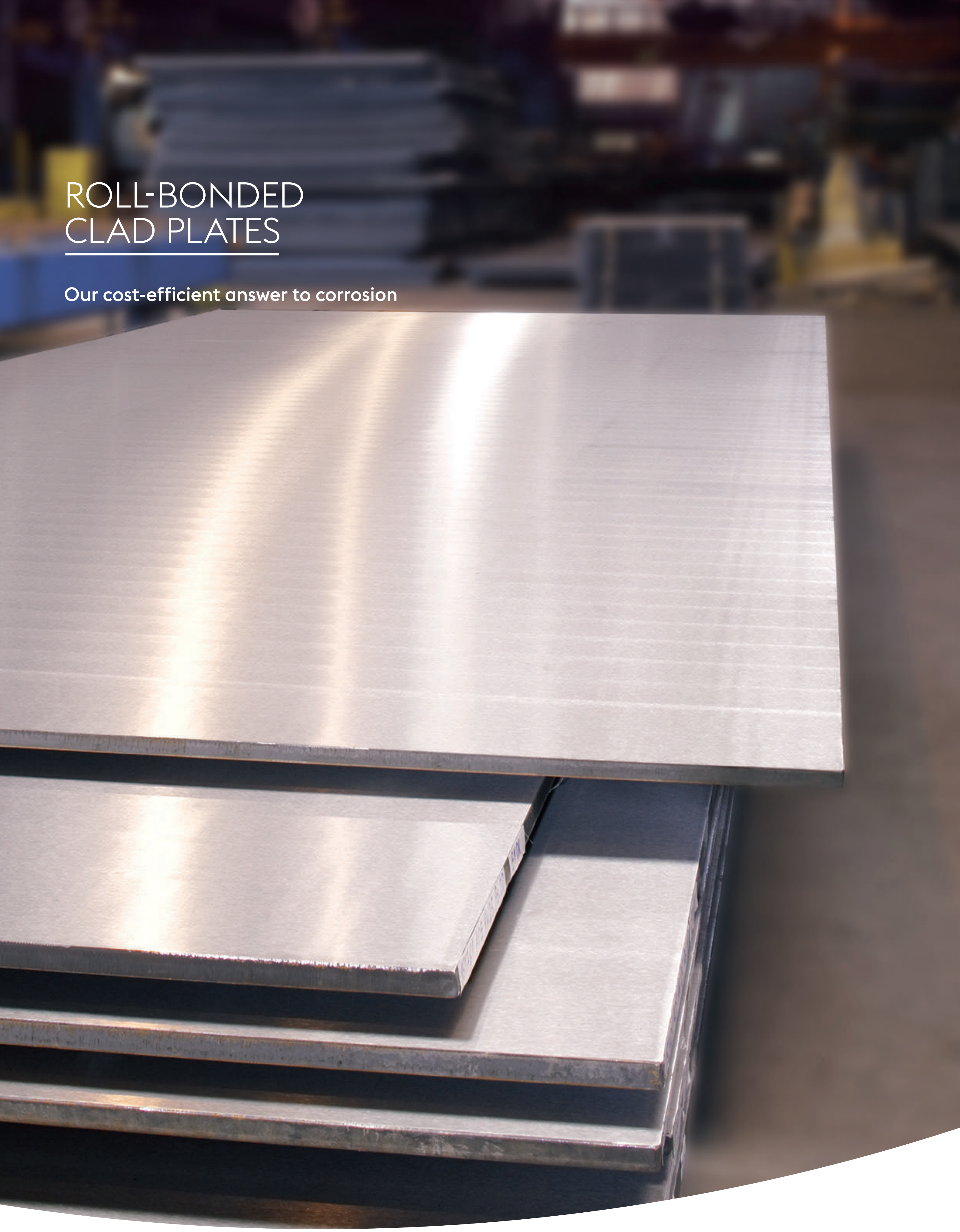
ROLL-BONDED CLAD PLATES

Our cost-efficient answer to corrosion



voestalpine
ONE STEP AHEAD.

voestalpine Grobblech GmbH
www.voestalpine.com/grobblech

MORE THAN JUST A COST-EFFICIENT ANSWER TO CORROSION

Ready for the future

voestalpine Grobblech is the world's leading manufacturer of roll-bonded clad plates. We offer clad plates, clad heads and clad cones from a single source. As a manufacturer with several decades of experience in roll bonding, we are your reliable partner in the linepipe, pressure vessel and apparatus industry. We understand our customers, provide the quality they need and have a large capacity to produce roll-bonded clad plates. These plates provide manufacturing and cost benefits during further processing.

CONVINCING ADVANTAGES

» We offer a cost-efficient answer to corrosion
» We provide outstanding quality
» We have the world's largest cladding capacity
» We run the world's most modern production line

„Stella Sustainable keeps you informed of greentec steel products, environmental protection and sustainability in the voestalpine Steel Division."
www.voestalpine.com/stella

To find out more about roll-bonded clad plates please visit us at
www.voestalpine.com/grobblech

DISCOVER ROLL-BONDED CLAD PLATES

Typical fields of application

As reliable partner for roll-bonded clad plates, our typical fields of application are the oil and gas production, refinery, petrochemical and chemical industry as well as flue gas desulphurisation plants and power plants.

OIL AND GAS PRODUCTION

- » Clad flowlines
- » Catenary riser pipes
- » Slug catchers

REFINERIES, PETROCHEMICAL AND CHEMICAL INDUSTRY

- » Fractionators
- » Vacuum towers
- » Coke drums
- » Process pipes
- » Columns
- » Pressure vessels
- » Reactors
- » Washers
- » Heat exchangers

FLUE GAS DESULPHURISATION PLANTS

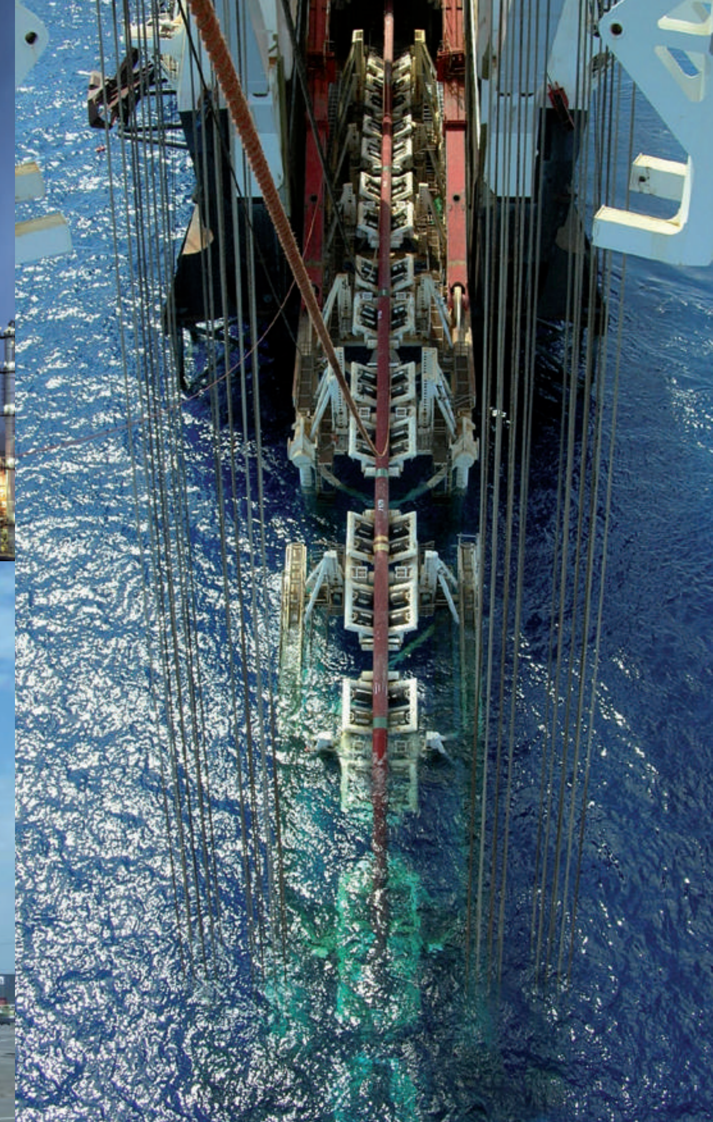
- » Flue gas channels
- » Chimneys
- » Flue gas scrubbers

POWER PLANTS

- » Accumulator tanks
- » Other applications

ICEBREAKER VESSELS

- » Ship hulls




CONVINCING ADVANTAGES

WE OFFER A COST-EFFICIENT ANSWER TO CORROSION

Compared with solid corrosion-resistant alloy (CRA) plates, cost advantages can be achieved by using roll-bonded clad plates. Not only material costs, but also the costs of filler metals can be reduced. The thicker the base material, the lower the overall costs while maintaining consistent corrosion resistance.

WE PROVIDE OUTSTANDING QUALITY

Our clad plates are made with very clean base materials produced exclusively in our own steel plant in Linz. To achieve outstanding quality we use clad materials in best condition without any precipitations. Furthermore, we achieve an ultra-clean bonding area by using vacuum technology.

WE HAVE THE WORLD´S LARGEST CLADDING CAPACITY

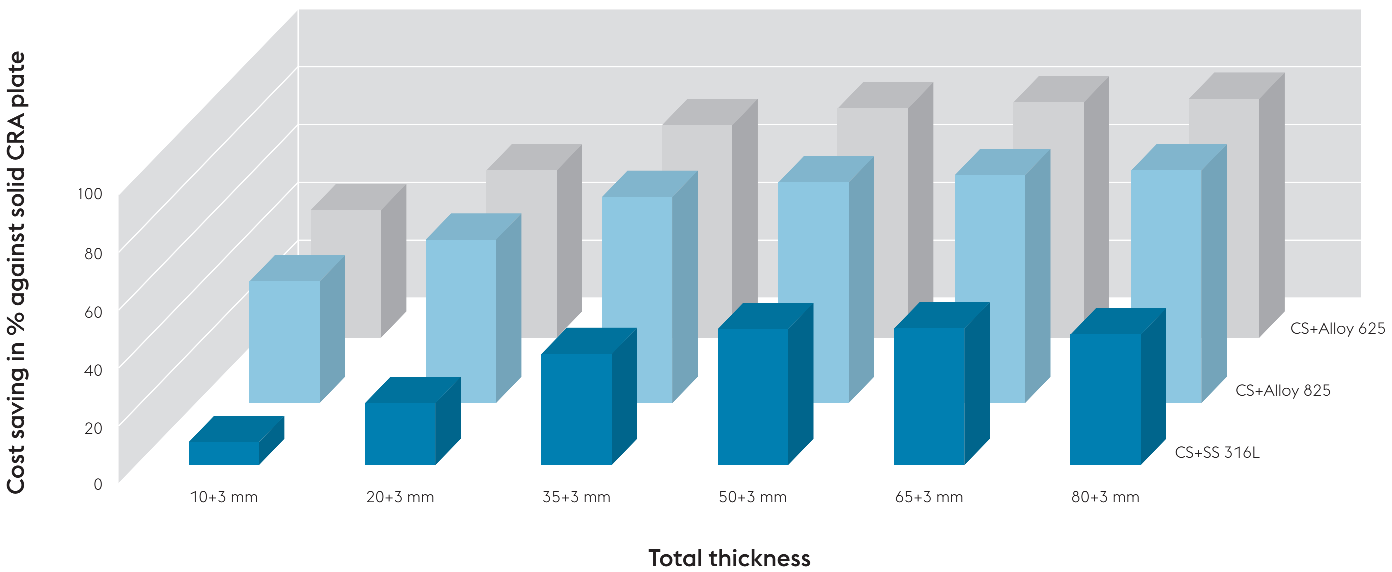
voestalpine Grobblech is the world's leading producer of roll-bonded clad plates with more than 50 years of experience and expertise. Our production capacity of 60,000 tons/year represents about one third of the entire worldwide capacity. This reduces our delivery times and consolidates our leading position in the market. We are able to supply huge single projects up to 40,000 tons within a reasonable period of time according to market requirements.

WE RUN THE WORLD'S MOST MODERN PRODUCTION LINE

Our production equipment is highly automated and provides narrow tolerances concerning dimensions, flatness and surface quality.

COST ADVANTAGES

Roll-bonded clad plates compared with solid CRA plates.



EXAMPLE

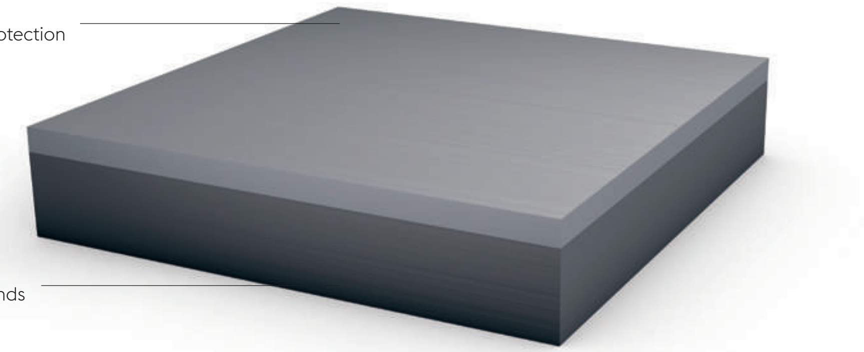
The cost saving of a roll-bonded clad plate of 10 mm carbon steel (CS) and 3 mm of alloy 625 (total thickness of 13 mm) is about 40 % against a solid CRA plate of alloy 625 in thickness of 13 mm.

DEFINITION OF ROLL-BONDED CLAD PLATES

A thin layer of expensive corrosion-resistant alloy provides excellent corrosion protection while the thicker but less expensive base-material of high-strength carbon steel ensures adequate structural strength and toughness. A metallurgical bond between the two materials is achieved in a computer-controlled hot-rolling process. Roll-bonded clad plates are the economic solution for corrosion-resistant applications in the oil and gas production, refineries, the chemical industry as well as flue gas desulphurisation plants and power plants.

DEFINITION

- Metallurgically bonded composite of two or more layers
- The bond is created by high temperature and high pressure during hot rolling
- A typical combination is a thin corrosion-resistant alloy (CRA) as clad material and a thick carbon steel as base material



ADVANTAGES OF ROLL-BONDED CLAD PLATES

Advantages in comparison to solid corrosion-resistant alloy (CRA) plates:
- Reduced material cost
- Less weight due to reduction of wall thicknesses
- Reduction of weld length due to larger dimensions
- Lower cost of filler metal
- Superior heat conductivity

Advantages in comparison to explosive cladding:
- Higher bonding quality
- Reduction of weld length due to larger dimensions
- Use of thinner clad material is possible
- No welds in the claddings for wide plates

Advantages in comparison to overlay welding:
- Improved surface quality
- No dilution from the base material
- Homogenous chemical composition

CLAD LINEPIPE PLATES

We are the world's largest producer of roll-bonded clad linepipe plates.

Roll-bonded clad plates are used for the manufacturing of clad linepipes.

HIGHEST RESISTANCE TO SOUR GAS

Roll-bonded clad plates are used for the manufacturing of clad linepipes. The sour gases occurring in linepipes used for the transport of oil and gas are highly corrosive.

Only the highest alloyed materials are capable to withstand this aggresive medium.

Our roll-bonded clad linepipe plates with corrosion-resistant claddings meet these extreme requirements. We are the world's largest producer of roll-bonded clad linepipe plates.

TMCP AND PROTECTIVE CLADDING

We provide thermomechanically rolled and accelerated cooled (TMCP) clad plates. This in-line process leads to high strength and excellent toughness combined with best weldability of the base material and maintains the extreme corrosion resistance of the protective cladding.

A typical material combination is X65 with nickel-based alloy 825 or 625 as cladding.

METALLURGICAL BOND

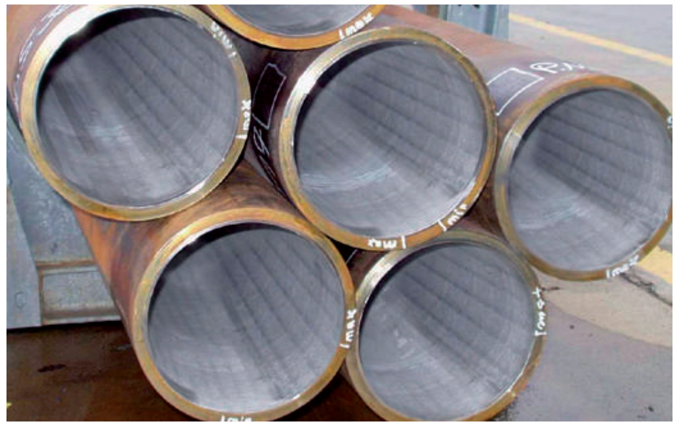
Our pipe partners process these clad plates into metallurgically bonded clad linepipes. The metallurgical bonding of the clad linepipes withstands the highest mechanical stress and dynamic loads, making the pipes especially suited to deep-sea applications under highly corrosive conditions.

REELING AND RISER PIPES

» Cost-efficient reeling of pipelines in comparison to on-board welding
» Roll-bonded clad plates for risers, bends and fittings
» Excellent properties of metallurgically bonded clad plates for the highest degree of compression strength

DELIVERY CONDITION

The conventional delivery condition of clad plates used for clad pipes is quenched and tempered. We also can provide thermomechanically rolled and accelerated cooled (TMCP) clad plates. This online processing leads to high strength and excellent toughness combined with best weldability of the base material and properly maintains corrosion properties of the clad material.



CLAD HEADS AND CONES

We produce clad heads and clad cones from roll-bonded clad plates in-house. We supply shell plates, heads and cones for pressure vessel manufacturing from a single source.

PLATES, HEADS AND CONES FROM ONE SOURCE

Benefits for our customers
» Advantages in processing, especially regarding welding when using the same steel for shell plates and heads
» Technical support and coordination from one research and quality department
» Coordinated production and delivery of shell plates and heads from a single source
» Reduced costs for our customers

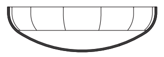
CLADDINGS

We offer ferritic and austenitic stainless steels (Cr, CrNi, CrNiMo), nickel and nickel-based alloys, copper and copper-nickel-alloys as cladding materials for clad heads and cones.

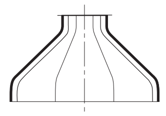
PRODUCTS AND DIMENSIONS

single-piece heads (pressed):
diameter: max. 3,700 mm*
thickness: max. 160 mm

single-piece heads (flanged):
diameter: max. 6,500 mm*
thickness: max. 65 mm
*from 3,400 – 6,500 mm with one weld seam



multi-piece heads (pressed):
diameter: max. 12,000 mm
thickness: max. 120 mm



multi-piece cones (pressed):
diameter: max. 12,000 mm
thickness: max. 120 mm

» Belt grinding or glass-bead blasting of clad surface
» Egde preparation for welding
» Heat treatment corresponding to material requirements; water quenching up to a diameter of 6,500 mm

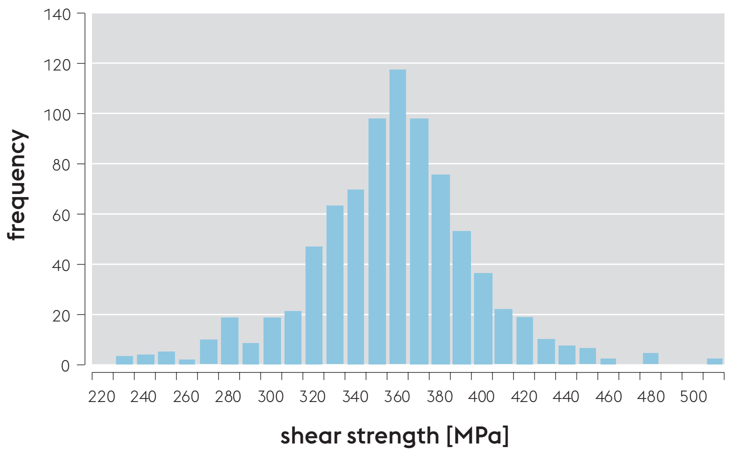
For more information about heads, please also refer to our special brochure "Heads and Cones".

QUALITY

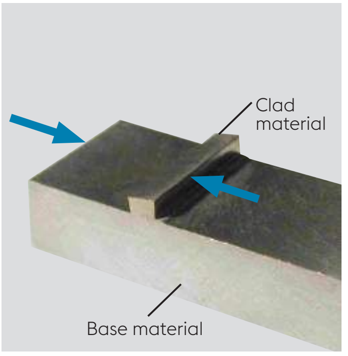
The high quality of roll-bonded clad plates is based on the mechanical properties of the base material, optimally combined with the corrosion resistance of the cladding material. Our materials fulfill the highest toughness properties (e.g. Drop Weight Tear Test, Charpy Impact Test and CTOD Test) and even HIC properties in the base material depending on the material combinations and plate thicknesses. A perfect surface finish completes this high-end product.

BOND QUALITY

The metallurgical bond between base and clad material is created by high pressure at high temperature during the hot rolling process. The bond is inseparable and far exceeds the minimum shear strength of 140 MPa required by ASTM.

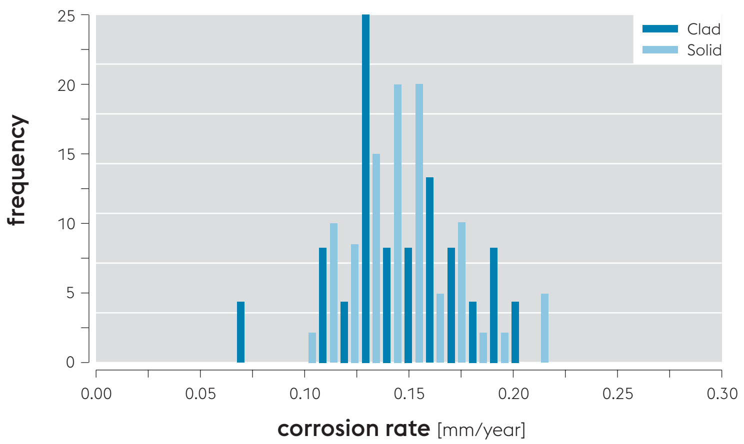


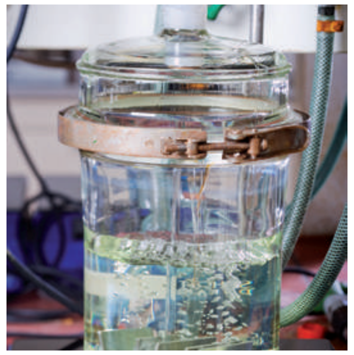
min. 140 MPa acc. to standard (ASTM A264)



CORROSION RESISTANCE

The corrosion resistance of clad material is equivalent to that of solid material.





HEAT TREATMENT

Based on the chemical composition, the mechanical-technological properties of the base material as well as the corrosion properties of the clad material are adjusted by choosing the appropriate production route and heat treatment.

- » As rolled with simulated heat treatment
- » Normalizing rolled
- » Normalized (furnace)
- » Normalized and tempered
- » Quenched and tempered
- » Thermomechanically rolled and accelerated cooled (TMCP)

SURFACE FINISH

The surface of the base material is usually "as rolled" or shot blasted. The surface of the clad material is usually ground with a grain size of 80. Other grain sizes are available on request. Any additional future surface treatment (e.g. fine grinding) of the clad surface by the customer must be indicated.

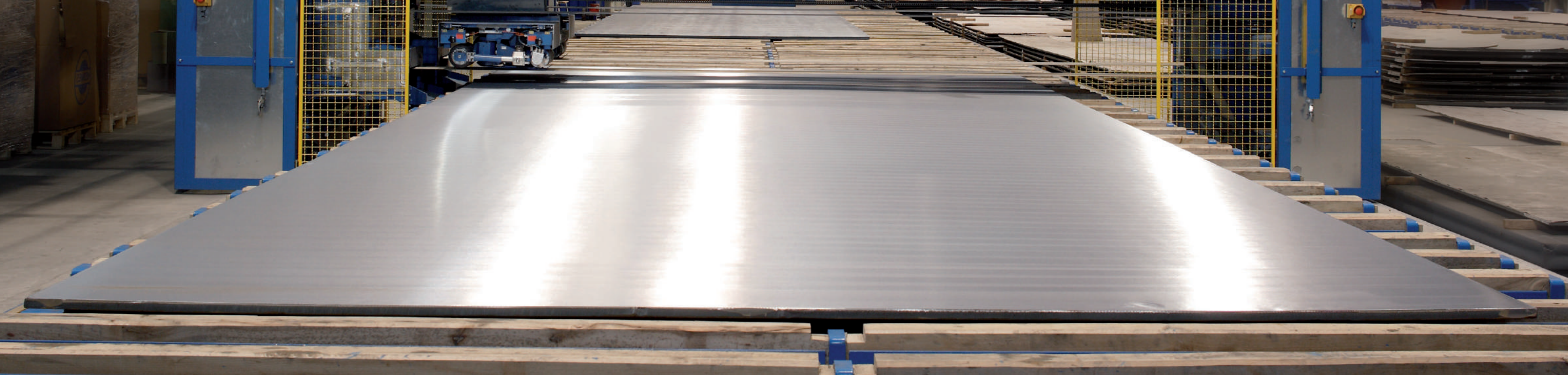
REFERENCE VALUES FOR ROUGHNESS

» Clad material: ferritic and austenitic stainless steel, nickel-based alloys

Grain size	80
Depth of roughness Rt in µm	< 40
Mean roughness Ra in µm	< 4.5

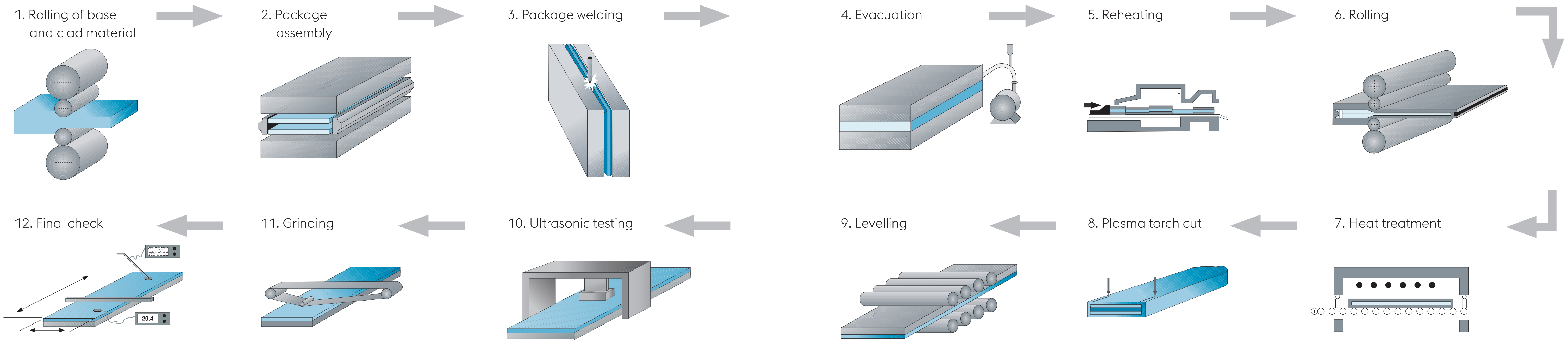
» Clad material: copper and copper alloys, nickel

Copper and copper alloys as well as nickel clad plates are ground with a grain size of 120.



CLADDING PROCESS

Our production equipment is highly automated and provides narrow tolerances concerning dimensions, flatness and surface quality.



WE TALK SOLUTIONS

That is why we will never be satisfied with excellent product quality alone. Comprehensive services and unlimited dedication to the challenges of our customers are at the core of our philosophy.

Highly specialized and closely linked, the companies of the voestalpine Steel Division have one common goal, which is providing our customers with optimized and individualized packages of benefits.

Progress through R&D
» Continual product and process development
» Innovative solutions for products and processes
» Independent and fully accredited testing facility on-site
» Simulations of material performance of weldability, deformation and edging behavior, fatigue tests and fracture mechanics
» Consultation in the fields of welding and processing

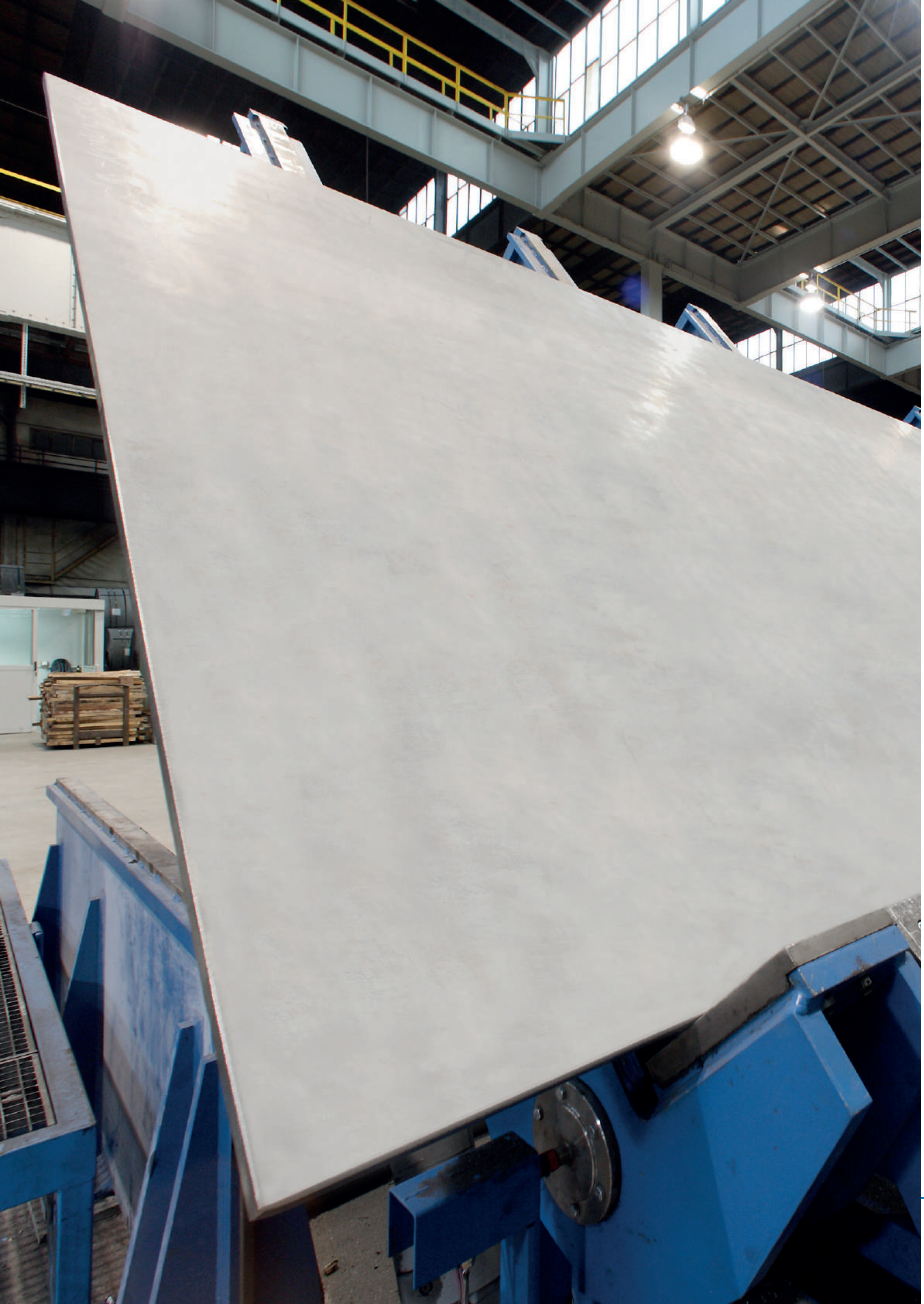
Product integrity by quality assurance
» Certified by Lloyds Register by ISO 9001
» Certified by "Verband der Technischen Überwachungsvereine"
  » AD-Merkblatt W0/TRD 100
  » Pressure Equipment Directive PED 97/23/EC

A unique logistics package
» Partnerships with our clients and customers
» Reliable and flexible delivery performance
» Professional project management ensuring successful delivery of complex orders
» Dedicated mill-based project management team for order management from pre-production to post-production to support
» Complete project documentation package (inspection and testing plan, manufacturing specifications, ultrasonic testing procedures)
» Prompt reaction to inquiries
» Web-based customer service center with customer access to order confirmations, invoices, test certificates and order status

TECHNICAL DETAILS

The following pages provide detailed information on dimensions, base materials and claddings. voestalpine Grobblech is pleased to provide technical expertise as well as processing and welding experience gained in decades of research and development work.

» Dimensions
» Base materials
» Claddings
» Processing
» Welding



DIMENSIONS

Depending on the type of clad material we can provide various dimensions. The clad materials mainly used are ferritic and austenitic stainless steels, nickel and nickel-based alloys and copper alloys.

» Clad material:
ferritic and austenitic stainless steel

Total thickness	6 - 150 mm
Clad thickness	1.5 - 10 mm
Width	max. 3,800 mm
Length Water quenched	max. 15,000 mm *) max. 12,400 mm *)
Weight per plate	min. 2 t / max. 20 t
Area	min. 6 m^2

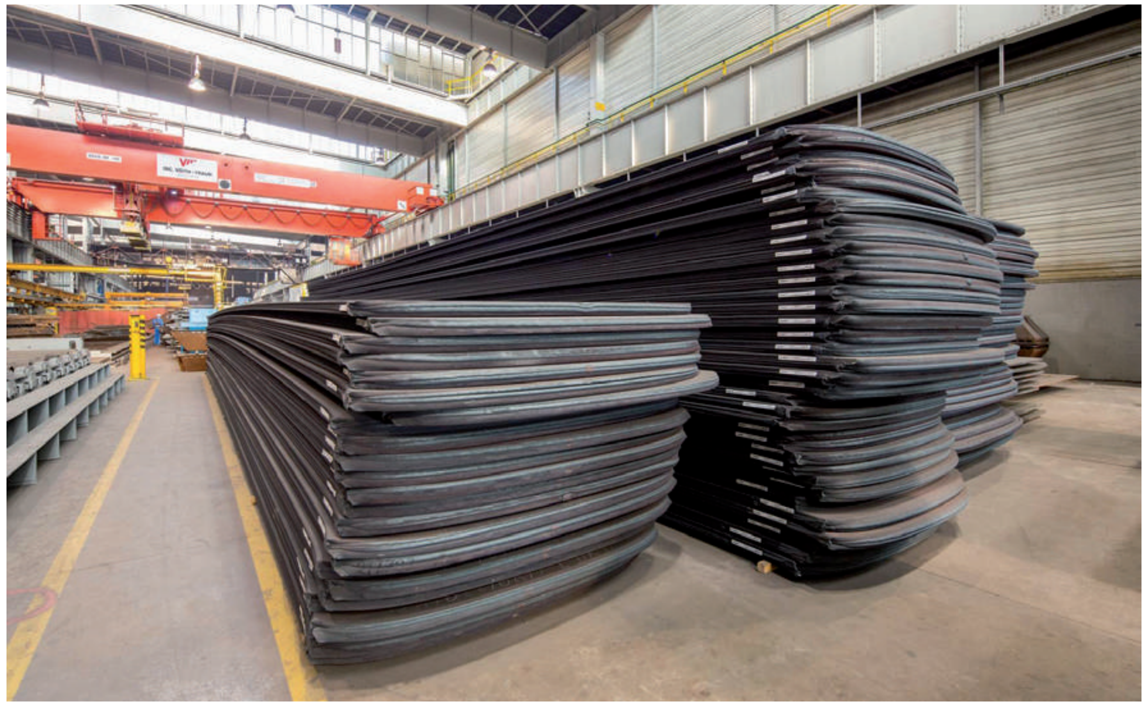
» Clad material:
copper alloys

Total thickness	6 - 65 mm
Clad thickness	1.5 - 10 mm
Width	max. 3,800 mm
Length water quenched	max. 15,000 mm *) max. 12,400 mm *)
Weight per plate	min. 2 t / max. 20 t
Area	min. 6 m^2

» Clad material:
nickel alloys 625, 825

Total thickness	6 - 120 mm
Clad thickness	1.5 - 10 mm
Width	max. 3,800 mm
Length Water quenched	max. 15,000 mm *) max. 12,400 mm *)
Weight per plate	min. 2 t / max. 14 t
Area	min. 6 m^2

*) Further dimensions upon request



BASE MATERIALS

The base materials for roll-bonded clad plates are made of slabs

cast at voestalpine steel mill on-site in Linz.

We mainly use
» Structural steels
» Pressure vessel steels
» Linepipe steels

Depending on the requirements of the respective standards and customer specifications as well as on the required corrosion resistance of the cladding materials, we provide the following delivery conditions:

» As rolled with simulated testing
» Normalizing rolled
» Normalized (furnace)
» Normalized and tempered
» Quenched and tempered
» Thermomechanically rolled and accelerated cooled (TMCP)

On the right you will find a summary of the most applicable base materials for roll-bonded clad plates. Other base materials on request. The indicated chemical and mechanical data refer to the smallest thickness group.

BASE MATERIALS: STRUCTURAL STEELS AND PRESSURE VESSEL STEELS ACCORDING TO EN 10025-2, EN 10028-2 AND EN 10028-3

		Chemical composition (heat analysis) %								Mechanical properties		
Standard	Steel grade	C [1] max.	Si max.	Mn max.	P max.	S max.	Cr max.	Ni max.	Mo max.	Yield strength [1] min.[MPa]	Tensile strength [1] [MPa]	Comparable ASTM-steel grade
EN 10025-2	S235JR	0.17	–	1.40	0.035	0.035	–	–	–	235	360 - 510	–
	S355JR	0.24	0.55	1.60	0.035	0.035	–	–	–	355	510 - 680	–
EN 10028-2	P235GH	0.16	0.35	0.60 - 1.20	0.025	0.010	0.30	0.30	0.08	235	360 - 480	A285 GradeC
	P265GH	0.20	0.40	0.80 - 1.40	0.025	0.010	0.30	0.30	0.08	265	410 - 530	A516 Grade60
	P295GH	0.08 - 0.20	0.40	0.90 - 1.50	0.025	0.010	0.30	0.30	0.08	295	460 - 580	A516 Grade65
	P355GH	0.10 - 0.22	0.60	1.10 - 1.70	0.025	0.010	0.30	0.30	0.08	355	510 - 650	A516 Grade70
	16Mo3	0.12 - 0.20	0.35	0.40 - 0.90	0.025	0.010	0.30	0.30	0.25 - 0.35	275	440 - 590	–
	20MnMoNi4-5	0.15 - 0.23	0.40	1.00 - 1.50	0.020	0.010	0.20	0.40 - 0.80	0.45 - 0.60	470	590 - 750	A533 Type B Class2
	13CrMo4-5	0.08 - 0.18	0.35	0.40 - 1.00	0.025	0.010	0.70 - 1.15	–	0.40 - 0.60	300	450 - 600	A387 Grade12 Class2
	10CrMo9-10	0.08 - 0.14	0.50	0.40 - 0.80	0.020	0.010	2.00 - 2.50	–	0.90 - 1.10	310	480 - 630	–
	12CrMo9-10	0.10 - 0.15	0.30	0.30 - 0.80	0.015	0.010	2.00 - 2.50	0.30	0.90 - 1.10	355	540 - 690	A387 Grade22 Class2
	13CrMoV9-10	0.11 - 0.15	0.10	0.30 - 0.60	0.015	0.005	2.00 - 2.50	0.25	0.90 - 1.10	455	600 - 780	A542 Type D Class4
EN 10028-3	P275 NH	0.16	0.40	0.80 - 1.50	0.025	0.010	0.30	0.50	0.08	275	390 - 510	A516 Grade60
	P275 NL1	0.16	0.40	0.80 - 1.50	0.025	0.008	0.30	0.50	0.08	275	390 - 510	A516 Grade60
	P275 NL2	0.16	0.40	0.80 - 1.50	0.020	0.005	0.30	0.50	0.08	275	390 - 510	A516 Grade60
	P355 NH	0.18	0.50	1.10 - 1.70	0.025	0.010	0.30	0.50	0.08	355	490 - 630	A516 Grade70
	P355 NL1	0.18	0.50	1.10 - 1.70	0.025	0.008	0.30	0.50	0.08	355	490 - 630	A516 Grade70
	P355 NL2	0.18	0.50	1.10 - 1.70	0.020	0.005	0.30	0.50	0.08	355	490 - 630	A516 Grade70
	P460 NH	0.20	0.60	1.10 - 1.70	0.025	0.010	0.30	0.80	0.10	460	570 - 730	A572 Grade65
	P460 NL1	0.20	0.60	1.10 - 1.70	0.025	0.008	0.30	0.80	0.10	460	570 - 730	A572 Grade65
	P460 NL2	0.20	0.60	1.10 - 1.70	0.020	0.005	0.30	0.80	0.10	460	570 - 730	A572 Grade65

[1] depending on thickness

BASE MATERIALS: STRUCTURAL STEELS AND PRESSURE VESSEL STEELS ACCORDING TO ASTM

Standard	Steel grade	Chemical composition (heat analysis) % C [1,2] max.	Si max.	Mn [2] max.	P max.	S max.	Cr max.	Ni max.	Mo max.	Mechanical properties Yield strength [1] min. [MPa]	Tensile strength [1] [MPa]	Comparable steel grade of EN 10028
ASTM	A285 GradeC	0.28	–	0.90	0.025	0.025	–	–	–	205	380 - 515	P235GH
	A516 Grade60	0.21	0.15 - 0.40	0.60 - 0.90	0.025	0.025	–	–	–	220	415 - 550	P275
	A516 Grade65	0.24	0.15 - 0.40	0.85 - 1.20	0.025	0.025	–	–	–	240	450 - 585	P355
	A516 Grade70	0.27	0.15 - 0.40	0.85 - 1.20	0.025	0.025	–	–	–	260	485 - 620	P355
	A572 Grade65 Type 1	0.23	0.40	1.65	0.040	0.050	–	–	–	450	≥ 550	P460
	A204 Grade A	0.18	0.15 - 0.40	0.90	0.025	0.025	–	–	0.45 - 0.60	255	450 - 585	16Mo3
	A204 Grade B	0.20	0.15 - 0.40	0.90	0.025	0.025	–	–	0.45 - 0.60	275	485 - 620	16Mo3
	A302 Grade B	0.20	0.15 - 0.40	1.15 - 1.50	0.025	0.025	–	–	0.45 - 0.60	345	550 - 690	18MnMo4-5
	A533 Type B Class1	0.25	0.15 - 0.40	1.15 - 1.50	0.025	0.025	–	0.40 - 0.70	0.45 - 0.60	345	550 - 690	20MnMoNi4-5
	A533 Type B Class2	0.25	0.15 - 0.40	1.15 - 1.50	0.025	0.025	–	0.40 - 0.70	0.45 - 0.60	485	620 - 795	20MnMoNi4-5
	A387 Grade11 Class2	0.05 - 0.17	0.50 - 0.80	0.40 - 0.65	0.025	0.025	1.00 - 1.50	–	0.45 - 0.65	310	515 - 690	13CrMoSi5-5
	A387 Grade12 Class2	0.05 - 0.17	0.15 - 0.40	0.40 - 0.65	0.025	0.025	0.80 - 1.15	–	0.45 - 0.60	275	450 - 585	13CrMo4-5
	A387 Grade22 Class2	0.05 - 0.15	0.50	0.30 - 0.60	0.025	0.025	2.00 - 2.50	–	0.90 - 1.10	310	515 - 690	12CrMo9-10
	A542 Type D Class4	0.11 - 0.15	0.10	0.30 - 0.60	0.015	0.010	2.00 - 2.50	0.25	0.90 - 1.10	380	585 - 760	13CrMoV9-10
	A841 Grade A Class1	0.20	0.15 - 0.50	0.70 - 1.60	0.030	0.030	0.25	0.25	0.08	345	485 - 620	P355

[1] depending on thickness
[2] if C-content is reduced, Mn-content may be increased

BASE MATERIALS: FITTING STEELS AND LINEPIPE STEELS ACCORDING TO ASTM, API 5L AND DNVGL-ST-F101

Standard	Steel grade	Chemical composition (heat analysis) % C [1,2] max.	Si max.	Mn [2] max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	V max.	Mechanical properties Yield strength [1] min. [MPa]	Tensile strength [1] [MPa]	Comparable steel grade of ASTM / DNVGL / API
ASTM	A106 GradeB	0.30	0.10	0.29 - 1.06	0.035	0.035	0.40	0.40	0.40	0.15	0.08	240	≥ 415	ASTM A516 Grade65
	A672 GradeC60	0.21	0.15 - 0.40	0.60 - 0.90	0.025	0.025	–	–	–	–	–	220	415 - 550	ASTM A516 Grade60
	A672 GradeC70	0.27	0.15 - 0.40	0.85 - 1.20	0.025	0.025	–	–	–	–	–	260	485 - 620	ASTM A516 Grade70
ASTM A860	WPHY 42	0.20	0.15 - 0.40	1.00 - 1.45	0.030	0.010	0.30	0.50	0.35	0.25	0.10	290	415 - 585	–
	WPHY 52											360	455 - 625	
	WPHY 60											415	515 - 690	
	WPHY 65											450	530 - 705	
API 5L	GradeB – PSL2	0.22	0.45	1.20	0.025	0.015	–	–	–	–	–	245 - 450	415 - 655	DNVGL SAWL 245
	X52 – PSL2	0.22	0.45	1.40	0.025	0.015	–	–	–	–	–	360 - 530	460 - 760	DNVGL SAWL 360
	X60 – PSL2	0.12	0.45	1.60	0.025	0.015	–	–	–	–	–	415 - 565	520 - 760	DNVGL SAWL 415
	X65 – PSL2	0.12	0.45	1.60	0.025	0.015	–	–	–	–	–	450 - 600	535 - 760	DNVGL SAWL 450
DNVGL-ST-F101	SAWL 245	0.12	0.40	1.25	0.020	0.010	0.30	0.30	0.35	0.10	0.04	245 - 450	415 - 760	API 5L GradeB
	SAWL 360	0.12	0.45	1.65	0.020	0.010	0.50	0.50	0.50	0.50	0.05	360 - 525	460 - 760	API 5L X52
	SAWL 415	0.12	0.45	1.65	0.020	0.010	0.50	0.50	0.50	0.50	0.08	415 - 565	520 - 760	APL 5L X60
	SAWL 450	0.12	0.45	1.65	0.020	0.010	0.50	0.50	0.50	0.50	0.10	450 - 570	535 - 760	API 5L X65

[1] depending on thickness
[2] if C-content is reduced, Mn-content may be increased

CLADDINGS

The clad materials for the roll-bonded clad plates are supplied by leading manufacturers as slabs or plates.

We mainly use
- Ferritic and austenitic stainless steels and heat-resistant steels
- Nickel and nickel-based alloys
- Copper and copper-alloys

On the right you will find a summary of the most frequently used clad materials for roll-bonded clad plates. Other clad materials on request.

CLADDINGS: STAINLESS STEELS AND HEAT-RESISTANT STEELS

Standard	EN material number	Steel grade	Chemical composition (heat analysis) % (extract)									Mean pitting resistance equivalent number (PREN) Cr+3.3Mo+16N [%]	Comparable ASTM A240 / ASME SA240 type
			C max.	Si max.	Mn max.	P max.	S max.	Cr	Ni	Mo	Others		
EN 10088	1.4000	X6Cr13	0.08	1.0	1.0	0.040	0.030	12.0 - 14.0	–	–	–	–	410S
	1.4301	X5CrNi18-10	0.07	1.0	2.0	0.045	0.030	17.5 - 19.5	8.0 - 10.5	–	N ≤ 0.10	–	304
	1.4306	X2CrNi19-11	0.03	1.0	2.0	0.045	0.030	18.0 - 20.0	10.0 - 12.0	–	N ≤ 0.10	–	304L
	1.4541	X6CrNiTi18-10	0.08	1.0	2.0	0.045	0.030	17.0 - 19.0	9.0 - 12.0	–	5xC < Ti ≤ 0.70	–	321
	1.4550	X6CrNiNb18-10	0.08	1.0	2.0	0.045	0.015	17.0 - 19.0	9.0 - 12.0	–	10xC < Nb ≤ 1.00	–	347
	1.4401	X5CrNiMo17-12- 2	0.07	1.0	2.0	0.045	0.030	16.5 - 18.5	10.0 - 13.0	2.0 - 2.5	N ≤ 0.10	25	316
	1.4404	X2CrNiMo17-12-2	0.03	1.0	2.0	0.045	0.030	16.5 - 18.5	10.0 - 13.0	2.0 - 2.5	N ≤ 0.10	25	316L
	1.4571	X6CrNiMoTi17-12-2	0.08	1.0	2.0	0.045	0.030	16.5 - 18.5	10.5 - 13.5	2.0 - 2.5	5xC < Ti ≤ 0.70	25	316Ti
	1.4432	X2CrNiMo17-12-3	0.03	1.0	2.0	0.045	0.030	16.5 - 18.5	10.5 - 13.0	2.5 - 3.0	N ≤ 0.10	27	316L Mod Mo ≥ 2.5
	1.4435	X2CrNiMo18-14-3	0.03	1.0	2.0	0.045	0.030	17.0 - 19.0	12.5 - 15.0	2.5 - 3.0	N ≤ 0.10	28	316L Mod Mo ≥ 2.5
	1.4429	X2CrNiMoN17-13-3	0.03	1.0	2.0	0.045	0.015	16.5 - 18.5	11.0 - 14.0	2.5 - 3.0	N = 0.12 - 0.22	29	316LN Mod Mo ≥ 2.5
	1.4438	X2CrNiMo18-15-4	0.03	1.0	2.0	0.045	0.030	17.5 - 19.5	13.0 - 16.0	3.0 - 4.0	N ≤ 0.10	31	317L
	1.4439	X2CrNiMoN17-13-5	0.03	1.0	2.0	0.045	0.015	16.5 - 18.5	12.5 - 14.5	4.0 - 5.0	N 0.12 - 0.22	35	317LMN
SEW 470	1.4828	X15CrNiSi20-12	0.20	1.5 - 2.5	2.0	0.045	0.015	19.0 - 21.0	11.0 - 13.0	–	N ≤ 0.10	–	–

Standard	UNS number	Steel grade	Chemical composition (heat analysis) % (extract)									Mean pitting resistance equivalent number (PREN) Cr+3.3Mo+16N [%]	Comparable grade of EN 10088
			C max.	Si max.	Mn max.	P max.	S max.	Cr	Ni	Mo	Others		
ASTM A240 and ASME SA240	S41008	410S	0.08	1.00	1.0	0.040	0.030	11.5 - 13.5	max. 0.60	–	–	–	1.4000
	S30400	304	0.07	0.75	2.0	0.045	0.030	17.5 - 19.5	8.0 - 10.5	–	N ≤ 0.10	–	1.4301
	S30403	304L	0.03	0.75	2.0	0.045	0.030	17.5 - 19.5	8.0 - 12.0	–	N ≤ 0.10	–	1.4306
	S32100	321	0.08	0.75	2.0	0.045	0.030	17.0 - 19.0	9.0 - 12.0	–	N ≤ 0.10 5x(C+N) < Ti ≤ 0.70	–	1.4541
	S34700	347	0.08	0.75	2.0	0.045	0.030	17.0 - 19.0	9.0 - 13.0	–	10xC < Nb ≤ 1.00	–	1.4550
	S31600	316	0.08	0.75	2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N ≤ 0.10	25	1.4401
	S31603	316L	0.03	0.75	2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N ≤ 0.10	25	1.4404
		316L Mod Mo ≥ 2.5	0.03	0.75	2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.5 - 3.0	N ≤ 0.10	27	1.4432/1.4435
	S31635	316Ti	0.08	0.75	2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N ≤ 0.10 5x(C+N) < Ti ≤ 0.70	25	1.4571
	S31653	316LN	0.03	0.75	2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N = 0.10 - 0.16	27	–
	–	316LN Mod Mo ≥ 2.5	0.03	0.75	2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.5 - 3.0	N = 0.10 - 0.16	29	1.4429
	S31703	317L	0.03	0.75	2.0	0.045	0.030	18.0 - 20.0	11.0 - 15.0	3.0 - 4.0	N ≤ 0.10	31	1.4438
	S31726	317LMN	0.03	0.75	2.0	0.045	0.030	17.0 - 20.0	13.5 - 17.5	4.0 - 5.0	N = 0.10 - 0.20	35	1.4439

CLADDINGS: SPECIAL STEELS, NON-FERROUS METALS AND ALLOYS

ASTM	Alloy type	Chemical composition (heat analysis) % (extract) C max.	Si max.	Mn max.	P max.	S max.	Cr	Ni	Mo	Others	Mean pitting resistance equivalent number (PREN) Cr+3.3Mo+16N [%]	EN material number	Comparable grades EN / DIN / SEW	VdTÜV material sheet
B 409 UNS N08800	Alloy 800	0.10	1.00	1.5	0.045	0.015	19.0 - 23.0	30.0 - 35.0	–	Al = 0.15 - 0.60 Ti = 0.15 - 0.60 Cu ≤ 0.75, Fe ≥ 39.5	–	1.4876	SEW 470	412
A 240/A 240M UNS N08904	Alloy 904 L	0.02	1.00	2.0	0.045	0.035	19.0 - 23.0	23.0 - 28.0	4.0 - 5.0	Cu = 1.0 - 2.0 N ≤ 0.10	36	1.4539		421
B 709 UNS N08028	Alloy 28	0.03	1.00	2.5	0.030	0.030	26.0 - 28.0	29.5 - 32.5	3.0 - 4.0	Cu = 0.60 - 1.40	39	1.4563	EN 10088	–
B 677 UNS N08926	Alloy 926	0.02	0.50	2.0	0.030	0.010	19.0 - 21.0	24.0 - 26.0	6.0 - 7.0	Cu = 0.50 - 1.50 N = 0.15 - 0.25	44	1.4529		502
B 463 UNS N08020	Alloy 20	0.07	1.00	2.0	0.045	0.035	19.0 - 21.0	32.0 - 38.0	2.0 - 3.0	Cu = 3.0 - 4.0 8xC < (Nb+Ta) < 1.0	28	2.4660	DIN 17744	–
B 424 UNS N08825	Alloy 825	0.05	0.50	1.0	–	0.030	19.5 - 23.5	38.0 - 46.0	2.5 - 3.5	Cu = 1.5–3.0 Ti = 0.60–1.20 Fe > 22.0, Al < 0.2	31	2.4858	DIN 17744	432
B 443 UNS N06625	Alloy 625	0.10	0.50	0.5	0.015	0.015	20.0 - 23.0	> 58.0	8.0 - 10.0	Fe < 5.0, (Co < 1.0) Nb = 3.15 - 4.15 Al < 0.40, Ti < 0.40	51	2.4856	DIN 17744	499
B 575 UNS N06022	Alloy C 22	0.015	0.08	0.5	0.020	0.020	20.0 - 22.5	rest	12.5 - 14.5	Fe = 2.0 - 6.0 W = 2.5 - 3.5 V < 0.35, Co < 2.50	66	2.4602	DIN 17744	479
B 575 UNS N06455	Alloy C 4	0.015	0.08	1.0	0.040	0.030	14.0 - 18.0	rest	14.0 - 17.0	Fe < 3.0 Ti < 0.70 Co < 2.0	67	2.4610	DIN 17744	424
B 575 UNS N10276	Alloy C 276	0.01	0.08	1.0	0.040	0.030	14.5 - 16.5	rest	15.0 - 17.0	W = 3.0 - 4.5 Fe = 4.0 - 7.0 Co < 2.5, V < 0.35	68	2.4819	DIN 17744	400
B 575 UNS N06059	Alloy 59	0.01	0.10	0.5	0.015	0.010	22.0 - 24.0	rest	15.0 - 16.5	Al = 0.1 - 0.4 Fe < 1.5, Co < 0.3 Cu < 0.5	75	2.4605	DIN 17744	505
B 333 UNS N10665	Alloy B 2	0.02	0.10	1.0	0.040	0.030	1.0	rest	26.0 - 30.0	Fe < 2.0 Co < 1.00	–	2.4617	DIN 17744	436
B 168 UNS N06600	Alloy 600	0.15	0.50	1.0	–	0.015	14.0 - 17.0	> 72.0	–	Fe = 6.0 - 10.0 Cu < 0.50	–	2.4816	DIN 17742	305
B 127 UNS N04400	Alloy 400	0.30	0.50	2.0	–	0.024	–	> 63.0	–	Cu = 28.0 - 34.0 Fe < 2.5	–	2.4360	DIN 17743	263
B 162 UNS N02200	Alloy 200	0.15	0.35	0.35	–	0.010	–	> 99.00	–	Fe < 0.4 Cu < 0.25	–	2.4066	DIN 17740	–
B 162 UNS N02201	Alloy 201	0.02	0.35	0.35	–	0.010	–	> 99.00	–	Fe < 0.4 Cu < 0.25	–	2.4068		345
B 152 UNS C10300	Copper	–	–	–	0.001 - 0.005	–	–	–	–	Cu > 99.95	–	2.0070	DIN 1787	–
B 152 UNS C12200	Copper	–	–	–	0.015 - 0.040	–	–	–	–	Cu > 99.90	–	CW 024 A		–
B 171 UNS C70600	Alloy CuNi 90/10	–	–	1.0	–	–	–	9.0 - 11.0	–	Fe = 1.0 - 1.8, Cu rest, Zn < 1.0, Pb < 0.05	–	CW 352 H	EN 1652	420
B 171 UNS C71500	Alloy CuNi 70/30	0.05	–	1.0	–	–	–	29.0 - 33.0	–	Fe = 0.40 - 1.0, Cu rest Zn < 1.0, Pb < 0.05	–	CW 354 H		–

PROCESSING

voestalpine Grobblech is pleased to provide expertise and technical experience in cutting, cold forming and hot forming, gained over decades of research and development work.

CUTTING

Roll-bonded clad plates are best cut using plasma torches. This cutting process provides clean cut edges, which are prepared for subsequent welding by simply removing the oxide skin. Note: The plasma cut is always performed from the clad side.

Thin clad plates can be shear cut (cladding material on top) without problems. Cutting is always performed ensuring sharp blades, exact setting of the cutting clearance and optimum bankholder force. It is also possible to use water jet cutting.

COLD FORMING

Cold forming of roll-bonded clad plates is possible by bending, pressing, dishing and rolling. Clean surfaces of the cladding and the tools are of great importance in all forming processes. Roll-bonded clad plates show excellent forming behavior.

The material-specific properties of the clad material must be taken into account. Specific information and recommendations on cold forming and heat treatment of stainless steel, non-ferrous metals and alloys can be found in the corresponding material data sheets of these clad materials provided by the manufacturer of those materials.

HOT FORMING

Roll-bonded clad plates are formed in accordance with accepted technologies and by taking into consideration the cladding material. The surfaces of the cladding materials must be free of contaminations like grease, oil, marking colors etc. in order to prevent carburization. It is very important to obtain an atmosphere with low sulfur content.

In some cases heat treatment is required after hot forming. High-alloy claddings can only achieve their optimum corrosion resistance by means of special temperature controls.

Therefore, voestalpine Grobblech should be contacted early in the beginning stages of component design. To avoid corrosion, the surface of the cladding material must be cleaned after the last processing step. Oxide skins, annealing colors, welding spatters, any scratches resulting from ferrous materials, marks, rust from external sources etc. must be removed.

WELDING

The instructions in this brochure are of a general nature. For detailed information, experienced welding engineers are at your disposal.

WELDING PROCESSES

As a rule the base materials are welded by applying shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), submerged arc welding (SAW), submerged arc strip cladding (SASC) and electro slag strip cladding (ESSC).

The following welding processes for cladding materials are used, when particularly low dilution with base metal is required:

- » SMAW
- » GTAW, pulse GTAW
- » FCAW
- » Electro slag strip cladding (ESSC)
- » Pulse GMAW
- » Submerged arc strip cladding (SASC)

FILLER METALS

The filler metals for welding the base materials of clad plates are the same as for non-clad plates. The recommended filler metals for the claddings in the tables on pages 24/25 and 26/27 are indicated in the tables on pages 30/31 and 32/33. Selections are made after considering the following aspects:

- » If possible, the first layer should be welded with over-alloyed fillers, in order to approximate the composition of the cladding during mixing with the base material.

- » For 13 % Cr steel claddings, not only the buffer is welded with an over-alloyed austenitic electrode, type 23 12 L, but frequently the cover pass as well. If standard fillers of 19/9-types are used, there is a risk of martensite formation at high dilution of 13 % Cr steel. A buffer with electrode type 23 12 L is also recommended for cover passes with 13 % Cr weld metals. When applying ESSC, the use of austenitic consumables is not mandatory, 17 % Cr (430L) ferritic strip allows to deposit 13 % Cr weld overlay.

- » For austenitic stainless steels and nickel alloys with more than 3.0 % Mo, the recommended filler materials for the filler and cover passes should be over-alloyed by a factor of 1.3 with respect to Mo. This is done to reduce the risk of pitting corrosion, where the PREN is decisive. In every cast material and especially in the non-solution-annealed weld metal, Mo is more segregated than in the cladding. Therefore Mo-depleted zones occur which have only 70-80 % of the average Mo-content.

- » Soldering brittleness may occur when welding Cu, CuNi 90/10 and CuNi 70/30 onto steel. Therefore we recommend a buffer with alloy 400 (table on page 32/33).

RECOMMENDED FILLER METALS FOR THE WELDING OF STAINLESS OR HEAT-RESISTANT CLADDINGS
According to EN ISO 3581-A, EN ISO 14343-A and EN ISO 17633-A
as well as AWS A 5.4, A 5.9 and A 5.22

Cladding		Filler metal type [1] multi-pass (SMAW) [2]								
		buffer			subsequent passes			single layer ESSC		
EN material number	ASTM A 240 type	EN ISO 3581	AWS 5.4	Recommended product	EN ISO 3581	AWS 5.4	Recommended product	EN ISO 14343	AWS 5.9	Recommended product
1.4000	410S	23 12 L	309L	BÖHLER FOX CN 23/12-A	19 9 Nb 13	347 410	BÖHLER FOX KW 10	B17	EQ 430	SOUDOTAPE 430 + RECORD EST 501
1.4301	304	23 12 L	309L	BÖHLER FOX CN 23/12-A	19 9 L	308 L	BÖHLER FOX EAS 2 BÖHLER FOX EAS 2-A	B 23 12 L B 22 11 L B 19 9 L	EQ 309L ~EQ309L EQ308L	SOUDOTAPE 309L + RECORD EST 501
1.4306	304L				19 9 L 19 9 Nb	308 L 347 [3]	BÖHLER FOX EAS 2 BÖHLER FOX EAS 2-A BÖHLER FOX SAS 2 BÖHLER FOX SAS 2-A			SOUDOTAPE 22.11L + RECORD EST 501 SOUDOTAPE 308L + RECORD EST 308-1
1.4541	321				19 9 Nb	347 [3]	BÖHLER FOX SAS 2 BÖHLER FOX SAS 2-A	B 23 12 Nb B 22 11 LNb B 19 9 Nb	~EQ 309LNb ~EQ347 EQ347	SOUDOTAPE 24.12LNb + RECORD EST 501
1.4550	347									SOUDOTAPE 21.11LNb + RECORD EST 501 SOUDOTAPE 347 + RECORD EST 347-1
1.4401	316	23 12 2 L	309L Mo	BÖHLER FOX CN 23/12 Mo-A	19 12 3 L [4] 19 12 3 Nb [4]	316L [4] 318 [4]	BÖHLER FOX EAS 4 M BÖHLER FOX EAS 4 M-A BÖHLER FOX SAS 4 BÖHLER FOX SAS 4-A	B 19 12 3 L B 21 13 3 L	EQ 316L ~EQ309LMo	SOUDOTAPE 316L + RECORD EST 316-1 SOUDOTAPE 21.13.3L + RECORD EST 501
1.4404	316L									
1.4571	316Ti									
1.4432	316L Mo ≥ 2.5				18 16 5 L 19 13 4 N L	317L mod 317L	BÖHLER FOX ASN 5 BÖHLER FOX ASN 5-A Avesta 317L/SNR	B 21 13 3 L	~EQ309LMo	SOUDOTAPE 21.13.3L + RECORD EST 501
1.4435	316 Mo ≥ 2.5									
1.4429	316LN Mo ≥ 2.5									
1.4438	317L	23 12 L	309L	BÖHLER FOX CN 23/12-A	18 16 5 L 19 13 4 N L	317L mod 317L	BÖHLER FOX ASN 5 BÖHLER FOX ASN 5-A Avesta 317L/SNR	B 21 13 3 L	~EQ309LMo	SOUDOTAPE 21.13.3L + RECORD EST 122Mo
1.4439	317LMN				20 25 6 Cu L	385 mod	BÖHLER FOX CN 20/25 M BÖHLER FOX CN 20/25 M-A	B 20 25 5 L Cu	EQ385	SOUDOTAPE 20.25.5LCu + RECORD EST 501
1.4828	309	18 8 Mn	307 mod.	BÖHLER FOX A 7 BÖHLER FOX A 7-A	22 12	309	BÖHLER FOX FF BÖHLER FOX FF-A	B 23 12 L	EQ 309L	SOUDOTAPE 309L + RECORD EST 501

[1] Some of the filler metals are not included in the standard, but available on the market
[2] For GTAW, GMAW or FCAW welding, types of similar composition are used
[3] To be applied for stress-relief annealing
[4] If stress-relief annealing is applied, please contact us

RECOMMENDED FILLER METALS FOR THE WELDING OF CLAD MATERIALS MADE OF SPECIAL STEELS, NON-FERROUS METALS AND ALLOYS

According to EN ISO 18274, EN ISO 14640 and/or EN ISO 3581-A, EN ISO 14343-A, EN ISO 17633-A, EN ISO 14172-A, EN ISO 12153 as well as AWS A 5.4, A 5.7, A 5.9, A 5.11, A 5.14, A 5.16, and A 5.22

Cladding		Filler metal type multi-pass (GTAW, GMAW, FCAW) buffer			Filler metal type multi-pass (GTAW, GMAW, FCAW) subsequent passes		
Alloy type	EN material number	EN ISO 18274	AWS	Recommended product	EN ISO 18274	AWS	Recommended product
Alloy 800	1.4876	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625	Ni 66 25 (NiCr22Mo9Nb)	Ni 66 25 (NiCr22Mo9Nb)	Thermanit 625
Alloy 904L	1.4539	23 12 L	309L	BÖHLER CN 23/12-IG	20 25 5 CuL	385	BÖHLER CN 23/12-IG
Alloy 28	1.4563	23 12 L	309L	BÖHLER CN 23/12-IG	27 31 4 CuL	383	-
Alloy 926	1.4529	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625
Alloy 20	2.4660	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625
Alloy 825	2.4858	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625
Alloy 625	2.4856	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Thermanit 625
Alloy C22	2.4602	Ni 60 22 (NiCr21Mo13W3)	NiCrMo-13	UTP A 759 / A722	Ni 60 22 (NiCrMo13W3)	NiCrMo-13	UTP A 759 / A722
Alloy C4	2.4610	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-13	UTP A 759	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-13	UTP A 759
Alloy C276	2.4819	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-13	UTP A 759	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-13	UTP A 759
Alloy 59	2.4605	Ni 60 59 (NiCr23Mo16)	NiCrMo-13	UTP A 759	Ni 60 59 (NiCr23Mo16)	NiCrMo-13	UTP A 759
Alloy B2	2.4617	-	-	-	-	-	-
Alloy 600	2.4816	Ni 60 82 (NiCr20Mn3Nb)	NiCr-3	Thermanit Nicro 82	Ni 60 82 (NiCr20Mn3Nb)	NiCr-3	Thermanit Nicro 82
Alloy 400	2.4360	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7	UTP A 80 M	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7	UTP A 80 M
Alloy 200	2.4066	Ni 20 61 (NiTi3)	Ni-1	UTP A 80 Ni	Ni 20 61 (NiTi3)	Ni-1	UTP A 80 Ni
Alloy 201	2.4068						
SE-Cu	CW021A	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7	UTP A 38 UTP A 387	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7	UTP A 38 UTP A 387
SF-Cu	CW024A						
CuNi 90/10	CW352H						
CuNi 70/30	CW354H						

RECOMMENDED FILLER METALS FOR THE WELDING OF CLAD MATERIALS MADE OF SPECIAL STEELS, NON-FERROUS METALS AND ALLOYS

According to EN ISO 18274, EN ISO 14640 and/or EN ISO 3581-A, EN ISO 14343-A, EN ISO 17633-A, EN ISO 14172-A, EN ISO 12153 as well as AWS A 5.4, A 5.7, A 5.9, A 5.11, A 5.14, A 5.16, and A 5.22

Cladding		single layer ESSC		
Alloy type	EN material number	EN ISO 18274	AWS	Recommended product [3]
Alloy 800	1.4876	BNi 66 25 (NiCr22Mo9Nb)	EQ NiCrMo-3	SOUDOTAPE 625 + RECORD EST 625-1
Alloy 904L	1.4539	BNi 66 25 (NiCr22Mo9Nb)	EQ NiCrMo-3	SOUDOTAPE 625 + RECORD EST 625-1
Alloy 28	1.4563	BNi 66 25 (NiCr22Mo9Nb)	EQ NiCrMo-3	SOUDOTAPE 625 + RECORD EST 625-1
Alloy 926	1.4529	BNi 66 25 (NiCr22Mo9Nb)	EQ NiCrMo-3	SOUDOTAPE 625 + RECORD EST 625-1
Alloy 20	2.4660	BNi 66 25 (NiCr22Mo9Nb)	EQ NiCrMo-3	SOUDOTAPE 625 + RECORD EST 625-1
Alloy 825	2.4858	BNi 66 25 (NiCr22Mo9Nb) BNi 8065 (NiFe30Cr21Mo3)	EQ NiCrMo-3 EQ NiFeCr-1	SOUDOTAPE 625 + RECORD EST 625-1 SOUDOTAPE 825HS + RECORD EST 825-1 HS
Alloy 625	2.4856	BNi 66 25 (NiCr22Mo9Nb) BNi 60 59 (NiCr23Mo16)	EQ NiCrMo-3 EQ NiCrMo-13	SOUDOTAPE 625 + RECORD EST 625-1 SOUDOTAPE NiCrMo59 + RECORD EST 259 [1]
Alloy C22	2.4602	BNi 60 22 (NiCr21Mo13Fe4W3)	EQ NiCrMo-10	SOUDOTAPE NiCrMo22 [2,3]
Alloy C4	2.4610	BNi 64 55 (NiCr16Mo16Ti)	EQ NiCrMo-7	SOUDOTAPE NiCrMo7 [2,3]
Alloy C276	2.4819	BNi 62 76 (NiMo16Cr15Fe6W4)	EQ NiCrMo-4	SOUDOTAPE NiCrMo4 [2,3]
Alloy 59	2.4605	BNi 60 59 (NiCr23Mo16)	EQ NiCrMo-13	SOUDOTAPE NiCrMo59 + RECORD EST 259 [2]
Alloy B2	2.4617	BNi 64 55 (NiCr16Mo16Ti)	EQ NiMo-7	SOUDOTAPE NiMo7 [2,3]
Alloy 600	2.4816	BNi 60 82 (NiCr20Mn3Nb)	EQ NiCr-3	SOUDOTAPE NiCr3 [2,3]
Alloy 400	2.4360	BNi 40 60 (NiCu30Mn3Ti)	EQ NiCu-7	SOUDOTAPE NiCu7 + RECORD EST 400 [2]
Alloy 200	2.4066	~BNi 20 61 (NiTi3)	~EQNi-1	SOUDOTAPE NiTi + RECORD EST 200 [2]
Alloy 201	2.4068			
SE-Cu	CW021A	Welding of Cu and Cu-Alloys onto carbon steel without buffer layer is not recommended.		
SF-Cu	CW024A			
CuNi 90/10	CW352H			
CuNi 70/30	CW354H			

1) Usage EQNICRMo-13 depending on corrision resistance
2) Bi-layer solution
3) Multi layer flux available for all Ni base strips RECORD EST 201 or RECORD EST 259 or RECORD EST 501

WELD SHAPES

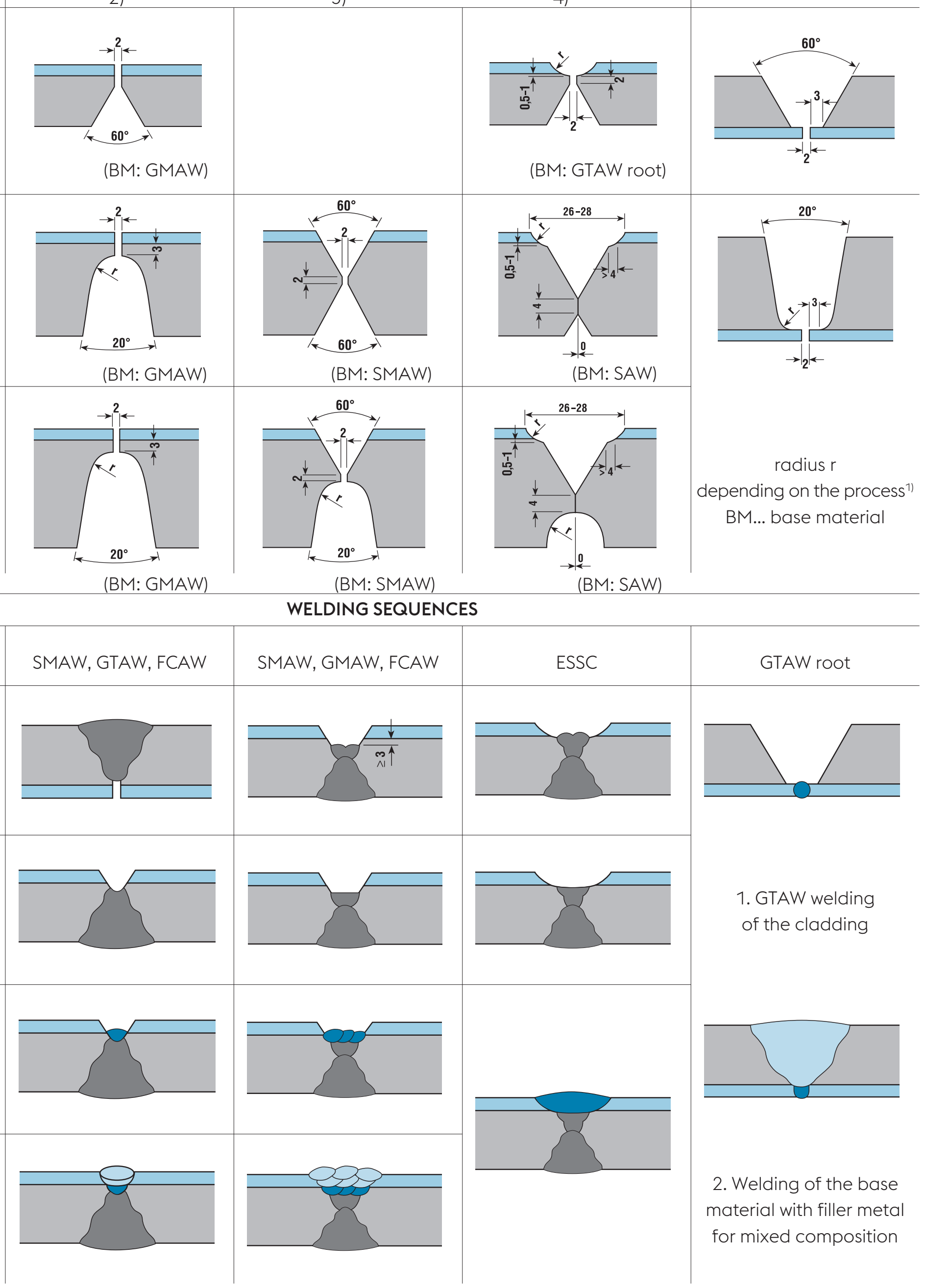
Preparation and execution of welding must be performed in such a way that the weld metal for the base material does not fuse the cladding. This prevents the formation of brittle or hot-crack sensitive weld metal. During pre-processing of the weld edges the actual thickness of the cladding needs to be taken into consideration. Any filling of the base material weld should be executed from the base material side, if possible, in order to avoid contamination of the cladding material.

Butt welds
The weld shapes shown on page 37 apply to nearly all clad plates.

Fillet welds
The bonding of the cladding in our roll-bonded clad plates is so strong, even considerably overdimensioned fillet welds do not cause any detachment of the cladding material. However, the standards for the ultrasonic testing of clad plates allow certain bonding defects. When welding fillet welds onto the cladding material, the plate must be carefully checked for proper bonding by ultrasonic testing in the area of the weld before and after the welding operation. Removal of the cladding with subsequent weld cladding to prepare vertical connection is only required in areas where bonding defects have been found in the ultrasonic test. Any melting through the cladding has to be compensated by a corresponding over-alloyed filler metal.

BUTT SEAM WELDING

Recommended weld shapes and welding sequences.



Thickness [mm]	WELD PREPARATION 1) access from both sides 2)	3)	4)	access from one side
5 - 19	(BM: GMAW)		(BM: GTAW root)	
20 - 30	(BM: GMAW)	(BM: SMAW)	(BM: SAW)	
> 30	(BM: GMAW)	(BM: SMAW)	(BM: SAW)	radius r depending on the process[1)]BM... base material
WELDING SEQUENCES				
Welding process for cladding	SMAW, GTAW, FCAW	SMAW, GMAW, FCAW	ESSC	GTAW root
Base material welding				
Grinding				1. GTAW welding of the cladding
Buffer layer welding				
Welding of the filler and cover layers				2. Welding of the base material with filler metal for mixed composition

[1)] The root gap, the thickness of the root face, the radii and the weld preparation angle depend on the welding processes used. The drawings show examples of dimensions and appropriate processes for welding of the base material. Favourable radii are: r = 8 mm for the base material; r = 4 mm for the clad material and welding with wire electrodes, r = 8 mm with strip electrodes.
[2)] Preferable weld shapes for all welding positions and high-alloyed claddings.
[3)] Weld shape for thicker plates; SAW for base material.
[4)] Weld shape if the total base material thickness is included in the calculation of the strength. The welded cladding should melt down the base material as little as possible. Mainly applied for manual arc welding process.

WELDING EXECUTION

Cleaning

The welding of the cladding layer requires the same cleanliness as when working with solid materials of a similar composition. Consequently, chippers, brushes etc., of stainless steel are to be used. In the case of Ni and Ni-alloys, prevention of all sulfur-containing contaminations is of utmost importance. Therefore only grinding materials with sulfur-free bonding agents (synthetic resin adhesion) should be used.

Weld design

With exception of ESSC, the full alloy content (or a limitation to a maximum of 5 % Fe for Ni or Alloy 400) is often only achieved in the third pass. Consequently, in most cases a weld reinforcement of 2 up to 3 mm is allowed on the side of the cladding material in order to obtain sufficient room for three passes. If a limit is set for the weld reinforcement, the first and the second pass must be carefully ground before welding is continued.

Preheating and heat control

Welding of the base material:
We recommend using EN 1011-2 for calculating the minimum preheating temperature, which depends on the substrate chemical analysis, the thickness and the welding process employed.

Welding of the buffer:
Most of the buffers are welded using austenitic filler materials which give off very little hydrogen to the base material. According to experience, the preheating temperature may therefore be lower than calculated:

» Approx. 50 °C lower for SMAW
» Up to 100 °C lower for GMAW, GTAW, FCAW and ESSC weld overlay.

Welding of the cladding material:
An overview of the heat control during welding of the cladding material is given in the table below.

Cladding	Filler	Preheating min. °C	Interpass temp. max. °C
13 % Cr-steels	austenitic matching	– 150	200 250
CrNi-steels	matching	none	150
Ni and Ni-alloys	matching	none (ESSC)	150
Cu	matching	> 400	600
CuNi and NiCu-alloys	matching	none	150

STRESS-RELIEF ANNEALING

Generally, stress-relief annealing of roll-bonded clad plates is only necessary as a requirement of the base material. By stress-relief annealing the properties of the cladding and the corresponding weld metal may deteriorate due to precipitation of carbides, intermetallic phases etc. Therefore, stress-relief annealing is to be avoided if possible or adjusted to the base and cladding materials. Only grinding materials with sulfur-free bonding agents (synthetic resin adhesion) should be used.

POST-TREATMENT OF THE WELDS

Smoothening of the weld to prevent deposits (crevice corrosion), pickling to remove annealing colors or similar measures may be required, depending on the type of the cladding material and the service condition.

WE LEAD THE WAY, SO OUR PARTNERS WILL BE ONE STEP AHEAD.

Many years of partnerships with renowned companies impressively prove our point.

11/2022

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