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NEMA STANDARDS PUBLICATION NO. CB 1

nema

Brushes for Electrical Machines

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 1300 N. 17th Street, Rosslyn, Virginia 22209

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NEMA Standards Publication CB 1-1995

Brushes for Electrical Machines

Published by

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Foreword

NEMA Standards Publication No. CB 1-1995, Brushes for Electrical Machines, revises and supersedes the previous edition, CB 1-1984. It represents the general practice in the design and manufacture of brushes by the electrical manufacturing industry and is issued to provide practical information and to assist the user in the proper selection of such brushes.

The standards in this publication are the result of many years of research and investigation and have been developed through continual consultation among manufacturers, users, and national engineering societies. When utilized by the industry, they have resulted in improved quality of electrical products and economy in manufacture.

These standards are subject to periodic review. They have been revised from time to time to meet changing economic conditions and technical progress. In keeping with the policy of the U.S. National Committee of the International Electrotechnical Commission (IEC), an effort has been made to bring this publication into conformity with existing IEC publications to the extent practical. This revision incorporates provisions of the IEC publications where practical and where they can be achieved without hardship to the user and the industry. This standards publication is, therefore, not in complete conformity with IEC standards. With reference to dimensional data, it should be noted that the bracketed values represent conversion of SI units and are not necessarily IEC specified values. To avoid confusion to the user, brushes manufactured in conformity with IEC tolerances should be so identified.

In the preparation of this standards publication the input of users and other parties of interest has been solicited through American National Standards Committee C64. Inquiries, comments, and proposed or recommended revisions should be submitted to the concerned NEMA product subdivision by contacting the:

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Section 1
GENERAL

1.1 SCOPE

These standards record definitions, dimensions and tolerances, test procedures for physical properties, and test procedures for shunt connections for brushes used in the electrical manufacturing industry. Included are carbon, carbon-graphite, graphite, electrographite, metal-graphite, metal-impregnated, and resin-bonded brushes.

IEC definitions, terms, symbols, and SI units are given in square brackets ( ).

1.2 DEFINITION OF BRUSH

A brush, as used in the electrical manufacturing industry, is a conductor, usually composed in part of some form of the element carbon, serving to maintain an electrical connection between stationary and moving parts of a machine or apparatus.

1.3 CLASSIFICATIONS OF BRUSHES ACCORDING TO MATERIAL

Brushes are classified according to the types of material used, as follows:

Type	Symbol
Carbon	(HC)
Carbon-graphite	(CG)
Electrographite	(EG)
Graphite	(NG)
Metal-graphite	(MG)
Metal-impregnated	(MI)
Resin-bonded	(BG)

1.3.1 Classes of Brush Materials

1.3.1.1 Carbon (HC) consists of various forms of amorphous carbon.

1.3.1.2 Carbon-graphite (CG) consists of a mixture of amorphous carbon and graphite.

1.3.1.3 Electrographite (EG) consists of various forms of amorphous carbon converted during manufacture to artificial graphite.

1.3.1.4 Graphite (NG) consists principally of graphite.

1.3.1.5 Metal-graphite (MG) consists of a mixture of metal(s) and graphite.

1.3.1.6 Metal-impregnated (MI) consists of carbon or graphite which has been impregnated with molten metal under pressure.

1.3.1.7 Resin-bonded (BG) consists of carbon or graphite bonded with synthetic resin.

1.4 CLASSIFICATION OF BRUSHES ACCORDING TO SIZE

Brushes are grouped into three classes, according to size, as follows:

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1.4.1 A miniature brush is a brush having a cross-sectional area of less than 0.016 square inch (10.3 mm^2).

1.4.2 A fractional-horsepower brush is a brush with a cross-sectional area of not less than 0.016 square inch (10.3 mm^2) and not greater than 0.25 square inch (161 mm^2) (thickness X width) (tangential dimension X axial dimension) and not exceeding 1.5 inches (38.1 mm) in length (radial dimension).

1.4.3 An industrial brush is a brush with a cross-sectional area of more than 0.25 square inch (161 mm^2) (thickness X width) (tangential dimension X axial dimension) or with a length (radial dimension) of more than 1.5 inches (38.1 mm).

1.5 CLASSIFICATION OF BRUSHES ACCORDING TO CONSTRUCTION

1.5.1 An insert or cored brush is a brush which has been drilled or slotted radially from the contact surface and the space(s) filled with another material.

1.5.2 Paired brushes (or a PAIR OF BRUSHES) consist of two individual brushes which are joined together by a common shunt or terminal. They are not to be confused with a split brush. See Figure 1-1.

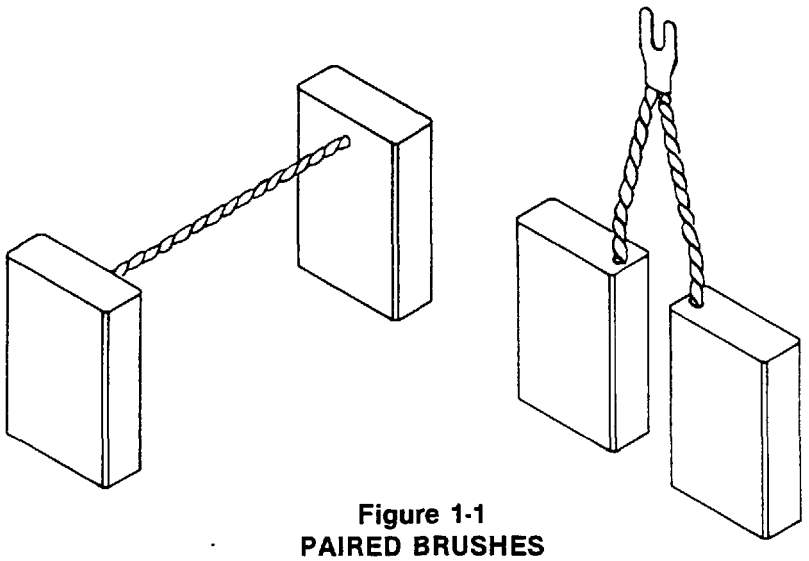


Figure 1-1
PAIRED BRUSHES

1.5.3 A sandwich brush consists of two or more brush sections which are rigidly joined together and used as one brush. The sections are of the same or different materials.

1.5.4 A split brush consists of two or more unbonded pieces forming the thickness. The pieces can move relative to each other and are to be used as one brush. The pieces are of the same or different materials, and are physically connected or unconnected. See Figure 1-2.

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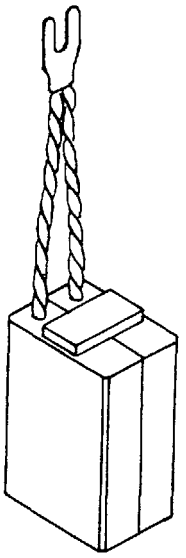


Figure 1-2
SPLIT BRUSH

1.6 DEFINITION OF SHUNT

A shunt is a stranded cable or other flexible conductor attached to the brush to connect it electrically to the machine or apparatus. Its purpose is to conduct the current which would otherwise flow from the brush to the brushholder or pressure finger.

1.6.1 Termination of brush or a brush shunt termination is a device attached to the shunt to facilitate connection with another conductor.

1.7 DEFINITIONS OF BRUSH SURFACES

See 2.1 for order of brush dimensions.

1.7.1 Bevels

1.7.1.1 A beveled corner is one where material has been removed from a corner leaving a triangular surface. See figure 1-3.

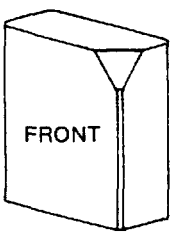


Figure 1-3
BEVELED CORNER

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1.7.1.2 A beveled edge refers to the removal of an edge to provide a slanting surface from which a shunt connection can be made or for clearance of pressure fingers or for any other purpose. See Figure 1-4.

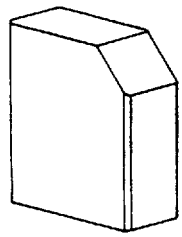


Figure 1-4
BEVELED EDGE

1.7.1.3 Beveled ends and toes. The bevel angle or cut portion is specified as the angle included between the beveled surface and a plane at right angles to the length. The toe is the uncut or flat portion on the beveled or beveled and concaved end. See Figures 1-5 and 1-15.

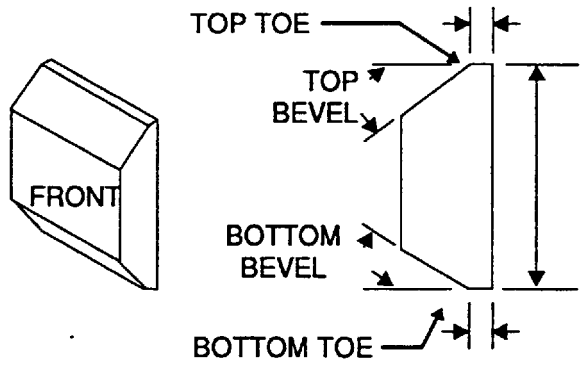


Figure 1-5
BEVELED ENDS AND TOES

When a brush has one or both ends beveled, the front of the brush is the short side or the side exposing the face bevel. See Figures 1-5 through 1-9.

1.7.1.4 A partial top bevel is the same as a top bevel, except that it does not extend across the full width (axial dimension) of the brush. Angles are the same as on a full top bevel. See Figure 1-10.

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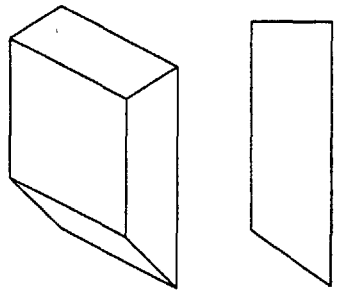


Figure 1-6
SINGLE BOTTOM BEVEL

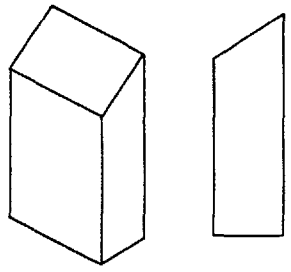


Figure 1-7
SINGLE TOP BEVEL

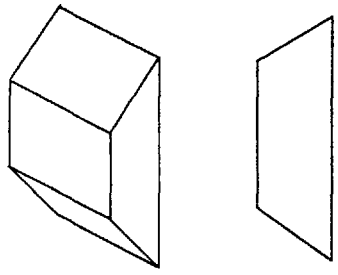


Figure 1-8
DOUBLE BEVEL

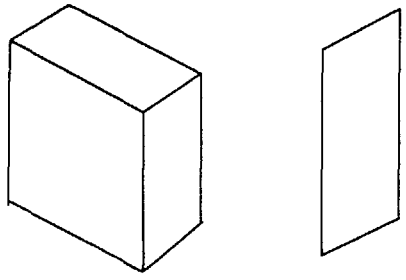


Figure 1-9
DOUBLE PARALLEL BEVEL

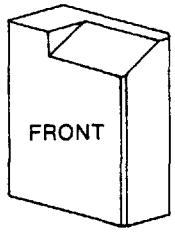


Figure 1-10
PARTIAL TOP BEVEL

1.7.2 Chamfers

A chamfer refers to the slight removal of a sharp edge. See Figure 1-11.

1.7.2.1 The angle of chamfers is such that an equal amount of material will be taken from the two adjacent surfaces. On rectangular brushes, the angle between the plane of the side of the brush and the plane of the face of the chamfer extended is 45 degrees as measured with a protractor.

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1.7.2.2 The depth of chamfer on each surface shall be measured along the plane of each of the two adjacent surfaces and not the width of the face of the cut portion. See Figure 1-11.

1.7.2.3 Alignment/Position Chamfer

An alignment/position chamfer may be full or partial and equal or unequal, at a recommended 45° angle.

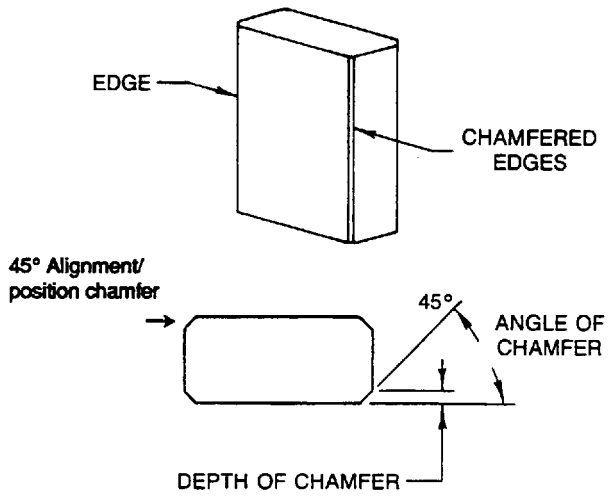


Figure 1-11
CHAMFERS

1.7.3 Convex and Concave Ends, and Toes

Convex and concave ends are surfaces of a given radius which may extend fully or partially across the width (axial dimension) of the brush. When these shapes are applied to bevels, both bevel angle and radius are given. See Figures 1-12 through 1-15. The toes are the uncut or flat portion of the leading or trailing edge. See Figure 1-15.

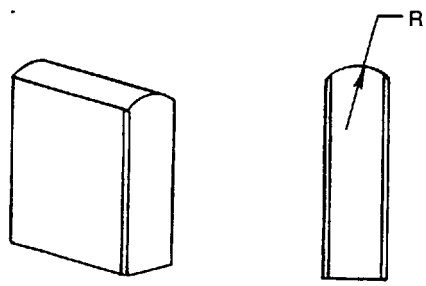


Figure 1-12
CONVEX END (TOP)

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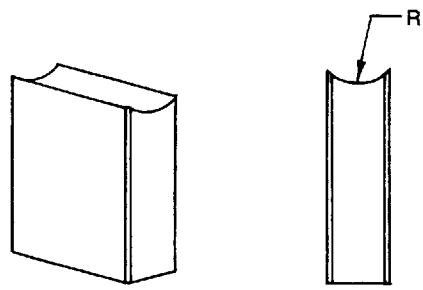


Figure 1-13
CONCAVE END (TOP)
(SHOWN WITHOUT TOES)

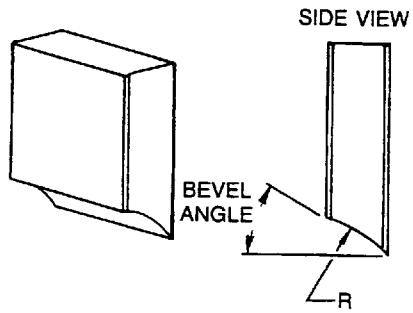


Figure 1-14
CONCAVE ON BEVEL END (FACE)
(SHOWN WITHOUT TOES)

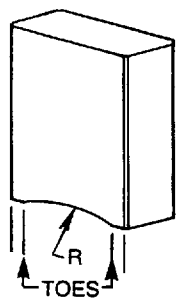


Figure 1-15
CONCAVE END (FACE)
(SHOWN WITH TOES)

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1.7.4 Corners

A corner of the brush is the point of intersection of any three surfaces. They are designated as top or face corners.

1.7.5 Edges

The edges of the brush are the intersection of any two brush surfaces. The leading edge (entering edge) is the edge at the brush face on the side of the brush into which the commutator or ring rotates. The trailing edge (leaving edge) is the edge at the brush face on the side of the brush away from which the commutator or ring rotates.

1.7.6 End, Face and Sides

1.7.6.1 The end of the brush are the surfaces defined by the width and thickness (axial dimension and tangential dimension) of the brush. It is designated as top or holder end.

1.7.6.2 The surface which is in contact with the commutator or ring is also known as the brush face. See Figure 1-16.

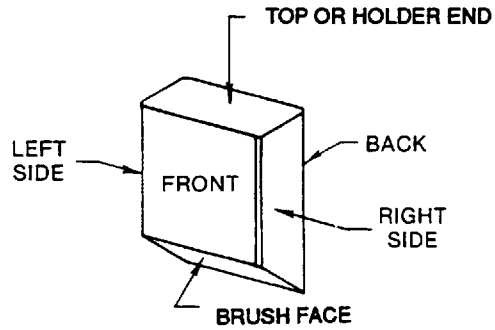


Figure 1-16
BRUSH FACES AND ENDS

1.7.6.3 The sides of the brush are defined as:

a. Front and back, bounded by width and length (axial dimension and radial dimension). If the brush has one or both ends beveled, the short side of the brush is the front. See Figure 1-16.

   If there are no top or bottom bevels and width (axial dimension) is greater than thickness (tangential dimension) and there is a top clip (see section 1.9), the side to which the clip is attached is the back, except in the case of angular clips where the front or short side is determined by the slope of the clip and not by the side to which it is attached.

b. Left side and right side, bounded by thickness and length (tangential dimension and radial dimension). See Figure 1-16.

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1.7.7 Headed Brushes

A headed brush is one having a top (cylindrical, conical, or rectangular) with a smaller cross section than the cross section of the body of the brush. The length of the head (ℓ) does not exceed 25 percent of the overall length of L(r). See Figures 1-17 through 1-20.

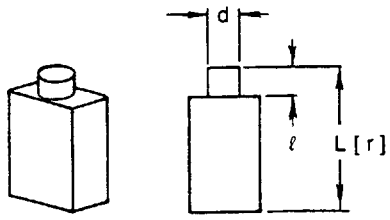


Figure 1-17
CYLINDRICAL HEAD

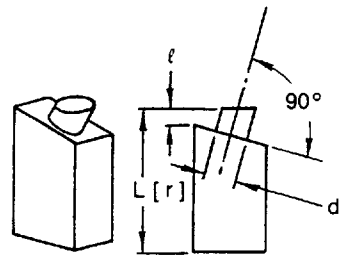


Figure 1-18
ANGULAR CYLINDRICAL HEAD

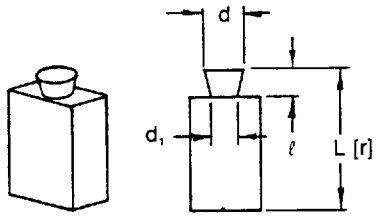


Figure 1-19
CONICAL HEAD

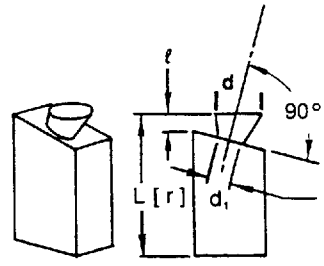


Figure 1-20
ANGULAR CONICAL HEAD

1.7.8 Holes, Counterbores, and Countersinks

The terms holes, counterbores, and countersinks referred to in this publication are used in accordance with commonly accepted practice. See Figures 1-21 through 1-23.

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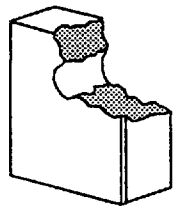


Figure 1-21
HOLE

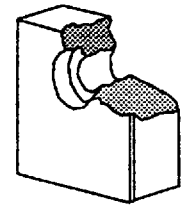


Figure 1-22
HOLE AND COUNTERBORE

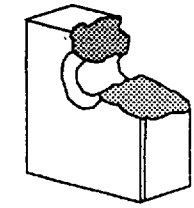


Figure 1-23
HOLE AND COUNTERSINK

1.7.9 Shoulders

When the top of the brush has a portion cut away by two planes at right angles to each other, this is designated as a shoulder. When necessary, the right or left shoulder is specified. See Figures 1-24 through 1-26.

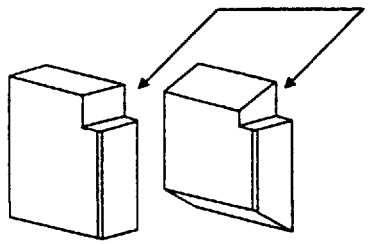


Figure 1-24
SINGLE SHOULDER

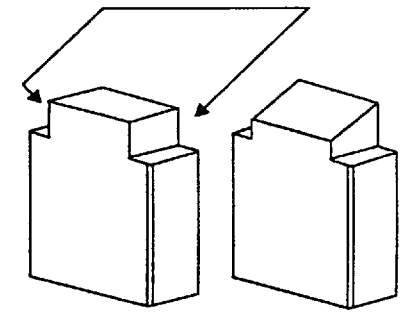


Figure 1-25
DOUBLE SHOULDER

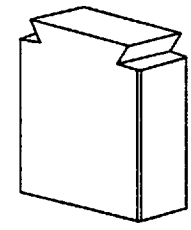


Figure 1-26
DOUBLE ANGLE SHOULDER

1.7.10 Slots, Grooves, and Notches

Slots, grooves, and notches are sections of materials removed from the brush. See Figures 1-27 through 1-31.

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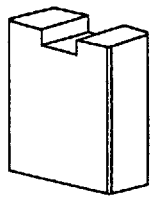


Figure 1-27
SLOT IN TOP

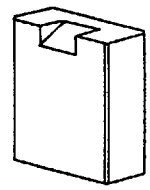


Figure 1-28
BEVELED SLOT

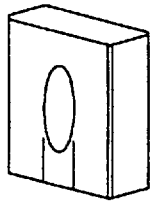


Figure 1-29
SLOT IN CENTER

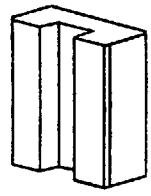


Figure 1-30
GROOVE IN SIDE

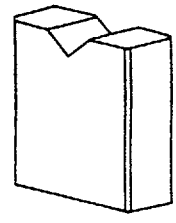


Figure 1-31
NOTCH IN TOP

1.8 BRUSH CONNECTIONS

1.8.1 Classification of Connection Types

1.8.1.1 Type M is a shunt which is molded into the brush. See Figure 1-32.

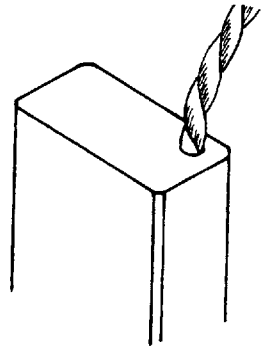


Figure 1-32
TYPE M

1.8.1.2 Type Q is a shunt which is held in place by a tamped conductive material. See Figure 1-33.

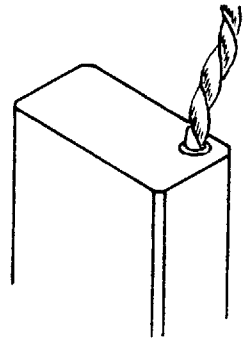


Figure 1-33
TYPE Q

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1.8.1.3 Type R[1] is a shunt consisting of a cable(s) which is held in place by means of a single rivet. See *Figure* 1-34.

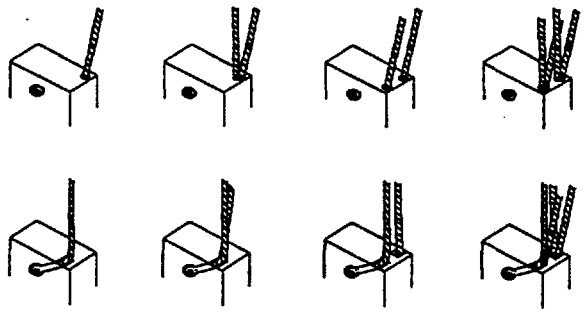


Figure 1-34
TYPE R

1.8.1.4 Type T[1] consists of two Type R connections made separately to the same brush. See Figure 1-35.

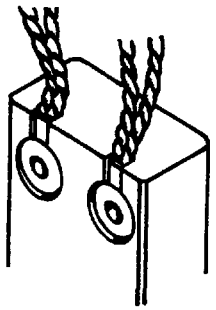


Figure 1-35
TYPE T

1.8.1.5 Type V[1] is a shunt consisting of one or two cables held in place by means of a bolt and nut instead of a rivet. See Figure 1-36.

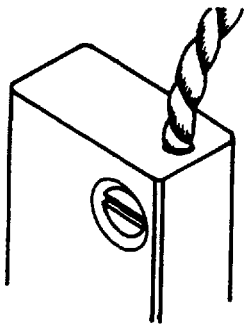


Figure 1-36
TYPE V

1.8.1.6 Type W[1] consists of two Type V connections made separately to the brush. See Figure 1-37.

[1]Brushes of these types have connections which may or may not be soldered. The solder composition is specified by the user.

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1.8.1.6 Type W[2] consists of two Type V connections made separately to the brush. See Figure 1-37.

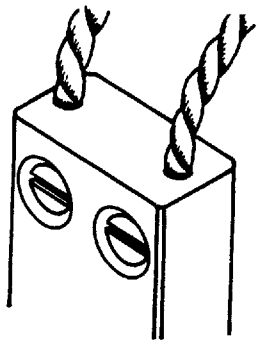


Figure 1-37
TYPE W

1.8.1.7 Type X[2] is a shunt which is fastened to a clip which, in turn is riveted to the brush. See Figures 1-38 and 1-39.

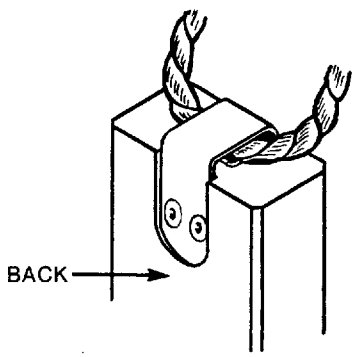


Figure 1-38
TYPE X

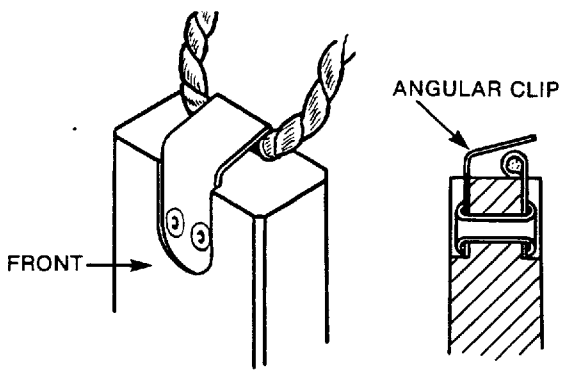


Figure 1-39
TYPE X

1.8.1.8 Type Z is a shunt(s) which is fastened to a metal strip(s) which in turn is riveted to the brush. See Figure 1-40.

[2]Brushes of these types have connections which may or may not be soldered. The solder composition is specified by the user.

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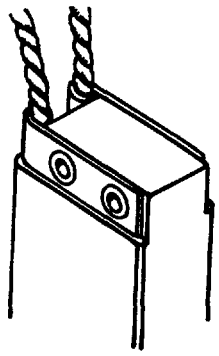


Figure 1-40
TYPE Z

1.8.2 Locations

The locations by position number for shunts and holes are illustrated in Figures 1-41 through 1-44.

Shunt positions 1 through 9 indicate that the shunt enters the top of the brush; position 10, the right side; position 11, the front, position 12, the left side; position 13, the back.

To determine the correct designation of locations, the following procedure is used:

a. If the brush has a beveled top or bottom, or both, (commutator type) observe with front side toward you in accordance with Figure 1-41.
b. If the brush has a greater thickness (tangential dimension) than width (axial dimension) (slip-ring type), observe in accordance with Figure 1-42. Hold with the front side toward you if beveled.
c. If the brush is tapered or wedge-shaped (wedge commutator type), observe with the thinner side to the left in accordance with Figure 1-43.
d. If the brush has no top or bottom bevel and has a top clip, the side of the brush to which the clip is attached is considered as the back if the width (axial dimension) is greater than the thickness (tangential dimension); otherwise, it is considered as the right side.

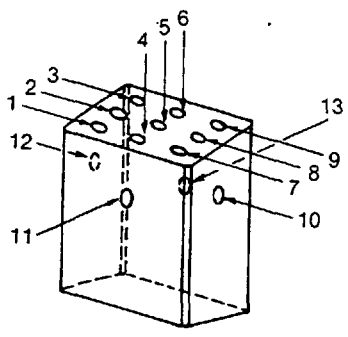


Figure 1-41
COMMUTATOR TYPE

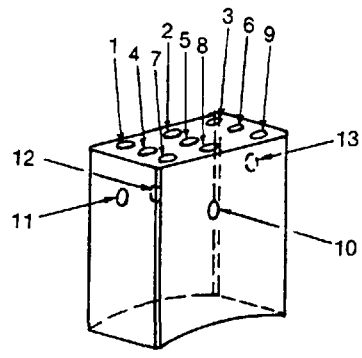


Figure 1-42
SLIP-RING TYPE

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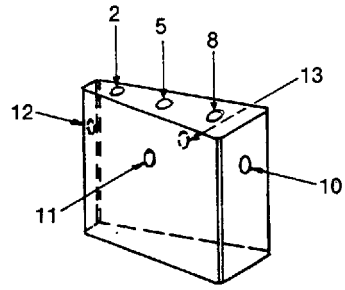


Figure 1-43
WEDGE COMMUTATOR TYPE

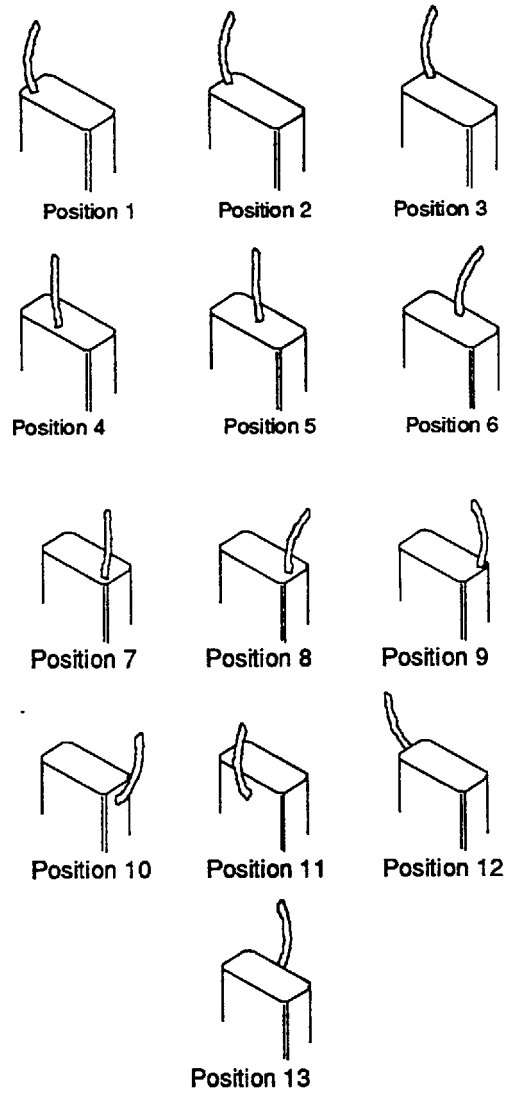


Figure 1-44
SHUNT LOCATIONS FOR COMMUTATOR AND SLIP-RING TYPES

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1.8.3 Shunt Length

The shunt length (L) is the distance from the extreme top of the brush material to the center of the hole or slot in the terminal, or the center of the inserted portion of a plug terminal or, if there is no terminal, to the end of the shunt.

To determine the length of the shunt, extend the cable straight from the top end in a line parallel with the axis of the brush. See Figures 1-45 and 1-46.

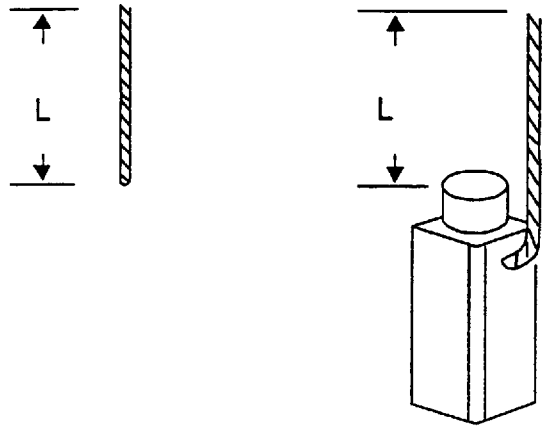


Figure 1-45
SHUNT LENGTH (NO TERMINAL)

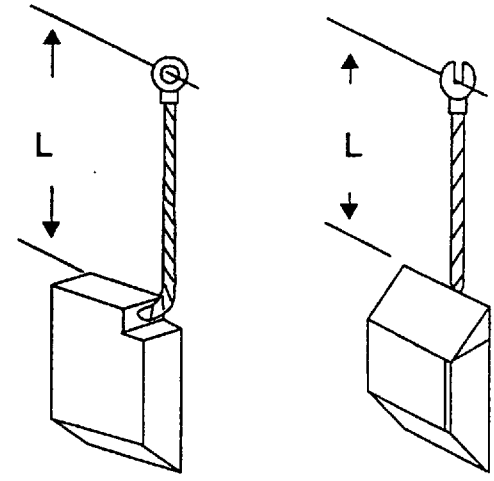


Figure 1-46
SHUNT LENGTH (WITH TERMINAL)

1.9 BRUSH CLIPS

Brush clips, referred to as "clips" in this publication, are parts attached to the brush which serve to accommodate the spring, spring finger, or hammer, or to act as guides. Where these serve to prevent the wear of the carbon due to the pressure finger, they are called "hammer" or "finger" clips. Some clips serve the purpose of lifting the brushes or providing a stop. The width of the clips is designated by K.

1.9.1 Hammer Clips

1.9.1.1 A Type A clip consists of a strip formed to lie on the top of the brush and attached to the side of the brush. See Figure 1-47.

1.9.1.2 A Type A extra wide clip is similar to the Type A clip, except that it covers nearly the whole top of the brush. See Figure 1-48.

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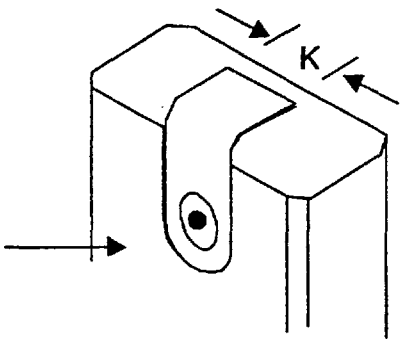


Figure 1-47
TYPE A

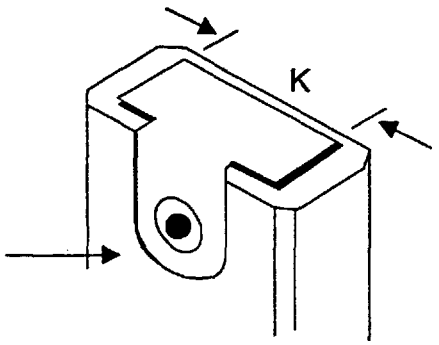


Figure 1-48
TYPE A – EXTRA-WIDE

1.9.1.3 An Offset A clip is similar to the Type A extra wide clip, except that the rivet is not placed at the centerline of the brush. See Figure 1-49.

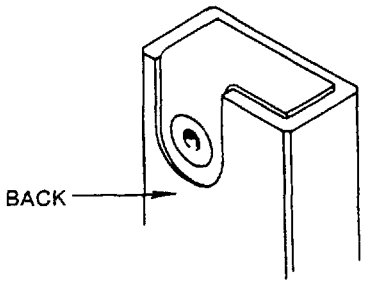


Figure 1-49
OFFSET A

1.9.1.4 An Extended A (Cantilever) clip is similar to the Type A clip but extends beyond the side of the brush to accommodate the brush pressure finger. Dimension "e" is measured in the plane shown in Figure 1-50 and is taken to a straight edge. Minimum thickness of clip material is .03 inches (0.71 mm). See ASTM A480, A568 or B248[2] for tolerances for thickness of the type of material used. An alternate method to dimension the A clip or protrusion shown in Figure 1-50 is to provide dimension U (see Figure 1-63). These methods may be applied to extended P measurements (also see Figure 1-63).

[2] Available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. The titles are as follows:
A480-80 General Requirements for Delivery of Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip
A568-74 General Requirements for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet, Hot-Rolled Strip, and Cold-Rolled Sheet
B248-11 General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar

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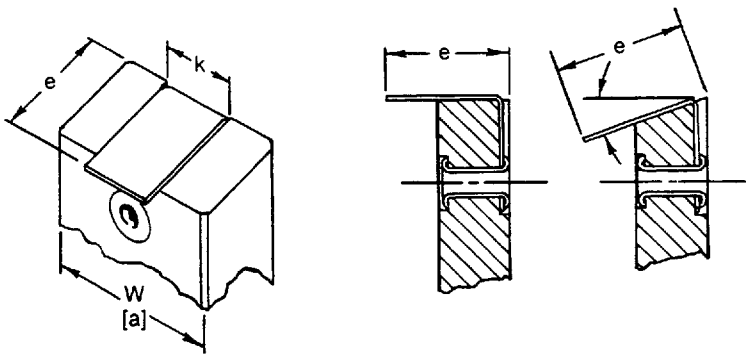


Figure 1-50
EXTENDED A CANTILEVER

1.9.1.5 An Angular A clip is similar to the Type A clip but is attached to an angle to accomplish the same purpose as beveling the holder end of the brush. See Figure 1-51.

1.9.1.6 A Channel A clip is similar to the Type A clip, except that it has the edges turned up as a guide to position the spring finger on top of the brush. See Figure 1-52.

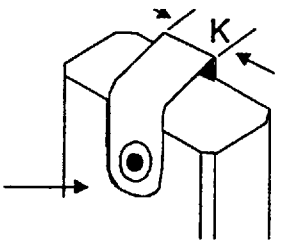


Figure 1-51
ANGULAR A

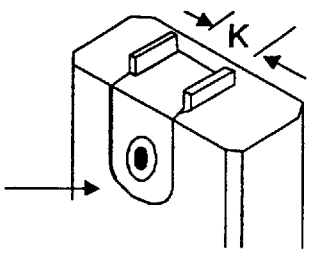


Figure 1-52
CHANNEL A

1.9.2 Lifting and Guide Clips

1.9.2.1 Type B is a lifting clip having two lugs, in one of which there is a hole and in the other a slot opening toward the side of the brush. The slot opening direction is optional, depending on the application. See Figure 1-53.

1.9.2.2 Type C is a guide clip. It is generally fastened into a groove in the brush by one or more rivets. See Figure 1-54.

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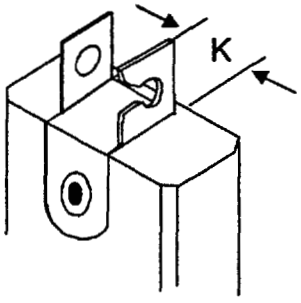


Figure 1-53
TYPE B

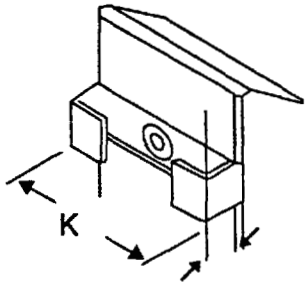


Figure 1-54
TYPE C

1.9.2.3 Type D is a bail-type lifting clip. The bail is fixed to the brush by a metal plate. See Figure 1-55.

1.9.2.4 Type E is a lifting clip formed into the shape of a hook. See Figure 1-56.

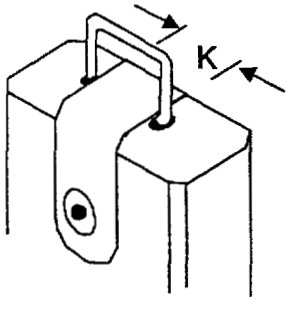


Figure 1-55
TYPE D

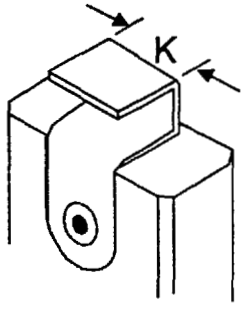


Figure 1-56
TYPE E

1.9.2.5 Type F is a lifting clip similar to the Extended A (Cantilever type) hammer clip and is usually made in double thickness or two pieces. See Figure 1-57. The clip protrusion is dimensioned perpendicularly from the brush surface to the end of the clip. An alternate method to dimension the A clip or protrusion is to provide dimension U as shown in Figure 1-63.

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1.9.2.6 Type G is a lifting clip having a raised portion which projects outward from the side of the brush. See Figure 1-58.

1.9.2.7 Type H is a lifting clip similar to the Type E (hook type) clip, except that it has a minor projection which extends outward from the side of the brush. See Figure 1-59.

1.9.2.8 Type K is a lifting clip combining the features of a Type E lifting clip and an Angular A hammer clip. See Figure 1-60.

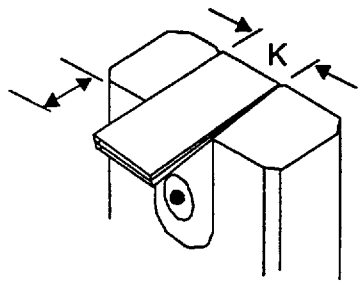


Figure 1-57
TYPE F

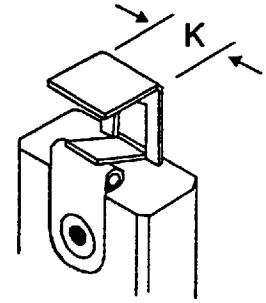


Figure 1-58
TYPE G

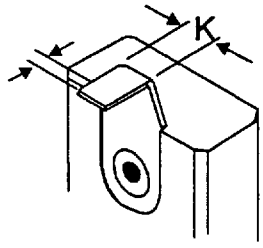


Figure 1-59
TYPE H

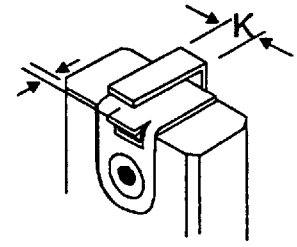


Figure 1-60
TYPE K

1.10 BRUSH PADS

Brush pads, referred to as "pads" (are designated by "P") in this publication, are resilient parts attached to the brush top to absorb vibration. Pads are composed of a resilient material or a combination of resilient and nonresilient materials. Pads are typed according to the shape of their top surface. All of these types are of the channel design which acts as a guide to position the spring or spring finger on top of the brush. See Figure 1-61 for an example of a typical channel design. The width of the pad is designated by "K."

1.10.1 Type P is a pad with a plain rectangular surface. See Figure 1-62.

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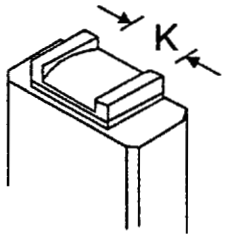


Figure 1-61
CHANNEL DESIGN PAD

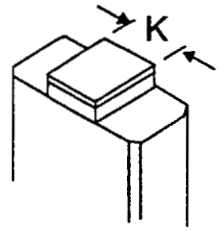


Figure 1-62
TYPE P

1.10.2 An Extended P pad protrusion is similar to a type P pad but extends beyond the side of the brush to accommodate the brush pressure spring or finger. See Figure 1-63. Depending on the materials selected, the pad extension is critical. An alternate method to dimension the P pad is to provide dimension U as shown in Figure 1-63.

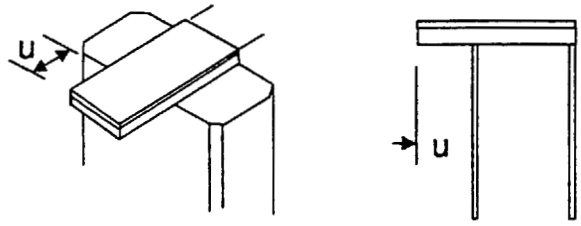


Figure 1-63
EXTENDED P

1.10.3 A convex P pad is similar to a Type P pad except that it has a convex top. See Figure 1-64. Radius R dimension is specified.

1.10.4 A Concave P pad is similar to a Type P pad but has a concave top. See Figure 1-65. Radius R is specified.

1.10.5 A Single-Angle P pad is similar to a type P pad except it has an angled top. See Figure 1-66.

1.10.6 A Double-Angle P pad is similar to a Type P pad but the top consists of two intersecting planes. See Figure 1-67.

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1.11 WEAR INDICATORS

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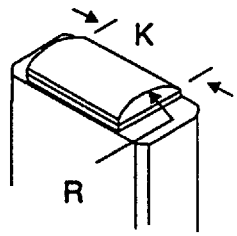


Figure 1-64
CONVEX P

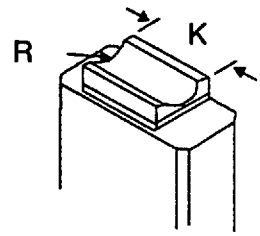


Figure 1-65
CONCAVE P

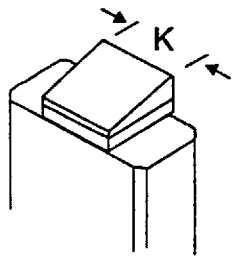


Figure 1-66
SINGLE-ANGLE P

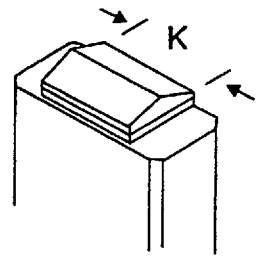


Figure 1-67
DOUBLE-ANGLE P

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Section 2
DIMENSIONS AND TOLERANCES

The dimensions and tolerances in this section apply only to fractional-horsepower and industrial-size brushes as classified in 1.4.2 and 1.4.3.

2.1 BRUSH DIMENSIONS

2.1.1 The dimension (D) of a brush is the dimension of the round portion and is at right angles to the length. See Figure 2-1.

2.1.2 The length (L) (radial dimension, r) of a brush is the maximum overall dimension of the carbon only, measured in the direction in which the brush feeds to the commutator or collector ring. Where the brush construction includes hardware (clips or other pressure bearing components) which protrudes above the top of the brush, the hardware dimension is in addition to brush length.

When designing a brush with hardware, the carbon length is adjusted so that the distance from the commutator or collector ring to the point of spring force application equals that of an equivalent brush without hardware.

2.1.3 The thickness (T) (tangential dimension, t) of the brush is the dimension at right angles to the length in the direction of rotation. See Figures 2-2 to 2-4.

2.1.4 The width (W) (axial dimension, a) of the brush is the dimension at right angles to the length and to the direction of rotation. See Figures 2-2 to 2-4.

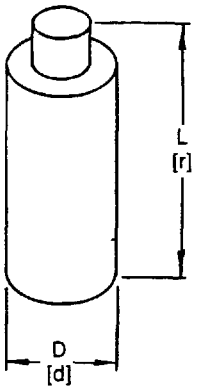


Figure 2-1
CYLINDRICAL BRUSH

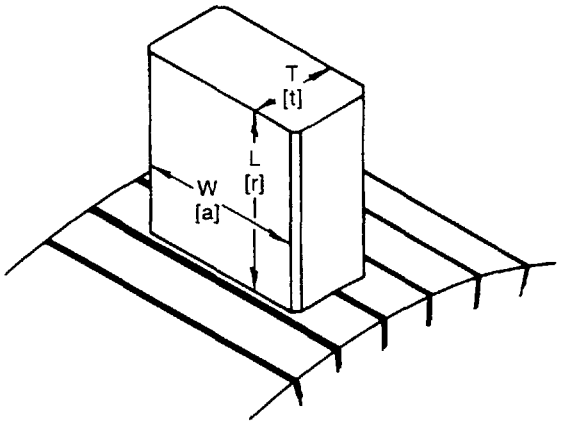


Figure 2-2
COMMUTATOR BRUSH

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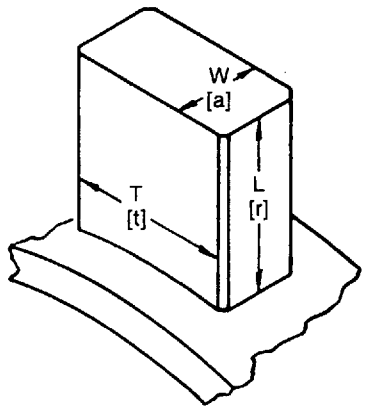


Figure 2-3
SLIP RING BRUSH

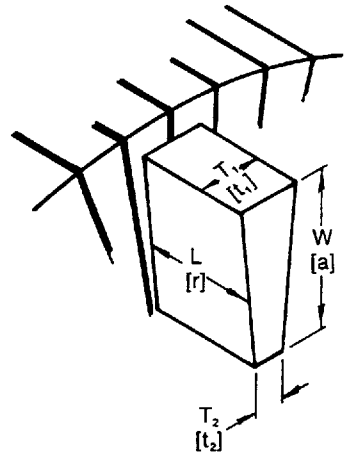


Figure 2-4
COMMUTATOR WEDGE-SHAPED BRUSH

2.2 ORDER OF BRUSH SURFACE DIMENSIONS

The dimensions for indicating the size of brushes is stated in the following order.

2.2.1 Rectangular Brushes (Rectangular Cross Section)

The dimensions shall be stated in the order "thickness x width x length" (T x W x L) (tangential dimension X axial dimension X radial dimension [t x a x r]). See Figures 2-2 and 2-3.

2.2.2 Wedge-Shaped Brushes (Trapezoidal Cross Section)

The dimensions shall be stated in the order "thickness x width x length" (T_1 x T_2 x W x L) (tangential dimension × axial dimension × radial dimension [t_1 x t_2 x a x r]). See Figure 2-4.

2.2.3 Cylindrical Brushes (Round Cross Section)

The dimensions are stated in the order "thickness x length" (D x L) (diameter x radial dimension [d x r]). See Figure 2-1.

2.3 DIMENSIONS—THICKNESS (TANGENTIAL DIMENSION), WIDTH (AXIAL DIMENSION), LENGTH (RADIAL DIMENSION), AND DIAMETER

Dimensions shall vary in steps as shown in Table 2-1.

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Table 2-1
BRUSH DIMENSIONS

		Size		Steps	
		Inches	(mm)*	Inches	(mm)*
A.	Rectangular brushes (see Figures 2-2 and 2-3)				
	Thickness (tangential dimension)	Less than 0.125	Less than 3.2	0.032	0.81
		0.125 to 0.5	3.2 to 12.7	0.063	1.6
		0.5 to 1	12.7 to 25.4	0.125	3.2
		1 to 2	25.4 to 50.8	0.25	6.4
	Width (axial dimension)	Less than 0.125	Less than 3.2	0.032	0.81
		0.125 to 0.25	3.2 to 6.4	0.063	1.6
		0.25 to 1	6.4 to 25.4	0.125	3.2
		1 to 2.5	25.4 to 63.5	0.25	6.4
	Length (radial dimension)	0.25 to 1	6.4 to 25.4	0.125	3.2
		1 to 2.5	25.4 to 63.5	0.25	6.4
		2.5 to 4	63.5 to 102	0.5	12.7
B.	Cylindrical brushes (see Figure 2-1)				
	Diameter	Less than 0.125	Less than 3.2	0.032	0.81
		0.125 to 0.313	3.2 to 7.9	0.032	0.81
		0.313 to 0.5	7.9 to 12.7	0.063	1.6
	Length (radial dimension)	0.25 to 1	6.4 to 25.4	0.125	3.2
		1 to 2.5	25.4 to 63.5	0.25	6.4

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

2.4 TOLERANCES—THICKNESS (TANGENTIAL DIMENSION), WIDTH (AXIAL DIMENSION), LENGTH (RADIAL DIMENSION), AND DIAMETER

Sides are flat and parallel or flat and perpendicular within the following tolerances unless other angle tolerances apply. (See Appendix D, Table D-1 for IEC limits and tolerances.)

2.4.1 Multi-wafer Brushes

For split brushes, the variation in length (radial dimension) is not more than 0.005 inch (0.13 mm) between the adjacent surfaces. The variation in width (axial dimension) is the same as for an equivalent solid brush. The total variation in thickness (tangential dimension) tolerance is the tolerance for an equivalent solid brush with an additional negative 0.001 inch (0.025 mm) tolerance for each additional wafer.

For example, a split brush 0.5 inch thick (12.7 mm tangential dimension) consisting of two wafers has a thickness (tangential dimension) tolerance of +0 in./-0.005 in. (+0 mm/-0.13 mm). The same size brush consisting of three wafers has a thickness (tangential dimension) tolerance of +0 in./-0.006 in. (+0 mm/-0.15 mm).

2.4.2 Brushes of Square Cross-section

For brushes of square cross-section or where the thickness (tangential dimension) is greater than the width (axial dimension), thickness (tangential dimension) tolerances apply to both the width (axial dimension) and thickness (tangential dimension). Where the width (axial dimension) and length (radial dimension) are the same, width (axial dimension) tolerances apply to both the width (axial dimension) and length (radial dimension).

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Table 2-2
BRUSH TOLERANCES

		Tolerances			
		Plus		Minus	
		Inches	(mm)*	Inches	(mm)*
A.	Carbon (HC), Carbon Graphite (CG), Electrographite (EG), Graphite (NG), Resin-bonded (BG), Metal-graphite (MG), and Metal-impregnated (MI) Brushes Containing Up to 50 Percent Metal by Weight				
	Thickness (tangential dimension)				
	less than 0.125 inch (3.2 mm)	0.000	0.00	0.002	0.05
	0.125 inch (3.2 mm) and over	0.000	0.00	0.004	0.10
	Width (axial dimension)				
	less than 0.125 inch (3.2 mm)	0.000	0.00	0.002	0.05
	0.125 inch (3.2 mm) to 0.75 inch (19.0 mm), incl.	0.000	0.00	0.015	0.38
	Length (radial dimension)				
	less than 0.375 inch (9.5 mm)	0.005	0.13	0.005	0.13
	0.375 inch (9.5 mm) up to less than 1 inch (25.4 mm)	0.010	0.25	0.010	0.25
	1 inch (25.4 mm) and over	0.032	0.81	0.032	0.81
	Diameter				
	less than 0.125 inch (3.2 mm)	0.000	0.00	0.002	0.05
	0.125 inch (3.2 mm) and over	0.000	0.00	0.004	0.10
B.	Metal -graphite (MG) and Metal-impregnated (MI) Brushes Containing 50 Percent and More Metal by Weight				
	Thickness (tangential dimension)				
	less than 0.125 inch (3.2 mm)	0.000	0.00	0.002	0.05
	0.125 inch (3.2 mm) to 0.5 inch (12.7 mm), incl.	0.000	0.00	0.004	0.10
	Over 0.5 inch (12.7 mm)	...	...	0.007 to 0.011	0.18 to 0.28
	Width (axial dimension)	0.000	0.00	0.002	0.05
	less than 0.125 inch (3.2 mm)	0.000	0.00	0.004	0.10
	0.125 inch (3.2 mm) to 0.5 inch (12.7 mm), incl.	0.000	0.00	0.004	0.10
	Over 0.5 inch (12.7 mm)	...	...	0.007 to 0.020	0.18 to 0.51
	Length (radial dimension)				
	less than 0.375 inch (9.5 mm)	0.005	0.13	0.005	0.13
	0.375 inch (9.5 mm) up to less than 1 inch (25.4 mm)	0.010	0.25	0.010	0.25
	1 inch (25.4 mm) and over	0.032	0.81	0.032	0.81
	Diameter				
	less than 0.125 inch (3.2 mm)	0.000	0.00	0.002	0.05
	0.125 inch (3.2 mm) and over	0.000	0.00	0.004	0.10

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword. See Appendix D for IEC limits and tolerances.

2.5 BEVELED ENDS AND CONCAVE FACES

2.5.1 Dimensions

Unless compensated for in other design features affecting the performance of brushes, bevel dimensions are provided in 2.5.1.1 and 2.5.1.2.

2.5.1.1 Top Bevels

Top bevels are 0, 15, 30, 35, and 40 degrees. Angular A clips are 15, 30, 35, or 40 degrees. See Figure 2-5.

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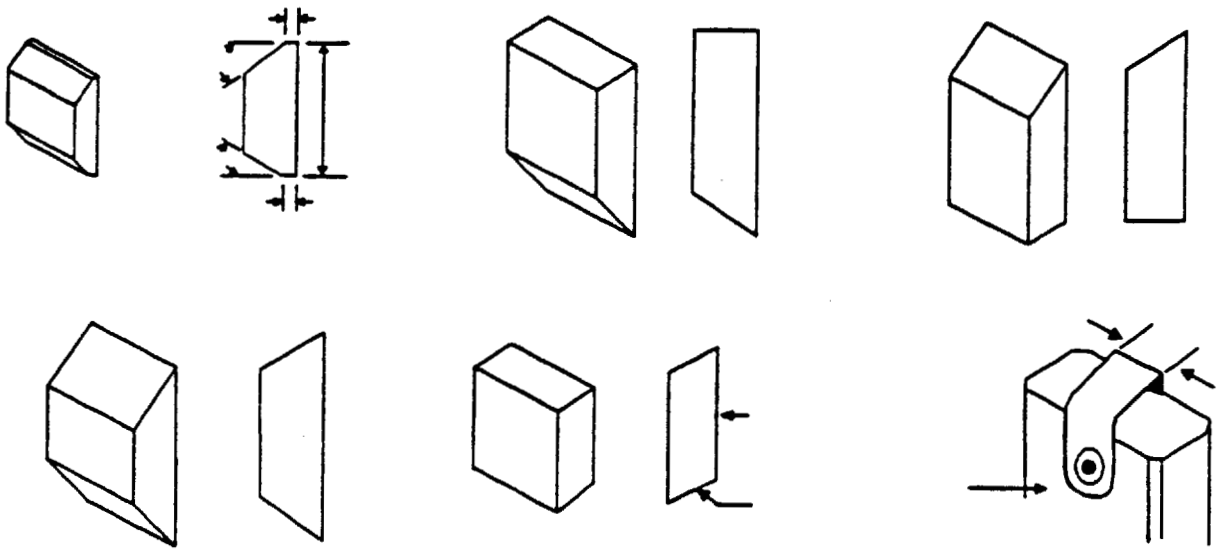


Figure 2-5
BEVEL DIMENSIONS

2.5.1.2 Bottom Bevels

Bottom bevels for leading or reaction brushes are a minimum of 30 degrees and maximum of 40 degrees (preferred angles are 30-, 35- and 40- degree). Bottom bevels for trailing brushes are from 0 degrees and a maximum of 20 degrees (preferred angles are 0-, 10-, 15- and 20-degrees).

2.5.2 Tolerances

Bevel angles and all right angles are accurate to within one degree above or below the nominal angle specified. Concave faces are accurate within ± 10 percent of the nominal radius.

2.6 BRUSH HEADS

2.6.1 Tolerances for brush head dimensions are shown in Table 2-3.

Table 2-3
BRUSH HEAD TOLERANCES

	Plus		Minus	
	Inches	(mm)*	Inches	(mm)*
Diameter	0.000	0.00	0.006	0.015
Length	0.016	0.41	0.000	0.00
Location	Center of head shall not vary more than 0.005 inches (0.13 mm) from center of brush at the place of the shoulder.			

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword. See Appendix D for IEC limits and tolerances.

2.6.2 Brush head dimensions are shown in Figures 1-17 to 1-20 in 1.7.7

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2.7 CHAMFERS

Dimensions of chamfers are shown in Table 2-4.

Table 2-4*
CHAMFER DIMENSIONS

Nominal Brush Thickness or Width (whichever is smaller)		Depth of Chamfer** (see Figure 2-6)			
Inches	(mm) †	inches	(mm) †	Inches	(mm) †
less than 0.125	less than 3.2	0.005	0.13	0.010	0.25
0.125 to less than 0.125	3.2 to less than 6.4	0.010	0.25	0.015	0.38
0.25 to less than 0.313	6.4 to less than 7.9	0.016	0.41	0.032	0.81
0.313 to less than 0.5	7.9 to less than 12.7	0.032	0.81	0.063	1.6
0.5 to less than 0.75	12.7 to less than 19.0	0.063	1.6	0.094	2.4
0.75 and over	19.0 and over	0.094	2.4	0.125	3.2

* This table excludes alignment/position chamfers

** For split brushes it is only necessary to chamfer the four external vertical edges of the assembly, using the over-all dimensions of the assembly to give the chamfer sizes (see Figure 1-2).

† These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

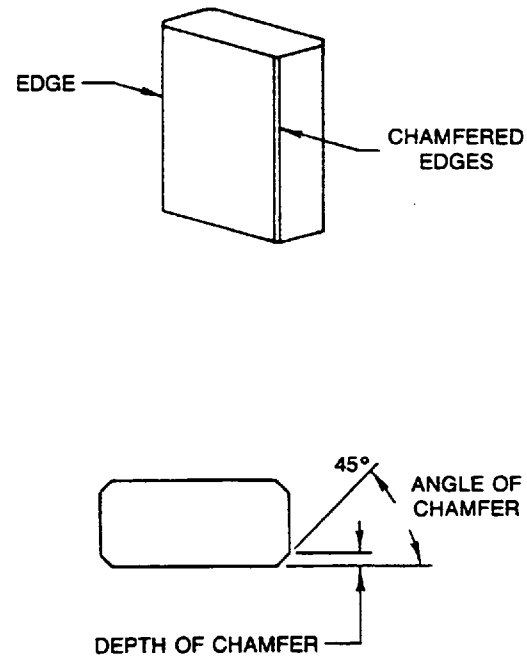


Figure 2-6
CHAMFERS

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2.8 HOLES, COUNTERBORES, AND COUNTERSINKS (SEE FIGURE 2-7)

Tolerances of holes, counterbores, and countersinks are shown in Table 2-5.

Table 2-5
TOLERANCES OF HOLES, COUNTERBORES, AND COUNTERSINKS

	Plus		Minus	
	Inches	(mm)*	Inches	(mm)*
Diameter				
Holes and counterbores	0.010	0.25	0.005	0.13
Countersinks	0.016	0.41	0.000	0.00
Depth of holes, counterbores and countersinks	0.016	0.41	0.000	0.00
Location of holes, counterbores, and countersinks	0.016	0.41	0.016	0.41

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

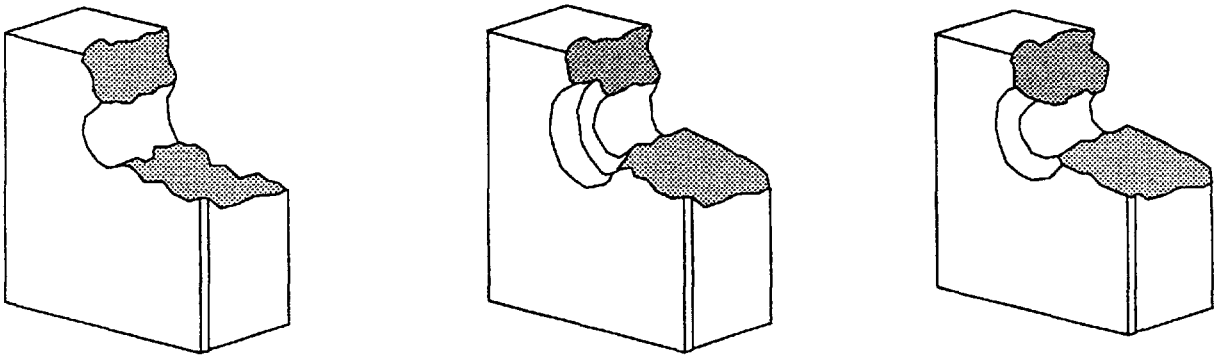


Figure 2-7
HOLES, COUNTERBORES, AND COUNTERSINKS

2.9 SHOULDERS, SLOTS, GROOVES, AND NOTCHES (SEE FIGURE 2-8)

Tolerances of shoulders, slots, grooves, and notches are shown in Table 2-6.

Table 2-6
TOLERANCES OF SHOULDERS, SLOTS, GROOVES, AND NOTCHES

	Plus		Minus	
	Inches	(mm)*	Inches	(mm)*
All dimensions	0.032	0.81	0.000	0.00
Location of slots or grooves	0.016	0.41	0.016	0.41

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

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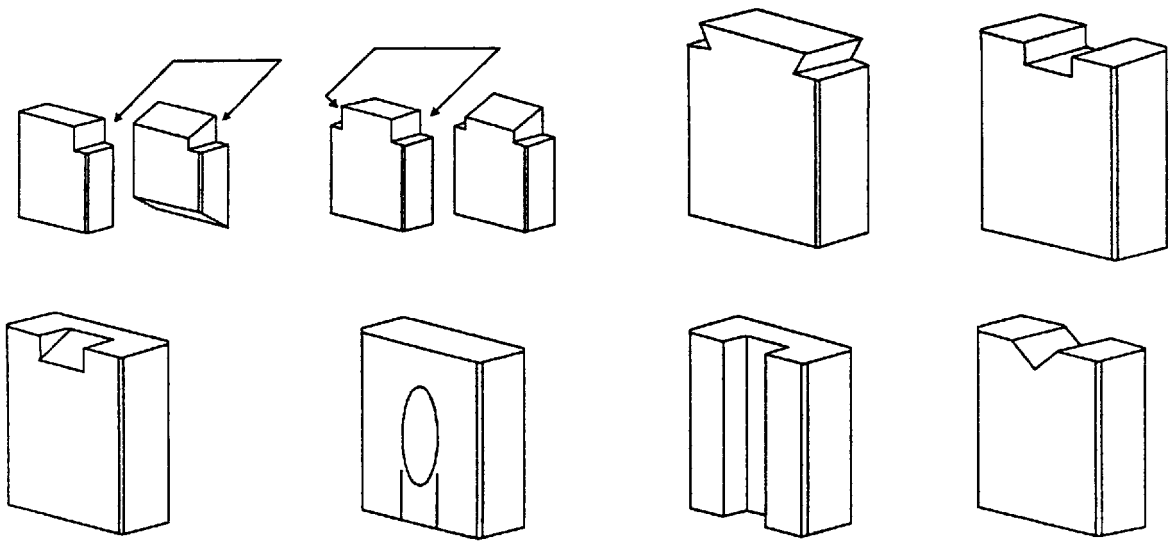


Figure 2-8
SHOULDERS, SLOTS, GROOVES, AND NOTCHES

2.10 TOES

When toes are used, the width of the toe is shown in Table 2-7.

Table 2-7
TOE

Brush Thickness		Maximum Width of Toe	
Inches	(mm)*	Inches	(mm)*
0.75 and less	19.0 and less	0.063	1.6
Over 0.75	Over 19.0	0.125	3.2

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

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2.10.1 Unless otherwise specified, toes at the leading (entering) and trailing (leaving) edges of a radial brush with a concave face (see Figure 2-9) are equal in width to within 0.01 inch (0.25 mm).

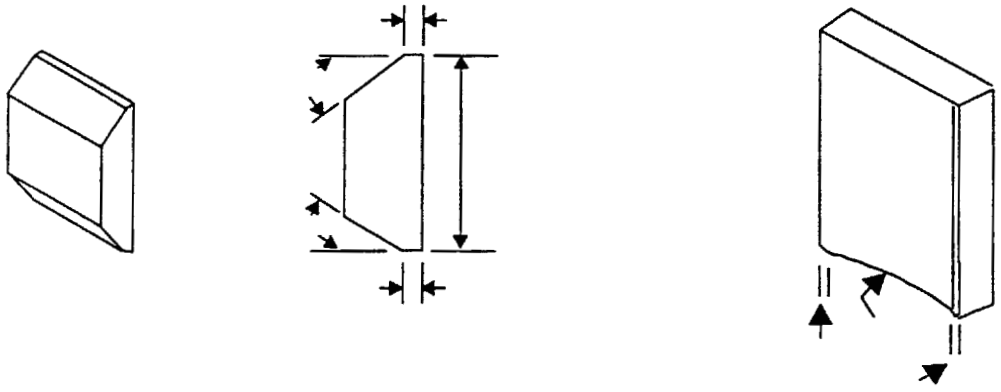


Figure 2-9
TOES

2.11 AVAILABLE AREA AT TOP OF BRUSH FOR APPLYING PRESSURE

The distance P between the shunts to be reserved on the top of the brush for applying pressure is 50% minimum of W (a)—axial dimension—for a commutator brush, or of T(t)—tangential dimension—for a ring brush. (See Figure 2-10.)

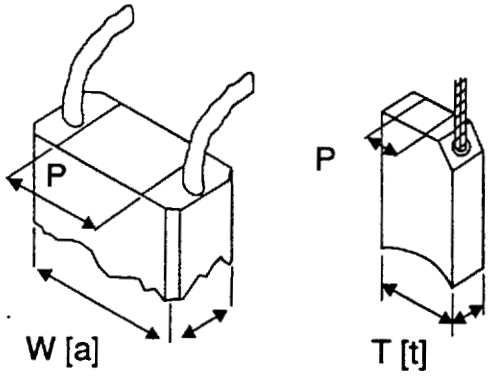


Figure 2-10
PRESSURE AREA

2.12 SHUNTS

2.12.1 Lengths and Tolerances

The nominal lengths and tolerances of shunts are shown in Table 2-8.

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Table 2-8
SHUNT LENGTHS AND TOLERANCES

Lengths		Tolerances			
		Plus		Minus	
Inches	(mm)*	Inches	(mm)*	Inches	(mm)*
0.625	15.9	0.125	3.2	0.000	0.00
1.0	25.4	0.125	3.2	0.000	0.00
1.25	31.8	0.125	3.2	0.000	0.00
1.5	38.1	0.125	3.2	0.000	0.00
2.0	50.8	0.125	3.2	0.000	0.00
2.5	63.5	0.25	6.4	0.000	0.00
3.0	76.2	0.25	6.4	0.000	0.00
3.5	88.9	0.25	6.4	0.000	0.00
4.0	102	0.25	6.4	0.000	0.00
4.5	114	0.25	6.4	0.000	0.00
5.0	127	0..375	9.5	0.000	0.00
5.5	140	0.375	9.5	0.000	0.00
6.0	152	0.375	9.5	0.000	0.00
6.5	165	0.375	9.5	0.000	0.00
7.5	190	0.375	9.5	0.000	0.00

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

2.12.2 Shunt Ratings and Sizes

The sizes of, and specifications for, bare copper cable for brush shunts are shown in Tables 2-9 and 2-10. The individual wire tolerance on the diameter is ±0.0001 inch (ASTM Specifications for Soft or Annealed Copper Wire, B3-74 [1980])[4] ,and the number of wires per cable do not vary more than 2 percent from that specified. (Any fraction is counted as the next whole number.)

Table 2-9*
SHUNT CABLE SIZES AND SPECIFICATIONS

Ampere Rating†				Nominal Diameter of Individual Wires, Inches**	Actual Area of Cable, Circular Mils ††	Nearest AWG Size of Cable	Approximate Diameter of Cable	
Continuous	3 Minutes or Less	Number of Strands	Number of Wires per Strand				Inches	(mm)
1.5	3	3	6	0.002	70.4	31	0.009	0.23
2	4	3	11	0.002	129.1	29	0.016	0.41
3.5	7	3	22	0.002	258.1	26	0.022	0.56
4	8	3	11	0.003	326.3	25	0.022	0.56
7	14	3	22	0.003	652.6	22	0.030	0.76
10	20	7	15	0.003	1038	20	0.040	1.02
15	30	7	9	0.005	1575	18	0.052	1.32
20	40	7	15	0.005	2625	16	0.067	1.70
30	60	7	24	0.005	4200	14	0.086	2.18
40	80	7	37	0.005	6475	12	0.102	2.59
50	100	7	59	0.005	10325	10	0.130	3.30
60	120	7	75	0.005	13125	9	0.140	3.56
70	140	7	95	0.005	16625	8	0.166	4.22
85	170	7	119	0.005	20625	7	0.188	4.78
100	200	7	150	0.005	26250	6	0.204	5.18

*Table 2-9 is based on Table 2-10.

**To convert to millimeters, multiply by 25.4.

†These ampere ratings are for bare copper cables in free air, based on an ambient temperature of 30°C (86°F) and a 60°C (108°F) rise in still air, and are suggested for use as a guide only. The actual values used for a given application will depend on such factors as ventilation, permissible temperature rise, and other conditions of service. If the cable is insulated, it may be necessary to increase the cable size.

††To convert to square millimeters, multiply by 5.067×10^{-4}.

[4] Copies are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

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Table 2-10 – Specifications of individual shunt cable wires

Nominal Diameter, Inches	AWG Size	Actual Diameter, Inches*	Actual Area Circular Mils**
0.002	44	0.00198	3.911
0.003	40	0.00314	9.888
0.005	36	0.005	25.00

*To convert to millimeters, multiply by 25.4
**To Convert to square millimeters, multiply by 5.067×10^{-4}

2.12.3 Brush Shunt Insulation

Insulation is applied to shunts when a dielectric is desired between the shunt and other parts of the machine. Insulation is normally applied after the shunt is affixed to the brush and therefore is usually of a sleeve type. Selection of an insulating sleeve takes into account temperature, atmosphere, required flexibility, abrasion resistance, and other operating factors. Silicone insulation is not used in totally enclosed machines.

2.13 TERMINATIONS OF BRUSH SHUNTS FOR SCREW OR BOLTED CONNECTION

Tables 2-11 through 2-13, and accompanying Figures 2-11 through 2-16, are used to enable machine designers to provide sufficient space for the terminal to be fastened to the machine. Where angle terminals are specified, the angles are 45 or 60 degrees from the plane of the C dimension. An angle terminal is one in which the fastening surface is bent at an angle to the plane of the shunt attachment.

The B and C dimensions are maximum dimensions.

The designation consists of the type letter(s) which is followed by a number which is equal to the average dimension of A (in decimal form) divided by 0.03125. (SI conversion is not applicable.)

2.13.1 Flag Type

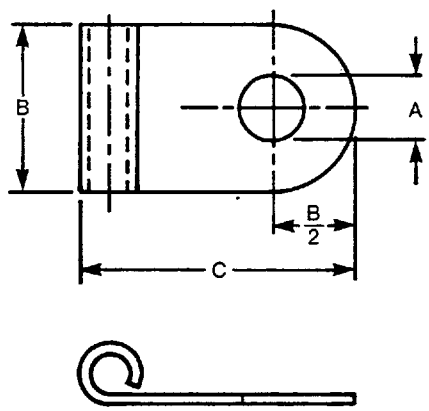


Figure 2-11
TYPE FH (FLAG TYPE WITH HOLE)
[CLOSED FLAG]

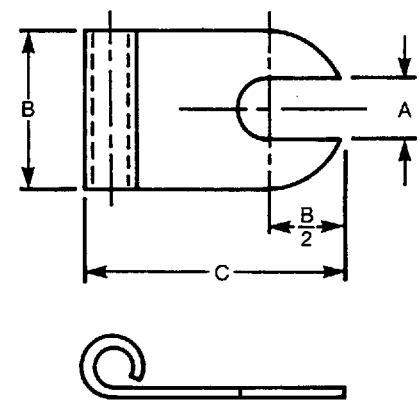


Figure 2-12
TYPE FS (FLAG TYPE WITH SLOT)
[OPEN FLAG]

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Table 2-11
SPECIFICATIONS FOR FLAG TYPE BRUSH SHUNT TERMINATIONS

Designation		Dimensions, Inches*					
		A		B	C	Maximum Shunt Size, Circular	Thickness Range
Type FH	Type FS	Minimum	Maximum	Minimum	Maximum	Mils**	Inches*
FH4	FS4	0.115	0.135	0.260	0.407	1575	0.020 – 0.025
FH5	FS5	0.146	0.166	0.291	0.438	2625	0.020 – 0.025
FH5A	FS5A	0.146	0.166	0.385	0.532	6475	0.025 – 0.030
FH7	FS7	0.209	0.229	0.385	0.595	6475	0.025 – 0.030
FH7A	FS7A	0.209	0.229	0.510	0.782	20825	0.030 – 0.040
FH9	FS9	0.271	0.291	0.635	0.907	26250	0.040 – 0.046

*To convert to millimeters, multiply by 25.4.
**To convert to square millimeters, multiply by 5,067 x 10^{-4}

2.13.2 Tubular or Folded Type

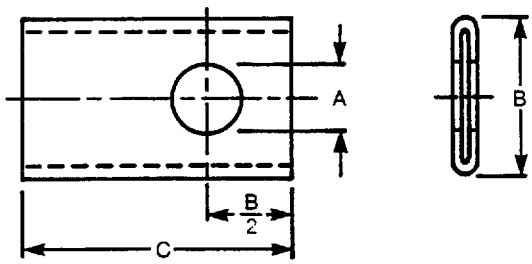


Figure 2-13
TYPE TH
(TUBULAR TYPE WITH HOLE)

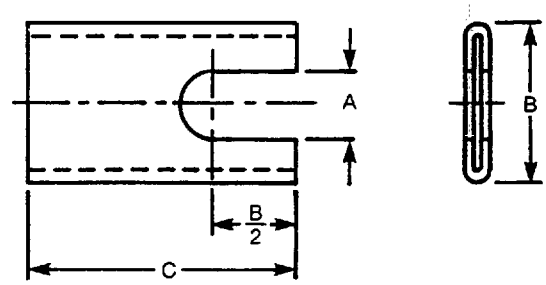


Figure 2-14
TYPE TS
(TUBULAR TYPE WITH SLOT)

Table 2-12
SPECIFICATIONS FOR TUBULAR OR FOLDED TYPE BRUSH SHUNT TERMINATIONS

Designation		Dimensions, Inches*					
		A		B	C	Maximum Shunt Size, Circular	Thickness Range*
Type FH	Type FS	Minimum	Maximum	Minimum	Maximum	Mils**	Inches*
TH9	TS9	0.271	0.291	0.573	1.032	52500	...
TH11	TS11	0.334	0.354	0.698	1.032	52500	...
TH13	TS13	0.396	0.416	0.823	1.032	52500	...

*To convert to millimeters, multiply by 25.4.
**To convert to square millimeters, multiply by 5,067 x 10^{-4}

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2.13.3 Straight or Spde Type

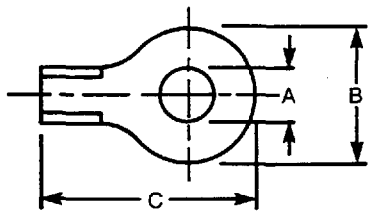


Figure 2-15
TYPE H (STRAIGHT TYPE WITH HOLE)
[CLOSED SPADE]

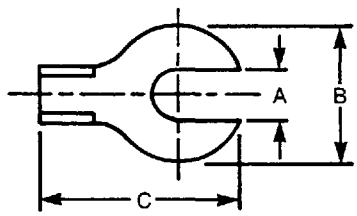


Figure 2-16
TYPE S (STRAIGHT TYPE WITH SLOT)
[OPEN SPADE]

Table 2-13
SPECIFICATIONS FOR STRAIGHT OR SPADE TYPE BRUSH SHUNT TERMINATIONS

Designation		Dimensions, Inches*					
		A		B	C	Maximum Shunt Size, Circular	Thickness Range,
Type H	Type S	Minimum	Maximum	Minimum	Maximum	Mils**	Inches*
H4	S4	0.115	0.135	0.291	0.532	6475	0.020 – 0.025
H5	S5	0.146	0.166	0.323	0.532	6475	0.020 – 0.030
H5A	S5A	0.146	0.166	0.323	0.657	10325	0.020 – 0.030
H6	S6	0.178	0.198	0.385	0.657	26250	0.020 – 0.030
H7	S7	0.209	0.229	0.448	0.907	26250	0.030 – 0.040
H9	S9	0.271	0.291	0.573	1.032	52500	0.030 – 0.040
H11	S11	0.334	0.354	0.698	1.157	52500	0.040 – 0.046
H13	S13	0.396	0.416	0.823	1.282	52500	0.040 – 0.046

*To convert to millimeters, multiply by 25.4.
**To convert to square millimeters, multiply by 5,067 x 10^{-4}

2.14 TERMINATION OF SHUNTS FOR BRUSHES TO BE USED IN CARTRIDGE-TYPE HOLDERS

The designation consists of the type letter(s) followed by the number, rounded to the nearest whole number, obtained by dividing the average dimension of D1 by 0.01563. (SI conversion is not applicable.)

2.14.1 Round type—stamped

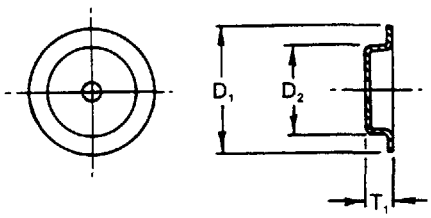


Figure 2-17
TYPE O (ROUND TYPE—STAMPED)

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Table 2-14
SPECIFICATIONS FOR ROUND TYPE—STAMPED—BRUSH SHUNT TERMINATIONS

	Dimensions, inches*					
	D_1		D_2		T_1	
Designation	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
O12	0.180	0.188	0.133	0.141	0.039	0.047
O16	0.242	0.250	0.164	0.172	0.070	0.078
O20	0.305	0.313	0.226	0.234	0.055	0.063
O24	0.367	0.375	0.424	0.250	0.055	0.063
O28	0.430	0.438	0.336	0.344	0.101	0.109
O36	0.555	0.563	0.430	0.438	0.117	0.125
O48	0.742	0.750	0.492	0.500	0.117	0.125

*To convert to millimeters, multiply by 25.4.

2.14.2 Round Type—Machined

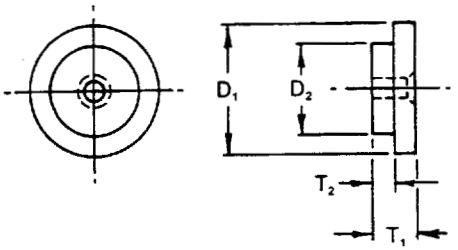


Figure 2-18
TYPE OM (ROUND TYPE—MACHINED)

Table 2-15
SPECIFICATIONS FOR ROUND TYPE—MACHINED—BRUSH SHUNT TERMINATIONS

	Dimensions, inches*							
	D_1		D_2		T_1		T_2	
Designation	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
OM14	0.211	0.219	0.164	0.172	0.086	0.094	0.039	0.047
OM16	0.242	0.250	0.195	0.203	0.086	0.094	0.055	0.063
OM18	0.273	0.281	0.242	0.250	0.117	0.125	0.055	0.063
OM20	0.305	0.313	0.273	0.281	0.117	0.125	0.055	0.063
OM22	0.336	0.344	0.273	0.281	0.117	0.125	0.055	0.063
OM32	0.492	0.500	0.336	0.344	0.117	0.125	0.055	0.063
OM36	0.55	0.563	0.398	0.406	0.117	0.125	0.055	0.063

*To convert to millimeters, multiply by 25.4.

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2.14.3 Eared Type

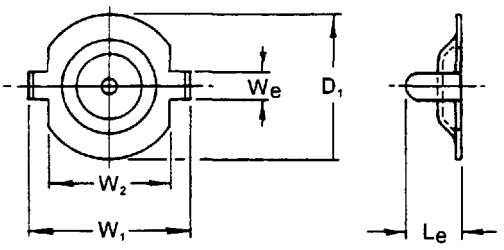


Figure 2-19
TYPE U (EARED TYPE)

Table 2-16
SPECIFICATIONS FOR EARED TYPE BRUSH SHUNT TERMINATIONS

	Dimensions, Inches*									
	D_1		W_1		W_2		W_e		L_e	
Designation	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
U16	0.242	0.250	0.211	0.219	0.180	0.188	0.070	0.078	0.172	0.203
U18	0.273	0.281	0.242	0.250	0.180	0.188	0.117	0.125	0.172	0.203
U22	0.336	0.344	0.273	0.281	0.211	0.219	0.211	0.219	0.203	0.234
U30	0.461	0.469	0.367	0.375	0.305	0.313	0.242	0.250	0.234	0.266
U38	0.586	0.594	0.492	0.500	0.430	0.438	0.242	0.250	0.359	0.391

*To convert to millimeters, multiply by 25.4.

2.15 QUICK CONNECT TERMINALS

Quick connect terminals are electrical connectors of male or female type which can be readily engaged without the use of tools. A male tab type terminal is shown in Figure 2-20.

Dimensions are shown in NEMA Publication No. DC 2[5].

[5] Copies are available from the National Electrical Manufacturers Association, 1300 N. 17th Street, Rosslyn, Virginia 22209.

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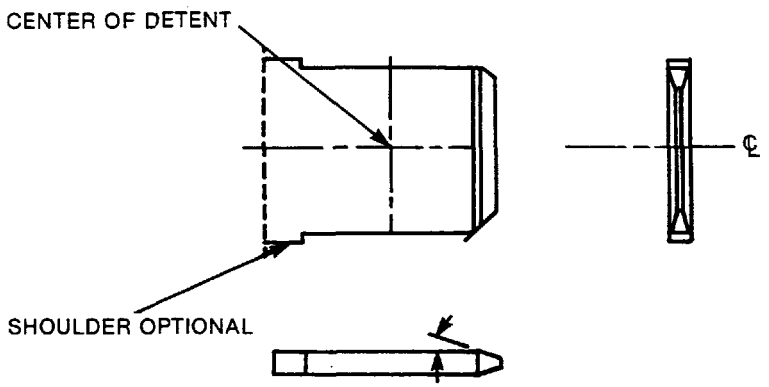


Figure 2-20
QUICK CONNECT TERMINAL
(MALE TAB TYPE)

2.16 PROCEDURE FOR DESCRIBING BRUSHES, INCLUDING SHUNTS, ETC.

The following sequence is used in describing brushes:

a. Grade
b. Brush size—thickness (T) (tangential dimension t), with (W) (axial dimension a), length (L) (radial dimension r). (If other than solid, indicate number of wafers.)
c. Bevels or radii, or both, or other details as shown in 1.6. (It is assumed that double bevels are not parallel unless they are specified as parallel.
d. Connection type
e. Beveled corner or edge (if used in combination with shunt)
f. Clip type or pad (if used)
g. Shunt location (see 1.8.2)
h. Shunt length (see 1.8.3)
i. Number of shunts and size (if known) (see 2.12.2)
j. Insulation type (if required) (see 2.12.3)
k. Terminal

2.16.1 Example Number 1 (Based on the English System Only)

Description:
Grade XYZ—0.75 x 2.0 x 2.5
RA (.75 k) 2 and 8; 5.5, 2-7 x 75 x 0.005; 2-S9

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Explanation:

Grade . . . . . XYZ
Brush size . . . . . 0.75 x 2.0 x 2.5 inches
R . . . . . Rivet-type connection
2 and 8 . . . . . Shunt positions 2 and 8
A . . . . . A clip, k = .75 inches
5.5 . . . . . Shunt is 5.5 inches long
2-7 X 75 X 0.005 . . . . . 2 shunts - shunt size
2-S9 . . . . . 2 terminals, straight type with 0.281-inch slot

Illustration: See Figure 2-21 and section 1.8.2(d)

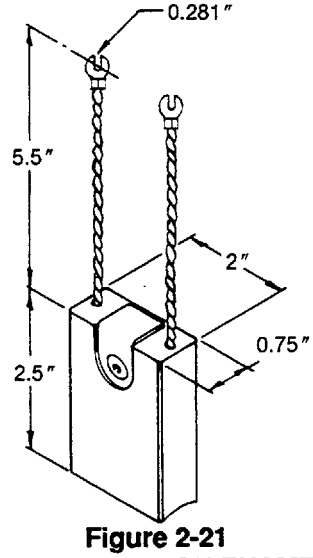


Figure 2-21
BRUSH DESCRIPTION EXAMPLE #1

2.16.2 Example Number 2—Slip-ring Type (Based on the English System Only)

Description:

Grade XYZ—1.25 x 0.75 x 2.25 Concave on face to 8-inch radius Q 4 Beveled Edge; 3, 1-7 x 59 x 0.005; H7

Explanation:

Grade . . . . . XYZ
Brush size . . . . . 1.25 x 0.75 x 2.25 inches
Concave on face . . . . . 8-inch radius on slip-ring end
Q . . . . . Tamped-type connection
4 . . . . . Shunt position 4
Beveled edge . . . . . Beveled edge where shunt enters brush
3 . . . . . Shunt is 3 inches long
1-7 x 59 x 0.005 . . . . . 1 shunt - shunt size
H7 . . . . . Terminal, straight type with 0.219-inch hole

Illustration: see Figure 2-22 and section 1.8.2(b).

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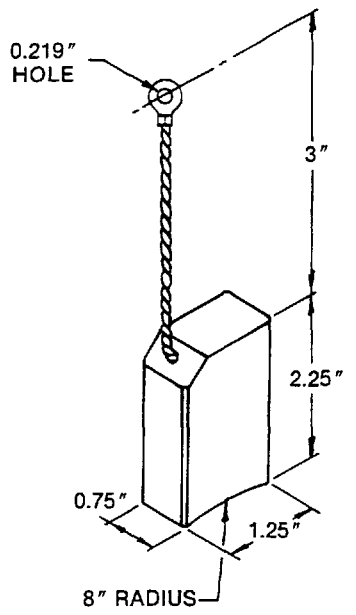


Figure 2-22
BRUSH DESCRIPTION EXAMPLE #2

2.16.3 Example Number 3 (Based on the English System Only)

Description:
Grade XYZ—0.75 x 2.0 x 2.5 RN Extra Wide A (1.25 k) 8; 5.5, 2-7 x 75 x 0.005; S9

Explanation:

Grade	XYZ
Brush Size	0.75 x 2.0 x 2.5 inches
RN	Rivet-type connection, tin soldered
Extra Wide A	Extra Wide A clip, k = 1.25 inches
8	Shunt position 8
5.5	Shunt is 5.5 inches long
2-7 x 75 x 0.005	Shunt size (2 shunts)
S9	Terminal, straight type with 0.281-inch slot

Illustration: see Figure 2-23 and 1.8.2(d).

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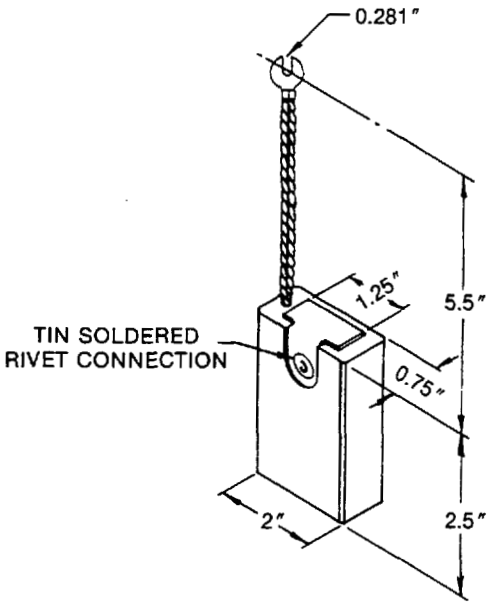


Figure 2-23
BRUSH DESCRIPTION EXAMPLE #3

2.16.4 Example Number 4 (Based on the English System Only)

Description:

Grade XYZ—0.5 x 1.5 x 2.0 30°/0 R2 Extended A (0.50k x 0.88e or U=.03); 5.5, 1-7 x 59 x 0.005; H7

Explanation:

Grade	XYZ
Brush size	0.5 x 1.5 x 2.0 inches
30°/0	Top bevel 30°—no bottom bevel
R	Rivet-type connection
2	Shunt position 2
Extended A	Extended A clip
0.50k x 0.88e or U = .03 (e)	Dimensions of clip (see Figure 1-63)
5.5	Shunt is 5.5 inches long
1-7 x 59 x 0.005	Shunt size (1 shunt)
H7	Terminal, straight type with 0.219-inch hole

Illustration: see Figure 2-24 and 1.8.2(a).

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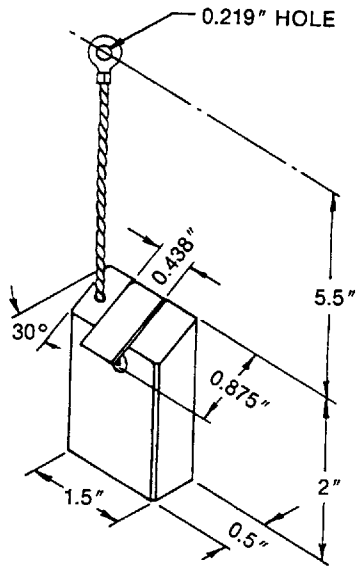


Figure 2-24
BRUSH DESCRIPTION EXAMPLE #4

2.16.5 Example Number 5 (Based on the English System Only)

Description:

Grade XYZ—Split Brush, Two Wafer. 0.75 (0.375 + 0.375) x 1.25 x 2.25 30°/15° concave on bevel face to 8-inch radius; QA(.38k)2 and Q2; 4, 2-7 x 37 x 0.005; TS9

Explanation:

Grade	XYZ
Split Brush	Shall be indicated as such to distinguish it from a one-piece brush
Brush size	0.75 (each wafer 0.375 inch thick) × 1.25 × 2.25 inches
30°/15°	Top and bottom bevels
Concave on bevel face	8-inch radius on commutator end
QA2	Tamped-type connection, position 2 with A clip (.38k)—Wafer 2
Q2	Tamped-type connection position 2—Wafer 1
4	Shunt is 4 inches long
2-7 × 37 × 0.005	Shunt size (2 shunts)
TS9	Terminal, tubular or folded type with 0.281-inch slot

Illustration: See Figure 2-25 and section 1.8.2(a).

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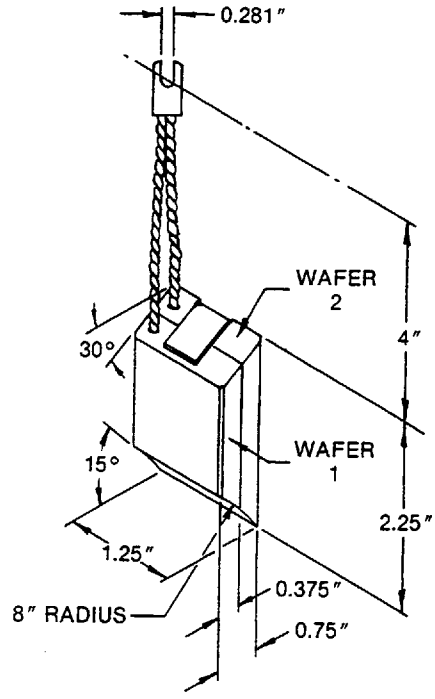


Figure 2-25
BRUSH DESCRIPTION EXAMPLE #5

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SECTION 3
TEST PROCEDURES FOR PHYSICAL PROPERTIES

3.1 GENERAL

The properties determined by these tests are inherent in the brush materials themselves as distinguished from performance characteristics in operation on electrical equipment. All tests should be conducted at 25°C ± 5°C unless otherwise specified.

Uniform test procedures for determining the following properties of brush materials are provided:

Test	See Paragraph
Hardness	
Scleroscope	3.2
Indentation	3.3
Resistivity	
Voltmeter-Ammeter Method	3.4.1
Kelvin Bridge Method	3.4.2
Flexural Strength	
Standard Method	3.5.1
Alternate Method	3.5.2
Density	
General	3.6.1
Apparent Density	
Measurement-and-Weight Method	3.6.2
Immersion Method	3.6.3
Oil-absorption Method	3.6.4
Real Density	
Oil-absorption Method	3.6.5
Pycnometer Method	3.6.6
Porosity	3.7
Ash Content	3.8

3.1.1 Test Specimen

The test specimen shall have a length to thickness ratio of at least eight and a width to thickness ratio of at least two. A test specimen of another size may be used but discretion must be used in analyzing data from these test specimens.

All test specimens must be cut so that the length and width are at right angles to the direction of compression for molded materials and along the axis of extrusion for extruded materials (see Figures 3-1 and 3-2). All adjacent surfaces must be at right angles.

For molded brushes where the length of the brush and the cross section precludes having the sample length at right angles to the direction of compression, the length of the specimen will be parallel to the direction of compression (see Figure 3-3).

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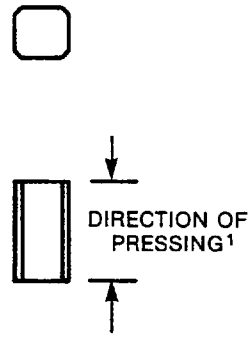
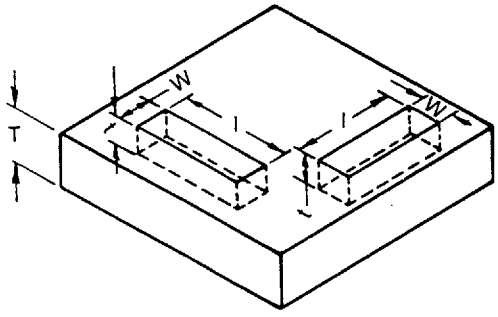
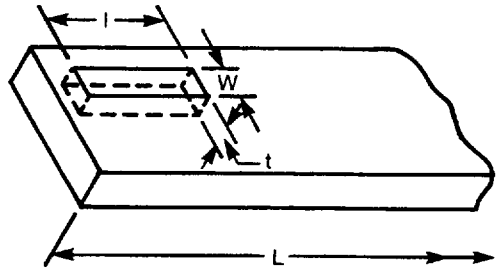


Figure 3-1
MOLDED BRUSH



T = DIRECTION OF MOLDING [1]

Figure 3-2
MOLDED BLOCK



L = DIRECTION OF EXTRUSION [1]

Figure 3-3
EXTRUDED BLOCK

For the indentation hardness test a specimen with a minimum dimension of 0.5 inch (12.7 mm)* must be used for all materials (see 3.3.3). Measurements taken on a smaller specimen may be subject to error due to the possible effects of cracking, crushing, and deformation.

*Bracketed values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

[1]Specimens shall be marked on the ends to indicate direction of pressing or extrusion to permit the width to be distinguished from the thickness, particularly for flexural strength and hardness test.

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3.2 SCLEROSCOPE HARDNESS

3.2.1 Test Equipment

A Shore Model C2 scleroscope (or the equivalent) equipped with a hammer for testing the carbon shall be used. The hammer and its components shall be as follows:

a. Weight—2.2 grams, ±5 percent

b. Outside diameter—0.234 + 0.0005 / - 0.000 inch (5.9 mm + 0.013 / - 0.00 mm)*

c. Overall length—0.815 to 0.840 inch (20.7 to 21.3 mm)*

d. Clearance between hammer and tube—0.0075 to 0.012 inch (0.19 to 0.30 mm) at top of tube and 0.0015 to 0.003 inch (0.038 to 0.076 mm) at bottom of tube

e. Height from which hammer falls—9.89 + 0.005 / - 0.015 inch (251 mm + 0.13 mm / - 0.38 mm)*

f. The tip of the hammer shall be a diamond, oval in shape and driven into a tapered hole in the hammer body. The body shall be a water-hardening drill rod containing approximately 1.2 percent carbon and shall be hardened and tempered after insertion of the diamond. Measured at the contact surface, the diamond shall have a curvature of 0.052 inch (1.32 mm)* radius, ±5 percent, measured over a 0.024-inch (0.61 mm)* long arc.

*Bracketed values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

3.2.2 Test Specimen (see 3.1.1)

The specimen shall have the skin removed, and the surface shall be machined, smooth, and free from defects, dirt, or grit.

A rectangular piece must have at least two parallel surfaces. A cylindrical piece must have a uniform diameter. Otherwise, the hammer will strike the piece with a glancing blow and false readings will result.

Test pieces shall be placed so that the hammer impact is applied in the direction of molding compression in the case of brush plate materials and perpendicular to the axis of extrusion for extruded materials. (It shall be permissible to make an exception for specimens cut from molded brushes.)

3.2.3 Test Procedure—Setting up the Instrument

a. Place the instrument on a firm support.

b. Level the instrument.

c. The "plumb bob" on the front of the instrument shall swing freely in the ring.

d. Check calibration.

e. Prepare the anvil for the test piece. If the test piece is circular in cross-section, use the vee block anvil. If the test piece is rectangular in cross-section, use the basic flat anvil (which is part of the instrument proper).

   Keep the anvils clean. Wipe dust and dirt particles off the anvils with a soft lintless cloth. When a vee block anvil is used, wipe the flat anvil and the mating surface of the vee block anvil clean before placing them together. Dirt particles between the two anvils will cause false readings.

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3.2.4 Test Procedure—Making the Hardness Test

a. Place the piece on the proper anvil. Lower the tube against the test piece and hold it firmly while the test is being made.

b. Release the hammer and read the height of the rebound.

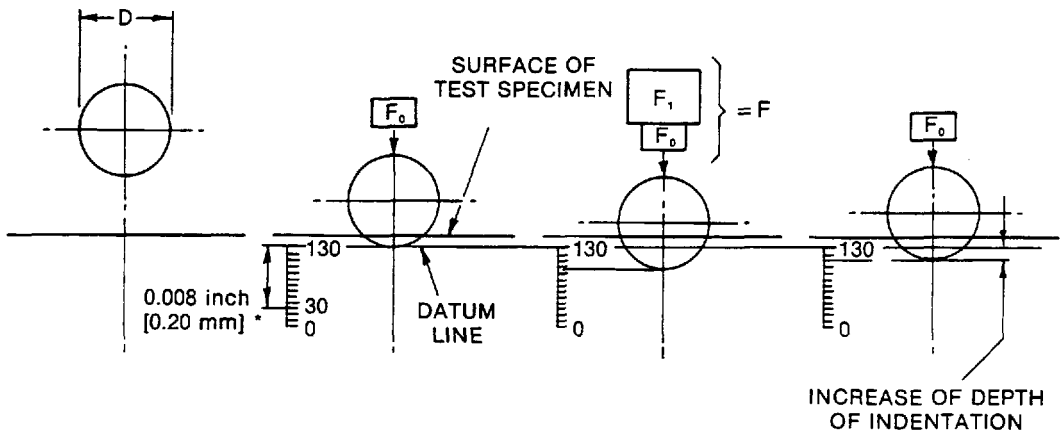
c. Take at least six readings at various spots on each of the two specified sides of a rectangular block (see 3.2.2). The average of the readings is the scleroscope hardness.

d. Take at least six readings on the diameter of round pieces. The average of the readings is the scleroscope hardness.

3.3 INDENTATION HARDNESS

3.3.1 General

The test consists of forcing a ball into the surface of a test piece in two operations and measuring the permanent increase of the depth of indentation of this ball under specified conditions (see Figure 3-4).



D = DIAMETER OF BALL PENETRATOR
F_0 = PRELIMINARY LOAD
F_1 = ADDITIONAL LOAD

Figure 3-4
HARDNESS TEST—INDENTATION METHOD

3.3.2 Test Equipment

a. Rockwell hardness test apparatus (penetrometer) (or the equivalent) with equipment for different loads F_0, F_1 and F as given in 3.3.4. A device (such as a dashpot) shall be incorporated to prevent the load from being applied suddenly and shall be adjusted so that the load will increase from F_0 to $F=F_0 + F_1$ within 2 to 8 seconds during the test.

*Bracketed values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

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b. Ball indenter made of polished material and having a diameter of 10 mm, +8 or -3 micrometers. The ball shall have a Vickers hardness of at least 850 (taking into account the curvature of the ball when testing) and shall be polished and free from surface defects. Any ball showing any deformation after the test greater than the tolerance specified above or any surface defect shall be rejected and the corresponding test discarded.[5]

c. Indicator (depth gauge) for measuring the permanent increase of depth of indentation. The indicator shall have a uniform dial scale reading from 0 to 130 where the distance between the scale divisions 30 and 130 corresponds to a depth of indentation of 0.008 inch (0.20 mm), i.e., one scale unit corresponds to 0.008 inch (0.0020 mm). The indicator shall be accurate to ±0.0001 inch (±0.0025 mm).

d. Rigid support for the test piece. The surface in contact with the support and the surface to be tested shall be clean and free from foreign matter.[5]

3.3.3 Test Specimen (See 3.1.1)

Tests are permitted to be made on finished brushes if they provide a section with a minimum dimension of at least 0.5 inch (12.7 mm).

As an alternative, the measurement of the hardness is to be made on the brush block material before the brushes are cut to size. Two parallel surfaces shall be carefully machined to the surface finish (e.g., 16 to 32 RMS) normally used for carbon brushes.

3.3.4 Test Conditions (see 3.1)

The test shall be made at ambient temperature.

The test specimen shall lie firmly on the support so that displacement cannot occur during the test. The specimen shall be placed so that the direction of the load during the hardness test will be applied in the direction of pressing pressure in the case of molded brush materials and perpendicular to the axis of extrusion for extruded materials.

The position of any indentation shall be chosen so that the distance between the centers of two adjacent indentations or from the center of any indentation to the edge of the specimen or to any cavity will be at least one ball diameter or 2.5 times the diameter of the impression.

A combination of ball diameter D, preliminary load F_o, and additional load F_1 shall be chosen to result in the average value of hardness being between 30 and 110. The following combinations shall be used:

Combination 1—for graphite materials

Combination 2—for metal graphite (MG) and resin-bonded (BG) materials

Combinations 3 and 4—for carbon-graphite (CG), electrographite (EG), carbon (NC), and metal-impregnated graphite (MI) materials.

If the combination for a specific material does not result in a value of hardness between 30 and 110, another combination shall be chosen.

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[5] After each change or removal and replacement of the ball indenter or the support, it shall be ascertained that the new indenter or the new support is correctly mounted in its housing. Throughout the test, the apparatus shall be protected from shock and vibration.

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If none of the foregoing combinations gives a suitable reading, a different size ball shall be used. In this situation, preference shall be given to using a ball 5 mm in diameter with the load combinations given in Table 3-1.

Table 3-1
TEST COMBINATIONS

	Combination Number			
	1	2	3	4
D—ball diameter, mm	10	10	10	10
F_0—preliminary load, kgf	10	10	10	10
F_1—additional load, kgf	10	50	90	140
$F = F_0 + F_1$, kgf	20	60	100	150

3.3.5 Test Procedure

a. Place the ball against the surface of the test specimen. Apply pressure gradually to the ball perpendicular to the surface and without sudden shock until the preliminary load F_0 of 10 ± 0.2 kgf is attained.

b. Set the dial of the indicator (depth gauge) at the initial position.

c. Increase the load, without sudden shock and within 2 to 8 seconds, by the value of additional load F_1, thus obtaining a total load of $F = F_0 + F_1$. The tolerance on F_1 is ± 0.5 percent.

d. When the needle of the indicator (depth gauge) is steady, which generally takes up to 10 seconds according to the material being tested, remove the additional load F_1, so as to bring the load back to the preliminary load F_0. Where the indicator continues to move, remove F_1 within 20 to 25 seconds. Read from the dial the permanent increase in depth of indentation while the preliminary load F_0 is still applied.

e. Make the following number of hardness tests on each specimen:

   1) On brushes where the two dimensions of the surface to be tested are both less than 0.625 inch (15.9 mm)—one test on each of the two surfaces.

   2) On brushes where the two dimensions of the surfaces to be tested are both at least 0.625 inch (15.9 mm)—two tests on each of the two surfaces.

   3) On brush block material—five tests on each of the two surfaces.

f. Record as the hardness value the arithmetical mean value of the readings taken on each specimen. However, for brush block material, the lowest value obtained on each face shall be disregarded and the arithmetical mean of the eight remaining readings shall be taken as the hardness value.

g. The hardness value obtained for a specified load shall be designated by the letters "HR" in combination with an index figure stating the ball diameter D, and total load F, used: e.g., $HR_{10/60}$.

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3.4 RESISTIVITY

3.4.1 Voltmeter-Ammeter Method (Standard Method)

3.4.1.1 Test Equipment

a. Source of direct current providing a range of 0 to 6 volts and 40 amperes (for instance, storage battery and variable resistance).

b. Millivoltmeter for direct current having a resistance of at least 1000 ohms/V and preferably having the following scales: 0 to 300, 0 to 150, 0 to 75, 0 to 30, 0 to 15, 0 to 7.5, and 0 to 3 mV.

c. Ammeter for direct current preferably having the following scales: 0 to 75, 0 to 30, 0 to 15, 0 to 7.5, and 0 to 3 amperes.

d. Resilient contact surfaces (silver-plated copper gauze with a backing of resilient insulating material at least 0.25 inch (6.4 mm) thick).

e. Sharp potential pointer having a spacing not less than either the width or the thickness of the test specimen and not greater than 50 percent of the length of the specimen.

3.4.1.2 Test Specimen

See 3.1.1.

3.4.1.3 Test Procedure

Direct current shall be passed through the specimen from end to end, through the resilient contact surfaces. The value of the current shall be such that it will give a millivolt reading greater than 20 percent of full scale.

The specimen shall be tested at a temperature of 25°C ± 10°C.

3.4.1.4 Calculations

The resistivity shall be calculated in accordance with the following formula:

$$\rho = \frac{Ewt}{Il}$$

Where:

ρ = Resistivity in ohm-inches (microhm-meters)
E = Voltage drop between potential probes in volts (millivolts)
w = Width of specimen in inches (mm)
t = Thickness of specimen in inches (mm)
I = Current in specimen in amperes
l = Length between potential probes in inches (mm)

3.4.2 Kelvin Bridge Method (Alternate Method)

3.4.2.1 Test Equipment

a. Source of direct current, contact surfaces, ammeter, and potential probe in accordance with 3.4.1.1
b. Kelvin bridge having a range of 10 microhms to 1 ohm
c. Galvanometer sensitive to 1 microampere per scale division
d. Key

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3.4.2.2 Test Specimen

See 3.1.1.

3.4.2.3 Test Procedure

Set the potential pointers, approximately centered, on the length of the specimen. Pass current between the contact surfaces lengthwise through the specimen. The current should be passed intermittently by means of a key so as not to overheat the specimen. With the current on, adjust the bridge resistances until the galvanometer has zero deflection. Read the specimen resistance (R).

3.4.2.4 Calculations

The resistivity shall be calculated in accordance with the following formula:

$$\rho = \frac{Rwt}{l}$$

Where:

- ρ = Resistivity in ohm-inches (microhm-meters)
- W = Resistance of specimen between potential pointers in ohms (milliohms)
- w = Width of specimen in inches (mm)
- t = Thickness of specimen in inches (mm)
- I = Current in specimen in amperes
- l = Length between potential pointers in inches (mm)

3.5 FLEXURAL STRENGTH

3.5.1 Standard Method

3.5.1.1 Test Equipment

a. Force device with a suitable force gauge or scale (for example, any hydraulic or mechanical press).

b. Three knife edges, rounded on a radius of 0.062 inch (1.6 mm).

3.5.1.2 Test Specimen

See 3.1.1.

The specimen shall be very carefully machined and identified so that the breaking force is applied in the direction of the molding pressure in the case of molded stock and at right angles to the axis of extrusion in the case of extruded stock. (An exception shall be permitted for specimens made from molded brushes).

3.5.1.3 Test Procedure

Test specimens shall be supported by two knife edges spaced apart 5 to 6 times the specimen thickness.

The stress shall be applied midway between the supporting knife edges by a third knife edge.

Force shall be applied at a uniform rate without shock so that the break occurs in not less than 5 seconds.

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The total net force at which the specimen breaks shall be noted.

3.5.1.4 Calculations

Flexural strength shall be calculated in accordance with the following formula:

$$FS = \frac{3lF}{2wt^2}$$

Where:

FS = Flexural strength in psi (MPa)
F = Total force in pounds (N) at the instant of rupture
w = Width of the specimen in inches (mm)
t = Thickness of specimen in inches (mm)
l = Distance between supporting knife edges in inches (mm)

3.5.2 Alternate Method

The flexural strength shall be determined in accordance with ASTM C651-70.

3.6 DENSITY

3.6.1 General

Manufactured carbon is an inherently porous material and, therefore, both real and apparent densities are useful to the manufacturer of carbon products as aids in control.

The following methods give results accurate to three significant figures.

The four standard methods of determining real or apparent density, or both, are:

a. Measurement-and-weight method (for apparent density only)

b. Immersion method (for apparent density only)

c. Oil-absorption method (for both real and apparent density)

d. Pycnometer method (for real density only)

The measurement-and-weight method is suitable for production quality control testing. The other methods are more suitable for laboratory investigation.

3.6.2 Apparent Density—Measurement-and-Weight Method

See 3.6.1.

3.6.2.1 Test Equipment

a. Micrometers suitable for measuring the test specimens to three decimal places.

b. Scale or balance suitable for weighing the test specimens in grams and having a sensitivity of 0.5 percent or better. (For specimens of the common small sizes, a balance having a capacity of 100 grams and a sensitivity of 0.01 gram is very suitable.)

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3.6.2.2 Test Specimen

The test specimen shall be in accordance with 3.1.1 or shall be any rectangular or cylindrical specimen of a suitable size with square ends.

3.6.2.3 Test Procedure

a. Using the micrometers, make the measurements necessary to calculate the volume of the test specimen. This means measuring the thickness, width, and length of rectangular pieces and the diameter and length of cylindrical pieces. These measurements shall be taken in inches (mm) to three decimal places.

b. Weigh the specimen in grams to four significant figures.

3.6.2.4 Calculations

Calculate the volume of the specimen in cubic centimeters.

Compute the apparent density in accordance with the following formula:

$$\text{Apparent density (grams / cm}^3\text{)} = \frac{\text{weight in grams}}{\text{volume in cm}^3}$$

3.6.3 Apparent Density—Immersion Method

See 3.6.1.

3.6.3.1 Test Equipment

a. Container of water large enough to immerse the test specimen

b. Scale or balance in accordance with 3.6.2.1(b)

c. Grease or other waterproof masking for coating the specimen to prevent the absorption of water

d. Thin (#40) thread to suspend the specimen while it is being weighed during immersion

3.6.3.2 Test Specimen

As this method may be used for irregularly shaped specimens, no preparation is necessary beyond making sure that the specimen is clean, dry, and free from metal or other foreign materials.

3.6.3.3 Test Procedure

a. Weigh the specimen to four significant figures (W_1)

b. Coat all surfaces of the specimen with a minimum amount of grease or other waterproof masking material and again weigh the specimen (W_2)

c. Suspend the specimen by a piece of thread from the balance. Immerse it completely in water, taking care to remove all air bubbles. Weigh it while it is immersed (W_3). Use the minimum possible length of thread.

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3.6.3.4 Calculations

The apparent density shall be calculated in accordance with the following formula:

$$\text{Apparent density, grams / cm}^3 = \frac{W_1}{W_2 - W_3}$$

3.6.4 Apparent Density—Oil-Absorption Method

See 3.6.1.

3.6.4.1 Test Equipment

a. Scale or balance in accordance with 3.6.2.1(b)

b. Hydrometer having a range in specific gravity of 0.800 to 0.900 at 20°C and graduated to 0.001

c. Hydrometer cylinder having a diameter of 40 mm and length of 300 mm

d. Thermometer having a range of -10°C to + 100°C

e. Vacuum flask having a wide mouth and a capacity of 1000 cubic centimeters

f. Vacuum pump capable of developing absolute pressure of 20 mm of mercury

g. Water bath held at a temperature below 20°C

h. Petroleum oil Grade SAE-10

i. Saw or other device for cutting the specimen to a suitable size

j. Grinding wheel or other device for smoothing off rough edges

3.6.4.2 Test Specimen

Cut a specimen weighing 25 to 100 grams. If the specimen is taken from a piece which originally had metal fittings, plating, etc., remove all such foreign material. Grind all surfaces reasonably smooth so there will be no burrs or sharp edges to spall off during the test procedure.

In general, metal-graphite (MG) grades and very dense materials should be tested in specimens larger than those taken from the usual carbon (HC) or electrographite (EG) grades.

3.6.4.3 Test Procedure

a. Weigh the specimen in air to four significant figures. Record this weight as W_1.

b. Place the specimen in the vacuum flask and cover it completely with oil. Place the thermometer in the flask with its bulb immersed in the oil.

c. Apply heat gently, and heat the oil gradually to 70°C.

d. While the heat is being applied, connect the pump to the flask and reduce the pressure gradually to 20 mm to 60 mm of mercury.

e. The rates at which the heat and vacuum are applied in (c) and (d) are controlled by the amount of entrapped air in the sample. These rates may be as rapid as possible without undue foaming in the flask.

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f. Maintain the temperature at 70°C and the pressure at 20 mm to 60 mm of mercury until the specimen stops emitting bubbles. This will usually be 3 to 5 hours.

g. Cool the flask and its contents to room temperature in air and then cool to below 20°C in the water bath.

h. Remove the flask from the bath and allow the temperature to rise to 20°C.

i. At this point, remove the specimen from the oil and wipe it dry.

j. Weigh the specimen in air to four significant figures. Record this weight as W_2.

k. Pour the oil from the flask into the hydrometer cylinder, bring its temperature up to 20°C, and read its specific gravity. Record this figure as d.

l. Weigh the oil-impregnated specimen submerged in the water as described in 3.6.3.3(c). Record this weight as W_3.

m. Calculate the weight of oil absorbed as:

$$W(\text{grams}) = W_2 - W_1$$

The volume of oil absorbed is:

$$V(cm^3) = \frac{W_0}{d}$$

The apparent density is:

$$AD(g/cm^3) = \frac{W_1}{W_2 - W_3}$$

3.6.5 Real Density—Oil-Absorption Method

See 3.6.1.

Using the data obtained in 3.6.4, calculate the real density in accordance with the following formula:

$$RD(g/cm^3) = \frac{W_1}{W_2 - W_3 - V}$$

3.6.6 Real Density—Pycnometer Method

3.6.6.1 Test Equipment

a. Pycnometer (specific gravity bottle), 50-mm size, equipped with combined stopper and thermometer and side tube with cap

b. Pulverizing equipment (mortar and pestle is commonly used)

c. A 325 mesh sieve (see ASTM E11-81)

d. Vacuum pump capable of developing absolute pressure of 20 mm of mercury

e. Analytical balance having a capacity of 200 grams and a sensitivity of 1/20 milligram

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f. Vacuum desiccator having an inside diameter of 200 mm or of a size sufficient to contain the pycnometer

g. Water bath maintained at a temperature of 35.6°C

h. Butanol which is normal butyl alcohol—$CH_3(CH_2)_3OH$

i. Manometer or vacuum gauge

3.6.6.2 Test Specimen

Carefully select a sample weighing approximately 10 grams for each test except that, in the case of very fluffy materials, a smaller sample should be selected. Grind the sample so that it all passes through the 325 mesh sieve and dry it in an oven for 2 hours at 110°C.

3.6.6.3 Test Procedure

3.6.6.3.1 Weight of the pycnometer empty (W_p) and filled with distilled water (W_w)

a. Weigh carefully a thoroughly clean and dry pycnometer. Return it to the desiccator and check its weight after 0.5 hours. The weights shall agree within 0.5 milligram.

b. Fill the pycnometer with freshly boiled distilled water, place it in a vacuum desiccator and reduce the pressure to 20 mm–60 mm of mercury until the water is free from bubbles. At the same time, have a small beaker of the distilled water in the vacuum desiccator.

c. Admit air slowly to the desiccator. Remove the pycnometer and fill it with water from the beaker to replace any loss due to bubbling to evaporation.

d. Put the thermometer stopper in place, but leave the cap off the capillary tube.

e. Place the pycnometer in the water bath until the temperature as indicated by its thermometer shows that the water in the pycnometer is 35°C. Remove the pycnometer quickly from the bath, remove the water bubble from its capillary tube, and put the cap in place. Dry the outside of the pycnometer carefully with a linen towel and weigh. Record this weight.

f. Repeat steps (a) through (e) four times, using a fresh lot of water each time, and take the average of the five tests as the weight of the pycnometer filled with water (W_w).

3.6.6.3.2 Find the weight of the pycnometer filled with butanol (W_1). Repeat the steps given in 3.6.6.3.1 except use butanol instead of water.

3.6.6.3.3 Determine the real density of the sample as follows:

a. Weigh approximately 10 grams of the dried sample in the pycnometer. The difference in weight between the pycnometer-with-sample and the empty pycnometer is recorded as W.

b. Add butanol to the pycnometer to cover the sample to a depth of 0.25 inch to 0.375 inch (6.4 mm to 9.5 mm.).

c. Place the pycnometer in the vacuum desiccator and evacuate in the same manner described for water in 3.6.6.3.1(b). Remove the pycnometer from the desiccator and fill it with butanol which has been evacuated in a similar way.

d. Heat to a temperature of 35°C in a water bath. Then remove, cover, dry and weigh in the same manner described for water in 3.6.6.3.1(e).

e. Record the weight of the pycnometer-plus-sample-plus-butanol as W_2.

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3.6.6.4 Calculations

3.6.6.4.1 Data Available

The following data is now available:

W_p = Weight of pycnometer empty

W_w = Weight of pycnometer filled with water

W_1 = Weight of pycnometer filled with butanol

S_1 = Specific gravity of water at 35°C = 0.994

W = Weight of dry sample

W_2 = Weight of pycnometer plus sample and filled with butanol

3.6.6.4.2 Calculation

The specific gravity of butanol at 35°C is:

$$S = \frac{(W_1 - W_p)}{(W_w - W_p)}$$

The real density is:

$$RD(g/cm^3) = \frac{S_1 \times W \times S}{W_1 + W - W_2} = \frac{0.994WS}{W_1 + W - W_2}$$

3.7 POROSITY

3.7.1 Definition

Porosity is the percentage of open space contained within the body of a piece of carbon or similar material. The pores may be interconnected or sealed. Porosity is calculated from the real and apparent density.

3.7.2 Calculations

The percent porosity shall be calculated in accordance with the following formula:

$$P = \frac{(RD - AD) \times 100}{RD}$$

Where:

P = Percentage porosity
RD = Real density
AD = Apparent density

3.8 ASH CONTENT

3.8.1 Test Equipment

a. Muffle furnace

b. Analytical balance

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c. Drying oven

d. Alundum capsules, 22 mm deep x 44 mm in diameter

e. Desiccator

In addition to the foregoing, the following equipment is required for metal-content brushes:

f. Filtering flask

g. Beakers

h. Funnel

i. Filter paper (quantitative analysis)

3.8.2 Test Specimen

It is best to break off pieces to be tested and crush them in a mortar sufficiently to yield a minimum of 10 grams of clean material, all minus 40 mesh. (See ASTM E11-81.[7]) Every possible precaution must be taken in the preparation of samples to exclude every form of foreign matter, such as brush hardware and surface contamination.

3.8.3 Test Procedure for Carbon (HC), Carbon-graphite (CG), Graphite (NG), Electrographite (EG), and Resin-bonded (BG) Materials

a. Dry the sample at 105°C and place it in the desiccator to cool. Clean the test capsule, ignite it to red heat, and place it in the desiccator to cool.

b. Weigh the capsule to within 0.001 gram.

c. Add approximately 10 grams of dried sample and weigh it to within 0.001 gram.

d. Place the capsule and sample in the cold muffle furnace and gradually raise the temperature to a minimum of 750°C. This should take about 2 hours. During this time, note and record any recognizable odors.

e. Continue to burn until no evidence of carbon remains.

f. Cool in the desiccator and weigh to within 0.001 gram.

g. Replace in the furnace and rapidly reheat.

h. Repeat f) and g) until a constant weight is obtained.

3.8.4 Test Procedure for Metal-Graphite (MG) and Metal-Impregnated (MI) Materials

a. Weigh the powdered sample

b. Dissolve the sample in nitric acid (HNO_3) 6 normal or stronger

c. Weigh the dry filter paper

d. Filter out the solids and carefully wash, dry, and weigh with paper

e. Place in the prepared capsule and follow the procedure given in 3.8.3

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[7] Copies are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

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3.8.5 Calculations

The percentage of ash shall be calculated in accordance with the following formula:

$$\text{Percent ash} = \frac{\text{weight of residue} \times 100}{\text{weight of dry sample}}$$

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Section 4
TEST PROCEDURES FOR SHUNT CONNECTIONS

4.1 GENERAL

These tests are designed to determine the electrical resistance and integrity of the brush shunt connections.

The value depends upon the design of the brush shunt connection, brush materials and tamping materials used.

4.2 RESISTANCE OF SHUNT CONNECTIONS

4.2.1 Test Equipment

a. Direct-current power supply (battery, direct-current generator, or full-wave rectifier) and variable resistance

b. Ammeter

c. Potentiometer, or suitable millivoltmeter, with an internal resistance of 1000 ohms per volt, and where the reading will be at least 10 percent of full scale

d. Probes. The probe points shall be made of stainless steel. The probe point for making contact with the brush shall be cylindrical with a 30-degree point. The probe point for making contact with the shunt shall be chisel shaped. See Figure 4-1.

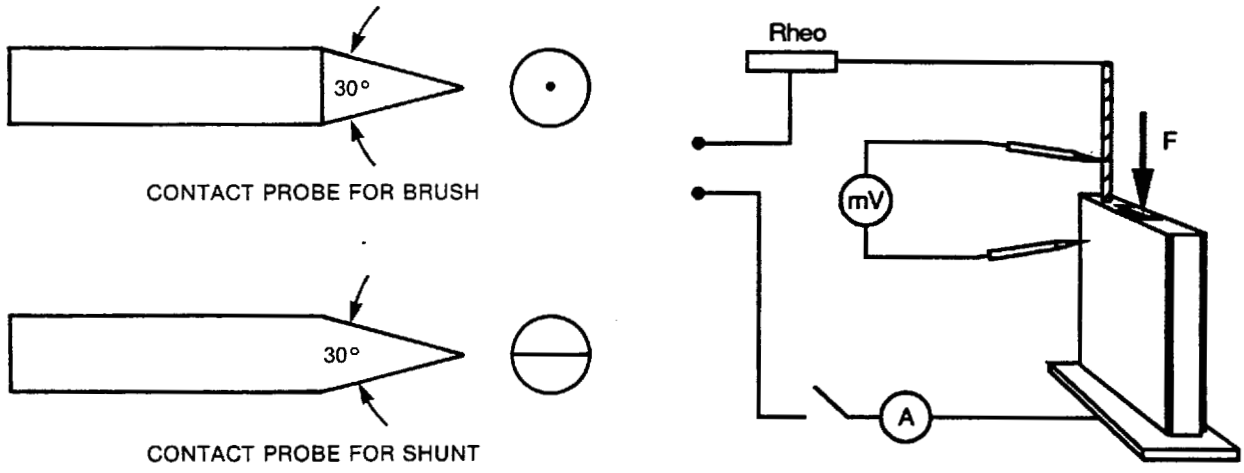


Figure 4-1
PROBE CONTACT WITH BRUSH AND SHUNT

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4.2.2 Test Specimen

The shunt connection test shall be made on representative sample brushes that have not been subjected to any other physical tests.

4.2.3 Test Procedure

The resistance of brush shunt connections shall be taken by the voltmeter-ammeter method. The brush shall be held firmly in a spring clamp to which is attached one current lead. The other current lead shall be attached to the brush shunt. Probes shall be applied in accordance with 4.2.4.

The test current shall be sufficient to give a millivolt deflection of at least 10 percent of full scale and shall be not more than the rated current of the shunt as given in 2.12.2. The minimum test current shall be 1 ampere. The readings shall be made within 30 seconds from the time current flows through the connection. The value of the resistance of the brush shunt connection shall be reported as millivolts per ampere (milliohms).

4.2.4 Position for Millivolt Probes

For description of types of shunt connections see 1.8.1.

4.2.4.1 Types M and Q

Where the shunt comes out of the top of the brush, one probe shall be placed on the shunt 0.25 inch (6.4 mm) from the brush. The other probe point shall be placed on the brush directly over the embedded connection on the front or back directly over the bottom of the shunt hole. (See Figure 4-2.)

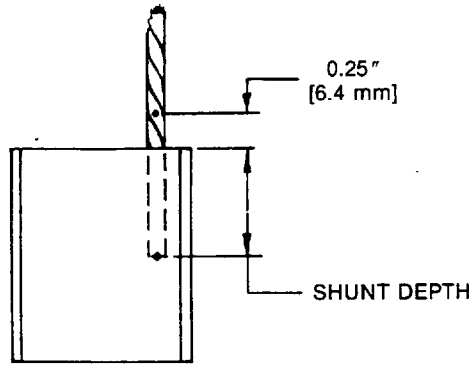


Figure 4-2
PROBE CONTACT WITH SHUNT CONNECTION TYPES M AND Q

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Where the shunt depth is not known, the resistance to the bottom of the shunt connection shall be determined by plotting millivolt readings taken at increments from the brush top. The curve will rise at the bottom of the shunt connection and become a straight line at an angle determined by the resistivity of the brush material and its cross section. The smallest millivolt reading which lies on the straight line represents the bottom of the shunt connection. The smaller the increments used in taking the measurements, the more accurate will be the locating of the bottom of the shunt. This explanation is covered graphically by Figure 4-3. For shunt positions 10, 11, 12, or 13, one probe shall be placed on the shunt 0.25 inch (6.4 mm) from the brush and the other probe shall be placed 0.125 inch (3.2 mm) directly below the connection on the same side in which the shunt is embedded. (See Figure 4-4.)

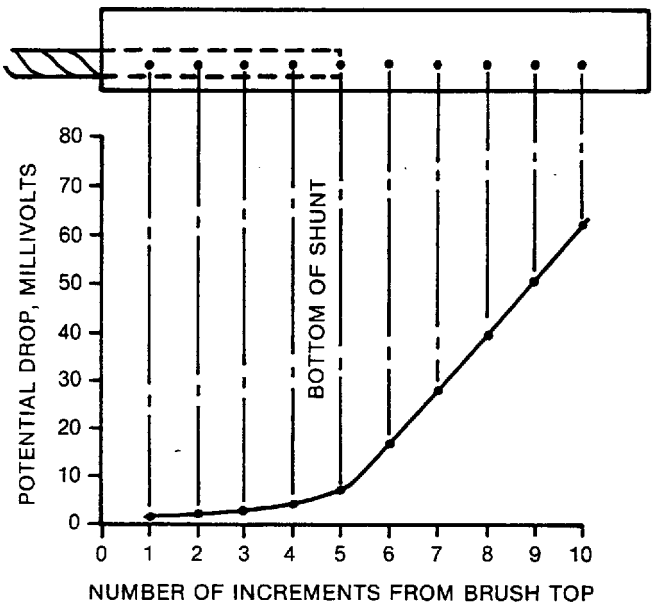


Figure 4-3
UNKNOWN SHUNT DEPTH

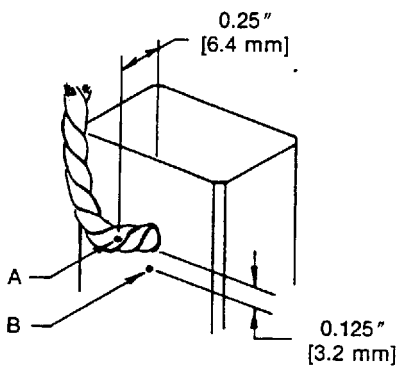


Figure 4-4
SHUNT POSITIONS 10, 11, 12, OR 13

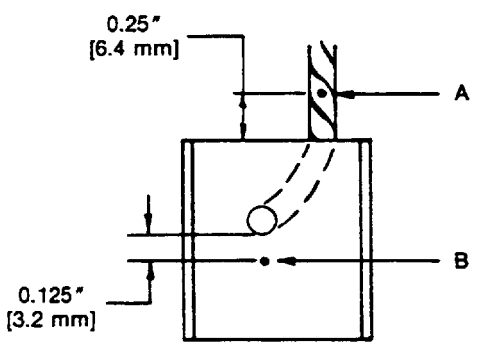


Figure 4-5
TYPES R, T, V, AND W

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4.2.4.2 Types R, T, V, and W

One probe shall be placed on the shunt 0.25 inch (6.4 mm) from the brush with the other probe 0.125 inch (3.2 mm) directly below the counterbore on the same side to which the shunt is fastened. (See Figure 4-5.)

NOTE—The millivolt-per-ampere values obtained when making measurements in accordance with Figures 4-4 and 4-5 may be higher than those obtained in accordance with Figure 4-2 even though the integrity of the connections is acceptable.

4.2.4.3 Types X and Z

One probe shall be placed on the shunt 0.25 inches (6.4 mm) from the clip with the other probe 0.125 inches (3.2 mm) directly below the counterbore on the same side as the current-carrying clip.

4.2.4.4 Soldered Metal Clips, Riveted Metal Caps, Copper-plated Brush Tops

One probe shall be placed on the shunt 0.25 inches (6.4 mm) from the cap, clip, or brush top with the other probe on the centerline of the brush as close as possible to the lower edge of the metal clip, cap, or copper skirt without touching it.

4.3 STRENGTH OF TYPE M AND Q SHUNT CONNECTIONS

4.3.1 Test Equipment

a. Tension device with a suitable force gauge or scale

b. Clamping means or restraining device for application to the brush material and to the shunt

4.3.2 Test Specimen

The shunt connection strength test shall be made on representative sample brushes.

4.3.3 Test Procedure

The clamping means or restraining device shall be secured to the brush material and to the shunt. The pull shall be in the direction of the axis of the tamping hole. To avoid impact, tension shall be applied at a steady rate.

Brushes which have been subjected to any form of shunt strength testing should be discarded.

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Appendix A
SPRING DESIGN INFORMATION

For proper spring design, the following should be applied (see Figure A-1):

a. Inside diameter of the brushholder (see dimension a)

b. Length of the brushholder from the bottom end of the holder to the bottom of the cap or the bottom of the recess in the cap (see dimension b)

c. Distance between the brushholder and the commutator or ring (see dimension c)

d. Length of new brush (see dimension d)

e. Length of head of brush (see dimension e)

f. Pressure desired on the commutator with the new and fully worn brush

g. Length of fully worn brush

h. Maximum temperature

i. Unusual conditions

j. Spring material (See Appendix B)

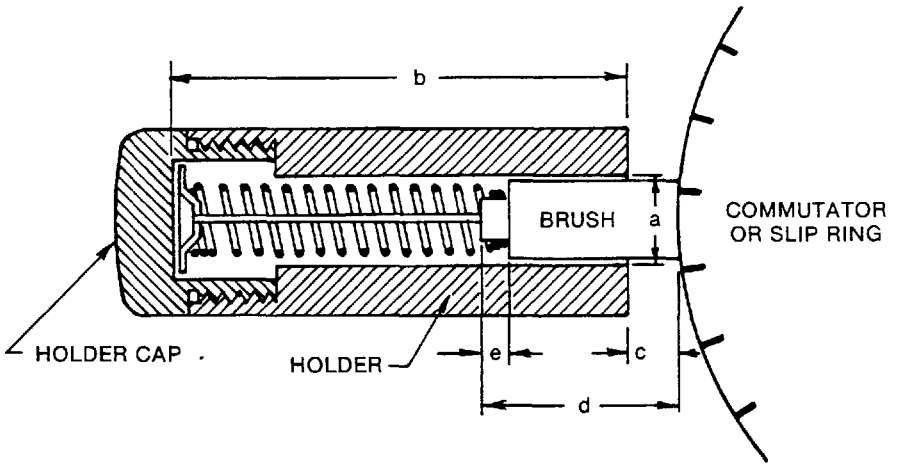


Figure A-1
SPRING DESIGN DIMENSIONS

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Appendix B
COIL SPRINGS FOR BRUSHES

Where heat-resistant material is required, the spring material should be beryllium-copper, stainless steel, or copper-clad stainless steel. Where heat-resistant material is not required, the spring material may be phosphor-bronze or steel.

If the spring is current carrying, the material should be beryllium-copper or copper-clad stainless steel irrespective of heat resistant requirements.

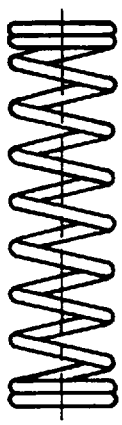


Figure B-1
CYLINDRICAL COIL SPRING

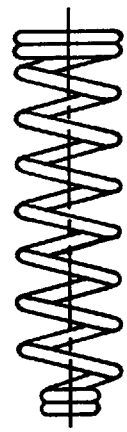


Figure B-2
CYLINDRICAL COIL SPRING WITH REDUCED END

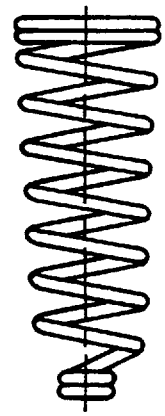


Figure B-3
CONICAL COIL SPRING

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Appendix C
RECOMMENDED MINIMUM CLEARANCE BETWEEN BRUSH AND BRUSHHOLDER
(See Table D-2 for IEC Recommendations; Appendix D)

The recommended minimum clearance between brush and brushholder, which should exist to assure proper brush performance, is shown below (see 2.3):

Table C-1
RECOMMENDED MINIMUM CLEARANCE BETWEEN BRUSH AND BRUSHHOLDER

		Inches	Size (mm)*	Minimum Clearance Between Brush and Brush Holder	
				Inches	(mm)*
A.	Carbon (HC), Carbon Graphite (CG), Electrographite (EG), Graphite (NG), Metal-graphite and Resin-bonded (RG) Brushes containing up to 50 percent metal by weight				
	Thickness (tangential dimensions)	all	all	0.002	0.05
	Width (axial dimension)	0.75 and less	19.0 and less	0.003	0.08
		Over 0.75	Over 19.0	0.005	0.13
	Diameter	all	all	0.002	0.05
B.	Metal-graphite (MG) and Metal-impregnated (MI) Brushes containing 50 percent and over metal by weight				
	Thickness (tangential dimension)	0.5 and less	12.7 and less	0.002	0.05
		Over 0.5	Over 12.7	0.009	0.23
	Width (axial dimension)	0.5 and less	12.7 and less	0.003	0.08
		Over 0.5	Over 12.7	0.012	0.30
	Diameter	all	all	0.002	0.05

*These values represent conversion to SI units and are not necessarily the same as the values specified by the International Electrotechnical Commission as explained in the Foreword.

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Appendix D
INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) LIMITS AND TOLERANCES

Until recently there have been no universally accepted manufacturing limits and tolerances for carbon brushes and their related holders. Consequently, a brush made in one country would not necessarily suit a holder of the same nominal size made in another country. As an example of this conflict, there have been two major groups.

In the USA, UK, France, and the Scandinavian countries, the maximum brush dimension was the same as the nominal size and the brushholder was always larger.

In Germany, Austria, Russia, and the countries which follow their lead in engineering matters, the minimum holder dimension was the nominal size and the carbon brushes were always smaller.

To reconcile these systems and provide a foundation for international standardization, the IEC Subcommittee concerned with brushgear prepared proposals which now figure as IEC recommendations, Dimensions of Brushes and Brush Holders for Electrical Machinery (IEC publication Series 136, Parts 1, 1A, and 2).†

The basis of these recommendations is a limited number of standard values for the dimensions 't' (tangential) and 'a' (axial). Brushes are made with two minus limits on the normal and brushholders with two plus limits. Many national standards incorporate this system and the symbols which identify brushes and holders made to the nominal dimensions and limits of the IEC recommendations. The mark □ is the symbol for the metric sizes. IEC Publication Series 136 also includes standard inch dimensions for which the symbol Δ has been allocated to avoid confusion with the metric nominal sizes.

Tables D-1 and D-2 show the limits and tolerances appropriate to IEC recommendations and applicable to the "principal" (i.e. nominal) dimensions set down in national standards that are based on IEC. These tables summarize the IEC principal metric dimensions, limits and tolerances.

†IEC 136 Publication Series, Dimensions of Brushes and Brush Holders for Electrical Machinery, includes Publications 136-1 (1962), Principal Dimensions and Tolerances; 136-1A (1972), First Supplement to Publication 136-1; and 136-2 (1967), Complementary Dimensions of Brushes—Terminations of Brushes. Copies are available through the American National Standards Institute, 11 West 42nd Street, New York, NY 10036, or from Sales Department, Central Office IEC, 3, rue de Varembé, 1211 Geneva 20, Switzerland.

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Table D-1
LIMITS AND TOLERANCES ON BRUSH DIMENSIONS 't', 'a', AND 'r'

Nominal dimensions			't' and 'a' dimensions			'r' dimensions		
			Upper limit	Lower limit	Tolerance	Upper limit	Lower limit	Tolerance
1.6	2	2.5	-0.03	-0.09	0.06	+0.3	-0.3	0.6
3.2								
4	5	6.3	-0.03	-0.11	0.08	+0.3	-0.3	0.6
8	10							
12.5		16	-0.04	-0.13	0.09	+0.5	-0.5	1.0
20		25						
32	40	50	-0.05	-0.15	0.10	+0.8	-0.8	1.6
64	80							

NOTE—All dimensions in millimeters

Table D-2
LIMITS FOR BRUSHHOLDER DIMENSIONS 't' AND 'a' AND BRUSH-TO-HOLDER CLEARANCES

Nominal dimensions			Brush Holder 't' and 'a'			Brush-to-Brush Holder Clearance	
			Upper limit	Lower limit	Tolerance	Maximum	Minimum
1.6	2	2.5	+0.054	+0.014	0.04	0.144	0.044
3.2			+0.068	+0.020	0.048	0.158	0.050
4	5		+0.068	+0.020	0.048	0.178	0.050
6.3	8	10	+0.083	+0.025	0.058	0.193	0.055
12.5		16	+0.102	+0.032	0.070	0.232	0.072
20		25	+0.124	+0.040	0.084	0.254	0.080
32	40	50	+0.150	+0.050	0.100	0.300	0.100

NOTE—All dimensions in millimeters

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Appendix E
RECOMMENDED WIDTH OF PRESSURE DEVICE

To reduce the possibility of the pressure device making contact with the shunt, the width of the pressure device should not exceed 80 percent of dimension "P" (see 2.11).

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Appendix F
BRUSH VOLTAGE DROP AND COEFFICIENT OF FRICTION

The brush potential drop is normally expressed in volts and is the sum of the drop across the anodic brush plus that across the cathodic brush.

Coefficient of friction of a brush may be defined as the ratio of tangential force to normal force at the face of the brush.

Both brush drop and coefficient of friction are influenced by operating and ambient conditions, such as spring pressure, current density, brush-face-to-collector-surface contact, interface temperature, surface films, relative humidity, ambient temperature, atmosphere, collector material, etc.

Recommended test procedures for measuring brush voltage drop and coefficient of friction are given in the ANSI/IEEE Standard Test Procedure for Carbon Brushes, Std 116-1975[8].

[8] Copies are available from the Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017.

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Appendix G
DESCRIPTIVE TERMINOLOGY



Figure G-1
ANODIC BRUSH



Figure G-2
CATHODIC BRUSH

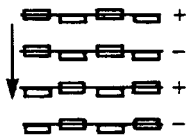


Figure G-3
CIRCUMFERENTIAL
STAGGER

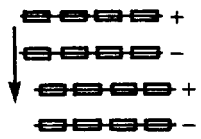


Figure G-4
AXIAL STAGGER

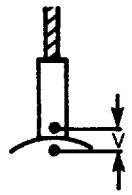


Figure G-5
BRUSH CONTACT DROP

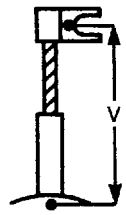


Figure G-6
TOTAL SINGLE
BRUSH DROP

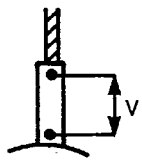


Figure G-7
INTERNAL BRUSH DROP

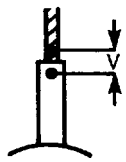


Figure G-8
CONNECTION DROP

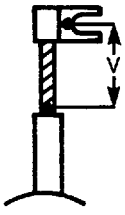


Figure G-9
SHUNT DROP

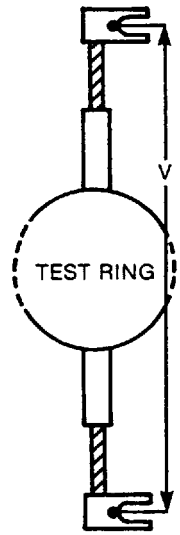


Figure G-10
TOTAL BRUSH DROP PER BRUSH PAIR

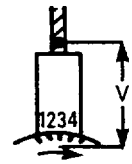


Figure G-11
COMMUTATOR/BRUSH POTENTIAL

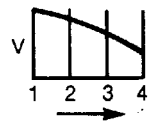


Figure G-12
BRUSH POTENTIAL CURVE

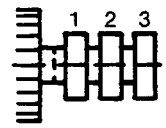


Figure G-13
NUMBERING OF SLIP-RINGS

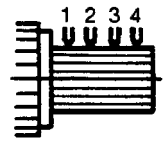


Figure G-14
NUMBERING OF BRUSH TRACKS

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Appendix H
GEOMETRICAL UNITS AND SYMBOLS

Symbol	Description	Units
A	Hammer Clip	
A	Hole or slot dimension of terminals	in., mm
A, Extra Wide	Broadened area hammer clip	
A, Offset (Offset A)	Broadened area in one direction from attachment tang	
A, Extended (Extended A)	Hammer clip which overhangs carbon portion of brush	
A, Angular (Angular A)	Hammer clip bent to form top angle of brush independent of carbon	
A, Channel (Channel A)	Hammer clip with turned up sides	
AD	Apparent density	g/cm^3
a	Axial dimension	mm
B	Lifting type clip	
B	Maximum width dimension of terminal	in., mm
BG	Resin-bonded	
C	Maximum length dimension of terminals	in., mm
C	Guide clips	
CG	Carbon-Graphite	
D	Diameter	in., mm
D	Bail-type lifting clip	
D	Diameter of ball penetrator on Rockwell tester	in., mm
D^1	Terminal overall diameter	in., mm
D^2	Terminal secondary diameter	in., mm
d	Specific gravity of oil	
	Diameter	in., mm
E	Voltage drop	Volts
E	Hook type lifting clip	
EG	Electrographite	
e	Hammer clip length from long face of brush	in., mm
F	Extended A type lifting clip	
F	Equal to $F_o + F_1$ (Rockwell tester)	Kg
F	Force	Pounds, Newtons
F	Preliminary load on Rockwell tester	Kg
F_1	Additional load on Rockwell tester	Kg
FH	Flag type terminal with hole	
FS	Flag type terminal with slot	
FS	Flexural Strength	psi, Mpa
G	Projecting and raised lifting clip	
H	Extra projection on type E lifting clip	
H	Straight type terminal with hole	
HC	Carbon brush material	
HR	Hardness Rockwell	

Table continued, next page

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Symbol	Description	Units
HR	Hardness Rockwell, 10mm ball Kg force	
I	Current	amps
IEC	International Electrotechnical Commission	
K	Type E combined with angular A clip	
k	Width dimension of A clips	in., mm
L	Length	in., mm
L	Direction of extrusion of brush material	
L	Length of ears on eared type terminal	in., mm
l	Length	in., mm
l	Span between potential probes	in., mm
l	Distance between supporting knife edges	in., mm
l	Specimen length	in., mm
M	Molded-in shunt	
MG	Metal-graphite brush material	
MI	Metal-impregnated brush material	
NG	Graphite brush material	
O	Round type, stamped terminal	
OM	Round type, machined terminal	
P	Plain rectangular resilient pad	
P	Width of brush top available for applying pressure source	in., mm
P	Percentage porosity	%
P, Extended (Extended P)	P pad which extends beyond brush side	
P, Convex (Convex P)	Resilient pad with convex surface	
P, Double angle (Double angle P)	Resilient pad with intersecting slanted sides	
P, Single angle (Single angle P)	Resilient pad with one slanted surface	
Q	Tamped shunt	
R	Radius	in., mm
R	Riveted shunt	
R	Resistance	ohms
RD	Real density	g/cm^3
r	Radial dimension	mm
S	Straight type terminal with slot	
S	Specific gravity of butanol at 35°C, See 3.6.6.4.2	
S_1	Specific gravity of water at 35°C	0.994
T	Thickness	in., mm

Table continued, next page

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Symbol	Description	Units
T	Two type R shunts in same brush	
T	Direction of molding brush material	
T_1	Formed thickness of round type terminations	in., mm
T_2	Terminal secondary thickness	in., mm
TH	Tubular or folded type terminal with hole	
TS	Tubular or folded type terminal with slot	
t	Tangential dimension	mm
t	Specimen thickness	in., mm
U	Dimension from short side of brush to end of clip extension (see Figure 1-63)	in., mm
V	Bolt and nut shunt connection	
V	Volts	volts
V	Volume	cm^3
w	Specimen width	in., mm
W	Width	in., mm
W	Two type V connections in same brush	
W	Weight of dry specimen	grams
W_o	Weight of oil absorbed	
W_1	Width of eared type terminal over ears	in., mm
W_1	Weight of sample in air	grams
W_1	Weight of Pycnometer filled with butanol	grams
W_2	Chord distance of eared type terminal	in., mm
W_2	Weight of sample plus grease	grams
W_2	Weight of pycnometer, specimen and butanol	grams
W_3	Weight of W_2 immersed in water	grams
W	Width of ears on eared terminal	in., mm
W_p	Weight of pycnometer empty	grams
W_w	Weight of pycnometer filled with distilled H_2O	grams
X	Clip for shunt riveted to brush	
Z	Strip for shunt riveted to brush	
ρ	Resistivity, or specific resistance	ohm-in. μohm-in.
Ω	Ohms	ohms

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Appendix I
Commutator surface conditions

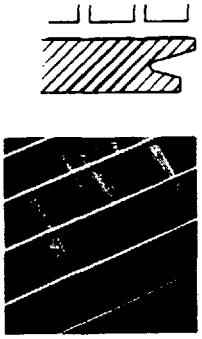


Figure I-1
FILM

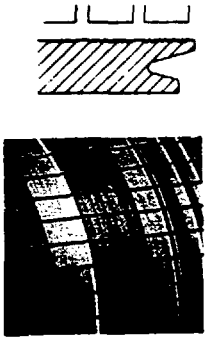


Figure I-2
RIBBING

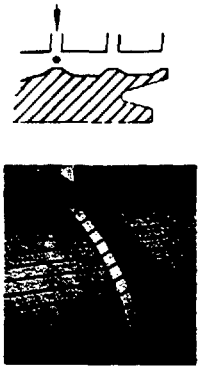


Figure I-3
RIDGING

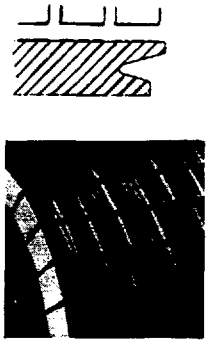


Figure I-4
STREAKING

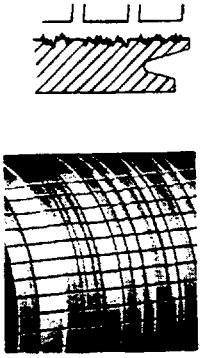


Figure I-5
THREADING



Figure I-6
COPPER DRAGGING



Figure I-7
BANDING



Figure I-8
GROOVING



Figure I-9
BURNING

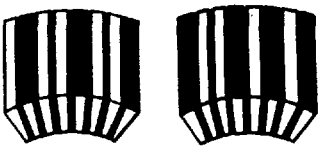


Figure I-10
MARKING
a) REGULAR BAR MARKING
b) IRREGULAR BAR MARKING

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Appendix J
TECHNICAL QUESTIONNAIRE

This technical questionnaire is intended for users of carbon brushes to provide the minimum essential details to enable the manufacturer to select a suitable brush grade for a new machine and to give assistance in diagnosing the cause of difficulty on an existing machine.

READ BEFORE COMPLETING

A. Where there is a line beside the text, give applicable information
B. Where no line is drawn, cross out words or inquiries which do not apply.
C. The questions in caps are of special importance.

NAME AND ADDRESS OF THE BRUSH USER

Letter Report/Reference

Date

1. Maker of machine _____
2. Maker's type _____
3. Serial number _____
4. Generator/Motor DC/AC/ rectified current Reversing/ nonreversing _____

		Operating	
5. Converter	Rated	Normal	Max.
DC-AC or AC-DC			

6. SPEED or rpm
7. VOLTAGE Volts_____
8. CURRENT Amps_____
9. POWER kw/hp_____
10. APPLICATION _____
11. DUTY CYCLE _____
12. Number of phases _____
13. Frequency Hz_____
14. Number of main poles_____
15. Commutating poles _____
16. Compensating winding_____
17. Excitation (shunt/separate/series/ compound)
18. Construction (open protected totally enclosed)
19. Cooling (open forced air liquid-cooling)
20. Ambient temperature °F/°C_____
21. Relative humidity %_____
22. Oil vapor _____
23. Corrosive gases (which)_____
24. Dust _____
25. Vibrations _____
26. Amount of end play _____
27. DIAMETER OF COMMUTATOR RING inch(mm)_____
28. Length of commutator face Width of ring inch(mm)_____
29. Number of commutator segments _____
30. IS MICA RECESSED_____
31. MATERIAL OF RINGS_____
32. Are rings helically grooved_____
33. Are the rings situated between or outside the bearings_____
34. ARE THE RINGS TOTALLY ENCLOSED
35. Are the brushes lifted when the machine is up to speed_____
36. CURRENT PER RING AND STATE WHETHER AC OR DC Amps_____
37. Working temperature of commutator/ring °F/°C_____
38. SURFACE CONDITION Good polished dull smooth/worn threaded uniform marked (Marking regular/irregular/burnt) color light/medium/dark
39. When was the commutator/ ring last conditioned (date)_____
40. NUMBER OF BRUSH-ARMS PER COMMUTATOR_____
41. NUMBER OF BRUSHES PER ARM _____
42. NUMBER OF RINGS_____
43. NUMBER OF BRUSHES PER RING _____

(Continued)

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Technical Questionnaire (continued)

44. Are all brushes on each arm in line or are they staggered circumferentially and by how much _____
45. Brush spring force lbs.-oz._____
46. MAKER AT PRESENT USED _____
47. Average brush-life (hrs./inch)_____
    (hrs.mm)_____
48. WHAT (IF ANY) TROUBLE IS EXPERIENCED _____
49. DIMENSIONS OF BRUSH FIGURES J-1 AND J-2—
    inch (mm)
    T(1)_____
    W(a)_____
    L(r)_____
50. NO. OF WAFERS _____
51. CONTACT BEVEL ANGLE OF BRUSH FIGURES J-3, J-4 J-5 α_____
52. Top bevel angle β of Brush Figure J-9 _____
53. Shunt location (Figure J-6) number_____
54. Shunt type (Figure J-7) Q/R_____
55. Length L of Shunt (Figure J-10) inch (mm)_____
56. Holder end protection none/clip pad specify width inch (mm)_____
57. Terminal (Figure J-8) Type_____
    Slot width inch (mm)_____
    or Hole diameter inch (mm)_____
58. Special work (if any). Describe or sketch:

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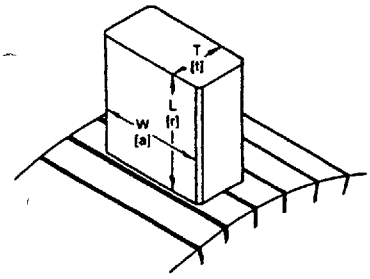


Figure J-1

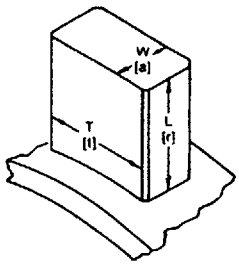


Figure J-2

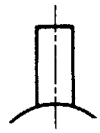


Figure J-3
RADIAL
$\alpha = 0$

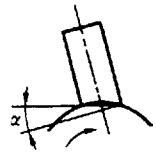


Figure J-4
TRAILING

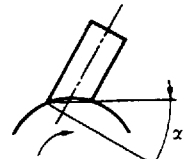
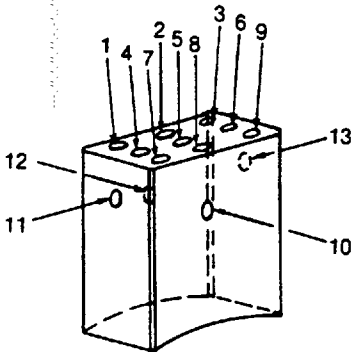


Figure J-5
REACTION



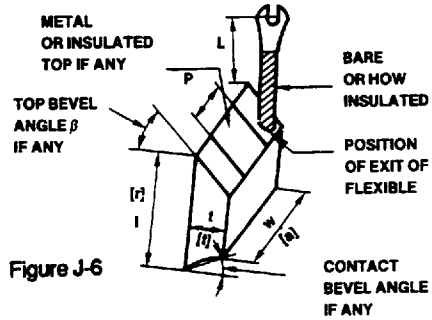
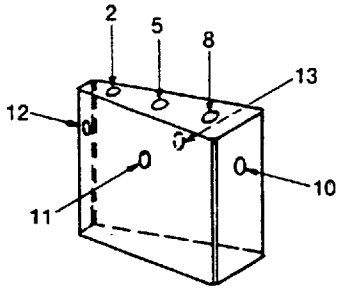
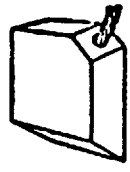
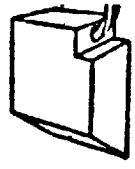


Figure J-6





SHUNT CABLE
LEAVING FROM
BEVELED EDGE



SHUNT CABLE
LEAVING FROM
SHOULDER

Figure J-8

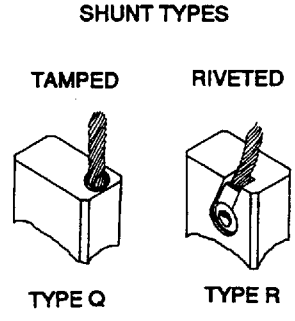


Figure J-9

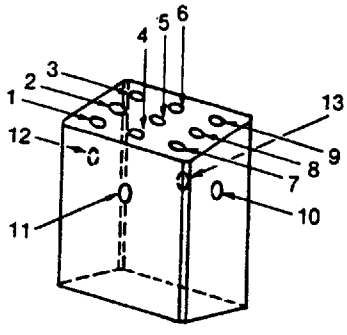


Figure J-7
SHUNT CABLE LOCATIONS

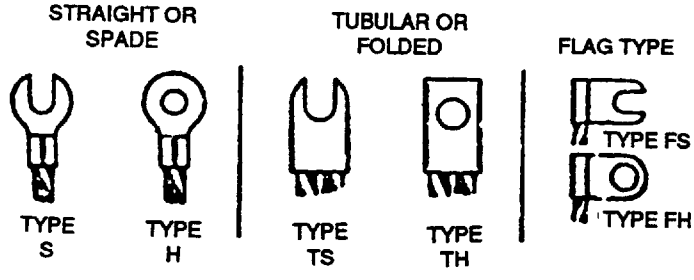


Figure J-10

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The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

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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 their particular needs. 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.

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, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

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.

(Standardization Policies and Procedures, p. 6)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
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.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

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, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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