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Seamless circular steel tubes for hydrogen service at elevated temperatures and pressures

Technical delivery conditions

DIN 17 176

Nahtlose kreisförmige Rohre aus druckwasserstoffbeständigen Stählen; technische Lieferbedingungen

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

The subclauses marked ● give specifications which are to be agreed upon at the time of ordering, and those marked ● ● give specifications which are optional and may be agreed upon at the time of ordering.

Contents

		Page
1	**Field of application**	1
2	**Concept**	1
3	**Steel grades**	1
4	**Designation and ordering**	1
4.1	Standard designation	1
4.2	Essential order details	2
4.3	Optional order details	2
5	**Requirements**	2
5.1	Manufacturing process	2
5.2	As delivered condition	2
5.3	Chemical composition	2
5.4	Mechanical properties	2
5.5	Weldability	2
5.6	Hot working and heat treatment	3
5.7	Surface appearance	3
5.8	Leak tightness	3
5.9	Imperfections	3
5.10	Dimensions, tolerances and mass per unit length	3
6	**Testing**	3
6.1	Materials testing certificates	3
6.2	Test site	3
6.3	Scope of testing	4
6.4	Sampling and sample preparation	4
6.5	Test procedure	4
6.6	Retests	5
7	**Marking**	5
8	**Complaints**	5
Appendix A	Estimated creep limit and stress rupture, and elevated temperature tensile strength values	12
Appendix B	Information on temperatures required for hot working and heat treatment	15

1 Field of application

This standard specifies requirements for seamless circular tubes manufactured from the steel grades listed in table 1. Such tubes are mainly intended for use in chemical plants for high pressure applications at service temperatures of 200 °C or more and simultaneous exposure to hydrogen (e.g. boiler or heat exchanger tubes).

2 Concept

Steel for hydrogen service at elevated temperature and pressure is steel that is not readily susceptible to decarburization by hydrogen at elevated pressures and temperatures and thus to hydrogen and grain boundary embrittlement. This characteristic is achieved by adding alloying elements that form carbides at the operating temperature.

3 Steel grades

3.1 The specifications of this standard relate to tubes made from the steel grades listed in table 1.

3.2 ● The selection of the steel grade is at the purchaser's discretion.

4 Designation and ordering

4.1 Standard designation

The standard designation of tubes covered in this standard shall give, in the following order:

- the name of product (tube);
- the number of this standard (DIN 17 176);
- the characteristic dimensions of the tube (outside diameter × wall thickness);

Continued on pages 2 to 16

- the material designation or number denoting the steel grade (cf. table 1);
- the symbol denoting the heat treatment condition, for steel grades 12 CrMo 19 5 and X 12 CrMo 9 1.

Example:

A tube complying with this standard, with an outside diameter of 127 mm and a wall thickness of 28 mm, made from steel 12 CrMo 19 5 (material number 1.7362), in the annealed condition (G), shall be designated:

Tube DIN 17 176 – 127 × 28 – 12 CrMo 19 5 G

or

Tube DIN 17 176 – 127 × 28 – 1.7362 G

4.2 ● Essential order details

The following order details are essential when ordering tubes as specified in this standard.

4.2.1 Quantity (e.g. desired total length of tubes in a consignment).

4.2.2 Name of product (tube).

4.2.3 Number of this standard (DIN 17 176).

4.2.4 Characteristic dimensions of tube (outside diameter × wall thickness).

4.2.5 Material designation or number denoting the steel grade (cf. table 1).

4.2.6 Symbol denoting the heat treatment condition on delivery (cf. table 3).

4.2.7 Type of length (cf. table 5), and unit length in the case of specified and exact lengths.

4.2.8 Type of DIN 50 049 certificate (cf. subclause 6.1) and, in the case of third party inspection, the testing agency and any specifications to be complied with.

Example of an order:

1000 m tube DIN 17 176 – 127 × 28 – 12 CrMo 19 5 G,
in as manufactured lengths, with
DIN 50 049 – 3.1 C certificate.

4.3 ●● Optional order details

The essential order details may, if so agreed, be supplemented by one or more of the following items.

4.3.1 Steelmaking process used (cf. subclause 5.1.1.2).

4.3.2 Check of chemical composition (by product analysis) (cf. subclause 5.3.2).

4.3.3 Hardness testing (cf. subclause 6.3.5).

4.3.4 Testing of elevated temperature 0,2 % proof strength (cf. subclause 6.3.6).

4.3.5 Non-destructive testing for transverse imperfections and/or laminations (cf. subclause 5.9.2).

4.3.6 Test pressure if higher than specified here (cf. subclause 6.5.6.1).

5 Requirements

5.1 Manufacturing process

5.1.1 The steel shall be produced either by an electric process or by the basic oxygen process.

5.1.1.1 ●● If so agreed, a different but equivalent process may be used.

5.1.1.2 ●● If so agreed, the purchaser shall be informed of the steelmaking process used.

5.1.2 Tubes shall be produced by hot or cold rolling, hot pressing, hot or cold drawing, or by a combination of these processes, at the manufacturer's discretion.

5.2 As delivered condition

Tubes shall be supplied in one of the heat treatment conditions listed in table 3.

Provided that hot forming ensures an adequately homogeneous microstructure, it may be sufficient to temper instead of quenching and tempering tubes made from steel 13 CrMo 4 4 and 10 CrMo 9 10.

5.3 Chemical composition

5.3.1 Ladle analysis

The chemical composition as determined by ladle analysis[1]) shall comply with the specifications of table 1.

5.3.2 ●● Product analysis

A product analysis may be agreed at the time of ordering (see table 7 for scope of testing). When a product analysis is carried out, the results may deviate from the values given in table 1 by the amounts listed in table 2.

5.3.3 Deviations

With the consent of purchaser or his representative, minor deviations of the chemical composition from the limiting values specified for the ladle analysis and product analysis are permitted provided that they do not adversely affect the mechanical properties, resistance to hydrogen attack and weldability of the tube.

5.4 Mechanical properties

5.4.1 The yield strength, tensile strength, elongation after fracture and impact strength of tubes in their as delivered condition (cf. subclause 5.2) and under the conditions specified in subclauses 6.4 and 6.5 shall, at ambient temperature, comply with the specifications given in table 3, and the elevated temperature proof strength, with those given in table 4.

5.4.1.1 ●● A hardness test for checking the homogeneity of the batch in terms of mechanical properties (cf. subclause 6.3.5) may be agreed.

5.4.2 Tables A.1 and A.2 give estimated values of 1 % creep limit, stress rupture and elevated temperature tensile strength.

5.4.2.1 The 1 % creep limit and stress rupture values specified in table A.1 for elevated temperatures shall not be taken to mean that steel can be subjected to these temperatures in continuous service, the limitations in their use being governed by the overall load in service and their resistance to hydrogen attack as defined in API Publication 941.

5.5 Weldability

5.5.1 Tubes made from steel as specified here are suitable for arc welding and pressure welding.

[1]) When sequential castings are supplied, as is possible in the case of continuously cast tubes, the term 'cast' should be read as 'casting unit'.

5.5.2 However, as set out in DIN 8528 Part 1, weldability is not only a function of the steel grade but also of the welding conditions, of the design and of the service conditions to which the component will be submitted.

5.5.3 Any welding filler metal required is to be selected on the basis of DIN 8575 Part 1.

5.6 Hot working and heat treatment

Table B.1 provides information on the temperature for hot working and heat treatment.

5.7 Surface appearance

5.7.1 Tubes shall have a smooth internal and external surface consistent with the manufacturing process.

5.7.2 Slight surface irregularities such as scabs, seams, slivers or gouges resulting from the manufacturing process are permitted provided that the wall thickness after dressing continues to meet the requirements specified in subclause 5.10.2 and the performance of the tube is not adversely affected (cf. subclause 8.1).

5.7.3 Dressing of imperfections by grinding or machining is permitted provided that the wall thickness after dressing continues to meet the requirements specified in subclause 5.10.2. Stopping of surface defects is not permitted, while making good of such defects by welding is only permitted with the purchaser's consent.

5.8 Leak tightness

Tubes shall remain tight when tested as specified in subclause 6.5.6.

5.9 Imperfections

5.9.1 When tubes are checked for longitudinal imperfections by non-destructive methods as specified in subclause 6.5.8, the requirements given in *Stahl-Eisen-Prüfblatt* (Iron and steel test sheet) 1915 shall be met.

5.9.2 ●● If so agreed at the time of ordering, tubes are tested by non-destructive methods for transverse imperfections and/or laminations, the requirements given in *Stahl-Eisen-Prüfblätter* 1918 and 1919 shall be fulfilled (cf. subclauses 6.5.9 and 6.5.10).

5.10 Dimensions, tolerances and mass per unit length

5.10.1 ● Dimensions

5.10.1.1 After consultation with the manufacturer, the purchaser is to specify the tube outside diameters and wall thicknesses required, preference being given to the dimensions specified in DIN 2448 and DIN 2391 Part 1.

5.10.1.2 Table 5 shall be observed when specifying the tube length.

5.10.2 Dimensional tolerances

The outside diameter and wall thickness are subject to the limit deviations specified in table 6.

At points where the surface of the tube has been dressed by mechanical means (e.g. by grinding), the actual outside diameter may be less than its lower limit of size provided that the wall thickness still lies within the tolerances specified.

5.10.3 Geometrical tolerances

5.10.3.1 Circularity

Tubes shall be as circular as possible. For tubes that are not solution quenched and tempered, the circularity tolerance, R, of the barrel shall be within the limit deviations specified for the outside diameter (cf. table 6), R being equal to 2 % for solution quenched and tempered tubes (cf. subclause 6.5.12). The circularity tolerance, as a percentage, shall be determined using the following formula:

$$R = 200 \cdot \frac{d_{a\,max} - d_{a\,min}}{d_{a\,max} + d_{a\,min}}$$

where $d_{a\,max}$ is the greatest and $d_{a\,min}$ is the smallest outside diameter measured.

Note. It is permitted that $d_{a\,max}$ or $d_{a\,min}$ exceed the upper or lower limit of size specified in table 6.

5.10.3.2 Straightness

Tubes shall be straight to the eye.

5.10.4 Finish of tube ends

Tubes shall be cut square with the tube axis and be free from burrs.

5.10.5 Tolerances on mass per unit length

Calculation of the mass per unit length shall be in accordance with ISO 4200, taking, however, the density as 7,76 kg/dm³ for grade X 20 CrMoV 12 1 (material number 1.4922).

The actual mass may deviate from the values so obtained by $^{+12}_{-8}$ % for a single tube, and $^{+10}_{-5}$ % for a consignment of not less than 10 t.

6 Testing

6.1 Materials testing certificates

Tubes complying with this standard shall be supplied with one of the DIN 50 049 certificates:

a) certificate DIN 50 049 – 3.1 A (inspection certificate A);
b) certificate DIN 50 049 – 3.1 B (inspection certificate B);
c) certificate DIN 50 049 – 3.1 C (inspection certificate C).

Table 7 summarizes the types and scope of tests to be performed as part of inspection and indicates the associated certificates.

6.1.1 Inspection certificates shall give the following details:

a) results of tests as described in subclause 6.3 and carried out in accordance with subclause 6.5;
b) details and results of any additional checks or tests agreed (cf. subclause 4.3);
c) marking (cf. clause 7).

Moreover, a DIN 50 049 – 2.2 certificate (test report) giving the results of the ladle analysis for all the elements listed in table 1 for the steel grade concerned shall be issued. These results may also be reported in the inspection certificate. Inspection certificates shall clearly correlate tube marking and associated results.

6.2 Test site

Tubes shall be tested at the manufacturer's works. Production shall not be unduly disturbed when acceptance inspection is carried out by experts who are not employees of the manufacturer.

6.3 Scope of testing

6.3.1 Tubes shall be inspected by batches, testing of as manufactured lengths being permitted, in which case this shall be indicated in the certificate. See table 7 for details.

6.3.1.1 For the purposes of testing, tubes shall be divided according to steel grade, cast and size, into batches each comprising 100 units. Remainders of up to 50 units may be distributed uniformly across the other batches, remainders over 50 units and consignments of less than 50 units being considered a whole batch.

6.3.2 For testing as described in subclauses 6.5.1 to 6.5.6, two sample tubes shall be taken from the first two batches (cf. subclause 6.3.1) and one sample tube from each further batch, as selected by the inspector, taking care to ensure that all casts are represented by the samples taken.

6.3.3 One test tube each shall be taken from consignments or batches containing not more than ten tubes.

6.3.4 The following tests shall be carried out on the sample tubes:

a) tensile test at ambient temperature;

b) impact test on tubes made from grades 25 CrMo 4, X 20 CrMoV 12 1 and 20 CrMoV 13 5 and having a wall thickness exceeding 10 mm; for the other grades, this test shall be performed on tubes with a wall thickness exceeding 30 mm.

6.3.5 ●● If Brinell hardness testing has been agreed at the time of ordering, each tube shall be tested. Where possible, the tube with the minimum hardness shall be subjected to a tensile test and that with the maximum hardness, to an impact test.

6.3.6 ●● If verification of the elevated temperature 0,2 % proof strength has been agreed at the time of ordering, the test temperature shall be stated. Unless otherwise agreed, one sample per cast and size shall be tested.

6.3.7 ●● If performance of a product analysis has been agreed at the time of ordering, one sample tube shall be checked.

6.3.8 Furthermore, each tube shall be

6.3.8.1 tested, at the manufacturer's works, for leak tightness, normally by an internal hydrostatic pressure test (cf. subclause 6.5.6);

6.3.8.2 subjected, at the manufacturer's works, to a materials identity test;

6.3.8.3 inspected for surface appearance;

6.3.8.4 inspected for its accuracy to size (cf. subclause 5.10);

6.3.8.5 subjected, at the manufacturer's works, to non-destructive testing for longitudinal imperfections (cf. subclause 6.5.8).

6.3.8.5.1 ●● If so agreed at the time of ordering, each tube shall be tested for transverse imperfections and/or laminations by a non-destructive method (cf. subclauses 6.5.9 and 6.5.10);

6.3.8.6 Both ends of tubes with a wall thickness smaller than 40 mm shall be subjected to a flattening test for each as manufactured length (cf. subclause 6.5.4).

6.3.8.7 Tubes with a wall thickness greater than 40 mm shall be subjected to a non-destructive test instead of a flattening test, testing being carried out on both tube ends over a length of 25 mm, as described in *Stahl-Eisen-Prüfblatt* 1919 (cf. subclause 6.5.10).

6.4 Sampling and sample preparation

See figure 1 for location and orientation of test pieces.

6.4.1 Tensile test

6.4.1.1 For the tensile test, a plate specimen as specified in DIN 50 140 or a cylindrical test piece as specified in DIN 50 125 shall be taken parallel to the tube axis. Test piece and specimen shall not be heat treated nor straightened within the gauge length.

For tubes with a wall thickness exceeding 30 mm, the centre line of the cylindrical test piece shall run at a distance of one quarter of the wall thickness from the external surface or as close as possible to this point.

6.4.1.2 At the discretion of the manufacturer, samples may be taken transverse to the tube axis and machined into flat or cylindrical test pieces (cf. DIN 50 125) in the case of tubes with an outside diameter of 200 mm or more, provided that no prior straightening of the material is required.

6.4.2 Impact test

For the impact test, a set of three ISO V-notch test pieces shall be taken transverse to the tube axis provided that no prior straightening of the material is required. Otherwise, the test pieces shall be taken parallel to the tube axis. For tubes with a wall thickness exceeding 30 mm, the centre line of the cylindrical test pieces shall run at a distance of one quarter of the wall thickness from the external surface or as close as possible to this point.

The test pieces shall be taken and prepared so that the notch axis runs at right angles to the tube surface.

6.4.3 Flattening test

The test pieces for the flattening test as described in DIN 50 136 shall be taken from both ends of an as manufactured length, the end from which the test piece was taken being clearly identified.

If ends of as manufactured lengths are cut into sections, no further test pieces need be taken from such sections provided that these can be traced to the original tube tested by means of suitable marking.

6.4.4 Chemical composition

For performing a product analysis, sample chips shall be taken at points uniformly distributed over the wall thickness, this also applying where a spectral analysis is to be carried out. Unless otherwise specified, sampling shall be in accordance with *Stahl-Eisen-Prüfblatt* 1805.

6.5 Test procedure

6.5.1 The tensile test shall be carried out as described in DIN 50 140 or DIN 50 145.

6.5.2 If determination of the elevated temperature 0,2 % proof strength has been agreed, this shall be determined as described in DIN 50 145.

6.5.3 The impact test shall be carried out as specified in DIN 50 115.

The minimum values specified in table 3 shall apply for the average from three single values, of which only one may be lower, by a maximum of 30 %, than the specified minimum value.

6.5.4 The flattening test shall be carried out as described in DIN 50 136, the test pieces or tube ends being flattened until a specified distance between platens, H, is reached. This distance, in mm, is to be calculated from the following equation:

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

where

s is the wall thickness, in mm;

d_a is the outside diameter, in mm;

c is a constant which is

- 0,07 for grades 13 CrMo 4 4, 10 CrMo 9 10, 12 CrMo 19 5 G, and X 12 CrMo 9 1 G;
- 0,05 for grades 25 CrMo 4, 12 CrMo 9 10, 12 CrMo 12 10, 12 CrMo 19 5 V 1 or V 2, X 12 CrMo 9 1 V, and X 20 CrMoV 12 1;
- 0,045 for grade 20 CrMoV 13 5.

If the ratio s/d_a exceeds a value of 0,17, the test piece areas adjoining the platens may be worked off until a flat surface is obtained, the width of which is approximately equal to the wall thickness of the tube.

6.5.5 The chemical composition shall be tested using methods specified by the Chemists' Committee of the *Verein Deutscher Eisenhüttenleute* (cf. 'Standards and other documents referred to' clause).

6.5.6 The leak tightness of tubes shall be checked by subjecting them to an internal hydrostatic pressure test as described in DIN 50 104, at a test pressure of 80 bar.

6.5.6.1 ●● A higher test pressure may be agreed.

6.5.6.2 The test pressure shall be maintained for at least five seconds.

6.5.6.3 If the conditions of the pressure test preclude that the load level exceeds a value equal to $0{,}7 \cdot R_{eH}$ (corresponding to about 1,5 times the safety margin with respect to the yield strength), the manufacturer may perform an appropriate non-destructive test (e.g. an electromagnetic inspection as specified in *Stahl-Eisen-Prüfblatt* 1925) instead of the hydrostatic pressure test.

6.5.7 The appearance of the outer and, if possible, inner tube surface shall be examined visually under appropriate lighting conditions by an inspector having normal vision. If so agreed, another method of checking the appearance may be used.

6.5.8 Non-destructive testing shall be performed in the form of an ultrasonic examination of the entire tube surface for longitudinal imperfections, as described in *Stahl-Eisen-Prüfblatt* 1915.

6.5.8.1 ●● If the wall thickness/diameter ratio precludes such an examination, it may be agreed that ultrasonic testing (e.g. ultrasonic testing as specified in *Stahl-Eisen-Prüfblatt* 1915) be performed at the next manufacturing stage of the tube permitting testing to be carried out.

6.5.9 If it has been agreed that tubes with an outside diameter exceeding 133 mm are to be examined for transverse imperfections, non-destructive testing as specified in *Stahl-Eisen-Prüfblatt* 1918 shall be carried out.

6.5.10 If it has been agreed that tubes with an outside diameter exceeding 133 mm and a wall thickness exceeding 8 mm are to be examined for laminations, non-destructive testing as specified in *Stahl-Eisen-Prüfblatt* 1919 shall be carried out, including ends of tubes with a wall thickness of 40 mm and more (cf. subclause 6.3.8.7).

6.5.11 The wall thickness shall be measured at the tube ends using suitable instruments.

6.5.12 The diameter and circularity of the tubes shall be determined by way of a two-point measurement using suitable instruments, the circularity being checked by measurement in one cross-sectional plane.

6.5.13 The hardness test shall be carried out as described in DIN 50 351, either on the tube surface or on test pieces taken for the flattening test.

6.5.14 The materials identity test shall be carried out in a suitable manner (e.g. by spectroscopy).

6.6 Retests

6.6.1 Tubes not satisfying the requirements when tested as specified in subclauses 6.5.4 and 6.5.6 to 6.5.12 shall be rejected. The manufacturer shall have the right to take suitable measures to make good defects or deficiencies established in the course of testing and to present these tubes for renewed acceptance inspection.

6.6.2 If one of the sample tubes fails in any of the tests specified in subclauses 6.5.1 and 6.5.3 and in any of the tests (where agreed) specified in subclauses 6.5.2 and 6.5.13, the manufacturer is entitled to repeat the test giving unsatisfactory results on twice the number of test pieces taken from the same tube. All such test pieces shall then satisfy the requirements. Otherwise, the tube shall be rejected.

Two further tubes shall be taken from the batch concerned in place of the rejected sample tube and submitted for testing as specified in subclauses 6.5.1 and 6.5.3, or 6.5.2 and 6.5.13 where applicable. If the requirements are still not fulfilled, the entire batch shall be considered not to comply with the standard. However, testing of individual tubes may be agreed.

6.6.3 If the defects or deficiencies established can be made good by means of heat treatment or other suitable measures, the supplier shall be given the opportunity to present a batch which was rejected for renewed acceptance inspection. If the test pieces still fail to satisfy the requirements, the entire batch shall be considered not to comply with the standard.

7 Marking

7.1 Tubes shall be clearly and durably marked, at a distance of about 300 mm from one end, as follows:

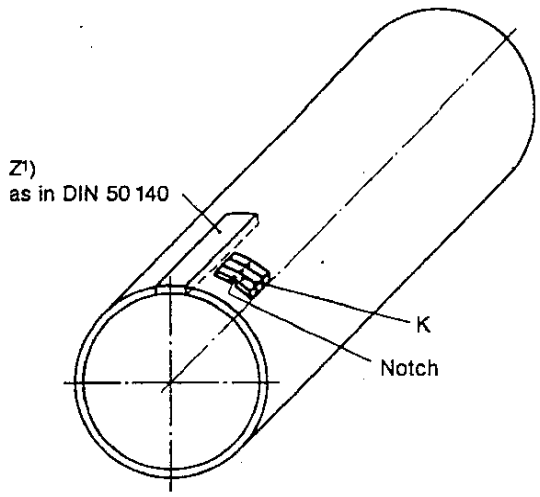
a) manufacturer's mark;
b) steel grade (material number);
c) symbol denoting heat treatment condition;
d) article number;
e) inspector's mark;
f) where applicable, symbol indicating that a non-destructive test as specified in subclause 6.3.8.5.1 has been carried out.

7.2 Marking as specified in subclause 7.1 shall generally be applied by stamping, embossing or printing. Alternatively, tubes with a smaller outside diameter and/or a small wall thickness may be marked by a different method (e.g. by labelling tubes in bundles).

8 Complaints

8.1 Under current law, warranty claims may only be raised against defective tubes if the defects impair their processing and use to a more than negligible extent. This shall apply unless otherwise agreed at the time of ordering.

8.2 It is normal and practical for the purchaser to give the supplier the opportunity to judge whether the complaints are justified, by submitting the tube objected to or samples of the tubes supplied, if possible.



In the illustration above,

K = set of three ISO V-notch test pieces, as specified in DIN 50 115;

Z = tensile test piece (cf. subclause 6.4.1).

Figure 1. Test piece location and orientation

[1]) Cf. subclauses 6.4.1.1 and 6.4.1.2.

Table 1. **Steel grades and their chemical composition as determined by ladle analysis**

Steel grade		Percentage by mass									
Material designation	Material number	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	V	Others
25 CrMo 4[1]	1.7218	0,22 to 0,29	≤ 0,40	0,60 to 0,90	0,035	0,030	0,90 to 1,20	0,15 to 0,30	–	–	
13 CrMo 4 4	1.7335	0,10 to 0,18[2]	0,10 to 0,35	0,40 to 1,00	0,025	0,020	0,70 to 1,10	0,40 to 0,65	–	–	
10 CrMo 9 10	1.7380	0,08 to 0,15	≤ 0,50	0,40 to 0,70	0,025	0,020	2,0 to 2,5	0,90 to 1,20	–	–	
12 CrMo 9 10	1.7375	0,10 to 0,15	≤ 0,30	0,30 to 0,80	0,015	0,015	2,0 to 2,5	0,90 to 1,10	< 0,30	–	Al ≥ 0,010 Cu < 0,20
12 CrMo 12 10	1.7381	0,06 to 0,15	≤ 0,50	0,30 to 0,60	0,025	0,020	2,65 to 3,35	0,80 to 1,06	–	–	
12 CrMo 19 5	1.7362	0,08 to 0,15	≤ 0,50	0,30 to 0,60	0,025	0,020	4,0 to 6,0	0,45 to 0,65	–	–	
X 12 CrMo 9 1	1.7386	0,07 to 0,15	0,25 to 1,00	0,30 to 0,60	0,025	0,020	8,0 to 10,0	0,90 to 1,10	–	–	
20 CrMoV 13 5	1.7779	0,17 to 0,23	0,15 to 0,35	0,30 to 0,50	0,025	0,020	3,0 to 3,3	0,50 to 0,60	–	0,45 to 0,55	
X 20 CrMoV 12 1	1.4922	0,17 to 0,23	≤ 0,50	≤ 1,00	0,025	0,020	10,0 to 12,50	0,80 to 1,20	0,30 to 0,80	0,25 to 0,35	

[1]) At the manufacturer's discretion, grade 24 CrMo 5, material number 1.7258, may be substituted for grade 25 CrMo 4.
[2]) For wall thicknesses not less than 30 mm, the carbon content may be up to 0,02 % higher.

Table 2. **Amounts by which the chemical analysis as determined by product analysis may deviate from the limiting values specified for ladle analysis**

Element	Limiting values as determined by ladle analysis, as in table 1, as a percentage by mass	Limit deviations in the product analysis from the limiting values specified for the ladle analysis, as a percentage by mass[1)]	Element	Limiting values as determined by ladle analysis, as in table 1, as a percentage by mass	Limit deviations in the product analysis from the limiting values specified for the ladle analysis, as a percentage by mass[1)]
C	≤ 0,29	0,02	Cr	≤ 1,00 > 1,00 ≤ 10,00 > 10,00 ≤ 12,50	0,05 0,10 0,15
Si	≤ 0,35 > 0,35 ≤ 1,00	0,05 0,06	Cu	≤ 0,20	0,05
Mn	≤ 1,00	0,05	Mo	≤ 0,35 > 0,35 ≤ 1,20	0,03 0,04
P	≤ 0,035	0,005			
S	≤ 0,030	0,005	Ni	≤ 0,80	0,05
Al	≥ 0,010	0,005	V	≤ 0,55	0,03

[1)] If a number of product analyses are to be carried out, the deviations shown by an element within one cast shall lie either only above the upper limit or below the lower limit of the range specified for the ladle analysis, but not both at the same time for one cast.

Table 3. **Mechanical properties at ambient temperature**

Steel grade		Heat treatment condition[1)]	Wall thickness, s[2)], in mm	Yield strength, R_{eH}[3)], in N/mm²	Tensile strength, R_m, in N/mm²	Minimum elongation after fracture, A_5, as a percentage		Minimum impact value[4)] (ISO V-notch test piece), in J	
Material designation	Material number					Longitudinal*)	Transverse*)	Longitudinal*)	Transverse*)
25 CrMo 4	**1.7218**	V	≤ 100	345	540 to 690	18	15	40	27
13 CrMo 4 4	**1.7335**	V	≤ 10	305	440 to 590	22	20	40	27
			> 10 ≤ 40	290					
			> 40 ≤ 60	280					
			> 60 ≤ 80	270					
10 CrMo 9 10	**1.7380**	V	≤ 40	280	450 to 600	20	18	40	27
			> 40 ≤ 60	270					
			> 60 ≤ 80	260					
12 CrMo 9 10	**1.7375**	V	≤ 100	355	540 to 690	20	18	80	64
12 CrMo 12 10	**1.7381**	V	≤ 100	355	540 to 690	20	18	64	48
12 CrMo 19 5	**1.7362**	G	≤ 100	175	410 to 540	22	18	55	39
		V 1	≤ 100	275	470 to 640	20	17	55	39
		V 2	≤ 100	390	570 to 740	18	16	55	39
X 12 CrMo 9 1	**1.7386**	G	≤ 100	210	460 to 640	21	19	55	34
		V	≤ 100	390	590 to 740	20	18	55	34
20 CrMoV 13 5	**1.7779**	V	≤ 100	590	740 to 880	17	13	55	34
X 20 CrMoV 12 1	**1.4922**	V	≤ 80	490	690 to 840	16	14	40	27

[1)] Key to symbols: G = annealed, V = solution or air quenched and tempered, V 1 and V 2 being used to distinguish between different heat treatment stages resulting in different mechanical properties.

[2)] ● ● For greater wall thicknesses, the mechanical properties are to be agreed.

[3)] If there is no pronounced yield strength, the values shall apply for the 0,2 % proof strength.

[4)] Average from three pieces, with only one single value lower, by not more than 30 %, than the specified minimum average value.

*) Refers to direction of sampling.

Table 4. **Minimum values of elevated temperature 0,2 % proof strength**

Steel grade		Heat treatment condition [1]	Wall thickness, s [2], in mm	Minimum 0,2 % proof strength, in N/mm², at a test temperature of									
Material designation	Material number			100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C	500 °C	550 °C
25 CrMo 4	**1.7218**	V	≤ 100	325	315	305	295	285	265	225	185	–	–
13 CrMo 4 4	**1.7335**	V	≤ 10	265	260	255	245	230	215	205	195	190	–
			> 10 ≤ 40	250	245	240	230	215	200	190	180	175	–
			> 40 ≤ 60	240	235	230	220	205	190	180	170	165	–
			> 60 ≤ 80	230	225	220	210	195	180	170	160	155	–
10 CrMo 9 10	**1.7380**	V	≤ 40	255	250	245	240	230	215	205	195	185	–
			> 40 ≤ 60	245	240	235	230	220	205	195	185	175	–
			> 60 ≤ 80	235	230	225	220	210	195	185	175	165	–
12 CrMo 9 10	**1.7375**	V	≤ 100	338	319	319	309	304	294	284	275	–	–
12 CrMo 12 10	**1.7381**	V	≤ 100	338	319	319	309	304	294	284	275	–	–
12 CrMo 19 5	**1.7362**	G	≤ 100	156	150	148	147	145	142	137	129	116	–
		V 1	≤ 100	245	237	230	223	216	206	196	181	167	–
		V 2	≤ 100	366	350	334	322	309	299	289	280	265	–
X 12 CrMo 9 1	**1.7386**	G	≤ 100	187	186	178	177	175	171	164	153	142	120
		V	≤ 100	375	365	355	345	335	325	315	295	275	–
20 CrMoV 13 5	**1.7779**	V	≤ 100	580	575	570	560	550	210	470	420	370	–
X 20 CrMoV 12 1	**1.4922**	V	≤ 80	460	445	430	415	390	380	360	330	290	250

[1] Key to symbols: G = annealed, V = solution or air quenched and tempered, V 1 and V 2 being used to distinguish between different heat treatment stages resulting in different mechanical properties.

[2] ●● For greater wall thicknesses, the values of 0,2 % proof strength are to be agreed.

Table 5. **Types of tube length and limit deviations**

Type of length		Limit deviations, in mm
As manufactured length[1]		[1]
Specified length		± 500
Exact length	Up to 6 m	+ 10 0
	Over 6 up to 12 m	+ 15 0
	Over 12 m	By agreement.

[1] The tubes are supplied in the as manufactured lengths.
● These lengths vary as a function of outside diameter, wall thickness and manufacturer, and shall be agreed at the time of ordering.

Table 6. **Limit deviations as a function of manufacturing process used**

Manufacturing process	Limit deviation of outside diameter, d_a		Limit deviation of wall thickness, s								
Cold forming	$\pm 0{,}75\ \% \ d_a$		$\pm 10\ \%$								
Hot forming	Up to 100 mm	$\pm 0{,}75\ \% \ d_a$	For d_a not exceeding 130 mm			For d_a over 130 mm up to 320 mm			For d_a over 320 mm up to 660 mm		
	Over 100 mm up to 320 mm	$\pm 0{,}9\ \% \ d_a$	...and s $\leq 2 \cdot s_n$	$2 \cdot s_n < s \leq 4 \cdot s_n$	$> 4 \cdot s_n$	$\leq 0{,}05\ d_a$	$0{,}05\ d_a < s \leq 0{,}11\ d_a$	$> 0{,}11\ d_a$	$\leq 0{,}05\ d_a$	$0{,}05\ d_a < s \leq 0{,}09\ d_a$	$> 0{,}09\ d_a$
	Over 320 mm	$\pm 1{,}0\ \% \ d_a$	+ 15 % − 10 %	+ 12,5 % − 10 %	± 9 %	+ 17,5 % − 12,5 %	± 12,5 %	± 10 %	+ 20 % − 15 %	+ 15 % − 12,5 %	+ 12,5 % − 10 %

Note. s_n is the recommended wall thickness specified in DIN 2448.

Table 7. **Scope of testing and DIN 50 049 certificates**

No.	Testing		Scope of testing	Type of certificate
	Type of test/check/analysis	Cf. subclause		
1	Ladle analysis	5.3.1	All elements for steel grade concerned as in table 1, per cast or casting unit.	DIN 50 049-2.2
2	Tensile test at ambient temperature	6.3.2 6.4.1 6.5.1	One test piece each, taken from two sample tubes of the first two batches and from one sample tube of each further batch.	DIN 50 049-3.1 A or DIN 50 049-3.1 B or DIN 50 049-3.1 C
3	Impact test	6.3.2 6.4.2 6.5.3	For wall thicknesses > 10 mm, one set of three test pieces per sample tube specified unter item No. 2.	DIN 50 049-3.1 A or DIN 50 049-3.1 B or DIN 50 049-3.1 C
4	Flattening test	6.3.8.6 6.4.3 6.5.4	For wall thicknesses < 40 mm, at both ends of each as manufactured length.	DIN 50 049-3.1 A or DIN 50 049-3.1 B or DIN 50 049-3.1 C
5	Non-destructive testing of tube ends for laminations	6.3.8.7 6.5.10	For wall thicknesses ≥ 40 mm, all tubes, over a length of 25 mm.	DIN 50 049-3.1 B
6	Non-destructive testing of tube ends for longitudinal imperfections	6.3.8.5 6.5.8	All tubes	DIN 50 049-3.1 B
7	Leak tightness test	6.3.8.1 6.5.6	All tubes	DIN 50 049-3.1 B
8	Visual examination	6.3.8.3 6.5.7	All tubes	DIN 50 049-3.1 A or DIN 50 049-3.1 B or DIN 50 049-3.1 C
9	Materials identity test	6.3.8.2 6.5.14	All tubes	DIN 50 049-3.1 B
10	Dimensional check	6.3.8.4 6.5.11 6.5.12	All tubes	DIN 50 049-3.1 A or DIN 50 049-3.1 B or DIN 50 049-3.1 C
11	●● Brinell hardness test as a preliminary stage to establish the homogeneity of the batch in terms of mechanical properties	6.3.5 6.5.13 (6.4.1) (6.5.1) (6.4.2) (6.5.3)	All tubes, plus one tensile test on tube with minimum hardness and one impact test on tube with maximum hardness.	DIN 50 049-3.1 B
12	●● Non-destructive testing for transverse imperfections and/or laminations	6.5.9 6.5.10	All tubes	DIN 50 049-3.1 B
13	●● Hot tensile test	6.3.6 6.5.2	Unless otherwise agreed, one test piece per cast and size.	DIN 50 049-3.1 A or DIN 50 049-3.1 B or DIN 50 049-3.1 C
14	●● Product analysis	5.3.2 6.3.7 6.4.4 6.5.5	One test on one sample tube per batch.	DIN 50 049-3.1 B

Appendix A

Estimated creep limit and stress rupture, and elevated temperature tensile strength values

Table A.1 gives provisional creep limit and stress rupture values for tubes as specified in this standard, which represent average values deriving from the dispersion of values obtained from tests performed to date. These average values will be reviewed from time to time in the light of new test results, and amended where necessary. Data obtained from creep tests indicate that the lower limit of dispersion of rupture stress values for the steel grades and temperatures listed lies about 20 % below the average values specified here.

Table A.1. **Estimated creep and stress rupture values**

Steel grade	Temperature, in °C	1 % creep limit[1], in N/mm², for		Rupture stress[2], in N/mm², for		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
25 CrMo 4	420	274	221	387	308	
	430	258	203	364	281	
	440	242	186	338	253	
	450	226	171	311	226	
	460	210	155	283	200	
	470	195	141	255	178	
	480	180	127	226	157	
	490	163	112	200	136	
	500	147	98	176	118	
	510	130	83	153	100	
	520	115	69	133	82	
	530	98	54	114	66	
	540	81	39	95	51	
	550	64	25	79	36	
13 CrMo 4 4	450	245	191	370	285	260
	460	228	172	348	251	226
	470	210	152	328	220	195
	480	193	133	304	190	167
	490	173	116	273	163	139
	500	157	98	239	137	115
	510	139	83	209	116	96
	520	122	70	179	94	76
	530	106	57	154	78	62
	540	90	46	129	61	50
	550	76	36	109	49	39
	560	64	30	91	40	32
	570	53	24	76	33	26
10 CrMo 9 10	450	240	166	306	221	201
	460	219	155	286	205	186
	470	200	145	264	188	169
	480	180	130	241	170	152
	490	163	116	219	152	136
	500	147	103	196	135	120
	510	132	90	176	118	105
	520	119	78	156	103	91
	530	107	68	138	90	79
	540	94	58	122	78	68
	550	83	49	108	68	58
	560	73	41	96	58	50
	570	65	35	85	51	43
	580	57	30	75	44	37
	590	50	26	68	38	32
	600	44	22	61	34	28

For [1] and [2], see end of table.

Table A.1 (continued).

Steel grade	Temperature, in °C	1 % creep limit[1], in N/mm², for		Rupture stress[2], in N/mm², for		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
12 CrMo 9 10	400			382	313	
	410			355	289	
	420			333	272	
	430			312	255	
	440			293	238	
	450			276	221	
	460			259	204	
	470			242	187	
	480			225	170	
	490			208	153	
	500			191	137	
	510			174	122	
	520			157	107	
12 CrMo 19 5 V1	350	206	189	330	299	287
	360	199	182	319	289	277
	370	192	174	308	278	266
	380	185	166	297	266	254
	390	178	158	286	252	240
	400	171	149	275	237	225
	410	163	139	264	221	209
	420	155	129	250	205	193
12 CrMo 19 5 V1 und V2	430	147	119	235	189	177
	440	139	109	220	173	161
	450	131	99	205	158	145
	460	123	91	190	143	129
	470	115	82	175	128	115
12 CrMo 19 5 V1 und V2, B	480	107	75	160	113	102
	490	99	70	145	100	89
	500	91	65	130	90	79
	510	83	60	119	81	70
	520	75	55	108	73	63
	530	67	50	98	65	56
	540	59	45	88	57	49
	550	52	40	79	50	42
	560	46	35	71	44	35
	570	41	30	64	38	30
	580	36	25	57	33	26
	590	32	20	50	28	23
	600	28	17	43	24	20
	610	-	-	38	21	17
	620	-	-	33	18	15
	630	-	-	29	16	13
	640	-	-	25	14	11
	650	-	-	22	12	10

For [1] and [2], see end of table.

Table A.1 (continued).

Steel grade	Temperature, in °C	1 % creep limit[1], in N/mm², for		Rupture stress[2], in N/mm², for		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
X 12 CrMo 9 1 V	400	345	280	395	355	338
	410	322	258	377	331	314
	420	299	237	359	306	291
	430	277	217	341	287	270
	440	256	198	323	267	250
	450	235	180	305	248	232
	460	217	166	287	232	216
	470	199	152	269	216	201
	480	182	138	251	201	186
	490	166	125	233	185	171
	500	150	112	215	170	156
	510	136	100	197	154	140
	520	122	89	180	138	125
	530	108	78	163	122	110
	540	96	68	146	106	95
	550	85	58	130	90	80
	560	75	50	115	78	67
	570	65	42	100	67	56
	580	56	35	87	56	46
	590	48	30	75	46	37
	600	41	27	64	38	32
	610	35	22	55	31	26
	620	30	18	47	27	23
	630	25	15	41	23	19
	640	21	12	35	19	16
	650	18	11	30	17	14
X 12 CrMo 9 1 G	460	164	-	275	190	-
	470	144	-	240	170	-
	480	125	-	210	150	-
	490	110	-	190	130	-
	500	98	-	170	115	-
	510	86	-	152	102	-
	520	76	-	134	89	-
	530	66	-	118	78	-
	540	57	-	104	67	-
	550	50	-	90	58	-
	560	43	-	78	49	-
	570	37	-	68	42	-
	580	33	-	60	37	-
	590	29	-	53	33	-
	600	26	-	48	30	-

For 1) and 2), see end of table.

Table A.1 (concluded).

Steel grade	Temperature, in °C	1 % creep limit[1], in N/mm², for		Rupture stress[2], in N/mm², for		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
20 CrMoV 13 5	410			490	460	
	420			470	420	
	430			440	370	
	440			410	310	
	450			360	260	
	460			310	220	
	470			270	190	
	480			240	165	
	490			210	145	
	500			186	127	
	510			169	114	
	520			152	101	
	530			134	87	
	540			117	74	
	550			98	59	
X 20 CrMoV 12 1	470	324	260	368	309	285
	480	299	236	345	284	262
	490	269	213	319	260	237
	500	247	190	294	235	215
	510	227	169	274	211	191
	520	207	147	253	186	167
	530	187	130	232	167	147
	540	170	114	213	147	128
	550	151	98	192	128	111
	560	135	85	173	112	96
	570	118	72	154	96	81
	580	103	61	136	82	68
	590	90	52	119	70	58
	600	75	43	101	59	48
	610	64	36	87	50	40
	620	53	30	73	42	33
	630	44	25	60	34	27
	640	36	20	49	28	22
	650	29	17	40	23	18

1) Stress related to initial cross section, which results in a 1 % permanent strain after 10 000 or 100 000 hours.

2) Stress related to initial cross section, which results in rupture after 10 000, 100 000 or 200 000 hours.

Table A.2. **Estimated elevated temperature tensile strength values**
(The values given are minimum values established to date.)

Steel grade		Heat treatment condition[1]	Wall thickness, s, in mm	Minimum tensile strength, in N/mm², at									
Material designation	Material number			100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C	500 °C	550 °C
25 CrMo 4	**1.7218**	V	≤ 100	500	480	470	460	450	430	390	350	310	–
13 CrMo 4 4	**1.7335**	V	≤ 80	–	–	390	390	390	390	385	365	335	–
10 CrMo 9 10	**1.7380**	V	≤ 80	–	–	390	390	390	390	385	365	335	–
12 CrMo 9 10	**1.7375**	V	≤ 100	500	480	460	450	440	430	410	380	–	–
12 CrMo 12 10	**1.7381**	V	≤ 100	500	480	460	450	440	430	410	380	–	–
12 CrMo 19 5	**1.7362**	G	≤ 100	360	350	340	340	340	330	320	300	270	–
		V 1	≤ 100	450	425	400	400	390	380	360	335	310	–
		V 2	≤ 100	550	525	500	480	460	440	415	390	350	–
X 12 CrMo 9 1	**1.7386**	G	≤ 100	380	360	350	350	350	350	330	305	280	–
		V	≤ 100	550	525	500	490	480	460	430	405	360	–
20 CrMoV 13 5	**1.7779**	V	≤ 100	690	670	650	630	610	570	520	465	410	–
X 20 CrMoV 12 1	**1.4922**	V	≤ 80	650	625	600	590	580	545	510	455	400	325

[1] Key to symbols: V = solution or air quenched; G = annealed, V 1 and V 2 being used to distinguish between different heat treatment stages resulting in different mechanical properties.

Appendix B

Table B.1. **Information on temperatures required for hot working and heat treatment**

Steel grade		Heat treatment condition[1]	Hot working temperature, in °C	Softening (soaking/cooling temperature/ duration/medium)	Quenching and tempering	
Material designation	Material number				Quench hardening at a temperature, in °C, of	Tempering at a temperature, in °C, of
25 CrMo 4	**1.7218**	V	1100 to 850[3]	–	880 to 920	620 to 680
13 CrMo 4 4	**1.7335**	V		–	910 to 940	660 to 730
10 CrMo 9 10[2]	**1.7380**[2]	V		–	900 to 960	700 to 750
12 CrMo 9 10	**1.7375**	V		–	900 to 960	680 to 710
12 CrMo 12 10	**1.7381**	V		–	900 to 960	680 to 710
12 CrMo 19 5	**1.7362**	G		See footnote 5 for procedure.	–	–
		V 1, V 2		–	930 to 980	710 to 760
X 12 CrMo 9 1	**1.7386**	G		See footnote 6 for procedure.	–	–
		V		–	960 to 1000	730 to 800[4]
20 CrMoV 13 5	**1.7779**	V		–	980 to 1030	680 to 730
X 20 CrMoV 12 1	**1.4922**	V		–	1020 to 1070	730 to 780

1) Key to symbols: G = annealed; V = solution or air quenched.

2) This grade may also be subjected to the following heat treatment: soaking at 900 to 960 °C, cooling in a furnace to 700 °C, soaking for not less one hour at 700 °C, followed by cooling in air.

3) In the process, the temperature may drop to 750 °C.

4) Tempering should immediately follow quench hardening treatment since hardened steel is susceptible to stress corrosion cracking.

5) Soaking at 920 to 980 °C, cooling in a furnace for 2 to 4 hours to 700 to 720 °C, followed by cooling in air. Or, soaking at 950 to 980 °C, retarded cooling in a furnace to 550 °C, followed by cooling in air.

6) Soaking at 950 to 980 °C, cooling in a furnace for 2 to 4 hours to 700 to 720 °C, followed by cooling in air. Or, soaking at 950 to 980 °C, retarded cooling in a furnace to 550 °C, followed by cooling in air.

Standards and other documents referred to

DIN 2391 Part 1	Seamless precision steel tubes; dimensions
DIN 2448	Seamless steel pipes and tubes; dimensions and mass per unit length
DIN 8528 Part 1	Weldability of metallic materials; concepts
DIN 8575 Part 1	Filler metals for arc welding of creep resisting steels; classification, designation and technical delivery conditions
DIN 17 204	Seamless circular tubes made of quenched and tempered steel; technical delivery conditions
DIN 50 049	Materials testing certificates in an internal pressure test
DIN 50 104	Testing the leak tightness of hollow bodies
DIN 50 115	Testing of metallic materials; notched bar impact test
DIN 50 125	Testing of metallic materials; tensile test pieces
DIN 50 136	Testing of metallic materials; flattening test on tubes
DIN 50 140	Testing of metallic materials; tensile testing of tubes and tube sections
DIN 50 145	Testing of metallic materials; tensile test
DIN 50 351	Testing of metallic materials; Brinell hardness test
ISO 4200 : 1985	Plain end steel tubes, welded and seamless; general tables of dimensions and masses per unit length.
Stahl-Eisen-Prüfblatt 1805*)	*Probenahme und Probenvorbereitung für die Stückanalyse bei Stählen* (Sampling and sample preparation for the product analysis of steel).
Stahl-Eisen-Prüfblatt 1915*)	*Ultraschallprüfung auf Längsfehler von Rohren aus warmfesten Stählen* (Ultrasonic testing for longitudinal defects in steel tubes with elevated temperature properties).
Stahl-Eisen-Prüfblatt 1918*)	*Ultraschallprüfung auf Querfehler von Rohren aus warmfesten Stählen* (Ultrasonic testing for transverse defects in steel tubes with elevated temperature properties).
Stahl-Eisen-Prüfblatt 1919*)	*Ultraschallprüfung auf Doppelungen von Rohren aus warmfesten Stählen* (Ultrasonic testing for laminations in steel tubes with elevated temperature properties)
Stahl-Eisen-Prüfblatt 1925*)	*Elektromagnetische Prüfung von Rohren zum Nachweis der Dichtheit* (Electromagnetic testing of tubes for verification of leak tightness).
Stahl-Eisen-Werkstoffblatt 590-61*)	*Druckwasserstoffbeständige Stähle* (Steels for hydrogen service at elevated temperatures and pressures).
*Handbuch für das Eisenhüttenlaboratorium**) (Loose-leaf collection)	
API Publication 941**)	Steels for hydrogen service at elevated temperatures and pressures in petroleum refineries and petrochemical plants.

Explanatory notes

This standard is based on *Stahl-Eisen-Werkstoffblatt* (Iron and steel materials sheet) 590-61 *Druckwasserstoffbeständige Stähle* issued by the *Verein Deutscher Eisenhüttenleute* (Society of German Ferrous Metallurgy Engineers). However, only grades 25 CrMo 4, 20 CrMoV 13 5 and X 20 CrMoV 12 1 have been adopted from this materials sheet. To meet current demands, six further grades have been included in this standard.

It should be noted that grade 25 CrMo 4 is also covered in DIN 17 204. However, since the steels specified here are to comply with more stringent requirements regarding resistance to hydrogen, the specifications regarding mechanical properties and heat treatment as given in this standard, differ from those of DIN 17 204. As the strength values given in this standard have proved adequate in piezochemistry for more than fifty years, it has been considered inappropriate to adopt specifications from DIN 17 204.

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**) Obtainable from the American Petroleum Institute, 2101 L Street, Washington, D.C., 20037.