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Standard Specification for MOLYBDENUM AND MOLYBDENUM ALLOY BILLETS FOR REFORGING¹

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1. Scope

1.1 *Materials*—This specification covers unalloyed molybdenum and molybdenum alloy billets as follows:

1.1.1 *Molybdenum 360*—Unalloyed arc-cast molybdenum.

1.1.2 *Molybdenum 361*—Unalloyed powder metallurgy molybdenum.

1.1.3 *Molybdenum Alloy 362*—Arc-cast molybdenum-0.5 % titanium.

1.1.4 *Molybdenum Alloy 363*—Arc-cast molybdenum-0.5 % titanium-0.1 % zirconium (TZM) alloy.

1.1.5 *Molybdenum Alloy 364*—Powder metallurgy molybdenum-0.5 % titanium-0.1 % zirconium (TZM type) alloy.

1.1.6 *Molybdenum 365*—Unalloyed arc-cast molybdenum, low carbon.

1.2 *Use*—These billets are primarily intended for further processing by forging to semifinished shapes.

NOTE—The values stated in U.S. customary units are to be regarded as the standard.

2. Basis of Purchase

2.1 Orders for material under this specification shall include the following information as applicable:

2.1.1 Material number and structure (Sections 1 and 5),

2.1.2 Product limitations (Section 4),

2.1.3 Restrictive chemistry (Tables 1 and 2),

2.1.4 Mechanical and physical requirements (Section 7 and Table 3),

2.1.5 Dimensions, weights, and tolerances (Section 8),

2.1.6 Finish and appearance (Section 10),

2.1.7 Marking (Section 14),

2.1.8 Workmanship and quality level requirements (Section 9),

2.1.9 Certification and reports (Section 12), and

2.1.10 Disposition of rejected material (Section 11).

3. Manufacture

3.1 The various molybdenum mill products covered by this specification shall be formed with the conventional extrusion, forging, or rolling equipment normally found in primary ferrous and nonferrous plants. The ingot metal for Materials 360, 362, 363, and 365 is arc melted in furnaces of a type suitable for reactive, refractory metals, and for Materials 361 and 364 it is consolidated by powder metallurgy methods.

4. Product Limitations

4.1 Billets for reforing are greater than 3½ in. (88.9 mm) in diameter or in equivalent cross-sectional area. Reforging billet stock with a smaller cross-sectional area is considered as bar or rod. As-sintered alloys 361 and 364 material, of any dimension, are classified under reforing billets.

5. Metallurgical Structure

5.1 Billets of Materials 360, 362, 363, and 365 shall be furnished in the recrystallized

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condition as defined in 7.1.

5.2 Billets also can be furnished in the as-worked or stress-relieved condition upon request of the purchaser.

5.3 Billets of Materials 361 and 364 shall be furnished in the as-sintered condition, as defined in Section 7, unless requested otherwise by the purchaser.

6. Chemical Requirements

6.1 The molybdenum and molybdenum alloy ingots and billets for conversion to finished products covered by this specification shall conform to the requirements as to chemical composition specified in Table 1.

6.2 Check Analysis:

6.2.1 Check analysis is an analysis made by the purchaser or the manufacturer of the metal after it has been processed into finished mill forms, and is either for the purpose of verifying the composition of heat or lot or to determine variations in the composition within a heat or lot.

6.2.2 Check analysis tolerances do not broaden the specified heat analysis requirements but cover variations between laboratories in the measurement of chemical content.

6.2.3 The manufacturer shall not ship material that is outside the limits specified in Table 1 for the applicable type, with the exception of oxygen and nitrogen, whose percentages may vary by the method of fabrication.

6.2.4 Check analysis limits shall be as specified in Table 2.

6.3 *Sampling*—Care shall be exercised to ensure that the sample selected for chemical analysis is representative of the material and form and is not contaminated by the sampling procedure.

6.4 *Methods of Chemical Analysis*—The chemical compositions enumerated in this specification shall, in case of disagreement, be determined in accordance with the methods approved for referee purposes by the American Society for Testing and Materials.² Where such methods of analysis are not available, methods of analysis as mutually agreed upon by the manufacturer and the purchaser shall be employed.

7. Mechanical and Physical Requirements

7.1 The hardness of billets supplied in the

recrystallized condition shall not exceed the values shown in Table 3.

7.2 Density:

7.2.1 *Material 361*—The density in the as-sintered condition shall be at least 9.59 g/cm³ (Mg/m³), unless otherwise specified (theoretical density-10.20 g/cm³ (Mg/m³)).

7.2.2 *Material 364*—The density in the as-sintered condition shall be at least 9.52 g/cm³ (Mg/m³), unless otherwise specified (theoretical density-10.13 g/cm³ (Mg/m³)).

8. Dimensions, Weights, and Tolerances

8.1 *Uniformity of Diameter*—Each billet shall display a uniform section along the entire length within $\pm \frac{1}{16}$ in. (1.59 mm) of the mean diameter for Materials 360, 362, and 365 and for Materials 361 and 364 with a turned surface; for Materials 361 and 364 with an as-sintered surface, the tolerance shall be $\pm \frac{1}{8}$ in. (3.18 mm); for Material 363 the tolerance shall be $\pm 2\%$ of the mean diameter.

8.2 *Billet to Billet Uniformity*—The mean diameter of Material 363 billet supplied shall not vary from the nominal diameter ordered by more than the following amounts:

Nominal Diameter, in. (mm)	Variation, in. (mm)
Over 3½ to 5½ (89 to 130)	$\pm \frac{1}{8}$ (3.18)
Over 5½ (130)	$\pm \frac{1}{4}$ (6.35)

8.3 *Uniformity of Sections Other than Rounds* shall be as agreed upon by the purchaser and the manufacturer.

8.4 *Length or Weight*—Billets that must be cut to length or weight shall be supplied to the following tolerances, unless otherwise specified:

Cut to specified length, + ½ in. (12.7 mm), -0
Cut to specified weight, + 10%, -0

9. Workmanship and Quality Level Requirements

9.1 Billets for reforging shall be free of injurious external and internal imperfections of a nature that will interfere with the purpose for which they are intended.

9.2 When specified, all billets shall be inspected by ultrasonic methods and dye-penetrant techniques. Ultrasonic inspection shall be performed in accordance with accepted techniques and any defective areas detrimental to

²Reference should be made to the *Annual Book of ASTM Standards*, Part 12.