



Designation: A232/A232M – 18

Standard Specification for Chromium-Vanadium Alloy Steel Valve Spring Quality Wire¹

This standard is issued under the fixed designation A232/A232M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification covers the highest quality of round and shaped chromium-vanadium alloy steel valve spring wire, uniform in quality and temper, intended for the manufacture of valve springs and other springs requiring high-fatigue properties when used at moderately elevated temperatures. It is similar to the grade VD (referenced in EN 10270-2) intended for high fatigue levels. This wire shall be either in the annealed and cold-drawn or oil-tempered condition as specified by the purchaser.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A941 Terminology Relating to Steel, Stainless Steel, Related

Alloys, and Ferroalloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E45 Test Methods for Determining the Inclusion Content of Steel

2.2 *Federal Standard:*³

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *European Standard:*⁴

EN 10270-2 Steel Wire for Mechanical Springs Part 2: Oil-Hardened and Tempered Spring Steel Wire of Unalloyed and Alloyed Steels

3. Terminology

3.1 *Definitions:*

3.1.1 For definition of terms used in this specification, refer to Terminology **A941**.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *billet, n*—an as-cast or forged section, typically available for transport, inspection, and conditioning, that is used as raw material for wire rod manufacture.

3.2.2 *bloom, n*—an as-cast or forged section used as raw material for billet manufacture.

3.2.3 *equivalent round diameter, n*—diameter of a round wire having equivalent cross sectional area to a given shaped wire.

3.2.4 *round wire, n*—wire having a circular cross section.

3.2.5 *shape factor, n*—a value used to obtain cross sectional area for shaped wires when multiplied by measured width and measured thickness.

3.2.6 *shaped wire, n*—wire having a non-circular cross section.

4. Ordering Information

4.1 Orders for material under this specification should include the following information for each ordered item:

³ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

⁴ Available from European Committee for Standardization, CEN-CENELEC Management Centre Avenue Marnix 17-B-1000 Brussels, Belgium.

¹ This specification is under the jurisdiction of ASTM Committee **A01** on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee **A01.03** on Steel Rod and Wire.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard



- 4.1.1 Quantity (mass),
- 4.1.2 Name of material (chromium-vanadium alloy steel valve spring quality wire),
- 4.1.3 Dimensions (Section 9),
- 4.1.4 Condition (Section 7), and
- 4.1.5 ASTM designation and year of issue.

4.2 The purchaser shall have the option to specify additional requirements, including but not limited to:

- 4.2.1 Requirements for certifications, heat analysis or test reports (6.2 and Section 14),
- 4.2.2 Special packing, marking, and loading requirements (Section 15), and
- 4.2.3 Other special requirements, if any.

NOTE 1—A typical ordering description is as follows: For SI units, 20 000 kg oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 6.00 mm in 150 kg coils to ASTM A232/A232M dated _____. For inch-pound units, 40 000 lb oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 0.250 in. in 350-lb coils to ASTM A232/A232M dated _____.

5. Materials and Manufacture

5.1 The steel shall be made by a steel making process combined with secondary ladle refining that is capable of satisfying the inclusion content requirements of this specification.

5.2 The steel shall be continuously cast into blooms and rolled into billets.

5.3 Billet conditioning shall precede wire rod manufacture. The resulting wire rods shall be of sufficient surface quality that when combined with a surface removal operation performed prior to or during the wire manufacturing operation the resulting wire shall satisfy the surface condition and decarburization requirements of this specification.

5.4 The finished wire shall be free from detrimental pipe and undue segregation.

5.5 Alternate manufacturing processes may be used upon agreement between purchaser and supplier provided that the minimum requirements of this standard are met.

6. Chemical Composition

6.1 The steel shall conform to the requirements for chemical composition specified in Table 1.

6.2 *Heat Analysis*—Each heat of steel shall be analyzed to determine the percentage of elements prescribed in Table 1. This analysis shall be made from a test specimen preferably

taken during the pouring of the heat. When requested, this shall be reported to the purchaser and shall conform to the requirements of Table 1.

6.3 *Product Analysis*—An analysis may be made by the purchaser from finished wire representing each heat of steel. The average of all the separate determinations made shall be within the limits specified in the analysis column. Individual determinations may vary to the extent shown in the product analysis tolerance column, except that the several determinations of a single element in any one heat shall not vary both above and below the specified range.

6.4 For referee purposes, Test Methods, Practices, and Terminology A751 shall be used.

7. Mechanical Properties

7.1 Tension Test:

7.1.1 *Requirements for Annealed and Cold Drawn Wires*—Tension test requirements, if any, shall be stated on the purchase order.

7.1.2 *Requirements for Oil Tempered Wires*—The material as represented by tension test specimens shall conform to the requirements in Table 2. Variation in tensile strength within a coil shall not exceed 70 Mpa [10.15 ksi].

7.1.3 *Number of Tests*—For oil-tempered wires, each coil in a lot shall be tested. When specified for annealed and cold drawn wires, one test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each heat in a given lot shall be tested.

7.1.4 *Location of Tests*—For oil-tempered wires, test specimens shall be taken from both ends of the coil. For annealed and cold drawn wires, it shall be permissible for test specimens to be taken from either end of the coil.

7.1.5 *Test Method*—The tension test shall be made in accordance with Test Methods and Definitions A370. Any tensile test specimen breaking in the tensile grips shall be discarded and a new specimen tested if the specified mechanical properties are not achieved. For shaped wires, cross sectional area shall be calculated either using the procedure in Test Methods E8/E8M for uniform but nonsymmetrical cross-sections, or measuring width and thickness and multiplying by a shape factor. Reduction of area for shaped wires shall be calculated by using this shape factor. Measure the maximum and minimum dimension on the necked down section and multiply by the shape factor to estimate the cross sectional area for use in the standard reduction of area calculation.

7.1.5.1 Upon agreement between purchaser and supplier, the shape factor for the design provided by the wire mill shall be permissible to be adopted for use. In other situations if the shape factor is not available from the wire mill, the shape factor shall be calculated by measuring the cross sectional area in accordance with Test Methods E8/E8M and dividing by the width and thickness.

7.2 Wrap Test:

7.2.1 Oil-tempered or cold-drawn wire 4.00 mm [0.162 in.] and smaller in diameter shall wind on itself as an arbor without breakage. Larger diameter wire up to and including 8.00 mm [0.312 in.] in diameter shall wrap without breakage on a

TABLE 1 Chemical Requirements

	Analysis, %	Product Analysis Tolerance, %
Carbon	0.48–0.53	±0.02
Manganese	0.70–0.90	±0.03
Phosphorus	0.020 max	+0.005
Sulfur	0.035 max	+0.005
Silicon	0.15–0.35	±0.02
Chromium	0.80–1.10	±0.05
Vanadium	0.15 min	–0.01

TABLE 2 Tensile Requirements^A

SI Units			
Diameter, ^B mm	MPa, min	MPa, max	Reduction of Area, min, % ^{C,D}
0.50	2060	2260	...
0.55	2050	2240	...
0.60	2030	2220	...
0.65	2010	2200	...
0.70	2000	2160	...
0.80	1980	2140	...
0.90	1960	2120	...
1.00	1940	2100	...
1.10	1920	2080	...
1.20	1900	2060	...
1.40	1860	2020	...
1.60	1820	1980	...
1.80	1800	1960	...
2.00	1780	1930	...
2.20	1750	1900	...
2.50	1720	1860	45
2.80	1680	1830	45
3.00	1660	1800	45
3.50	1620	1760	45
4.00	1580	1720	40
4.50	1560	1680	40
5.00	1520	1640	40
5.50	1480	1620	40
6.00	1460	1600	40
6.50	1440	1580	40
7.00	1420	1560	40
8.00	1400	1540	40
9.00	1380	1520	40
10.00	1360	1500	40
11.00	1340	1480	40
12.00	1320	1460	40

Inch-Pound Units			
Diameter, in.	ksi, min	ksi, max	Reduction of Area, min, % ^{C,D}
0.020	300	325	...
0.032	290	315	...
0.041	280	305	...
0.054	270	295	...
0.062	265	290	...
0.080	255	275	...
0.105	245	265	45
0.135	235	255	45
0.162	225	245	40
0.192	220	240	40
0.244	210	230	40
0.283	205	225	40
0.312	203	223	40
0.375	200	220	40
0.438	195	215	40
0.500	190	210	40

^A Tensile strength values for intermediate diameters shall be interpolated.^B Preferred sizes.^C The reduction of area test is not applicable to wire diameters under 2.34 mm [0.092 in.]. For intermediate diameters, the reduction of area requirement shall be that of the next larger wire diameter.^D "... " Indicates that there is no requirement.

mandrel twice the wire diameter. The wrap test is not applicable to wire over 8.00 mm [0.312 in.] in diameter. For shaped wires, mandrel size shall be selected based on the equivalent round diameter.

7.2.2 Number of Tests—One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each heat in a given lot shall be tested.

7.2.3 Location of Test—It shall be permissible to take test specimens from either end of the coil.

7.2.4 Test Method—The wrap test shall be made in accordance with Test Methods and Definitions A370.

7.3 Special Surface Inspection—The entire length of every coil shall be inspected for surface imperfections with a rotating and stationary probe eddy current defect analyzer, or equivalent. Imperfections deeper than 0.04 mm [0.0016 in.] shall be properly marked so the purchaser has the ability to identify and discard that length of wire; other depths may be agreed upon. Number of allowable marks per coil shall be agreed upon between the manufacturer and purchaser. This test is not applicable to wire diameters or equivalent round diameters below 2.5 mm [0.098 in.].

NOTE 2—Special surface inspection of certain cross sectional shapes may not be technically feasible.

8. Metallurgical Requirements

8.1 Surface Condition:

8.1.1 The surface of the wire as received shall be free of imperfections such as pits, die marks, scratches, seams, and other defects tending to impair the fatigue value of the springs.

8.1.2 Number of Tests—One test specimen shall be taken from each end of every coil.

8.1.3 Test Method—The surface shall be examined after etching in a solution of equal parts of hydrochloric acid and water that has been heated to approximately 80°C for up to 2 min in order to remove the oxide scale layer from the wire surface. Test ends shall be examined using 10× magnification.

Decarburization:

8.2.1 Transverse sections of the wire properly mounted, polished, and etched shall show no completely decarburized (carbon-free) areas when examined at 100× magnification. Partial decarburization shall not exceed a depth of 0.025 mm [0.001 in.] on wire 5.00 mm [0.192 in.] and smaller or 0.038 mm [0.0015 in.] on larger than 5.00 mm [0.192 in.]. For shaped wires, equivalent round wire diameter shall apply. Measure the worst area present excluding decarburization associated with seams or other surface imperfections. Complete decarburization exists when only free ferrite is present. Partial decarburization exists when ferrite is found mixed with pearlite or tempered martensite. Structures of 100 % tempered martensite shall be defined as not decarburized.

8.2.2 To reveal the decarburization more accurately in the untempered wire, the specimen shall be hardened and tempered before microscopical examination. Prior to hardening, the specimen shall be filed flat on one side enough to reduce the diameter at least 20 %. The subsequent mounted specimen shall show the flattened section, as well as the original wire edge. Any decarburization on this flattened section shall necessitate a new specimen for examination.

8.2.3 Number of Tests—One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each in a given lot shall be tested.

8.2.4 Location of Tests—It shall be permissible to take test specimens from either end of the coil.



TABLE 3 Maximum Inclusion Content

NOTE 1—The surface zone is from the wire surface to $\frac{1}{3}$ radius deep. The core is the balance.

Zone	Inclusion Type							
	A		B		C		D	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
Surface	1	1	1	$\frac{1}{2}$	1	1	1	$\frac{1}{2}$
Core	2	$1\frac{1}{2}$	2	1	2	$1\frac{1}{2}$	2	1

8.3 *Microstructure*—A longitudinal section shall show a fine homogeneous tempered martensitic structure.

8.4 Inclusion Content:

8.4.1 The inclusion content of the wire or wire rod in the worst case shall not exceed the limits shown in Table 3 as described in Test Methods E45, Plate I-A, Method D, except that alternate methodologies are acceptable upon agreement between purchaser and supplier provided minimum requirements are not lower than those of Test Methods E45, Method D.

8.4.1.1 If any coil exceeds the limits listed in Table 3, all coils in the lot will be inspected. Each coil that fails to meet the requirements will be rejected.

8.4.2 *Number of Tests*—One test specimen shall be taken for each ten coils, or fraction thereof, in the lot.

8.4.3 *Location of Tests*—It shall be permissible to take test specimens from either end of the coil.

8.4.4 *Test Method*—A longitudinal section approximately 12.7 mm [0.5 in.] long shall be ground to the centerline and properly mounted and polished. Examination shall be made in accordance with Test Methods E45.

8.4.5 Upon agreement by the purchaser and supplier, the inclusion requirements may be waived.

9. Dimensions and Permissible Variations

9.1 The permissible variations in the diameter of the wire shall be as specified in Table 4.

TABLE 4 Permissible Variations in Wire Diameter

Diameter, mm	SI Units ^A	
	Permissible Variations,	Permissible Out-of-Round,
	±mm	mm
0.5 to 2.0, incl	0.02	0.02
Over 2.0 to 4.00, incl	0.03	0.03
Over 4.00 to 9.50, incl	0.04	0.04
Over 9.50	0.05	0.05
Diameter, in.	Inch-Pound Units	
	Permissible Variations, ±in.	Permissible Out-of-Round, in.
	±in.	in.
0.020 to 0.075, incl	0.0008	0.0008
Over 0.075 to 0.148, incl	0.001	0.001
Over 0.148 to 0.375, incl	0.0015	0.0015
Over 0.375 to 0.500, incl	0.002	0.002

^A For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E29.

9.2 *Number of Tests*—One test specimen shall be taken from each end of every coil.

10. Workmanship, Finish, and Appearance

10.1 *Annealed and Cold Drawn*—The wire shall have been given a sufficient amount of cold working to meet the purchaser's coiling requirements. The wire shall be in a suitable condition to respond to heat treatment. The wire shall not be kinked or improperly cast. To test for cast, a few convolutions of wire shall be cut loose from the coil and placed on a flat surface. The wire shall lie substantially flat on itself and not spring up nor show a wavy condition.

10.2 *Oil Tempered*—The wire shall be uniform in quality and temper and shall not be wavy or crooked.

10.3 Each coil shall be one continuous length of wire properly coiled and firmly tied.

10.4 No welds are permitted in the finished product and any welds made during processing shall be removed.

11. Retests

11.1 If any tested specimen exhibits an obvious defect or condition of non-conformance that is not representative of the coil from which it was collected, or shows the presence of a weld, it shall be discarded and another specimen substituted.

11.2 If any tested specimen exhibits an obvious defect or condition of non-conformance that is representative of a portion of the coil from which it was collected, the manufacturer shall remove from the coil the portion containing the obvious defect or condition of non-conformance before collecting another test specimen from the coil for the purpose of retesting.

12. Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time

the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.



13. Rejection and Rehearing

13.1 Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer as soon as possible so that an investigation may be initiated.

13.2 The material shall be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

14. Certification

14.1 When specified in the purchase order or contract, a manufacturer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

14.2 The certification shall include the specification number, year date of issue, and revision letter, if any.

15. Packaging, Marking, and Loading for Shipment

15.1 The coil mass, dimensions, and the method of packaging shall be agreed upon between the manufacturer and purchaser.

15.2 The size of the wire, purchaser's order number, ASTM specification number, heat number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

15.3 Unless otherwise specified in the purchaser's order, packaging, marking, and loading for shipments shall be in accordance with those procedures recommended by Practices A700.

15.4 *For Government Procurement*—Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

16. Keywords

16.1 alloy; chromium-vanadium; valve spring; wire

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A232/A232M – 05 (2011) ⁶¹) that may impact the use of this standard. (Approved Sept. 1, 2018.)

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| <p>(1) Revised 1.1 and 1.2.</p> <p>(2) Added Test Methods E8/E8M, E45, and EN 10270-2 to list of referenced documents (Section 2). Removed ANSI B32.4, MIL-STD-163, and AIAG B-5.</p> <p>(3) Added Terminology (Section 3) and renumbered all subsequent sections accordingly.</p> <p>(4) Removed 4.1.5 through 4.1.7 and added 4.2 through 4.2.3. (5) Revised Section 5 and added 5.5.</p> <p>(6) Revised 6.2.</p> | <p>(7) Revised Section 7 and added 7.1.5.1 and Note 2.</p> <p>(8) Revised 8.2.1 and 8.2.4 and added 8.4 and Table 3.</p> <p>(9) Revised 10.1 and 10.4.</p> <p>(10) Revised 11.1 and added 11.2.</p> <p>(11) Revised 13.2.</p> <p>(12) Revised 15.4 and removed 15.5.</p> <p>(13) Added new Table 3 and renumbered previous Tables 1, 2, and 3.</p> <p>(14) Revised Tables 2 and 4.</p> |
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