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May 1979

Electric Pressure-welded Steel Tubes for Elevated Temperatures

Technical Conditions of Delivery

DIN 17 177

Elektrisch pressgeschweisste Rohre aus warmfesten Stählen; Technische Lieferbedingungen

For connection with the International Standard **ISO 2604/III** issued by the International Organization for Standardization (ISO), see Explanations.

The Sections marked with a solid circle (•) contain particulars on agreements which shall, or may be, reached at the time of ordering.

1 Scope

This Standard applies to electric resistance or induction welded tubes [1] manufactured from the heat-resisting steels listed in Table 1 [2] for the construction of boilers, pipework, pressure vessels and equipment based on the existing selection of steels [2] used in part for temperatures up to 530 °C and at simultaneous high pressures, where the total stress and the relevant scaling conditions can raise or lower the temperature limit.

2 Other relevant Standards and documents

DIN 1626 Part 1	Welded steel pipes in unalloyed and low alloy steels for supply purposes, process plant and tanks; general specifications, survey, recommendations for use.
DIN 2393 Part 1	Welded steel precision tubes of special grade accuracy; dimensions
DIN 2394 Part 1	(at present still in draft form) Welded and sized steel precision tubes; dimensions
DIN 2413	Steel pipes; calculation of wall thickness subjected to internal pressure
DIN 2458	Welded steel tubes; dimensions and weights
DIN 2915	Seamless and welded steel tubes for water-tube boilers; survey
DIN 17 007 Part 2	Material numbers; system of the principle group 1: steel
DIN 50 049	Certificates on material tests
DIN 50 125	Testing of metallic materials; tensile test specimens, directions for their preparation
DIN 50 135	Testing of metallic materials; drift expanding test for tubes
DIN 50 136	Testing of metallic materials; ring flattening tests on tubes
DIN 50 137	Testing of steel; ring expanding test on tubes
DIN 50 138	Testing of metallic materials; tensile test for tubes and strips from tubes without extensometer
DIN 50 140	Testing of metallic materials; tensile test
DIN 50 145	Testing of metallic materials; tensile test
DIN-Normenheft 3	Code numbers and material numbers in DIN Standards and Stahl-Eisen Werkstoffblätter (Beuth Verlag GmbH, Berlin and Köln; Verlag Stahleisen mbH, Düsseldorf)
Stahl-Eisen Prüfblatt (Steel-Iron Test Sheet) 1805	Sampling and sample preparation for the random analysis of steels (Verlag Stahleisen mbH, Düsseldorf)
Stahl-Eisen Prüfblatt (Steel-Iron Test Sheet) 1915	Ultrasonic testing of heat resisting steel tubes for longitudinal defects (Verlag Stahleisen mbH, Düsseldorf)
Stahl-Eisen Prüfblatt (Steel-Iron Test Sheet) 1917	Non-destructive testing of electric pressure-welded tubes (Verlag Stahleisen mbH, Düsseldorf)
Stahl-Eisen Prüfblatt (Steel-Iron Test Sheet) 1918	Ultrasonic testing of heat resisting steel tubes for transverse defects (Verlag Stahleisen mbH, Düsseldorf)
Stahl-Eisen Prüfblatt (Steel-Iron Test Sheet) 1919	Ultrasonic testing of heat resisting steel tubes for laminations (Verlag Stahleisen mbH, Düsseldorf)
Stahl-Eisen Prüfblatt (Steel-Iron Test Sheet) 1925	Eddy current testing of tubes for leak-tightness (Verlag Stahleisen mbH, Düsseldorf)

1) In the case of tubes for boiler parts which have to satisfy the "Technische Regeln für Dampfkessel" (Steam Boiler Code) (TRD) published by the Deutscher Dampfkesselausschuss (German Boiler Committee) (DDA), these specifications will have to be additionally observed. If required, the "Technische Regeln für Druckbehälter" (Pressure Vessel Code) — AD-Merkblätter) should also be taken into consideration.

2) Electronic resistance or induction welded tubes for alloy steels other than 15 Mo 3 may be supplied to this Standard provided the necessary proof of the suitability of the industrial tubemaking process has been obtained in an authorized approval test.

Continued on pages 2 to 14
Explanations on page 15

Handbuch für das
Eisenhüttenlaboratorium,
Vol. 2:
Analysis of metallic materials, Düsseldorf 1966 (Verlag Stahleisen mbH, Düsseldorf)
Handbuch für das
Eisenhüttenlaboratorium,
Vol. 5 (supplementary volume):
A 4.1 — Compilation of recommended arbitration analysis,
B — Sampling methods,
C — Analytical methods, always the latest edition (Verlag Stahleisen mbH, Düsseldorf)

3 Definition

Steels possessing good mechanical properties (even under longtime stressing) at elevated temperatures, occasionally up to 530 °C, shall be regarded as being heat-resistant for the purpose of this Standard.

4 Classification

This Standard covers the tube steel grades listed in Table 1.

● The choice of the particular steel grade is at the discretion of the customer. (See also Section 6.2).

5 Designation and ordering

5.1 The code numbers for the grades of steel were formed in accordance with Sections 2.1.1.1 and 2.1.2.2 of the Explanations to DIN Normenheft 3, and the material numbers according to DIN 17 007 Part 2.

5.2 The code number or the material number for the grade of steel shall be appended to the Symbol for the product according to the following example:

Example:

Designation of an electric induction or resistance welded tube of 38 mm outside diameter and 2.6 mm wall thickness according to DIN 2458 of steel St 37.8, material number 1.0315:

Tube DIN 2458 — St 37.8 — 38 x 2.6
or **Tube DIN 2458 — 1.0315 — 38 x 2.6**

5.3 ● The order shall not only specify the designation according to Section 5.2 but also in every case the desired total length and the desired test certificate, and for unalloyed steel tubes also the quality grade. In addition, further details in compliance with the other Sections marked with a solid circle (●) can be agreed at the time of ordering.

6 Requirements

6.1 Manufacturing process

6.1.1 The tubes to this Standard shall be manufactured from hot or cold rolled strip by means of electric resistance or induction welding. If required, they are additionally hot reduced and/or cold formed (see Section 6.3.1). Welding should ensure a weld efficiency $v = 1$ [3].

6.1.2 The steel used shall be made by the oxygen blowing process, the open hearth furnace or the electric furnace.

All steels shall be killed.

● **Note:** Within the framework of the rulings in Section 6.1.2 the steelmaking process is left entirely to the discretion of the supplier. On request the steelmaking process must be made known.

6.2 Quality grades

6.2.1 The tubes can be supplied in two quality grades I and III which, among others, are characterized by different testing requirements (cf. Table 3). For tubes of plain carbon steels both quality grades from Table 3 may apply, though for 15 Mo 3 steel tubes, only quality grade III applies.

The higher demands made on quality grade III tubes generally call for special measures during steelmaking or processing (e.g. flame scarfing or peeling) or for a particularly careful selection of casts.

6.2.2 ● The choice of quality grade is left to the customer. It depends on the operating loads. This choice must conform with existing specifications or technical regulations such as the technical regulations for boiler and superheater tubes issued by the Deutscher Dampfkesselausschuss (German Boiler Committee), stay tubes for ships boilers (TRD 102). The limits of applicability are specified in Table 4 of this Standard.

6.3 "As delivered" condition

6.3.1 The tubes shall be supplied suitably heat-treated over their entire length.

The condition for an efficient heat-treatment shall be regarded as satisfied, if hot working, as the last tubemaking operation, guarantees a good and reasonably uniform structure.

6.3.2 ● If the tube surfaces are intended to be coated with a corrosion inhibitor providing protection for a limited period, this shall be agreed at the time of ordering.

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3) The rules for granting the works a license for the manufacture of welded tubes as laid down in DIN 1626 Part 1, January 1965 edition, Section 2, apply. In particular it should be noted that the works must be suitably equipped for welding, inspection and control.

The tubemaking process must be tested in order to prove that it merits a license.

Furthermore the production process must be continuously checked.

The competency as a licensed works extends solely to the analysis, dimension ranges, and to the welding process which are listed in the license certificate issued on the basis of the performed qualifying test. This license certificate will have to be updated whenever changes in the above conditions occur.

6.4 Chemical composition

The chemical composition of steels based on the ladle analysis [4]) must correspond to Table 1. Minor deviations from these values are permissible, provided they do not impair the mechanical and technological properties, according to the requirements in Tables 5 to 7.

Checking the finished tube, the deviations listed in Table 2 are permissible in comparison with the data in Table 1.

6.5 Mechanical properties

6.5.1 The tensile strength, yield strength and elongation at fracture of the tubes at room temperature must satisfy the requirements set down in Table 5, and the 0.2 % yield limit at elevated temperatures must satisfy the requirements set down in Table 6. These are valid for the delivery condition and for the relevant test conditions according to Section 8 of this Standard.

6.5.2 The 1 % creep limits and creep strengths of the steels are given in Appendix A to this Standard. The figures quoted in this supplement represent the mean values of the scatter band up to the present time; these values will be checked periodically and possibly revised after further test results have been made available.

Note: The publication of the 1 % creep limits or the creep strengths up to the high temperatures quoted in Appendix A does not mean that the steels are allowed to be used up to these temperatures. This depends primarily on the overall working conditions, in particular scaling.

6.6 Technological properties

The tubes shall conform to the requirements for the ring tests according to Section 8.6.4. Provisional data on the expansion (change in diameter) in the ring expanding test is given in Table 7.

No inadmissible defects (e.g. cracks, scale, laps and laminations) must be visible in the tests.

6.7 Surface finish

6.7.1 The tubes must have a smooth external and internal surface in keeping with the manufacturing process. A distinction is to be made between hot worked and cold worked finishes. The tubes shall be free from cracks, scale and laps. Minute protuberances, depressions or shallow longitudinal grooves caused by the manufacturing process are permissible, provided that the wall thickness remains within the dimensional tolerances and the serviceability of the tubes is not adversely affected. The removal of shallow surface defects by mechanical means (e.g. grinding) is permissible provided the minimum thickness tolerance is not exceeded.

6.7.2 The external weld bead shall be removed. The internal weld bead of tubes ≧20 mm bore shall be dressed leaving a residual bead not higher than 0.3 mm; the permissible minimum wall thickness must not be exceeded.

• For more stringent conditions and for tubes < 20 mm bore a separate agreement shall be reached on the internal weld bead.

6.8 Non-destructive testing

The requirements corresponding to the relevant Stahl-Eisen Prüfblätter (Steel-Iron Testing Sheets) have to be satisfied in the non-destructive tests according to Sections 8.4.6 and 8.6.5.

6.9 Physical properties

A special Stahl-Eisen Werkstoffblatt (Steel-Iron Data Sheet) (Publisher: Verein Deutscher Eisenhüttenleute, Postfach 82 09, 4000 Düsseldorf) with data on the physical properties, is in preparation.

6.10 Dimensions and permissible dimensional and form deviations

6.10.1 • The dimensions generally conform to DIN 2458 and DIN 2915; DIN 2393 Part 1 and DIN 2394 Part 1 (at present still in draft form) may be used in special cases.

6.10.2 The following conditions apply to the permissible dimensional and form deviations.

6.10.2.1 The permissible deviations for the outside diameter are:

6.10.2.1.1 The following permissible deviations apply on the outside diameter with the exception according to Section 6.10.2.1.2:

- for outside diameters ≦ 150 mm ± 0.75 % (minimum ± 0.5 mm),
- for outside diameters > 150 mm ≦ 200 mm ± 1 %.

• If narrower diameter deviations are demanded for the tube ends, then the following values can be maintained for the permissible deviations of the outside diameter over a length of approximately 100 mm by means of subsequent sizing of the ends:

- for outside diameters ≦ 45 mm ± 0.25 mm,
- for outside diameters > 45 mm ≦ 100 mm ± 0.4 mm,
- for outside diameters > 100 mm ≦ 200 mm ± 0.5 %.

6.10.2.1.2 • The following permissible deviations from the outside diameter apply to orders for cold worked tubes:

- for outside diameters ≦ 120 mm
  if wall thickness/outside diameter ≧ 1/20 ± 0.6 % (minimum ± 0.25 mm),
  if wall thickness/outside diameter < 1/20 ± 0.75 % (minimum ± 0.3 mm),
- for outside diameters > 120 mm ± 0.75 %.

In special cases narrower permissible deviations for the outside diameters can be negotiated.

6.10.2.1.3 At points where the tube surface has been repaired by mechanical means (e.g. grinding), e.g. as a result of indications received during non-destructive testing, it is permissible to exceed the permissible minus deviation by a small amount over a length of not more than 1 m, on condition that the permissible minimum wall thickness is retained.

[4]) On delivery of sequentially cast material, such as is the normal practice in continuous casting, the term "cast" shall be replaced by the term "casting unit". The concomitant alterations required in the relevant particulars of this Standard still have to be worked out.

6.10.2.2 The permissible deviations for the inside diameter are derived from the permissible deviations for the outside diameter (see Section 6.10.2.1) and for the wall thickness (see Section 6.10.2.3) where particular attention has to be paid to stipulations for the weld bead in Section 6.7.2.

• **Note:** In the case of tube ends intended for rolling in, narrower deviations for the inside diameter can be negotiated between customer and supplier.

6.10.2.3 The undermentioned ± deviations apply for the permissible wall thickness deviations of the tubes:

The permissible deviations for the wall thickness for both quality grades amount to:

- for hot reduced tubes ± 10 %,
- for cold finished tubes
  for wall thicknesses ≦ 3 mm $^{+0.30}_{-0.25}$ mm,

  for wall thicknesses > 3 mm ≦ 10 mm $^{+0.45}_{-0.35}$ mm,

  for wall thicknesses > 3 mm subject to agreement.

The permissible minimum wall thickness laid down in the permissible wall thickness deviations, may, at isolated points, additionally be exceeded by 5 % of the nominal wall thickness over a length of not more than twice the outside diameter of the tube, and 300 mm at the most. This is likely to occur at small isolated places caused by the removal of a defect through grinding.

6.10.2.4 • The permissible length deviations are listed in Table 8.

6.10.2.5 The following applies for the permissible form deviations.

6.10.2.5.1 The ovality of the tubes shall be within the permissible deviations for the nominal size. The tubes shall be straight to the eye.

• Special requirements on straightness are subject to separate agreement.

6.10.2.5.2 The tube ends shall be cut as square as possible with a machining tool; they shall be free from burrs.

6.11 Weights and permissible weight deviations

6.11.1 The weights per metre of tubing shall be taken from the relevant dimensional Standard, provided they are quoted.

6.11.2 If the tubes are non-standard size, or if the weights are not given in the dimensional Standard, the weight shall be calculated from the nominal dimensions and a density of 7.85 kg/dm^3.

6.11.3 The following permissible weight deviations are specified:

- for a single tube $^{+10}_{-8}$ %.
- for a wagon load of at least 10 t ± 7.5 %.

7 Heat-treatment and subsequent working

7.1 The reference data on the heat-treatment temperatures are listed in Table 9.

7.2 The steels can be hot worked in the temperature range between approximately 1100 and 850 °C, where the temperature may drop to 750 °C during processing. The regulations governing hot forming apply equally for fitting and straightening operations on site during which a close watch must be kept on temperature.

It would be expedient to perform forging and upsetting operations in the upper region of this temperature range i.e. between 1100 and 900 °C. Hot-bending and similar tube forming processes shall be carried out in the lower region of this temperature range i.e. between 1000 and 850 °C, where the temperature may drop to 750 °C during processing.

Subsequent normalizing is superfluous in cases when the workpiece has been heated above the normalizing temperature but not above 1000 °C before the last hot forming operation or in case of a single hot forming operation, and when the hot forming operation was completed above 750 °C or above 700 °C, if the amount of deformation did not exceed 5 % in the last operation.

In the case of repeated and/or prolonged hot forming operations at temperatures between approximately 1000 to 1100 °C the workpiece shall be cooled to temperatures below approximately 350 °C before the last hot forming operation. The temperature must not exceed 1000 °C in the subsequent hot forming operation, if normalizing is to be dispensed with.

7.3 Tubes from steels to this Standard can be cold worked, e.g. bent, expanded, drawn and rolled.

No heat-treatment is required after cold bending, cold expansion and cold drawing with a normal amount of cold work [5].

For greater amounts of cold work, annealing for at least 15 minutes at the temperatures specified in Table 10 is generally adequate.

7.4 The steels referred to in this Standard are weldable (see also DIN 8528 Part 1). Table 10 lists suitable welding processes and data on the heat-treatment of tubes after welding.

8 Testing

8.1 Testing of initial material

Strip for quality grade III tubes manufactured from pre-rolled slabs shall be tested nearest to the crop end for freedom from laminations.

8.2 • Acceptance tests

Tubes to this Standard are only supplied acceptance-tested [1]. The type of inspection certificate according to DIN 50 049 shall be agreed at the time of ordering. The acceptance test [1] is subject to the requirements in Section 8.3 to Section 8.8. In addition the requirements

[1] See page 1

[5] Consult the VGB – Instructions issued by the Technische Vereinigung der Grosskraftwerksbetreiber (Association of Operators of Large Power Stations) on the construction and supervision of heavy-duty steam boilers (available from the VGB – Dampftechnik GmbH, Essen)

of Sections 8.5 and 8.6 apply also for re-tests in response to complaints.

8.3 General testing requirements

8.3.1 All tests including acceptance shall be carried out in the manufacturing works such that the production flow is not unnecessarily impeded.

8.3.2 The manufacturing works shall take appropriate steps to prevent rejected tubes and those whose repair is not permissible from being despatched to the customer.

8.4 Extent of testing (see also Table 3)

8.4.1 The tubes shall be tested in batches. They shall be divided into batches of 100 according to the grade of steel, quality grades and dimensions – tubes of 15 Mo 3 if possible also according to cast –. Tubes up to an outside diameter ≦ 51 mm must come from the same heat-treated batch.

Surplus amounts of up to 50 tubes may be distributed evenly between the individual batches. Batches and surplus amounts between 51 and 100 tubes shall be considered as a single complete batch.

8.4.2 • If an agreement has been reached in the order to check the chemical analysis of the finished tube, this will normally consist of one test per cast and consignment.

8.4.3 For the tensile test two tubes shall be tested from each of the first two batches, in accordance with Section 8.4.1, and one tube from each subsequent batch chosen at random by the inspector.

If a consignment consists of a batch containing a maximum of 10 tubes only one tube shall be selected.

8.4.4 • If the 0.2% yield limit at elevated temperature is to be checked this must be explicitly stated in the order together with the required test temperature; this test shall be carried out on one sample per cast and size, unless otherwise agreed.

8.4.5 The tubes shall be ring-tested (see Table 11)

8.4.5.1 Quality grade I steel tubes [6] selected according to Section 8.4.3 shall be ring-tested (allowing for the dimensions quoted in Table 11) using samples taken from one end.

8.4.5.2 Quality grade III steel tubes shall be ring-tested on cut lengths of 30 m maximum (allowing for the dimensions quoted in Table 11), with the extent of testing being defined as follows:

for tubes with an outside diameter ≦ 51 mm (see Section 8.4.5.2.1) and

for tubes with an outside diameter > 51 mm (see Section 8.4.5.2.2).

At a subsequent subdivision of the cut lengths into part-lengths no further samples need to be taken, provided suitable markings show that the part-lengths belong to the tested cut lengths. If this cannot be guaranteed, the test on the cut lengths shall be dropped and their part-lengths tested instead.

8.4.5.2.1 Each cut length from quality grade III tubes ≦ 51 mm outside diameter shall be tested at one end. Each part-length which is not related to the cut length shall be tested at one end.

The extent of testing can be reduced to 20% of the cut lengths or part-lengths, provided the manufacturer has previously proved in non-destructive tests performed by him that the probability of defect detection is thereby not impaired [7]. The 20% cut lengths or part-lengths requiring testing shall be selected at random from the entire batch. As far as heat-treated tubes are concerned steps must be taken to ensure that the part-lengths come from batches which had been subjected to the same heat-treatment. As far as tubes with hot-formed ends are concerned (see Section 6.3.1, Clause 2) steps must be taken to ensure that the part-lengths belong to batches from the same production run, i.e. an identical heating practice.

8.4.5.2.2 Each cut length from quality grade III tubes > 51 mm outside diameter shall be tested at both ends. Each part-lengths which is not related to the cut length shall be tested at both ends.

Each part-length of tubes > 51 mm outside diameter can be ring-tested at one end only, provided it has been verified once for the relevant manufacturing process and manufacturing works that the ring test performed at one end of a part-length furnishes the same information as the information gained in a test with ring specimens taken from both ends of the original cut length.

8.4.6 The weld of all tubes of both quality grades shall be non-destructively tested. All quality grade III tubes shall also be non-destructively tested for longitudinal defects over the entire tube circumference.

• In addition a non-destructive test for transverse defects and/or for laminations can be agreed on in the order for quality grade III tubes.

8.4.7 The internal and external condition of all tubes must be checked.

8.4.8 The outside diameter and the wall thickness of all tubes shall be gauged.

8.4.9 All tubes must be tested for leak tightness, that is at the discretion of the manufacturer either by an internal pressure test with water or by a suitable non-destructive method (e.g. eddy current according to Steel-Iron Test Sheet 1925).

8.4.10 The manufacturer shall submit all tubes of the steel 15 Mo 3 or other only alloy steels to an appropriate material identification test.

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6) This extent of testing applies only, if it has been proved that appropriate quality-securing measures are continuously employed. If no such proof exists, each tube from a batch shall be ring-tested at one end.

7) This reduction of the extent of testing to 20% is only valid in cases where quality-securing measures are continuously employed.

8.5 Sampling

8.5.1 • If an agreement has been reached in the order to check the chemical analysis of finished tubes, for wet analysis the required turnings shall be taken over the entire wall thickness of the tube; an appropriate procedure shall be adopted for spectographic analysis [8].

8.5.2 Flat samples in accordance with Section 8.4.3, normally extending over the entire wall thickness and cut longitudinally from the tubes, shall be used for tensile testing. The samples shall be taken at an angle of 90° to the weld. They must not be heat-treated nor straightened over the gauge length. The removal of local inequalities from the flat samples is permissible, but the rolling skin must be allowed to remain as far as it is possible on the thinnest section samples.

Small diameter tubes can be tested as a whole.

Tubes of ≧200 mm outside diameter can be tensile-tested on transverse samples provided this is compatible with the tube dimensions without requiring straightening. In this case a tube ring shall be cut off and so halved that the cuts are 90° and 270° offset relative to the weld so that one sample is without the weld and the other with the weld in the centre.

8.5.3 • Section 8.5.2 applies logically in cases where agreement has been reached in the order on the determination of the 0.2% yield limit at elevated temperatures. However, the hot tensile test is normally performed, where possible, on round samples; if the occasions arises, sampling however may require prior agreement.

8.5.4 The samples for the ring tests shall be taken according to DIN 50 136 (ring flattening test), DIN 50 137 (ring expanding test) or DIN 50 138 (ring tensile test) and, if necessary, also DIN 50 135 (drift expanding test) (see Table 3).

8.5.5 All samples for the tests according to Section 8.5.2 to Section 8.5.4 shall be adequately identifiable by punch marks, in order to show which tubes and samples go together.

8.6 Applicable test methods

8.6.1 The chemical analysis shall be carried out in accordance with the methods prescribed by the "Chemikerausschuss des Vereins Deutscher Eisenhüttenleute" [9].

8.6.2 The tensile test shall be carried out in accordance with DIN 50 145, using the short proportional test bar in accordance with DIN 50 125 or with samples according to DIN 50 140.

8.6.3 The 0.2% yield limit at elevated temperatures is determined in accordance with DIN 50 145.

8.6.4 The ring tests shall be carried out in accordance with the Standards given in Section 8.5.4 for the ring flattening, ring expanding and ring tensile tests and, if necessary, for the drift expanding test subject to the undermentioned specifications.

8.6.4.1 In the ring flattening test according to DIN 50 136, the weld shall be placed into the most severely stressed zone (3 o'clock position). The samples or the tube ends shall be squeezed together until a definite distance H is reached between the pressure plates. For this distance H (in mm)

$$H = \frac{(1 + c) \cdot s}{c + s/d_a}$$

where s = wall thickness in mm, d_a = outside diameter in mm and c is a constant. For the steel St 37.8 c is 0.09, and for the remaining steels to this Standard it is 0.07.

• If the ratio s/d_a is greater than 0.15, the distance between the plates shall be negotiated.

In a ring flattening test peformed according to Section 8.4.5 the test can be continued to fracture until a crack appears, so as to make it possible to assess the appearance of the fractured surface. The decisive factor is that the prescribed distance between the plates is reached without cracking.

8.6.4.2 The ring tensile test according to DIN 50 138 shall be carried out with the weld 90° offset relative to the direction of the pull.

8.6.4.3 The ring expanding test shall be carried out according to DIN 50 137 where the change in the diameter of the sample expanded to fracture shall also be measured. The evaluation of the deformability of ring expansion samples is based on the appearance of the fracture and the fracture surfaces.

8.6.4.4 • The testing conditions for the drift expanding test according to DIN 50 135 are subject to agreement.

8.6.5 • The non-destructive test shall always be carried out before the ring samples are cut off. Ultrasonic, eddy current or magnetic flux leakage methods are suitable for testing.

Testing shall be done:

a) according to Steel-Iron Test Sheet 1917 for quality grade I tubes,

b) according to Steel-Iron Test Sheet 1915 when testing quality grade III tubes of ≧10 mm outside diameter for longitudinal defects,

c) according to Steel-Iron Test Sheet 1918 after agreement has been reached on testing quality grade III tubes having an outside diameter > 133 mm for transverse defects,

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8) The sampling practice conforms, as a rule, to Steel Iron Test Sheet 1805 — Sampling and sample preparation for the random analysis of steels (Verlag Stahleisen mbH, Düsseldorf).

9) Handbuch für das Eisenhüttenlaboratorium, Vol. 2: Die Untersuchung der metallischen Stoffe (Analysis of metallic materials), Düsseldorf, Verlag Stahleisen mbH, 1966; Vol 5 (Supplement): A 4.1 — Aufstellung empfohlener Schiedsverfahren (Compilation of recommended arbitration analysis), B — Probenahmeverfahren (Sampling methods), C — Analysenverfahren (Analytical methods), always the most up to date edition: Verlag Stahleisen mbH.

d) according to Steel-Iron Test Sheet 1919 after agreement on testing quality grade III tubes having an outside diameter > 133 mm and a wall thickness > 8 mm, for laminations.

8.6.6 Visual inspection of the tubes[10]) with the naked eye requires that:

a) the entire external tube surface shall be examined in suitable lighting for surface defects,

b) the inner tube surface shall be examined in suitable lighting from both ends for surface defects.

The surface finish of the tubes must permit detection of significant defects. For quality grade III tubes this generally denotes descaled surfaces, unless the chosen method of production or heat-treatment ensures a suitable surface finish for visual inspection and ultrasonic testing.

8.6.7 The dimensions shall be checked with suitable instruments.

8.6.8 • The internal pressure test with water (see Section 8.4.9) carried out for testing the leak tightness shall generally be done at a uniform test pressure of 80 bar. Higher test pressures require prior agreement. The test pressure shall always be limited so that the yield point at 20 °C will not be reached or exceeded (cf. DIN 2413, June 1972 edition, Section 4.6)

In the case of thin-walled large-diameter tubes this will already have to be considered at pressures of 80 bar.

8.7 Re-tests

8.7.1 If one of the selected tubes fails to pass the tests according to Section 8.6.2 (tensile test) and in the case of quality grade I tubes according to Section 8.6.4 (ring test), it shall be rejected, and two further tubes shall be taken from the batch and the tests repeated. In these new tests each tube must satisfy the requirements otherwise the whole batch must be rejected.

8.7.2 If one sample from a cut or part-length of quality grade III steel tubes of ≦ 51 mm outside diameter according to Section 8.4.5.2.1 fails in a random ring check test, the test shall be repeated on the same end of the relevant cut length or part-length. If this replacement sample proves unsatisfactory, the relevant cut length or part-length shall be rejected and the test repeated at one end of a further 20 % of the cut or part-lengths. If another sample fails again, the test will have to be extended to all cut lengths or part-lengths of the batch. Cut or part-lengths which fail in the ring test shall be rejected.

If one ring sample from a cut length or part-length fails in the single test on quality grade III tubes according to Section 8.4.5.2.2 and also Section 8.4.5.2.1, the test shall be repeated on the same cut length or part-length. If this sample also fails, the relevant cut length, or part-length shall be rejected. On rejection of a cut length it is left to the discretion of the manufacturer to ring-test the corresponding part-lengths.

8.7.3 If the unsatisfactory test results were due to inappropriate heat-treatment, it is at the discretion of the manufacturer's works to submit the rejected batch to further heat-treatment and re-submit it for acceptance. The manufacturer's works are entitled to remove the defects detected in the tests according to Sections 8.4.5 (ring test), 8.4.6 (non-destructive test) and 8.4.7 (visual inspection) by suitable means and to re-submit the tubes for acceptance.

8.8 Test certificates

8.8.1 • The acceptance test[1]) shall be certified by an Inspection Certificate A, B or C according to DIN 50 049, July 1972 edition, Section 3.

Note: The certificates shall give the full wording of the identification marks, according to Section 9.1.

8.8.2 • If certificates have to be issued only for part of the requirements guaranteed by Inspection Certificates A or C according to DIN 50 049, the manufacturer shall additionally confirm for quality grade I tubes in a Works Certificate according to DIN 50 049, and for quality grade III tubes in an Inspection Certificate B according to DIN 50 049, that the tube material corresponds in steel grade and steel quality to DIN 17 177, that all tubes have passed the leak-tightness test and have an unobstructed bore, that they have been correctly heat-treated over their entire length in a manner consistent with the tube material and that quality grade III tubes have been manufactured from roughed-down slabs, that the end nearest to the ingot crop has been tested for freedom from laminations, that the chemical composition was determined according to the ladle analysis and, if agreed at the time of ordering, also the steelmaking process has been quoted. Furthermore the execution of the non-destructive test shall be confirmed in Inspection Certificate B according to DIN 50 049.

9 Identification of tubes

9.1 The finished tubes shall be marked approximately 300 mm from the end.

The identification consists normally of a stamp mark. Another identification practice may be adopted for thin-walled tubes. The following identification marks shall be applied

on both ends:

Material designation (code number of steel grade), for unalloyed steels the quality grade (unless quality grade I), and

the inspector's stamp;

on one end:

for quality grade III tubes the tube number,

for tubes of steel 15 Mo 3 the cast number or an identification mark for the cast, provided the nominal size is ≧ 159 mm.

9.2 The stamp mark can be made more conspicuous according to Section 9.1, e.g. by a coloured line; the lines of the colour identification may be used for this.

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1) See page 1

10) A proven, suitable non-destructive testing process can also be used instead of the visual inspection method.

10 Complaints

10.1 External and internal defects justify complaints, if they seriously affect the workability and serviceability of the type of steel and shape of the product.

10.2 The customer shall give the supplier an opportunity to prove[11] that the complaints were justified, preferably by submission of samples from the unsatisfactory material delivered.

[11] Consult: Explanations to the "Complaints Clause" in Quality Standards for Iron and Steel. DIN-Mitt. 40 (1961) No. 2, pp. 111/112.

Further Standards

DIN 2401 Part 1 Structural members under internal and external pressure; pressure and temperature data, definitions, nominal pressure stages

DIN 8528 Part 1 Weldability; metallic materials, definitions

Table 1. **Heat-resistant steels for electric resistance and induction welded tubes, their chemical composition (according to the ladle analysis) and colour designation of tubes**

Steel grade [1]		Chemical composition in % by wt.						
Code number	Material number	C	Si	Mn	P maximum	S maximum	Mo	Colour designation [2]
St 37.8 [3]	1.0315	≦ 0.17	0.10 to 0.35 [4]	0.40 to 0.80	0.040	0.040		two white rings
St 42.8 [3]	1.0498	≦ 0.21	0.10 to 0.35 [4]	0.40 to 1.20	0.040	0.040		two yellow rings
15 Mo 3	1.5415	0.12 to 0.20	0.10 to 0.35	0.40 to 0.80	0.035	0.035	0.25 to 0.35	one yellow ring and two carmine rings

[1] Electric pressure-welded tubes of alloy steels other than steel 15 Mo 3 may be supplied to this Standard provided the necessary proof of the suitability of the industrial tubemaking process has been obtained in an authorized approval test.

[2] • In normal practice both ends are painted with rings in the colour required. If requested, it can be agreed at the time of ordering that the paint marking in the relevant colours should extend over the entire length of the tube.

[3] The steels St 37.8 and St 42.8 satisfy the "Technical Regulations for Steam Boilers" published by the Deutscher Dampfkesselausschuss (German Steam Boiler Committee) in the same way as St 35.8 and St 45.8 according to DIN 17 175

[4] The minimum silicon content is allowed to fall below 0.10 % when the steel is aluminium – killed or vacuum – deoxidized.

Table 2. **Permissible deviations in the chemical composition of the sample analysis from limiting values quoted in the cast analysis** (see Table 1)

Element	Limiting values quoted in ladle analysis according to Table 1 % by wt.	Permissible deviation [7] of sample analysis from the limiting values quoted in the ladle analysis according to Table 1 % by wt.
C	≦ 0.21	± 0.02
Si	≦ 0.35	± 0.03
Mn	≦ 1.00 > 1.00 ≦ 1.20	± 0.04 ± 0.05
P and S	≦ 0.040	+ 0.010
Mo	≦ 0.35	± 0.04

1) In a cast the deviation of an element in a sample analysis is permitted to be below the minimum value or only above the maximum value of the range stipulated for the ladle analysis, though not both at the same time.

Table 3. **Extent of testing for electric pressure welded tubes in both quality grades**

No.	Extent of testing	According to Section	Quality grade I	Quality grade II	Authority for the execution of the test [1]
1	Tensile test [2]	8.4.3	on two tubes per batch from the first two batches, on one tube from each subsequent batch	on two tubes per batch from the first two batches, on one tube from each subsequent batch	S. A.
2	Ring test [3]	8.4.5	on one end of the tubes acc. to No. 1	depending on the diameter (see Section 8.4.5) on 20 % of the cut or part-lengths at one end or on 100 % of the cut or part-lengths at both ends if necessary though also at one end, see Section 8.4.5.2.2	S. A.
3	Non-destructive test	8.4.6	weld examination on all tubes	as for quality grade I, additionally over the complete tube circum-ference	M. W.
4	Visual inspection	8.4.7	all tubes	all tubes	S. A.
5	Gauging	8.4.8	all tubes	all tubes	S. A.
6	Leakage test	8.4.9	all tubes	all tubes	M. W.
7	Identification test	8.4.10	–	on all alloy tubes	M. W.
	Special tests [4] No. 8, No. 9				
8	Analysis checks	8.4.2	subject to agreement	subject to agreement	M. W.
9	Hot tensile test	8.4.4	unless otherwise agreed 1 sample per cast and size or 1 sample per cast and annealed batch (heat-treated batch)	unless otherwise agreed 1 sample per cast and size or 1 sample per cast and annealed batch (heat-treated batch)	S. A.

1) S. A. = subject to agreement; M. W. = Manufacturing works.
2) One sample or set of samples suffices for batches containing up to 10 tubes.
3) Note the particulars on the dimension range governing the application of these tests in Table 11.
4) • Special tests shall be carried out only after agreement between manufacturer and customer.

Table 4. **Limits governing the application of quality grades I and III**

Quality grade [1]	Outside diameter of tube ≤ 63.5 mm		> 63.5 mm	
	Temperature [2] °C	Permissible working pressure [3] bar	Temperature [2] °C	Permissible working pressure [3] bar
I	≤ 450	≤ 80	≤ 450	≤ 32
III	> 450	> 80	> 450	> 32

1) If pressure and temperature data do not belong to the same quality group, the higher group applies.
2) Temperature of conveyed fluid.
3) See DIN 2401 Part 1.

Table 5. **Mechanical properties of electric resistance or induction welded tubes of heat-resistant steels at room temperature**

Steel grade		Tensile strength	Yield point [1] for wall thicknesses up to 16 mm	Elongation at fracture ($L_o = 5 \cdot d_o$)	
				Long	Trans-verse
Code number	Material number	N/mm²	N/mm² minimum	% minimum	
St 37.8	1.0315	360 to 480	235	25	23
St 42.8	1.0498	410 to 530	255	21	19
15 Mo 3	1.5415	450 to 600	270 [2]	22	20

1) For tubes of ≦ 30 mm outside diameter and ≦ 3 mm wall thickness the minimum values are by 10 N/mm² lower.
2) A 15 N/mm² higher minimum value applies for ≦ 10 mm wall thickness.

Table 6. **Minimum 0.2 % yield limit of electric resistance and indication welded tubes of heat-resistant steels at elevated temperatures**

Steel grade		Wall thickness	0.2 %-yield limit at						
			200 °C	250 °C	300 °C	350 °C	400 °C	450 °C	500 °C
Code number	Material number	mm	N/mm² minimum						
St 37.8	1.0315	≦ 16	185	165	140	120	110	105	–
St 42.8	1.0498	≦ 16	205	185	160	140	130	125	–
15 Mo 3	1.5415	≦ 16 [1]	225	205	180	170	160	155	150

1) For wall thicknesses ≦ 10 mm, 15 N/mm² higher minimum 0.2 % yield limits apply at all temperatures.

Table 7. **Provisional expansion data [1] (change in diameter) in the ring expanding test**

Steel grade		Expansion [2] in ring expanding test (provisional data) for diameter rations d_i/d_a					
		≧ 0.9	≧ 0.8 < 0.9	≧ 0.7 < 0.8	≧ 0.6 < 0.7	≧ 0.5 < 0.6	< 0.5
Code number	Material number	% minimum					
St 37.8	1.0315	8	10	12	20	25	30
St 42.8	1.0498						
15 Mo 3	1.5415	6	8	10	15	20	30

1) These values shall be regarded as initial recommendations which are based on a series of tests and will have to be re-assessed in the light of future experience.
2) The deformability of ring expanding samples will additionally be assessed in terms of the appearance of the fracture and fracture surfaces.

Table 8. **Permissible length deviations**

For orders specifying	Permissible length deviation in mm
Production lengths	1)
Approximate lengths	± 500
Exact lengths from ≤ 6 m (nominal dimension)	$^{+10}_{0}$
from > 6 m ≤ 12 m (nominal dimension)	$^{+15}_{0}$
from > 12 m	Subject to agreement

1) The products are supplied in production lengths which differ according to diameter, wall thickness and production plant.

Table 9. **Reference data for the hot working and the normalizing of heat-resistant steels for electric pressure-welded tubes**

Steel grade		Hot working	Normalizing
Code number	Material number	°C	°C
St 37.8	**1.0315**	between 1100 and 850 2)	900 to 930
St 42.8	**1.0498**		870 to 900
15 Mo 3	**1.5415**		910 to 940

1) The workpieces must attain the specified temperature over the entire cross-section. Provided this has been accomplished, for normalizing a further holding at these temperatures is unnecessary.

2) The temperature can drop to 750 °C during processing.

Table 10. **Welding methods and data for the post-heat-treatments**

Steel grade		Welding methods	Annealing temperature 1) and holding time 2), 3) at the specified post-heat treatment °C
Code number	Material number		
St 37.8	1.0315	All fusion welding methods and flash butt welding	520 to 600
St 42.8	1.0498		
15 Mo 3	1.5415		530 to 620

1) If required (see Section 7.3), these temperatures apply also for annealing after cold working.
2) The holding time for the specified temperatures depends on the wall thickness. A minimum holding time of 15 minutes is recommended.
3) The annealing treatment shall also comply with the data supplied by the manufacturer of the filler metal.

Table 11. **Dimension ranges for the application of mechanical and technological methods for testing tubes in both qualities.**

Outside diameter of tubes mm	Nominal wall thicknesses of tubes	
	< 2 mm	2 ≧ mm ≦ 16 mm
≦ 21.3	Tensile test Ring flattening test 1)	Tensile test Ring flattening test 1)
> 21.3 ≦ 146	Tensile test Ring flattening test	Tensile test Ring expanding test
> 146	–	Tensile test Ring tensile test

1) If the weld seam is not discernable, the drift expanding test shall be carried out.

Appendix A

The following Table gives tentative figures for the longtime high-temperature strength of the heat-resistant steels. The figures listed are mean values for the scatter range representing the results so far available. These mean values will be examined from time to time and amended, where necessary, as further results become available. From the data so far at hand from long-time creep tests it can be assumed that the bottom limit of this scatter range at the stated temperature for the steel grades listed is about 20 % lower than the mean values quoted.

Note: The values quoted here are based on investigations of the base material. Some limited experience has suggested that the values are also applicable to welded tubes.

Table A.1

Steel grade	Temperature	1 % creep limit [1], [2] for		Creep strength [2], [3] for		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
Code number	°C	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
St 37.8 St 42.8	380	164	118	229	165	145
	390	150	106	211	148	129
	400	136	95	191	132	115
	410	124	84	174	118	101
	420	113	73	158	103	89
	430	101	65	142	91	78
	440	91	57	127	79	67
	450	80	49	113	69	57
	460	72	42	100	59	48
	470	62	35	86	50	40
	480	53	30	75	42	33
15 Mo 3	450	216	167	298	245	228
	460	199	146	273	209	189
	470	182	126	247	174	153
	480	166	107	222	143	121
	490	149	89	196	117	96
	500	132	73	171	93	75
	510	115	59	147	74	57
	520	99	46	125	59	45
	530	84	36	102	47	36
	540	(70)	(28)	(82)	(38)	(28)
	550	(59)	(24)	(64)	(31)	(25)

1) This being the stress referred to the original cross-section which leads to a permanent elongation of 1 % after 10 000 or 100 000 hours (h).

2) A bracket denotes that the steel should preferably no longer be used for continuous service at the relevant temperature.

3) This being the stress referred to in the original cross-section which results in rupture after 10 000, 100 000 or 200 000 hours (h).

Explanations

The increasing use of electric pressure-welded tubes in the construction of steam boilers and pressure vessels dictated the publication of this Standard after the issue of the International Standard 2604/III

Steel products for pressure purposes – Quality requirements – Part III: Electric resistance and induction welded tubes

The publication of the Standard was delayed because on the one hand it had been intended to wait for the forthcoming international negotiations and on the other one did not, and could not, anticipate the simultaneous and far more important negotiations on the revision of DIN 17 175 – Seamless steel tubes for elevated temperatures; technical conditions of delivery. The content and layout of this Standard closely resembles that of DIN 17 175. Differences from DIN 17 175 obviously arise in the manufacturing method (see Section 6.1), testing the initial material (see Section 8.1) and in the dimensions and permissible dimensional deviations, by the insistance or non-destructive examination of the weld (see Section 8.4.6) and specifications regarding the weld bead (see Section 6.7.2), furthermore by taking the drift expanding test into consideration (see Footnote 1, Table 11) and by restricting the range of steels to the unalloyed steels St 37.8 (1.0315) and St 42.8 (1.0498) and to the alloy steel 15 Mo 3 (1.5415) whilst DIN 17 175 additionally includes the steels 17 Mn 4 (1.0481), 19 Mn 5 (1.0482), 13 CrMo 4 4 (1.7335), 10 CrMo 9 10 (1.7380), 14 Mo 6 3 (1.7715) and X 20 CrMoV 12 1 (1.4922) (according to the Footnote in Table 1 electric resistance and induction welded tubes can also be supplied according to DIN 17 177 in other alloy steels provided certain conditions are satisfied). In addition, owing to the restriction in wall thickness to 16 mm, DIN 17 177 as opposed to DIN 17 175 contains no requirements on the notched-bar impact test.

DIN 17 177 differs from ISO 2604/III in the following major points:

a) Apart form the steels listed in DIN 17 177, ISO 2604/III contains the steels 17 Mn4 and 13 CrMo 4 4, as well as the steel TW 2 not commonly used in Germany, and steels without hot strength specifications; see tabular comparison at end of Explanations.

b) The room temperature yield points are 20 N/mm² higher in DIN 17 177 (see Table 5) than in ISO 2604/III.

c) Up to 350 °C the values for the 0.2 % yield limit at elevated temperatures (see Table 6) of the unalloyed steels are slightly higher in DIN 17 177, at higher temperatures they are slightly lower than in ISO 2604/III. The values for the steel 15 Mo 3 are always higher than in ISO 2604/III.

d) Appendix A to DIN 17 177 lists both the creep strengths and the 1 % creep limits. The sole agreement in the creep strengths has so far been found in the 10 000 hour-values for the steel 15 Mo 3.

e) The quality grades I and III according to DIN 17 177 are not directly comparable with testing categories II to V according to ISO 2604/III. Quality grades I and III resemble testing categories II and V most closely, with an allowance having to be made for the different extent of testing in the ring tests.

Comparison of steels envisaged for use at elevated temperatures according to ISO 2604/III with equivalent German steels

1)	Steels according to			
	German Documents		ISO 2604/III	
	Code number	Material number	Code number	2)
–	–	–	TW 2	–
DIN	St 37.8	1.0315	TW 5	●
DIN	St 42.8	1.0498	TW 9 H	●
3)	17 Mn 4	1.0481	TW 14	●
DIN	15 Mo 3	1.5415	TW 26	●
3)	13 CrMo 4 4	1.7335	TW 32	●

1) DIN = contained in DIN 17 177.

2) This column shows the degree of agreement in the chemical composition of the German steels on the one hand and the steels according to ISO 2604/III on the other; the solid circle (●) denotes minor deviations.

3) This steel is not expressly mentioned in DIN 17 177 (see Footnote 1 in Table 1), it is, however, listed in DIN 17 175.