

Specification for Wire Rope

API SPECIFICATION 9A
TWENTY-SEVENTH EDITION, AUGUST 2020

ADDENDUM 1, MAY 2023



American
Petroleum
Institute

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A significant technical change was implemented in Section 5.2.4.1 to align the method of measuring the breaking force of a rope with industry recognized test procedures. Section 5.2.4.1 now references ASTM A931, *Standard Test Method for Tension Testing of Wire Ropes and Strand* and removes the testing requirement previously described within Annex H.

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Introduction

This standard was developed in response to worldwide demand for minimum specifications for wire ropes for use on equipment and machinery associated with the petroleum and natural gas industries.

In recognition of equipment already in use and originally designed to accommodate wire rope sizes (nominal wire rope diameters) based on “English” units, some of the more common “converted SI unit” sizes have also been included.

In addition, and in recognition of equipment already in use and designed to operate with wire ropes having specific wire rope grades (e.g. IPS), based on “U.S.” wire levels, these grades have also been included to give prominence to the required minimum values of breaking force associated with these grades and help to ensure that existing design safety levels are maintained.

Having due regard to size and breaking force for a particular wire rope class or construction, in some cases it is possible to safely substitute a U.S. customary size and grade with one based solely on SI units and grade, and vice-versa. To assist in this process, this standard gives a size range for each nominal wire rope diameter and equivalent minimum breaking forces (converted from U.S. customary units) for comparison, although it is recommended that the equipment designer or wire rope manufacturer (or other competent person) is consulted prior to ordering a substitute rope.

It should also be noted that a particular design of wire rope may be capable of offering a higher breaking force value than the one specified either in the relevant table in this standard or by the manufacturer in their catalog. In such cases, a higher minimum breaking force value (or actual breaking force value if the wire rope has already been manufactured and tested) may be provided by the manufacturer before an order is placed.

Designers of new equipment are encouraged to select wire ropes having the preferred SI units and grades.

Specification for Wire Rope

1 Scope

This standard specifies the minimum requirements and terms of acceptance for the manufacture and testing of steel wire ropes for the petroleum and natural gas industries. The following products are covered by this specification:

- bright- or drawn-galvanized wire rope,
- well-measuring wire, and
- well-measuring strand.

Typical applications include tubing lines, rod hanger lines, sand lines, cable-tool drilling and clean out lines, cable tool casing lines, rotary drilling lines, winch lines, horse head pumping unit lines, torpedo lines, mast-raising lines, guideline tensioner lines, riser tensioner lines, and mooring and anchor lines. Wire ropes for lifting slings and cranes, and wire for well-measuring and strand for well-servicing, are also included.

The minimum breaking forces for the more common sizes, grades, and constructions of stranded wire rope not exceeding 2160 grade and well measuring wire are given in tables. However, this standard does not restrict itself to the classes covered by those tables. Other types, such as wire ropes with compacted strands and compacted (swaged) wire ropes, may also conform with its requirements. The minimum breaking force values for these wire ropes and wire are provided by the manufacturer.

For information only, other tables present the minimum breaking forces for large diameter wire ropes and spiral ropes (i.e. spiral strand and locked coil), while approximate nominal length masses for the more common wire rope constructions and large diameter stranded and spiral ropes are also given.

2 Normative References

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

ASTM A931, *Standard Test Method for Tension Testing of Wire Ropes and Strand*

ISO 2232:1990,¹ *Round drawn wire for general purpose non-alloy steel wire ropes and for large diameter steel wire ropes—Specifications*

ISO 4345, *Steel wire ropes—Fiber main cores—Specification*

ISO 4346, *Steel wire ropes for general purposes—Lubricants—Basic requirements*

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

ISO 7800, *Metallic materials—Wire—Simple torsion test*

ISO 7801, *Metallic materials—Wire—Reverse bend test*

ISO 17893, *Steel wire ropes—Vocabulary, designation, and classification*

¹ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

3 Terms and Definitions

For the purposes of this document, the terms and definitions given in ISO 17893 apply.

4 Requirements

4.1 Material

4.1.1 Wire

The wires for stranded wire ropes and well-servicing strand of carbon steel shall, before fabrication, conform to the diameter, tensile, torsion, and when applicable, zinc-coating requirements specified in [Annex A](#).

The methods of test for wires of tensile strength grades 1370 N/mm², 1570 N/mm², 1770 N/mm², 1960 N/mm², and 2160 N/mm² shall be in accordance with those given in ISO 2232.

The methods of test for wires of tensile strength grades Levels 2, 3, 4, and 5 shall be in accordance with [Annex B](#).

For those wire ropes where a wire rope grade is applicable, the tensile strength grade of the wires shall be subject to the limits given in [Table 1](#).

NOTE The minimum breaking force values of those ropes of grades 1770, 1960, and 2160 as covered by Tables [C.1](#) through [C.16](#) are calculated on the basis of wire rope grade and not individual wire tensile strength grades or levels.

Table 1—Range of Wire Tensile Strength Grades

Rope Grade	Wire Tensile Strength Grades N/mm ²
1770	1570 or Level 2 to 1960 or Level 4
1960	1770 or Level 3 to 2160 or Level 5
2160	1960 or Level 4 to 2160 or Level 5
IPS	Level 2 or 1570 to Level 4 or 1960
EIP	Level 3 or 1770 to Level 5 or 2160
EEIP	Level 4 or 1960 to Level 5 or 2160

For those wire ropes (e.g. larger diameter wire ropes) where a wire rope grade is not applicable, the tensile strength grades of the wires shall be one, or a combination, of those given in [Annex A](#).

All wires of the same nominal diameter in the same wire layer shall be of the same tensile strength grade.

Well-measuring wire and wires used in the manufacture of well-servicing strand shall normally be of carbon steel but other materials (e.g. stainless steel) may be used.

The purchaser may specify any particular material requirements.

NOTE Well-measuring wire and wires used in the manufacture of well-servicing strand are typically composed of carbon steel but other materials (e.g. stainless steel) may be used.

4.1.2 Core

The purchaser may specify the type of core.

Fiber cores shall conform to ISO 4345.

The fiber cores for single-layer stranded ropes larger than 8 mm diameter shall be doubly closed (i.e. from yarn into strand and from strand into rope). Natural fiber cores shall be treated with an impregnating compound to inhibit rotting and decay.

Steel cores shall be either an independent wire rope (IWRC) or wire strand (WSC).

Steel cores of single-layer stranded ropes larger than 12 mm diameter shall be an IWRC, unless specified otherwise.

NOTE Cores of stranded ropes are typically composed of steel or fiber, although other types, such as composites (e.g. steel plus fibers or plastics) or cores made of solid polymer, may also be supplied.

4.1.3 Lubricant

Lubricants shall conform to ISO 4346.

4.2 Rope Manufacture

4.2.1 General

In stranded ropes, all the wire layers in a strand shall have the same direction of lay. The lay lengths of corresponding wire layers in strands of the same size, construction, and strand layer shall be uniform.

The core of a stranded rope, except for compacted (swaged) ropes, shall be designed (steel) or selected (fiber) so that in a new rope under no load there is clearance between outer strands.

The rope ends shall be secured such that they are prevented from unlaying.

4.2.2 Wire Joints

Diameters shall be continuous, but, for wires other than well-measuring wires, if joints are necessary in wires over 0.4 mm, they shall have their ends joined by brazing or welding.

For stranded ropes, the minimum distance between joints within one strand shall be $18 \times$ rope diameter (d).

For spiral ropes, the minimum distance between joints in any wire layer shall be $36 \times$ diameter of the wire layer.

Wires up to and including 0.4 mm may be joined by twisting or by ends being simply inserted into the strands' formation.

4.2.3 Preformation and Postformation

Stranded ropes shall be preformed or postformed, or both, unless specified otherwise by the purchaser.

NOTE Some parallel-closed ropes and rotation-resistant ropes may be nonpreformed.

4.2.4 Construction

The rope construction shall be either one of those covered in [Annex C](#) or as stated by the manufacturer.

The constructions of compacted strand wire ropes, compacted (swaged) wire ropes, large diameter (i.e. over 60 mm) stranded ropes, and spiral ropes (i.e. spiral strand and full-locked coil), shall be stated by the manufacturer.

Where only the wire rope class is specified by the purchaser, the construction supplied shall be stated by the manufacturer.

For well-servicing strand, the construction shall be either $1 \times 16M$ or $1 \times 19M$ or as stated by the manufacturer.

4.2.5 Rope Grade

The wire rope grades for the more common classes and sizes of stranded ropes shall be as given in [Annex C](#).

Intermediate grades may be supplied by agreement between the purchaser and the manufacturer or supplier.

NOTE Not all wire ropes (e.g. large diameter stranded ropes and spiral ropes) will necessarily have a nominated rope grade.

4.2.6 Wire Finish

The finish of the wires shall be uncoated (bright), zinc-coated class B, or zinc-coated class A.

For wire ropes of bright wire finish, substitution of bright wires by zinc-coated wires shall be limited to inner wires, center wires, filler wires, and core wires.

For ropes of zinc-coated wire finish, all the wires shall be zinc-coated, including those of any steel core.

Where zinc-coated is specified, this may also include zinc alloy Zn95/Al5.

4.2.7 Direction and Type of Wire Rope Lay

The direction and type of wire rope lay for stranded ropes shall be one of the following:

- a) right ordinary lay (sZ)²,
- b) left ordinary lay (zS)³,
- c) right lang lay (zZ)⁴,
- d) left lang lay (sS)⁵,
- e) right alternate lay (aZ)⁶,
- f) left alternate lay (aS)⁷.

Well-servicing strand shall be left lay (S).

Spiral ropes (i.e. spiral strand and full-locked coil) shall be either right (Z) or left lay (S).

The direction and type of rope lay should be specified by the purchaser.

4.2.8 Designation and Classification

For the purposes of this standard, the designation and classification systems according to ISO 17893 shall apply.

² Formerly referred to as right-hand ordinary (designated RHO) and right regular lay (designated RRL).

³ Formerly referred to as left-hand ordinary (designated LHO) and left regular lay (designated LRL).

⁴ Formerly referred to as right-hand langs (designated RHL) or right lang lay (designated RLL).

⁵ Formerly referred to as left-hand langs (designated LHL) or left lang lay (designated LLL).

⁶ Formerly designated RAL.

⁷ Formerly designated LAL.

4.3 Diameter

4.3.1 General

The nominal diameter shall be that by which the wire, strand, or wire rope is designated.

4.3.2 Tolerance

When measured in accordance with [5.2.3](#), the measured (actual) diameter of stranded ropes shall be within the tolerances given in [Table 2](#).

Table 2—Tolerances on Rope Diameter (Stranded Rope)

Nominal Rope Diameter d mm	Tolerance as Percentage of Nominal Diameter	
	Wire Ropes with Strands That are Exclusively of Wire or Incorporate Solid Polymer Centers	Wire Ropes with Strands That Incorporate Fiber Centers
$2 \leq d < 4$	+8 0	+9 0
$4 \leq d < 6$	+7 0	+9 0
$6 \leq d < 8$	+6 0	+8 0
≥ 8	+5 0	+7 0

When measured in accordance with [5.2.3](#), the measured (actual) diameter of strand shall be within $^{+5}_0$ % of the nominal diameter.

When measured in accordance with [5.2.3](#), the measured (actual) diameter of well-servicing strand shall be within the tolerances given in [Annex D](#).

4.3.3 Difference Between Diameter Measurements

For stranded and spiral ropes, the difference between any two of the four measurements taken in accordance with [5.2.3](#) and expressed as a percentage of the nominal diameter shall not exceed the values given in [Table 3](#).

Table 3—Permissible Differences Between Any Two Diameter Measurements

Nominal Wire Rope Diameter d mm	Wire Ropes with Strands That are Exclusively of Wire or Incorporate Solid Polymer Centers and Spiral Ropes %	Wire Ropes with Strands That Incorporate Fiber Centers %
$2 \leq d < 4$	7	—
$4 \leq d < 6$	6	8
$6 \leq d < 8$	5	7
≥ 8	4	6

4.4 Lay Length

For single-layer ropes of 6 × 7 class, the length of lay of the finished wire rope shall not exceed 8 × rope diameter (d).

For other single-layer ropes with round strands (except those with three or four strands), parallel-lay closed wire ropes and rotation-resistant wire ropes with round strands or shaped strands, the length of lay of the finished wire rope shall not exceed 7.25 × rope diameter (d).

For single-layer wire ropes with shaped strands, e.g. triangular strand, the length of lay of the finished wire rope shall not exceed 10 × wire rope diameter (d).

For well-servicing strand, the length of lay of the finished strand shall not exceed 10 × strand diameter (d).

4.5 Breaking Force

4.5.1 Well-measuring Wire

The minimum breaking force for a given diameter of well-measuring wire shall be as given in [I.1](#).

The wire shall be tested in accordance with the method specified in [I.2](#). The measured breaking force shall be greater than or equal to the minimum breaking force.

4.5.2 Well-servicing Strand

The minimum breaking force for a given diameter and construction shall be either of the following:

- a) as given in [Annex D](#), or
- b) as stated by the manufacturer.

When tested in accordance with Method 1 (see [5.2.4.1](#)), the measured breaking force shall be greater than or equal to the minimum breaking force.

4.5.3 Stranded Ropes and Spiral Ropes

4.5.3.1 General

The minimum breaking force, $F_{\min}$, for a given wire rope diameter and construction shall be either of the following:

- a) as given in [Annex C](#) for stranded ropes, or
- b) as stated by the manufacturer.

NOTE 1 Values of minimum breaking force for large diameter stranded and spiral ropes are given for information in [Annex E](#).

For those ropes covered in [Annex C](#), the minimum breaking force of intermediate wire rope diameters shall be calculated with the respective minimum breaking force factors in accordance with [Annex F](#).

When tested in accordance with Method 1 of [5.2.4.1](#), the measured breaking force, F_m , shall be greater than or equal to the minimum breaking force, $F_{\min}$.

Breaking force testing requirements shall be in accordance with [Table 4](#).

NOTE 2 The requirements for breaking force take into account the following: a) the wire rope size; b) whether or not wire ropes are produced in series, i.e. repeatedly produced; c) whether or not the minimum breaking force factor is constant.

throughout a range of diameters; d) whether or not the manufacturer is operating a quality system in accordance with ISO 9001, certified by an accredited third-party certification body.

Table 4—Breaking Force Testing Requirements

Wire Rope Diameter d mm	Minimum Breaking Force Factor	Manufacturer Operating a Quality System in Accordance with ISO 9001, Certified by an Accredited Third-party Certification Body	Manufacturer NOT Operating a Quality System in Accordance with ISO 9001, Certified by an Accredited Third-party Certification Body
$d \leq 60$	Same factor throughout a sub-group of rope diameters.	Breaking force test in accordance with 5.2.4.1 (Method 1) on a sample from each production length; or, if produced in series, type testing in accordance with H.1.1 plus periodic test in accordance with 5.2.4.1 (Method 1), 5.2.4.2 (Method 2), or 5.2.4.3 (Method 3) on a sample from every 20th production length relating to the sub-group of diameters.	Breaking force test in accordance with 5.2.4.1 (Method 1) on a sample from each production length.
	Different factor throughout a sub-group of wire rope diameters.	Breaking force test in accordance with 5.2.4.1 (Method 1) on a sample from each production length; or, if produced in series, type testing in accordance with G.1.2 plus periodic test in accordance with 5.2.4.1 (Method 1), 5.2.4.2 (Method 2), or 5.2.4.3 (Method 3) on a sample from every 20th production length of a given rope diameter and construction.	Breaking force test in accordance with 5.2.4.1 (Method 1) on a sample from each production length.
$d > 60$		Breaking force test in accordance with 5.2.4.1 (Method 1), 5.2.4.2 (Method 2), or 5.2.4.3 (Method 3) on a sample from each production length, or either of the following: if produced in series, type testing in accordance with H.2 plus periodic test in accordance with 5.2.4.1 (Method 1), 5.2.4.2 (Method 2), or 5.2.4.3 (Method 3) on a sample from every 20th production length; or if produced for supply as a set of ropes of the same design for a specific installation, the alternative breaking force testing and sampling as also given in G.2 .	Breaking force test in accordance with 5.2.4.1 (Method 1), 5.2.4.2 (Method 2), or 5.2.4.3 (Method 3) on a sample from each production length.
NOTE The result from Method 1 is known as measured breaking force. The result from Method 2 is known as calculated measured (post-spin) breaking force. The result from Method 3 is known as calculated measured (pre-spin) breaking force.			

4.5.3.2 Wire Ropes Produced in Series—Manufacturer Operating a Quality System in Accordance with ISO 9001, Certified by an Accredited Third-party Certification Body

The manufacturer shall be able to provide the results from type testing in accordance with the sampling and acceptance criteria given in [Annex G](#).

Type testing shall be repeated on any wire rope that has its design changed in any way which results in a modified (e.g. increased) breaking force. If the same design, apart from wire tensile strength grades, is used for wire ropes of a lower grade or lower breaking force, or both, than the one which has successfully passed the type testing requirements, it shall not be necessary to repeat the tests on those wire ropes provided the breaking force is calculated with the same spinning loss.

Subsequent production lengths of wire ropes produced in series shall be deemed to conform to the breaking force requirements when the manufacturer has satisfactorily completed the following on a sample from every 20th production length:

- a) the appropriate type tests (see [Annex G](#)), and
- b) a periodic breaking force test in accordance with Method 1 or one of the alternative methods, known as Methods 2 and 3 (see [5.2.4.2](#) and [5.2.4.3](#)).

4.6 Length

For those wire ropes not forming part of an assembly, the actual length of wire rope supplied shall be the specified nominal length subject to the following tolerances.

Up to and including 400 m: ${}^{+5}_0$ % of the specified length.

Over 400 m, up to and including 1000 m: ${}^{+20}_0$ m.

Over 1000 m: ${}^{+2}_0$ % of the specified length.

The wire rope shall be measured under no load.

Wire ropes required with smaller length tolerance should be the subject of agreement between the purchaser and the manufacturer.

5 Verification of Requirements and Test Methods

5.1 Processes Requiring Validation

The completed wire, strand, and wire rope covered in this specification are subject to physical testing and do not require validation of the processes used in manufacturing. Except for wire joints (see [4.2.2](#)), the processes used in manufacturing shall not require validation. Welding and brazing shall be validated to demonstrate the ability of these processes to achieve specified results. A third-party validation or certification of welding personnel is not required.

5.2 Stranded Ropes and Spiral Ropes

5.2.1 Materials

Conformance with the wire, core, and lubricant requirements shall be through a visual verification of the inspection documents supplied with the wire, core, and lubricant.

5.2.2 Rope Manufacture

Conformance with the requirements for wire joints and preformation shall be through visual verification.

5.2.3 Test on Rope for Diameter

Diameter measurements shall be taken on a straight portion of wire rope, either under no tension or a tension not exceeding 5 % of the minimum breaking force, at two positions spaced at least 1 m apart. At each position, two measurements, at right angles, of the circumscribed circle diameter shall be taken. The measuring equipment shall extend over at least two adjacent strands (see [Figure 1](#)). The average of these four measurements shall be the measured diameter.

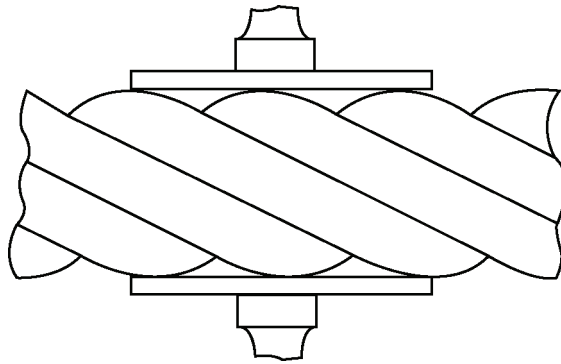


Figure 1—Method of Measuring Wire Rope Diameter

5.2.4 Test on Wire Rope for Breaking Force

5.2.4.1 Method 1—Measured Breaking Force

The method shall be in accordance with ASTM A931.

5.2.4.2 Method 2—Calculated Measured (Post-spin) Breaking Force

The measured breaking forces of all individual wires shall be added together after they have been removed from the wire rope, and this value shall be multiplied by either of the following:

- a) the spinning loss factor derived from [Annex E](#), or
- b) the partial spinning loss factor obtained from the results of type testing.

The partial spinning loss factor used in the calculation shall be the lowest of the three values obtained from type testing. In the case of triangular strand ropes, the triangular center of the strand may be considered as an individual wire. The wires shall be tested in accordance with the wire tensile test specified in [B.2](#) or in ISO 6892.

NOTE The result from this test is known as the “calculated measured (post-spin) breaking force.”

When this method (i.e. Method 2) is used for the periodic test (see [Table 4](#)) and the calculated measured (post-spin) breaking force value is less than the intended minimum breaking force value, another test shall be repeated using Method 1.

If the measured (actual) breaking force in this second test fails to meet the intended minimum breaking force value, the minimum breaking force shall be de-rated to a value not exceeding the measured (actual) breaking force value and type testing shall be repeated using Method 1.

In such cases, the wire rope shall be de-rated to a grade that shall not exceed the actual breaking force value. The de-rated grade of the wire rope shall be documented in the wire rope certificate. See [Section 6](#).

5.2.4.3 Method 3—Calculated Measured (Pre-spin) Breaking Force

The measured breaking forces of all the individual wires shall be added together before they are laid into the wire rope, and this value shall be multiplied by the total spinning loss factor obtained from the results of type testing. The total spinning loss factor used in the calculation shall be the lowest of the three values obtained from type testing.

The wires shall be tested in accordance with the wire tensile test specified in ISO 6892.

NOTE The result from this test is known as the “calculated measured (pre-spin) breaking force.”

When this method (i.e. Method 3) is used for the periodic test (see Table 4) and the calculated measured (pre-spin) breaking force value is less than the intended minimum breaking force value, another test shall be performed using Method 1.

If the measured (actual) breaking force in this second test fails to meet the intended minimum breaking force value, the minimum breaking force shall be de-rated to a value not exceeding the measured (actual) breaking force value and type testing shall be repeated using Method 1.

In such cases, the wire rope shall be de-rated to a grade that shall not exceed the actual breaking force value. The de-rated grade of the wire rope shall be documented in the wire rope certificate. See [Section 6](#).

5.2.5 Tests on Wires from the Wire Rope

When tests, if any, are required to be performed on wires taken from the wire rope after fabrication, sampling, test methods, and acceptance criteria shall be specified by the purchaser.

If tests on the wires are required to be performed, this should be stated in the purchaser's order.

NOTE See [Annex H](#) for guidance on testing and acceptance criteria.

5.3 Tests on Well-measuring Wire

The tests shall consist of a simultaneous elongation and tensile test and a separate torsion test. Testing methods and acceptance criteria shall be in accordance with [Annex J](#).

5.4 Tests on Well-servicing Strands

The tests shall consist of a measured diameter in accordance with [5.2.3](#) and a breaking force test in accordance with [5.2.4.1](#).

5.5 Facilities for Witnessing Tests

The manufacturer shall offer the purchaser or purchaser's representative all necessary facilities for the witnessing of tests (when these are performed) or for the examination of records of type tests to be assured of compliance with this standard, or both.

Test lengths required by the purchaser should be ordered as additional lengths.

6 Information for Use

6.1 Certificate

6.1.1 General

A certificate shall confirm conformance with this standard and, unless specified otherwise by the purchaser, shall give at least the following information:

- a) certificate number,
- b) name and address of the manufacturer,
- c) wire rope designation or wire rope description,
- d) minimum breaking force,
- e) date of issue of the certificate and authentication.

NOTE See [Annex J](#) for information that should be provided by the purchaser.

Quantity and nominal length of rope may also be included.

The certificate shall enable traceability of the wire rope.

6.1.2 Test Results

When actual test results are required to be certified (see above), the certificate shall additionally give either Item a) or Item b) or both, as follows:

- a) breaking force test on wire rope—state which value, i.e.
 - 1) measured breaking force, or
 - 2) calculated measured (post-spin) breaking force, or
 - 3) calculated measured (pre-spin) breaking force;
- b) tests on wires—
 - 1) number of wires tested,
 - 2) nominal dimension of wire,
 - 3) measured dimension of wire (diameter or height of profile),
 - 4) breaking force of wire,
 - 5) tensile strength of wire (based on nominal dimension),
 - 6) number of torsions completed (and test length),
 - 7) mass of coating.

6.2 Packaging and Marking

6.2.1 Packaging

Wire ropes shall be supplied in coils or on reels at the discretion of the manufacturer.

The purchaser should specify any particular packaging requirements.

Rotation-resistant wire ropes should be supplied on reels.

6.2.2 The wire rope manufacturer's or supplier's name and address, certificate number if appropriate (see [6.1](#)), length, and wire rope designation shall be legibly and durably marked on a tag attached to each coil or reel of wire rope.

Annex A (normative)

Dimensional and Mechanical Properties of Round Wires (Before Rope Fabrication)

A.1 Tensile Strength Grades 1370 N/mm², 1570 N/mm², 1770 N/mm², 1960 N/mm², and 2160 N/mm²

The permitted variations in tensile strengths of non-alloyed steel wires shall not exceed the nominal values by an amount greater than those given in [Table A.1](#). The values of tensile strength grade are the lower (minima) limits for each tensile strength grade.

Table A.1—Permitted Variations in Tensile Strength

Nominal Diameter mm	Permitted Variation in Tensile Strength Above Nominal N/mm ²
$0.2 \leq \delta < 0.5$	390
$0.5 \leq \delta < 1.0$	350
$1.0 \leq \delta < 1.5$	320
$1.5 \leq \delta < 2.0$	290
$2.0 \leq \delta < 3.5$	260
$3.5 \leq \delta < 7.0$	250

In the case of alloy steel wires, the maximum values shall be no greater than the minimum value plus 15 %.

The diameter tolerances, minimum number of torsions, and minimum masses of coating shall be in accordance with the values given in [Table A.2](#).

NOTE The values in [Table A.2](#) are based on ISO 2232 with an extended size range and additional tensile strength grades at the lower and higher ends.

Table A.2—Diameter Tolerances, Minimum Number of Torsions, and Minimum Masses of Zinc for Tensile Strength Grades 1370 N/mm², 1570 N/mm², 1770 N/mm², 1960 N/mm², and 2160 N/mm²

Nominal Diameter of Wire	Tolerance		Minimum Number of Torsions Based on 100δ										Min. Mass Zn
	Bright and Galv. or Zn95/AI5	Galv. or Zn95/AI5	Bright and Galvanized or Zn95/AI5					Galvanized or Zn95/AI5					Galv. or Zn95/AI5
			Quality B		Quality A		Quality B		Quality A				
			Tensile Strength Grade (N/mm ²)										
mm	mm		1370	1570	1770	1960	2160	1370	1570	1770	1960	B	A
0.20 ≤ δ < 0.25	±0.008	—	—	—	—	—	—	—	—	—	—	20	—
0.25 ≤ δ < 0.30	±0.008	—	—	—	—	—	—	—	—	—	—	30	—
0.30 ≤ δ < 0.40	±0.01	±0.025	—	—	—	—	—	—	—	—	—	30	—
0.40 ≤ δ < 0.50	±0.01	±0.025	—	—	—	—	—	—	—	—	—	40	75
0.50 ≤ δ < 0.55	±0.015	±0.03	34	30	28	25	23	—	—	—	—	50	90
0.55 ≤ δ < 0.60	±0.015	±0.03	34	30	28	25	23	—	—	—	—	50	90
0.60 ≤ δ < 0.65	±0.015	±0.03	34	30	28	25	23	—	—	—	—	60	120
0.65 ≤ δ < 0.70	±0.015	±0.03	34	30	28	25	23	—	—	—	—	60	120
0.70 ≤ δ < 0.75	±0.015	±0.03	34	30	28	25	23	21	19	17	17	60	120
0.75 ≤ δ < 0.80	±0.015	±0.03	34	30	28	25	23	21	19	17	17	60	120
0.80 ≤ δ < 0.85	±0.015	±0.03	34	30	28	25	22	—	21	19	17	60	140
0.85 ≤ δ < 0.90	±0.015	±0.03	34	30	28	25	22	—	21	19	17	60	140
0.90 ≤ δ < 0.95	±0.015	±0.03	34	30	28	25	22	—	21	19	17	70	150
0.95 ≤ δ < 1.00	±0.015	±0.03	34	30	28	25	22	—	21	19	17	70	150
1.00 ≤ δ < 1.10	±0.02	±0.04	33	29	26	23	21	—	20	18	13	80	160
1.10 ≤ δ < 1.20	±0.02	±0.04	33	29	26	23	21	—	20	18	13	80	160
1.20 ≤ δ < 1.30	±0.02	±0.04	33	28	25	22	20	—	18	15	10	90	170
1.30 ≤ δ < 1.40	±0.02	±0.04	33	28	25	22	19	—	18	15	10	90	170
1.40 ≤ δ < 1.50	±0.02	±0.04	33	28	25	22	19	—	18	15	10	100	180
1.50 ≤ δ < 1.60	±0.02	±0.04	33	28	25	22	19	—	18	15	10	100	180
1.60 ≤ δ < 1.70	±0.02	±0.04	33	28	25	22	19	—	18	15	10	100	200
1.70 ≤ δ < 1.80	±0.02	±0.05	33	28	25	22	19	—	18	15	10	100	200
1.80 ≤ δ < 1.90	±0.025	±0.05	32	27	24	21	18	—	17	14	9	100	200

Table A.2—Diameter Tolerances, Minimum Number of Torsions, and Minimum Masses of Zinc for Tensile Strength Grades 1370 N/mm², 1570 N/mm², 1770 N/mm², 1960 N/mm², and 2160 N/mm² (Continued)

Nominal Diameter of Wire	Tolerance		Minimum Number of Torsions Based on 100δ										Min. Mass Zn			
	Bright and Galv. or Zn95/Al5	Galv. or Zn95/Al5	Quality B	Quality A	Quality B	Quality A	Bright and Galvanized or Zn95/Al5								Galvanized or Zn95/Al5	
							Tensile Strength Grade (N/mm ²)								Galvanized or Zn95/Al5	
							1370	1570	1770	1960	2160	1370	1570	1770	1960	B
mm	mm		Tensile Strength Grade (N/mm ²)										g/m ²			
1.90 ≤ δ < 2.00	±0.025	±0.05	32	27	24	21	18	—	17	14	9	110	215			
2.00 ≤ δ < 2.10	±0.025	±0.05	32	27	24	21	18	—	17	14	9	110	215			
2.10 ≤ δ < 2.20	±0.025	±0.06	32	27	24	21	18	—	17	14	9	110	215			
2.20 ≤ δ < 2.30	±0.025	±0.06	31	27	24	21	18	20	17	14	9	125	230			
2.30 ≤ δ < 2.40	±0.025	±0.06	30	27	24	21	18	20	17	14	9	125	230			
2.40 ≤ δ < 2.50	±0.025	±0.06	29	26	23	20	18	19	15	12	7	125	230			
2.50 ≤ δ < 2.60	±0.025	±0.06	29	26	23	20	18	19	15	12	7	125	230			
2.60 ≤ δ < 2.70	±0.025	±0.06	29	26	23	20	18	19	15	12	7	125	230			
2.70 ≤ δ < 2.80	±0.025	±0.06	29	26	23	20	18	19	15	12	7	135	240			
2.80 ≤ δ < 2.90	±0.03	±0.07	28	26	23	20	18	19	15	12	7	135	240			
2.90 ≤ δ < 3.00	±0.03	±0.07	28	26	23	20	18	18	15	12	7	135	240			
3.00 ≤ δ < 3.10	±0.03	±0.07	27	25	21	18	16	18	12	8	5	135	240			
3.10 ≤ δ < 3.20	±0.03	±0.07	27	25	21	18	16	13	12	8	5	135	240			
3.20 ≤ δ < 3.30	±0.03	±0.07	27	25	21	18	16	13	12	8	5	135	250			
3.30 ≤ δ < 3.40	±0.03	±0.07	27	25	21	18	16	13	12	8	5	135	250			
3.40 ≤ δ < 3.50	±0.03	±0.07	27	25	21	18	16	13	12	8	5	135	250			
3.50 ≤ δ < 3.60	±0.03	±0.07	26	24	20	16	14	11	10	6	5	135	250			
3.60 ≤ δ < 3.70	±0.03	±0.07	26	24	20	16	14	11	10	6	5	135	260			
3.70 ≤ δ < 3.80	±0.03	±0.07	25	23	19	15	13	11	8	6	5	135	260			
3.80 ≤ δ < 3.90	±0.03	±0.07	24	22	18	14	12	11	7	6	4	135	260			
3.90 ≤ δ < 4.00	±0.03	±0.07	24	22	18	14	12	10	7	6	4	135	260			
4.00 ≤ δ < 4.20	±0.03	±0.08	23	21	17	13	11	9	6	6	4	150	275			

Table A.2—Diameter Tolerances, Minimum Number of Torsions, and Minimum Masses of Zinc for Tensile Strength Grades 1370 N/mm², 1570 N/mm², 1770 N/mm², 1960 N/mm², and 2160 N/mm² (Continued)

Nominal Diameter of Wire	Tolerance		Minimum Number of Torsions Based on 100δ										Min. Mass Zn
	Bright and Galv. or Zn95/Al5	Galv. or Zn95/Al5	Quality A	Quality B	Quality A								Galv. or Zn95/Al5
					Quality A								
					Quality A								
mm	mm	Tensile Strength Grade (N/mm ²)										g/m ²	
		1370	1570	1770	1960	2160	1370	1570	1770	1960	B	A	
4.20 ≤ δ < 4.40	±0.03	±0.08	21	19	15	11	—	8	6	5	4	150	275
4.40 ≤ δ < 4.60	±0.03	±0.08	20	18	14	10	—	7	6	5	—	150	275
4.60 ≤ δ < 4.80	±0.03	±0.08	18	16	12	8	—	6	5	4	—	150	275
4.80 ≤ δ < 5.00	±0.03	±0.08	17	14	11	7	—	5	4	3	—	150	275
5.00 ≤ δ < 5.20	±0.03	±0.08	17	14	11	7	—	5	4	3	—	150	300
5.20 ≤ δ < 5.40	±0.03	±0.08	14	12	10	—	—	5	4	3	—	160	300
5.40 ≤ δ < 5.60	±0.04	±0.09	12	10	8	—	—	4	3	2	—	160	300
5.60 ≤ δ < 5.80	±0.04	±0.09	10	8	6	—	—	3	2	2	—	160	300
5.80 ≤ δ < 6.00	±0.04	±0.09	8	6	6	—	—	3	2	2	—	160	300
6.00 ≤ δ < 6.25	±0.04	±0.09	8	6	6	—	—	3	2	2	—	160	300
6.25 ≤ δ < 6.50	±0.04	±0.09	7	6	5	—	—	2	2	—	—	160	300
6.50 ≤ δ < 6.75	±0.04	±0.09	6	5	4	—	—	2	2	—	—	160	300
6.75 ≤ δ < 7.00	±0.04	±0.10	6	5	4	—	—	2	2	—	—	160	300

A.2 Tensile Strength Grades Levels 2, 3, 4, and 5

The diameter tolerances of bright and drawn galvanized wires shall be in accordance with [Table A.3](#).

The diameter tolerances of final galvanized wires shall be in accordance with [Table A.4](#).

The individual minimum breaking loads of bright and drawn galvanized wires and minimum number of torsions shall be in accordance with [Table A.5](#).

The individual minimum breaking loads and torsions of final galvanized wires shall be in accordance with those given in [Table A.5](#)—subject to a reduction of 10 %.

The maximum values of tensile strength shall be no more than 207 N/mm² (30,000 lb/in.²) greater than the minimum values.

The minimum masses of zinc for drawn galvanized and final galvanized wires shall be in accordance with [Table A.6](#) and [Table A.7](#), respectively.

Table A.3—Diameter Tolerances for Bright and Drawn Galvanized Wires

Nominal Diameter of Wire		Total Variation			
		Minus		Plus	
mm	(in.)	mm	(in.)	mm	(in.)
$0.25 \leq \delta \leq 0.64$	$(0.010 \leq \delta \leq 0.025)$	0.01	(0.0003)	0.02	(0.0007)
$0.64 < \delta \leq 1.50$	$(0.025 < \delta \leq 0.060)$	0.01	(0.0005)	0.03	(0.001)
$1.50 < \delta \leq 2.36$	$(0.060 < \delta \leq 0.093)$	0.03	(0.001)	0.03	(0.001)
$2.36 < \delta \leq 3.61$	$(0.093 < \delta \leq 0.142)$	0.03	(0.001)	0.04	(0.0015)
$3.61 < \delta \leq 5.08$	$(0.142 < \delta \leq 0.200)$	0.04	(0.0015)	0.05	(0.002)
$5.08 < \delta \leq 6.35$	$(0.200 < \delta \leq 0.250)$	0.05	(0.002)	0.05	(0.002)

Table A.4—Diameter Tolerances for Final Galvanized Wires

Nominal Diameter of Wire		Total Variation			
		Minus		Plus	
mm	(in.)	mm	(in.)	mm	(in.)
$0.64 \leq \delta \leq 1.55$	$(0.025 < \delta \leq 0.061)$	0.03	(0.001)	0.03	(0.001)
$1.55 < \delta \leq 2.01$	$(0.061 < \delta \leq 0.079)$	0.05	(0.002)	0.05	(0.002)
$2.01 < \delta \leq 3.61$	$(0.079 < \delta \leq 0.142)$	0.08	(0.003)	0.08	(0.003)
$\delta > 3.61$	$(\delta \geq 0.142)$	0.10	(0.004)	0.10	(0.004)

Table A.5—Minimum Breaking Force and Minimum Number of Torsions for Levels 2, 3, 4, and 5

Nominal Diameter of Wire		Level 2		Level 3		Level 4		Level 5	
		Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion
mm	(in.)	N	(lb)	N	(lb)	N	(lb)	N	(lb)
0.25	0.010	76	17	89	20	98	22	107	24
0.28	0.011	93	21	107	24	120	27	129	29
0.30	0.012	111	25	129	29	142	32	151	34
0.33	0.013	129	29	151	34	165	37	178	40
0.36	0.014	151	34	173	39	191	43	205	46
0.38	0.015	173	39	200	45	218	49	236	53
0.41	0.016	196	44	227	51	249	56	267	60
0.43	0.017	222	50	254	57	280	63	302	68
0.46	0.018	249	56	285	64	316	71	338	76
0.48	0.019	276	62	320	72	351	79	378	85
0.51	0.020	307	69	351	79	387	87	418	94
0.53	0.021	338	76	387	87	427	96	458	103
0.56	0.022	369	83	427	96	467	105	503	113
0.58	0.023	405	91	467	105	512	115	552	124
0.61	0.024	440	99	507	114	556	125	600	135
0.64	0.025	476	107	547	123	605	136	649	146
0.66	0.026	516	116	592	133	654	147	703	158
0.69	0.027	556	125	641	144	703	158	756	170
0.71	0.028	596	134	689	155	756	170	814	183
0.74	0.029	641	144	738	166	810	182	872	196
0.76	0.030	685	154	787	177	867	195	934	210
0.79	0.031	729	164	841	189	925	208	996	224
0.81	0.032	778	175	894	210	983	221	1059	238
0.84	0.033	827	186	952	214	1045	235	1125	253
0.86	0.034	876	197	1010	227	1112	250	1192	268
0.89	0.035	930	209	1068	240	1174	264	1263	284
0.91	0.036	983	221	1130	254	1245	280	1339	301
0.94	0.037	1036	233	1192	268	1312	295	1410	317

Table A.5—Minimum Breaking Force and Minimum Number of Torsions for Levels 2, 3, 4, and 5 (Continued)

Nominal Diameter of Wire		Level 2			Level 3			Level 4			Level 5		
		Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion
mm	(in.)	N	(lb)		N	(lb)		N	(lb)		N	(lb)	
0.97	0.038	1094	246	66	1259	283	61	1383	311	56	1486	334	49
0.99	0.039	1152	259	64	1326	298	59	1454	327	55	1566	352	48
1.02	0.040	1210	272	62	1392	313	57	1530	344	53	1646	370	46
1.04	0.041	1272	286	61	1463	329	56	1606	361	52	1726	388	45
1.07	0.042	1334	300	59	1535	345	55	1686	379	51	1810	407	44
1.09	0.043	1397	314	58	1606	361	53	1766	397	50	1899	427	43
1.12	0.044	1459	328	57	1681	378	52	1846	415	48	1988	447	42
1.14	0.045	1526	343	55	1757	395	51	1930	434	47	2077	467	41
1.17	0.046	1592	358	54	1833	412	50	2015	453	46	2166	487	40
1.19	0.047	1664	374	53	1913	430	49	2104	473	45	2260	508	39
1.22	0.048	1735	390	52	1993	448	48	2193	493	44	2357	530	38
1.24	0.049	1806	406	51	2077	467	47	2282	513	43	2455	552	38
1.27	0.050	1877	422	50	2162	486	46	2375	534	42	2553	574	37
1.30	0.051	1953	439	49	2246	505	45	2469	555	42	2655	597	36
1.32	0.052	2028	456	48	2335	525	44	2566	577	41	2758	620	35
1.35	0.053	2108	474	47	2424	545	43	2664	599	40	2865	644	35
1.37	0.054	2184	491	46	2513	565	42	2762	621	39	2971	668	34
1.40	0.055	2264	509	45	2607	586	41	2865	644	38	3082	693	33
1.42	0.056	2349	528	44	2700	607	41	2967	667	38	3194	718	33
1.45	0.057	2429	546	43	2793	628	40	3074	691	37	3305	743	32
1.47	0.058	2513	565	43	2891	650	39	3180	715	36	3421	769	32
1.50	0.059	2598	584	42	2989	672	38	3287	739	36	3536	795	31
1.52	0.060	2687	604	41	3091	695	38	3398	764	35	3652	821	30
1.55	0.061	2776	624	40	3194	718	37	3509	789	35	3772	848	30
1.57	0.062	2865	644	40	3296	741	37	3625	815	34	3896	876	29
1.60	0.063	2958	665	39	3398	764	36	3741	841	33	4021	904	29
1.63	0.064	3047	685	38	3505	788	35	3856	867	33	4146	932	28
1.65	0.065	3145	707	38	3616	813	35	3977	894	32	4275	961	28

Table A.5—Minimum Breaking Force and Minimum Number of Torsions for Levels 2, 3, 4, and 5 (Continued)

Nominal Diameter of Wire		Level 2		Level 3		Level 4		Level 5	
		Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion
mm	(in.)	N	(lb)	N	(lb)	N	(lb)	N	(lb)
1.68	0.066	3238	728	3723	837	4097	921	4404	990
1.70	0.067	3336	750	3834	862	4217	948	4533	1019
1.73	0.068	3434	772	3945	887	4341	976	4666	1049
1.75	0.069	3532	794	4061	913	4466	1004	4804	1080
1.78	0.070	3634	817	4177	939	4595	1033	4942	1111
1.80	0.071	3736	840	4297	966	4724	1062	5080	1142
1.83	0.072	3839	863	4412	992	4853	1091	5218	1173
1.85	0.073	3941	886	4533	1019	4986	1121	5360	1205
1.88	0.074	4048	910	4657	1047	5120	1151	5507	1238
1.91	0.075	4154	934	4777	1074	5258	1182	5653	1271
1.93	0.076	4266	959	4906	1103	5395	1213	5800	1304
1.96	0.077	4372	983	5031	1131	5533	1244	5947	1337
1.98	0.078	4484	1008	5160	1160	5676	1276	6098	1371
2.01	0.079	4599	1034	5289	1189	5818	1308	6254	1406
2.03	0.080	4710	1059	5418	1218	5960	1340	6410	1441
2.06	0.081	4862	1088	5551	1248	6107	1373	6565	1476
2.08	0.082	4942	1111	5685	1278	6254	1406	6721	1511
2.11	0.083	5062	1138	5822	1309	6405	1440	6886	1548
2.13	0.084	5182	1165	5956	1339	6552	1473	7046	1584
2.16	0.085	5302	1192	6098	1371	6708	1508	7210	1621
2.18	0.086	5422	1219	6236	1402	6859	1542	7375	1658
2.21	0.087	5547	1247	6378	1434	7014	1577	7544	1696
2.24	0.088	5671	1275	6521	1466	7175	1613	7713	1734
2.26	0.089	5796	1303	6668	1499	7330	1648	7882	1772
2.29	0.090	5925	1332	6810	1531	7490	1684	8055	1811
2.31	0.091	6049	1360	6957	1564	7655	1721	8229	1850
2.34	0.092	6183	1390	7108	1598	7820	1758	8407	1890
2.36	0.093	6312	1419	7259	1632	7984	1795	8585	1930

Table A.5—Minimum Breaking Force and Minimum Number of Torsions for Levels 2, 3, 4, and 5 (Continued)

Nominal Diameter of Wire		Level 2			Level 3			Level 4			Level 5		
		Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion
mm	(in.)	N	(lb)		N	(lb)		N	(lb)		N	(lb)	
2.39	0.094	6445	1449	26	7410	1666	24	8149	1832	22	8763	1970	19
2.41	0.095	6579	1479	25	7562	1700	23	8318	1870	22	8945	2011	19
2.44	0.096	6712	1509	25	7717	1735	23	8491	1909	21	9127	2052	18
2.46	0.097	6845	1539	25	7873	1770	23	8660	1947	21	9310	2093	18
2.49	0.098	6983	1570	25	8033	1806	23	8834	1986	21	9496	2135	18
2.51	0.099	7121	1601	24	8189	1841	22	9012	2026	21	9683	2177	18
2.54	0.100	7264	1633	24	8349	1877	22	9185	2065	20	9875	2220	18
2.57	0.101	7401	1664	24	8513	1914	22	9363	2105	20	10,066	2263	18
2.59	0.102	7544	1696	24	8678	1951	22	9545	2146	20	10,262	2307	17
2.62	0.103	7686	1728	23	8843	1988	21	9723	2186	20	10,453	2350	17
2.64	0.104	7833	1761	23	9007	2025	21	9910	2228	20	10,653	2395	17
2.67	0.105	7980	1794	23	9176	2063	21	10,093	2269	19	10,849	2439	17
2.69	0.106	8126	1827	23	9345	2101	21	10,279	2311	19	11,049	2484	17
2.72	0.107	8273	1860	22	9514	2139	21	10,466	2353	19	11,249	2529	16
2.74	0.108	8425	1894	22	9688	2178	20	10,657	2396	19	11,454	2575	16
2.77	0.109	8576	1928	22	9861	2217	20	10,844	2438	19	11,658	2621	16
2.79	0.110	8727	1962	22	10,035	2256	20	11,040	2482	18	11,867	2668	16
2.82	0.111	8878	1996	22	10,213	2296	20	11,231	2525	18	12,076	2715	16
2.84	0.112	9034	2031	21	10,391	2336	20	11,427	2569	18	12,285	2762	16
2.87	0.113	9190	2066	21	10,568	2376	19	11,623	2613	18	12,494	2809	15
2.90	0.114	9345	2101	21	10,746	2416	19	11,823	2658	18	12,708	2857	15
2.92	0.115	9505	2137	21	10,929	2457	19	12,023	2703	18	12,926	2906	15
2.95	0.116	9661	2172	21	11,111	2498	19	12,223	2748	17	13,139	2954	15
2.97	0.117	9826	2209	20	11,298	2540	19	12,428	2794	17	13,357	3003	15
3.00	0.118	9986	2245	20	11,485	2582	18	12,632	2840	17	13,580	3053	15
3.02	0.119	10,146	2281	20	11,672	2624	18	12,837	2886	17	13,798	3102	15
3.05	0.120	10,310	2318	20	11,858	2666	18	13,046	2933	17	14,025	3153	14
3.07	0.121	10,475	2355	20	12,050	2709	18	13,255	2980	17	14,247	3203	14

Table A.5—Minimum Breaking Force and Minimum Number of Torsions for Levels 2, 3, 4, and 5 (Continued)

Nominal Diameter of Wire		Level 2		Level 3		Level 4		Level 5	
		Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion	Minimum Breaking Force	Torsion
mm	(in.)	N	(lb)	N	(lb)	N	(lb)	N	(lb)
3.10	0.122	10,644	2393	12,241	2752	13,464	3027	14,474	3254
3.12	0.123	10,813	2431	12,432	2795	13,678	3075	14,701	3305
3.15	0.124	10,978	2468	12,628	2839	13,891	3123	14,932	3357
3.18	0.125	11,151	2507	12,824	2883	14,105	3171	15,163	3409
3.20	0.126	11,320	2545	13,019	2927	14,323	3220	15,395	3461
3.23	0.127	11,494	2584	13,215	2971	14,541	3269	15,630	3514
3.25	0.128	11,667	2623	13,415	3016	14,758	3318	15,866	3567
3.28	0.129	11,841	2662	13,615	3061	14,981	3368	16,102	3620
3.30	0.130	12,018	2702	13,820	3107	15,203	3418	16,342	3674
3.33	0.131	12,192	2741	14,025	3153	15,426	3468	16,582	3728
3.35	0.132	12,370	2781	14,229	3199	15,653	3519	16,822	3782
3.38	0.133	12,552	2822	14,434	3245	15,879	3570	17,067	3837
3.40	0.134	12,730	2862	14,643	3292	16,106	3621	17,312	3892
3.43	0.135	12,913	2903	14,852	3339	16,333	3672	17,561	3948
3.45	0.136	13,095	2944	15,061	3386	16,564	3724	17,810	4004
3.48	0.137	13,282	2986	15,270	3433	16,800	3777	18,059	4060
3.51	0.138	13,464	3027	15,483	3481	17,031	3829	18,312	4117
3.53	0.139	13,651	3069	15,697	3529	17,267	3882	18,562	4173
3.56	0.140	13,838	3111	15,915	3578	17,503	3935	18,819	4231
3.58	0.141	14,025	3153	16,128	3626	17,743	3989	19,073	4288
3.61	0.142	14,216	3196	16,346	3675	17,983	4043	19,331	4346
3.63	0.143	14,407	3239	16,569	3725	18,223	4097	19,589	4404
3.66	0.144	14,598	3282	16,787	3774	18,468	4152	19,851	4463
3.68	0.145	14,790	3325	17,009	3824	18,713	4207	20,114	4522
3.71	0.146	14,985	3369	17,232	3874	18,957	4262	20,376	4581
3.73	0.147	15,181	3413	17,458	3925	19,202	4317	20,643	4641
3.76	0.148	15,377	3457	17,681	3975	19,451	4373	20,910	4701
3.78	0.149	15,572	3501	17,908	4026	19,700	4429	21,177	4761

Table A.5—Minimum Breaking Force and Minimum Number of Torsions for Levels 2, 3, 4, and 5 (Continued)

Nominal Diameter of Wire		Level 2			Level 3			Level 4			Level 5		
		Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion	Minimum Breaking Force		Torsion
mm	(in.)	N	(lb)		N	(lb)		N	(lb)		N	(lb)	
3.81	0.150	15,773	3546	16	18,139	4078	14	19,954	4486	13	21,448	4822	11
3.84	0.151	15,973	3591	15	18,366	4129	14	20,203	4542	13	21,720	4883	11
3.86	0.152	16,173	3636	15	18,597	4181	14	20,456	4599	13	21,991	4944	11
3.89	0.153	16,373	3681	15	18,828	4233	14	20,714	4657	13	22,267	5006	11
3.91	0.154	16,578	3727	15	19,064	4286	14	20,968	4714	13	22,542	5068	11
3.94	0.155	16,782	3773	15	19,295	4338	14	21,226	4772	13	22,818	5130	11
3.96	0.156	16,987	3819	15	19,531	4391	14	21,488	4831	13	23,098	5193	11
3.99	0.157	17,192	3865	15	19,771	4445	14	21,746	4889	13	23,379	5256	11
4.01	0.158	17,401	3912	15	20,007	4498	13	22,009	4948	12	23,659	5319	11
4.04	0.159	17,605	3958	15	20,247	4552	13	22,271	5007	12	23,944	5383	11
4.06	0.160	17,814	4005	14	20,487	4606	13	22,538	5067	12	24,228	5447	10
4.09	0.161	18,028	4053	14	20,732	4661	13	22,805	5127	12	24,513	5511	10
4.11	0.162	18,237	4100	14	20,972	4715	13	23,072	5187	12	24,802	5576	10
4.14	0.163	18,450	4148	14	21,217	4770	13	23,339	5247	12	25,091	5641	10
4.17	0.164	18,664	4196	14	21,462	4825	13	23,610	5308	12	25,380	5706	10
4.19	0.165	18,877	4244	14	21,711	4881	13	23,881	5369	12	25,674	5772	10
4.22	0.166	19,095	4293	14	21,960	4937	13	24,153	5430	12	25,967	5838	10
4.24	0.167	19,309	4341	14	22,209	4993	13	24,428	5492	12	26,261	5904	10
4.27	0.168	19,527	4390	14	22,458	5049	13	24,704	5554	12	26,555	5970	10
4.29	0.169	19,749	4440	14	22,707	5105	12	24,980	5616	12	26,853	6037	10
4.32	0.170	19,967	4489	14	22,961	5162	12	25,260	5679	11	27,151	6104	10
4.34	0.171	20,189	4539	13	23,214	5219	12	25,536	5741	11	27,453	6172	10
4.37	0.172	20,412	4589	13	23,472	5277	12	25,816	5804	11	27,756	6240	10
4.39	0.173	20,634	4639	13	23,726	5334	12	26,101	5868	11	28,058	6308	10
4.42	0.174	20,857	4689	13	23,984	5392	12	26,386	5932	11	28,360	6376	10
4.45	0.175	21,084	4740	13	24,242	5450	12	26,670	5996	11	28,667	6445	9
4.47	0.176	21,306	4790	13	24,504	5509	12	26,955	6060	11	28,974	6514	9
4.50	0.177	21,533	4841	13	24,766	5568	12	27,240	6124	11	29,286	6584	9