INTERNATIONAL STANDARD

ISO 6931-1

Second edition
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Stainless steels for springs —

Part 1:
Wire

Aciers inoxydables pour ressorts —
Partie 1: Fils

Reference number
ISO 6931-1:1994(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 6931-1 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This second edition cancels and replaces the first edition (ISO 6931-1:1989), which has been technically revised.

ISO 6931 consists of the following parts, under the general title *Stainless steels for springs*:

— *Part 1: Wire*

— *Part 2: Strip*

Annex A of this part of ISO 6931 is for information only.

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Stainless steels for springs —

Part 1:
Wire

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1 Scope

1.1 This part of ISO 6931 applies to the grades of wrought stainless steels listed in table 1, which are used in the work-hardened condition in the form of wire up to about 10 mm in diameter, for the production of springs and spring parts that are exposed to corrosive effects and sometimes slightly increased temperatures (see A.1 in annex A).

1.2 In addition to the steels listed in table 1, certain of the steel grades covered by ISO 683-13 are also used for springs, although to a much lesser extent. In these cases, the physical properties (tensile strength etc.) shall be agreed between user and supplier.

1.3 In addition to this part of ISO 6931, the general technical delivery requirements of ISO 404 are applicable.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 6931. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 6931 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 377-1:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 1: Samples and test pieces for mechanical test.*

ISO 377-2:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 2: Samples for the determination of the chemical composition.*

ISO 404:1992, *Steel and steel products — General technical delivery requirements.*

ISO 683-13:1986, *Heat-treatable steels, alloy steels and free-cutting steels — Part 13: Wrought stainless steels.*

ISO 6892:1984, *Metallic materials — Tensile testing.*

ISO 7802:1983, *Metallic materials — Wire — Wrapping test.*

ISO/TR 9769:1991, *Steel and iron — Review of available methods of analysis.*

ISO 10474:1991, *Steel and steel products — Inspection documents.*

3 Ordering

The purchaser shall state in his enquiry and order

a) the desired quantity;

b) the wire diameter;

c) the number of this part of ISO 6931 (ISO 6931-1);

d) the steel grade (see table 1);

e) the delivery condition (see 4.2.2.1 and 4.2.2.2);

f) the surface condition (see 4.2.2.3);

g) the delivery form (see 4.2.1);

h) the required type of document (see 5.1.1).

EXAMPLE

— 2 t stainless spring wire, 2,00 mm, according to ISO 6931-1, steel grade 1, spring hard-drawn condition (C), normal strength (NS), coated, in coils. Inspection certificate 3.1.B according to ISO 10474,

or

— 2 t stainless spring wire, 2,00 mm, ISO 6931-1, grade 1, condition C, strength NS, coated, coils, document 3.1.B.

4 Requirements

4.1 Manufacture of the steel and the product

Unless otherwise agreed in the order, the processes used in making the steel and the product are left to the discretion of the manufacturer.

4.2 Delivery

4.2.1 Delivery form

Wire is usually supplied on spools, in coils or in cut lengths. Several coils may be assembled on a carrier.

4.2.2 Delivery condition

4.2.2.1 The condition in which the wire is to be delivered shall always be specified by the purchaser.

The possible delivery conditions are given in table 2.

The tempered condition (T) of grade 3 is not a standard delivery condition but can be agreed upon at the time of enquiry and order. The tempering may cause discoloration, see A.5.2.2.

4.2.2.2 Each coil shall consist of one continuous length of wire, wound so that there are no kinks. Wire delivered on spools or on a carrier may consist of a maximum of two wire lengths agreed upon at the time of enquiry and order.

Wire from a spool shall be in a circular cast of diameter not less than the barrel diameter of the spool and not more than 2,5 times this.

Wire in a coil shall be in a circular cast of diameter not less than the original coil diameter and not more than 1,5 times this.

Other diameters of circular casts can be agreed upon at the time of enquiry and order.

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Table 1 — Chemical composition of the steel (cast analysis)

Steel grade		Chemical composition[1] % (*m/m*)						
Number	Designation	C max.	Si max.	Mn max.	Al	Cr	Mo	Ni
1	X 9 CrNi 18-8	0,12	1,5	2,0	—	16,0 to 19,0	—	6,5 to 9,5
2	X 5 CrNiMo 17-12-2	0,07	1,0	2,0	—	16,5 to 18,5	2,0 to 2,5[2]	10,5 to 13,5
3	X 7 CrNiAl 17-7	0,09	1,0	1,0	0,75 to 1,50	16,0 to 18,0	—	6,5 to 7,5[3]

1) For all grades ⩽ 0,045 % (*m/m*) P and ⩽ 0,030 % (*m/m*) S.

2) Where the corrosion resistance is of particular importance, one can also agree to the delivery of type 20a of ISO 683-13, with the specifications of this part of ISO 6931 applicable for steel grade 2.

3) By special agreement, the steel, when intended for cold deformation, may also be ordered with 7,00 % (*m/m*) to 8,25 % (*m/m*) Ni.

Table 2 — Tensile strength in the spring hard-drawn condition (C) and additionally for grade 3 in the tempered condition (T)

Nominal diameter	Tensile strength, N/mm^2 1) 2) 3) 4) 5) 6)				
	Grade 1		Grade 2	Grade 3	
	Condition C		Condition C	Condition C	Condition T
	Normal strength (NS)	High strength (HS)			
mm	min.	min.	min.	min.	min.
⩽ 0,20	2 200	2 350	1 725	1 975	2 275
> 0,20 ⩽ 0,30	2 150	2 300	1 700	1 950	2 250
> 0,30 ⩽ 0,40	2 100	2 250	1 675	1 925	2 225
> 0,40 ⩽ 0,50	2 050	2 200	1 650	1 900	2 200
> 0,50 ⩽ 0,65	2 000	2 150	1 625	1 850	2 150
> 0,65 ⩽ 0,80	1 950	2 100	1 600	1 825	2 125
> 0,80 ⩽ 1,00	1 900	2 050	1 575	1 800	2 100
> 1,00 ⩽ 1,25	1 850	2 000	1 550	1 750	2 050
> 1,25 ⩽ 1,50	1 800	1 950	1 500	1 700	2 000
> 1,50 ⩽ 1,75	1 750	1 900	1 450	1 650	1 950
> 1,75 ⩽ 2,00	1 700	1 850	1 400	1 600	1 900
> 2,00 ⩽ 2,50	1 650	1 750	1 350	1 550	1 850
> 2,50 ⩽ 3,00	1 600	1 700	1 300	1 500	1 800
> 3,00 ⩽ 3,50	1 550	1 650	1 250	1 450	1 750
> 3,50 ⩽ 4,25	1 500	1 600	1 225	1 400	1 700
> 4,25 ⩽ 5,00	1 450	1 550	1 200	1 350	1 650
> 5,00 ⩽ 6,00	1 400	1 500	1 150	1 300	1 550
> 6,00 ⩽ 7,00	1 350	1 450	1 125	1 250	1 500
> 7,00 ⩽ 8,50	1 300	1 400	1 075	1 200	1 450
> 8,50 ⩽ 10,00	1 250	1 350	1 050	1 150	1 400

1) The tensile strength is measured on the actual diameter.

2) After straightening, the tensile strength is approximately 7 % lower. By tempering, the loss in strength can be almost compensated for. The tempering can cause out-of-straightness and also discoloration, see A.5.2.2.

3) For wire with a high deformation stress, lower tensile strength values may be agreed upon.

4) See also 4.4.2.

5) Tolerance on tensile strength: + 15 % of minimum value.

6) $1\ N/mm^2 = 1$ MPa

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The spring wire shall be drawn free from helix cast. This requirement is regarded as being fulfilled for wire of diameter up to 5 mm, if the axial displacement l between the two ends of an individual wap (convolution of wire) does not exceed a value given by the equation

$$l = \frac{0{,}2D}{\sqrt[4]{d}}$$

where

D is the mean diameter, in millimetres of the individual wap;

d is the diameter, in millimetres, of the wire.

The circular cast and helix cast shall be tested in accordance with 5.4.2.4.

4.2.2.3 The surface condition for stainless steel spring wire should be agreed upon at the time of enquiry and order.

4.3 Chemical composition

4.3.1 The chemical composition of the steels, as given by the cast analysis, shall be in accordance with the specifications in table 1.

4.3.2 The permissible deviations between the values specified in table 1 and the product analysis are given in table 3.

4.4 Mechanical properties

4.4.1 For the tensile strength in the spring hard-drawn condition (C) and for the tempered condition (T) of grade 3, the data in table 2 apply.

Tempering of grades 1 and 2 also increases the tensile strength but less than for grade 3, see A.2 and figure A.1.

4.4.2 The maximum difference in tensile strength between the two ends of a coil or spool of wire shall be as given in table 4 (see also 5.2).

The difference in tensile strength within a batch from the same heat shall be a maximum of 9 % of the minimum tensile strength.

Table 3 — Permissible deviations of the product analysis from the limiting values for cast analysis in table 1

Element	Permissible maximum content in the cast analysis % (*m/m*)	Permissible deviation[1] % (*m/m*)
C	⩽ 0,12	+ 0,01
Si	⩽ 1,0 > 1,0 ⩽ 1,5	+ 0,05 + 0,10
Mn	⩽ 1,0 > 1,0 ⩽ 2,0	+ 0,03 + 0,04
P	⩽ 0,045	+ 0,005
S	⩽ 0,030	+ 0,005
Al	0,75 ⩽ 1,50	± 0,10
Cr	16,0 ⩽ 19,0	± 0,20
Mo	2,0 ⩽ 2,5	± 0,10
Ni	6,0 ⩽ 10,0 > 10,0 ⩽ 13,5	± 0,10 ± 0,15

1) For a cast, the deviation of an element in the product analysis may be only below the minimum or only above the maximum value of the range specified for the cast analysis, but not both at the same time.

Table 4 — Tensile strength difference in the same spool or coil

Wire diameter d mm	Maximum tensile strength difference N/mm^2
⩽ 1,5	100
> 1,5 ⩽ 10,0	70

4.5 Technological properties, surface condition and inner soundness

4.5.1 Technological properties and surface condition

4.5.1.1 For evaluation of uniformity of coiling and surface condition, in the case of wire of diameter 0,5 mm to 1,5 mm, the coiling test is applied. The spring, coiled in accordance with 5.4.2.2, shall show a perfect surface condition and a uniform pitch of the turns.

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4.5.1.2 For evaluation of ductility and surface condition, the following tests are applied.

— Wrapping test: wire diameter 0,3 mm to 4,0 mm.

— Bend test: wire diameter greater than 4,0 mm up to 10,0 mm.

The specifications and requirements for these tests are given in 5.4.2.3.

4.5.1.3 The surface of the wires shall be as far as possible free from grooves, pits and other surface defects, in order that the usability is not appreciably impaired.

4.5.1.4 If, for wire which is intended for high-duty springs, the requirements according to 4.5.1.1 to 4.5.1.3 are not sufficient, special agreements shall be reached at the time of enquiry and order.

4.5.2 Inner soundness

The wire shall be free from internal defects that could have a significant effect on usability. Tests appropriate for an assessment of the internal condition, for example the wrapping test, may be agreed upon at the time of ordering.

4.6 Dimensions and dimensional tolerances

4.6.1 The tolerances on diameter are given in table 5.

Table 5 — Tolerances on diameter

Dimensions in millimetres

Nominal diameter	Diameter tolerance	
	Spools or coils	Lengths
⩽ 0,20	± 0,005	± 0,009
> 0,20 ⩽ 0,40	± 0,008	± 0,013
> 0,40 ⩽ 0,80	± 0,010	± 0,016
> 0,80 ⩽ 1,60	± 0,015	± 0,025
> 1,60 ⩽ 3,20	± 0,020	± 0,035
> 3,20 ⩽ 6,00	± 0,025	± 0,045
> 6,00 ⩽ 10,00	± 0,035	± 0,060

4.6.2 The tolerances for roundness, i.e. the difference between the largest and smallest diameter in the same cross-section of the wire, shall not exceed half of the tolerance on diameter.

4.6.3 The tolerances on length of straightened lengths:

Diameter up to 0,60 mm: ± 20 mm

Diameter above 0,60 mm: ± 10 mm

Other tolerances may be agreed upon at the time of enquiry and order.

5 Testing

5.1 Agreement on tests and inspection documents

5.1.1 For each delivery, the issue of any document according to ISO 10474 shall be agreed upon at the time of enquiry and order.

5.1.2 If, in accordance with such an agreement, specific inspection is to be carried out, the specifications given in 5.2 to 5.4 shall be observed.

5.2 Number of tests

The data in table 6 apply for the composition of test units and for the number of tests per test unit, subject to the following exception for tensile strength.

If proof of uniformity of tensile strength (in accordance with 4.4.2) is agreed upon at the time of ordering, a test piece shall be taken from both ends of each coil or spool. If, from one rod coil, several coils or spools of wire are produced and these are numbered in sequence, it is only necessary to take a test piece from the beginning of each consecutively produced coil or spool.

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Table 6 — Test units and amount of testing during acceptance tests

Quality requirement[1]	[2]	Test unit	Number of products per test unit	Number of samples per product	Number of test pieces per sample
Product analysis[3]	o	Cast	[4]	1	1
Tensile test without checking the uniformity of tensile strength	m	Cast and production batch[5]	1 per 10 spools or coils	1	1
Tensile test for checking the uniformity of tensile strength	o	Cast and production batch[5]	[6]	[6]	[6]
Coiling test for checking uniformity and surface condition, d = 0,3 mm to 1,5 mm	o	Cast and production batch[5]	To be agreed when ordering		
Tests for checking ductility and surface condition:		Cast and production batch[5]	To be agreed when ordering		
Wrapping test, d = 0,3 mm to 4,0 mm	o				
U-bend test, d > 4,0 mm to 10,0 mm	o				

1) If other tests are required, for example for the determination of the modulus of elasticity, this shall be agreed when ordering.

2) m = the test shall be carried out in each case;

o = the test shall be carried out only if agreed when ordering.

3) If no product analysis is ordered, the chemical composition according to the cast analysis shall be given by the manufacturer for the elements listed in table 1.

4) Unless otherwise agreed when ordering, one test piece shall be taken per cast.

5) The production batch is defined as the quantity of products subjected to the same heat-treatment conditions and having the same cross-sectional reduction.

6) See 5.2.

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5.3 Selection and preparation

5.3.1 General

The general conditions given in ISO 377-1 and ISO 377-2 for the selection and preparation of samples and test pieces shall apply.

5.3.2 Product analysis

For product analysis, the selection and preparation of samples shall be carried out in accordance with the requirements of ISO 377-2.

5.3.3 Tensile and technological tests

5.3.3.1 The test pieces for the tensile test and the wrapping test shall be taken at a sufficient distance from the end of the coil or spool. In cases of dispute, the minimum distance from the end of the coil or spool shall be 5 m for wire of diameter less than or equal to 6,0 mm.

5.3.3.2 The test piece, consisting of one piece of wire for the tensile test, shall be as straight as possible and not have any surface defects or kinks. If necessary, the test piece shall be straightened

a) by hand without tools; or

b) using a hammer and a flat surface, both made of wood, plastics or copper.

During straightening, care shall be taken to ensure that the surface of the test piece is not damaged and that both the properties and the cross-section of the test piece stay unchanged as far as possible. In particular, any twisting of the test piece shall be avoided.

5.4 Methods of test

5.4.1 Chemical analysis

In cases of dispute, the methods used for chemical analysis shall be those established by the relevant International Standards (see ISO/TR 9769). If no International Standards are available, the methods shall be agreed upon at the time of enquiry and order.

5.4.2 Tensile and technological tests

5.4.2.1 The tensile test shall be carried out in accordance with ISO 6892.

The tensile strength shall be calculated using the actual wire diameter.

5.4.2.2 Coiling test for uniformity

An approximately 500 mm long test piece is tightly coiled on a mandrel, the diameter of which shall be three times the nominal diameter of the wire and at least 1 mm. Then the test piece is lengthened and unburdened again so that the length of the unburdened spring corresponds to at least twice and at most four times the coiling length. After this treatment, the test piece coil shall have uniform pitch with no splits or fractures.

Although this kind of wrapping test is not generally recognized, it is the only one which permits the detection of inner stresses. Doubtful test results should not lead to rejection of the wire and the interested parties concerned should try to clarify the cause.

5.4.2.3 Tests for ductility and surface condition

a) Wrapping test for diameters 0,3 mm to 4,0 mm.

The wire shall not show signs of fracture when coiled eight complete turns around a mandrel of diameter equal to that of the wire. In addition, the general specifications of ISO 7802 apply.

b) Bend test for diameters greater than 4,0 mm up to 10,0 mm.

The wire shall show no signs of surface cracks when bent 180° around a mandrel. For diameters greater than 4,0 mm up to 6,0 mm, the mandrel size should be twice the diameter of the wire or smaller. For larger diameters, the mandrel size should be three times the diameter of the wire or smaller.

In carrying out the test, the wire shall be free to move longitudinally in the forming device.

5.4.2.4 For testing the circular cast and helix cast, sufficient wire from a coil or spool shall be cut off to produce a full free wap (single convolution of wire), ensuring it is not bent or damaged (see figure 1).

To measure the circular cast, i.e. the inside diameter of the wap, the wap shall be placed on a flat horizontal surface and the average diameter measured. See figures 2 and 3 which also show the definition of closed and open circular casts.

To measure the helix cast (the displacement of the cut ends at right angles to the wap), either

a) suspend the wap from a piece of rod or a pencil etc., so that the cut ends are at the lowest point, and measure the separation of the ends at right angles to the plane of the wap [see figure 4 a)] or

b) place the wap on a flat horizontal surface and measure and record the vertical distance between the ends of the wap [see figure 4 b)]. This test method shall only be used when the combination of wire diameter and circular cast does not create conditions which reduce or eliminate the helix cast measured in this way.

The test report shall indicate the test method.

6 Complaints

The conditions for dealing with complaints laid down in ISO 404 shall apply.

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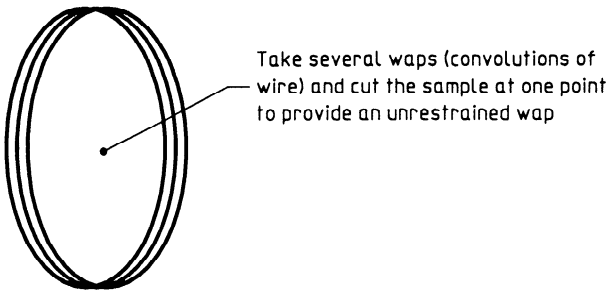


Figure 1 — Sampling of wire

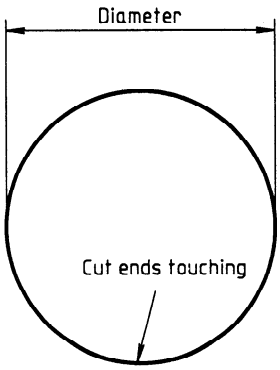


Figure 2 — Closed circular cast

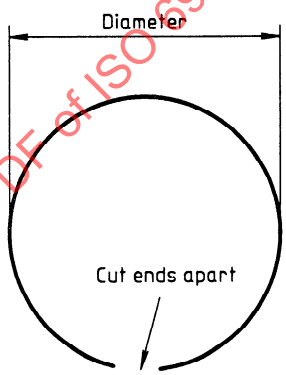
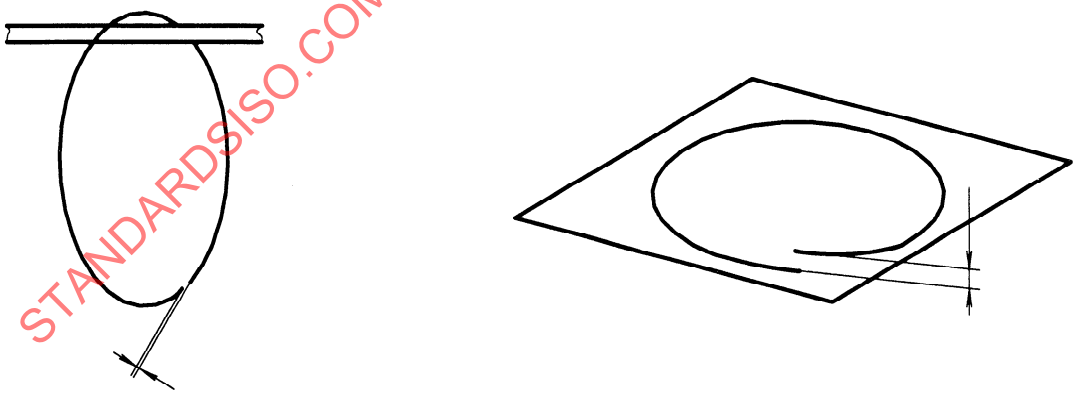


Figure 3 — Open circular cast



a) Wap suspended vertically.
Horizontal displacement of cut ends

b) Wap laid on flat surface.
Vertical displacement of cut ends

Figure 4 — Helix cast

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Annex A
(informative)

Additional information

A.1 Indications for classification of steel grades

Depending on stress, the maximum temperature of use of the steel of grade number 1 (see table A.1) may be between 120 °C and 250 °C. If greatest resistance to corrosion is required for one of the steels covered by this part of ISO 6931, the austenitic steel of grade number 2 may be used, also depending on stress for a maximum temperature of use between 120 °C and 250 °C. The maximum temperature of use of the precipitation-hardenable austenitic-martensitic steel of grade number 3 may be between 250 °C and 300 °C depending on stress. This steel has a high fatigue strength and an increased strength at elevated temperatures, but a reduced resistance to corrosion.

The three grades of steel have slightly different values for the modulus of elasticity, determined on longitudinal test pieces, and for the shear modulus (see table A.1). It should be taken into account that the values of the modulus of elasticity and the shear modulus decrease with increasing temperature.

A.2 Alteration of tensile strength by tempering

Tempering will increase tensile strength values as compared with the spring hard-drawn condition. A treatment of this kind will also remove the processing stresses produced by the spring forming.

The precipitation-hardenable steel, grade 3, gives a greater increase in the tensile strength by tempering than the other grades in this part of ISO 6931.

Consequently, final tempering of precipitation hardening of the finished springs is a basic recommendation. Reference data on the increase in tensile strength which can be achieved after tempering or artificial ageing are given in figure A.1.

A.3 Physical properties

Reference data for the modulus of elasticity and shear modulus are given in table A.1.

A.4 Magnetic properties

It should be noted that, depending upon the chemical composition and treatment condition, these steels have some degree of magnetic permeability.

A.5 Guidelines for processing and heat treatment

A.5.1 Processing

Forming is carried out by cold deformation. Therefore, account has to be taken of the fact that the deformability of spring-hard cold-worked wire is limited. Depending on the forming requirements, a lower tensile strength may be agreed upon when ordering (see footnote 3 to table 2).

A.5.2 Heat treatment

A.5.2.1 Table A.2 contains reference data on heat treatment to be carried out on finished springs in order to achieve suitable strength and elastic properties. In special cases, modified heat treatments, to be determined by practical trials, will be necessary to meet specific requirements.

A.5.2.2 The springs should be thoroughly cleaned before heat treatment. If the colours produced by heat treatment are not permissible for visual or corrosion-resistance reasons, the heat treatment may be carried out in a protective atmosphere, or a suitable cleaning process may be used which does not impair the spring properties.

A.5.3 Peening with globular abrasives

If the springs are to be peened, care should be taken that the peened surface is not adversely affected, for example by using stainless grit.

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Table A.1 — Reference data for the modulus of elasticity and rigidity (mean values)

For the finished spring, lower values may be ascertained. Therefore, standards for the calculation of springs may specify values different from those given here based on measurements of wire.

Steel grade		Modulus of elasticity[1]		Modulus of rigidity[2]	
Number	Designation	delivery condition C	condition C + T[3]	delivery condition C	condition C + T[3]
		kN/mm^2		kN/mm^2	
1	X 9 CrNi 18-8	180	185	70	73
2	X 5 CrNiMo 17-12-2	175	180	68	71
3	X 7 CrNiAl 17-7	190	200	73	78

1) The reference data for the modulus of elasticity (E) are calculated from the modulus of rigidity (G) using the formula $G = E/2\ (1 + \nu)$ where ν (Poisson's constant) is set at 0,3. The data are applicable for a mean tensile strength of 1 800 N/mm^2. For a mean tensile strength of 1 300 N/mm^2, the values are 6 kN/mm^2 lower. Intermediate values may be interpolated.

2) The reference data for the modulus of rigidity are applicable to wires with a diameter $\leqslant$ 2,8 mm for measurements made with a torsion pendulum, for a mean tensile strength of 1 800 N/mm^2. For a mean tensile strength of 1 300 N/mm^2, the values are 2 kN/mm^2 lower. Intermediate values may be interpolated. Values ascertained using an Elastomat are not always comparable with values ascertained using a torsion pendulum.

3) See table A.2, figure A.1 and table 2.

Table A.2 — Reference data for heat treatment of springs made of wire (see also A.5.2)

Steel grade		Temperature	Duration	Means of cooling
Number	Designation	°C		
1	X 9 CrNi 18-8	250 to 425	30 min to 4 h	Air
2	X 5 CrNiMo 17-12-2			
3	X 7 CrNiAl 17-7	450 to 480	30 min to 1 h	Air

NOTES

1 See classification of the tensile strength data in table 2 and figure A.1.

2 The optimum tempering conditions may be very different. The spring manufacturer shall choose the tempering conditions answering the purpose, see also A.5.2.1.

3 The tempering data refer to compression springs and tension springs without initial tension.

Generally, tension springs with initial tension are not to be treated at the same high temperatures as the springs in this table. If a moderate loss of initial tension can be accepted, tempering temperatures of max. 200 °C for grades 1 and 2 and max. 300 °C for grade 3 are recommended.

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