TC 17

INTERNATIONAL STANDARD

ISO 6931-1

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Stainless steels for springs —

Part 1: Wire

Aciers inoxydables pour ressorts —

Partie 1: Fil

Reference number
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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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6931-1 was prepared by Technical Committee ISO/TC 17, *Steel.*

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

1 Scope

1.1 This part of ISO 6931 applies to the grades of wrought stainless steels listed in table 1, which are currently generally used in the work-hardened condition in the form of wire up to about 6 mm in diameter, for the production of springs and spring parts that are exposed to corrosive effects and sometimes slightly increased temperatures (see annex A, clause A.1).

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.

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 listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 377 : 1985, *Wrought steel — Selection and preparation of samples and test pieces.*

ISO 404 : 1981, *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 7800 : 1984, *Metallic materials — Wire — Simple torsion test.*

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

3 Ordering

The purchaser shall state in his inquiry and order

a) the steel type (see table 1);

b) the wire diameter;

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

Steel grade designation	Chemical composition[1] % (m/m)						
	C max.	Si max.	Mn max.	Al	Cr	Mo	Ni
X 5 CrNi 18 10	0,07	1,0	2,0	—	17,0 to 19,0	—	8,0 to 11,0
X 12 CrNi 17 7	0,12	1,5	2,0	—	16,0 to 18,0[2]	⩽0,8	6,0 to 9,0[2]
X 6 CrNiMo 17 12 2	0,07	1,0	2,0	—	16,5 to 18,5	2,0 to 2,5[3]	10,5 to 13,5
X 7 CrNiAl 17 7	0,09	1,0	1,0	0,75 to 1,50	16,0 to 18,0	—	6,5 to 7,75[4]

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

2) A maximum Cr content of 18,5 % (m/m) and/or a maximum Ni content of 9,5 % (m/m) may be agreed upon at the time of inquiry and order.

3) 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 type X 6 CrNiMo 17 12 2.

4) By special agreement, the steel, when it is to be delivered in the cold-drawn condition, may also be ordered with 7,00 % (m/m) to 8,25 % (m/m) Ni.

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

d) the delivery condition (see 4.2.2);

e) the desired quantity;

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

Example:

— 2 t wire of steel X 12 CrNi 17 7 according to ISO 6931-1, diameter 2,00 mm, delivery condition C:

2 t wire 2,00
steel X 12 CrNi 17 7 C - ISO 6931-1

4 Requirements

4.1 Manufacture of the steel and of 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 in coils or on reels; small diameter wire mainly on reels. Several coils or reels may be assembled on a carrier. Unless otherwise agreed in the order, the choice of the delivery form within the context of these specifications is left to the discretion of the manufacturer.

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 delivery conditions possible are those given in table 2.

In special cases products may, if this is agreed, also be delivered in the treatment conditions given in table A.2 (see annex A), which are normally reserved for finished springs.

Table 2 — Nominal diameters and tolerances — Tensile strength and reduction of area after fracture in the spring-hard drawn condition (C) and additionally for steel X 7 CrNiAl 17 7 in the solution-annealed condition

Nominal diameter mm	Tolerance on diameter mm	Tensile strength [1) 2) 3) 4)], N/mm² X 5 CrNi 18 10 (C)	X 12 CrNi 17 7 (C)	X 6 CrNiMo 17 12 2 (C)	X 7 CrNiAl 17 7 (C)	X 7 CrNiAl 17 7 (Solution-treated)	Reduction of area after fracture % min.
0,10 0,11 0,12 0,14 0,16 0,18	±0,004	2 150 to 2 400	2 200 to 2 450	1 650 to 1 900	1 950 to 2 200		
0,20 0,22 0,25 0,28 0,30 0,32 0,34 0,36 0,38 0,40 0,43 0,45 0,48	±0,008	2 050 to 2 300	2 100 to 2 350	1 600 to 1 850	1 930 to 2 180		
0,50 0,53 0,56 0,60 0,63 0,65 0,70 0,80	±0,010	1 950 to 2 200	2 000 to 2 250	1 600 to 1 850	1 850 to 2 100		—
0,85 0,90 0,95 1,00 1,05 1,10 1,20 1,25 1,30 1,40	±0,015	1 850 to 2 100	1 900 to 2 150	1 530 to 1 780	1 800 to 2 050	800 to 1 000	
		1 750 to 2 000	1 800 to 2 050	1 450 to 1 700	1 700 to 1 950		
1,50 1,60 1,70 1,80 1,90 2,00 2,10 2,25 2,40 2,50 2,60 2,80 3,00 3,20	±0,020	1 650 to 1 900	1 700 to 1 950	1 400 to 1 650	1 600 to 1 850		
		1 550 to 1 800	1 600 to 1 850	1 320 to 1 570	1 500 to 1 750		
3,40 3,60 3,80 4,00 4,25 4,50 4,75 5,00 5,30 5,60	±0,025	1 450 to 1 700	1 500 to 1 750	1 230 to 1 480	1 400 to 1 650		> 40
		1 350 to 1 600	1 400 to 1 650	1 100 to 1 350	1 300 to 1 550		
6,00	±0,035						

1) After straightening into bars, the tensile strength is approximately 7 % lower. By tempering or artificial ageing, the loss in stress can be almost compensated for.

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

3) When ordering, a narrower range may be agreed upon.

4) See also 4.4.2.

4.2.2.2 Each reel or coil shall consist of one continuous length of wire, wound so that there are no kinks.

After removal of bonding wire, individual rings of wire taken from the reel may have a diameter larger but not less than the core diameter of the reel. This enlargement shall be approximately uniform for one reel and for all the reels of one delivery.

The spring wire shall be drawn free from twist. 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 ring tested in accordance with 5.4.2.4 does not exceed a value given by the equation

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

where

D is the mean diameter of the individual ring;

d is the diameter of the wire.

4.2.2.3 In the condition "C", wire with diameter up to approximately 0,4 mm is usually delivered with a bright surface. Wire with diameter above approximately 0,4 mm may be ordered and delivered with a bright or smooth or coated surface, whichever is agreed upon.

NOTE — The diameter from which wire with a smooth or coated surface can be ordered and delivered differs from works to works and also depends on the type of lubricant.

Wire of steel type X 7 CrNiAl 17 7 in the condition "solution annealed" may be delivered, depending on the manufacturer's choice, with a bright annealed or pickled surface.

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 of spring-hard drawn wire, the data in table 2 apply.

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

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 C	Permissible deviation[1)]
C	$C \leqslant 0{,}12$	+0,01
Si	$C \leqslant 1{,}0$ $1{,}0 < C \leqslant 1{,}5$	+0,05 +0,10
Mn	$C \leqslant 1{,}0$ $1{,}0 < C \leqslant 2{,}0$	+0,03 +0,04
P	$C \leqslant 0{,}045$	+0,005
S	$C \leqslant 0{,}030$	+0,005
Al	$0{,}75 \leqslant C \leqslant 1{,}50$	±0,10
Cr	$16{,}0 \leqslant C \leqslant 19{,}0$	±0,20
Mo	$C \leqslant 0{,}80$ $2{,}0 \leqslant C \leqslant 2{,}5$	±0,05 ±0,10
Ni	$6{,}0 \leqslant C \leqslant 10{,}0$ $10{,}0 < C \leqslant 13{,}5$	±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, N/mm²

Wire diameter d mm	Coil or reel mass m $m \leqslant 50$ kg	$m > 50$ kg
$d < 1{,}5$	100	150
$d \geqslant 1{,}5$	70	100

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 up to 1,5 mm, the wrapping test is applied. The spring, coiled in accordance with 5.4.2.2, shall show an unobjectionable surface condition and a uniform pitch of the turns.

4.5.1.2 In the torsion test (which takes the form of an alternating torsion test as specified in 5.4.2.3), wire with diameter greater than 1,5 mm and less than or equal to 6,0 mm shall satisfy the requirements of 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 inquiry 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 nominal diameters and the tolerances on diameter are given in table 2.

4.6.2 The tolerance 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.

5 Testing

5.1 Agreement on tests and documents

5.1.1 For each delivery, the issue of any document according to ISO 404 shall be agreed upon at the time of inquiry 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 5 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 reel. If, from one rod coil, several coils or reels 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 reel.

Table 5 — 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[5] without checking the uniformity of tensile stregth	m	Cast and production batch[6]	1 per 10 reels or coils	1	1
Tensile test[5] for checking the uniformity of tensile strength	o	Cast and production batch[6]	[7]	[7]	[7]
Wrapping test[8]	o	Cast and production batch[6]	To be agreed when ordering		
Torsion test (alternating torsion test)[9]	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) For diameters above 1,5 mm to 6 mm, the reduction of area after fracture is determined in addition to the tensile strength.

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

7) See 5.2.

8) Only for diameters $\leqslant$ 1,5 mm.

9) Only for diameters $>$ 1,5 mm and $\leqslant$ 6 mm.

5.3 Selection and preparation

5.3.1 General

The general conditions given in ISO 377 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 conformity with the requirements of ISO 377.

5.3.3 Tensile and technological tests

5.3.3.1 The test pieces for the tensile test, the torsion test (alternating torsion test) and the wrapping test shall be taken at a sufficient distance from the end of the coil or reel. In cases of dispute, the minimum distance from the end of the coil or reel 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 and torsion tests, 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, plastic 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. If no International Standards are available, the methods shall be agreed upon at the time of inquiry 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.

For calculating the tensile strength, the nominal cross-section shall be taken for wires with a nominal diameter greater than 2 mm and the actual cross-section for wires with a nominal diameter less than or equal to 2 mm.

5.4.2.2 For the wrapping test, 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. The surface condition of the wire and the uniformity of coiling are then tested. In addition, the general specifications of ISO 7802 apply.

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 For the torsion test (alternating torsion test), the test piece shall be at least 100 mm longer than the test length. Unless otherwise agreed at the time of ordering, the test length shall be 100 d for wire diameters greater than or equal to 1,5 mm but less than 5 mm and shall be 50 d for wire diameters greater than or equal to 5 mm. The test piece shall be clamped into the device in such a manner that its longitudinal axis is aligned with the axis of the clamping heads and the test piece remains straight during the test. After clamping the test piece in the test machine, one of the clamping heads is twisted back and forth twice. In addition, the general conditions of ISO 7800 apply.

This test is intended to make any cracks or other surface defects visible when inspecting the test piece with the naked eye.

5.4.2.4 For testing the freedom of twist after removal of binding wire, one individual ring of wire shall be taken from the reel. In the suspended condition, the mean diameter of the individual ring and the axial displacement between the two ends of the wire are measured.

6 Complaints

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

Annex A
(informative)

Additional information

A.1 Indications for classification of steel grades

Depending on stress, the maximum temperature of use of the steels X 5 CrNi 18 10 and X 12 CrNi 17 7 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 X 6 CrNiMo 17 12 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 X 7 CrNiAl 17 7 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 four 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 with increasing temperature the values of the modulus of elasticity and the shear modulus decrease.

A.2 Alteration of tensile strength by tempering or artificial ageing

A.2.1 Tempering or, in the case of steel X 7 CrNiAl 17 7, artificial ageing as indicated in table A.2 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.

Consequently, final tempering or 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.2.2 The solution-annealed condition of steel X 7 CrNiAl 17 7 can be converted into a harder condition by means of a double heat treatment after processing into springs (see figure A.2 and table A.2), but this conditions will not be as hard as cold-worked material that has been given an appropriate heat treatment.

Table A.1 — Reference data for the modulus of elasticity and rigidity (mean values) [1) 2) 3)]

Steel grade	Modulus of elasticity[1] in the		Modulus of rigidity[2] in the	
	delivery condition C	condition C + T[4]	delivery condition C	condition C + T[4]
	kN/mm²		kN/mm²	
X 5 CrNi 18 10	185	195	70	73
X 12 CrNi 17 7	185	195	70	73
X 6 CrNiMo 17 12 2	180	190	68	71
X 7 CrNiAl 17 7	195	200	73	78

1) The reference data for the modulus of elasticity are applicable to measurements on longitudinal tensile test pieces for a mean tensile strength of 1 800 N/mm²; for a mean tensile strength of 1 300 N/mm², the values are 6 kN/mm² lower. Intermediate values may be interpolated.

2) The reference data for the modulus of rigidity are applicable to wires with a diameter ⩽ 2,8 mm for measurements by means of a torsion pendulum, for a mean tensile strength of 1 800 N/mm². For a mean tensile strength of 1 300 N/mm², the values are 2 kN/mm² lower. Intermediate values may be interpolated. Values ascertained ~~by means of~~ an Elastomat are not always comparable with values ascertained ~~by means of a~~ torsion pendulum.

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

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