Designation: E1652 – 21

An American National Standard

Standard Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators Used in the Manufacture of Base Metal Thermocouples, Metal-Sheathed Platinum Resistance Thermometers, and Noble Metal Thermocouples[1]

This standard is issued under the fixed designation E1652; 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.

1. Scope

1.1 This specification covers the requirements for magnesium oxide (MgO) and aluminum oxide (Al_2O_3) powders and crushable insulators used to manufacture base metal thermocouples, metal-sheathed platinum resistance thermometers (PRTs), noble metal thermocouples, and their respective cables.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

B329 Test Method for Apparent Density of Metal Powders and Compounds Using the Scott Volumeter

C809 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Aluminum Oxide and AluminumOxide-Boron Carbide Composite Pellets

C832 Test Method for Measuring Thermal Expansion and Creep of Refractories Under Load

D2766 Test Method for Specific Heat of Liquids and Solids (Withdrawn 2018)[3]

E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer

E235 Specification for Type K and Type N Mineral-Insulated, Metal-Sheathed Thermocouples for Nuclear or for Other High-Reliability Applications

E344 Terminology Relating to Thermometry and Hydrometry

E585/E585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable

E1137/E1137M Specification for Industrial Platinum Resistance Thermometers

E1225 Test Method for Thermal Conductivity of Solids Using the Guarded-Comparative-Longitudinal Heat Flow Technique

E2181/E2181M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable

3. Terminology

3.1 The definitions given in Terminology E344 shall apply to this specification.

4. Significance and Use

4.1 Magnesium oxide and aluminum oxide are used to electrically isolate and mechanically support the thermoelements of a thermocouple (see Specifications E235, E585/E585M, and E2181/E2181M) and the connecting wires of a PRT (see Specification E1137/E1137M) within a metal sheath. The metal sheath is typically reduced in diameter to compact the oxide powder or crushable oxide insulators around the thermoelements or wires.

[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.13 on Thermocouples - Materials and Accessories Specifications.

Current edition approved Nov. 1, 2021. Published November 2021. Originally approved in 1995. Last previous edition approved in 2015 as E1652 – 15. DOI: 10.1520/E1652-21.

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

4.2 In order to be suitable for this purpose, the materials shall meet certain criteria for purity and for mechanical and dimensional characteristics. Material that does not meet the purity criteria may cause premature failure of the sensor.

4.3 Use of this specification for the procurement of powder and crushable insulators will help to ensure that the product obtained is suitable for the intended purpose.

4.4 Useful information about alumina and magnesia is given in the appendixes.

5. Classification

5.1 The purchaser shall specify the appropriate Material and Type from 5.2 through 5.6 below.

5.2 MgO Type 1 in accordance with Table 1.

5.3 Al_2O_3 Type 1 in accordance with Table 1.

5.4 MgO Type 1P in accordance with Table 2.

5.5 Al_2O_3 Type 1P in accordance with Table 2.

5.6 MgO Type 2 in accordance with Table 3.

NOTE 1—There is no corresponding Al_2O_3 Type 2 designation at this time.

5.7 The final product shall be chemically analyzed using appropriate methods listed in 9.1. Major impurities shall not exceed the limits indicated in Table 1 through Table 3 for the appropriate grade. Any detected impurity with a concentration greater than 0.001 % (mass) shall be reported to the purchaser.

6. Ordering Information

6.1 The purchaser shall specify the following when ordering:

6.1.1 *Material and Type in accordance with Section 5.*

6.1.2 *Insulator Outside Diameter.*

6.1.3 *Hole Diameter.*

6.1.4 *Number of Holes.*

6.1.5 *Hole Pattern.*

6.1.6 *Length.*

6.1.7 *Particle Size* (if supplied as powder).

TABLE 1 Chemical Requirements for Al_2O_3 Type 1 and MgO Type 1[A, B]

Aluminum Oxide (Al_2O_3) 99.65 % (mass) min		Magnesium Oxide (MgO) 99.40 % (mass) min	
Impurity	Concentration, % (mass)	Impurity	Concentration, % (mass)
CaO	0.08 max	CaO	0.35 max
SiO_2	0.08 max	SiO_2	0.35 max
MgO	0.08 max	Al_2O_3	0.15 max
Fe_2O_3	0.04 max	Fe_2O_3	0.07 max
ZrO_2	0.08 max		
Na_2O	0.06 max		
C	0.01 max	C	0.02 max
S	0.005 max	S	0.0025 max
B	0.001 max	B	0.0035 max
Cd	0.001 max	Cd	0.001 max
		B+Cd	0.004 max

[A] Platinum thermoelements and Noble Metal thermocouples for use above 650 °C shall specify Type 1P composition according to Table 2.
[B] Base metal thermocouples for nuclear environments in accordance with Specification E235 shall specify Type 1P composition according to Table 2.

TABLE 2 Chemical Requirements for Al_2O_3 Type 1P and MgO Type 1P[A]

Aluminum Oxide (Al_2O_3) 99.65 % (mass) min		Magnesium Oxide (MgO) 99.40 % (mass) min	
Impurity	Concentration, % (mass)	Impurity	Concentration, % (mass)
CaO	0.08 max	CaO	0.35 max
SiO_2	0.08 max	SiO_2	0.13 max
MgO	0.08 max	Al_2O_3	0.15 max
Fe_2O_3	0.04 max	Fe_2O_3	0.04 max
ZrO_2	0.08 max		
Na_2O	0.06 max		
C	0.01 max	C	0.02 max
S	0.005 max	S	0.0025 max
B	0.001 max	B	0.0035 max
Cd	0.001 max	Cd	0.001 max
		B+Cd	0.004 max

[A] Platinum thermoelements and noble Metal thermocouples for use below 650 °C may optionally specify Type 1 composition according to Table 1.

TABLE 3 Chemical Requirements for MgO Type 2

Magnesium Oxide (MgO) 97.00 % (mass) min	
Impurity	Concentration, % (mass)
CaO	1.50 max
Al_2O_3	1.00 max
SiO_2	3.00 max
Fe_2O_3	0.15 max
C	0.02 max
S	0.0025 max
B	0.0050 max
Cd	0.001 max
B + Cd	0.0050 max
MgO + CaO + Al_2O_3 + SiO_2	99.50 min

6.2 The purchaser may specify the following additional information when ordering:

6.2.1 *Minimum Inside Diameter (at Maximum Material Condition (MMC)) of the Tubing,* (into which insulators will be inserted, see 8.3).

6.2.2 *Maximum Outside Diameter of Wire which will be inserted into the insulators,* (see 8.3).

6.3 Consult the insulator manufacturer for limitations of relationships between outside diameter, hole diameters, hole patterns, and length.

7. Physical Properties

7.1 *Density*—The density of crushable magnesium oxide and aluminum oxide insulators typically ranges from 2060 kg/m^3 (0.074 lbm/in.^{3}) to 3060 kg/m^3 (0.111 lbm/in.^{3}). Specific density requirements, as well as the test method to be used to determine density, shall be negotiated between the purchaser and manufacturer. See Appendix X3 for suggested test methods.

7.2 *Modulus of Rupture (MOR)*—In the past, a breaking force test that is based on a relative modulus of rupture and is related to crushability has been used. However, with variations in modulus from 21 to 83 MPa (3000 to 12 000 lb/in.^{2}) influenced by insulator configuration, number of holes, and cross-sectional dimensions, specific modulus requirements cannot be listed for each configuration. The modulus of rupture is best used for lot-to-lot comparison of a given insulator size

and configuration. See Appendix X4 for a suggested test method and X2.4 for recommended tolerances.

8. Dimensional Requirements

8.1 Outside diameter and hole diameter tolerances for insulators shall be as specified in Table 4 and Table 5, respectively, unless otherwise agreed to between the purchaser and manufacturer.

8.2 The wall and web thicknesses (see Fig. 1) shall be equal within outside the total allowable outside diameter tolerance as specified in Table 5 and the minimum measured web or wall shall be no smaller than 75 % of the maximum measured web or wall, unless otherwise agreed to between the purchaser and manufacturer.

8.3 The camber shall not exceed 0.3 % of the length. The insulator shall be capable of passing through a rigid straight tube longer than the insulator and with an inside diameter as specified in 6.2.1. Local camber defects caused by "knees" or "doglegs" shall not impede the insertion of wire.

8.4 The helical twist of holes shall not exceed 2° per cm (5° per in.) of the length.

8.5 The length shall be as specified in 6.1.6 with a tolerance of +6/–0.00 mm (+0.25/–0.00 in.).

8.6 The ends of each insulator should be cut square and shall be essentially chip-free as agreed upon between the supplier and purchaser.

9. Test Methods

9.1 *Chemical Composition:*

9.1.1 Wet chemical analysis, X-ray florescence, inductively coupled plasma spectrometry (ICP), or a combination of test methods, can be used for quantitative determination of silicon dioxide (SiO_2), iron oxide (Fe_2O_3), and zirconium oxide (ZrO_2) with gravimetric determination for SiO_2 and Fe_2O_3. The SiO_2 filtrate can be used for further calcium oxide (CaO) determination. Boron and cadmium can be measured using ICP and other minor components. Sulfur and carbon can be measured using infrared spectrometry.

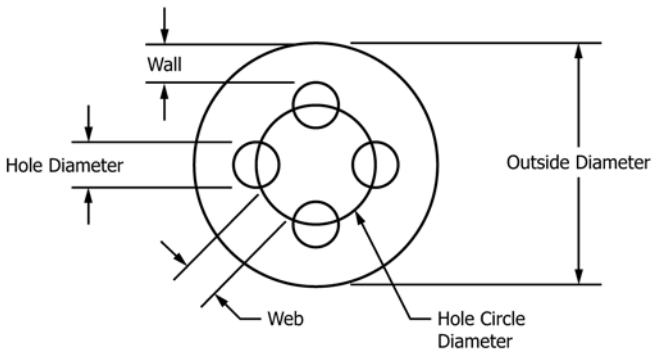
TABLE 4 Outside Diameter (O.D.) Tolerances

Nominal Insulator O.D.	O.D. Tolerance
Over 0.25 to 1.00 mm (0.010 to 0.039 in.), inclusive	±0.05 mm (±0.002 in.)
Over 1.00 to 1.50 mm (0.039 to 0.059 in.), inclusive	±0.08 mm (±0.003 in.)
Over 1.50 to 5.00 mm (0.059 to 0.197 in.), inclusive	±0.10 mm (±0.004 in.)
Over 5.00 to 8.00 mm (0.197 to 0.315 in.), inclusive	±0.13 mm (±0.005 in.)
Over 8.00 to 10.00 mm (0.315 to 0.394 in.), inclusive	±0.15 mm (±0.006 in.)
Over 10.0 mm (0.394 in.)	±1.75%

TABLE 5 Hole Diameter Tolerance[A]

Nominal Insulator Hole Diameter	Hole Diameter Tolerance
Over 0.18 to 1.00 mm (0.007 to 0.039 in.), inclusive	±0.05 mm (±0.002 in.)
Over 1.00 to 2.00 mm (0.040 to 0.079 in.), inclusive	±0.08 mm (±0.003 in.)
Over 2.00 to 2.50 mm (0.079 to 0.098 in.), inclusive	±0.10 mm (±0.004 in.)
Over 2.50 mm (0.098 in.) and larger, inclusive	±05 %

[A] See X2.3 for recommended inspection procedure.



4 hole insulator shown.
Other hole patterns are available – consult manufacturer.

FIG. 1 Wall and Web Thicknesses

9.1.2 Test Method C809 can be used for quantitative analysis of elemental impurities.

9.1.3 Any method used for quantitative determination of MgO, Al_2O_3, CaO, SiO_2, and ZrO_2 should have a detection sensitivity of at least 0.01 % (mass). Test methods used for the quantitative analysis of boron, cadmium, sulfur, carbon and iron oxide should have a detection sensitivity of 0.0001 % (mass).

9.2 *Density (Powder)*—Test Method B329 can be used for determining the density of Al_2O_3 and MgO powders.

9.3 Appendix X5 lists other optional test methods.

10. Handling and Storage Precautions

10.1 Powders and crushable insulators shall be shipped and stored in containers that prevent contamination and breakage. Powders and crushable insulators should be stored in sealed containers to prevent contamination by moisture absorption. (See Appendix X2.)

11. Keywords

11.1 aluminum oxide; crushable; insulator; magnesium oxide; mineral-insulated, metal-sheathed cable; platinum resistance thermometer; thermocouple, base metal; thermocouple, noble metal