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NEMA STANDARDS PUBLICATION NO. CB 2

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Characterizing the Physical and Chemical Properties of Electrical Discharge Machining (EDM) Graphite

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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CB 2

CHARACTERIZING THE PHYSICAL AND CHEMICAL PROPERTIES OF ELECTRICAL DISCHARGE MACHINING (EDM) GRAPHITE

Published by

National Electrical Manufacturers Association
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Foreword

These NEMA Standards and Authorized Engineering Information for electrical discharge machining graphite were prepared by the Carbon Section of the National Electrical Manufacturers Association, which periodically reviews them for any revisions necessary to keep them up to date with advancing technology. User needs have been considered in the development of this NEMA Standards Publication. Proposed revisions or comments are welcomed and should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

Scope

This Standards Publication defines those physical and chemical properties which are relevant to the material characteristics of electrical discharge machining (EDM) graphite electrodes. No attempt is made to incorporate in these standards any application performance standards relative to EDM graphites.

It is the intent of this publication to provide both the users and producers of electric disharge machining (EDM) graphite with a common reference standard for the material characterization of this product.

The types of EDM electrode material included in these standards are:

1. Electrographite consisting of substantially pure carbon that has been converted during manufacturing to artificial graphite.
2. Electrographite as in (1) above, impregnated to modify the base material's physical or electrical properties, or both.

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Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

The following publications are adopted, in whole or in part as indicated, by reference in this Standards Publication.

American National Standards Institute
1430 Broadway
New York, NY 10018

ANSI/NEMA CB 1-1984	*Brushes for Electrical Machines*
ANSI B74.13-1982	*Markings for Identifying Grinding Wheels and Other Bonded Abrasives*

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

ASTM C559-79	*Test Method for Bulk Density by Physical Measurement of Manufactured Carbon and Graphite Articles*
ASTM C611-84	*Test Method for Electrical Resistivity of Manufactured Carbon and Graphite Articles*
ASTM C651-70(R1977)	*Test Method for Flexural Strength of Manufactured Carbon Graphite Articles Using Four-Point Loading at Room Temperature*
ASTM C709-85	*Definitions of Terms Relating to Manufactured Carbon and Graphite*
ASTM E228-71(R1979)	*Test Method for Linear Thermal Expansion of Rigid Solids with a Vitreous Silica Dilatometer*
ASTM C886-83	*Scleroscope Hardness Testing of Fine Grained Carbon and Graphite Materials*
ASTM C748-73	*Rockwell Hardness Testing of Fine Grained Graphite Materials*
ASTM C561-85	*Test Method for Ash in Graphite*

1.2 DEFINITIONS

Apparent Density

The mass of a unit volume of material including both permeable and impermeable voids.

Ash

The residual product following oxidation of the base carbon as determined by prescribed methods.

Carbon

An element, atomic number 6, symbol C, that exists in several allotropic forms.

Coefficient of Thermal Expansion (CTE)

The change in length per unit temperature change. Since the coefficient of thermal expansion of graphite varies with temperature, the temperature range should be defined.

Electrical Discharge Machining

A metal removal process utilizing the energy of an electrical spark to remove material from a workpiece under controlled conditions.

Electrical Resistivity

That property of a material which determines its resistance to the flow of an electrical current.

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Electrode

The tool in the electrical dischare machining process. It must be made from an electrically conductive material.

Flexural Strength

A property of solid material that indicates its ability to withstand a flexural or transverse load.

Grain Direction (Conventionally Molded Material)

a. With grain—perpendicular to the direction of the applied molding force.
b. Against grain—parallel to the direction of the applied molding force.

Grain Direction (Extruded Material)

a. With grain—in the direction of extrusion.
b. Against grain—perpendicular to the direction of extrusion.

Grain Direction (Isostatically Molded Material)

a. With grain—the direction of the lowest linear thermal expansion.
b. Against grain—the direction of the highest linear thermal expansion.

Hardness

The resistance of a material to deformation, particularly permanent deformation, indentation, or scratching.

Manufactured Graphite

A bonded granular carbon body whose matrix has been subjected to a temperature typically in excess of 2400 °C and whose matrix is thermally stable below that temperature.

Material Grade Designation

The designation given a material by a manufacturer such that it is always reproduced to the same specifications established by the manufacturer.

Maximum Grain Size

The largest particle of the granular component as determined by its major dimension. In practice this is commonly given by the nominal opening of the coarsest screen used to prepare the initial raw materials in making the product and through which substantially all initial raw material will pass, or other measuring techniques, such as by Fisher subsieve, Coulter counter, etc.

Metal Content

The weight percentage of intentionally added metallic constitutents.

NEMA Standard 7-22-1987.

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Section 2
GENERAL

2.1 CLASSIFICATION OF GRAIN SIZE

Electrical discharge machining graphite material can be classified by grain size as follows:

a. *Ultrafine (or micrograin graphite)*—less than 10 microns maximum grain size.
b. *Superfine*—between 10 and 50 microns maximum grain size.
c. *Fine*—greater than 50 but less than or equal to 100 microns maximum grain size.
d. *Medium*—greater than 100 microns maximum grain size.

The above classifications are commonly based on size measuring techniques of the initial raw materials. It should be noted that the measuring techniques involved are not applicable to the finished product.

Authorized Engineering Information 7-22-1987.

2.2 TEST PROCEDURES FOR MATERIAL

The measurement and recording of the following information should sufficiently characterize an EDM graphite for quality control purposes. (These characteristics are not necessarily pertinent to electrode performance.)

- Material grade designation
- Grain direction (if known)
- Flexural strength
- Hardness
- Electrical resistivity
- Apparent density
- Ash content
- Metal content (for metal-impregnated EDM materials only)

Authorized Engineering Information 7-22-1987.

2.2.1 Flexural Strength

The flexural strength shall be determined in accordance with ASTM C651 or in accordance with the procedure specified in 4.7 of ANSI/NEMA CB 1.

Test data derived from use of these test procedures shall identify the method used.

NEMA Standard 7-22-1987.

2.2.2 Hardness—Nonmetal Impregnated Graphite

Nonmetal impregnated graphite shall be tested by either the scleroscope hardness method specified in 3.2 of ANSI/NEMA CB 1 or ASTM C886 or the indentation hardness method specified in 3.3 of ANSI/NEMA CB 1 or ASTM C748.

Test data shall identify the method used.

For metal impregnated graphite, a hardness test is not meaningful.

NEMA Standard 7-22-1987.

2.2.3 Electrical Resistivity

The electrical resistivity of electrical discharge machining graphite shall be tested in accordance with the voltmeter-ammeter method specified in 3.4 of ANSI/NEMA CB 1 or ASTM C611.

NEMA Standard 7-22-1987.

2.2.4 Density (Apparent)

Electrical discharge machining graphite shall be tested by using the immersion method specified in 3.6.3 of ANSI/NEMA C1, the oil absorption method specified in 3.6.4 of ANSI/NEMA CB 1, or the weight in air method given in ASTM C559. Test data shall identify the method used.

NEMA Standard 7-22-1987.

2.2.5 Ash Content

Ash content shall be determined using the procedure specified in 3.8 of ANSI/NEMA CB 1, or ASTM C561.

NEMA Standard 7-22-1987.

2.2.6 Metal Content

The weight percent of intentionally added metallic constituents shall be determined by the procedure shown in 3.8.4 of ANSI/NEMA CB 1, modified to record the weight percent solubles in nitric acid and the metal content.

NEMA Standard 7-22-1987.

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Section 3

GUIDANCE FOR MACHINING GRAPHITE AND IMPREGNATED GRAPHITE EDM ELECTRODES

(Section 3 approved as Authorized Engineering Information)

3.1 INTRODUCTION

The machining method for specific graphite electrode materials may be furnished by the manufacturer of the material itself. Since graphite is machined quite differently from metals, a few pointers on the general machining of this material may be helpful.

As with other machining operations, much will depend upon the quantity of electrodes to be produced, and also whether the machining operation is on relatively large surfaces or small surfaces. Some specific comments relating these distinguishing factors will be mentioned later.

Whatever machining operations are used, the use of a dust extracting system of the industrial type is strongly recommended. If the dust is not properly extracted, it can interfere with proper close tolerance machining of the electrode.

When fluids other than dielectrics are used, this fluid should be removed prior to the machining.

3.2 GENERAL

In general, electrodes of simple shape are formed by common machines such as lathes, mills, grinders, and drills. The power requirement for machining graphite is usually about half that required for steel. In all cases, the slides and other moving parts of the machine tool should be protected from the slightly abrasive graphite dust. Dust accumulations may cause electrical malfunctions and hazards.

3.3 TOOLS

It is suggested that where there are fairly large quantities of electrodes to be machined, the machine operator use tungsten carbide-tipped or insert tools of a grade that would be suitable for cast iron for longer tool life. Where an EDM tool is in the form of a wheel, the shaping of the wheel can be done with high speed tool steels, or tools coated with tungsten carbide. Where large quantities of very precise electrodes are made, particularly where the graphite electrode material is hard or very dense, it is suggested that diamond wheels be used.

The following cutting angles are suggested:

- *Clearance*—10-12°
- *Cutting*—90°

Grinding wheels should have the following characteristics:

- *Roughing*—37C-36J—5V
- *Finishing*—37C-60J—5V
- *Very fine finishing (high precision)*—superporous grade 80K

3.4 GENERAL HINTS ON THE MACHINING OF GRAPHITE

Graphite is mechanically strong and easy to machine, but is somewhat brittle due to its ceramic nature.

Two important rules should therefore be observed to obtain satisfactory results:

a. Use quality tools.
b. The breaking strength of the graphite should not be exceeded.

With respect to this last point, it is recommended that the operator support the back face of the graphite from which the tools will emerge when drilling, turning, or milling.

When this method cannot be used, the first operation should be to machine about ¼ inch from the back face before starting the main operation from the front face. This effectively avoids break-out edges.

3.5 FIXING OR MOUNTING GRAPHITE ELECTRODES FOR USE IN EDM MACHINES

The following material is included for reference and general interest only. No representation is made as to its suitability in regard to any specific application.

Small precision electrodes can be held in clamps or special holders or may be glued to a flat plate, using an appropriate adhesive. The appropriate adhesive in this case should be one that when used as a thin film will allow the passage of current.

Blocks for large electrodes may be screwed to the baseplate of aluminum, steel, or plastic. When the electrode is made of several blocks, they should be bonded with an adhesive. Where electrodes are bonded to the base with a nonconductive cement layer, a separate electrical connection from the electrode to the base plate should be provided.

As a general rule, adhesive joints at right angles to the base plate may be electrically insulating without disturbing the passage of the electric current to the electrode, but adhesive joints parallel to the base should be either conductive or bypassed by a separate electrical connection.

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The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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