TPS TECHNITUBE®
RÖHRENWERKE GMBH

SEAMLESS TUBES

Stainless Steel | Nickel Alloys | Titanium

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For more than 40 years now, TPS-Technitube Röhrenwerke GmbH has been recognised as a market leader in the manufacture of high quality seamless tubes.

With continuous investment we have been able to make further technical improvements to our already modern and progressive cold pilger mills.

In addition considerable commercial investment in inventory has resulted in our capability to manufacture tubes in titanium and high performance alloys.

Wherever your location, our quotations can be tailored to meet your emergency breakdown or planned maintainance requirements.

TPS SIZE RANGE OF SEAMLESS COLD FINISHED TUBES

Outside Diameter		
4,55 - 44,50 mm	0,179 - 1,752"	1/4" NB- 1 3/4" NB
Wall Thickness:		
0,89 - 6,90*mm	0,035 - 0,272"* BWG 20 - BWG 3*	Sch5- Sch80
Length		
0,8 m - 18m*	2,62 - 59,05 ft*	

* depends on OD

ASME/ASTM	ASME SA /ASTM A 213	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat Exchanger Tubes
	ASME SA/ASTM A 268	Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service
	ASTM A 269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
	ASME SA/ASTM A 312	Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
	ASME SA/ASTM A 789	Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
	ASME SA/ASTM A 1016	General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel and Stainless Steel Tubes
	ASME SB/ASTM B 161	Nickel Seamless Pipe and Tube (UNS N02200, N02201)
	ASME SB/ASTM B 163	Seamless Nickel and Nickel Alloy Condenser and Heat Exchanger Tubes
	ASME SB/ASTM B 165	Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
	ASME SB/ASTM B 167	Nickel-Chromium-Iron Alloys (UNS N06600, N06601), Seamless Pipe and Tube
	ASME SB/ASTM B 407	Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
	ASME SB/ASTM B 423	Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825) Seamless Pipe and Tube
	ASME SB/ASTM B 444	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Pipe and Tube
	ASME SB/ASTM B 622	Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube (UNS N06455, N10276)
	ASME SB/ASTM B 668	UNS N08028 Seamless Pipe and Tube
	ASME SB/ASTM B 729	Seamless UNS N08020 Nickel Alloy Pipe and Tube
	ASME SB/ASTM B 338	Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
	ASME SB/ASTM B 829	General requirements for Nickel and Nickel Alloys Seamless Pipe and Tube

DIN/EN	EN 10216-5	Seamless Steel Tubes for Pressure Purposes – Technical delivery conditions – Stainless Steel Tubes
	EN 10297-2	Seamless Steel Tubes for Mechanical and General Engineering Purposes – Technical delivery conditions - Stainless Steel
	EN 13445-2	Unfired pressure vessels - Part 2: Materials
	EN ISO 1127	Stainless Steel Tubes - Dimensions, Tolerances and Conventional Masses per Unit Length
	EN 10305-1	Steel tubes for precision applications - Technical delivery conditions
	DIN 28180	Seamless Steel Tubes for Tubular Heat-Exchangers: Dimensions, Tolerances and Materials
	DIN 17850	Titanium, Chemical Compostion
	DIN 17861	Titanium and Titanium Alloy Seamless Circular Tubes; Technical Conditions of Delivery
VdTÜV-WB	VdTÜV-WB 230/2	Tubes Titanium unalloyed and low alloyed
	VdTÜV-WB 263	Nickel-Copper Alloy (2.4360)
	VdTÜV-WB 305	Nickel-Chromium-Iron Alloy (2.4816)
	VdTÜV-WB 345	Low-Carbon-Nickel Alloy (2.4068)
	VdTÜV-WB 400	High-Corrosion Resistant Alloy (2.4819)
	VdTÜV-WB 412	Rolled and Forged Steel (1.4876)
	VdTÜV-WB 418	Rolled and Forged Ferritic-Austenitic Steel (1.4462)
	VdTÜV-WB 421	Rolled and Forged Austenitic Steel (1.4539)
	VdTÜV-WB 424	High-Corrosion Resistant Alloy (2.4610)
	VdTÜV-WB 432/2	High-Corrosion Resistant Nickel-Based Alloy (2.4858)
	VdTÜV-WB 499	High-Corrosion Resistant Nickel-Based Alloy (2.4856)

QUALITY MANAGEMENT

Lloyd's Register

Certificate of Approval

This is to certify that the Management System of:

TPS Technitube Roehrenwerke GmbH

Julius-Saxler-Straße 2 & 7, 54550 Daun, Germany

has been approved by Lloyd's Register to the following standards:

IATF 16949:2016 (excluding product design)

Approval number(s): IATF 16949 – 0018147-001

This certificate is valid only in association with the certificate schedule bearing the same number on which the locations applicable to this approval are listed.

The scope of this approval is applicable to:

Manufacture of seamless tubes in ferritic and/or austenitic stainless steel, nickel alloys and titanium.

Paul Graaf

Chief Operating Officer, Management Systems, MSIS

Issued by: Lloyd's Register Quality Assurance Limited

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CERTIFICATE

TPS-Technitube Röhrenwerke GmbH
Julius-Saxler-Str. 7
D-54550 Daun

directive 2014/68/EU, annexe I, section 4.3

Lloyd's Register

Certificate of Approval

This is to certify that the Management System of:

TPS Technitube Roehrenwerke GmbH

Julius-Saxler-Straße 2 & 7, 54550 Daun, Germany

has been approved by Lloyd's Register to the following standards:

ISO 9001:2015

Approval number(s): ISO 9001 – 0018147-501

The scope of this approval is applicable to:

Manufacture of seamless tubes and U-bends as well as parts of them in ferritic and/or austenitic stainless steel, copper and nickel alloys and titanium, stock holding and processing (cutting to length, deburring, picking) of tubes / trade of seamless and welded tubes and the equipment in steel includingstainless steel and non ferrous materials.

Paul Graaf

Area Operations Manager North Europe

Issued by: Lloyd's Register Deutschland GmbH

for and on behalf of: Lloyd's Register Quality Assurance Limited

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In 1989 TPS-Technitube Röhrenwerke GmbH was the first German producer of seamless stainless steel tubes to be ISO certified. Consequently, TPS has more than 30 years of experience with the ISO 9000 system. Therefore, the ISO system is not just a marketing parameter for TPS. It is a useful tool, from which both - the company itself and especially the customers - are able to benefit significantly.

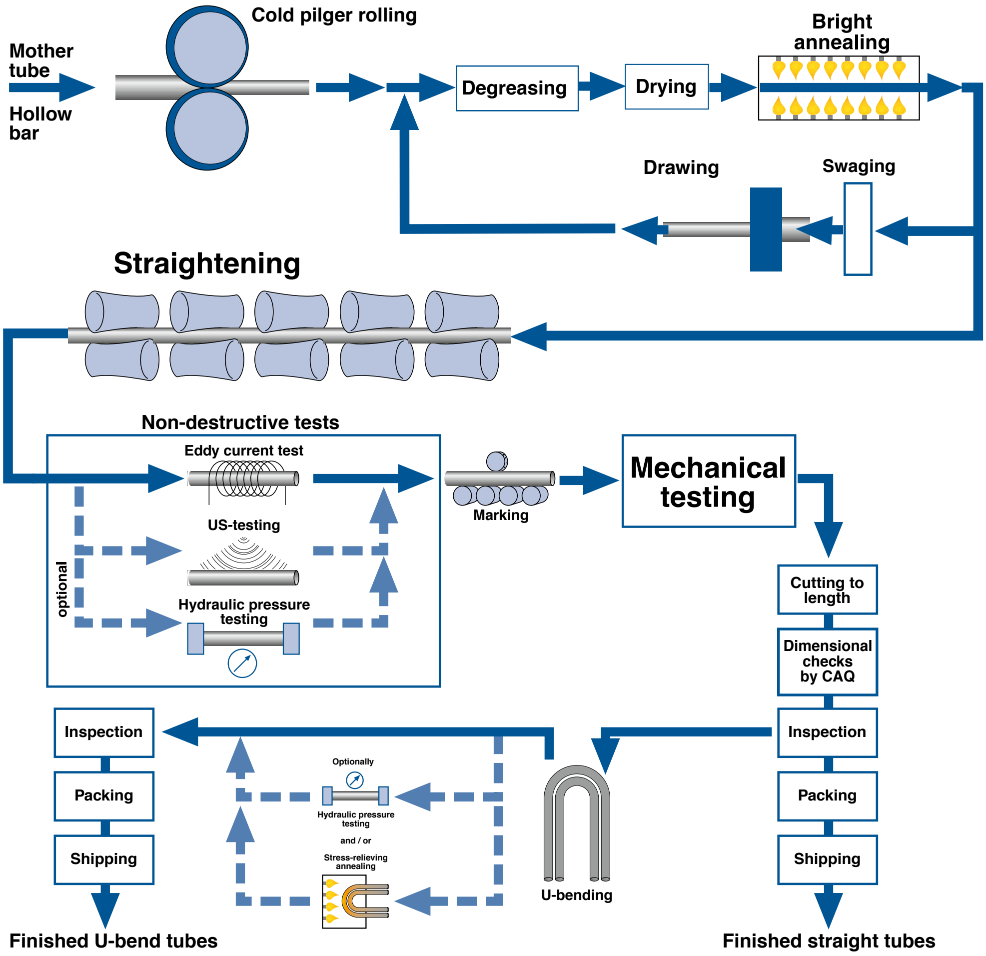
The quality management systems of the following departments of TPS are ISO 9001:2015 certified:

- Manufacture of seamless tubes and U-bends
- Stock holding of seamless and welded tubes
- Trade of seamless and welded tubes.
- Production of OCTG products (Oil Country Tubular Goods), primarily for the oil and gas industry.

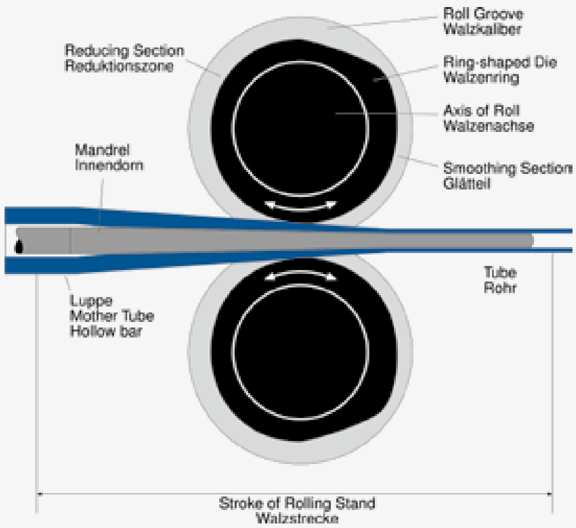
Since 2008 **TPS-Technitube Röhrenwerke GmbH** is also certified acc. to **IATF 16949:2016.**

Besides the **ISO 9001:2015** and **IATF 16949:2016** TPS holds the following approvals and qualifications:

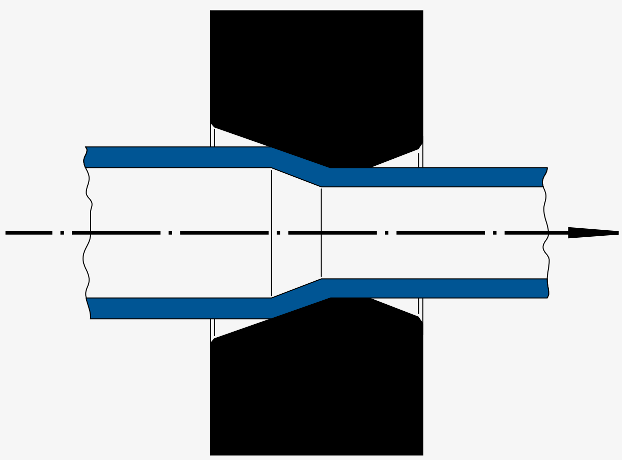
- Directive 2014/68/EU, Annexe I, Section 4.3
- AD-2000 Merkblatt W0
- DNV-GL
- IGR 12-0604
- API 5CT
- API 5D
- API 5L
- API ISO 9001:2015
- API Q1
- Aramco Overseas
- ADNOC



Cold pilgering



Cold drawing



Hollow drawing

Standard Grades | Composition | Applications | Properties

AUSTENITIC STEEL

TP304 | UNS S30400 | 1.4301/1.4307 | X 5 Cr Ni 18-10/X 2 Cr Ni 18-9 | TPS-INOX-4301-304

The most popular stainless steel has an economic balance of alloying elements to ensure its good cold formability, corrosion resistance, toughness and good mechanical properties with no excessive work-hardening. It performs well in unpolluted atmospheres but can tarnish or lightly rust in damp atmospheres around some industrial and on/offshore locations.

The steel has been used extensively for potable water tubing and in fresh feedwater systems where precautions are taken to avoid crevice attack under deposits, etc. Performance in aerated seawater is not good without adequate galvanic or cathodic protection. Stability and toughness at cryogenic temperatures is high.

TP 304H | UNS S30409 | 1.4948 | X 6 Cr Ni 18-10

TP 304H with guaranteed carbon content of min. 0,04% gives a better creep resistance. Similar oxidation resistance to TP 304. Main applications: Heat exchangers, chemical and petrochemical furnaces.

TP 304L | UNS S30403 | 1.4306 | X 2 Cr Ni 19-11 | TPS-INOS-4306-304L

Low carbon version of TP 304 guaranteed no creep resistance above 500°C. Good high temperature oxidation resistance up to 900°C. General corrosion characteristics are similar to TP 304.

Stability and toughness at cryogenic temperatures is high. Main applications: Pipe and heat exchanger tubes in chemical, petrochemical and food industries.

TP 316/TP 316L | UNS S31600/31603 | 1.4401/1.4404 | X 5 Cr Ni Mo 17-12-2 /X 2 Cr Ni Mo 17-12-2 TPS-INOX-4401/4404-316/316L

These grades belong to the family of 17%Cr12-13%Ni steels containing 2,0-3,0% Mo. This standard grade is used where specific attributes of other members of the family are not necessary - eg. no likelihood of intercrystalline corrosion caused by welding. Special for TP 316L, low carbon content, minimizes chromium carbide preciptation and improves resistance to intercrystalline corrosion. After TP 304/304L type steels, these TP 316/316L grades are the most widely used austenitics.

Good high temperature oxidation resistance up to 900°C. In the damp industrial or onshore atmospheres of Europe, they perform better than TP 304/304L and ferritic grades. In low temperature seawater they offer limited resistance to pitting but are susceptible to crevice attack. Their short- and longtime properties at elevated temperatures are also superior to those of comparable TP 304/304L grades. Main applications: Pipe and heat exchanger tubes in chemical and petrochemical plant, in boilers and food industry.

TP 316L Mo | UNS S31603 | 1.4435 | X2 Cr Ni Mo 18-14-3 | TPS-INOX-4435-316LMo

Due to the lower carbon content, intercrystalline corrosion resistance is also guaranteed after welding. The increased molybdenum content improves the general corrosion resistance, particularly to reduced acids and chloride-containing fluids. Weldability according all processes (except for autogenous welding) without subsequent heat treatment. TPS-INOS 4435-316LMO is used in the pharmaceutical industry, the synthetic fiber manufacturing industry, the pulp and cellulose industry and for chemical fertilizer production plants. This steel is polishable. TPS-INOS 4435 complies with the requirements of Basler standard 2. In case of continuous operation up to 400°C it is resistant to intercrystalline corrosion. The machinability of this grade is reduced.

TP 316H | UNS S31609 | 1.4919 | X 6 Cr Ni Mo 17-13 | TPS-INOX-316H

This grade with guaranteed carbon content of min. 0,04% enhances strength at elevated temperatures. Similar oxidation resistance to TP 316. Main applications: Heat exchangers, furnaces, chemical and petrochemical plant.

TP 316Ti | UNS S31635 | 1.4571 | X 6 Cr Ni Mo Ti 17-12-2 | TPS-INOX-4571-316Ti

This is one of the family of 17%Cr12-13%Ni steels containing Mo of 2,0-2,4% stabilized with Ti which minimizes chromium carbide precipitation and improves resistance to intergranular corrosion. In the damp industrial or coastal atmospheres of Europe, they perform better than TP 304/304L and ferritic grades. In low temperature seawater they offer limited resistance to pitting but are susceptible to crevice attack. Their short- and long-time properties at elevated temperatures are also superior to those of comparable TP 304/304L grades.

TP 321 | UNS S32100 | 1.4541 | X 6 Cr Ni Ti 18-10 | TPS-INOX-4541-321

High carbon steels prone more to intercrystalline attack in weld zones and slower cooling sections. This steel avoids such attacks through its stabilization with Ti. The corrosion behaviour of this alloy in natural environments is very similar to the TP 304/304L alloys. Architecturally, it may not be adequate for near-industrial or onshore locations in Europe. Satisfactory in many low-chloride waters, it is prone to pitting or crevice corrosion in seawater. Water treatment, galvanic protection and deaeration can influence the performance.

TP 321H | UNS S32109 | 1.4878 | X 8 Cr Ni Ti 18-10 | TPS-INOX-4878-321H

This is the high carbon version of TP 321 which ensures greater creep resistance. Behaves much the same as TP 321 in oxidation resistance. Main applications: Heat exchangers, furnaces, boilers in chemical and petrochemical plant.

UNS S31254 | 1.4547 | 254SMO | X1 Cr Ni Mo Cu N 20-18-7

UNS S31254 is an austenitic grade in which the additions of chromium, molybdenum and nitrogen give high resistance to pitting in sea water. This alloy has a mean Pitting Resistance Equivalent Number (‚PREN' = Cr+3.3Mo+16N) of 43.8. Tests indicate high resistance to crevice-corrosion attack in seawater and to stress corrosion cracking in hot concentrated sodium chloride.Compared with CrNiMo 17 12 2.5 steels, it shows superior corrosion resistance in many acids at similar concentrations and its yield strength is approximately 50% higher. Good weldability using Ni-Cr-Mo consumables. Quench annealing and short periods within the 600-1000°C range avoids the possible development of deleterious sigma phase, which may embrittle and impair corrosion resistance.

Standard Grades | Composition | Applications | Properties

SUPER-AUSTENITIC STEEL

TP 904L | UNS N08904 | 1.4539 | X 1 Ni Cr Mo Cu 25-20-5 | TPS-Technichromo 904L

This high-alloy austenitic is very resistant to attack from diluted sulphuric acid, phosphoric acid and acetic acid. It resists pitting in neutral chloride solutions. Its resistance to stress corrosion cracking in some hot chlorides is much superior to that of the
lower nickel austenites. This steel has good formability and weldability. This material is present in all common standards like ASTM and EN, however with some differences. Design stresses up to 370°C are included in ASME II.

FERRITIC AND MARTENSITIC STEEL

TP 405 | UNS S40500 | 1.4002 | X 6 Cr Al 13 | TPS-FS-4002-405

TP 405 is a low carbon, 12% chrome steel, not subject to appreciable hardening through air cooling from high temperatures. This tendency retards the formation of hardening cracks caused by welding. Practically the same corrosion and oxidation resistance as TP 410. Can be machined, drawn, spun and formed without difficulty. Used for applications where hardening upon cooling from high temperatures must be avoided. Has excellent long-time stability up to 1200°F.

TP 410 | UNS S41000 | 1.4006 | X 12 Cr 13 | TPS-FS-4006-410

This 12% chrome steel is very deep hardening,
meaning that hard martensite is formed at cooling rates as slow as 20°C/minute. The hard brittle martensites require prompt tempering at a high enough temperature to improve impact properties. Increasing nickel achieves a better combination of properties. Not very resistant to aerated seawater. Welding is limited because high preheat and immediate postweld tempering is necessary to minimize the risk of hardzone cracking. Type 410 is not equal to the austenitic steels in corrosion resistance, but satisfactorily withstands the effects of the milder acids, alkalies, fresh water and atmospheric conditions. It is the least costly of the stainless steels, containing just enough to yield stainless properties.

TP 430 | UNS S43000 | 1.4016 | X 6 Cr 17 | TPS-FS-4016-430

Stainless steel type 1.4016 is also commonly known as grade 430. Type 430 stainless steel combines good corrosion resistance with good formability and ductility.

It is a ferritic, non-hardenable plain Chromium stainless steel with excellent finish quality. Grade 430 also has excellent resistance to nitric attack, which makes it well suited to use in chemical applications.

DUPLEX

UNS S31803/UNS S32205 | 1.4462 | X 2 Cr Ni Mo N 22-5-3 | Techniduplex TD2205

A widely used duplex steel combining high strength and corrosion resistance in various organic acids, anorganic acids, aggressive coolingwaters and hydrous H_2S/NaCl mixtures. With a near equal mix of austenite and ferrite, they give yield strength 30% higher and tensile strengths marginally higher than comparable nitrogen-containing austenitics. High resistance to general corrosion and specifically to pitting and crevice corrosion.

Their resistance to stress-corrosion cracking in neutral chlorides is superior to that of the austenites.

In high chloride acidic or moderately sour environments where hydrogen or sulphide stress cracking is more likely, higher alloyed austenitics need also to be
considered. Impact values are high and transition temperatures of base materials vary around - 50°C. However, the proportion and orientation of ferrite in welds and base materials may significantly affect toughness at subzero temperatures. Exposure to moderate and high temperatures and less rapid cooling may cause embrittlement.

SUPER DUPLEX

UNS S32750 | 1.4410 | X 2 Cr Ni Mo N 25-7-4 |

In the solution annealed condition, Super Duplex UNS S32750 – 1.4410 has a balanced austenitic-ferritic microstructure, is mechanically highly resistant and shows an excellent corrosion resistance in seawater. Due to its high resistance, weight and therefore material costs can be saved compared to other qualities. This material grade is particularly suitable for applications in the Oil & Gas industry, in desalination plants, in the Chemical industry as well as for geothermal applications.

The characteristics of UNS S 32750 are as follows:

- high stress corrosion resistance in chloride- and hydrosulphide-containing environment
- high corrosion resistance to seawater
- high resistance to pitting, crevice corrosion and general corrosion
- mechanically very resistant
- very good weldability
- good thermal conductivity with low thermal expansion

UNS S32760 | 1.4501 | X2 Cr Ni Mo Cu W N 25-7-4 | Technisuperduplex TSD2507

UNS S32760 - 1.4501 is a super ferritic-austenitic grade with high mechanical properties and superior corrosion resistance. Besides the ferritic-austenitic structure, S32760 has an excellent resistance to pitting and crevice corrosion and is therefore particularly suitable for sea water applications and for process systems on offshore platforms, respectively in all situations where there is a risk of stress corrosion.

The high tensile properties are twice comparing with TP 316L stainless steel. The service range is between - 50°C up to + 275°C. More detailed informations about this particular grade are described in our data sheet.

Standard Grades | Composition | Applications | Properties

NICKEL ALLOYS

UNS N02200 | 2.4066 | Ni 99.2 | TPS-TECHALLOY 200
UNS N02201 | 2.4068 | LC-Ni 99 | TPS-TECHALLOY 201

ALLOY 200/201 is technically pure nickel with good mechanical properties and excellent resistance to corrosive media. Even when exposed to high temperatures, ALLOY 200/201 retains its strength and is ductile at low temperatures. ALLOY 200/201 is a multipurpose grade and is used in applications where alloys are not essential. It also has good magnetic and magnetostrictive properties, high thermal and electrical conductivity as well as low gas content in electronics industry. Furthermore ALLOY 200/201 is of interest for its good weldability.

UNS N04400 | 2.4360 | Ni Cu 30 Fe | TPS-TECHALLOY 400

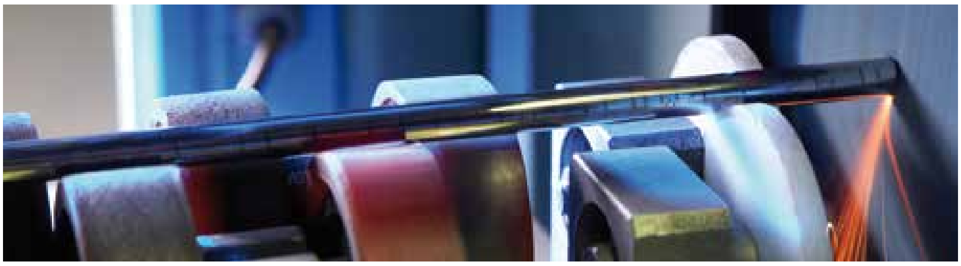
ALLOY 400 combines high strength, ductility and excellent resistance to corrosion, is a general purpose. Retains exential characteristics through manufacturing, fabrication and service life. Strength equal to structural steel, strength can be increased by mechanical working, but not by heat treating. This tubing is used in chemical and processing equipment, pulp and paper machinery, food processing and packing machinery, petroleum, petrochemical and power-generating apparatus. Also in heating elements, solenoid valves, antennas, lube oil coolers, electron tubes, electrical connectors, atomizer assemblies, marine windshield wipers, spray systems and lines for handling hydraulic fluids and acids.

UNS N06600 | 2.4816 | Ni Cr 15 Fe | TPS-TECHALLOY 600

ALLOY 600 is a high nickel-chromium-iron alloy. Outstanding in strength, corrosion resistance, and oxidations resistance at elevated temperatures up to 1180°C. Offers an extremly useful combination of high strength and workability. This tubing resists ordinary forms of corrosion throughout the range from annealed to heavily cold worked. Widely used for thermocouple protection tubing, muffle tubes, jet and rocket engine fuel lines and instruments, oil coolers, oxygen nozzles in glass furnaces, cooling tubes for spot welders, bellows in assemblies for fire detection systems. Also for food processing equipment, dental and surgical instruments, gas and oxygen burner tips, phonograph cartridges, igniters for portable heaters and pushrods in electrical relays.

UNS N06455 | 2.4610 | Hastelloy C-4 | Ni Mo 16 Cr 16 Ti

Hastelloy C-4 (Alloy C-4) shows excellent stability against intergranular corrosion, pitting corrosion and stress corrosion as well as reductive mineral acids and chlorides, inorganic and organic chloride-contaminated media. Material 2.4610 (Alloy C-4) is mainly used in inorganic chemistry, fertilizer industry, and with acetic acid.



UNS N06625 | 2.4856 | Ni Cr 22 Mo 9 Nb | TPS-TECHALLOY 625

ALLOY 625 is a high nickel-chromium-Molybdenum-columbium alloy. This tubing is used for offshore technology, chemical industry, production of phosphate acid, flue gas desulphurating plants, waste incineration plants. It is sea water resistent.

UNS N08020 | 2.4660 | Ni Cr 20 Cu Mo | TPS-TECHALLOY 20

ALLOY 20 is a nickel-iron-chromium alloy with addition of copper and Molybdenum. Stabilized with niobium against sensitization and resultant intergranular corrosion. ALLOY 20 has exellent resistance to general corrosion, pitting and crevice corrosion in chemicals containing chlorides and sulfuric, phosphoric and nitric acids.

UNS N08800 | 1.4876 | X 10 Ni Cr Al Ti 3220 | TPS-TECHALLOY 800

ALLOY 800 is a nickel-chromium-iron alloy with good resistance to oxidation, retains its strength at elevated temperatures, has good workability and welding properties. Superior to ALLOY 600 in resistance to sulfur, green rot, and cyanid salts, inferior on resistance to nitriding, halogen gases and molten caustics. Excellent corrosion resistance can be expected under oxidizing conditions which are most harmful to ordinary steel and nonferrous metals, good resistance can also be expected in many organic acids and their compounds. Limited resistance may be expected under reducing acid conditions. Applications in calrod units, furnace muffles and heat exchangers.

UNS N08825 | 2.4858 | Ni Cr 21 Mo | TPS-TECHALLOY 825

ALLOY 825 is a nickel-iron-chromium alloy containing Molybdenum and copper to make it very resistant to reducing environments such as sulfuric or phosphoric acid. It is also resistant to chloride stress corrosion.

UNS N10276 | 2.4819 | Hastelloy C-276 | Ni Mo 16 Cr 15 W

HASTELLOY C-276 is a nickel-chromium-molybdenum alloy with universal corrosion resistance unmatched by any other alloy. It has outstanding resistance to a wide variety of chemical process environments including ferric and cupric chlorides, hot contaminated mineral acids, solvents, chlorine and chlorine contaminated (both organic and inorganic), dry chlorine, formic and acetic acids, acetic anhydride, sea water and brine solutions and hypochlorite and chlorine dioxide solutions. Hastelloy C-276 also resists formation of grain boundary precipitates in the weld heat affected zone making it useful for most chemical processes in the as-welded condition. It has excellent resistance to pitting and stress corrosion cracking.

Chemical Composition | Mechanical Properties | Heat Treatment

1. AUSTENITIC STEELS

Chemical composition, in % by mass

Norm	Grade	C	Si	Mn	P	S	Cr	Ni	Mo
		max.	max.	max.	max.	max.			
	X5 CrNi 18-10								
EN 10216-5	**1.4301**	0,070	1,00	2,00	0,040	0,015	17,0 - 19,5	8,0 - 10,5	
ASME SA/ASTM A 213	**TP 304**	0,080	1,00	2,00	0,045	0,030	18,0 - 20,0	8,0 - 11,0	
	X6 CrNi 18-10								
EN 10216-5	**1.4948**	0,04 - 0,08	1,00	2,00	0,035	0,015	17,0 - 19,0	8,0 - 11,0	
ASTM A 213	**TP 304 H**	0,04 - 0,10	1,00	2,00	0,045	0,030	18,0 - 20,0	8,0 - 11,0	
	X2 CrNi 19-11								
EN 10216-5	**1.4306**	0,030	1,00	2,00	0,040	0,015	18,0 - 20,0	10,0 - 12,0	
ASME SA/ASTM A 213	**TP 304 L**	0,035	1,00	2,00	0,045	0,030	18,0 - 20,0	8,0 - 12,0	
	X2 CrNi 18-9								
EN 10216-5	**1.4307**	0,030	1,00	2,00	0,040	0,016	17,5 - 19,5	8,0 - 10,0	
	X5 CrNiMo 17-12-2								
EN 10216-5	**1.4401**	0,070	1,00	2,00	0,040	0,015	16,5 - 18,5	10,0 - 13,0	2,0 - 2,5
ASME SA/ASTM A 213	**TP 316**	0,080	1,00	2,00	0,045	0,030	16,0 - 18,0	10,0 - 14,0	2,0 - 3,0
	X2 CrNiMo 17-12-2								
EN 10216-5	**1.4404**	0,030	1,00	2,00	0,040	0,015	16,5 - 18,5	10,0 - 13,0	2,0 - 2,5
ASME SA/ASTM A 213	**TP 316 L**	0,035	1,00	2,00	0,045	0,030	16,0 - 18,0	10,0 - 14,0	2,0 - 3,0
	X2 CrNiMo 18-14-3								
EN 10216-5	**1.4435**	0,030	1,00	2,00	0,040	0,015	17,0 - 19,0	12,5 - 15,0	2,5 - 3,0
ASME SA/ASTM A 213	**TP 316 L-Mo**	0,035	1,00	2,00	0,045	0,030	16,0 - 18,0	10,0 - 14,0	2,0 - 3,0
	X6 CrNiMoTi 17-12-2								
EN 10216-5	**1.4571**	0,080	1,00	2,00	0,040	0,015	16,5 - 18,5	10,5 - 13,5	2,0 - 2,5
ASME SA/ASTM A 213	**TP 316 Ti**	0,080	0,75	2,00	0,045	0,030	16,0 - 18,0	10,0 - 14,0	2,0 - 3,0
	X6CrNiM017-13-2								
EN 10216-5	**1.4918**	0,04-0,08	0,75	2,00	0,035	0,015	16,0-18,0	12,0-14,0	2,0-2,5
ASME SA/ASTM A 213	**TP 316H**	0,04-0,10	1,00	2,00	0,045	0,030	16,0-18,0	11,0-14,0	2,0-3,0
	X2 CrNiMo 18-15-4								
DIN 10088-3	**1.4438**	0,030	1,00	2,00	0,045	0,030	17,5 - 19,5	13,0 - 16,0	3,0 - 4,0
ASME SA/ASTM A 213	**TP 317L**	0,035	1,00	2,00	0,045	0,030	18,0 - 20,0	11,0 - 15,0	3,0 - 4,0
	X6 CrNiTi 18-10								
EN 10216-5	**1.4541**	0,080	1,00	2,00	0,040	0,015	17,0 - 19,0	9,0 - 12,0	
ASME SA/ASTM A 213	**TP 321**	0,080	1,00	2,00	0,045	0,030	17,0 - 19,0	9,0 - 12,0	
	X8 CrNiTi 18-10								
EN 10297-2	**1.4878**	0,100	1,00	2,00	0,045	0,015	17,0 - 19,0	9,0 - 12,0	
ASME SA/ASTM A 213	**TP 321 H**	0,04 - 0,10	1,00	2,00	0,040	0,030	17,0 - 19,0	9,0 - 12,0	
	X6 CrNiNb 18-10								
EN 10216-5	**1.4550**	0,080	1,00	2,00	0,040	0,015	17,0 - 19,0	9,0 - 12,0	
ASME SA/ASTM A 213	**TP 347**	0,080	1,00	2,00	0,045	0,030	17,0 - 20,0	9,0 - 13,0	
	X1 CrNiMoCuN 20-18-7								
EN 10216-5	**1.4547**	0,020	0,70	1,00	0,030	0,010	19,5 - 20,5	17,5 - 18,5	6,0 - 7,0
ASME SA/ASTM A 213	**UNS S 31254**	0,020	0,80	1,00	0,030	0,010	19,5 - 20,5	17,5 - 18,5	6,0 - 6,5

Rp 0,2 = Yield Strength   Rp 1,0 = Yield Strength   Rm = Tensile Strength   A = Elongation

Mechanical properties and heat treatment

Ti	Others	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Hardness	Heat treatment
		min.	min.	min. max.	min. %	HRB max.	
	N 0,10 max.	195	230	500 - 700	40		solution annealed
		205		515	35	90	solution annealed
	N 0,10 max.	185	225	500 - 700	40		solution annealed
		205		515	35	90	solution annealed
	N 0,10 max.	180	215	460 - 680	40		solution annealed
		170		485	35	90	solution annealed
		180	215	460 - 680	40		solution annealed
	N 0,10 max.	205	240	510 - 710	40		solution annealed
		170		485	35	90	solution annealed
	N 0,10 max.	190	225	490 - 690	40		solution annealed
		170		485	35	90	solution annealed
	N 0,10 max.	190	225	490 - 690	40		solution annealed
		205		515	35	90	solution annealed
5x%C max.0,70		210	245	500 - 730	35		solution annealed
5x% (C+N) max.0,70	N 0,10 max.	205		515	35	90	solution annealed
	N 0,10 max.	205	245	490-690	35		solution annealed
		205		515	35	90	solution annealed
	N 0,11 max.	200	235	500 - 700	40		solution annealed
		205		515	35	90	solution annealed
5x%C max.0,70		200	235	500 - 730	35		solution annealed
5x%(C+N) max.0,70		205		515	35	90	solution annealed
5x%C max.0,80		190	230	500	40		solution annealed
4x% (C+N) max.0,70		205		515	35	90	solution annealed
10x%C max.1,00		205	240	510 - 740	35		solution annealed
10x%C max.1,10		205		515	35	90	solution annealed
	N 0,18-0,25; Cu 0,50-1,00	300	340	650 - 850	35		solution annealed
	N 0,18-0,22; Cu 0,50-1,00	310		675	35	96	solution annealed

2. SUPER AUSTENITIC STEELS

Chemical composition, in % by mass

Norm	Grade	C	Si	Mn	P	S	Cr	Ni	Mo
		max.	max.	max.	max.	max.			
ASME SA/ASTM A 213	**X1 NiCrMoCu 25-20-5**								
EN 10216-5	**1.4539**	0,020	0,70	2,00	0,030	0,010	19,0 - 21,0	24,0 - 26,0	4,0 - 5,0
VD-TÜV 421	**1.4539**	0,020	0,70	2,00	0,030	0,015	19,0 - 21,0	24,0 - 26,0	4,0 - 5,0
ASTM A 213	**UNS N08904**	0,020	1,00	2,00	0,040	0,030	19,0 - 23,0	23,0 - 28,0	4,0 - 5,0

3. FERRITIC AND MARTENSITIC STEELS

Chemical composition, in % by mass

Norm	Grade	C	Si	Mn	P	S	Cr	Ni	Mo
		max.	max.	max.	max.	max.			
	X6 CrAl 13								
EN 10297-2	**1.4002**	0,080	1,00	1,00	0,040	0,030	12,0 - 14,0		
ASME SA/ASTM A 268	**TP 405**	0,080	1,00	1,00	0,040	0,030	11,5 - 14,5	0,50	
	X12 Cr 13								
DIN 17456	**1.4006**	0,08 - 0,12	1,00	1,00	0,045	0,030	12,0 - 14,0	0,75	
ASME SA/ASTM A 268	**TP 410 (UNS S 41000)**	0,150	1,00	1,00	0,040	0,030	11,5 - 13,5		
	X6 Cr 13								
ASME SA/ASTM A 240/ A268	**TP 410 S (UNS S 41008)**	0,080	1,00	1,00	0,040	0,030	11,5 - 14,5	0,60	
	X6 Cr 17								
EN 10297-2	**1.4016**	0,080	1,00	1,00	0,040	0,030	16,0 - 18,0		
ASME SA/ASTM A 268	**TP 430**	0,120	1,00	1,00	0,040	0,030	16,0 - 18,0		

Rp 0,2 = Yield Strength   Rp 1,0 = Yield Strength   Rm = Tensile Strength   A = Elongation

Mechanical properties and heat treatment

	Ti	Others	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Hardness	Heat treatment
			min.	min.	min. max.	min. %	HRB max.	
		Cu 1,20 - 2,00, N 0,15 max.	230	250	520 - 720	35		solution annealed
		Cu 1,20 - 2,00, N 0,04 - 0,15 max.	230	260	530 - 720	35		solution annealed
		Cu 1,00 - 2,00, N 0,10 max.	215		490	35	90	solution annealed

Mechanical properties and heat treatment

	Ti	Others	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Hardness	Heat treatment
			min.	min.	min. max.	min. %	HRB max.	
		Al 0,1 - 0,3	210	220	400	17		annealed
		Al 0,1 - 0,3	205		415	20	95	annealed
			200	250	450 - 650	20		annealed
			205		415	20	95	annealed
			205		415	22	89	annealed
			240	250	430	20		annealed
			240		415	20	90	annealed

Chemical Composition | Mechanical Properties | Heat Treatment

4. DUPLEX

Chemical composition, in % by mass

Norm	Grade	C	Si	Mn	P	S	Cr	Ni	Mo
		max.	max.	max.	max.	max.			
	X2 CrNiMoN 22-5-3								
EN 10216-5	**1.4462**	0,030	1,00	2,00	0,035	0,015	21,0 - 23,0	4,5 - 6,5	2,5 - 3,5
VD-TÜV 418	**1.4462**	0,030	1,00	2,00	0,030	0,015	21,0 - 23,0	4,5 - 6,5	2,5 - 3,5
ASME SA/ASTM A 789	**UNS S 31803**	0,030	1,00	2,00	0,030	0,020	21,0 - 23,0	4,5 - 6,5	2,5 - 3,5
ASME SA/ASTM A 789	**UNS S 32205**	0,030	1,00	2,00	0,030	0,020	22,0 - 23,0	4,5 - 6,5	3,0 - 3,5

5. SUPER DUPLEX

Chemical composition, in % by mass

Norm	Grade	C	Si	Mn	P	S	Cr	Ni	Mo
		max.	max.	max.	max.	max.			
	X2 CrNiMoN 25-7-4								
EN 10216-5	**1.4410**	0,030	1,00	2,00	0,035	0,015	24,0 - 26,0	6,0 - 8,0	3,0 - 4,5
ASME SA/ASTM A 789/790	**UNS S 32750**	0,030	0,80	1,20	0,035	0,020	24,0 - 26,0	6,0 - 8,0	3,0 - 5,0
	X2 CrNiMoCuWN 25-7-4								
EN 10216-5	**1.4501**	0,030	1,00	1,00	0,035	0,015	24,0 - 26,0	6,0 - 8,0	3,0 - 4,0
ASME SA/ASTM A 789/790	**UNS S 32760**	0,030	1,00	1,00	0,030	0,010	24,0 - 26,0	6,0 - 8,0	3,0 - 4,0

Rp 0,2 = Yield Strength Rp 1,0 = Yield Strength Rm = Tensile Strength A = Elongation

Mechanical properties and heat treatment

Ti	Others	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Hardness	Heat treatment
		min.	min.	min. max.	min. %	HRC max.	
	N 0,10 - 0,22	450		640 - 880	22		solution annealed
	N 0,10 - 0,22	450		640 - 880	22		solution annealed
	N 0,08 - 0,20	450		620	25	30	solution annealed
	N 0,14 - 0,20	485		655	25	30	solution annealed

Mechanical properties and heat treatment

Ti	Others	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Hardness	Heat treatment
		min.	min.	min. max.	min. %	HRC max.	
	N 0,20 - 0,35	550		800 - 1000	20		solution annealed
	N 0,24 - 0,32; Cu 0,50 max.	550		800	15	32	solution annealed
	N 0,2-0,3; Cu 0,5-1,0; W 0,5-1,0	550		800 - 1000	20		solution annealed
	N 0,2-0,3; Cu 0,5-1,0; W 0,5-1,0	550		750	25	32	solution annealed

Chemical Composition | Mechanical Properties | Heat Treatment

6. NICKEL ALLOYS

Chemical composition, in % by mass

Norm	Grade	C	Si	Mn	P	S	Cr	Ni	Mo
		max.	max.	max.	max.	max.			
	Ni 99,2								
DIN 17740	**2.4066**	0,100	0,25	0,35		0,005		99,2 min.	
ASME SB/ASTM B 161/163	**UNS N 02200**	0,150	0,35	0,35		0,010		99,0 min.	
	LC-Ni 99								
DIN 17740	**2.4068**	0,020	0,25	0,35		0,005		99,0 min.	
VD-TÜV WB 345	**2.4068**	0,020	0,20	0,35		0,010		99,0 min.	
ASME SB/ASTM B 161/163	**UNS N 02201**	0,020	0,35	0,35		0,010		99,0 min.	
	NiCu30Fe								
DIN 17743	**2.4360**	0,150	0,50	0,20		0,020		63,0 min.	
VD-TÜV WB 263	**2.4360**	0,160	0,50	2,00		0,020		63,0 min.	
ASME SB/ASTM B 163/165	**UNS N 04400**	0,300	0,50	2,00		0,024		63,0 min.	
	NiCr15Fe								
DIN 17742	**2.4816**	0,025-0,100	0,50	1,00	0,020	0,015	14,0 - 17,0	72,0 min.	
VD-TÜV WB 305	**2.4816**	0,100	0,50	1,00	0,015	0,015	14,0 - 17,0	72,0 min.	
ASME SB/ASTM B 163/167	**UNS N 06600**	0,150	0,50	1,00		0,015	14,0 - 17,0	72,0 min.	
	NiCr22Mo9Nb								
DIN 17744	**2.4856**	0,100	0,50	0,50	0,020	0,015	20,0 - 23,0	58,0 min.	8,0 - 10,0
VD-TÜV WB 499	**2.4856**	0,030	0,40	0,50	0,010	0,010	21,0 - 23,0	rem.	8,0 - 10,0
ASME SB/ASTM B 444	**UNS N 06625**	0,100	0,50	0,50	0,015	0,015	20,0 - 23,0	58,0 min.	8,0 - 10,0
	NiCr20CuMo								
DIN 17744/17751	**2.4660**	0,070	1,00	2,00	0,025	0,015	19,0 - 21,0	32,0 - 38,0	2,0 - 3,0
ASME SB/ASTM B 729	**UNS N 08020**	0,070	1,00	2,00	0,045	0,035	19,0 - 21,0	32,0 - 38,0	2,0 - 3,0
	X10NiCrAlTi32-21								
EN 10297-2	**1.4876**	0,120	1,00	2,00	0,030	0,015	19,0 - 23,0	30,0 - 34,0	
VD-TÜV WB 412	**1.4876**	0,04 - 0,10	1,00	1,50	0,030	0,020	19,0 - 23,0	30,0 - 34,0	
ASTM B 163/407	**UNS N 08800**	0,100	1,00	1,50	0,030	0,015	19,0 - 23,0	30,0 - 35,0	
	NiCr21Mo								
DIN 17744/17751	**2.4858**	0,025	0,50	1,00	0,025	0,015	19,5 - 23,5	38,0 - 46,0	2,5 - 3,5
VD-TÜV WB 432/2	**2.4858**	0,025	0,50	1,00	0,020	0,010	19,5 - 23,5	38,0 - 46,0	2,5 - 3,5
ASTM B 163/423	**UNS N 08825**	0,050	0,50	1,00		0,030	19,5 - 23,5	38,0 - 46,0	2,5 - 3,5
	NiMo16Cr15W								
DIN 17744/17751	**2.4819**	0,010	0,08	1,00	0,020	0,015	14,5 - 16,5	rem.	15,0 - 17,0
VD-TÜV WB 400	**2.4819**	0,010	0,08	1,00	0,025	0,010	14,5 - 16,5	rem.	15,0 - 17,0
ASME SB/ASTM B 622	**UNS N10276**	0,010	0,08	1,00	0,040	0,030	14,5 - 16,5	rem.	15,0 - 17,0
	NiMo16Cr16Ti								
DIN 17744/17751	**2.4610**	0,015	0,08	1,00	0,025	0,015	14,0 - 18,0	rem.	14,0 - 17,0
VD-TÜV WB 424	**2.4610**	0,009	0,05	1,00	0,020	0,010	14,5 - 17,5	rem.	14,50 - 17,50
ASME SB/ASTM B 622	**UNS N 06455**	0,015	0,08	1,00	0,040	0,030	14,0 - 18,0	rem.	14,0 - 17,0

Rp 0,2 = Yield Strength Rp 1,0 = Yield Strength Rm = Tensile Strength A = Elongation

Mechanical properties and heat treatment

Ti	Others	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Hardness	Heat treatment
		min.	min.	min. max.	min. %	HRB max.	
0,100	Cu 0,25 max.; Fe 0,40 max.; Mg 0,15 max.	100	125	370	40		soft annealed
	Cu 0,25 max.; Fe 0,40 max.	105		380	35		annealed
0,100	Cu 0,25 max.; Fe 0,40 max.; Mg 0,15 max.	80	105	340	40		soft annealed
0,100	Cu 0,25 max.; Fe 0,40 max.; Mg 0,15 max.	80	105	340 - 540	40		soft annealed
	Cu 0,25 max.; Fe 0,40 max.	80		345	35		annealed
	Cu 28,0-34,0; Fe 1,0-2,5; Al 0,5 max.; Ti 0,30 max	180	210	450	35	80	soft annealed
	Cu 28,0-34,0; Fe 1,0 -2,5 max.; Al 0,50 max	175		450 - 600	30		annealed
	Cu 28,0-34,0; Fe 2,5 max.	193		483	35		annealed
0,30 max.	Cu 0,5 max.; Fe 6,0-10,0	180	210	500	35	90	solution annealed
0,30 max.	Cu 0,5 max.; Fe 6,0-10,0; Al 0,30 max	200		550 - 750	30		soft annealed
	Cu 0,5 max.; Fe 6,0-10,0	241		552	30		annealed
0,400 max.	Co 1,0 max.; Fe 5,0 max.; Al 0,4 max.	415	445	830	30		soft annealed
0,400	Co 1,0 max.; Fe 5,0 max.; Al 0,4 max.; Cb+Ta 3,20 - 3,80	400		830 - 1000	35		soft annealed
0,400 max.	Co 1,0 max.; Fe 5,0 max.; Al 0,4 max.; Cb+Ta 3,15 - 4,15	414		827	30		annealed
Co. 1,50	Cu 3-4; Nb+Ta 8xC max.; Fe rem.	240		550	40	95	soft annealed
	Cu 3-4; Nb+Ta 8xC min. 100 max.; Fe rem.	240		550	30		annealed
0,15 - 0,60	Al 0,15-0,6	170	210	450	28		annealed
0,15 - 0,60	Cu 0,75max.; Al 0,15-0,6; Co 1,0 max.	170	200	450 - 700	30		solution annealed
0,15 - 0,60	Cu 0,75max.; Al 0,15-0,6; Fe 39,5 min.	207		517 - 688	30		annealed
0,60 - 1,20	Co 1,0; Cu 1,5-3,0; Al 0,2; Fe rem.	235	265	550	30	90	soft annealed
0,60 - 1,20	Cu 1,5-3,0; Al 0,2 max.; Fe rem.	235	265	550 - 750	30	90	soft annealed
0,60 - 1,20	Cu 1,5-3,0; Al 0,2 max.; Fe 22,0 min.	241		586	30		annealed
-	Cu 0,5 max.; Fe 4,0-7,0; Co 2,5 max.; W 3,0-4,5; V 0,35 max.	280	300	690	40	100	solution annealed
-	Fe 4,0-7,0; Co 2,5 max.; W 3,0-4,5; V 0,35 max.	310	330	730 - 1000	30		annealed
-	Fe 4,0-7,0; Co 2,5 max.; W 3,0-4,5; V 0,35 max.	283		690	40		annealed
0,70	Fe 3,0 max.; Co 2,0 max.; Cu 0,50 max.	275	295	690	40	100	solution annealed
0,70	Fe 3,0 max.; Co 2,0 max.	280	315	700-900	40		solution annealed
0,70	Fe 3,0 max.; Co 2,0 max.	276		690	40		solution annealed

Chemical Composition | Mechanical Properties | Heat Treatment

7. TITANIUM ALLOYS

Chemical composition, in % by mass

Norm	Grade	N	C	H	Fe	O	Al	V	Pd	Mo
		max	max	max	max	max				
DIN 17850/17861	**Ti 1 - 3.7025**	0,05	0,06	0,013*	0,15	0,12				
VD-TÜV WB 230/2	**Ti 1 - 3.7025**	0,05	0,06	0,013*	0,15	0,12				
ASME SB/ASTM B 338	**Grade 1**	0,03	0,08	0,015	0,20	0,18				
DIN 17850/17861	**Ti 2 - 3.7035**	0,05	0,06	0,013*	0,20	0,18				
VD-TÜV WB 230/2	**Ti 2 - 3.7035**	0,05	0,06	0,013*	0,20	0,18				
ASME SB/ASTM B 338	**Grade 2**	0,03	0,08	0,015	0,30	0,25				
DIN 17850/17861	**Ti 3 - 3.7055**	0,05	0,06	0,013*	0,25	0,25				
VD-TÜV WB 230/2	**Ti 3 - 3.7055**	0,05	0,06	0,013*	0,25	0,25				
ASME SB/ASTM B 338	**Grade 3**	0,05	0,08	0,015	0,30	0,35				
DIN 17851/17861	**Ti 2 Pd - 3.7235**	0,05	0,06	0,013*	0,20	0,18			0,15 - 0,25	
VD-TÜV WB 230/2	**Ti 2 Pd - 3.7235**	0,05	0,06	0,013*	0,20	0,18			0,15 - 0,25	
ASME SB/ASTM B 338	**Grade 7**	0,03	0,08	0,015	0,30	0,25			0,12 - 0,25	
DIN 17851/17861	**Ti Al 3 V 2,5 - 3.7195**	0,04	0,05	0,015	0,30	0,12	2,5 - 3,5	2,0 - 3,0		
ASME SB/ASTM B 338	**Grade 9**	0,03	0,08	0,015	0,25	0,15	2,5 - 3,5	2,0 - 3,0		
DIN 17851/17861	**Ti 1 Pd -3.7225**	0,05	0,06	0,013*	0,15	0,12			0,15 - 0,25	
VD-TÜV WB 230/2	**Ti 1 Pd -3.7225**	0,05	0,06	0,013*	0,15	0,12			0,15 - 0,25	
ASME SB/ASTM B 338	**Grade 11**	0,03	0,08	0,015	0,20	0,18			0,12 - 0,25	
DiN 17851/17861	**Ti Ni 0,8 Mo 0,3 - 3.7105**	0,03	0,06	0,013*	0,25	0,25				0,2 - 0,4
ASME SB/ASTM B 338	**Grade 12**	0,03	0,08	0,015	0,30	0,25				0,2 - 0,4

* In case wallthickness is under 2 mm, the Hydrogenium-content up to 0,015 % is allowed

Mechanical properties and heat treatment

Ni	Other		Titan	Rp 0,2 MPa	Rp 1,0 MPa	Rm MPa	A	Heat treatment
	Single	Together		min. max.	min.	min. max.	min. %	
	0,1	0,4	rem.	180	200	290 - 410	30	soft annealed
	0,1	0,4	rem.	180	200	290 - 410	30	soft annealed
	0,1	0,4	rem.	138 - 310		240	24	annealed
	0,1	0,4	rem.	250	270	390 - 540	22	soft annealed
	0,1	0,4	rem.	250	250	390 - 540	22	soft annealed
	0,1	0,4	rem.	275 - 450		345	20	annealed
	0,1	0,4	rem.	320	350	460 - 590	18	soft annealed
	0,1	0,4	rem.	320	320	460 - 590	18	soft annealed
	0,1	0,4	rem.	380 - 550		450	18	annealed
	0,1	0,4	rem.	250	270	390 - 540	22	soft annealed
	0,1	0,4	rem.	250	270	390 - 540	22	soft annealed
	0,1	0,4	rem.	275 - 450		345	20	annealed
	0,1	0,4	rem.	520		620	15	soft annealed
	0,1	0,4	rem.	725		860	10	annealed
	0,1	0,4	rem.	180	200	290 - 410	30	soft annealed
	0,1	0,4	rem.	180	200	290 - 410	30	soft annealed
	0,1	0,4	rem.	138 - 310		240	24	annealed
0,6 - 0,9	0,1	0,4	rem.	345	370	480	18	soft annealed
0,6 - 0,9	0,1	0,4	rem.	345		483	18	annealed

Rp 0,2 = Yield Strength Rp 1,0 = Yield Strength Rm = Tensile Strength A = Elongation

Pipes and Heat Exchanger Tubes

Seamless cold-finished tubes in the size range 5,0 up to 60,3 mm OD particularly in heatexchanger and condenser tube dimensions can be supplied in fix- and random lengths, in straight lengths as well as in U-bend execution. Seamless tubes in stainless steel, nickel alloys and titanium as mentioned are applied

in Chemical-, Petrochemical-, Fertilizer-, Power-, Thermal Processing Plants and Shipbuilding Industry all over the world. Even when applied under most severe operating conditions **Seamless Tubes** have proved that they meet highest requirements in respect to quality, performance and resistance.

COLD FINISHED TUBING AND PIPES

Manufacturing Standard	EN 10216-5	ASME SA/ASTM A 268	ASTM A 269	ASME SA/ASTM A 312
Tolerance Standard	EN 10216-5 Table 13 EN ISO 1127 DIN 28180 DIN EN 10305-1	ASME SA/ASTM A 268	ASTM A 269	ASME SA/ASTM A 1016

Tubes according to these specifications must not be used as heat exchanger tubes.

COLD FINISHED HEAT EXCHANGER TUBES

Manufacturing Standard	EN 10216-5 VD-TÜV-WB	ASME SA/ASTM A 213	ASME SB/ASTM B 338	ASME SA/ASTM A 789
Tolerance Standard	EN ISO 1127 DIN 28180 EN 10216-5 Table 13	ASME SA/ASTM A 1016	ASME SB/ASTM B 338	ASME SA/ASTM A 789

Tubes according to these specifications can be used as line pipes as well.

COLD FINISHED PIPES AND TUBES

ASME/ASTM						
Specification	**Outside Diameter**				**Wall Thickness**	
SA/A 1016	**< 25 mm** < 1,000"	**25 - 40 mm** 1,000 -w 1,500"	**> 40 - < 50 mm** > 1,500" - < 2,000"	**50 - < 65 mm** 2,000" - < 2,500"		
	+/- 0,10 mm +/- 0,004"	**+/- 0,15 mm** +/- 0,006"	**+/- 0,20 mm** +/- 0,008"	**+/- 0,25 mm** +/- 0,010"	**-0/+20% (min. wall) (average wall +/- 10% not included)**	
SA/A 268	**< 12,7 mm** < 0.500"	**12,7 - 38,1 mm** 0.500" - 1.500"	**< 88,90 mm** < 3.500"		**< 12,7 mm (0.500")** +/- 15%	
	+/- 0,13 mm +/- 0.005"	**+/- 0,13 mm** +/- 0.005"	**+/- 0,25 mm** +/- 0.010"		**12,70 - 88,90 mm (0.500" - 3.500")** +/- 10%	
A 269	**< 13,00 mm** < 0.500"	**13,0 - 38,0 mm** 0.500" - 1.500"	**38,0 - 89,0 mm** 1.500" - 3.500"		**< 13,0 mm (0.500")** +/- 15%	
	+/- 0,13 mm +/- 0.005"	**+/- 0,13 mm +/- 0,005"**	**+/- 0,025 mm** +/- 0.010"		**13 - 89 mm (0.500" - 3.500")** +/- 10%	
SA/A 789	**+/- 0.005"**	**+/- 0.005"**	**+/- 0.010"**		**OD < 12,7 mm**	**+/- 15% - average wall +30-0% - minimum wall**
					OD < 38,1 mm	**+/- 10% - average wall +20/-0% - minimum wall**
					OD < 88,9 mm	**+/-10% - average wall +20/-0% - minimum wall**
SB/B 338	**< 25,4 mm** < 1,000"	**25,4 - < 38,1 mm** 1,000" - < 1,500"	**38,1 - < 50,8 mm** 1,500" - < 2,000"	**50,8 - < 63,5 mm** 2.000" - < 2.500"		
	+/- 0,102 mm +/- 0,004"	**+/- 0,127 mm** +/- 0,005"	**+/- 0,152 mm** +/- 0,006"	**+/- 0,178 mm** +/- 0.007"	**+/- 10%**	

EN 10216-5 Table 13 / EN ISO 1127			
Specification		**Outside Diameter**	**Wall Thickness**
Tolerance Class	D2	**+/- 1,00% min. +/- 0,5 mm**	**T2 +/- 12,5% min. +/- 0,40 mm**
	D3	**+/- 0,75% min. +/- 0,3 mm**	**T3 +/- 10,0% min. +/- 0,20 mm**
	D4	**+/- 0,50% min. +/- 0,1 mm**	**T4 +/- 7,50% min. +/- 0,15 mm**

DIN 28180							
Specification		**Outside Diameter**				**Wall Thickness**	
		16-20 mm	**25 mm**	**30 mm**	**38 mm**	**≤ 2 mm**	**> 2 mm**
Tolerance Class	TC1	+/- 0,10mm	+/- 0,12 mm	+/- 0,15 mm	+/- 0,20 mm	+/- 0,20 mm	+/- 10 %
	TC2	+/- 0,30 mm	+/- 0,30 mm	+/- 0,30 mm	+/- 0,40 mm	+/- 0,20 mm	+/- 10 %
	TC3	-	-	-	-	+/- 0,20 mm	+15%/-10%

DIMENSIONS AND WEIGTHS

BWG (Birmingham Wire Gauge)

Wall Thickness									
BWG		22	20	18	16	14	12	11	10
mm		0,711	0,889	1,245	1,651	2,108	2,769	3,048	3,404

Outside Diameter		Weight in kg/m (for stainless steel only)							
inches	mm								
1/4"	6,350		0,122	0,159	0,194				
5/16"	7,950		0,157	0,209	0,260				
3/8"	9,525		0,192	0,258	0,326	0,392			
1/2"	12,700	0,213	0,263	0,357	0,457	0,559	0,688	0,737	
5/8"	15,875	0,270	0,334	0,456	0,588	0,727	0,908	0,979	
3/4"	19,050		0,404	0,555	0,719	0,894	1,130	1,220	1,330
7/8"	22,225	0,383	0,475	0,654	0,851	1,060	1,350	1,460	1,600
1"	25,400	0,440	0,546	0,752	0,982	1,230	1,570	1,710	1,870
1 1/4"	31,750	0,553	0,687	0,950	1,240	1,570	2,010	2,190	2,420
1 1/2"	38,100	0,666	0,828	1,150	1,510	1,900	2,450	2,680	2,960
1 3/4"	44,450	0,779	0,970	1,350	1,770	2,240	2,890	3,160	3,500
2"	50,800	0,892	1,110	1,540	2,030	2,570	3,330	3,650	4,040
2 1/2"	63,500			1,940	2,560	3,240	4,210	4,610	5,120

SWG (Standard Wire Gauge)

Wall Thickness									
SWG		22	20	18	16	14	12	11	10
mm		0,711	0,914	1,219	1,626	2,032	2,642	2,946	3,251

Outside Diameter		Weight in kg/m (for stainless steel only)							
inches	mm								
1/4"	6,350		0,124	0,157	0,192				
5/16"	7,950		0,161	0,205	0,257				
3/8"	9,525		0,197	0,253	0,321	0,381			
1/2"	12,700	0,213	0,270	0,350	0,451	0,543	0,665	0,720	
5/8"	15,875	0,270	0,342	0,447	0,580	0,704	0,875	0,954	
3/4"	19,050		0,415	0,544	0,709	0,866	1,090	1,190	1,290
7/8"	22,225	0,383	0,488	0,641	0,838	1,030	1,300	1,420	1,550
1"	25,400	0,440	0,560	0,738	0,967	1,190	1,510	1,660	1,800
1 1/4"	31,750	0,553	0,706	0,931	1,230	1,510	1,930	2,130	2,320
1 1/2"	38,100	0,666	0,851	1,130	1,480	1,840	2,350	2,590	2,840
1 3/4"	44,450	0,779	0,996	1,320	1,740	2,160	2,770	3,060	3,350
2"	50,800	0,892	1,140	1,510	2,000	2,480	3,190	3,530	3,870
2 1/2"	63,500			1,900	2,520	3,130	4,030	4,470	4,910

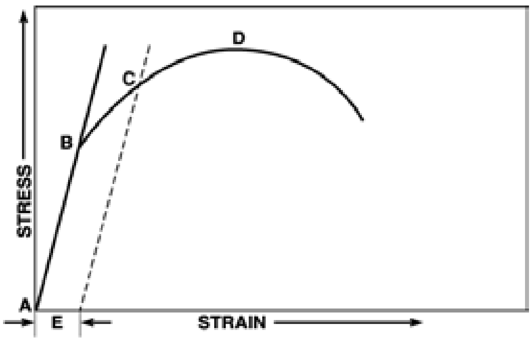
MECHANICAL | NON-DESTRUCTIVE | CORROSION

Stainless steel, nickel and titanium alloy tubes are manufactured on most modern production equipment, whereby the applied production methods assure the highest possible standard of quality. Moreover, for continuous quality assurance and -control, our independent testing department is equipped with most modern testing facilities, i.e. tensile test machinery, hardness measuring apparatus, ultrasonic and eddy-current testing line, coldwater-pressure test equipment and many other modern destructive and non-destructive test instruments. All tests carried out on material or finished products can be split into major categories: Mechanical and technological tests, microstructure examination, Non-Destructive tests and Corrosion tests. The tests mentioned below will be carried out according to the relevant material specification or on special request to be agreed upon in the purchase order.

MECHANICAL TESTS

Tensile Test acc. to ASTM A 370 / EN 10002-1 / EN 10002-5

A longitudinal specimen of known cross sectional area is taken from the material and gripped at each end, pulled apart until rupture occurs. By recording the load applied and the extension during loading a Stress-Stain Graph can be plotted (see diagram).



A-B	Elastic deformati-on range
B	Elastic limit
C	Proof stress
D	Ultimate tensile stress
E	Specified strain

From this graph the following values can be computed:

Ultimate tensile strength (D)
The maximum load applied during the test divided by the original cross-sectional area of the test-piece.

Proof stress (C)
This is the load at which the sample is permanently elongated by a specific percentage of the original length (e.g. 0.2%).

Elastic limit (B)
The highest load at which there is no permanent de-formation of the test piece.

Yield point
The lowest stress at which the elongation of the test-piece proceeds without any increase in load.

Tensile Test acc. to ASTM A 370 / EN 10002-1 / EN 10002-5

Elongation
This is the extension of the test-piece expressed as a percentage of its original length.

Reduction of areas
This is the reduction in cross-sectional area of the test-piece after tensile fracture expressed as a percentage of the original cross-sectional area.

Flattening Test acc. to ASTM A 370 / DIN EN 10233

This is usually applied to tube and involves flattening sample of tube between two parallel faces without showing flaws or cracks. The length of the test-piece and degree to which it is to be flattened is specified. The latter usually expressed in terms of the wall thickness of the tube.

Flare or Drift Test acc. to ASTM A 370 / DIN EN 10234

This is a form of ductility test and applies to tube. The end of the tube is required to be expanded by a specified increase in diameter without splits or cracks. The included angle of drift is also specified.

Hardness Tests These tests determine the resistance of material to indentation

Brinell hardness test HBW (ASTM E10, DIN EN 6506-1)
A standard size hardened steel ball is indented into the surface of material by an applied standard load for a duration of 15 seconds. The diameter of the impression is measured accurately by microscope and the hardness value calculated.

Rockwell hardness test (HRB, HRC, HR30T) (ASTM E18, DIN EN 6508-1)
This determines hardness by measuring the depth to which a diamont cone or hardened steel ball, under specific load, penetrates the material. The hardness number is indicated on a scale according to the load applied.

Vickers hardness test (HV) (ASTM E92, DIN EN 6507-1)
This determines hardness by measuring the impression left in material by diamond pyramid under a standard load for a specified time. The square impression is measured, accurately, diagonally and is area calculated. The hardness value is calculated.

NON-DESTRUCTIVE TESTS

Eddy Current Testing acc. ASTM E 309 / ASTM E 426 / EN ISO 10893-1 / EN ISO 10893-2 / E 571

This involves inducing eddy currents into the material by exciting a coil which surmounts two narrow search coils surrounding the material. Any discontinuities in material are found by comparing the electrical conditions that exist in the two search coils. The fault
signals are amplified and can be shown on a cathode ray tube or as an audible signal.

Ultrasonic Testing acc. ASTM E 213 / EN ISO 10893-10 (transverse and longitudinal imperfections)

This test involves ultrasonic sound waves being aimed, via a coupling medium, at the material to be tested. A proportion sound is bounced back at the coupling medium/material interface but the remainder enters the material and is bounced back from the internal surface, to the external surface, where a transducer converts the sound into electrical energy. This is then monitored on a cathode ray tube.

If a calibrated standard is shown on the tube, any deviation from the standard will be immediately visible, thus indicating cracks or internal defects.

Hydrostatic Testing (450 bar max.)

This is used to test the manufactured items under a test pressure equivalent or greater than pressure encountered in operation. It involves filling the tube with demineralized water, which cannot be compressed, and increasing the pressure, to that specified, inside the tube. The pressure is transmitted to the tube by the water and therefore a pressure to which the tube has been tested is obtained.

Dye-Penetrant Test acc. ASTM E 165 / ASTM E 1418 / EN 571-1

This is used to detect cracks and involves spraying a dye on the area to be tested. After allowing time for penetration the surplus dye is removed and the area is then sprayed with a white developer.

Any faults are releaved as coloured lines or spots caused by the developer absorbing the dye seeping from the cracks.

PMI (Positive Material Identifikation) - Mix-Up Control Test

The PMI-test is a quantitative method of sorting which is based on the most important alloy components. This test is only carried out on the customer´s request and it is documented in a PMI report.
The Mix-up control test is a non-quantitative method of sorting based on the major alloy components. The test is documented in the inspection certificate 3.1.

Structural examination / Micro section

The structure is examined through micro sections. On the basis of the polished section, the grain size, grain structure, impurities, intermetallic phases and the ferrite content can be determined.

Microstructure Test acc. to ASTM E 112 / EN ISO 643

These test methods of determination of average grain size in metallic materials are primarily measuring procedures and, because of their purely geometric basis, are independent of the metal or alloy concerned. The basis procedures may also be used for the estimation of average grain, crystal or cell size in nonmetallic materials. The comparison method by planimetric (or Jeffries) procedure is used if the structure to the material approaches the appearance of one of the standard comparison charts.

CORROSION TESTS

Various corrosion tests are available using different corrosive environments to indicate the performance of material under heavy duty applications.

Moneypenny-Strauss Test acc. to ASTM A 262 Practice E / EN ISO 3651-2

This test detects inter-crystalline corrosion and involves the use of boiling copper sulphate/sulphuric acid solution which must contain solid electrolytic copper. The test samples are immersed in the solution for 15 hours. After immersion the samples are bent through 90°. Those samples which bend without cracking are considered resistant to inter-crystalline corrosion.

Huey Test acc. to ASTM A 262 Practice C / EN ISO 3651-1

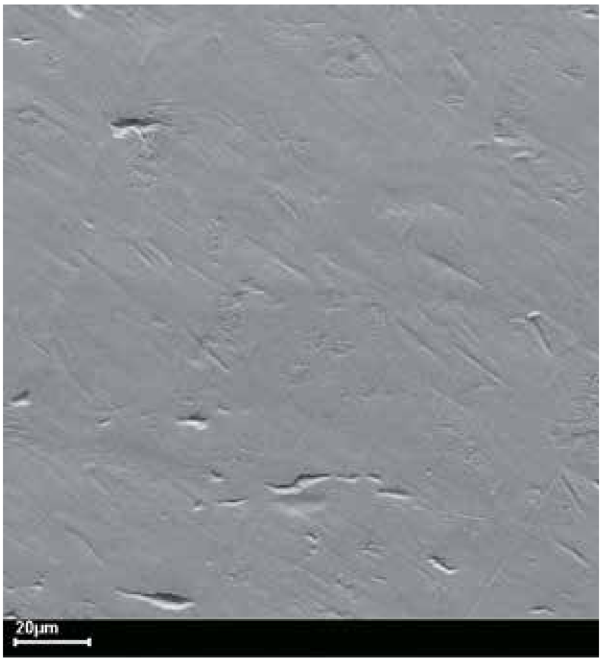
This test detects the susceptibility to intergranular attack and involves the use of boiling nitric acid. The test samples are immersed in the solution at a concentration of 65% nitric acid by weight for five 48 hour periods.
The effects of the acid on the material is measured by the loss in weight after each period and the corrosion rate assessed as a thickness loss in a given time.

TPS standard SBS Level 2 | Cold pilgered & bright annealed tubes

TPS have developed a special bright annealing process, which doesn´t require the use of any acids or alkalis. The heat treatment is performed in a so called closed furnace. The heat treated material is protected by an inert gas atmosphere. This atmosphere guarantees that oxygen can not enter the furnace or come into contact with the material and react to form scale on or tarnish the material.

The tendency, for deposits to form on undamaged bright annealed tube surfaces, is considerably lower than for pickled or ground surfaces.

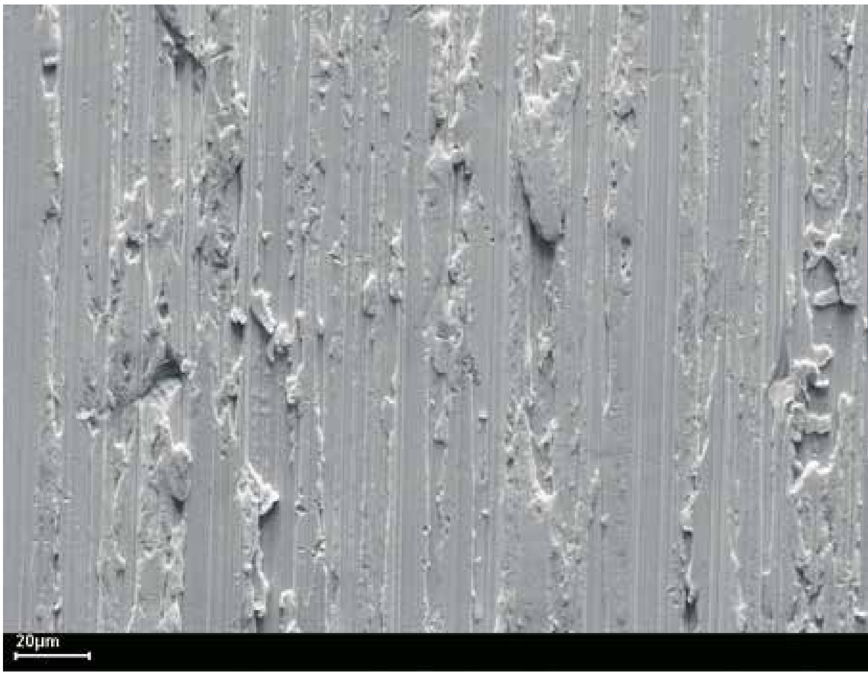
The reason for this is the topography of the surface. The irregular hills and valleys in the surface structure of pickled or ground surfaces favour the adhesion of particles. On request we are also able to produce tubes in electropolishable execution with an inside roughness of Ra 0,4 µm (TPS SBS Level 1)



TPS standard Super Bright Surface Level 2: bright annealed surface roughness Ra max. 0,8 µm

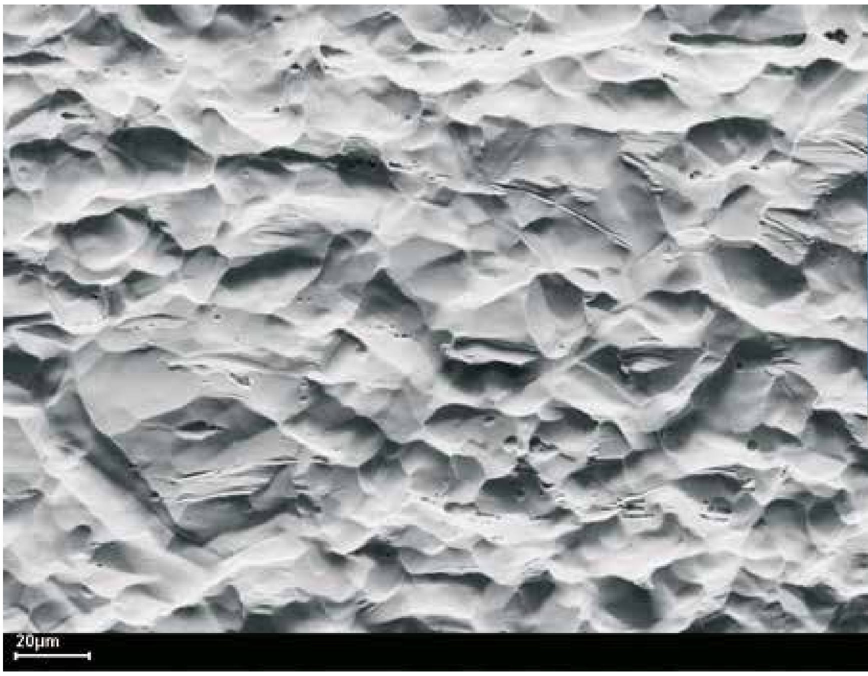
TPS standard SBS Level 2: bright annealed surface outside inside roll polished and bright annealed roughness outside Ra max. 0,8 µm | roughness inside Ra max. 0,8 µm

For more details please see our catalogue **„Surfaces of Stainless Steel Tubes“**



ground surface

surface ground by 320 grit
roughness Ra approx. 2,0 µm



pickled surface

roughness Ra approx. 2,5 µm

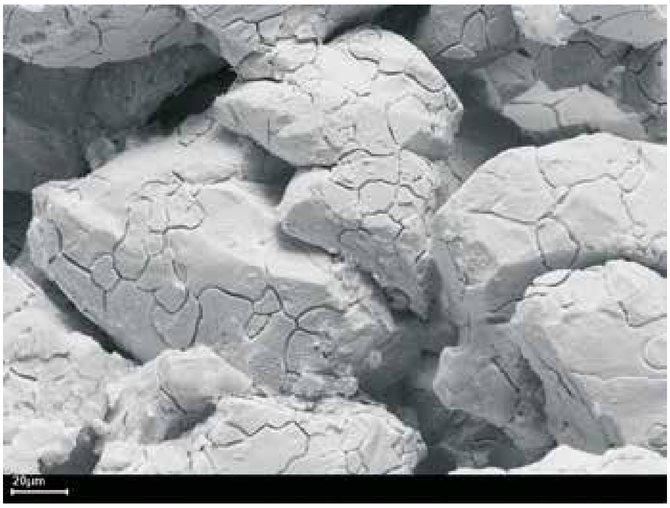
Many different types of corrosion exist and positive identification of the results of corrosion often pinpoint the cause and consequently a potential remedy. The following are the more generally encountered:

Stress Corrosion

The presence of residual stresses within a fabrication, caused by deformation, welding etc. may produce an accelerated form of corrosive attack, especially when the environment contains chloride. This phenomenon is more prevalant in austenitic steels than those with a duplex structure. This type of corrosive attack may be obviated by a stress relieving annealing at a temperature of 880°C or above.

Intercrystalline Corrosion

This type of corrosion is to be found fundamentally in the austenitic steels. If an austenitic stainless steel is maintained during a certain period of time at temperatures between 400°C and 900°C a precipitation of carbides at the grain boundaries is provoked which depletes the chrome of the adjoining areas.
If, in these conditions, the steel is subjected to
reactive media, there may be intergranular oxidation known as intercrystalline corrosion. It is essential to avoid slow cooling through the critical temperature range. The cause of the precipitation may be incorrect heat treatment, defective heating or cooling during the transformation of the steel, heating during welding.



Intercrystalline corrosion

Selective Corrosion or Pitting

When a series of conditions forces the passivity to disappear from some points of the surface of a stainless steel they transform into anodes giving way to the creation of galvanic pairs. In general it is shown by very fine pitting which rapidly develops in depth and in length. A typical case of this corrosion is produced by sea water in almost all steels, and it is dangerous because it is difficult to detect. The chlorides, bromides and hipochlorides are those which present the greatest aggressivity. The composition of the steel and its structure are factors which also influence this type of corrosion. If dirt accumulates on the surface of a stainless steel, the access of oxygen is avoided on the covered areas, pitting forming as a result of the loss of passivity. The austenitic steels with Molybdenum show good resistance and this improves if they are copper alloyed. Nitrogen also reduces the tendency towards corrosion by pitting.

Types of inspection documents DIN EN 10204

Table A.1 of EN 10204					
EN 10204 reference	**Designation of document type**			**Document content**	**Document validated by**
	English Version	**German Version**	**French Version**		
Type 2.1	Declaration of compliance with the order	Werks-bescheinigung	Attestation de conformité à la commande	Statement of comliance with the order	The manufacturer
Type 2.2	Test report	Werkszeugnis	Relève de con-trôle	Statement of compliance with the order with indication of results of non-spe-cific inspection	The manufacturer
Type 3.1	Inspection certificate 3.1	Abnahme-prüfzeugnis 3.1	Certificat de réception 3.1	Statement of compliance with the order with indication of results of specific inspection	The manufacturer's autho-rized inspection represen-tative independent of the manufacturing department
Typ 3.2	Inspection certificate 3.2	Abnahme-prüfzeugnis 3.2	Certificat de réception 3.2	Statement of compliance with the order with indi-cation of results of specific inspection	The manufacturer's autho-rized inspection represen-tative independent of the manufacturing department and either the purchaser's authorized inspection representative or inspectoi designated by the official regulations

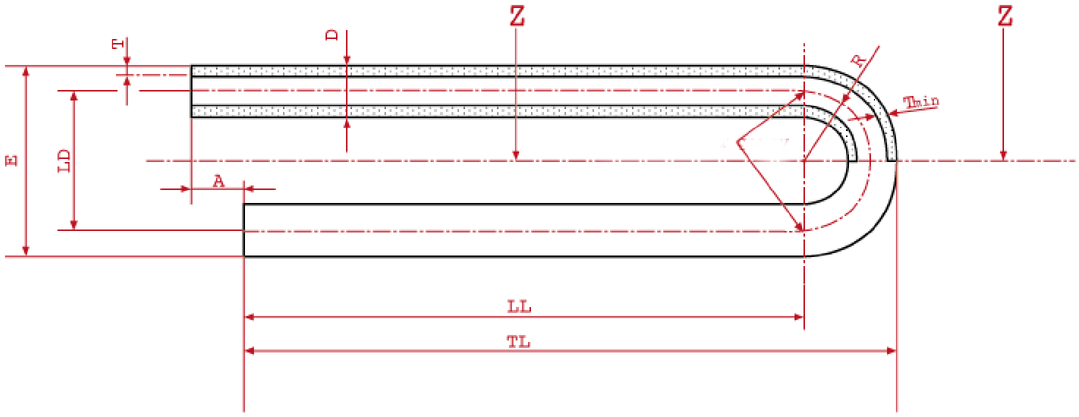
Definition

U-tubes as per this technical delivery standard are bend hairpin tubes which are usually used in heat exchangers.

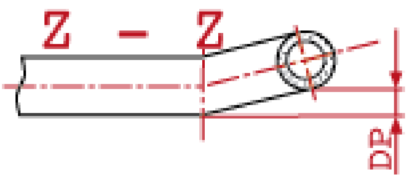
Scope

This technical delivery standard refers to seamless austenitic, duplex, ferritic and martensitic steel, nickel alloys, titanium and titanium alloy U-bend tubes with radii from 1,5 D. Tolerances for smaller radii have to be agreed with the customer. If customer requirements differ from these values, the customer requirements replace this standard after exmination.

Hairpin U-bend tube with one 180 deg. bend



Square U-bend tube with 90 deg. bends



Meaning of measurements and symbols:

A	leg length difference
E	(2R + D): 2x radius plus outside diameter
D	nominal outside diameter
D_{max}	max. outside diamater
D_{min}	min. outside diamater
LD	leg length distance measured from points of tangency
LL	leg length
TL	total length

R	centerline bend radius
R_{min}	min. radius
T	wall thickness
T_{min}	min. wall thickness in outside bending area
SW	smallest wall thickness of straight tube
O	ovality
DP	deviation from plane of bend
Z	section

→ For more details please see our catalogue „U-Tubes for Heat Exchangers“

Wall thinning of bending area

acc. DIN 28179	$T_{min} \geq SW \times \frac{(2R + D)}{2 \times (R + D)}$ mm

According to TEMA R-2.3 1 for radii from 1,5D: max. 17% wall thinning based on the minimum wallthickness of the straight tube.

Tolerance on straight leg length

straight leg	≤ 6000 mm	-0/+3 mm
straight leg	> 6.000 mm - ≤ 9.000 mm	-0+/4 mm
straight leg	> 9.000 mm	-0/+5mm

Tolerance on total length

The total length specifies the length of the external bend tangent line to the end of straight leg.

TL = LL + 0,5 D + R

Tolerances	≤ 6000 mm	- 0/+ 5 mm
	> 6000 mm	- 0/+ 8 mm

Tolerance on ovality

Allowable deviation from ovality in

≤ 4 D	$\frac{D}{5R}$ 100 = %
< 4 D ≤ 5 %	

The deviation O of the ovality will be calculated as follows:

$$O = 200 \frac{D_{max} - D_{min}}{D_{max} + D_{min}} = \%$$

Flattening on bend (TEMA R.C.B. 2.31 only)

Flattening does not exceed 10% of nominal diameter

Difference in leg length

leg length	≤ 6000 mm	- 0/+ 3 mm
leg length	> 6000 mm	- 0/+ 5 mm

Deviation from plane of bend

DP max $^{1}/_{16}$" = 1,5 mm

HEAT TREATMENT PROCEDURE OF BENDING AREA

General

Partial heat treatment can be agreed upon on order placement indicating the corresponding radii.
Austenitic U-tubes with radii > 1,3 x D usually are not subject to heat treatment acc. to German regulation AD-Merkblatt HP 7/3 after bending .
The conventional practices carried out on austenitic, duplex, ferritic and martensitic steels, nickel alloys, titanium and titanium alloys are mentioned below. Any deviation or additional requirements have to be agreed between and the customer in written form. Usually the bend portion plus 305 mm (1 ft) of straight leg length are heated by electric resistance annealing.

Cleaning of tube surface

Before heat treatment of the U-tube, the surface must be cleaned in order to remove any residue of lubricant and colour marking on the tube.

Method/Annealing Process

The bend and max. 300 mm of the straight leg length are heated to the material-specific temperature in the form of resistance annealing.
The measuring of the temperature is effected with an infra-red camera on the tube surface. During the annealing process, the inside of the tube is rinsed with inert gas as a protection against oxidation.
A light oxide scale is permitted according ASTM A688. On request, the oxide scale on the outside surface can be removed mechanically.

Procedure

Electric resistance heat treatment without holding time; temperature controlles by an automatic Infra-Red-Camera.

From the heating up to the removal of the bend from the annealing installation, the tube is rinsed inside with protective gas to avoid any oxidation.
The discolouration on the outer tube surface can be removed on request (see ASTM A 688).
The clambing jaws of the heating facilities are checked with regard to short circuit.

Documentation

Inspection certificate 3.1./EN 10204 mentioning heat treatment parameter.

Dye-Penetrant-Test (optional)

Dye-Penetrant Test of bending area can be agreed indicating the corresponding radii.

INSPECTION | DOCUMENTATION | PACKING

Free Passage (optional)

If requested, the free passage can be proved by a ball passage test. The diameter of the ball is as follows:
Inside diameter - flattening - 2 mm

Tightness Test (optional)

As final operation tightness test by cold water pressure testing with demineralized water can be performed according to specification or to be agreed upon.

Tube end protection

Tube end protection can be performed by plastic plugs.

Dimensional Inspection

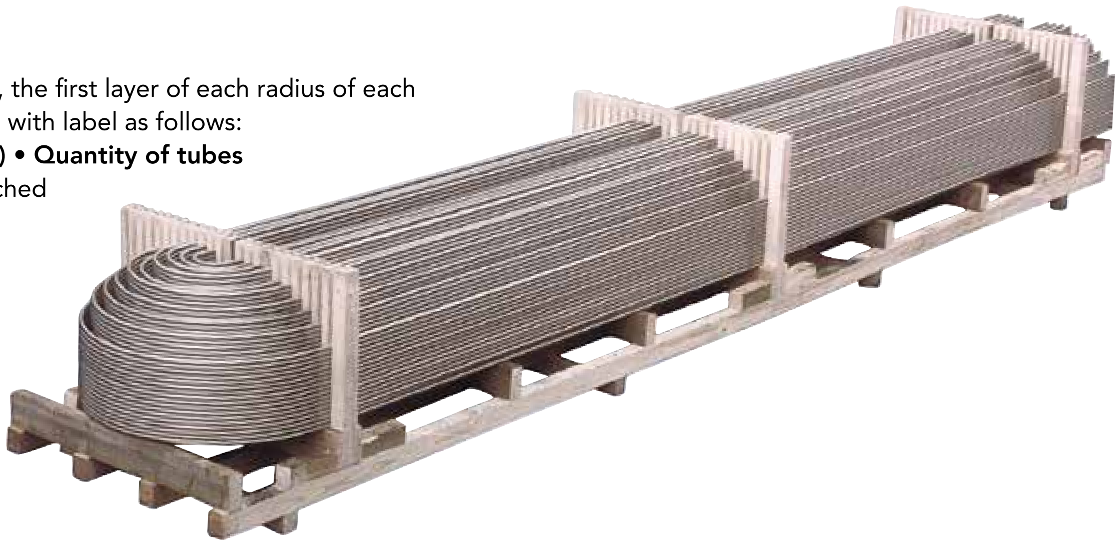
Radius and total length are inspected on each U-bend tube. Usually one sample of smallest radius of each thickness are inspected with regard to minimum wallthickness on bend area and flattening.

Cleanliness

The cleanliness of the inside and outside surface is inspected on each U-tube. Impurities caused by oil, grease and crude is not considered acceptable.

Marking

If not agreed otherwise, the first layer of each radius of each pallet or case is marked with label as follows:
Row No. • Radius (mm) • Quantity of tubes
Packing list will be attached to each packing unit.



Documentation

If not agreed otherwise, inspection certificate 3.1., according to EN10204 is executed. If required, test certificate 3.2, by third party inspection can be provided. The TPI (third party inspector) has to be nominated; TPI fees are covered by client.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Project Office


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