ROLLED CLAD PLATES

www.voestalpine.com

voestalpine - Division **Stahl**

ONE STEP AHEAD.

voestalpine GROBBLECH

Technical progress and economic growth have always been closely connected with steel. This will be particularly so in the future.
In close co-operation with the customer, voestalpine Grobblech is constantly developing new material solutions in the field of clad plates. Our roll-bonded clad plates meet the strictest requirements – whether in steel and apparatus engineering, pipeline construction, mechanical engineering, desalination or flue gas desulphurization plants and chimneys.

ROLLED CLAD PLATES

EXPERIENCE

voestalpine Grobblech is among the pioneers in the field of roll bonding and has more than 40 years of experience. In 1962 the patent was filed for the vacuum-cladding process developed by the company. Today, voestalpine Grobblech is by far the leading roll bonding company in Europe and is one of the world's three largest suppliers.

ADVANTAGES OF ROLL-BONDED CLAD PLATES

Advantages over solid plates

Roll-bonded clad plates are the economical alternative to expensive high-alloy solid plates.

- Ideal combination of the mechanical properties of the base material and the corrosion resistance of the cladding material.
- Less weight due to reduction of wall thicknesses
- Reduction of weld length due to larger sizes
- Lower cost of filler materials
- Applicability of all proven welding processes
- Better thermal conductivity as compared to solid plates
- Lower material costs
- Use of brittle materials susceptible to stress cracking

Advantages over overlay welding

Roll-bonded clad plates offer the best surface characteristics and narrow tolerances.

- Improved surface condition
- No dilution from the base material
- Testability (US, corrosion, thickness ...)

Advantages over explosion cladding

Roll-bonded clad plates are available in large sizes with homogeneous properties.

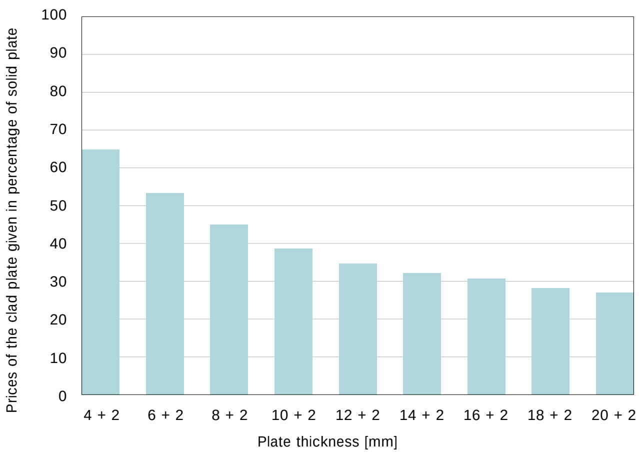
- Reduction of weld length due to larger sizes
- Use of hard and brittle materials is possible
- Homogeneous bonding

Advantages over rubber coatings and linings

Roll-bonded clad plates are a durable and proven metallurgical solution.

- Metallic bonding
- Clearly longer service life
- Temperature resistance
- Low maintenance costs
- Easy repair and thus short standstill times
- Recyclability
- Vacuum suitability
- Cleaning

COMPARISON OF PRICES: ROLLED CLAD PLATE VS SOLID PLATE, EXAMPLE OF ALLOY 59



THE MARKET

PRODUCT RANGE

Roll-bonded clad plates have a wide range of applications.

As developments during the past few years have shown, roll-bonded clad plate is used more and more and in many different ways. This development is not only attributable to proven economic advantages, but above all to the product's technical superiority over other materials.

CHEMICAL INDUSTRY

- columns
- pressure vessels
- pipes
- washers
- heat exchangers
- thin-film evaporators

PETROCHEMICAL INDUSTRY

- columns
- reactors
- crackers
- cokers

OIL AND GAS PRODUCTION

- separators
- absorbers
- pipelines

ENVIRONMENTAL TECHNOLOGY

- flue gas desulphurisation plants
- stacks, chimneys
- flue gas channels
- garbage incineration plants

DESALINATION PLANTS

- pipelines
- heat exchangers
- evaporators
- valve boxes

PAPER INDUSTRY

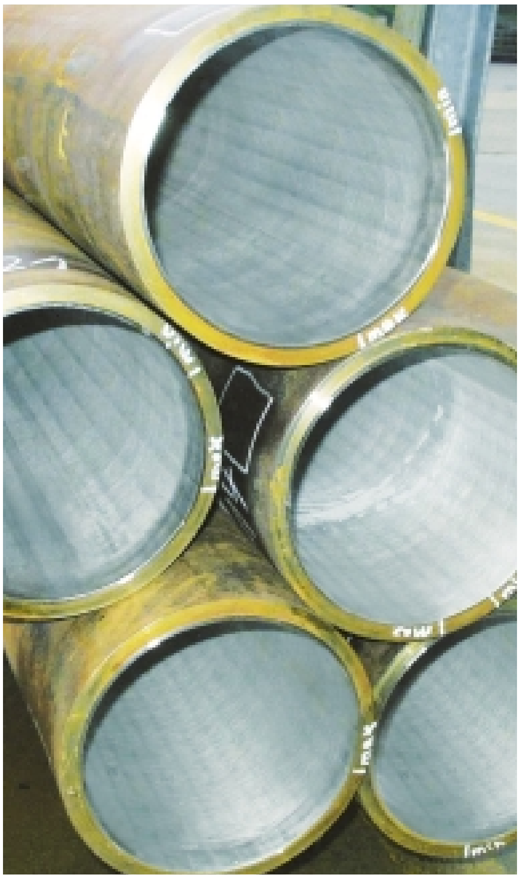
- pulp boilers
- evaporator pipe plates
- bleaching plants

FOOD INDUSTRY

- boiling pans for breweries
- equipment for industrial kitchens
  (tiltable frying pans, stove plates)
- thin-film evaporators
- bottlers

OTHER APPLICATIONS

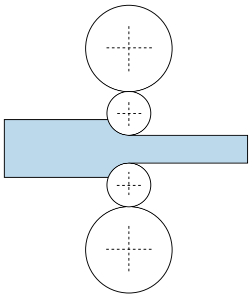
- hardening pots
- melting pots
- bus bars for electric furnaces
- chemical tankers, ice breakers
- power stations
- rotary kilns



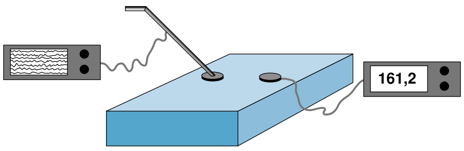
PRODUCTION

During roll-cladding under vacuum, a moderately priced composite material is produced by means of metallic bonding between carbon steel used as base material and a high-quality corrosion-resistant alloy used as cladding material. This composite material serves as a basic material for numerous applications.

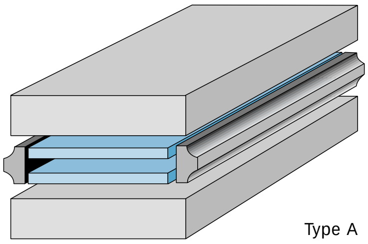
1. Rolling of cladding and base material

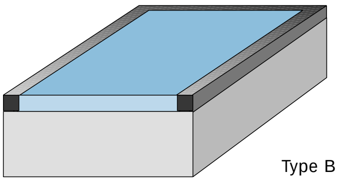


ultrasonic test (internal)

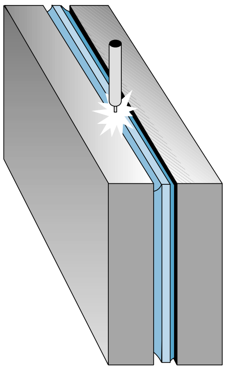


2. Assembling of the package

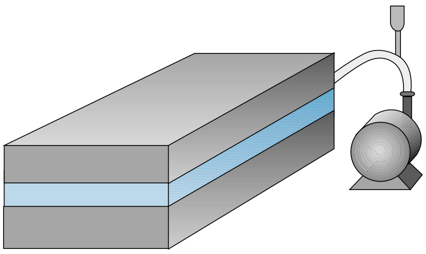




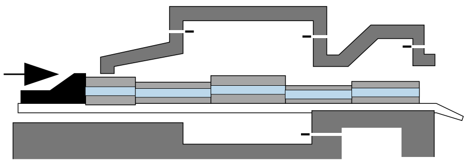
3. Welding of the package

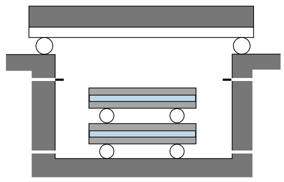


4. Evacuation

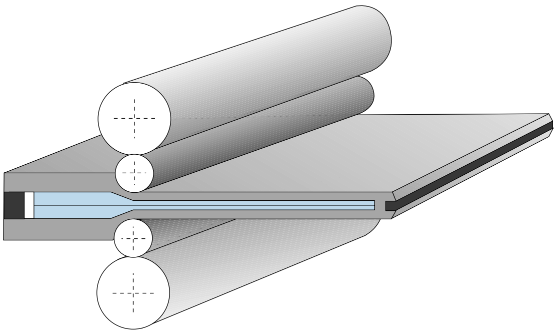


5. Pusher-type furnace or pit furnace





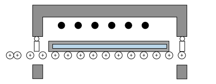
6. Rolling of the cladding package



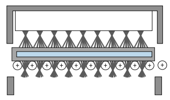
7. Heat treatment

7.1 Controlled rolling

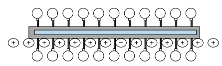
7.2 Normalizing



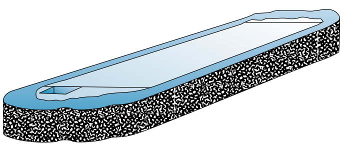
7.3 Quenching and tempering



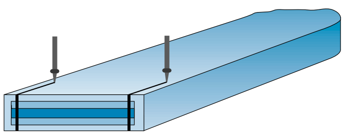
7.4 Controlled rolling with accelerated cooling



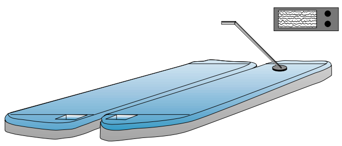
8. Ultrasonic edge testing and sample cutting



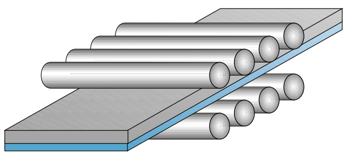
9. Plasma cutting



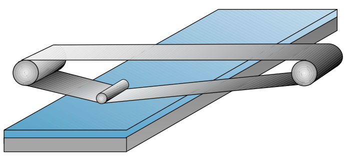
10. Ultrasonic test (bonding, layer thickness)



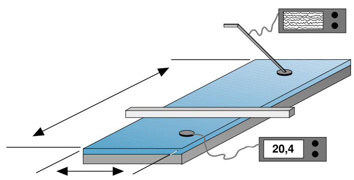
11. Levelling



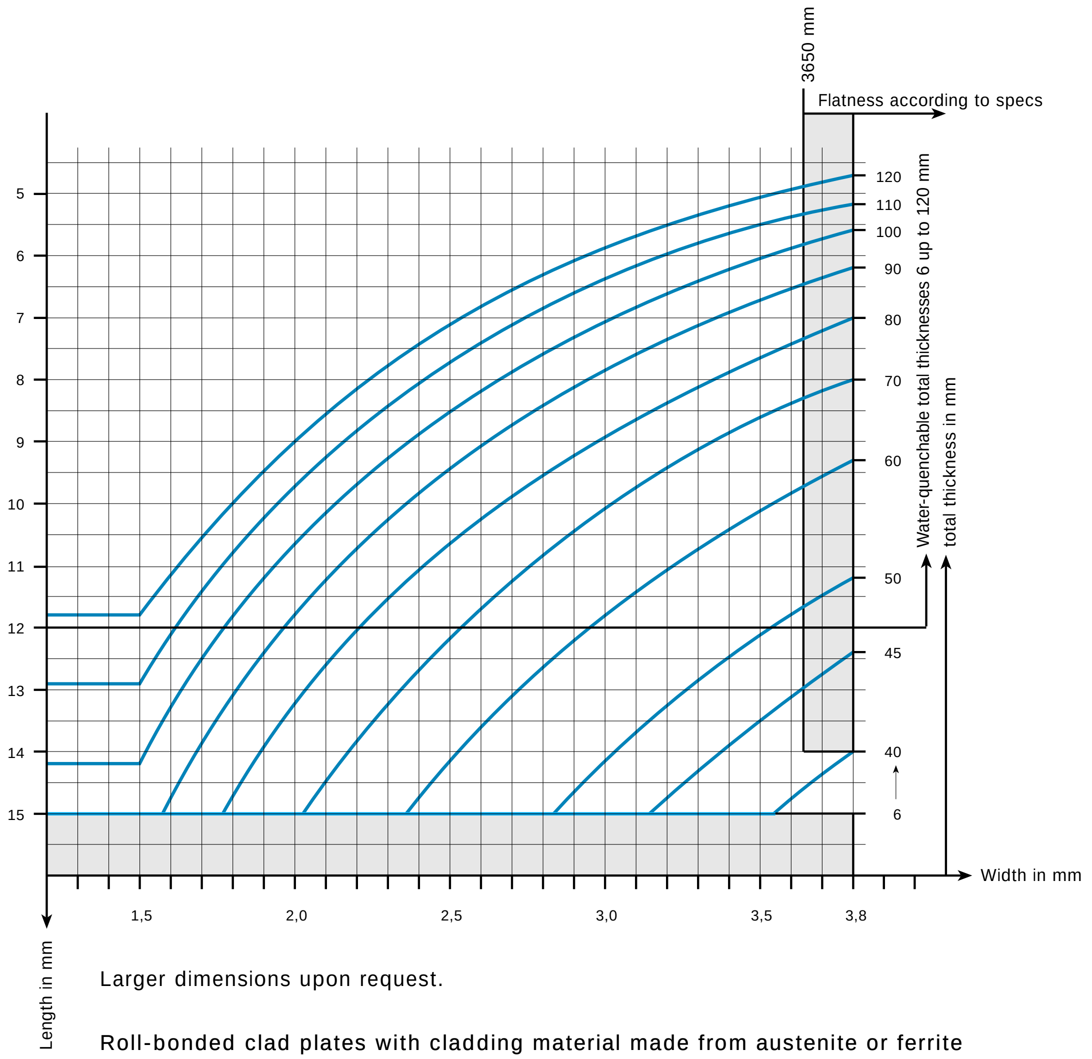
12. Grinding



13. Final check



AVAILABLE DIMENSIONS



Larger dimensions upon request.

Roll-bonded clad plates with cladding material made from austenite or ferrite
Total thicknesses 6–120 mm
Thickness of overlay material 1.5–8 mm
Width 3,800 mm max.
Length 15,000 mm max.
Unit weight 17 tons max.
Water quenching possible up to a maximum length of 12,000 mm

Roll-bonded clad plates with cladding material made from non-ferrous
(50 % Ni or higher) or copper alloys
Total thicknesses 6–60 mm
Thickness of overlay material 1.5–8 mm
Width 3,800 mm max.
Length 15,000 mm max.
Unit weight 12 tons max.
Water-quenching possible up to a maximum length of 12,000 mm

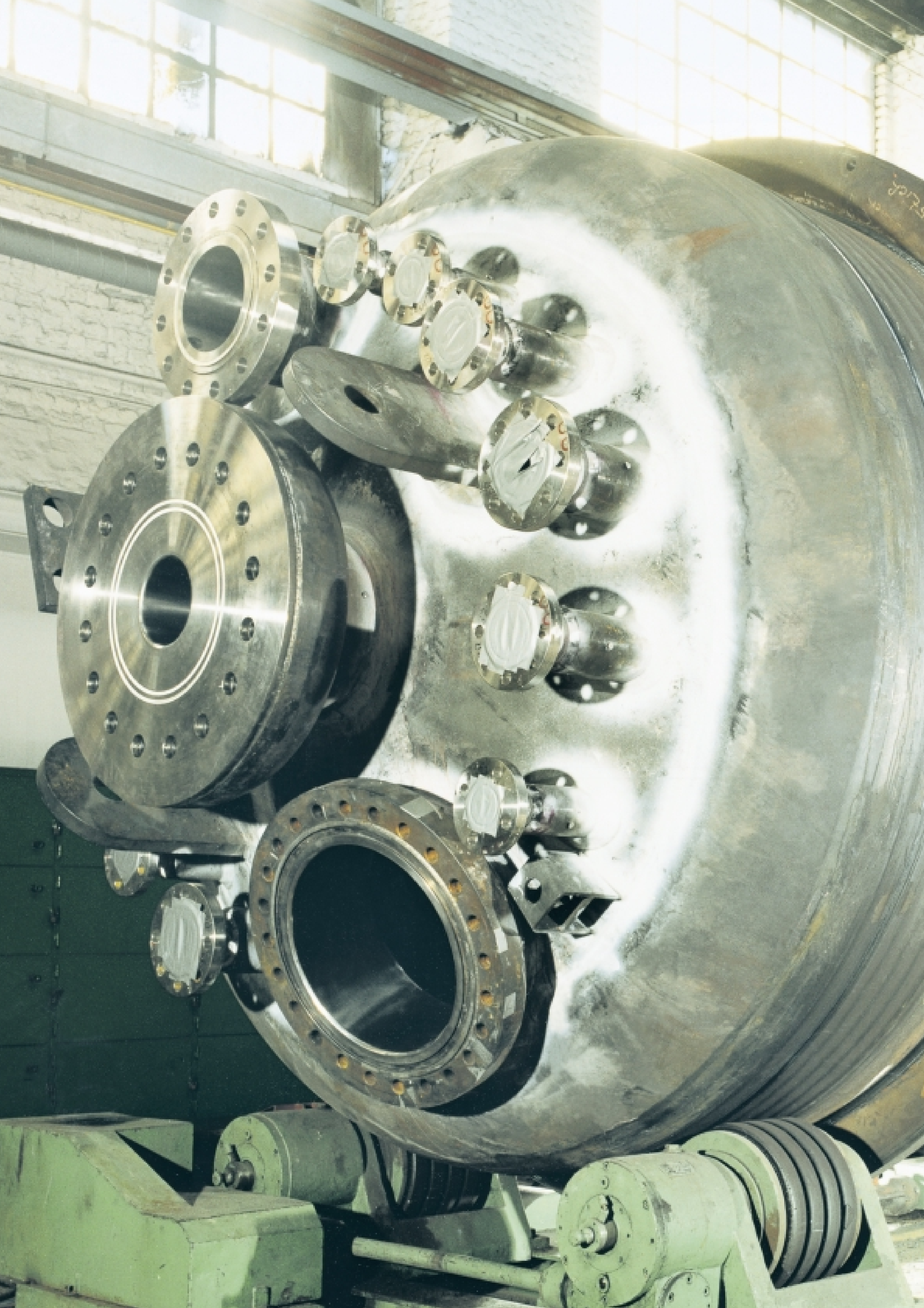
Roll-bonded clad plates with cladding material made from titanium
Total thicknesses 6–25 mm
Thickness of overlay material 1.5–8 mm
Width 3,000 mm max.
Length 12,000 mm max.
Unit weight 3 tons max.
Larger thicknesses upon request.

SURFACE FINISH

Normally, grain size 80 is used for surface grinding of cladding materials. Other grain sizes are available upon request. Any additional future surface treatment (e.g. fine grinding, polishing) of the cladding surface by the customer must be indicated at the time of ordering.
A special order may be placed for surface finishing type „non-ground“.

REFERENCE VALUES FOR DEPTH OF ROUGHNESS (R_t) AND MEAN ROUGHNESS VALUE (R_a) IN µM:

Grain size	80	120	180	240	360
Rt	18	11	6	2.5	1.2
Ra	2.6	1.7	1.2	0.8	0.4



HEADS FOR PRESSURE VESSELS

Cladded heads can be ordered in any shape needed in accordance with all national and international standards and are made from roll-bonded clad plates with the following cladding materials:

- ferrite
- austenite
- nickel and nickel-based alloys
- copper and copper-based alloys
- titanium
- special alloys

PRODUCT RANGE

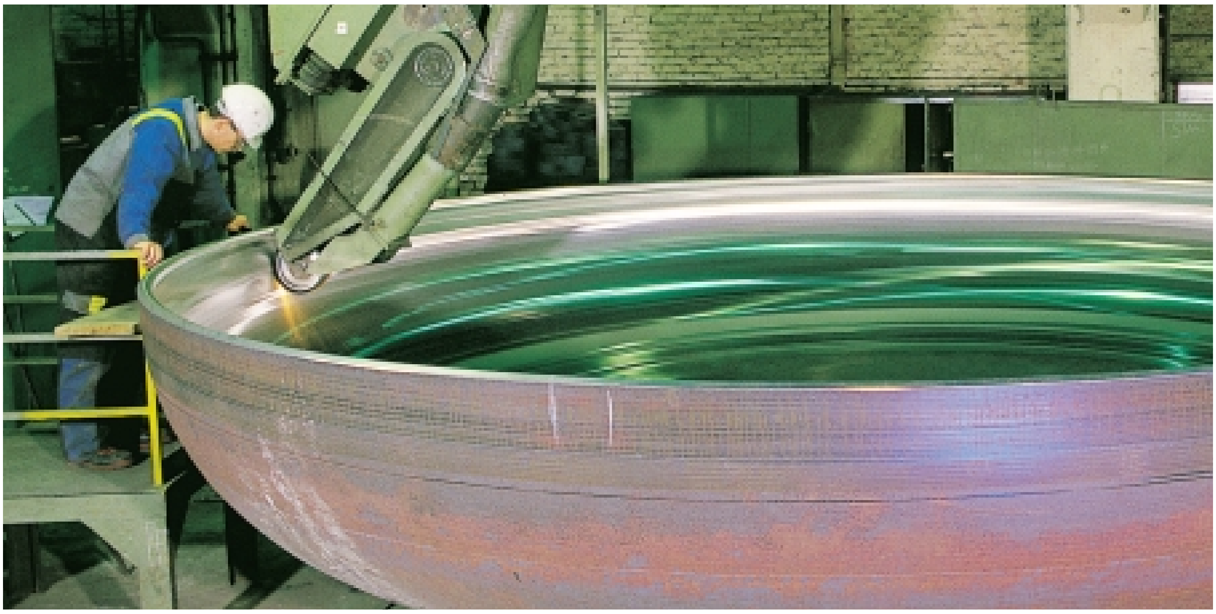
- torispherical heads
- semi-elliptical heads
- elliptical heads
- hemispherical heads

DESIGN

- any desired edge preparation
- any heat treatment corresponding to the material requirements, water quenching up to a diameter of 6,000 mm
- surface treatments such as sandblasting or flame descaling as well as grinding and glass-bead blasting of clad surfaces
- any destructive and non-destructive material tests
- special treatment upon request

PRODUCTION PARAMETERS

Shape	Dimensions
Torispherical, semi-elliptical and elliptical heads	diameter 1,000 up to 7,000 mm in one piece, from approx. 3,200 mm with weld, pressed: thickness 160 mm max. up to a diameter of 3,600 mm, larger diameters flanged, maximum thickness 55 mm
Hemispherical heads	up to a diameter of 2,800 mm in one piece, larger diameters from crown and petals



BASE MATERIALS

As base material for roll-bonded clad plates

- structural steels
- fine-grain structural steels
- pressure vessel steels
- line pipe steels
- shipbuilding steels

are used in accordance with the respective applicable standards or customer specifications. The material is selected by the customer in view of the strength and toughness requirements under specific operating conditions. Upon request, **voest**alpine Grobblech will offer support and advice in the selection. **voest**alpine Grobblech has developed special base materials for roll-bonded clad plates with cladding materials requiring special heat treatments for the purpose of corrosion resistance. A brief summary of the applicable base materials according to European standards EN and ASTM can be found on pages 14/15 and 16.

The indicated chemical and mechanical key data refer to the smallest thickness group.

STRUCTURAL STEELS AND PRESSURE VESSEL STEELS
according to EN 10025-2 and EN 10028-2.

Standard	Steel grade Abbreviation	Chemical composition (heat analysis) %								Mechanical properties	
		C	Si	Mn	P max.	S max.	Cr	Ni	Mo	Yield strength N/mm² min.	Tensile strength N/mm²
EN 10025-2	S235JR	≦ 0.17	–	≦1.40	0.025	0.025	–	–	–	235	360-510
	S355JR	≦ 0.24	≦ 0.55	≦1.60	0.035	0.035	–	–	–	355	470-630
EN 10028-2	P235GH	≦ 0.16	≦ 0.35	0.60–1.20	0.025	0.015	≦ 0.30	≦ 0.30	≦ 0.08	235	360–480
	P265GH	≦ 0.20	≦ 0.40	0.80–1.40	0.025	0.015	≦ 0.30	≦ 0.30	≦ 0.08	265	410–530
	P295GH	0.08–0.20	≦ 0.40	0.90–1.50	0.025	0.015	≦ 0.30	≦ 0.30	≦ 0.08	295	460–580
	P355GH	0.10–0.22	≦ 0.60	1.10–1.70	0.025	0.015	≦ 0.30	≦ 0.30	≦ 0.08	355	510–650
	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
	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
	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	0.010	0.010	2.00–2.50	≦ 0.30	0.90–1.10	355	540-690

STRUCTURAL STEELS AND PRESSURE VESSEL STEELS
according to ASTM

Standard		Grade	Class	Chemical composition (heat analysis) % (Extract)								Mechanical properties	
				C %	Si %	Mn %	P % max.	S % max.	Cr %	Ni %	Mo %	Rp0,2 MPa	Rm MPa
ASTM	A36			max. 0.25	max. 0.40		0.04	0.05				250	400
	A283	C		max. 0.24	max. 0.40	0.90	0.035	0.04				205	380-515
ASTM	A285	C		max. 0.28		0.90	0.035	0.035				205	380-515
	A516	60		max. 0.21	0.15-0.40	0.60-0.90	0.035	0.035				220	415-550
	A516	65		max. 0.24	0.15-0.40	0.85-1.20	0.035	0.035				240	450-585
	A516	70		max. 0.27	0.15-0.40	0.85-1.20	0.035	0.035				260	485-620
	A537		1	max. 0.24	0.15-0.50	0.70-1.35	0.035	0.035	max. 0.25	max. 0.25	max. 0.08	345	min. 485
	A537		2	max. 0.24	0.15-0.50	0.70-1.35	0.035	0.035	max. 0.25	max. 0.25	max. 0.08	415	min. 550
	A533	B	1	max. 0.25	0.15-0.40	1.15-1.50	0.035	0.035		0.40-0.70	0.45-0.60	345	550-690
	A533	B	2	max. 0.25	0.15-0.40	1.15-1.50	0.035	0.035		0.40-0.70	0.45-0.60	485	620-795
	A517	P		0.12-0.21	0.45-0.70	0.20-0.35	0.035	0.035	0.85-1.20	1.20-1.50	0.45-0.60	690	795-930
ASTM	A204	A		max. 0.18	0.15-0.40	0.90	0.035	0.035			0.45-0.60	255	450-585
	A204	B		max. 0.20	0.15-0.40	0.90	0.035	0.035			0.45-0.60	275	485-620
	A302	B		max. 0.20	0.15-0.40	1.15-1.50	0.035	0.035			0.45-0.60	345	550-690
	A387	11	1	0.05-0.17	0.50-0.80	0.40-0.66	0.035	0.035	1.00-1.50		0.40-0.65	245	415-585
	A387	11	2	0.05-0.17	0.50-0.80	0.40-0.65	0.035	0.035	1.00-1.50		0.40-0.65	275	450-585
	A387	12	1	0.05-0.17	0.15-0.40	0.40-0.65	0.035	0.035	0.80-1.15		0.40-0.60	230	380-550
	A387	12	2	0.05-0.17	0.15-0.40	0.40-0.65	0.035	0.035	0.80-1.15		0.40-0.60	275	450-585
	A387	22	1	0.05-0.15	max. 0.50	0.30-0.60	0.035	0.035	2.00-2.50		0.90-1.10	210	415-585
	A387	22	2	0.05-0.15	max. 0.50	0.30-0.60	0.035	0.035	2.00-2.50		0.90-1.10	310	515-690

FINE-GRAIN STRUCTURAL STEELS
according to EN 10028-3 and 10028-6

Standard	Steel grade Abbreviation	Chemical composition (heat analysis) % (Extract)								Mechanical properties	
		C max.	Si max.	Mn	P max.	S max.	Cr max.	Ni max.	Mo max.	Yield strength N/mm² min.	Tensile strength N/mm²
EN 10028-3	P 275 N P 275 NH P 275 NL1	0.16	0.40	0.80-1.50	0.025	0.015	0.30	0.50	0.08	275	390–510
	P 275 NL2	0.16	0.40	0.80-1.50	0.020	0.010	0.30	0.50	0.08	275	390-510
	P 355 N P 355 NH P 355 NL	0.18	0.50	1.10-1.70	0.025	0.015	0.30	0.50	0.08	355	490-630
	P 355 NL2	0.18	0.50	1.10-1.70	0.020	0.010	0.30	0.50	0.08	355	490-630
	P 460 N P460 NH P 460 NL1	0.20	0.60	1.10-1.70	0.025	0.015	0.30	0.80	0.10	460	570-720
	P 460 NL2	0.20	0.60	1.10-1.70	0.020	0.010	0.30	0.80	0.10	460	570-720
EN 10028-6	P 355 Q P 355 QH	0.16	0.40	1.50	0.025	0.015	0.30	0.50	0.25	355	490-630
	P 355 QL1 P 355 QL2	0.16	0.40	1.50	0.020	0.010	0.30	0.50	0.25	355	490-630
	P 460 Q P 460 QH	0.18	0.50	1.70	0.025	0.015	0.50	1.00	0.50	460	550-720
	P 460 QL1 P 460 QL2	0.18	0.50	1.70	0.020	0.010	0.50	1.00	0.50	460	550-720
	P 500 Q P 500 QH	0.18	0.60	1.70	0.025	0.015	1.00	1.50	0.70	500	770-590
	P 500 QL1 P 500 QL2	0.18	0.60	1.70	0.020	0.010	1.00	1.50	0.70	500	770-590
	P 690 Q P 690 QH	0.20	0.80	1.70	0.025	0.015	1.50	2.50	0.70	690	770-940
	P 690 QL1 P 690 QL2	0.20	0.80	1.70	0.020	0.010	1.50	2.50	0.70	690	770-940

CLADDINGS

Cladding material is selected by the customer. Depending on application and requirements, a broad range of grades is available. The most frequently used claddings are listed in the tables on pages 17 and 18/19.

STAINLESS AND HEAT-RESISTANT STEEL GRADES

Standard	Material No.	Abbreviation	Chemical composition (heat analysis) % [1] (Extract)							ASTM A240 ASME SA 240 Type
			C max.	Si max.	Mn max.	Cr	Ni	Mo	Others	
EN 10088	1.4000	X6Cr13	0.08	1.00	1.00	12.00–14.00	–	–	–	410S
	1.4002	X6CrAl13	0.08	1.00	1.00	12.00–14.00	–	–	Al 0.10–0.30	405
	1.4301	X5CrNi18-10	0.07	1.00	2.00	17.00–19.50	8.00–10.50	–	N ≦ 0.11	304
	1.4306	X2CrNi19-11	0.030	1.00	2.00	18.00–20.00	10.00–12.00	–	N ≦ 0.11	304L
	1.4541	X6CrNiTi18-10	0.08	1.00	2.00	17.00–19.00	9.00–12.00	–	Ti ≧ 5x%C%0.70	321
	1.4550	X6CrNiNb18-10	0.08	1.00	2.00	17.00–19.00	9.00–12.00	–	Nb ≧ 10x%C%1.0	347
	1.4401	X5CrNiMo17-12- 2	0.07	1.00	2.00	16.50–18.50	10.00–13.00	2.00–2.50	N ≦ 0.11	316
	1.4404	X2CrNiMo17-12-2	0.030	1.00	2.00	16.50–18.50	10.00–13.00	2.00–2.50	N ≦ 0,11	316L
	1.4571	X6CrNiMoTi17-12-2	0.08	1.00	2.00	16.50–18.50	10.50–13.50	2.00–2.50	Ti ≧ 5x%C%0.70	316Ti
	1.4435	X2CrNiMo18-14-3	0.030	1.00	2.00	17.00–19.00	12.50–15.00	2.50–3.00	N ≦ 0.11	316L ≧ 2.5 Mo
	1.4436	X3CrNiMo17-13-3	0.05	1.00	2.00	16.50–18.50	10.50–13.00	2.50–3.00	N ≦ 0.11	316 ≧ 2.5 Mo
	1.4429	X2CrNiMoN17-13-3	0.030	1.00	2.00	16.50–18.50	11.00–14.00	2.50–3.00	N 0.12–0.22	316LN ≧ 2.5 Mo
	1.4438	X2CrNiMo18-15-4	0.030	1.00	2.00	17.50–19.50	13.00–16.00	3.00–4.00	N ≦ 0.11	317L
	1.4439	X2CrNiMoN17-13-5	0.30	1.00	2.00	16.50–18.50	12.50–14.50	4.00–5.00	N 0.12–0.22	–
SEW 470	1.4828	X 15 CrNiSi 20 12	0.20	1.5–2.5	2.0	19.0–21.0	11.0–13.0	–	–	305

[1] P 0.045 max., S 0.030l max.

SPECIAL STEELS, NON-FERROUS METALS AND ALLOYS [1)]

EN Material No.	Abbreviation	Chemical composition (heat analysis) % (Extract)							
		C max.	Si max.	Mn max.	P max.	S max.	Cr	Ni	Mo
2.4660	NiCr20CuMo	0.07	1.00	2.0	0.025	0.015	19.0–21.0	32.0–38.0	2.0–3.0
1.4539	X1NiCrMoCu 25-20-5	0.020	0.70	2.00	0.030	0.010	19.00–21.00	24.00–26.00	4.00–5.00
1.4563	X1NiCrMoCuN 31-27-4	0.020	0.7	2.00	0.030	0.010	26.00–28.00	30.00–32.00	3.00–4.00
1.4529	X1NiCrMoCuN 25-20-7	0.020	0.5	1.00	0.030	0.010	19.00–21.00	24.00–26.00	6.00–7.00
1.4876	X 10 NiCrAlTi 32 20	0.12	1.0	2.0	0.030	0.020	19.0–23.0	30.0–34.0	–
2.4858	NiCr21Mo	0.025	0.50	1.00	0.020	0.015	19.5–23.5	38.0–46.0	2.5–3.5
2.4816	NiCr15Fe	0.025-0.10	0.50	1.00	0.020	0.015	14.0–17.0	≧ 72.0	–
2.4856	NiCr22Mo9Nb	0.10	0.5	0.50	0.020	0.015	20.0–23.0	≧ 58.0	8.0–10.0
2.4602	NiCr21Mo14W	0.010	0.08	0.50	0.025	0.015	20.0–22.5	Rest	12.5–14.5
2.4610	NiMo16Cr16Ti	0.015	0.08	1.00	0.025	0.015	14.50–18.0	Rest	14.0–17.0
2.4819	NiMo16Cr15W	0.010	0.08	1.0	0.020	0.015	14.5–16.5	Rest	15.0–17.0
2.4605	NiCr23Mo16Al	0.010	0.10	0.50	0.025	0.015	22.0–24.0	Rest	15.0–16.5
2.4617	NiMo 28	0.010	0.08	1.00	0.025	0.015	≦1.0	Rest	26.0–30.0
2.4600	NiMo29Cr	0.010	0.10	3.00	0.025	0.015	0.5–3.0	≧ 65.0	26.0-32.0
2.4360	NiCu30Fe	0.15	0.5	2.0	–	0.02	–	≧ 63	–
2.4066	Ni99,2	0.10	0.25	0.35	–	0.005	–	≧ 99.2	–
2.4068	LC-Ni99	0.02	0.25	0.35	–	0.005	–	≧ 99.0	–
2.0070	SE-Cu	–	–	–	0.003	–	–	–	–
CW 024 A	Cu-DHP	–	–	–	0.015–0.040	–	–	–	–
CW 352 H	CuNi10Fe1Mn	0.05	–	0.5–1.0	–	0.05	–	9.0–11.0	–
CW 354 H	CuNi30Mn1Fe	0.05	–	0.5–1.5	–	0.05	–	30.0–32.0	–
3.7025	Ti1	0.06	–	–	–	–	–	–	–
3.7035	Ti2	0.06	–	–	–	–	–	–	–

[1)] Stress-relief annealing only after consulting with the manufacturer.

[2)] For comparison of the materials with respect to resistance to perforation corrosion; value not specified.

	Mean effective sum %Cr+3,3x%Mo[2]	VdTÜV Material sheet	EN DIN SEW	Comparable materials			
Others				ASTM	Alloy type	Registered trademark[3]	VDM designation
Cu 3.0–4.0 Nb ≧ 8x%C-1.00 Fe Rest	28	–	DIN 17744	B 463 UNS N08020	Alloy 20	–	Nicrofer 3620 Nb®
Cu 1.20–2.00 N ≦ 0.15	35	421	EN 10088	B 625 UNS N08904	Alloy 904 L	–	Cronifer 1925 LC®
Cu 0.70–1.50 N ≦ 0.11	39	–		B 709 UNS N08028	Alloy 28	–	Nicrofer 3127 LC®
Cu 0.50–1.50 N 0.15–0.25	41	502		B 625 UNS N08925	Alloy 925	–	Cronifer 1925 hMo®
Al 0.15–0.6 Ti 0.15–0.6		412	SEW 470	B 409 UNS N08800	Alloy 800	Incoloy 800®	Nicrofer 3220®
CU 1.5–3.0 Ti 060–1.20 Fe Rest	31	432	DIN 17744	B 424 UNS N08825	Alloy 825	Incoloy 825®	Nicrofer 4221®
Fe 6.0–10.0 Cu ≦ 0.50		305	DIN 17742	B 168 UNS N06600	Alloy 600	Inconel 600®	Nicrofer 7216®
Fe ≦ 5.0 Nb 3.15–4.15 Al ≦ 0.40 Ti ≦ 0.40	51	499	DIN 17744	B 443 UNS N06625	Alloy 625	Inconel 625®	Nicrofer 6020 hMo®
Fe 2.0–6.0 W 2.5–3.5 V ≦ 0,35 Co ≦ 2.5	66	479	DIN 17744	B 575 UNS N06022	Alloy C 22	Hastelloy C 22®	Nicrofer 5621 hMoW®
Fe ≦ 3.0 Ti ≦ 0.70 Co ≦ 2.0	67	424	DIN 17744	B 575 UNS N06455	Alloy C 4	Hastelloy C 4®	Nicrofer 6616 hMo®
W 3.0–4.5 Fe 4.0–7.0 Co ≦ 2.5 V ≦ 0.35 Cu ≦ 0.5	68	400	DIN 17744	B 575 UNS N10276	Alloy C 276	Hastelloy C 276®	Nicrofer 5716 hMoW®
Al 0.1–0.4 Fe ≦ 1.5 Co ≦ 0.3	75	505	DIN 17744	B 575 UNS N06059	Alloy 59	–	Nicrofer 5923 hMo®
Fe ≦ 2.0 Co ≦ 1.00		436	DIN 17744	B 333 UNS N10665	Alloy B 2	Hastelloy B 2®	Nimofer 6928®
Al 0.10–0.50		512	DIN 17744	B 333 UNS N10629	Alloy B4		Nimofer 6629®
Cu 28–34 Fe 1.0–2.5 Al ≦ 0.5		263	DIN 17743	B 127 UNS N04400	Alloy 400	Monel 400®	Nicorros®
Fe ≦ 0.4 Cu ≦ 0.25		–	DIN 17740	B 162 UNS N02200	Alloy 200	Nickel 200®	Ni 99.2
Fe ≦ 0.4 Cu ≦ 0.25		345		B 162 UNS N02201	Alloy 201	Nickel 201®	LC-Ni 99.2
Cu ≧ 99.90		–	DIN 1787	–	–	–	–
Cu ≧ 99.90		–	EN 1652	B 152 UNS No.C12200	–	–	–
Fe 1.0–2.0 Cu Rest		420		B 171 UNS No.C70600	Alloy CuNi 90/10	–	Cunifer 10®
Fe 0.40–1.0 Cu Rest		–		B 171 UNS No.C71500	Alloy CuNi 70/30	–	Cunifer 30®
Fe ≦ 0.15 O ≦ 0.12 Ti Rest		230	DIN 17850	B 265 Grade 1	Titan Grade 1	–	–
Fe ≦ 0.20 O ≦ 0.18 Ti Rest		230		B 265 Grade 2	Titan Grade 2	–	–

[3] Incoloy, Inconel, Monel – registered trademarks of Special Metals Corporation
Hastelloy – a registered trademark of HAYNES International

Cronifer, Nicrofer, Nimofer, Nicorros, Cunifer – registered trademarks of Thyssen Krupp VDM GmbH

PROCESSING

voestalpine is pleased to provide customers with the know-how and technical experience gained in decades of research and development work.

CUTTING

Rolled clad plates are best cut using plasma torches. This cutting process produces clean cut edges which are prepared for subsequent welding by simply removing the oxide skin.

Note: The cut is always administered from the clad side. It is also possible to use oxy-gas cutting (starting from the base material side) or oxy-gas cutting with flux addition (starting from the clad side). However, this is rarely done because it produces irregular cut edges.
Thin clad plates can be shear cut (cladding material on top) without problems. The following general rules are applicable: sharp blades, exact setting of the cutting gap and optimum blank-holder force.

COLD FORMING

Cold forming of roll-bonded clad plates is possible by applying the following techniques:

- bending
- pressing
- dishing
- rolling

Clean surfaces of the cladding and tools are of great importance in all forming processes. Roll-bonded clad plates demonstrate excellent forming behaviour.
The material-specific properties must be taken in to account, particularly in the case of stainless ferritic claddings.

In cases where cold forming is performed by dishing and rolling, this must be indicated in the inquiry.

HOT FORMING

Roll-bonded clad plates are formed in accordance with accepted technologies and by taking into consideration the cladding material. Should there be any questions, please feel free to contact us. The surfaces of the cladding materials must be free from contaminations stemming from grease, oil, marking colours, etc. in order to prevent carburisation. It is very important to obtain an atmosphere with low sulphur 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 should be contacted as early as in the beginning stages of component design. To avoid corrosion, the surface of the cladding material must be cleaned after every processing step. Oxide skins, annealing colours, spatters, any scratches resulting from ferrous materials, indentations, 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 manual metal arc welding, GMAW, submerged-arc welding and GTAW (root).

We use the following welding processes for cladding materials where base materials are less diluted, such as

- shielded metal arc
- GTAW, pulse GTAW welding
- pulse GMAW welding
- ESW cladding or SAW strip cladding

FILLER METALS

The same filler metals are used for welding the base metals as for plates without cladding.

The recommended filler metals for the claddings from the tables on pages 17 and 18/19 are indicated in the tables on pages 24 and 25. Selections were made after considering the following aspects:

- If possible, the first layer should be welded with overalloyed metals, in order to attain approximation with the composition of the cladding during mixing with the base material.

- For 13 % Cr steel claddings, not only is the buffer welded with an over-alloy, austenitic electrode, type 23 12 L, but frequently also the cover pass. If standard 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.

- In contrast to weld metal that is similar in composition to the base material, low-carbon 18-8 CrNi and CrNiMo steels do not become susceptible to intergranular corrosion during stress-relief annealing at 500–700 °C for 2 hours. Should subsequent stress-relief annealing prove to be necessary, we recommend Nb-stabilised low-carbon weld metal.

- For austenitic steels and Ni alloys with more than 2.5 % Mo, the recommended filler materials for the filler and cover passes should be over-alloyed by a factor of 1.2 with respect to Mo. This is done to reduce the risk of perforation corrosion, where the effective sum of %Cr + 3.3% Mo is decisive. In the weld metal Mo is more segregated than in the cladding so that zones occur which have only 70–80 % of the average Mo content.

- Brittleness may occur when welding Cu, CuNi 90/10, and CuNi 70/30 onto steel. Therefore, the table on page 25 recommends an Alloy 400 buffer.

WELD SHAPES

Preparation and/or execution of welding must be performed in such a way that the weld material 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 gouging of the base material weld should be conducted from the base material side, if possible, in order to avoid contamination of the cladding material.

Butt Welds

The weld shapes shown on page 23 apply to nearly all clad plates. In the case if titanium, however, the base material and the cladding material must not be connected with each other by means of fusion welding due to the formation of brittle intermetallic phases. Therefore, bridge welds are chosen to butt weld roll-bonded titanium plates.

Fillet Welds

The bonding of the cladding in our roll-bonded clad plates is so strong that 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 for certain bonding defects. When welding fillet welds to the cladding material, the plate must be carefully checked for proper fusion by means of 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 of the cladding has to be compensated by a corresponding over-alloyed filler material.

WELDING EXECUTION

Cleaning

During welding of the cladding layer the cleanliness demands are met as for solid material of similar composition. Consequently, chippers, brushes, etc., of stainless steel are used. In the case of Ni and Ni alloys, prevention of all sulphur-containing contaminations is of utmost importance. Therefore only grinding wheels and bonding agents without sulphur (synthetic resin adhesion) are used.

Weld Design

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 heavily ground before welding is continued.

Preheating and Heat Control

Welding of the base material:
We recommend to use EN 1011-2 as a basis for calculating the minimum preheating temperature, which depends on the 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, namely

- approx. 50 °C lower for manual electric welding
- up to 100 °C lower for GMAW, GTAW- and ESW (SA) strip welding.

Welding of the cladding material:
A survey of the heat control during welding of the cladding material is given in the table on page 22.

STRESS-RELIEF ANNEALING

Generally, stress-relief annealing of roll-bonded clad plates is only necessary as a result of the base material. In the event of 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 avoided whenever possible or adjusted to the base and cladding materials.

POST-TREATMENT OF THE WELDS

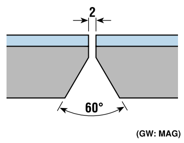
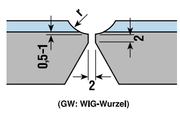
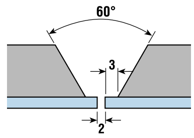
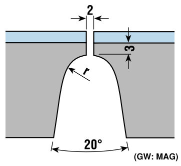
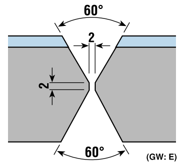
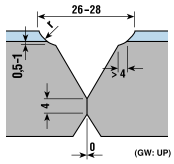
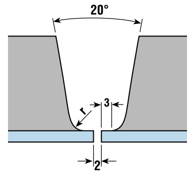
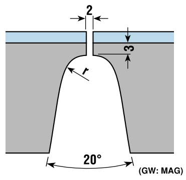
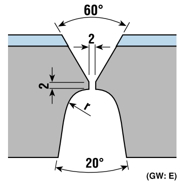
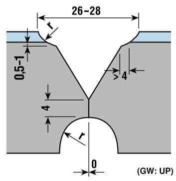
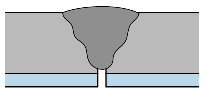
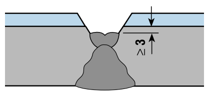
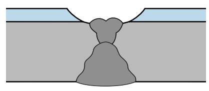
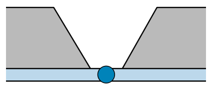
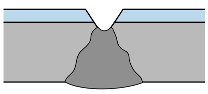
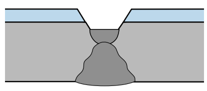
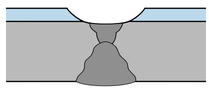
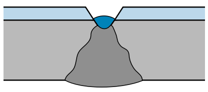
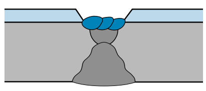
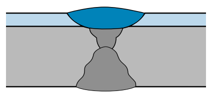
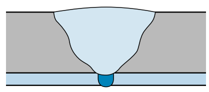
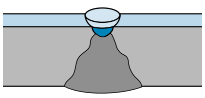
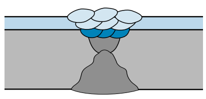
Smoothening of the weld to prevent deposits (crevice corrosion), pickling to remove annealing colours or similar measures may be required, depending on the type of the cladding material and the attacking medium.

WELDING OF THE CLADDING

Cladding	Filler	Preheating min. °C	Interpass temp. max. °C	Heat input
13 % Cr-Steels	austenitic	–	200	low
	matching	150	250	low
CrNi-Steels	matching	none	150	low to medium
Ni and Ni alloys	matching	none	(100) 150	low
Cu	matching	3 mm: 100 4 mm: 200 5 mm: 300 ≥ 6 mm: 300 –400	400	medium
CuNi and NiCu alloys	matching	none	180	low to medium
Ti	matching	none	150	low

BUTT SEAM WELDING

Examples of weld shapes and welding sequences
(not applicable to roll-bonded titanium plates).

WELD PREPARATION [4]				
thickness [mm]	access from both sides			access from one side
	1)	2)	3)	
5 - 19				
20 - 30				
> 30				r depending on the process
WELDING (EXAMPLES)				
Welding Process for Cladding	SMAW, GTAW	SMAW, GMAW, FCAW	ESW (SAW) strip single-pass	GTAW root
Base Metal Welding				
Grinding				1. GTAW welding of the cladding
Buffer layer Welding				
Welding of the Filler and cover layers				2. Welding of the base metal with filler material for the buffer layer

[1] Preferable weld shapes for all welding positions and high-alloy claddings.

[2] Weld shape for thicker plates; ESW or SAW base metal welding.

[3] Weld shape only if the base material thickness is included in the calculation of the strength. The welded cladding should melt down the base material as little as possible. Suitable for all cladding processes, mostly SMAW- or ESW(SAW)strip.

[4] 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 overlay material and welding with wire electrodes, r = 8 mm with strip electrodes.

EXAMPLES OF FILLER METALS FOR WELDING OF STAINLESS OR HEAT-RESISTANT CLADDINGS

according to EN 1600 and/or EN 12072 as well as AWS A 5.4, A 5.9 and A 5.14

Cladding		Filler material Type[1]					
		multi-pass (SMAW)[2]				single-pass ESW (SAW) strip[3]	
		buffer		subsequent passes			
EN Material No.	ASTM A 240 Type	EN	AWS	EN	AWS	EN	AWS
1,4000	410S	23 12 L	E309L	22 12	E309	X2 CrNi 24 12	ER309L
1.4002	405			13 L[6]	E410L[6]	X5 Cr 17[6]	ER430L[6]
1.4301	304	23 12 L	E309L	19 9 L	E308L	X2 CrNi 23 11 X2 CrNi 24 12 X2 CrNiNb 21 10[4] X2 CrNiNb 24 12[4]	ER309L ER309CbL[4]
1.4306				19 9 L 19 9 Nb L	E308L E347L[4]		
1.4541	321			19 9 Nb	E347	X2 CrNiNb 21 10	ER309CbL[4]
1.4550	347			19 9 Nb L	E347L[4]	X2 CrNiNb 24 12	
1.4401	316	23 12 2 L	E309 MoL	19 12 3 L[5] 19 12 3 Nb[5]	E316L[5] E318[5]	X2 CrNiMo 21 13[5] X2 CrNiMnMoN 20 16[5]	ER309MoL[5]
1.4404	316L						
1.4571	316Ti						
1.4435	316L Mo ≧ 2,5			18 16 4 L[7]	E317L	X2 CrNiMoCu 20 25	ER385
1.4436	316 Mo ≧ 2,5						
1.4429	316LN Mo ≧ 2,5						
1.4438	317L	20 25 6 Cu L[8]	–	18 16 5 L 20 25 6 Cu L[8]	–	UP-NiCr21Mo9Nb (Alloy 625)	ERNiCrMo-3 (Alloy 625)
1,4439	–			20 25 6 Cu L[8]	–		
1.4828	305	23 12 L	E309L	22 12	E309	X2 CrNi 23 11 X2 CrNi 24 12	ER309L

[1] Some of the filler materials are not included in the standards, but available on the market.

[2] For GTAW or GMAW welding, types of similar composition are used.

[3] The selection of the strip depends on the welding process (ESW, SAW), the flux, the base material, the required weld bead thickness, etc. We would be glad to provide you with a comprehensive consultation.

[4] To be applied for stress-relief annealing.

[5] If stress-relief annealing is applied, please contact us.

[6] In the event the attacking medium (gas with a higher S content) requires weld metal of similar composition as the base material.

[7] e.g. Böhler FOX CN 18/16 M-A

[8] e.g. Böhler FOX CN 20/25 M

EXAMPLES OF FILLER METALS FOR WELDING OF CLADDING MATERIALS MADE FROM SPECIAL STEELS, NON-FERROUS METALS AND ALLOYS

according to DIN 1733, DIN 1736 and/or EN 1600, EN 12072 as well as AWS A 5.7, A 5.14 and A 5.16

Cladding		Filler Metal Type					
EN Material No.	Alloy Type	multi-pass (GTAW, GMAW)[1]				single-pass ESW (SAW) strip	
		buffer		subsequent passes			
		DIN/EN	AWS	DIN/EN	AWS	DIN/EN	AWS
2.4660	Alloy 20	SG-NiCr21Mo9Nb	ERNiCrMo-3	SG-NiCr21Mo9Nb	ERNiCrMo-3	UP-NiCr21Mo9Nb	ERNiCrMo-3
1.4539	Alloy 904L	20 25 5 Cu L[6]	ER 385(mod.)[6]	20 25 5 Cu L[6]	ER 385(mod.)[6]	UP-NiCr21Mo9Nb	ERNiCrMo-3
1.4563	Alloy 28	SG-NiCr21Mo9Nb	ERNiCrMo-3	SG-NiCr21Mo9Nb	ERNiCrMo-3		
1.4529	–					UP-NiMo16Cr16Ti[3]	ERNiCrMo-7[3]
1.4876	Alloy 800	SG-NiCr21Mo9Nb	ERNiCrMo-3	SG-NiCr21Mo9Nb	ERNiCrMo-3	UP-NiCr21Mo9Nb	ERNiCrMo-3
2.4858	Alloy 825						
2.4816	Alloy 600			SG-NiCr21Mo9Nb SG-NiCr20Nb	ERNiCrMo-3 ERNiCr-3	UP-NiCr20Nb	ERNiCr-3
2.4856	Alloy 625	SG-NiCr21Mo9Nb SG-NiMo16Cr16Ti	ERNiCrMo-3 ERNICrMo-7	Sg-NiMo16Cr16Ti	ERNiCrMo-7	UP-NiMo16Cr16Ti[3]	ERNiCrMo-7[3]
2.4602	Alloy C22	SG-NiCr21Mo14W	ERNiCrMo-10	SG-NiCr21Mo14W[3]	ERNiCrMo-10[3]	UP-NiCr21Mo14W[2,3]	ERNiCr21 Mo-14W[2,3]
2.4610	Alloy C4	SG-NiMo16Cr16Ti	ERNiCrMo-7	SG-NiMo16Cr16Ti[3]	ERNiCrMo-7[3]	UP-NiMo16Cr16Ti[2,3]	ERNiCrMo-7[2,3]
2.4819	Alloy C-276	SGNiMo16Cr16W	ERNiCrMo-4	SG-NiMo16Cr16W[3]	ERNiCrMo-4[3]	UP-NiMo16Cr16W[2,3]	ERNiCrMo-4[2,3]
2.4605	Alloy 59	SG-NiCr23Mo16	ERNiCrMo-12	SG-NiCr23Mo16	ERNiCrMo-12	UP-NiCr23Mo16[2]	ERNiCrMo-12[2]
2.4617	Alloy B2	SG-NiMo27	ERNiMo-7	SG-NiMo27	ERNiMo-7	UP-NiMo27[2]	ERNiMo-7[2]
2.4360	Alloy 400	SG-NiCu30MnTi	ERNICu-7	SG-NiCu30MnTi	ERNiCu-7	UP-NiCu30MnTi[2]	ERNiCu-7[2]
2.4066 2.4068	Ni 200 Ni 201	SG-NiTi4	ERNi-1	SG-NiTi4	ERNi-1	UP-NiTi4[2]	ERNi-1[2]
2.0070	SE-Cu	SG-NiCu30MnTi	ERNiCu-7	SG-CuAg[5]	–	–	–
CW024A	SF-Cu			SG-CuSn	ERCu		
CW352H	–			SG-CuNi10Fe SG-CuNi30Fe	– ERCuNi	UP-NiCu30MnTi[4]	ERNiCu-7[4]
CW354H	CuNi 70/30			SG-CuNi30Fe	ERCuNi		
3.7025	Ti-Gr. 1	Titanium should not melt down, therefore only bridge welds.		3.7025	ERTi-2	–	–
3.7035	Ti-Gr. 2			3.7035	ERTi-3	–	–

[1] Bar electrodes are not available in all cases.

[2] Matching – at least two passes are required

[3] Over-alloyed – for maximum corrosion resistance – e.g. ERNiCrMo-12

[4] e.g. suitable as a buffer

[5] for higher electrical conductivity

[6] with approx. 6 % Mo (e.g. Böhler CN 20/25 M-IG.)

CERTIFICATES AND APPROVALS

Optimum quality is the main goal of the corporate philosophy of voestalpine Grobblech. This includes, among other things, corresponding certification and material approvals. According to the world-wide application of our roll-bonded clad plates we have also a comprehensive range of certifications and approvals.

The environmental management system satisfies prerequisites stipulated according to ISO 14001. The testing technique equipment is certified in accordance with EN 45000seqq. The quality management system fulfils the requirements of ISO 9001. Accordingly, we are also an approved manufacturer in accordance with the European Pressure Equipment Directive, effective as of 29 May 2002. The directive is the continuation of previous national approvals such as AD Specification W0/TRD 100, VdTÜV, PD 5500, Raccolta or Codap. The classification societies from which we have obtained certifications include, among others, Lloyd's Register, Det Norske Veritas, USSR Register, Bureau Veritas or American Bureau of Shipping.

RESEARCH, DEVELOPMENT AND TESTING TECHNIQUE

RESEARCH AND DEVELOPMENT

The continued development of our product range, service and earmarked investments contribute to meeting the growing requirements of our customers.

Our efficient research and development department guarantees our customers materials of the latest state of technology. In addition, we offer individual advice as well as support with respect to material selection, packing and corrosion.

TESTING TECHNIQUE

To conduct physical and chemical tests, we have installed the most modern facilities which are directly connected with the production sequence via the EDP-controlled production scheduling system.

In all tests, the application of our quality management system in accordance with ISO 9001 plays an important role. Furthermore our test facilities are accredited by GAZ (Gesellschaft für Akkreditierung und Zertifizierung in Düsseldorf) and the competent federal ministry in Austria.

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