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Stainless steels for springs —

Part 1: **Wire**

Aciers inoxydables pour ressorts —

Partie 1: Fils

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This third edition cancels and replaces the second edition (ISO 6931-1:1994), 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: Narrow strip*

Stainless steels for springs —

Part 1:
Wire

1 Scope

This part of ISO 6931 specifies the grades of stainless steels which are generally used in the cold drawn condition in the form of wire of circular cross-section up to 10,00 mm in diameter, for the production of springs and spring parts exposed to corrosive effects and sometimes to slightly increased temperatures (see Annex A).

Certain steel grades covered by ISO 16143-2 are also used for springs, although to a much lesser extent. In these cases, the mechanical properties (tensile strength, etc.) will be agreed between purchaser and supplier. Similarly, diameters between 10,00 mm and 15,00 mm can be ordered according to the specifications of this part of ISO 6931, in which case the parties will agree upon the required mechanical characteristics.

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

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

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

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

ISO 15510, *Stainless steels — Chemical composition*

ISO 16143-2, *Stainless steels for general purposes — Part 2: Corrosion-resistant semi-finished products, bars, rods and sections*

ISO 22034-1, *Steel wire and wire products — Part 1: General test methods*

ISO 22034-2, *Steel wire and wire products — Part 2: Tolerances on wire dimensions*

ISO/TS 4949, *Steel names based on letter symbols*

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

3 Information to be supplied by the purchaser

The purchaser shall clearly state in his enquiry or order the product and following information:

a) the desired quantity;

b) the term spring steel wire or straightened and cut lengths;

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

d) the steel grade (see Table 1) and for grade 4301-304-00-I, 4310-301-00-I and 4462-318-03-I also the tensile strength level (see Table 2);

e) the nominal wire diameter and the class for the diameter tolerance (see Table 5) and additional for cut length the length and the length tolerance class (see Table 6);

f) the surface finish (see 4.3, i.e. coating);

g) the form of delivery (see 4.2);

h) the type of inspection document to be supplied (see 5.1);

i) any particular agreement made.

EXAMPLE 2 t stainless steel spring wire according to this part of ISO 6931, grade 4310-301-00-I, normal tensile strength level and nominal diameter 2,50 mm, diameter tolerance class T15, in coils with inspection document 3.1 according to ISO 10474:

2 t spring steel wire ISO 6931-1 – 4310-301-00-I – NS – 2,50 T15 – in coils, ISO 10474 – 3.1

4 Requirements

4.1 Manufacturing process

Unless otherwise agreed in the order, the manufacturing process used in the making of the stainless steel wire is left to the discretion of the manufacturer. The starting condition (+AT: solution annealed) of the wire (rod) is specified in ISO 16143-2.

4.2 Form of delivery

The wire shall be supplied in coils, on spools, on coreless spools or on carriers. Several coils may be assembled on a carrier. Unless otherwise specified, the form of delivery shall be at the manufacturer's discretion. They shall, however, inform the purchaser about the form of delivery.

The delivery requirements are specified in 4.7. Wire in straight lengths is normally supplied in bundles.

4.3 Surface finish

The wire may be coated or not. The specific coating and finish for stainless steel spring wire shall be agreed upon at the time of enquiry and order, e. g. uncoated, polished finish, nickel coated.

4.4 Chemical composition

4.4.1 The requirements for the chemical composition given in Table 1 apply to the cast analysis.

4.4.2 The permissible deviation of the product analysis from the values specified in Table 1 shall be in accordance with the provision in ISO 16143-2. For a single heat, 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 heat analysis but not both at the same time.

Table 1 — Chemical composition (cast analysis)

Steel grade		% by mass [a, b]								
Name[c]	Number[c]	C	Si	Mn	P	S	Cr	Mo	Ni	Other elements
Austenitic steels										
X10CrNi18-8	4310-301-00-I	0,05 to 0,15	2,00	2,00	0,045	0,015[f]	16,0 to 19,0	0,80	6,0 to 9,5	N: 0,10
X9CrNi18-9	4325-302-00-E	0,030 to 0,15	1,00	2,00	0,045	0,030	17,0 to 19,0	-	8,0 to 10,0	N: 0,10
X5CrNiN19-9	4315-304-51-I	0,08	1,00	2,50	0,045	0,030	18,0 to 20,0	-	7,0 to 10,5	N: 0,10 to 0,30 Nb: 0,15
X5CrNi18-10	4301-304-00-I	0,07	1,00	2,00	0,045	0,015[f]	17,5 to 19,5	-	8,0 to 10,5	N: 0,10
X5CrNiMo17-12-2[d]	4401-316-00-I[d]	0,07	1,00	2,00	0,045	0,015[f]	16,5 to 18,5	2,00 to 3,0	10,0 to 13,0	N: 0,10
X1NiCrMoCu25-20-5	4539-089-04-I	0,020	0,75	2,00	0,035	0,015	19,0 to 22,0	4,0 to 5,0	23,5 to 26,0	N: 0,15 Cu: 1,20 to 2,00
Austenitic-ferritic (duplex) steel										
X2CrNiMoN22-5-3	4462-318-03-I	0,030	1,00	2,00	0,035	0,015	21,0 to 23,0	2, 50 to 3,5	4,5 to 6,5	N: 0,10 to 0,22
Precipitation hardening steel										
X7CrNiAl17-7	4568-177-00-I	0,09	0,70	1,00	0,040	0,015	16,0 to 18,0	-	7,0 to 8,5[e]	Al: 0,70 to 1,50

[a] Maximum values unless indicated otherwise.

[b] Alternative compositions may be used by agreement.

[c] "Name" and "Number" are derived in accordance with ISO/TS 4949 and ISO 15510, respectively.

[d] Steel 4436-316-00-I may be used to provide increased corrosion resistance compared with 4401-316-00-I, with the specification of this part of ISO 6931-1 applicable for steel 4401-316-00-I.

[e] In ISO 15510 and ISO 16143, this steel grade is given with 6,5 % to 7,8 % Ni; for spring application, these values are raised to the values in the table.

[f] These steels are given in ISO 15510 and ISO 16143 with S max. 0,030; for spring application, this value is diminished to the value in the table.

4.5 Mechanical properties

4.5.1 For the tensile strength in the as drawn condition, the data of Table 2 shall apply.

Table 2 — Tensile strength in the as drawn condition

Nominal diameter mm[f]	Tensile strength (MPa) [a b c d e] for the following steel grades																			
	4310-301-00-I				4325-302-00-E 4315-304-51-I		4301-304-00-I			4401-316-00-I		4539-089-04-I		4462-318-03-I				4568-177-00-I[g]	
	Normal tensile strength (NS)		High tensile strength (HS)				Normal tensile strength (NS)	High tensile strength (HS) min.						Normal tensile strength (NS) -		High tensile strength (HS) -			
	min.	max.	min.	max.	min.	max.	min.		max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
$d \leq 0{,}20$	2 200	2 530	2 350	2 710	2 150	2 400	2 000	2 150	2 300	1 725	1 990	1 600	1 840	2 150	2 480	2 370	2 730	1 975	2 280
$0{,}20 < d \leq 0{,}30$	2 150	2 480	2 300	2 650	2 050	2 300	1 975	2 050	2 280	1 700	1 960	1 550	1 790	2 100	2 420	2 370	2 730	1 950	2 250
$0{,}30 < d \leq 0{,}40$	2 100	2 420	2 250	2 590	2 050	2 300	1 925	2 050	2 220	1 675	1 930	1 550	1 790	2 000	2 300	2 370	2 730	1 925	2 220
$0{,}40 < d \leq 0{,}50$	2 050	2 360	2 200	2 530	1 950	2 200	1 900	1 950	2 190	1 650	1 900	1 500	1 750	2 000	2 300	2 370	2 730	1 900	2 190
$0{,}50 < \mathrm{d} \leq 0{,}65$	2 000	2 300	2 150	2 480	1 900	2 150	1 850	1 950	2 130	1 625	1 870	1 450	1 670	1 900	2 190	2 370	2 730	1 850	2 130
$0{,}65 < d \leq 0{,}80$	1 950	2 250	2 100	2 420	1 850	2 100	1 800	1 850	2 070	1 600	1 840	1 450	1 670	1 900	2 190	2 230	2 570	1 825	2 100
$0{,}80 < d \leq 1{,}00$	1 900	2 190	2 050	2 360	1 850	2 100	1 775	1 850	2 050	1 575	1 820	1 400	1 610	1 800	2 070	2 140	2 470	1 800	2 070
$1{,}00 < d \leq 1{,}25$	1 850	2 130	2 000	2 300	1 750	2 000	1 725	1 750	1 990	1 550	1 790	1 350	1 560	1 800	2 070	2 090	2 410	1 750	2 020
$1{,}25 < d \leq 1{,}50$	1 800	2 070	1 950	2 250	1 700	1 950	1 675	1 750	1 930	1 500	1 730	1 350	1 560	1 700	1 960	2 090	2 410	1 700	1 960
$1{,}50 < d \leq 1{,}75$	1 750	2 020	1 900	2 190	1 650	1 900	1 625	1 650	1 870	1 450	1 670	1 300	1 500	1 700	1 960	2 000	2 300	1 650	1 900
$1{,}75 < d \leq 2{,}00$	1 700	1 960	1 850	2 130	1 650	1 900	1 575	1 650	1 820	1 400	1 610	1 300	1 500	1 700	1 960	2 000	2 300	1 600	1 840
$2{,}00 < d \leq 2{,}50$	1 650	1 900	1 750	2 020	1 550	1 800	1 525	1 550	1 760	1 350	1 560	1 300	1 500	1 550	1 790	1 900	2 190	1 550	1 790
$2{,}50 < d \leq 3{,}00$	1 600	1 840	1 700	1 960	1 450	1 700	1 475	1 550	1 700	1 300	1 500	1 300	1 500	1 550	1 790	1 860	2 140	1 500	1 730
$3{,}00 < d \leq 3{,}50$	1 550	1 790	1 650	1 900	1 450	1 700	1 425	1 450	1 640	1 250	1 440	1 300	1 500	1 550	1 790	1 850	2 050	1 450	1 670
$3{,}50 < d \leq 4{,}25$	1 500	1 730	1 600	1 840	1450	1 700	1 400	1 450	1 610	1 225	1 410	1 250	1 440	1 450	1 670	1 750	1 950	1 400	1 610
$4{,}25 < d \leq 5{,}00$	1 450	1 670	1 550	1 790	1 350	1 600	1 350	1 350	1 560	1 200	1 380	1 250	1 440	1 450	1 670	1 700	1 900	1 350	1 560

Grade 4310-301-00-I and 4462-318-03-I can be delivered in normal tensile strength (NS) or high tensile strength (HS).

For steel 4568-177-00-I, the characteristics of the springs are not only determined by the characteristics of the drawn wire but also by the heat-treatment of the spring (see A.2). Therefore, the steel should be of a quality such that by the heat treatment after drawing the mechanical properties are met.

[a] Tensile strength calculated on actual diameter.

[b] The range of tensile strength values within a production batch of the same heat shall be a maximum of 9 % of the minimum values in this table.

[c] After straightening, it is recognized that the tensile strength may reduce by up to 10 % but the minimum values of this table have to be fulfilled.

[d] When better formability is required, lower tensile strength values may be agreed upon.

[e] The wire is supplied in the cold drawn condition. The tensile strength in the finished spring may be substantially influenced by a heat treatment; particularly, precipitation hardening of grade 4568-177-00-I results in substantially higher tensile strength (see A.5.2 and Table A.3).

[f] Larger diameters may be specified in which case the parties shall agree the tensile strength at the time of enquiry and order.

[g] When the tensile test of 4568-177-00-I is performed on test piece after precipitation hardening heat treatment (air cooling after heating at 470 ± 20 °C for up to 1 h) as agreed upon between the purchaser and supplier, the increment in tensile strength shall be 250 MPa or over. This requirement applies for nominal diameters ≤6,0 mm.

Table 2 *(continued)*

Nominal diameter mm[f]	Tensile strength (MPa) [a b c d e f] for the following steel grades																	
	4310-301-00-I				4325-302-00-E 4315-304-51-I		4301-304-00-I			4401-316-00-I		4539-089-04-I		4462-318-03-I				4568-177-00-I[g]	
	Normal tensile strength (NS)		High tensile strength (HS)				Normal tensile strength (NS)	High tensile strength (HS)						Normal tensile strength (NS) -		High tensile strength (HS) -			
	min.	max.	min.	max.	min.	max.	min.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
5,00 < *d* ≤ 6,00	1 400	1 610	1 500	1 730	1 350	1 600	1 300	1 350	1 500	1 150	1 330	1 250	1 440	1 350	1 560	–	–	1 300	1 500
6,00 < *d* ≤ 7,00	1 350	1 560	1 450	1 670	1 270	1 520	1 250	1 300	1 440	1 125	1 300	1 200	1 380	1 350	1 560	–	–	1 250	1 440
7,00 < *d* ≤ 8,50	1 300	1 500	1 400	1 610	1 130	1 380	1 200	1 300	1 380	1 075	1 240	1 150	1 330	–	–	–	–	1 250	1 440
8,50 < *d* ≤ 10,00	1 250	1 440	1 350	1 560	980	1 230	1 175	1 250	1 360	1 050	1 210	–	–	–	–	–	–	1 250	1 440

Grade 4310-301-00-I and 4462-318-03-I can be delivered in normal tensile strength (NS) or high tensile strength (HS).

For steel 4568-177-00-I, the characteristics of the springs are not only determined by the characteristics of the drawn wire but also by the heat-treatment of the spring (see A.2). Therefore, the steel should be of a quality such that by the heat treatment after drawing the mechanical properties are met.

[a] Tensile strength calculated on actual diameter.

[b] The range of tensile strength values within a production batch of the same heat shall be a maximum of 9 % of the minimum values in this table.

[c] After straightening, it is recognized that the tensile strength may reduce by up to 10 % but the minimum values of this table have to be fulfilled.

[d] When better formability is required, lower tensile strength values may be agreed upon.

[e] The wire is supplied in the cold drawn condition. The tensile strength in the finished spring may be substantially influenced by a heat treatment; particularly, precipitation hardening of grade 4568-177-00-I results in substantially higher tensile strength (see A.5.2 and Table A.3).

[f] Larger diameters may be specified in which case the parties shall agree the tensile strength at the time of enquiry and order.

[g] When the tensile test of 4568-177-00-I is performed on test piece after precipitation hardening heat treatment (air cooling after heating at 470 ± 20 °C for up to 1 h) as agreed upon between the purchaser and supplier, the increment in tensile strength shall be 250 MPa or over. This requirement applies for nominal diameters ≤6,0 mm.

4.5.2 In addition to the requirements of Table 2, the maximum tensile strength range within one unit package (individual coil, spool or reel, etc.) shall satisfy Table 3.

For straightened and cut lengths, the values of Table 3 apply for the individual bundles.

Table 3 — Tensile strength range within an individual unit package (coil/spool/bundle)

Wire diameter, d mm	**Max. range** MPa
$d \leq 1{,}50$	100
$1{,}50 < d \leq 10{,}00$	70

4.6 Technological properties

4.6.1 Coiling test

For evaluation of uniformity of coiling and surface condition, the coiling test may be applied to wire with a diameter of 0,50 mm to 1,50 mm. The spring coiled in accordance with 5.4.3 shall show a defect free surface condition without splits or fracture; the coil shall have uniform pitch of the turns and a fair dimensional regularity of its diameter.

Although the usefulness of the coiling test is not generally recognized, it has been retained since it offers the possibility of revealing internal stresses. If doubtful test results are obtained, the wire concerned should not be rejected immediately but efforts should be made by the parties concerned to elucidate the cause.

4.6.2 Wrapping test

The wrapping test may be applied to wire with a diameter of 0,30 mm to 3,00 mm. The wire shall not show any sign of cracks or surface imperfections when closely wrapped eight turns around a mandrel of a diameter equal to the wire size (see also 5.4.4).

4.6.3 Simple bend test

Where requested, the bend test may be applied for wire with a diameter over 3,00 mm. The wire shall withstand the test without any sign of failure (see also 5.4.5).

NOTE In some applications, the material is severely deformed by bending. Such is the case for extension springs with tight hooks, springs with bends on legs, spring wire forms, etc. In such cases, the bend test provides for a wire test very close to actual use.

4.7 Supply conditions of wire on coils/reels and spools

4.7.1 General

The wire of each coil shall consist of one single length of wire originating from only one heat. It shall be wound so that there are no kinks.

Where wire is delivered on spools, spoolless cores or carriers up to 10 % of delivery number may consist of a maximum of two wire lengths. Joints on end product diameter shall be suitably marked and labelled, unless otherwise agreed.

4.7.2 Coil size

The internal diameter of unit packages (coil/reels or spools) shall reach at least the values given in Table 4, unless otherwise agreed.

Table 4 — Wire diameter and associated minimum coil internal diameter

Wire diameter, d mm	Minimum internal diameter mm
$d \leq 0{,}18$	To be agreed at the time of enquiry and order
$0{,}18 < d \leq 0{,}28$	100
$0{,}28 < d \leq 0{,}50$	150
$0{,}50 < d \leq 0{,}70$	180
$0{,}70 < d \leq 1{,}60$	250
$1{,}60 < d \leq 4{,}50$	400
$4{,}50 < d$	500

4.7.3 Circular wire cast

The wire shall be uniformly cast and take a circular cast. Unless otherwise specified, the wap diameter of the wire supplied in coils/reels may expand when the binding wires are removed but should usually not retract to less than the unit internal diameter, other than by agreement between supplier and purchaser. The expansion shall be approximately even within a single unit package and within all the units in a production batch.

4.7.4 Helix cast of wire

The wire shall be dead cast, free from helix cast. The requirement shall be considered fulfilled in the case of wire below 5,00 mm if the following condition is satisfied.

An individual wap taken from a unit package and freely hung on a hook may show an axial displacement, f_a, at the ends of the wap (see Figure 1); the displacement f_a shall not exceed a value given by Formula (1):

$$f_a \leq \frac{0,2W}{\sqrt[4]{d}} \tag{1}$$

where

f_a is the axial displacement in mm;

W is the diameter of the free wap in mm;

d is the diameter of the wire in mm.

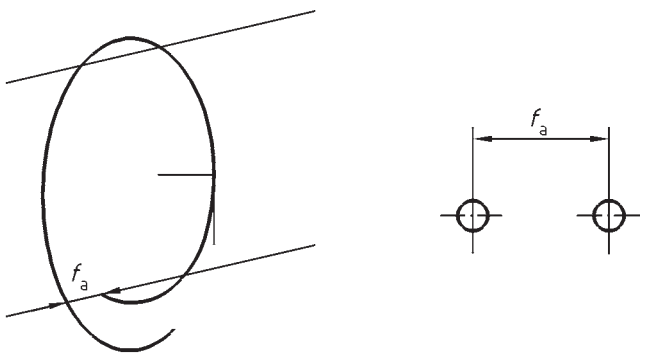


Figure 1 — Helix cast of wire

4.8 Surface quality

4.8.1 The surface of the wire shall be, as far as practically possible, free from grooves, pits and other surface defects, which could impair proper use of the wire. One method to reveal surface discontinuities is the reverse torsion test (see 5.4.6).

4.8.2 In cases where the wire is intended for high-duty springs, the purchaser and the supplier may agree at the time of order about special surface requirements and tests.

4.9 Inner soundness

The wire shall be sound and free from any inhomogenity or defect which significantly limits its use.

Tests appropriate for an assessment of the inner soundness of the wire, such as the wrapping test, may be agreed upon at the time of ordering.

4.10 Dimensions and dimensional tolerances

4.10.1 Tolerances on diameter

The tolerances on diameter are given in Table 5. If no diameter tolerance class was requested by the purchaser at the time of enquiry and order tolerance, class T14 shall be delivered.

Table 5 — Diameter tolerances

Nominal diameter, d mm	**Diameter tolerance** mm				
	Spoils or coils				**Cut lengths**
	T12	T13	T14	T15	T14
$d \leq 0{,}20$	±0,010	±0,008	±0,005	±0,004	+0,009 −0,005
$0{,}20 < d \leq 0{,}25$	±0,010	±0,008	±0,005	±0,004	+0,009 −0,005
$0{,}25 < d \leq 0{,}40$	±0,015	±0,010	±0,008	±0,005	+0,018 −0,008
$0{,}40 < d \leq 0{,}64$	±0,015	±0,010	±0,008	±0,005	+0,018 −0,008
$0{,}64 < d \leq 0{,}80$	±0,020	±0,015	±0,010	±0,008	+0,025 −0,010
$0{,}80 < d \leq 1{,}00$	±0,020	±0,015	±0,010	±0,008	+0,025 −0,010
$1{,}00 < d \leq 1{,}60$	±0,025	±0,020	±0,015	±0,010	+0,040 −0,015
$1{,}60 < d \leq 2{,}25$	±0,025	±0,020	±0,015	±0,010	+0,050 −0,015
$2{,}25 < d \leq 3{,}19$	±0,030	±0,025	±0,020	±0,015	+0,070 −0,020
$3{,}19 < d \leq 4{,}00$	±0,030	±0,025	±0,020	±0,015	+0,080 −0,020
$4{,}00 < d \leq 4{,}50$	±0,035	±0,030	±0,025	±0,020	+0,100 −0,025
$4{,}50 < d \leq 6{,}00$	±0,035	±0,030	±0,025	±0,020	+0,120 −0,025

Table 5 *(continued)*

Nominal diameter, d mm	Diameter tolerance mm				
	Spoils or coils				Cut lengths
	T12	T13	T14	T15	T14
$6{,}00 < d \leq 6{,}25$	±0,035	±0,030	±0,025	±0,020	+0,120 −0,025
$6{,}25 < d \leq 7{,}00$	±0,040	±0,035	±0,030	±0,025	+0,135 −0,030
$7{,}00 < d \leq 9{,}00$	±0,040	±0,035	±0,030	±0,025	+0,160 −0,030
$9{,}00 < d \leq 10{,}00$	±0,045	±0,040	±0,035	±0,030	+0,185 −0,035

4.10.2 Out of roundness

The out of roundness, i.e. the difference between the maximum and minimum diameter of the wire in the same cross-section of the wire, shall not be more than 50 % of the total permissible deviation for wire in coils, specified in Table 5. For special applications, tighter tolerances may be agreed at the time of enquiry and order.

4.10.3 Tolerance on the length of straightened and cut lengths

The tolerance on the length Δl shall only be on the positive keeping the same tolerance range (see Table 6).

Table 6 — Tolerance on the length of straightened and cut wire

Nominal length, l mm	Length tolerance, Δl		
	Class 1	Class 2	Class 3
$l \leq 300$	$0 \text{ mm} \leq \Delta l \leq +1{,}00 \text{ mm}$	$0 \text{ mm} \leq \Delta l \leq +0{,}01 \times l$	$0 \text{ mm} \leq \Delta l \leq +0{,}02 \times l$
$300 < l \leq 1\,000$	$0 \text{ mm} \leq \Delta l \leq +2{,}00 \text{ mm}$		
$1\,000 < l$	$0 \text{ mm} \leq \Delta l \leq +0{,}002 \times l$		

The requirements for the tolerance on straightness shall be according to ISO 22034-2.

5 Testing and inspection

5.1 Inspection and inspection documents

Products conforming with this part of ISO 6931 shall be delivered with specific testing (see ISO 6892-1) and the relevant inspection document (see ISO 10474) agreed at the time of enquiry and order.

If the order does not contain any specification of the type of inspection document, an inspection certificate 3.1 shall be issued. If an inspection certificate 3.2 is specified, the purchaser shall notify the manufacturer of the name and address of the organization or person who is to carry out the inspection and produce the inspection document. It shall also be agreed which party shall issue the certificate.

The inspection document shall include the following information:

— the document number;

— the date of issue;

— the customer's order number and name;

— the confirmation that the material complies with the requirements of the order;

— the tests, the results and where appropriate presented in a statistical manner;

— the identification by production lot number and heat number;

— the heat analysis;

— results of optional tests agreed.

5.2 Extent of testing for specific testing

The extent of testing shall be in accordance with Table 7.

Table 7 — Extent of testing and sampling for specific testing and summary of the information on test procedure and requirements

	1 Test method	2 Applies to wire diameters and wire grades	3 Mandatory/optional[a]	4 Test unit	5 Number of products per test unit	6 Number of samples per product	7 Number of test pieces per sample	8 Sampling	9 Test procedure acc. to	10 Requirement, see .....
1	Product analysis	All	o[b]	Quantity supplied per heat	1	1	1	As per ISO 14284	5.4.1	4.4
2	Tensile test	All	m	Quantity supplied per production batch[d]	10 %[c]	1	1	Test pieces taken from the ends of the coils	5.4.2	4.5
3	Coiling test	0,5 mm ≤ d ≤ 1,5 mm	o						5.4.3	4.6.1
4	Wrapping test	0,3 mm ≤ d ≤ 3 mm	o		The scope of testing shall be agreed on ordering.				5.4.4	4.6.2
5	Bend test	d > 3 mm	o						5.4.5	4.6.3
6	Wire cast characteristics	1 for circular wire cast	m		10 %[c]	1	1		5.4.7	4.7.3
		1 for helix cast of wire for diameters < 5mm								4.7.4
7	Testing for surface quality	All	o		To be agreed at the order				5.4.6	4.8
8	Check on dimensions	All	m		100 %	1	1		-	4.10

[a] m (= mandatory): the test is to be carried out in each case/o (= optional): the test is carried out only if so agreed at the time of ordering.

[b] The results of the cast analysis for the elements listed in Table 1 for the grade concerned shall be notified to the customer in all cases.

[c] 10 % of the wire units in the production batch, at least two but no more than 10 coils/reels or spools.

[d] A production batch is defined as a quantity of production originating from the same cast, which has been subjected to the same conditions of heat treatment, and with the same reduction in cross-section and with the same surface finish.

5.3 Sampling

Sampling and testing preparation shall be in accordance with ISO 377 and ISO 14284.

Samples shall be taken at the end of the coils, reels or spools or at random for wire in the form of straightened and cut lengths. Table 7, column 8 gives further details.

5.4 Test methods

5.4.1 Chemical composition

Unless otherwise agreed at the time of ordering, the choice of a suitable physical or chemical method of analysis for the determination of product analysis shall be at the discretion of the supplier.

In cases of dispute, the analysis shall be carried out by a laboratory approved by the two parties. The method of analysis to be applied shall be agreed upon, where possible in accordance with ISO/TR 9769.

5.4.2 Tensile test

The tensile test shall be carried out according to ISO 6892-1, on samples with the full cross-section of the wire. For the calculation of the tensile strength, the actual cross-section based on the actual wire diameter is applied.

5.4.3 Coiling test

The coiling test shall be carried out in the following manner: a test piece, approximately 500 mm in length, shall be closely wound, under slight but reasonably uniform tension on a mandrel three to three and a half times the nominal diameter. The mandrel diameter shall, however, be at least 1,00 mm. The close coil shall be stretched so that after releasing the stress it sets to approx. three times its original length.

The surface condition of the wire and the regularity of the spring pitch and individual windings shall be inspected with the test piece in this condition.

5.4.4 Wrapping test

The wrapping test for ductility shall be carried out according to ISO 22034-1. The wire shall be wrapped eight turns around a mandrel with a diameter equal to the wire diameter.

5.4.5 Simple bend test

For the bend test, a wire sample of sufficient length shall be bent in U form around a mandrel with a diameter equal to twice the wire diameter for sizes above 3,00 mm to 6,50 mm and equal to three times the wire diameter for sizes above 6,50 mm. For practical reasons, the wire shall be deemed to have met the requirements of this part of ISO 6931 if it withstands bending around a mandrel smaller than the one specified.

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

5.4.6 Reverse torsion test

The torsion test shall be carried out according to ISO 22034-1 with the specific requirement that the wire is twisted first two complete turns in one direction and then two turns back in the other direction without revealing surface cracks visible to the naked eye.

The distance between the clamps shall be 100 d with a maximum of 300 mm.

5.4.7 Wire cast

The circular and helix cast as defined in ISO 22034-1 shall be tested on a sufficiently long piece of wire so as to form a full free wap (single convolution of wire) ensuring that it is not bent or mechanically damaged.

5.5 Retests

Retests shall be carried out according to ISO 404.

6 Marking and packaging

Each unit shall be properly marked and identified so as to permit identification, traceability and reference to the inspection documents. The labels shall withstand normal handling and show the information according to Table 8. Other information shall be subject of an agreement between the parties.

Wire shipments shall be suitably protected against mechanical damage and/or contamination during transport.

Table 8 — Information on the labels

Designation	[a]
Manufacturer	+
Nominal diameter and diameter tolerance class	+
Steel grade	+
Tensile strength grade	+[b]
Surface finish	(+)
Cast number	(+)
Identification number	+[b]
Coating	+[b]

[a] Symbols:

\+ the information shall be mentioned on the labels;

(+) the information shall be mentioned on the labels if so agreed.

[b] Only where applicable.

Annex A
(informative)

Additional information

A.1 Indications for classification of steel grades

Depending on stress, the maximum temperature of use of the steel grade number 1.4310 is up to 250 °C.

If the greatest resistance to corrosion is required for one of the steels covered by this part of ISO 6931, the austenitic grade number 4401-316-00-I may be used, also depending on stress for a maximum temperature of use up to 250 °C.

The maximum temperature for the precipitation-hardenable austenitic-martensitic steel grade number 4568-177-00-I is up to 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 various 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 shear modulus decrease.

Table A.1 — Reference data for the modulus of elasticity and shear modulus (mean values)[a b c]

Steel grade		Modulus of elasticity[a]		Shear modulus[b]	
Name	Number	Delivery condition	Condition HT[e]	Delivery condition	Condition HT[e]
		GPa[d]	GPa[d]	GPa[d]	GPa[d]
X10CrNi18-8	4310-301-00-I	180	185	70	73
X9CrNi18-9	4325-302-00-E	180	185	70	73
X5CrNiN19-9	4315-304-51-I	170	180	65	68
X5CrNi18-10	4301-304-00-I	185	190	65	68
X5CrNiMo17-12-2	4401-316-00-I	175	180	68	71
X1NiCrMoCu25-20-5	4539-089-04-I	180	185	69	71
X2CrNiMoN22-5-3	4462-318-03-I	200	205	77	79
X7CrNiAl17-7	4568-177-00-I	190	200	73	78

[a] The reference data for the modulus of elasticity (E) are calculated from the shear modulus (G) by means of the formula $G = E/2\,(1+\nu)$ where ν (Poisson's constant) is set to 0,3. The data are applicable for a mean tensile strength of 1 800 MPa. For a mean tensile strength of 1 300 MPa, the values are 6 GPa lower. Intermediate values may be interpolated.

[b] The reference data for the shear modulus (G) 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 MPa. For a mean tensile strength of 1 300 MPa, the values are 2 GPa 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.

[c] 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 measurement of wire.

[d] 1 Mpa = 1 N/mm^2, 1 GPa = 1 kN/mm^2.

[e] HT treated: See A.5 and Table A.2.

A.2 Alteration of tensile strength by heat treatment

The heat treatment of stress-relieving (tempering), or in the case of steel grade 4568-177-00-I, precipitation hardening, will increase tensile strength and yield strength values as compared with the cold drawn condition (+C). Heat treatments of this kind will also reduce the internal stresses in the wire produced by drawing and spring forming.

The increase in the tensile strength of grade 4568-177-00-I caused by the precipitation hardening is greater than that caused by the stress relieving of other grades in this part of ISO 6931. Where the wire has been straightened before the heat treatment, the loss in tensile strength caused by the straightening can be almost compensated for.

Consequently, final stress-relieving or precipitation hardening of the finished springs is a basic recommendation. Reference data for the heat treatment are given in A.5.2 and Table A.2.

Data on the increase in tensile strength by this heat treatment are given in Figure A.1, Table A.3 for 4568-177-00-I +P, Table A.4 for 4462-318-03-I and Table A.5 for 1.4538.

The heat treatment can cause out of straightness and also some discolouration.

A.3 Physical properties

Reference data for the modulus of elasticity and shear modulus are given in Table A.1. Further physical properties (e.g. density, etc.) are given in ISO 15510.

A.4 Magnetic properties

It should be noted that, depending upon chemical composition and degree of cold deformation condition, these steels show some degree of magnetic permeability (see ISO 15510.)

A.5 Guidelines for processing and heat treatment

A.5.1 Spring forming

Forming is carried out by cold deformation. Therefore, special care is necessary because of the limited deformability of cold-worked, cold-drawn wire. Depending on the forming requirements, a lower tensile strength may be agreed upon when ordering (see Footnote d to Table 2).

Table A.2 — Reference data for heat treatment of springs made of wire [a] [b] [c] (see also A.5.2)

Steel grade		Temperature	Duration	Means of cooling
Name	Number	°C		
X10CrNi18-8	4310-301-00-I[d]	250 to 425	30 min to 4 h	air
X9CrNi18-9	4325-302-00-E	350 to 400	30 min to 1 h	air
X5CrNiN19-9	4315-304-51-I	350 to 400	30 min to 1 h	air
X5CrNi18-10	4301-304-00-I[d]	250 to 425	30 min to 4 h	air

Generally, tension springs and torsion springs with initial tension are not to be treated at the same high temperature as the above-mentioned springs. If moderate loss of initial tension can be accepted, heat treatment temperatures of max. 200 °C for grades number 4301-304-00-I, 1.4310, 4401-316-00-I and 300 °C for grade number 4568-177-00-I are recommended.

[a] See classification of the tensile strength data in Table 2 and Figure A.1.

[b] The optimum heat treatment conditions may be very different. The spring manufacturer shall choose those conditions answering the purpose (see also A.5.2.1).

[c] The heat treatment data refer to compression springs, torsion and tension (springs without initial tension).

[d] The lower temperature is recommended for extension springs with prestress.

Table A.2 *(continued)*

Steel grade		Temperature	Duration	Means of cooling
Name	Number	°C		
X5CrNiMo17-12-2	4401-316-00-I[d]	250 to 425	30 min to 4 h	air
X1NiCrMoCu25-20-5	4539-089-04-I[d]	250 to 425	30 min to 4 h	air
X2CrNiMoN22-5-3	4462-318-03-I$_d$	250 to 450	1h to 3h	air
X7CrNiAl17-7	4568-177-00-I	450 to 490	up to 1 h	air

Generally, tension springs and torsion springs with initial tension are not to be treated at the same high temperature as the above-mentioned springs. If moderate loss of initial tension can be accepted, heat treatment temperatures of max. 200 °C for grades number 4301-304-00-I, 1.4310, 4401-316-00-I and 300 °C for grade number 4568-177-00-I are recommended.

[a] See classification of the tensile strength data in Table 2 and Figure A.1.

[b] The optimum heat treatment conditions may be very different. The spring manufacturer shall choose those conditions answering the purpose (see also A.5.2.1).

[c] The heat treatment data refer to compression springs, torsion and tension (springs without initial tension).

[d] The lower temperature is recommended for extension springs with prestress.

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 If the colours produced **by** heat treatment are not permissible for visual or corrosion-resistance reasons, the springs may be suitably cleaned before the heat treatment or the heat treatment may be carried out in a protective atmosphere.

Table A.3 — Expected minimum tensile strength for precipitation hardened 4568-177-00-I

Nominal diameter mm	Tensile strength MPa
$d \leq 0{,}20$	2 275
$0{,}20 < d \leq 0{,}30$	2 250
$0{,}30 < d \leq 0{,}40$	2 225
$0{,}40 < d \leq 0{,}50$	2 200
$0{,}50 < d \leq 0{,}65$	2 150
$0{,}65 < d \leq 0{,}80$	2 125
$0{,}80 < d \leq 1{,}00$	2 100
$1{,}00 < d \leq 1{,}25$	2 050
$1{,}25 < d \leq 1{,}50$	2 000
$1{,}50 < d \leq 1{,}75$	1 950
$1{,}75 < d \leq 2{,}00$	1 900
$2{,}00 < d \leq 2{,}50$	1 850
$2{,}50 < d \leq 3{,}00$	1 800
$3{,}00 < d \leq 3{,}50$	1 750
$3{,}50 < d \leq 4{,}25$	1 700
$4{,}25 < d \leq 5{,}00$	1 650
$5{,}00 < d \leq 6{,}00$	1 550

Table A.3 *(continued)*

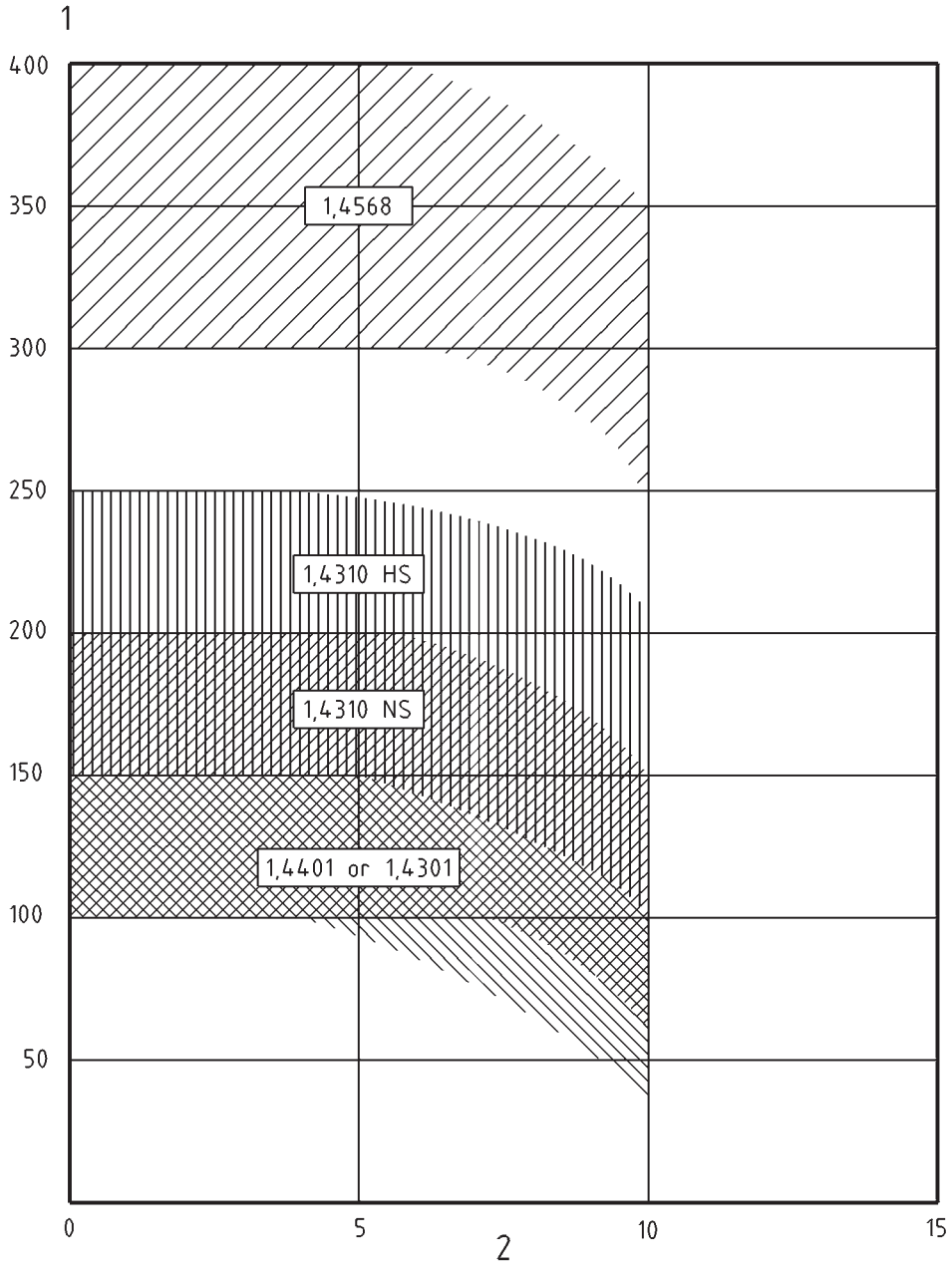
Nominal diameter mm	Tensile strength MPa
6,00 < d ≤ 7,00	1 500
7,00 < d ≤ 8,50	1 500
8,50 < d ≤ 10,00	1 500

Table A.4 — Expected minimum tensile strength increase for 4462-318-03-I

Nominal diameter mm	Tensile strength MPa
0,20 ≤ d ≤ 1,00	300 to 450
1,00 < d ≤ 8,5	200 to 400

Table A.5 — Expected minimum tensile strength increase for 4539-089-04-I

Nominal diameter mm	Tensile strength MPa
0,15 ≤ d ≤ 8,5	50 to 100



Key

1 increase in tensile strength, MPa

2 wire diameter, mm

Figure A.1 — Reference data for the increase in tensile strength of cold drawn wire by heat treatment (see Table A.2)

Bibliography

[1] ISO 4955*Heat-resistant steels*

[2] ISO 6929, *Steel products — Vocabulary*

[3] EN 10270-3, *Steel wire for mechanical springs — Part 3: Stainless spring steel wire*

[4] JIS G4314:2013, *Stainless steel wires for springs*

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