TT-WN 023-D

TUBE-TEC Factory standard

Rev. 04: June 2024

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1. General information:

1.1 Scope and purpose

The TT-WN applies to all GOODS manufactured or supplied by TUBE-TEC. It must be ensured that these GOODS are within certain, defined tolerance limits and correspond to a uniform quality.
The TT-WN can be used in two ways for this purpose.

a. For products in the legally regulated area (e.g. pressure equipment according to PED / DGRL or steel structures according to EUROCODE) as a supplement to the relevant manufacturing standard (e.g. EN12952 or EN1090), e.g. for construction tolerances. The requirements of the manufacturing standard are superior to those of the TT-WN
b. For products without a recognizable intended use within a legally regulated area, the TT-WN can also be used as a manufacturing standard. In this case, it is the CUSTOMER's responsibility to check whether the TT-WN meets the requirements.

1.2 Linked documents

Standards linked in the TT-WN are only indicated as standards in the text. The valid issue date is maintained in Table 1: "Linked documents".

Table 1: Linked documents

	Standard	Issue	Description
1	AD2000	05.2020	AD 2000 regulations
2	PED	2014/68/EU	Pressure Equipment Directive (implementation of the PED)
3	PED	2014/68/EU	Pressure Equipment Directive
4	VGB-S-013-00	2014-12-EN	VGB Guideline (formerly VGB R-501)
5	DIN 8580	2022-12	Manufacturing processes - terms, classification
6	DIN 28182	2007-09	Tube bundle heat exchanger - Pipe divisions, Borehole diameter
7	DIN 28187	2009-09	Tube bundle heat exchanger - Tube/tube sheet Mounting
8	DIN ISO 2768-1	1991-01	General tolerances for length and angle dimensions
9	DIN ISO 2768-2	1991-04	General tolerances for shape and position
10	DIN EN 1708-1	2010-05	Welding - Joining elements for welding steel
11	DIN EN 1779		
12	DIN EN 10028	2017-10	Flat products made of pressure vessel steels (Part 1 - 7)
13	DIN EN 10160	1999-09	US testing of flat products
14	DIN EN 10204	2005-01	Types of inspection certificates
15	DIN EN 10216	2014-03	Seamless steel pipes Compressive stresses (Part 1 - 5)
16	DIN EN 10217	2019-08	Welded steel pipes for pressure applications (Part 1 - 7)
17	DIN EN 10220	2003-03	Seamless and welded steel tubes: Tables for dimensions
18	DIN EN 10228	2016-10	NDT of steel forgings (parts 1 - 4)
19	DIN EN 10222	2017-06	Steel forgings for compressive stress (Part 1 - 5)
20	DIN EN 10253	2021-11	Fittings for welding in (part 2 - 4)
21	DIN EN 10272	2016-10	Stainless steel bars for pressure vessels
22	DIN EN 10273	2016-10	Suitable for welding rods made of steel at elevated temperatures
23	DIN EN 10307	2002-03	Ultrasonic testing of flat products made of austenitic and austenitic-ferritic stainless steel
24	DIN EN ISO 3834	2021-08	Quality requirements for fusion welding
Table 1 continued			
25	DIN EN ISO 4017	2022-10	Metric hexagon head screws (formerly DIN 933)
26	DIN EN ISO 4032	2013-04	Metric hexagon nuts (formerly DIN 934)
27	DIN EN ISO 4063	2023-07	Welding, brazing, soldering and cutting - list of processes and serial numbers
28	DIN EN ISO 5817	2023-07	Assessment groups of irregularities
29	DIN EN ISO 7089	2000-11	Washers (formerly DIN 125)
30	DIN EN ISO 9692-1	2013-12	Types of weld seam preparation - Part 1
31	DIN EN ISO 10893	2020-10	NDT of steel pipes (part 1 - 10)
32	DIN EN ISO 13920	2023-08	General tolerances for welded constructions

33	DIN EN ISO 14175	2008-06	Welding consumables - gases and mixed gases for arc welding and related processes
34	DIN EN ISO 14343	2017-08	Welding consumables - wire electrodes, strip electrodes, wires and rods for arc welding of stainless and heat-resistant steels
35	DIN EN ISO 14731	2019-07	Welding supervision - tasks and responsibilities
36	DIN EN ISO 14732	2023-04	Welding personnel - Testing of operators and setters for mechanical and automatic welding
37	DIN CEN ISO 15608	2020-07	Group classification of metallic materials
38	DIN EN ISO 15609-1	2019-12	Requirement and qualification of welding procedures for metallic materials - Welding procedure specification
39	DIN EN ISO 15614-1	2020-05	Requirements and qualification of welding procedures for metallic materials - Welding procedure qualification
40	DIN EN ISO 22081	2022-10	General geometric and dimensional specifications (replacement of DIN ISO 2768-2:1991-04)
41	TT-AA_07_002	Rev. 01	TUBE-TEC internal shipping instructions
42	TT-AA-7.5	n.a.	TUBE-TEC internal work instructions for weld seam preparation and welding of materials
43	TT-AA-7.7	n.a.	TUBE-TEC internal work instructions for the storage of welding consumables
44	TT-AA_07_009	Rev. 01	TUBE-TEC internal work instruction Intermediate and final inspection
45	TT-AA_07_015	Rev. 01	TUBE-TEC internal work instruction Repair of weld seams
46	TT-AA_07_017	Rev. 01	TUBE-TEC internal work instructions for painting components
47	TT-AA_07_017	Rev. 01	TUBE-TEC internal work instructions for pickling and passivation
48	TT-AA-7.33	n.a.	TUBE-TEC internal work instructions for the transfer of material markings
49	TTS-P	n.a.	Order-specific TT test instructions for tube-to-tubesheet connections

1.3 Terms

The following terms are used in this works standard, in some cases as abbreviations, in accordance with Table 2: "Terms used in TT-WN 023".

Table 2: Terms used in TT-WN 023

	Term	**Explanation**
1	TUBE-TEC	Tube-Tec Rohrverformungstechnik GmbH in 57647 Nistertal - Germany
2	CUSTOMER	Client who has a supply contract with TUBE-TEC on the basis of an order
Table 2 continued		
3	FINAL CUSTOMER	Users of the GOODS supplied by TUBE-TEC
4	GOODS	from TUBE-TEC supplied goods and services, both from in-house production as well as traded goods
5	QA	Quality assurance
6	Quality department	Department responsible for quality assurance, quality management and welding technology
7	NDT	Non-destructive testing of goods and primary materials
8	TT-WN	TUBE-TEC works standard TT-WN-023
9	VGB-R501H	VGB - Guideline R501H / VGB - Guideline S013
10	VGB-R110L	VGB - Guideline R110L
11	APZ	Acceptance test certificate / material certificate according to EN10204:2004
12	Manufacturing standard	Manufacturing and testing principles (e.g. EN 12952, ASME BPVC, EN1090)
13	Pressure-bearing parts	Goods with an operating overpressure P >= 0.5 bar(g)
14	Pressureless parts	Goods with an operating pressure P < 0.5 bar(g) and those that are not explicitly defined as pressure-bearing parts.
15	Welding technology	Department responsible for welding issues / welding supervisor
16	WPS	Welding instructions
17	WPQR	Welding procedure test

18	Pipe bend	Weld-in standard pipe fitting according to EN10253 or ASME B16.9
19	Curved tube	Curved pipe bend in two- or three-dimensional design, with freely selectable radii and angular dimensions and straight legs
20	Bending	Shaped area of a pipe, e.g. inside a flat coil

1.4 Formula symbol

In this works standard, the following formula symbols are used for formulae and drawings in accordance with Table 3:
"Formula character used in TT-WN 023".

Table 3: Formula symbols in TT-WN 023

	Formula symbol	**Explanation**
1	a	Fillet weld thickness
2	amine	min. nominal weld seam thickness minus permissible tolerances according to DIN EN ISO 5817:2014 Assessment group D
3	amax	Max. nominal weld seam thickness minus permissible tolerances
4	D	Nominal outside diameter of pipe
5	Tue	Inner diameter tube
6	DB	Bore diameter
7	L	Leakage rate during leak tests in mbar l/s
8	t	Standard wall thickness Tube
9	t	Actual wall thickness of pipe
10	small	Thinner nominal wall thickness of the parts to be welded
11	tmin	Minimum pipe wall thickness (after forming)
12	tSR	Nominal wall thickness of the manifold nozzle in the manifold connection area
13	e	Standard sheet thickness
14	Rm	Medium bending radius
15	OVB	Out-of-roundness or ovality in the arch area
16	OVR	Out-of-roundness or ovality in the straight pipe
17	PT	Test pressure in bar(g)
18	PB	Operating pressure in bar(g)
19	SVL	Leg extension of a bent pipe
20	L1	Expansion length when laying pipes in pipe plates
Table 3 continued		
21	L2	Rolling length when rolling pipes into pipe plates
22	HQ	Adhesion expansion during rolling-in according to Kotthaus&Busch
23		
24		
25		
26		

2. Design and calculation

2.1 Relevant documents

Only those documents explicitly mentioned in TUBE-TEC's order confirmation shall be deemed to be relevant for production, testing and acceptance. These include drawings, parts lists, specifications and, where stated, the manufacturing standard.
It is the CUSTOMER's responsibility to prepare the relevant documents and, if necessary, to have them checked by a notified body.
The following ranking of documents applies according to Table 4: "Documents"

Table 4: Documents

	Ranking	Designation
1	1	TUBE-TEC order confirmation
2	2	Documents mentioned in the TUBE-TEC order confirmation
3	3	Legal regulations
4	4	This works standard TT-WN
5	5	Customer order
6	6	Documents mentioned in the customer order

2.2 (Design) responsibility / design and calculation

TUBE-TEC assumes no responsibility that the GOODS to be delivered are suitable for the CUSTOMER's intended use. TUBE-TEC guarantees, within the framework of German law, that the work will be carried out correctly in accordance with the relevant documents as described in the TUBE-TEC order confirmation.
It is the CUSTOMER's responsibility to dimension the goods to be delivered sufficiently and in accordance with the intended use and service life and to define the relevant information clearly, unambiguously and clearly in the relevant documents. This includes, for example, minimum wall thicknesses including corrosion and other wear allowances and materials appropriate to the application and duration of use.

TUBE-TEC does not check and / or verify the plausibility of the specifications. TUBE-TEC also accepts no responsibility for misleading or contradictory information in the relevant documents.

If the CUSTOMER wishes TUBE-TEC to assume responsibility for the design, it is the CUSTOMER's responsibility to clarify this possibility with TUBE-TEC before placing the order and to explicitly state the scope of responsibility in the order.

Unless agreed and ordered separately, TUBE-TEC will not design and invoice non-pressurized parts. Non-pressurized parts also include all non-pressurized attachments and welded-on parts on pressure vessels, such as retaining fins or support structures.
Unless otherwise agreed in the relevant documents, the weld seam thicknesses according to Table 5: "Weld seam thicknesses" are observed as specifications during production.

2.3 Minimum wall thicknesses

For unformed parts, the minimum wall thicknesses of the respective semi-finished product standard apply. These may be undercut by a maximum of 0.3 mm due to local damage. For formed parts, the following minimum wall thicknesses can be guaranteed depending on the manufacturing process:

For curved parts, the minimum wall thicknesses achievable in production can be determined using Table 7: "Minimum wall thicknesses" can be calculated as follows:

Table 5: Weld seam thicknesses

Table 6: Minimum wall thicknesses

	Procedure	Bending tension zone	Bending pressure zone
1	Mandrel bending	t_{min} = 0.9 x ((t x 0.875) - $\frac{t \times 0{,}875 \times (D+2)}{4 \times Rm}$) [mm]	t_{min} = 0.9 x ((t x 0.875) + $\frac{t \times 0{,}875 \times (D-2)}{4 \times Rm}$) [mm]
2	Bend-Press	t_{min} = 0.9 x ((t x 0.875) - $\frac{t \times 0{,}875 \times (D+2)}{4 \times Rm}$) [mm]	t_{min} = 0.9 x ((t x 0.875) + $\frac{t \times 0{,}875 \times (D-2)}{4 \times Rm}$) [mm]
3	3-roller	t_{min} = 0.9 x ((t x 0.875) - $\frac{t \times 0{,}875 \times (D+2)}{4 \times Rm}$) [mm]	t_{min} = 0.9 x ((t x 0.875) + $\frac{t \times 0{,}875 \times (D-2)}{4 \times Rm}$) [mm]
4	Special sheet	t_{min} = 0.6 x ((t x 0.875) - $\frac{t \times 0{,}875 \times (D+2)}{4 \times Rm}$) [mm]	t_{min} = 0.9 x ((t x 0.875) + $\frac{t \times 0{,}875 \times (D-2)}{4 \times Rm}$) [mm]
5	Sheet metal, rolled	Not specified	
6	Sheet metal, folded	Not specified	

Caution: The minimum wall thicknesses stated are solely for manufacturing reasons and are not calculated according to the operating conditions. Sufficient dimensioning must be checked by the CUSTOMER.

2.4 Weld seam thicknesses

Tube-Tec does not design weld seams unless explicitly agreed. See also chapter 4.4

2.5 Process engineering design

Unless separately agreed and ordered, TUBE-TEC does not guarantee any process or performance parameters such as steam output, heat output or the functioning of chemical processes.

2.6 Drawings / documents for acceptance

Unless otherwise agreed in writing in the order, TUBE-TEC shall manufacture exclusively on the basis of the documents provided by the CUSTOMER. These must be provided by the CUSTOMER within the periods specified in section 1.4 (DOCUMENT) DEADLINES.
Production drawings and documents prepared by TUBE-TEC for internal use are not the basis of the design and/or acceptance.
It is the CUSTOMER's responsibility to ensure that the documents provided contain all necessary requirements and that these are clear and unambiguous. A plausibility check of the documents provided (e.g. deviations between drawing and design review report) shall not be carried out by TUBE-TEC. Any resulting errors in the GOODS shall be borne by the CUSTOMER

2.7 Safety devices

No safety devices, e.g. to protect against overpressure or overheating, are provided for in this works standard. It is generally assumed that these are provided on site.

3. Materials and semi-finished products

Only the materials specified in the relevant documents in accordance with the semi-finished product standards specified therein shall be used for the manufacture of the GOODS. The CUSTOMER shall be solely responsible for the selection of suitable materials with regard to the intended use and service life, as well as their implementation in the relevant documents.
If TUBE-TEC proposes alternative materials in the course of clarifying the order, the CUSTOMER must check and approve these for usability. In this case, TUBE-TEC does not guarantee that the proposed materials are suitable for the application intended by the CUSTOMER.
Unless otherwise agreed in the order and the relevant documents, materials in accordance with EN standards with test certificates in accordance with section 3.7 are preferred.
There are no restrictions on suppliers or countries of origin.

3.1 Goods for areas not regulated by law

For goods that are not used in a legally regulated area (e.g. EUROCODE or PED) and are not explicitly specified in the relevant documents, TUBE-TEC is free to choose the semi-finished product standard and the material (see also chapter 3.4)

3.2 Goods for legally regulated areas (pressure-bearing parts)

Within the scope of legally regulated areas, this standard is to be understood as a supplement. The requirements of the regulations used to fulfill the statutory provisions and any additional statutory provisions apply.
In general, all requirements and options for materials not explicitly defined in the relevant documents are not agreed. Their fulfillment or non-fulfillment is the responsibility of TUBE-TEC. It is the sole responsibility of the CUSTOMER to define materials and their optional properties in accordance with the intended use.
It is assumed that any necessary individual material assessments (PMA), e.g. for compliance with the PED / PED Directive, have been commissioned by the CUSTOMER and that their requirements are stored in the relevant documents.

3.3 Carbon steel, alloy steels, stainless steels, non-ferrous materials

Unless otherwise specified, the following material abbreviations apply in accordance with Table 8: "Materials":

Table 7: Materials

	Abbreviation / abbreviation	Material	Material standard
1	CS; carbon steel, carbon steel	S235JR	DIN EN 10025
		P235GH TC1	DIN EN 10216 / 10217 / 10028
2	Heat-resistant, alloyed steel, alloyd steel	16Mo3 (1.5415)	DIN EN 10216 / 10217 / 10028
3	SS; stainless steel; stainless steel, CrNi steel	1.4301	DIN EN 10088
4	SICRO	1.4724	DIN EN 10095
5	Aluminum	EN AW-6061-T4 (3.3206)	DIN EN 573
6	Titanium	3.7035 (Grade 2)	VdTÜV Wb 230

3.4 Purchased semi-finished products (pipes, fittings, flanges, sheet metal, shaped steel, nuts)

When selecting raw materials, an attempt is made to adapt them to the specified operating conditions. If no such information such as minimum or maximum temperatures, pressure, corrosion and others is available, TUBE-TEC is free to select available semi-finished products.
EN standards are used wherever possible. Table 9: "Semi-finished product standards" provides an overview of the standards used as standard for the procurement of semi-finished products. Unless otherwise agreed or required by the respective standard, no options are ordered. Test class 1 (TC1) generally applies as the test class. Assured tests are only

- Chemical analysis (only in the case of an APZ 3.1 or APZ 3.2)
- Tensile strength and yield strength at room temperature (20°C)
- Elongation at break at room temperature (20°C)

Table 8: Semi-finished product standards

	Semi-finished product type	Semi-finished product standard	Material standard	Miscellaneous
1	Seamless tubes	DIN EN 10216	DIN EN 10216	n.a.
2	Welded tubes	DIN EN 10217	DIN EN 10217	n.a.
3	Weld-in fittings	DIN EN 10253	DIN EN 10253	Reduced degree of utilization (type A)

4	Flanges	DIN EN 1092-1	DIN EN 10028 DIN EN 10222 DIN EN 10272 DIN EN 10273	Sealing surface B1 or B2
5	Sheet metal, unpressurized	DIN EN 10029	DIN EN 10025 (structural steel) DIN EN 10088 (stainless steel) DIN EN 10095 (heat-resistant steels)	Independent of the sheet thickness t
6	Sheet metal, pressure-bearing	DIN EN 10028	DIN EN 10028	None Z-grade determination
7	Shaped steel, unpressurized	DIN EN 10059 DIN EN 10060	s. Sheet metal, unpressurized	
8	Shaped steel, pressure-bearing	DIN EN 10222 DIN EN 10272 DIN EN 10273	DIN EN 10222 DIN EN 10272 DIN EN 10273	
9	Screws	DIN 933 / DIN EN ISO 4017		Metric standard thread Steel bright, 8.8
10	Nuts	DIN 934 / DIN EN ISO 4032		Metric standard thread Steel bright, 8
11	Washers	DIN 125 / DIN EN ISO 7089		Form A without chamfer
12	Bolts, threaded rods, U-bolts	DIN EN 10060	DIN EN 10025	Manufactured from round steel Metr. standard thread Material S355JR
13	Seals			Only for suitable for pressure tests

Semi-finished products not listed in Table 9, also in special material grades, can be freely selected by TUBE-TEC.
For semi-finished products manufactured by TUBE-TEC see chapter 3.5

3.5 Semi-finished products manufactured in-house (sheets and flanges)

Fittings manufactured by TUBE-TEC are produced, tested and certified with an APZ 3.1 in accordance with AD2000 data sheet HP8/3.
TUBE-TEC only manufactures smooth flanges type 01 and blind flanges type 05 in the dimensions of EN 1092-1. These can be manufactured from flat products (sheets according to DIN EN 10028) or from rolled or forged bars according to DIN EN 10222 or DIN EN 10272 or 10273 by turning or milling.
Bars as primary materials are subjected to a US test for longitudinal defects in accordance with DIN EN 10228-3 or DIN EN 10228-4 quality class 1.
Sheet metal as primary material is always subjected to a surface test in accordance with DIN EN 10160 quality class $_{S0}$ (square dimension of the grid 200 mm). If the flanges are later installed in such a way that the sheet metal is stressed in the thickness direction, an additional edge zone test is carried out in accordance with DIN EN 10160 quality class $_{E0}$.
The finished flanges are 100% MT or PT tested in accordance with DIN EN 10228-1 or DIN EN 10228-2 quality class 1. This test is carried out automatically on the primary material or manually afterwards.

3.6 Welding consumables

Unless explicitly defined in the relevant documents, welding consumables are specified by TUBE-TEC.
Operating parameters such as minimum and maximum operating temperature, notched bar impact requirements or corrosion resistance are only taken into account if this is explicitly stated in the relevant documents. Welding consumables can also be defined in the welding documents according to the manufacturer's designation.
Welding consumables are stored in accordance with TT-AA-7.7.

3.7 Acceptance test certificates (APZ)

Unless otherwise stipulated in the order or manufacturing standard, raw materials shall be supplied in accordance with Table 10:
"Acceptance test certificates" ordered the following APZ in accordance with EN10204:2004 and attached to the documentation:

Table 9: Inspection certificates

	Kind	**Certificate level**	**Part of the TUBE-TEC documentary?**
1	Pressure-bearing primary materials	3.1	Yes
2	Pressureless pre-materials - Part of the WAREN -	2.2	Yes
3	Pressureless pre-materials - Auxiliary materials -	2.2	No
4	Fasteners	Without	No
5	Welding consumables	2.2	No

The supplied APZs can be double-certified in accordance with several regulations. By default, no additional requirements such as AD2000 material sheets, VdTÜV material sheets, class material for ship classes or others are taken into account.
No certificates of origin or (long-term) supplier declarations are ordered.
Traceability is ensured by proper transfer of the marking in accordance with TT-AA-7.33.

4. Manufacturing

4.1 Incoming goods and storage

All delivered goods, whether purchased from TUBE-TEC or provided by CUSTOMERS, are subjected to a random incoming goods inspection upon delivery. This includes the following 4 points:

- Quantity control
- Checking the component dimensions
- Checking the material labeling
- Verification of the material

Especially with larger quantities, the incoming goods inspection cannot be carried out 100%. Acceptance of goods by TUBE-TEC is therefore always subject to reservation. TUBE-TEC does not guarantee that the GOODS fully comply with the agreed properties or that they are free of defects. TUBE-TEC shall not be liable for any defects discovered in the later course of production.

The storage of GOODS in dry, ventilated rooms is aimed for wherever possible, but cannot be guaranteed. Special precautions and requirements must be explicitly stated by the CUSTOMER in the relevant documents, otherwise TUBE-TEC shall be free to choose the storage method at its reasonable discretion (GOODS made of materials susceptible to corrosion should preferably be stored in closed rooms or outdoors under tarpaulins. GOODS made of weather-resistant materials may also be stored outdoors).
Slight flash rust or soiling cannot be ruled out and do not constitute a defect.

4.2 Cutting

Cutting subsumes all cutting production processes as defined in DIN 8580. Unless explicitly required otherwise in the relevant documents, TUBE-TEC is free to choose the cutting process and to determine the process parameters (e.g. cutting speed). The selection is made according to economic aspects, whereby a negative influence on the base material is avoided in accordance with good engineering practice. Cutting edges are only deburred.
The tolerances for blanks are regulated in chapter 5.
Residual pieces that are not intended for further processing are disposed of, unless

- A length of 1,000 mm is exceeded for pipes and other long goods (round steel, beams, etc.)
- In the case of sheet metal, a residual area of 250,000 mm² is exceeded and the length and width are greater than 500 mm.

Blanks and offcuts are restamped in accordance with TT-AA-7.33 to ensure material traceability. Blanks are nested before the cutting process in order to minimize waste. If there is any doubt about the optimization, the CUSTOMER must provide appropriate nesting plans at least 2 working days before the start of production. Subsequent complaints will not be accepted.
Remaining pieces are stored in accordance with chapter 4.1.

4.3 Reshaping (bending)

Forming at TUBE-TEC usually takes place as cold forming. This theoretically means at temperatures of the material below its transformation temperature Ac1, but usually at room temperature. Exceptions to this are purchased induction-bent tubes and press bends produced in-house.
Press bends are manufactured in a combined, 2-stage production process of cold pre-bending followed by hot forming. All press bends are then subjected to post-bending heat treatment (PBHT). The type and annealing parameters are created by the welding technology department on an order-related basis in accordance with the material in an associated annealing instruction. For more detailed information, including the scope of testing, see chapter 4.6 Post heat treatment.
Various processes are available for cold bending, which are selected by TUBE-TEC according to the requirements of the components to be manufactured. The bending ratio Rm / D and the material are the main factors taken into account. Further criteria are requirements for the required minimum tube wall thickness t_{min} and the maximum permissible out-of-roundness in the bend area o_{VB}. Table 11:
"Bending process reference values" provides information on the selection of the bending process and its manufacturing limits.

Table 10: Reference values for bending process

	Bending process	R_m / D*2	Material	D [mm]	T [mm]	R_m [mm]	PBHT
1	Mandrel bending	1.0 to 15.0	Carbon steel	Max. 219.1	2,0 - 20,0	20,0 - 1.000,0	*1
		1.3 to 15.0	All others	Max. 219.1	2,0 - 20,0	20,0 - 1.000,0	no
2	Bend-press method	1.0 to 4.0	Carbon steel	Max. 168.3	2,0 - 20,0	20,0 - 225,0	*1
		1.3 to 4.0	All others	Max. 168.3	2,0 - 20,0	20,0 - 225,0	no
3	3-roll bending tube	greater than 15.0	Carbon steel	Max. 219.1	2,0 - 20,0	From 15 x D	no
		greater than 20.0	Austenite	Max. 219.1	2,0 - 10,0	From 20 x D	no
4	3-roll bending sheet metal	greater than 10.0	All	n.a.	2,0 - 20,0	From 500	no
5	3-roller bending profile	greater than 25.0	All	n.a.	1,0 - 10,0	From 500	no
6	Press sheet	Smaller 1.0	All	Max. 168.3	3,6 - 8,8	½ x D to D	Yes
7	Special sheet	greater than 3.0	All	Max. 406.4	Max. 4.0	Max. 2,500	no

*1: No PBHT as standard, verification via bending procedure test in accordance with EN 12952-5 Annex A
*2: For profiles e.g. leg dimension of the angle, for sheet metal and square thickness in bending direction

TUBE-TEC can provide a tool list for further information. TUBE-TEC's design department will provide precise information on request based on the exact parameters provided by the CUSTOMER.
The achievable manufacturing tolerances are described in chapter 5.1.

4.4 Welding

General information:
TUBE- TEC is a DIN EN ISO 3834-2 certified welding company with a welding supervisor organized according to DIN EN ISO 14731. This creates and maintains all welding documentation and heat treatment instructions.
If required by the relevant documents, the welding supervisor shall ensure that only certified welders/operators and qualified welding processes are used for the intended welding task. Otherwise, TUBE-TEC is responsible for selecting the welding process and determining the corresponding parameters and the layer structure.

Joints that are to be welded must always be specified by the customer in the relevant documents. Joints that are not marked as weld seams in the relevant documents are not welded.

- T-joints or lap joints that are to be welded but where no seam type is defined in the relevant documents are executed as fillet welds.
- Butt joints that are to be welded but where no seam type is defined in the relevant documents are executed either as single-sided butt welds, single-sided butt welds with backing or double-sided welded butt welds, depending on accessibility. The choice is left to Tube-Tec.

Weld seam thicknesses:

Fillet welds:
Fillet welds without a specified seam thickness are executed as standard with a-dimension= 0.5 x t_{small} and a-dimension>= 2 mm

Butt seams:
Butt seams on butt joints are designed as solid connections $s=small$ as standard, unless otherwise specified

Seams on pipe branches:
Pipe branches for which the design is not specified are attached and executed as fully connected butt welds.

Weld seam quality:
Unless otherwise specified in the relevant documents, the execution of weld seams is generally subject to at least ISO 5817 evaluation group "D" and, in addition, the following specification:

No. after ISO 5817	Order no. To ISO 6520-1	Irregularity	Workpiece thickness	Limit values for irregularity
1.23	602	Welding spatter	all	Occasionally permitted
1.24	610	Tarnishing (visible oxide layer)	all	Blue

In the case of stainless and high-alloy steels, a bottom seam protection/root protection gas is generally used to prevent damage to the material and minimize tarnishing.

4.5 Tightening screws / mounting flanges

Flanges are positioned as axially free as possible. If installation parameters are to be taken into account, these must be specified in the relevant documents. The screws are tightened in at least two steps and "crosswise", taking into account the tightening torques from Table 12: "Tightening torques". No washers or lubricant are used. Sealing parameters are not taken into account.
Unless otherwise required, screws, nuts and seals used in a cold water pressure test are not replaced after the test has been completed.

Table 11: Tightening torques for screws

	Thread dimension	**Tightening torque [Nm]**				**Tightening procedure**
	Strength	**4.6**	**8.8**	**10.9**	**12.9**	
1	M8	9,35	24,93	35,06	42,07	With manually operated Wrench if necessary. with suitable Extension
2	M10	18	49	70	83	
3	M12	32	86	121	146	
4	M14	52	138	194	233	
5	M16	81	215	302	363	
6	M18	112	296	417	500	
7	M20	157	420	590	709	With torque wrench or other torque-controlled Procedure
8	M22	215	574	807	968	
9	M24	272	726	1020	1224	
10	M27	400	1067	1500	1800	
11	M30	542	1445	2032	2438	
12	M33	739	1969	2770	3323	
13	M36	948	2528	3555	4266	

4.6 Heat treatment

General information:
Post-weld heat treatment of components can be carried out both after welding (PWHT) and after forming (PBHT). Post-weld heat treatment (PWHT) or post-forming heat treatment (PBHT) shall only be carried out by Tube-Tec if this is explicitly stated in the relevant documents. Otherwise, it is assumed that any required post-weld heat treatment will be carried out by the CUSTOMER.

The surface of components may be discolored or scaled as a result of heat treatment. As long as no specific surface quality after heat treatment is explicitly defined in the relevant documents, this does not constitute a defect.

Heat treatment can be carried out locally, e.g. with resistance heating mats, induction or as furnace annealing (with or without protective atmosphere or vacuum). Unless defined in the relevant documents, the choice of annealing process is left to Tube-Tec.

Simulating heat treatment:
If a material or weld seam test after simulated annealing is required in the relevant documents, several identical annealing cycles can be combined into one equivalent annealing cycle. The conversion is carried out according to Hollomon-Jaffe parameters.

4.7 Rework / repair

Rework on components is coordinated by the quality department. If necessary, repair instructions are issued. For special regulations on increasing the scope of testing in these cases, see section 5.1.

4.8 Surface treatment

Unless explicitly specified in the relevant documents, no surface treatment of the finished components shall be carried out. It is assumed that, if necessary, this will be carried out on the finished component by the CUSTOMER. This delivery condition of the surface is described as "raw black". Rust, scale, oil and grease may remain on the surface.
If a different, defined surface is required, the surface treatment types and characteristics according to Table 13: "Surface treatment" and the description below apply, unless more precise details are given in the relevant documents. The following generally applies:
Unless explicitly ordered otherwise, the surface treatment is only carried out on the outside. If the inside is also or instead to be treated as a surface in contact with the media, this must be explicitly stated.
It should be noted that abrasive surface treatments (blasting, grinding) reduce the (wall) thickness and the outer diameter. It is the CUSTOMER's responsibility to explicitly define any minimum requirements in the relevant documents in advance.

(Sand) blasting:
(Sand) blasting is used to clean the surface. A standard purity grade Sa2 according to DIN EN ISO 8501-1 is aimed for. TUBE-TEC is responsible for selecting the blasting material. No blasting material made of stainless steel or iron is used for stainless materials.
Blasting only takes place in the areas where contamination is present. This may result in differences in the surface, even after further processing steps such as staining. This does not constitute a defect. If a uniform surface is required for the end product, this must be specified by the CUSTOMER in advance in the relevant documents, including a specification for the surface treatment to be carried out.

Brushes:
The aim is to achieve a standard cleanliness level ST3 in accordance with DIN EN ISO 8501-1. Stainless materials are processed with brushes also made of stainless material.

Grinding:
A standard cleanliness level ST3 in accordance with DIN EN ISO 8501-1 is aimed for. Non-rusting materials are processed with appropriate abrasives of TUBE-TEC's choice or, if grinding is carried out by subcontractors, at the grinding company's discretion.
If there is no specification for the desired surface in the relevant documents, abrasives with a grit size of 120 (corresponds approximately to an $_{Ra}$ of 1.5 µm) are used. A defined surface roughness ($_{Ra}$ or $_{Rm}$ in µm) is not guaranteed and is also not measured.

As semi-finished products such as pipes or sheet metal allow local surface defects, it may not be possible to achieve the specified surface quality at these points without grinding the semi-finished product to an unacceptably thin finish. These areas are not reworked.
Unless explicitly required in the relevant documents, grinding is carried out on undeformed semi-finished products. During further processing, there may be differences in the appearance of the surface, e.g. at weld seams. These do not constitute a defect as long as the required surface roughness is maintained.

If the GOODS are to be subsequently electropolished, this must be specified by the CUSTOMER in the relevant documents in advance so that this can be taken into account during the grinding process.

Stain:
Pickling treatments are carried out by external suppliers. They determine the parameters of the pickling process (type of pickling treatment, composition of the pickling agent, temperature, exposure time) based on the material to be treated. Unless explicitly required in the relevant documents, only the outer surface is treated using immersion or spray pickling processes
Stain treatment of interior surfaces can be carried out using the immersion or circulation method. In the circulation process, the process is checked using a comparative sample.
Following the pickling process, the surface is cleaned and then passivated in ambient air. Complete removal of pickling residues cannot be guaranteed, especially in the case of undercuts or screw-on parts.

The result is a bright metallic surface, not a guaranteed surface roughness. It should be noted that the appearance of the surface may vary, e.g. in the area of brushed weld seams. This does not constitute a defect.

Coating

In the case of coatings, a distinction must be made between temporary corrosion protection for transportation and storage purposes and a final coating.

Temporary corrosion protection is only effective for a limited time. Depending on the environmental conditions, from a few days to a maximum of 6 months. It is the CUSTOMER's responsibility to monitor the effectiveness of the temporary corrosion protection over the desired period of use and to rework it if necessary. Component surfaces are only cleaned of coarse adhesions before the temporary corrosion protection is applied. Further treatments such as brushing or sandblasting must be explicitly noted in the relevant documents. Mobilarma LT or Demistol X450 are used as standard corrosion protection. Weld seam preparation

In the case of a permanent coating, both with primer and complete coating system, the surface is cleaned to at least standard cleanliness level ST3 in accordance with DIN EN ISO 8501-1. Edges are broken and welding spatter removed. Unless otherwise specified in the relevant documents, a coating is applied with zinc dust paint in silver-grey RAL 7001. The coating is applied in a single layer in layer thicknesses of min. 40 µm and max. 80 µm.

The temperature resistance of the coating system to be guaranteed must be explicitly stated in advance in the relevant documents.

4.10 Insulation

Insulation is carried out exclusively in accordance with the specifications in the relevant documents. These must define the insulation material including specific weight, the alignment of the layers, the fastening (using anchors or adhesive), the number of anchors or adhesives depending on the type of fastening, minimum thicknesses, temperature resistance, resistance to chemical attack and the maximum permissible external temperature. Sheet metal sheathing or coatings (for increased resistance to flow velocities) must be explicitly specified separately.

If nothing else is defined, insulation is provided with ceramic insulating wool, 128 kg/m³, fixed with anchors. The surface under the insulation is not coated or treated.

5. Construction dimension control

Dimensional tests are used to check geometric dimensional specifications that are intended to ensure the installation of components. Tests in the context of product or process safety, such as minimum wall thicknesses or surface or volumetric defects, are dealt with in chapter 6. The tests are carried out by appropriately trained personnel using calibrated measuring tools. Permissible deviations from target dimensions are described in the following chapters.
The documentation of the tests can be carried out as an as-built drawing or by means of a dimensional report. Unless otherwise specified, the decision is the responsibility of TUBE-TEC.
The following applies to all dimensions not tolerated in this works standard:

- For welded and cold-formed components:
  Tolerances for lengths and angles
  in accordance with DIN EN ISO 13920:1996-11
  Tolerance class D Tolerances for straightness, flatness
  and parallelism in accordance with DIN EN ISO
  13920:1996-11 Tolerance class H

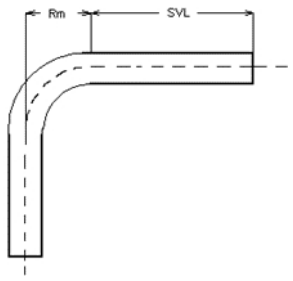
- Tolerances for lengths and angles for cut-to-size parts and
  machined components
  according to DIN ISO 2768-1:1991-06 Tolerance class
  c Tolerances for straightness, flatness and parallelism
  according to DIN ISO 2768-2:1991-04 Tolerance class
  L

Construction dimensions are such
dimensions, unless otherwise
specified Parallelism: Measured
with

5.1 Cut-to-size sheet metal / straight tubes

5.2 Milled and turned parts

5.3 Curved pipes (mandrel and bending compression method)



	≤ 50	> 50 ≤ 100	> 100 ≤ 250	> 250 ≤ 500	> 500 ≤ 1000	> 1000 ≤ 3000	> 3001
Leg extension SVL	+/- 1	+/- 1,5	+/- 2	+/- 3	+/- 4	+/- 6	+/-8
Intermediate dimension Z	+/- 1	+/- 1,5	+/- 2	+/- 3	+/- 4	+/- 6	+/-8
Installation dimensions Li	+/- 1	+/- 1,5	+/- 2	+/- 3	+/- 4	+/- 6	+/-8
Bending radius Rm	+/- 1,5	+/- 2	+/- 3	+/- 4	+/- 5	n.a.	n.a.
Parallelism t [mm]							
Flatness e [mm]							

The tolerances for angles on pipe bends and pipe bends are as follows, depending on the degree of accuracy:

Angle	<= 90°	<= 180°	> 180°

Degree of accuracy*	f	m	g	f	m	g	n.a.
Bending angle α [°]	+/- 0,5°	+/- 1,0°	+/- 2,0°	+/- 0,5°	+/- 1,0°	+/- 2,0°	+/- 2,0°
Rotation angle δ [°]	+/- 0,5°	+/- 1,0°	+/- 2,0°	+/- 0,5°	+/- 1,0°	+/- 2,0°	+/- 2,0°
	*If no details are given, the degree of accuracy m applies.						

5.4 Bent pipes (press bends)

5.5 Curved pipes (special / delivery pipe bends)

Bending process	**3-roll process**	**3D bending process, 3-roll process**
Pipe outside diameter	< 101.6mm	≥ 101.6mm
Average bending radius ≤ 1500mm	± 10mm	± 30mm
Average bending radius 1500 - 2500mm	± 20mm	± 50mm
Mean bending radius ≥ 2500mm	± 30mm	± 80mm

Surface

Depending on the process, an inner and outer surface with slight drawing depths in the longitudinal and transverse direction is permissible, as are spiral-shaped indentations inside the pipe in the area of the outer bend zone. Smooth transitions on the inner surface from the undeformed to the deformed area are permissible.

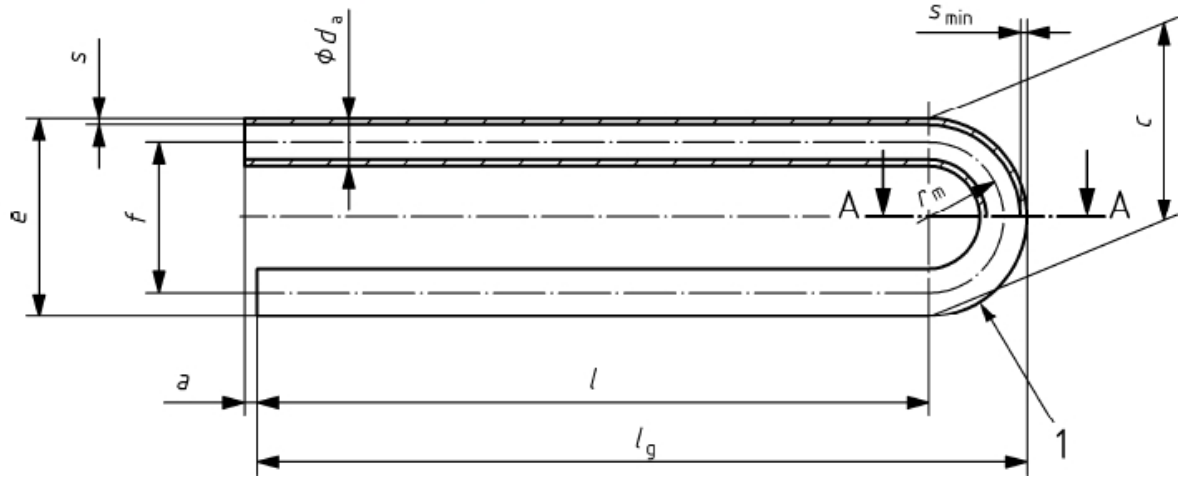
Drawing grooves

More or less deep and visible grooves left by the tools on the workpiece surface, e.g. when bending, rolling or sawing, are permissible.

When bending according to special bending processes, so-called drawing grooves may occur on the outside and/or inside, which are permissible.

Curved pipes (U-tubes)

U-Rohre mit rundem Bogen (Form R)



Meaning of dimensions and formula units:

a	leg length difference
	cDistance between the legs, measured at the bend tangent
	da outer pipe diameter
as max	largestmeasured outside diameter of the U-
	tube in the bend
as min	smallestmeasured outside diameter of the U-
	tube in the bend
	eDistance between the legs, measured at the pipe tangents
	Rt Radial tolerance
fLeg distance	, in relation to the tube centers at the end of the
	leg
l	Leg length
	lgInstallation length of the U-pipe, measured from the
	pipe end to the tangent of the back of the bend
rm	Bending radius
	sNominal wall thickness of the U-tube
	sminMinimum wall thickness at the back of the arch
	of the initial tube before forming into a U-tube t
	Flatness tolerance
	Rpermissible deviation of roundness

Tolerances according to DIN 28179

5.6 Flat snakes

Measured on the floor, without external force, free position preferably on two line supports, not necessarily in the installation position

5.7 Cylindrical tube coils and rolled bends (3-roll bending process)

5.8 Collector

5.9 Container (unpressurized)

5.10 Pressure vessel

6. Non-destructive testing (NDT)

Chapters 6 and 7 define the minimum requirements for the scope, performance, evaluation and documentation of tests on TUBE-TEC goods and the qualification of test personnel.
Tests on primary materials are defined in chapter 4.1 Incoming goods.
Tests can be carried out non-destructively on the GOODS to be delivered or destructively on test pieces specially manufactured for this purpose. Test times can be

- Before start of production (e.g. sample sheet)
- During production
- after completion of all work.

Unless defined by the CUSTOMER in the relevant documents or required by the MANUFACTURING STANDARD, TUBE-TEC shall be responsible for determining the time of testing.
Tests can be carried out both by TUBE-TEC employees and by external service providers and laboratories. Unless specified by the CUSTOMER, the decision lies with TUBE-TEC. The tests are carried out by appropriately trained personnel using calibrated measuring tools. The documentation of the tests can be provided as a collective certificate or with details of the measured values. Unless otherwise specified, the decision is the responsibility of TUBE-TEC.

Non-destructive testing (NDT) refers to all tests on GOODS and primary material that allow these parts to be used again. Samples that have only undergone non-destructive testing can be classified as good parts.
With NDT, a distinction must be made between indications and errors.
Indications are irregularities that lie above the recording limits of the respective test method used. Indications that lie outside the admissibility limits are to be evaluated as faults, indications that lie within the admissibility limits are not faults. Faults and indications are listed in the test report if such detailed documentation is required.
NDTs are carried out on the basis of TUBE-TEC's own test instructions or those of external test companies approved by TUBE-TEC, which describe the test technology, tester qualifications and the evaluation and its criteria. These test instructions can be inspected on request at the company headquarters in the event of an order. They will not be sent or included in the documentation. For documentation purposes, the inspector qualifications are summarized in the "Group list of NDT inspection personnel", document number QS-AS/EN-GNDEA-01-00.
With the exception of the tests in accordance with sections 6.2 and 6.3 (which must be carried out by level 2 inspectors in accordance with DIN EN ISO 9712), NDT can also be carried out by trained employees under the supervision of a qualified inspector (min. level 2 in accordance with DIN EN ISO 9712). In this case, the responsibility lies with the qualified Level 2 inspector.

Unless otherwise specified in the relevant documents, the scope of the tests must be specified in the order confirmation. If no NDT is defined either in the relevant documents or in the order confirmation, an inspection scope of exclusively 100% VT in accordance with the specifications in 6.1 and a random dimensional check in accordance with chapter 5 shall apply.
If a specific NDT is required but no inspection scope is defined, this is carried out on a random basis. Random NDT means an inspection scope of 2% of all parts to be inspected, with the following additional requirements:

- For bent parts, at least 1 piece per material group according to DIN EN ISO 15608 with the highest degree of deformation U (for definition, see section 6.8). A random sample test scope can already be fulfilled with sample sheets.
- For weld seams, at least 1 seam per seam ID in the welding procedure specification and welder.

An inspection scope of 100% means that the number of all parts is inspected, not that 100% of the part (e.g. the surface) is also inspected. The following still applies for inspection scopes < 100%:

- It is intended, but not guaranteed, that at least 1 part of each type of component to be tested (bend, weld seam, etc.) will be tested.
- The same applies to employees (e.g. welders) or machine type.
- The inspection density can be higher at the start of production to ensure process reliability.
  It is not guaranteed that all delivery lots will have the same inspection density in the case of partial

deliveries. If defects are detected in the course of the tests, the scope of testing is increased as follows:
From random to 10%, then to 15%, 25%, 50%, 75% and finally 100%. Unless specifically requested, no documentation or evaluation of the errors is carried out.

6.1 Visual inspection VT

Visual inspections are carried out on the basis of the test instruction TT-PA-VT-EN in the respective valid revision. The evaluation is carried out in accordance with DIN EN ISO 5817, evaluation group D, the documentation as a collective certificate on the visual inspection report form (Doc.: QS-EN-VT-R-01-00)

The test is preferably carried out as a direct test, in exceptional cases as an indirect test using a videoscope or mirror. When testing with a videoscope, the magnification of the measuring instrument must be taken into account during evaluation. An exact determination of the display size cannot be guaranteed.

6.2 Surface crack detection (MT and PT)

Surface crack tests are carried out on the basis of the test instructions TT-PA-PT-EN (for dye penetrant testing PT) and TT-PA-MT-EN (for magnetic particle testing MT) in the respective valid revision. The evaluation is carried out according to DIN EN ISO 5817, evaluation class D, the documentation as a collective certificate on the form Report on dye penetrant testing (Doc.: QS-EN-PT-R-01-00) or Report on magnetic particle testing (Doc.: QS-EN-MT-R-01-00).
If material and accessibility permit, MT is preferred.
PT is used for non-magnetic materials (e.g. austenite or Ni-based) and for surface crack testing of pipe bends.
When testing weld seams, the top layer and at least 15 mm on each side of the weld bead are tested. When testing bends, the tensile zone of the formed area and at least 15 mm.

6.3 Volumetric testing (RT and UT)

TUBE-TEC carries out volumetric tests either as radiographic testing (RT) or ultrasonic testing (UT).

RT is carried out directly by TUBE-TEC using only X-ray tubes. Depending on the component dimensions or for reasons of accessibility, the test can be carried out by external service providers using isotope emitters (Se75). In any case, testing and evaluation are carried out in accordance with the test instructions TT-PA-RT- EN in the respective valid revision.
The evaluation is carried out according to DIN EN ISO 5817, evaluation class D, the documentation on form Report on radiographic testing (Doc.: QS-EN-RT-R-01-00). In contrast to the collective certificates for VT and PT / MT, the test results of the respective weld seam and RT film are assigned and shown individually here.
RT films can be viewed by the CUSTOMER at TUBE-TEC if required in the course of acceptance. They shall not be sent to CUSTOMERS or third parties. Due to legal regulations, the RT films shall remain with TUBE-TEC for safekeeping.

UT is carried out exclusively as a manual test by external service providers on the basis of their test instructions approved by TUBE-TEC. The evaluation of irregularities on weld seams is carried out in accordance with DIN EN ISO 5817 evaluation class D, and the documentation is carried out on forms provided by the respective service provider. The results are shown separately for each individual seam instead of in a collective certificate.
Automated procedures such as phased array or TOFD are explicitly excluded and must be organized and carried out by the CUSTOMER.

UT for longitudinal or transverse defects on tubes is carried out in accordance with DIN EN ISO 10893-10. UT on sheets for testing for longitudinal and transverse defects as well as for doublings (surface and edge zone testing) in accordance with DIN EN 10160 for steel and DIN EN 10307 for austenitic materials. The evaluation is carried out according to quality class $_{S1}$ for surface tests and $_{E1}$ for edge zone tests.
UT on forgings is carried out in accordance with DIN EN 10228 Part 3 (steel) or Part 4 (austenitic materials). The evaluation is carried out according to quality class 1.
UT on bars is carried out according to DIN EN 10308, the evaluation according to quality class 1.
Other volumetric tests, e.g. automated test methods on semi-finished products such as eddy current testing ET, are not part of this company standard and must be requested and defined separately in the relevant documents.
For UT to determine the wall thickness, see chapter 6.7

6.4 Pressure tests

Pressure tests within the meaning of this chapter are used to check the strength, not the tightness, of a component. Based on the later operating temperature and operating pressure, a test pressure is determined at room temperature in order to guarantee the strength of the component under the operating parameters taken into account. It is the CUSTOMER's responsibility to define the test pressure and the holding time in the relevant documents. Otherwise, the following parameters apply:

- The test is carried out with cold water (temperature >= 10°C, chloride content <= 30 ppm). Tests with gases such as air are not part of this factory standard and must be defined separately in the relevant documents. The increased hazard potential due to the compressibility of the test medium must be taken into account separately when carrying out the test.
- The minimum required test pressure p_T = 1.5 x operating pressure p_B. Pressures are specified in bar(g). If neither a test pressure nor an operating pressure is specified, no pressure test is carried out.
- The maximum permissible test pressure $p_{T,max}$ is not determined on the basis of the material characteristics (in order to prevent overstretching and thus damage to the component). The CUSTOMER is responsible for specifying the maximum permissible test pressure.
- To prevent pressure fluctuations due to temperature changes in the test medium, it must be filled in beforehand without pressurization. The test pressure p_T is applied in at least 2 stages (50% and 100% p_T).
- The minimum holding time is 30 minutes. During this time, the test pressure may drop by a maximum of 4 bar or 5% of the theoretical test pressure (the lower value applies).

Unless explicitly requested by the CUSTOMER, cold water pressure tests are carried out as a final test. This means that no further welding work or heat treatment is carried out after the pressure test. Coatings and insulation, however, are only to be applied after the cold water pressure test.
For leak tests, see chapter 6.5.

6.5 Leak tests

Leak tests are carried out as local tests by applying a test pressure p_T = 0.5 bar(g) inside the component and testing from the outside using soapy water. This test is also known as the air/necal test.
For special applications with significantly higher leakage rate requirements, He leakage tests can be carried out by external service providers. These tests are carried out in accordance with DIN EN 1779 and the test method would be A3, local vacuum method with test gas helium. The required leakage rate must be specified in the relevant documents, otherwise L <= 1 x 10^{-6} mbar l/s applies

6.6 Ball flow test

The free passage in formed pipes and weld seams can be tested by means of a ball passage test.
The test is deemed to have been passed if the ball can be moved through the component to be tested with the required minimum diameter without any aids.

	Theoret. Pipe inner diameter	**Outer diameter of test sphere**
1	Di < 20.0 mm	$Dk_{,min}$ = Di - 8 mm
2	Di >= 20.0 mm and <= 49.0 mm	In accordance with VGB-S-013 Section 7.2.5
3	Di > 49.0 mm	$Dk_{,min}$ = Di - 8 mm
4	Di > 50.0 mm	No ball flow test possible

6.7 Wall thickness measurement

Wall thickness measurements are carried out as a comparative measurement to check compliance with a required minimum wall thickness. The test can only be carried out on a random basis and does not guarantee that the minimum wall thickness has been adhered to at all points. Critical points should be given priority when determining the measuring point.
Wall thickness measurements are carried out using a US hand-held device, caliper gauge or mechanical probe. Unless otherwise agreed, 1 measurement is taken at 1 measuring point on each component to be tested (e.g. weld seam or bent pipe).
For pipe bends, the measurement is taken at half the bending angle. For example, for a 90° bend, the measurement is taken at 45° on the tension side of the pipe bend.
For weld seams, the measurement is carried out in the seam area (lightly ground if required) at a freely selectable point on the circumference.
For straight pipes, the test is carried out at a freely selectable point on the entire surface, for longitudinally welded pipes outside the weld seam.
The minimum wall thickness to be complied with results from a calculation to be provided by the CLIENT, an explicit specification in other relevant documents, e.g. in the drawing. The measurement results are recorded and compared with the specified minimum wall thickness. With the specified minimum wall thickness, it is assumed that the measuring tolerance of the measuring equipment is limited by

calculation surcharges is included. The individual measured values are not specified in the documentation.

Wall thickness measurements using a US hand-held measuring device can be used to determine the root sag or recess of a weld seam. Three measurements are carried out on the weld seam: 1 measurement to determine the thickness of the weld metal and 1 measurement each to determine the wall thickness of the welded base pipes in the area of the respective heat-affected zone (HAZ).
The evaluation is carried out according to DIN EN ISO 5817 evaluation group D

6.8 Ovality / out-of-roundness

The ovality or out-of-roundness OV describes the percentage deviation of the actual pipe cross-section from the ideal round shape.
The out-of-roundness OV is determined using the formula from VGB-S-013 - Section 7.2.3:

$$OV = 200x\ \frac{Dmax\text{-}Dmin}{Dmax+Dmin}\ [\%]$$

Depending on the degree of deformation or the ratio of the mean bending radius $_{Rm}$ to the theoretical outer pipe diameter D

The degree of deformation U is calculated from the mean bending radius $_{Rm}$ and the theoretical pipe outside diameter D as follows:

$$U = \frac{D\,x\,100}{2\,x\,Rm}[\%]$$

The out-of-roundness for the bend area applies up to max. 5 mm or up to 0.5 x D in the SVL leg extension at the bend inlet and outlet. From then on, the permissible tolerances of EN10216-2 class D2/T2 apply.
For bent pipes without leg dimension SVL, the out-of-roundness in the bend area also applies at the end. In the 3-roll bending process, a maximum out-of-roundness of U < 2.0% applies at the end of the bend.

1	Degree of deformation U	>50%	< 50% >= 38,5%	< 38,5% >= 20%	< 20% >= 12,5%	< 12,5% >= 5%	< 5%
2	$_{Rm}$ / D	< 1,0	>= 1,0 < 1,3	>= 1,3 < 2,5	>= 2,5 < 4,0	>= 4,0 < 10,0	>= 10,0
3	Out-of-roundness in the arch area	Max. 20%	Max. 15%	Max. 12.5%	Max. 10%*1	Max. 5.0%*2	Max. 4.0%*3 Max. 8.0%*4
		[1] *After consultation with the TUBE-TEC quality department up to 12.5% permissible [2] *Up to 7.5% permissible after consultation with the TUBE-TEC quality department *3 3D bending process *4 3-roll bending process					

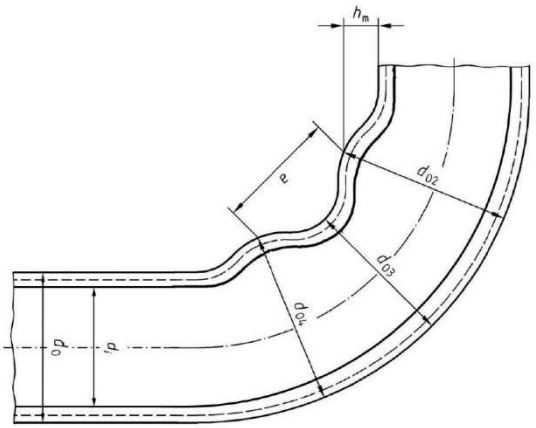
A definition of out-of-roundness based on the deviation from the theoretical cross-sectional area is not part of this company standard and must be agreed separately in the relevant documents.

6.9 Wave formation

The occurrence of waves in the bending pressure zone must always be avoided. If a corrugation occurs due to an unfavorable radius / wall thickness ratio, due to the material or otherwise, the tolerance listed here must be observed after consultation with the responsible production manager or QA.

hm $= \frac{d02+d04}{2}$ [mm] <= 0.03 x d_{01}

a >= 15 x h_m



h_m = mean wave height
a= wave spacing
d_0 = Nominal outside diameter D d_{02} = diameter of the largest shaft
d_{03} = diameter of the valley between d_{02} and d_{04}
d_{04} = diameter of the shaft adjacent to da2

Due to the manufacturing process, there may be a single upsetting at the bend exit. This is not a wave and must meet the requirements for the ovality of the pipe bend (see chapter 6.8).

6.10 Further tests

In addition to the NDT procedures described above, further tests can be agreed in the relevant documents.
Material mix-up tests (PMI) are used to identify the material on primary materials or weld seams. Testing is carried out using the NITON XL2 980 handheld device in accordance with test instruction TT-PA-PMI-01. The test report Doc: QS-AS/EN-PMI-R-01-00 is a collective certificate. No alloy components are shown and / or compared with specifications. A PMI can only be carried out on alloyed materials, as the test device cannot show a C content.
Raw materials are randomly tested once per melt. Welding consumables cannot be tested.
Weld seams are measured at one measuring point in the weld metal for each seam. Weld seams are tested randomly, but at least once for each filler metal and welder used.

	NDT procedure	**Abbreviation**	**Test instruction**	**Minimum test scope**	**Rating**	**Test report**
1	Visual inspection	VT	TT-PA-VT-EN	100%	DIN EN ISO 5817 - D	QS-EN-VT-R-01- 00
2	Magnetic particle testing	MT	TT-PA-MT-EN	2%	DIN EN ISO 5817 - D	QS-EN-MT-R-01-00
3	Dye penetrant testing	PT	TT-PA-PT-EN	2%	DIN EN ISO 5817 - D	QS-EN-PT-R-01- 00
4	Radiographic testing	RT	TT-PA-RT-EN	2%	DIN EN ISO 5817 - D	QS-EN-RT-R-01- 00 *1
5	Ultrasonic testing	UT	*2	2%	DIN EN ISO 5817 - D*	*2
6	Pressure test	LT	TT-PA-PT-02-EN	—	—	FM-07.03.01-QS-EN-LT-R
7	Leak test	LT	TT-PA-PT-02-EN	—	—	FM-07.03.01-QS-EN-LT-R
8	Material mix-up test	PMI	TT-PA-PMI-01	Min. 1x per melt	—	QS-AS/EN-PMI-R-01-00
9	Hardness test	HT	TT-PA-HT-01	2%	VGB-S-013 Chap. 4.1	QS-AS/EN-HT-R-01-00
10	Ball flow test	—	—	Min. sample sheet	VGB-S-013 Section 7.2.5	QS-AS/EN-DC-TB-R-01-00
11	Determination of ferrite content	—	TT-PA-FC-01	—	Customer specification	
12	Eddy current testing	ET	*2	—		*2
13	Residual magnet test	—				
	*1: Alternatively, test reports from external test companies can be used *2: only by external testing companies					

Hardness tests can be carried out on weld seams as well as on components after bending or following heat treatment in accordance with test instruction TT-PA-HT-01. If no specifications are made regarding the maximum permissible hardness values, the requirements from VGB-S-013 Chapter 4.1 apply. Testing is carried out twice per weld (once in the weld metal and once in the HAZ) or once per bend.

6.11 Test equipment (calibration)

Only calibrated measuring equipment is used for testing. This can be done internally and/or externally every 2 years at the latest. The required accuracy class is determined by TUBE-TEC QS.

7. Destructive tests (laboratory tests)

Chapters 6 and 7 define the minimum requirements for the scope, performance, evaluation and documentation of tests on TUBE-TEC goods and the qualification of test personnel.
Tests on primary materials are defined in chapter 4.1 Incoming goods.
Tests can be carried out non-destructively on the GOODS to be delivered or destructively on test pieces specially manufactured for this purpose. Test times can be

- Before start of production (e.g. sample sheet)
- During production
- after completion of all work.

Unless defined by the CUSTOMER in the order or required by the MANUFACTURING STANDARD, TUBE-TEC shall be responsible for determining the time of testing.
Tests can be carried out both by TUBE-TEC employees and by external service providers and laboratories. Unless specified by the CUSTOMER, the decision lies with TUBE-TEC. The tests are carried out by appropriately trained personnel using calibrated measuring tools. The documentation of the tests can be provided as a collective certificate or with details of the measured values. Unless otherwise specified, the decision is the responsibility of TUBE-TEC.

Destructive tests refer to all tests on GOODS and primary material that do not allow any further use of these parts.
Destructive testing of primary material may be necessary if

- additional requirements beyond the regulations of the manufacturing standard are necessary, e.g. from a design point of view (additional notched bar impact tests, corrosion tests, tensile tests at operating temperature, etc.)
- If additional tests for class material are required in the course of production and testing according to ship class
- If materials require an individual material appraisal (PMA) as part of the PED.

In the case of material provided, it is always assumed that the destructive tests have already been carried out by the customer. If agreed separately, TUBE-TEC may carry out such destructive material tests. In this case, the CUSTOMER must ensure that sufficient additional primary material is provided for each melt to be tested.
Destructive testing of GOODS may be necessary if

- Heat treatment was carried out above the transformation temperature
- process tests (welding and bending process tests) are carried out.
- welder or operator tests can be carried out.
- semi-finished products manufactured by TUBE-TEC can, for example, be subjected to a burst test to determine their tensile strength.

Tests in the laboratory are carried out in accordance with test instructions issued by TUBE-TEC QS. The CUSTOMER shall explicitly and unambiguously define any special requirements for the performance, parameters, number, position and dimensions of samples in the relevant documents in advance. Otherwise, TUBE-TEC shall be responsible for the definition.

The execution including sample preparation, processing and evaluation as well as the preparation of the test report requires at least 4 weeks. This must be taken into account by the CUSTOMER when planning the delivery date. Production releases before the results are available are at the CLIENT's risk.

Destructive tests are always carried out and certified by a notified body.

8. Acceptance

All TUBE-TEC GOODS are finally inspected in the course of their acceptance prior to shipment on the basis of TT work instruction AA_07_009_01 before they can be released for shipment. In the case of GOODS with subsequent surface treatment, insulation or packaging, acceptance may take place in two stages.

The final and/or pressure test checks whether the requirements of the production and test basis have been met. For this purpose, the NDT protocols are created, the material identification is checked and, if necessary, the pressure test is carried out.
We aim to prepare the final documentation and issue the test certificate on the day of the final inspection, but cannot guarantee this.

The goods are **released for dispatch** after all contractual services, e.g. coating or packaging, have been checked.

The CUSTOMER is free to take part in the acceptance procedure. It is generally assumed that this will take place on a single date. If the CUSTOMER decides to take part in the final inspection and pressure test, his consent (by countersigning the test report or the ITP) shall also be deemed to be release for dispatch.
If the CUSTOMER decides to participate in the acceptance procedure, it is his responsibility to check parameters that are critical for him. By participating, the CUSTOMER assumes at least partial responsibility for defects that could have come to his attention in the course of his participation under normal circumstances and with reasonable effort. Any conflicting formulations in order documents etc. are invalid.

9. Packaging

Unless otherwise agreed, all GOODS shall **be packed in standard commercial packaging**. This may consist of wooden racks or crates as well as steel racks. Transportation in a truck and under tarpaulin is assumed. Additional corrosion protection by coating, gas filling or foil must be agreed separately.
The packaging is not designed for storage of the GOODS. If this is intended by the CUSTOMER, the additional precautions necessary for storage must be specified by the CUSTOMER. Simply stating the storage location is not sufficient.
In the event that shipment by truck is not possible, e.g. for widths over 2.4 m, it is the CUSTOMER's responsibility to define the load securing and protection of the goods during transportation (tarpaulin cover etc.).
Loading and unloading by forklift truck is the aim wherever possible. Depending on the weight or dimensions, crane loading can be provided. Unless explicitly defined, the decision is the responsibility of TUBE-TEC. Unless explicitly ordered, no treated timber (ISPM 15) is used. Sea or air freight requirements must be noted by the CUSTOMER in the relevant documents.

10. Documentation

The documentation is the written proof of the production, testing and delivery of goods in accordance with the agreed manufacturing standard:

	Test certificate APZ	Production and test basis						
		Drawing	TT-WN	PED	ASME	EAC	Ship class	Steel construction
1	Without acceptance	x	x	x	x	x	x	x
2	Restamping certificate	x	x	x	x	x	x	x
3	Dimensional check / As-built drawing	x	x	x	x	x	x	x
4	APZ 3.1 by TUBE-TEC QS	x	x	x	x	x	x	x
5	APZ 3.2 / Partial construction test certificate			x	x	x	x	x
6	Certificate of conformity			x		x		x
7	(Partial) Data Report M(P)DR				x			
8	Container passport					x		

In this case, **without acceptance** means that the agreed tests (see chapters 6 and 7) have been carried out, but no verification document is created.

With a **restamping certificate** (Doc.: QS-AS/EN-TM-R-01-00), TUBE-TEC QS establishes the traceability of the delivered goods to the semi-finished products used and the factory certificates. Unless explicitly agreed otherwise in the relevant documents, this is carried out for all manufacturing and test bases except ASME, only on the basis of the melt (see also AA_07_033_01 Umstempel
/ relabeling of materials). In the case of production and testing in accordance with ASME, the re-stamping certificate guarantees traceability to the complete original pipe marking. Even if no ASME stamp has been agreed. From an external pipe diameter D > 63.5 mm, the original marking is transferred in the presence of a Notified Body (NoBo). In this case, the re-stamping certificate is signed off by the NoBo.

The **dimensional check** can take the form of a table attached to the drawing or an as-built drawing with manual entries and is created by TUBE-TEC QA. The TARGET values are compared with the ACTUAL values and checked against the permissible dimensional deviations (see also chapter 5). If no test dimensions are defined in the relevant documents, only the main and connection dimensions are checked.

APZ 3.1 and APZ 3.2 generally consist of the following components

- Test certificate (also Certificate of Conformity CoC) in levels 3.1 (Doc.: QS-AS/EN-APZ3.1-01-00) or 3.2 (partial construction test report) in accordance with DIN EN 10204. Partial construction test reports are provided with a consecutive registration number of the testing company.
- Material certificates APZ 3.1 or APZ 3.2 Material certificates of levels 2.1 or 2.2 in accordance with DIN EN 10204 are not enclosed. In the case of pressure-bearing parts, only certificates for pressure-bearing parts and parts welded to pressure-bearing parts are enclosed. No certificates of weld filler metals are attached. An overview list (Doc. QS-AS/EN-LMC-01-00) of the material certificates attached as described above is created with allocation to component dimensions and melt and attached to the documentation.
- NDT result reports (see also chapter 5). At least the visual inspection (VT) and the dimensional check. Further NDT only if explicitly agreed. Individual measurement results are only specified if explicitly ordered in the relevant documents.
- If welding work has been carried out, a collective certificate of certified welders (FM-07.05.00-QS-AS-EN-WCL) and the welding, heat treatment and test plan (FM- 07.12.00-QS-AS-EN-WTP). Welded products, WPS and WPQR can be viewed in the TUBE-TEC QS if required when an order is placed.
- If heat post-treatments were carried out, protocols of the heat post-treatments (Doc.: QS-AS/EN-PWHT-R-01-00) are attached.
- All other protocols and components must be explicitly agreed in the event of an order.

Components that are not within the scope of the test certificate are explicitly excluded.

A **certificate of conformity** within the meaning of Directive 2014/68/EU (PED / PED) contains the following documents in addition to APZ 3.2

- Design review by a notified body (drawing, calculation and design review report)
- Operating instructions
- Risk analysis
- Mandatory a report on the final inspection and pressure test

The manufacturer of the pressure equipment must provide the draft declaration of conformity, the design review, the operating instructions and hazard analysis and a draft of the company nameplate including CE marking. It is generally assumed that the CUSTOMER is the manufacturer and must provide the relevant documents. TUBE-TEC carries out the conformity assessment procedure on behalf of the customer together with the notified body, obtains the certificate of conformity and affixes the type plate.
A **certificate of conformity** within the meaning of TR ZU 032/2013 (EAC) includes the corresponding container passport, which TUBE-TEC prepares with appropriate external partners.

(Partial) Data Reports in the sense of ASME BPVC contain the documents of APZ 3.2 in the corresponding ASME-compliant version in addition to the corresponding Data Report. In principle and unless explicitly agreed, TUBE-TEC supplies parts without design responsibility.

Documentation is sent as a file in .PDF format by e-mail or, if the file size requires it, made available as a download for a limited period of time.