COMMUTATORS, COLLECTOR RINGS, INTERRUPTERS, AND BRUSHES MAINTENANCE REQUIREMENTS AND PROCEDURES

1. GENERAL

1.01 This section covers the requirements and procedures necessary to maintain commutators, collector rings, interrupters, and brushes in a condition which will give satisfactory operation.

1.02 This section is reissued to specify flint paper as the approved abrasive for fitting brushes; to specify the flexible abrasive as an alternate burnishing agent; to specify "untreated" canvas; and to revise the method of determining brush pressure. In addition the list of tools, gauges, and materials has been revised, the use of petroleum spirits removed, and a commutator check chart added.

1.03 The information contained herein can be applied to most rotating machines using commutators, collector rings, or interrupters. Where the requirement for a machine is contrary to the requirement shown in this section, the information given for the particular machine concerned should be followed.

1.04 Most of the requirements and procedures listed refer to commutators. For the purpose of this section, the term commutator will be used exclusively. When maintaining collector rings or interrupters, follow the pertinent information for commutators.

1.05 This section covers the maintenance of the existing commutator surface up to the point where resurfacing becomes necessary. Proper application of the methods described herein should reduce to a minimum the necessity for commutator resurfacing. Section 171-110-801 covers the methods used to resurface commutators, collector rings, and interrupters when necessary, and Section 171-110-802 covers the replacement data for brushes.

1.06 The frequency of checking the requirements shown will depend upon the size of the equipment concerned and the conditions under which it is used. Local experience and routines will usually be sufficient.

1.07 The primary purpose of this section is to train and assist the maintenance man in methods used to prevent trouble. When a trouble condition does arise, Table A (on last pages of this section) may be valuable to the operator. Several items are listed under possible causes which do not apply, in general, to telephone power plants. However, they are included both for use in rare trouble cases and as a condensed means of presenting educational information on the location of trouble in rotating machines. The table does not cover all possible trouble conditions, but should be sufficient for use in any Bell System power rooms.

1.08 Important considerations in commutator maintenance are general cleanliness and maintenance of a good commutator film. A routine program of blowing out and cleaning, together with proper maintenance, will help to give efficient operation and long equipment life. It is important to keep oil and dirt from collecting on the commutator or on the brushes. Periodically, blow out the dust and dirt from the machine windings, commutator slots, and brush-holder rigging with compressed air or a hand bellows. Use commutator burnisher regularly.

1.09 *Commutation* on dc generators is dependent on so many factors, both of machine idiosyncrasies and local conditions, that it has never been an exact science. With standard brushes and standard maintenance as outlined herein, the vast majority of machines commutate reasonably well without excessive brush or commutator wear but an occasional machine presents problems very difficult to correct. The chief importance of the recommended brown film of cuprous oxide is mechanical to reduce friction and wear. It also reduces circulating currents in the contact surfaces. It has electrical disadvantages but these are much less serious where the film is uniform and the machine is operating under appreciable load. The presence of a uniform film is still considered the best indication of satisfactory operation and the best protection against excessive commutator wear.

1.10 *Machine Differences:* Predictable factors such as brush current densities, brush characteristics, commutator material, airgaps, and magnetic circuits are carefully considered during machine design and results are checked on the test floor. Even with these precautions and with a line that is generally satisfactory, an occasional machine refuses to commutate properly, usually at either light load or heavy load. While such irregularity is infrequent and probably due to uncontrollable irregularities in materials or factory procedures, the machine manufacturer has usually assumed the responsibility.

1.11 *Operating Conditions:* Many local conditions not controllable by strict conformity with this section affect commutation and their effect is relative, so that quantitative values can seldom be used in discussing them. Some such conditions are listed below.

(1) Current too high or too low. High current aggravates sparking and overload causes both sparking and overheating. As discussed in 1.12, operation for long periods at low loads causes deterioration of commutating film.

(2) Commutator resurfacing per Section 171-110-801 too often or not often enough. Sanding, fitting brushes with a brush seater, and stoning remove the commutating film. While stones held in a tool rest remove eccentricity, hand stoning tends to increase eccentricity. Neglect of threaded or grooved surfaces leads to increased expense and poor operation.

(3) Contaminants in the atmosphere as discussed in 1.13.

(4) Atmosphere too dry. This is usually at high altitudes, but may be during the summer in some of the plain states or at any time when heating equipment, boilers, or other heat-producing equipment dries out the air.

(5) Incorrect brush. Brush selection is at best a compromise. Every attempt is made to recommend the best brush for the job but there will always be individual machines in particular locations that will do better with special brushes. Where the need for special brushes is suspected, the machine manufacturer usually cooperates in recommending brushes for trial. Electrographitic brushes have been standardized for certain machines and are being considered for others. Such brushes, in some instances, may give improved operation on individual machines for which they are not standard. In general, however, nonstandard application of electrographitic brushes should be used only when recommended by the machine manufacturer for the particular machine.

1.12 *Low-Current Operation:* In general, commutating films build up during periods of higher loads and deteriorate during periods of lighter loads, so that the length of time of operation at a particular load becomes significant. With automatic plants, the daily load distribution for a particular office can easily result in one machine, for instance G2, operating for long periods at light load. One solution for this is to set the controls to bring in G2 at three quarter load on G1, but this reduces the plant capacity and is not always feasible. An alternate solution is to reduce the number of brushes on G2, but this again reduces the plant capacity. Newer plants are arranged to bring G2 in at a lower load while keeping the full capacity of G1 available, if needed.

1.13 *Contaminants in the Atmosphere:* Many contaminants in the atmosphere adversely affect commutation, usually by softening the film so that it is scraped off irregularly by the brushes. The more serious of the frequently encountered contaminants are sulphur fumes, sulphuric-acid spray, volatile solvents such as those in KS-8446 ethyl glycol and KS-8372 trichloroethylene, and fumes from large freshly painted areas. Somewhat less contamination may be experienced from sources such as petroleum spirits, gasoline, diesel fuel, and the exhaust gases from engines. Exposure to such contaminants should be reduced as practicable, possibly by extra ventilation during their presence in the power room and by performing as much as feasible of the work involving them in other rooms. In any case of exposure, much of the damage can be averted by prompt and thorough use of the commutator burnisher.

2. REQUIREMENTS

2.01 *Commutation:* With the machine meeting the requirements of the associated machine maintenance section and without altering the position of the brush-holder yoke (when present), the generator shall commutate successfully at any current between no load and full load.

Gauge by eye.

2.02 *Sparking:* The sparking between brushes and commutators shall be kept to a minimum. There shall be no sparking between brushes and collector rings.

2.03 *Commutator Color:* The commutator shall have a clean, smooth surface which is free from any discoloration other than the brown color considered indicative of the best commutating condition.

2.04 *Commutator Slots:* The slots between the commutator bars shall be free of any dirt, oil, graphite, carbon dust, copper dust, copper dragging, etc. On machines now being furnished, the mica between the commutator segments is usually undercut.

Gauge by eye.

2.05 *Commutator Surface:* The commutator shall be free from scoring, pitting, streaking, grooving, cutting, etching, burning, copper dragging, or other deformation of the surface or structure except that caused by normal wear.

Gauge by eye or feel.

2.06 *Commutator Cleaning and Care:* The commutator shall be cleaned and otherwise cared for periodically and when necessary to meet the other requirements of the section. The commutator shall be burnished after any lead-antimony cell in the same room or in an adjoining room with an opening into the generator room has been charged at 2.35 volts or higher, or after any lead-calcium cell in the same room or in an adjoining room with an opening into the generator room has been charged at 2.50 volts or higher. Also, it should be burnished after exposure to any other contaminant in the atmosphere. See 1.13.

2.07 *Physical Defects:* The commutator shall have no high, low, or loose segments or flat spots. Eccentricity of the commutator shall not be enough to cause poor commutation or poor operation of the machine.

> *Note:* The smaller the eccentricity the better, and eccentricities below 0.001 inch are desirable and not uncommon. Eccentricity greater than 0.003 inch is quite likely to cause poor commutation.

2.08 *Brush Type:* The machine shall have the correct type of brushes. See 1.11 (5) and Section 171-110-802.

2.09 *Brush Condition:* The brushes shall be free of dirt, dust, grease, oil, carbon particles, and copper picking.

2.10 *Brush Holders and Yokes*

(a) The clearance between the commutator and the lower edge of the brush holders shall be as specified in the maintenance section for the machine concerned.

(b) The brush holder shall be set at the correct angle when the angle is adjustable. This angle will be prescribed in the maintenance section for the machine concerned. (Some manufacturers use chisel marks to designate the correct setting of the brush holders.)

(c) The brush-holder yoke, if any, shall be set to the correct position in relation to the commutator. (Some manufacturers use chisel marks or a dowel pin to designate the correct setting of the brush-holder yoke.)

2.11 *Brush Fit*

(a) Brushes shall not bind in their holders nor shall they be loose enough to cause poor commutation.

(b) The contact surfaces of the brushes shall be fitted to the commutator so as to insure successful commutation.

2.12 ***Brush Length:*** The brush length should be sufficient to allow the brush spring to maintain correct brush pressure. See the maintenance section for the machine concerned for specific brush length requirements.

2.13 ***Brush Pressure:*** The brush pressure shall be in accordance with the requirements stated in the maintenance section for the machine concerned. Usually there are no requirements for the pressure of brushes on machines equipped with tubular-type or constant pressure-type brush holders. However, the compression on the spring shall be sufficient to give successful commutation.

2.14 ***Brush Alignment and Brush Spacing***

(a) The brush holders shall be so located that the brushes do not overlap the end of the commutator (or groove) or ride upon that part of the commutator used for connection to the armature conductors under any condition of normal operation.

Gauge by eye.

(b) When possible, brushes on two adjacent studs shall cover the same portion of the commutator and the brushes on the next two studs shall cover the space between the brushes on the first two studs.

(c) The brushes shall be spaced evenly around the commutator. Use scale.

Note: If the generator commutates successfully, it will not be necessary to check this requirement.

3. ADJUSTING PROCEDURES

3.001 ***List of Tools, Gauges, and Materials***

CODE OR SPEC NO.	DESCRIPTION
TOOLS	
KS-6320	Orange Stick
R-2969	Typewriter Brush
—	10-inch Hand Bellows
—	Commutator Burnisher, Locally Prepared
—	Pocket Knife
—	Ideal Brush Seater, Soft Grade Abrasive(s), Standard 4-3/4 x 1-1/8 x 5/8 (unless otherwise required), Ideal Industries, Inc
—	3-inch C Screwdriver (or the replaced 3-inch Cabinet Screwdriver)
—	Crown Brush Seater Holder No. 2601, Crown Industrial Products Co
—	Ideal Flexible Abrasive, as required (5/8 x 1 x 5, or 1 x 2 x 5 inches)
GAUGES	
KS-6909	Gauge
R-1032, Detail 1	—5° to +150°C Thermometer (or equivalent spirit-filled thermometer)
R-8550	6-inch Steel Scale
—	Spring Balance, Scale as required
—	Push-pull Tension Gauge, as required
MATERIALS	
KS-14666	Cleaning Cloth
—	Abrasive Paper Extra Fine Flint
—	Wooden Block
—	Felt Pad, or equivalent

3.01 ***Commutation*** (Reqt 2.01)

(1) Generally speaking, successful commutation may be said to have been obtained if neither the brushes nor the commutator is burned or injured to the extent that abnormal maintenance is required. The presence of some visible sparking is not necessarily evidence of unsuccessful commutation.

(2) Specifically stated, successful commutation has been obtained if all the other requirements of this section have been satisfied. Failure of the equipment to meet any one of the requirements listed will probably cause increased maintenance or serious trouble. It is obvious that successful commutation is not a function of the brush alone or of the commutator or electrical circuit alone, but results from optimum electrical and mechanical brush-to-commutator conditions.

3.02 ***Sparking*** (Reqt 2.02)

(1) Not all sparking may be of an injurious or destructive nature. To determine whether damage is taking place, the commutator bars should be closely examined. If evidence of copper etching (small pits or streaks found on the leaving edges of the bars) is observed, the sparking is destructive, and the commutator should be dressed with a commutator stone. If used when commutators first begin to show signs of roughness, a few minutes application of a stone is all that is necessary. See Section 171-110-801.

(2) If in doubt as to whether the commutator is etched or only flecked (a carbon deposit often found on the leaving edge of bars), rub the commutator with a pencil eraser. If the mark is removed, the bar is only flecked and it may be assumed that sparking of a destructive nature is not taking place.

(3) Pin sparking of the noninjurious type may be frequently observed on the older-type noninterpole motors or generators and some sparking is likely to take place on machines subject to quick and radical load changes at the time the load change is taking place. This is due to the lag of the commutating field flux behind the current in the main armature coils.

(4) When certain grades of brushes are applied to a newly resurfaced commutator, excessive sparking may be expected for a day or two until the copper surface has had time to become darkened with oxides and brush deposits characteristic of the brush grade used. This condition is caused by circulating currents in the brush faces and results from the low contact drop of the brush when applied to a new commutator. For this reason, no machine adjustments should be made until the commutator has become well darkened. Feather-edge mica is a frequent cause of sparking and the mica should be undercut, if necessary, as described in Section 171-110-801.

(5) Some of the more frequent causes of destructive brush sparking are shown in Table A.

3.03 ***Commutator Color*** (Reqt 2.03)

(1) A dark bronze or chocolate-colored commutator is very desirable and should not be mistaken for a burned commutator. If a commutator presents this appearance, is clean, smooth, and the commutation is satisfactory, it should be left alone. Occasionally a commutator may be operating satisfactorily and not have this appearance. If all other requirements are met, it should be left alone. See 1.09.

Note: Refer to the commutator check chart (Fig. 2) for a visual aid in recognizing satisfactory commutator surfaces.

(2) Discoloration of the commutator surface may indicate excessive temperature, contaminated atmosphere (see 1.13), or the presence of oil on the commutator. Discoloration from heat is usually recognizable as such. In the case of a contaminated atmosphere, it is necessary to make frequent use of the canvas burnisher described in 3.06(4). Oil on the commutator surface tends to develop a dark, high-resistance glaze which may lead to burning of the surface. It also increases the tendency of the brush faces to pick up copper. Oil

sometimes creeps from the bearings to the commutator surface and is sometimes deposited from oil mist in the air.

3.04 *Commutator Slots* (Reqt 2.04)

(1) Periodically clean out the slots between the commutator bars, using a compressed air gun or blower. Copper dragging should be removed by using a slotting file or slot scraper. Persistent particles can be removed using the hand slotter described in Section 171-110-801. Avoid the use of polishing compounds or cleaning agents including petroleum spirits, as they tend to accumulate dust and dirt in the slots and may adversely affect the commutating film. Blow out the slots and adjacent windings after any cleaning or cutting operation.

(2) In general, the undercutting given the mica in a commutator is sufficient until the commutator itself requires turning down, but a commutator which has run for a long period without having been turned should be checked for mica flush with or projecting above the bars. Section 171-110-801 describes the methods used to undercut or trim the mica.

3.05 *Commutator Surface* (Reqt 2.05)

(1) The line of demarcation between a commutator which needs cleaning or burnishing and one which needs resurfacing is sometimes very thin and subject to the judgment of the operator. (Consult supervisor if in doubt.) Consequently, some of the information contained in Section 171-110-801 has been repeated here.

Note: Refer to the commutator check chart (Fig. 2) for a visual aid in recognizing surface markings.

(2) *Streaking:* A uniform commutator surface is one of the most important factors in securing long brush life and low maintenance costs. An even commutator film enables the brushes to operate at a relatively low rate of wear. It forms a lubricating medium over the commutator in much the same manner as oil on a bearing surface.

(3) A streaked collector indicates a breakdown of this film. Fortunately, it can be detected at a glance because the film is normally intact over most of the surface and the streaks appear as shiny paths of raw copper of brush width or more. The cause for such abrasive action is generally found to be copper imbedded in the brush face. This condition is known as copper picking and is explained in detail in 3.09(2).

(4) Streaking that has not progressed to the point of forming grooves may be arrested by use of a commutator stone as described in Section 171-110-801. Removing the film from the commutator allows the current to balance in all the brushes. This, in turn, makes it possible for a new film to form over the entire surface. See 3.06(5).

(5) *Grooving or Threading:* The terms grooving and threading are used differently by different maintenance men. Fig. 1 illustrates the terms as used in this section. Grooves or threads may or may not be harmful. If the groove has commutating film both on the top and bottom, and the commutation is satisfactory, leave it alone. Threads with raw copper, with sharp tops and bottoms, not polished, are usually harmful and should be corrected. In such cases, the surface of the brush will not be smooth and shiny but may be burned blue and will have light grooves and evidence of small copper particles. It is this copper picking [see 3.09(2)] that wears the threads and, if not corrected, will get progressively worse. Some machines are more susceptible than others to threading. When it is considered necessary to resurface the commutator, refer to Section 171-110-801.

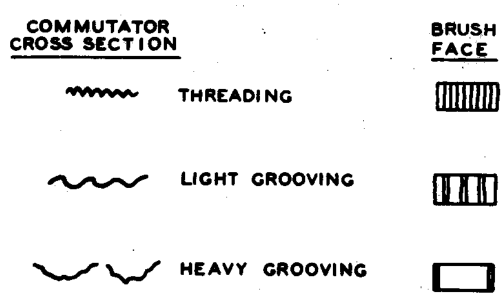
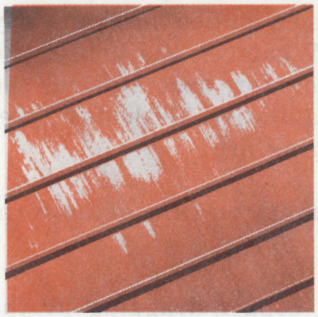


Fig. 1 — Types of Grooving and Threading

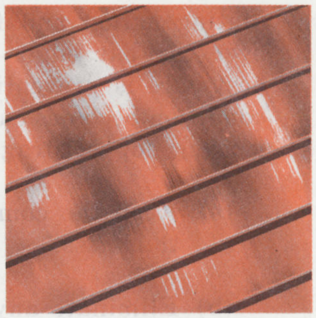
COMMUTATOR CHECK CHART

FOR COMPARING COMMUTATOR SURFACE MARKINGS

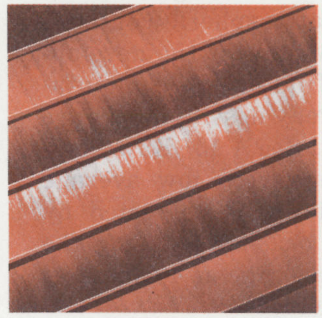
SATISFACTORY COMMUTATOR SURFACES



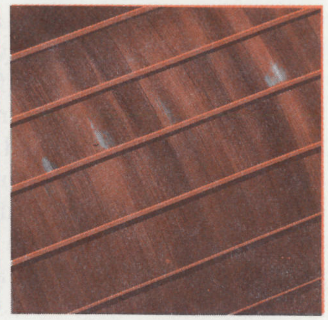
LIGHT TAN FILM over entire commutator surface is one of many normal conditions often seen on a well-functioning machine.



MOTTLED SURFACE with random film pattern is probably most frequently observed condition of commutators in industry.

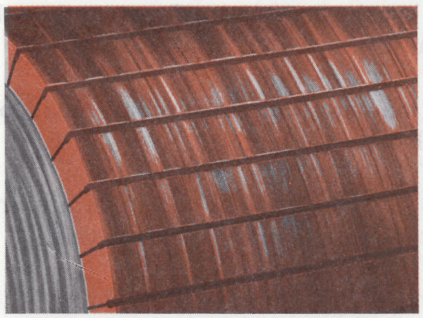


SLOT BAR-MARKING, a slightly darker film, appears on bars in a definite pattern related to number of conductors per slot.

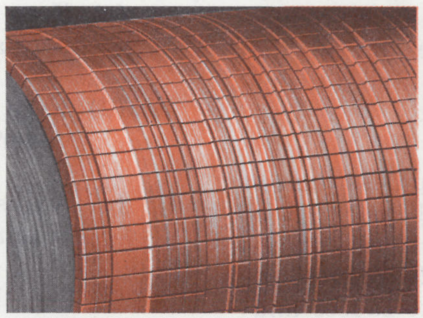


HEAVY FILM can appear over entire area of efficient and normal commutator and, if uniform, is quite acceptable.

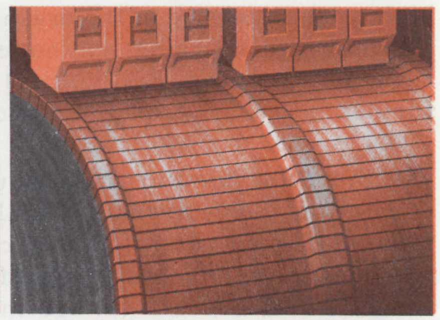
WATCH FOR THESE DANGER SIGNS



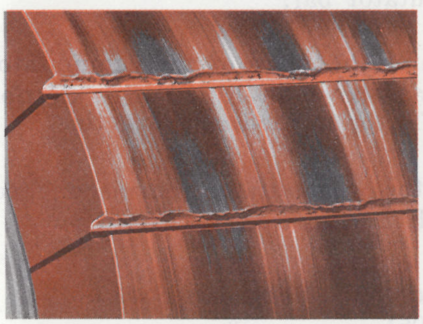
STREAKING on the commutator surface signals the beginning of serious metal transfer to the carbon brush. Check the chart below for possible causes.



THREADING of commutator with fine lines results when excessive metal transfer occurs. It usually leads to resurfacing of commutator and rapid brush wear.

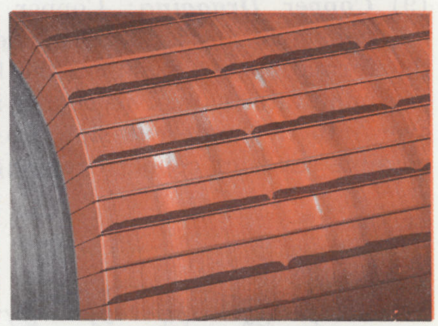


GROOVING is a mechanical condition caused by abrasive material in the brush or atmosphere. If grooves form, start corrective action.



COPPER DRAG, an abnormal build-up of commutator material, forms most often at trailing edge of bar. Condition is rare but can cause flashover if not checked.

PITCH BAR-MARKING produces low or burned spots on the commutator surface. The number of these markings equals half or all the number of poles on the motor.



HEAVY SLOT BAR-MARKING can involve etching of trailing edge of commutator bar. Pattern is related to number of conductors per slot.

CAUSES OF POOR COMMUTATOR CONDITION

Frequent visual inspection of commutator surfaces can warn you when any of the above conditions are developing so that you can take early corrective action. The chart below may indicate some possible causes of these conditions, suggesting the proper productive maintenance.

	Electrical Adjustment	Electrical Overload	Light Electrical Load	Armature Connection	Unbalanced Shunt Field	Brush Pressure (light)	Vibration			Contamination	
										Gas	Abrasive Dust
Streaking			X			X				X	X
Threading			X			X				X	
Grooving											X
Copper Drag						X	X			X	
Pitch bar-marking				X	X	X	X				
Slot bar-marking	X	X								X	

How to Get the Most Value from This Chart

The purpose of the Commutator Check Chart is to help you spot undesirable commutator conditions as they develop so you can take corrective action before the condition becomes serious. This chart will also serve as an aid in recognizing satisfactory surfaces.

Fig. 2 – Courtesy of the General Electric Co

(6) ***Raw Surface:*** A raw or bright metallic copper surface on the commutator is not desirable. Among the more common causes of raw commutator surface are the use of abrasive brushes, serious accumulation of copper in brush faces, atmospheric contamination, and operation at too low average current density. Some forms of atmospheric contamination impede or entirely prevent the development of a good surface film on the commutator or, when they occur, may destroy a surface film already established. See 1.13. Raw commutator surface resulting from low average current density can usually be corrected by removing enough of the brushes to bring the current density up to an average of 40 amperes per square inch. See 3.11(12).

(7) ***Bar Etching:*** Bar etching or incipient burning of commutator bars usually results from visible sparking or a band of very high current density in the brush face producing interface sparking not noticeable at the edges of the brush. See 3.02 (1) and (4) for further information on this topic.

(8) ***Bar Burning:*** Burned bars, unless the result of some transient fault such as a flashover or an external short circuit, represent merely an advanced stage of bar etching. Refer to 3.02 (1) and (4) for the causes and method of treatment of this condition.

(9) ***Copper Dragging:*** Copper dragging or copper foiling is the term used to describe the formation of copper on the leaving edges of commutator bars. This copper is then pulled over into the undercut slot. See Fig. 3. One possible cause of copper dragging is mechanical, resulting from the hammer action of chattering brushes and causing a plastic slipping of the more ductile metal over the leaving edges of the bars. Another possible cause of the copper displacement is electrolytic action within the arc on the leaving edge of the brush, with the foil formed by an electroplating action and then pulled mechanically over the bar edge. Whatever the cause, the best cure is prevention for, once started, the condition becomes cumulative. Methods of preventing copper dragging are:

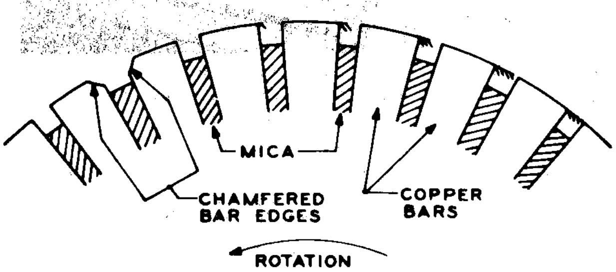


Fig. 3 – Progressive Stages of Copper Dragging

(a) Keep the commutator film of uniform thickness.

(b) Eliminate any copper dragging by the use of a slotting file, as described in Section 171-110-801 under commutator undercutting. Also see 3.04(1).

(c) Keep brush tension uniform and well regulated.

(d) Keep load normal. Do not overload or underload.

(e) Adjust brush tension to the minimum required for good brush operation.

(f) See that brushes are not "sloppy" in the holders and the holders do not have more than the recommended clearance from the commutator bar.

(g) Chamfer the edges of the commutator bars as shown in Fig. 3. See Section 171-110-801 for method of doing this.

(h) Use the commutator burnisher frequently.

3.06 *Commutator Cleaning and Care* (Reqt 2.06)

(1) ***Untreated Canvas:*** One of the best methods of producing and maintaining a satisfactory commutator surface is by periodic use of a wiping and burnishing device as shown in Fig. 4 and made in accordance with (4). As a wiping device, the canvas is simply pressed against the rotating commutator and

slowly moved from side to side. In this way, oil, grease, smudge, and gummy substances are removed from the surface of the commutator bars. Applied with sufficient pressure, it will also remove smut caused by sparking and in many cases forestall the development of serious bar burning.

(2) ***Flexible Abrasive:*** An alternate method of removing or equalizing the commutator surface film is with the use of a cleaning and burnishing device, commercially known as a flexible abrasive. This device cleans like an eraser, generates very little dust, and quickly removes high resistance film, dirt, grease, and smut. As a commutator cleaner, it is used by simply holding it against the commutator and moving it back and forth several times as the machine is running.

(3) The method of cleaning will depend mostly on the local tendency for surface deposits to accumulate. If the canvas wiper is employed, daily application will usually do the job. The flexible abrasive generally is not needed as frequently.

(4) ***Wiping and Burnishing Device:*** A convenient device for applying canvas to a commutator surface with safety is shown in Fig. 4. Several layers of 6- or 8-ounce untreated hard-woven canvas or duck are wrapped over the end of a strip of strong, pliable wood and attached by rivets. Countersinking the strip at the points where the rivets are inserted reduces the danger of the rivet heads coming in contact with the commutator. When the outer layers of canvas become too dirty for effective use, they can be cut away successively near the cord binding and removed. The following approximate dimensions will be found suitable for use on the smaller generators but, for larger ones, they should be increased: length 15 inches, width 1 inch, thickness 3/16 inch.

(5) A burnishing device of this type is adapted to use on either large or small machines. The canvas should be held against the commutator under heavy pressure to be effective in removing all surface deposit. The pliable handle reduces the tendency for chattering to occur. On large machines, application is made from the end of the commutator with the strip held parallel to the shaft of the armature. However, for most machines found in telephone power plants, the burnishing device should be applied "end on" to the commutator with heavy pressure.

(6) ***Burnishing:*** After the surface of a commutator has been cleaned, it is desirable to burnish or cure it before putting the machine into service again. Untreated canvas or a flexible abrasive may be used to give a more highly polished or burnished surface than abrasive paper will give. This may be desirable, particularly for larger machines that must immediately carry full load. Canvas may be applied with a wood block curved to the surface of the commutator (see Fig. 5) or in the form of a burnishing device (see Fig. 3). With the commutator running at as near normal speed as practicable, apply the canvas or the flexible abrasive with considerable pressure.

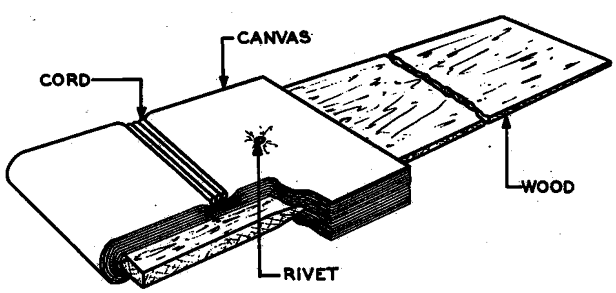


Fig. 4 — Typical Commutator Wiping and Burnishing Device

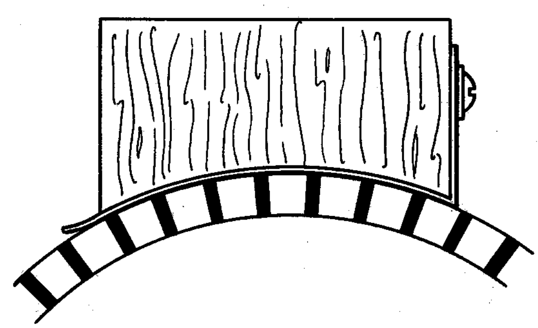


Fig. 5 — Canvas (Untreated) Attached to Wood Block

The friction and heat will tend to burnish, or cure or season the surface and, if done long enough, will result in a surface almost as good as that obtained by actual service. It is possible, however, to produce excessive temperatures and cause distortion in the commutator assembly; consequently, it is best, if possible, to have this done by someone with experience in the operation.

(7) After any operation affecting the commutating surface or brush fit, it is very desirable that the machine be operated for several hours at light load before heavy load is applied. (Light load is preferred to no load because of the tendency of some brushes to thread, groove, or form excessive film at no load.) The brush surfaces should then be observed for several days to be sure that they are not picking up copper. The length of time for light load runs and for observation of brushes depends on the extent of the work done on the commutator.

(8) ***Sanding:*** Any degree of sanding of the commutator is considered to be a resurfacing operation and is covered in Section 171-110-801.

3.07 ***Physical Defects*** (Reqt 2.07)

(1) Any of these conditions require resurfacing and the operator should refer to Section 171-110-801.

3.08 ***Brush Type*** (Reqt 2.08)

(1) Brushes are available in several types and grades. All brush grades are made from four general classes of material: carbon, electrographitic, graphite, and copper graphite. However, the brushes used on Bell System machines are those which have been recommended by the machine manufacturer and are listed in Section 171-110-802. See 1.11(5).

3.09 ***Brush Condition*** (Reqt 2.09)

(1) Again, it is important to point out the necessity for general cleanliness. Because of the intimate contact and relation between the brushes and the commutator surface, any accumulation of foreign material on or near the brushes and brush rigging will have a detrimental effect on the surface of the commutator. Frequent use of a compressed air hose or hand bellows on and around the brushes and brush rigging and frequent use of the commutator burnisher will do much to prevent troubles.

Note: Brushes that are contaminated with oil or grease should be removed and replaced with new brushes since they can not be successfully cleaned.

(2) ***Copper Picking:*** Streaks on the surface of the commutator are often caused by copper picking. The cause for this abrasive action is generally found to be copper imbedded in the brush face. It results in minute particles of the commutator becoming plated on the brush contact surface by load current as it passes from the commutator to the brush. It originates from an overload on one or more brushes (selective action).

(3) The cause of the brush overload is not usually excessive machine load. It may be due to light or nonuniform brush tension, or a number of other conditions that cause individual brushes to carry a disproportionate load. Since the copper in the brush face is abrasive, it quickly cuts through the commutator film and the contact resistance of the picking brush is reduced. This causes the brush to take a larger share of the working current. The process becomes cumulative and upsets the current balance in other brushes so that they in turn will become copper pickers.

(4) The use of a flexible abrasive to remove streaking is described in 3.06(2). If the copper picking is not severe, the use of a flexible abrasive to remove streaking may at the same time remove the copper deposits on the brush face. Light copper picking can also be removed with a pocketknife. However, if the picking is heavy, it will be necessary to remove the brushes and sand them down. After cleaning by abrasive paper, it is necessary to refit the brushes to the commutator as described in 3.11(3).

3.10 ***Brush Holders and Yokes*** (Reqt 2.10)

(1) The method of setting the brush holders and yokes (when adjustable) varies with the machines being worked on; therefore, this information will be found in the maintenance section for the machine concerned.

3.11 ***Brush Fit*** (Reqt 2.11)

(1) Binding of brushes in holders is often caused by brush dust produced in the normal operation of the machine. Remove the brushes from their holders and wipe them with a clean, hard, nonlinting cloth. Replace the brushes in the same holders and in the same position in the holder as they were before removal.

(a) In replacing a brushholder cap over a brush with a coil spring and pigtail, see that the inside of the cap and the contact on the pigtail are clean and smooth so that there is no possibility of the pigtail becoming twisted as the cap is screwed on.

(b) When replacing brushes in constant-pressure brush holders, see that the coiled spring that forms part of the brush holder bears directly on the brush and that it is not entangled with the pigtail leads of the brush.

(2) If brushes are too loose in their holders, they should be replaced with new brushes.

(3) Brushes may be fitted by the following methods.

(a) To fit a brush to a commutator, cut a strip of extra-fine flint paper slightly← wider than the width of the brush and preferably as long as the circumference of the commutator. Place the strip of flint paper← under the brush with the abrasive side next to the brush and hold the paper so that it will bear on as much of the commutator surface as practicable. Draw the flint paper un-← der the brush or rock the commutator until the brush has the same curvature as the commutator surface. The final cuts shall be made in the direction of rotation.

(b) An alternate method of fitting brushes is by the use of a brush seater, a rectangular stick of loosely bound abrasive that utilizes the rotation of the commutator to shape the contact surface of the brush to a proper fit. The brush seater should be placed into the brush seater holder, the friction members holding it snug against excess feed. A second brush seater should be placed above the one in use to act as a plunger for the gradual feeding of the brush seater material as it wears. Brushes should be seated singly by placing the brush seater exactly at the lead edge of the brush and pressing down on the brush while holding the brush seater in contact with the rotating commutator surface. The brush seater holder is designed to reach in and to contact the brush lead edge, without danger to the operator's hands.

(c) The brush seater method of fitting brushes is considered to have advantages because the brushes can be seated more perfectly in quicker time without removing the machine from operation (for a single brush replacement), and with a minimum of lost time if the machine is run at no load for the purpose of fitting a whole set of new brushes.

(d) There are certain inherent disadvantages in the brush seater method of fitting brushes that should be considered and they are as follows.

Considerably dustier and requires more critical control of dust removing equipment.

Requires caution in the application to avoid removing too much carbon from the brushes and too much commutation film from the commutator surface.

Requires more careful inspection and cleaning of brushes after fitting.

May become a personnel hazard when carelessly used.

(e) After the brushes have been fitted by the brush seater method, a flexible abrasive stick [3.06(2)] may be used to start restoring the commutation film.

(4) On generators having a brush-holder yoke and brush-holder studs where a single brush is to be fitted by other than the brush-seater method, the adjacent brushes on the same stud and the corresponding brushes on each of the adjacent studs should be removed in order to give the maintenance man more room to work.

(5) Where a complete set of brushes is to be sanded in, a piece of extra-fine flint paper as wide as the commutator shall be used and all of the brushes on the stud sanded in at one time. The brushes on the adjacent studs may be removed while sanding the brushes of any one stud in order to give the maintenance man more room to work.

(6) After fitting, remove the brushes, remove any sharp edges, clean the commutator and windings with compressed air, and wipe the brushes and commutator surfaces with cloth. Mark brushes and corresponding holders before removing brushes. In fitting a brush, it is desirable to have it make contact over its entire arc and have as much of its contact surface as possible bear on the commutator. In replacing the brushes, see that they are put back in the same holders and in the same position in which they were fitted.

(7) On machines with tubular-type brush holders, the new brushes should be fitted in place if space permits. Otherwise, shape the brush contact surface, if not already so prepared, to approximate the curvature required (use old brush as a model) to assure contact at each end of the arc. Then run the machine for an hour or more at light load. Where a grinding wheel of approximately the diameter of the commutator is not available for shaping brushes, extra-fine flint paper on a cylinder of approximately the same diameter may be used.

(8) After fitting any brushes, burnish the commutator surface with a canvas burnisher or a flexible abrasive as described in 3.06(6).

(9) ***The location of a noisy brush with the machine stopped*** may avoid trouble, particularly where there are not many brushes. With the machine stopped, remove the brushes (to be replaced in the same position in the same holders) and check for brush fit on commutator and in holders, brush pressure, defective pigtails, cracked or chipped brushes, leading edge of brush worn so long that it bumps on each commutator segment, foreign matter in the face of the brush, irregularity of material, and burning.

(10) ***Noisy brushes*** can sometimes be located with the ***machine running.*** This method may be used with box-type brush holders but should be attempted by experienced men only or under supervision, and only on generators for 65 volts or less. It should not be attempted after the generator has run long enough for the parts to become too hot to touch. Rings, wrist watches, neckties, etc, should not be worn while working on brushes or brush rigging with the generator running. This check for noisy brushes consists of raising the brushes, one brush at a time, just off the commutator until the noisy brush is found. The slight pull is usually applied to the pigtail while keeping pressure from the brush spring or finger on the brush to avoid its leaving the holder. When the pigtail is attached to the extreme corner of the brush and without a rivet (see Section 171-110-802, Fig. 1, Shape N), lifting by the pigtail may break off the corner of the brush. In such cases, the brush spring or finger may be lifted slightly to allow the brush to clear the commutator. This operation, however, requires care and skill. In some cases, the noisy brush can be located with the machine running by pushing on the brushes one at a time with a piece of wood to change their position or pressure.

Caution: Brush pressures should not be adjusted or brushes removed from their holders with the machine running. Brushes reach temperatures too hot for bare hands. Do not touch at the same time parts including brushes, brush rigging, and machine frame which may be at different potentials. Avoid use of tools above moving commutators.

(11) ***A noisy brush*** may also be located by alternately ***starting and stopping*** the generator. This is the method to be used with

tubular-type brush holders. Remove a brush with the generator stopped. Start the generator and, if the noise continues, stop it, replace the first brush, and remove the other. Restart the generator. The absence of noise indicates that the noisy brush has been removed. Guard against touching brushes that are too hot to handle.

(12) In the case of a generator run habitually at light load, improved operation of the commutator and brushes can be obtained by removing some of the brushes from each stud. The same number of brushes should be removed from each stud and enough should be left on to carry the maximum anticipated load. Stagger the brushes so that the entire commutator surface receives approximately the same amount of wear. This factor should be checked particularly in new offices where machine capacity often exceeds the maximum load demand. Replace the same number of brushes on each stud at any one time as needed by growth of maximum office load.

3.12 ***Brush Length*** (Reqt 2.12)

(1) Replace any short brushes.

3.13 ***Brush Pressure*** (Reqt 2.13)

(1) Except in the case of brushes in constant-pressure brush holders and brushes in tubular brush holders, the brush pressure may be determined by measuring the spring tension as the brush finger touches or "seats" the brush. Using a slip knot, secure a piece of cord around the brush finger as near the point where it touches the brush as possible and, with the free ends of the cord, form a loop approximately 3 inches in diameter. By means of a spring balance or the push-pull tension gauge hooked into the loop, exert a radial pull on the brush finger. Release the pressure slowly until the finger touches the brush. There will be a slight sliding of the brush finger as it "seats" the brush. Reading should be noted at this point. To establish a feel for brush finger tension, raise and lower the brush finger a few times before taking a reading. A brush that has a tendency to slip from its holder as the brush finger is raised should be held in place.

(2) An alternate method of determining spring pressure on brushes is to place a strip of bond paper between the brush and commutator. By means of a spring balance or push-pull gauge hooked into a cord loop secured to the brush finger as in (1), exert a radial pull on the brush finger and apply a gentle steady pull to the paper strip. The reading is taken when the paper strip is released and starts to move.

(3) The pressure may be adjusted by increasing or decreasing the tension of the brush spring.

(4) On small generators having the brushes and brush coil springs in tubular holders beneath screw caps, it will be impractical to measure the brush pressure. In this instance, unless the temper has been lost by heat, the brush coil spring should be stretched, if required, to increase spring pressure. Usually, a shortened spring is the result of a twisted pigtail and the desired spring extension may be obtained by untwisting the copper pigtail and the spring will then expand and give the desired length.

(5) ***Information:*** Consideration should always be given to the spring tension applied to the brushes. Although a simple matter, its neglect is the cause of much unnecessary maintenance work. The spring pressure applied to brushes has a marked influence on brush performance. After a new set of brushes has been installed, each brush should be inspected to see that the tension is adjusted to the value recommended. There is a tendency to keep the spring tension low in order to reduce brush wear, but the resulting effect may be opposite to the one intended. Brush pressure should be checked frequently and adjusted to compensate for the loss of tension due to the wear of the brushes. Besides loss in brush life, tension much below the ideal will cause selective action, copper picking, streaking, and grooving of the commutator.

(6) Excessive brush pressure produces mechanical wear, whereas insufficient pressure results in greater damage to the equipment through pitting of the commutator and

wear of the brushes due to sparking. As specified, the requirements represent a practical balance between the two and should result in satisfactory commutation. Due to slight manufacturing irregularities, different atmospheric conditions, etc, some machines may operate better with brush pressures near the minimum while optimum operation of other machines may be with brush pressures near the maximum. Fig. 6 shows the usual relation between brush wear and brush pressure.

3.14 ***Brush Alignment and Brush Spacing*** (Reqt 2.14)

(1) Readjust the brush holders in accordance with information in the maintenance practice for the particular machine concerned. Generally speaking, generators using tubular brush holders cannot have the brush alignment adjusted.

(2) Fig. 7 shows the correct method of staggering brushes. Unless the factory adjustment has been tampered with, it is usually not necessary to check or readjust this setting.

(3) The spacing of the rows of brushes may be determined by measuring off a piece of paper the length of the circumference of the commutator, dividing the length of the paper into as many equal sections as there are studs, and suitably marking each division. Lay the paper out around the commutator underneath the brushes, and bring the toes of the brushes on each stud in line with one of the marks.

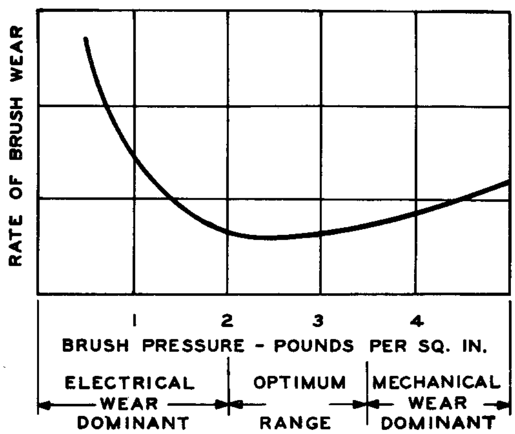


Fig. 6 — Typical Brush Pressure Brush-Wear Relation

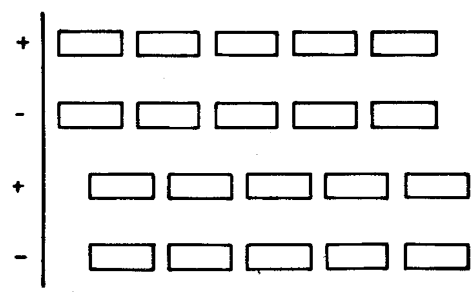


Fig. 7 — Correct Method of Staggering Brushes

TABLE A — TROUBLE CHART

TROUBLE	POSSIBLE CAUSE	
	GENERAL	**SPECIFIC**
Indications Appearing at Commutator Surface		
Rough or uneven surface	—	A1, A2, A3, A4, C4
Dull or dirty surface	—	A5, E6
Eccentric surface	—	A1, C6, F2
High commutator bar	—	C4

TABLE A — TROUBLE CHART (Cont)

TROUBLE	POSSIBLE CAUSE — GENERAL	POSSIBLE CAUSE — SPECIFIC
Indications Appearing at Commutator Surface (Cont)		
Low commutator bar	Sparking	A2, D1
Streaking or threading of surface	Sparking Copper or foreign material in brush face Glowing	E5, E6, E7, E10 A2, A3, E7, E8, E9 See glowing at brush face
Bar etching or burning	Sparking Flashover	A2, A3, B1, B6 A5, B5, C1, E1, E2, F3
Bar marking at pole pitch spacing	Sparking	D1
Bar marking at slot pitch spacing	Sparking	B1, B6
Flat spot	Sparking Flashover Lack of attention	C6, D1, E4, F3 A5, B5, C1, E1, E2, F3 A1, A5, B5
Discoloration of surface	High temperature Atmospheric condition	See heating at commutator E6, E7
Raw copper surface	Embedded copper Bad service condition	See copper in brush face E5, E8, E10
Rapid commutator wear with blackened surface	Burning Severe sparking	A2, A3, B5, C1 See sparking
Rapid commutator wear with bright surface	Foreign material in brush face	E5, E8, E10
Indications Appearing at Brushes		
Sparking	Commutator surface condition Overcommutation Undercommutation Too rapid reversal of current Faulty machine adjustment Mechanical fault in machine Electrical fault in machine Bad load condition Poorly equalized parallel operation Vibration Chattering of brushes	A1, A2, A3, E5, E6, E7, E10 B1, B6 B1, B6 B1, B6 B2, B3, B5 C1, C2, C3, C4, C5, C6, C7, C8 D1, D3, D4, D5 E1, E2, E3, E4 B1, B7 F1, F2 See chattering or noisy brushes
Etched or burned bands on brush face	Overcommutation Undercommutation Too rapid reversal of current	B1, B6 B1, B6 B1, B6
Pitting of brush face	Glowing Embedded copper	See glowing at brush face See copper in brush face

TABLE A — TROUBLE CHART (Cont)

TROUBLE	POSSIBLE CAUSE — GENERAL	POSSIBLE CAUSE — SPECIFIC
Indications Appearing at Brushes (Cont)		
Rapid brush wear	Commutator surface condition	See specific surface fault in evidence
	Severe sparking	See sparking
	Imperfect conduct with commutator	B5, C1, C2, C3, F1, F2
Glowing at brush face	Embedded copper	See copper in brush face
	Faulty machine adjustment	B1, B6
	Severe load condition	E1, E2, E4
	Bad service condition	E7, E8
Copper in brush face	Commutator surface condition	A2, A3
	Bad service condition	E5, E7, E8, E9, E10
Flashover at brushes	Machine condition	C1
	Bad load condition	E1, E2, F3
	Lack of attention	A5, B5
Chattering or noisy brushes	Commutator surface condition	See specific surface fault in evidence
	Looseness in machine	C2, C3, C4
	Faulty machine adjustment	B4, B5
	High friction	E5, E10, F2
Brush chipping or breakage	Commutator surface condition	See specific surface fault in evidence
	Looseness in machine	C2, C3, C4
	Vibration	F2
	Chattering	See chattering or noisy brushes
	Sluggish brush movement	C1
Indications Appearing as Heating		
Heating in windings	Severe load condition	E1, E4, F3
	Unbalanced magnetic field	C5, C6, C7, C8, D3, D4, D5
	Unbalanced armature currents	B2, C6, D1, D3, D4, D5
	Poorly equalized parallel operation	B1, B7
	Lack of ventilation	A6
Heating at commutator	Severe load condition	E1, E4
	Severe sparking	B1, B2, B3, B6, C7
	High friction	B4, B5, E5, E10
	Poor commutator surface	See specific surface fault in evidence
Heating at brushes	Severe load condition	E1, E4
	Faulty machine adjustment	B1, B4, B5, B6, D2
	Severe sparking	See sparking
	Raw streaks on commutator surface	See streaking or threading of surface
	Embedded copper	See copper in brush face

TABLE A — TROUBLE CHART (Cont)

LIST OF SPECIFIC CAUSES

A. Preparation and Care of Machine

1. Poor preparation of commutator surface
2. High mica
3. Feather-edge mica
4. Bar edges not chamfered after undercutting
5. Need for periodic cleaning
6. Clogged ventilating ducts

B. Machine Adjustment

1. Brushes in wrong position
2. Unequal brush spacing
3. Poor alignment of brush holders
4. Incorrect brush angle
5. Incorrect spring tension
6. Interpoles improperly adjusted
7. Series field improperly adjusted

C. Mechanical Fault in Machine

1. Brushes tight in holders
2. Brushes too loose in holders
3. Brush holders loose at mounting
4. Commutator loose
5. Loose pole pieces of pole-face shoes
6. Loose or worn bearings
7. Unequal airgaps
8. Unequal pole spacing

D. Electrical Fault in Machine

1. Open or high resistance connection at commutator
2. Poor connection at shunt terminal
3. Short circuit in field or armature winding
4. Ground in field or armature winding
5. Reversed polarity on main pole or interpole

E. Load or Service Condition

1. Overload
2. Rapid change of load
3. Reversing operation of noninterpole machine
4. Dynamic braking
5. Low average current density in brushes
6. Contaminated atmosphere
7. Oil on commutator or oil mist in air
8. Abrasive dust in air
9. Humidity too high
10. Humidity too low

F. Disturbing External Condition

1. Loose or unstable foundation
2. External source of vibration
3. External short circuit or very heavy load surge