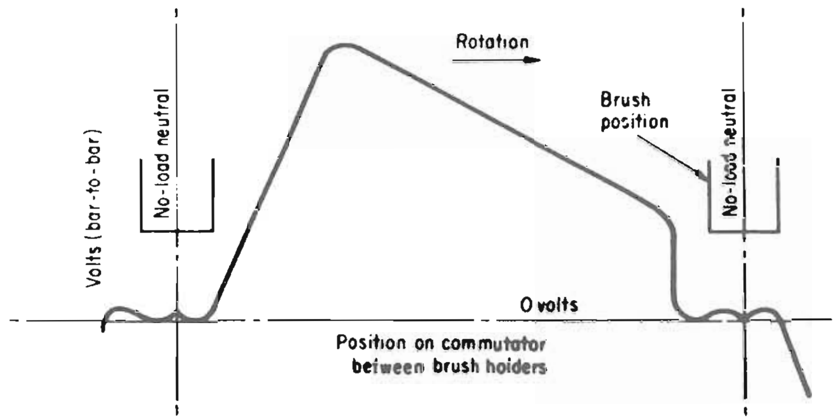
FIG. 1. Motor field-form curve



Brushes, Sparking and Machine Maintenance

"The little brush gets all the blame" is a statement commonly heard in the industry, but the blame is usually misdirected. Here are some of the common machine ailments and their cures, with hints on how to obtain longer brush life and better performance.

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THE much-maligned carbon brush is not responsible for most of the machine malfunctions attributed to it. Sparking at the brush face is usually the first symptom of trouble elsewhere.

To properly appraise and remedy the difficulties, the technician must understand what a brush is supposed to do and what special qualities it must have to accomplish its purpose.

Brush Qualities

(1) A brush must be a good conductor. In a dc machine the full load is carried through the brushes.

(2) It must assist the fields, interpoles, and compensating windings in reversing the current quickly as each pair of commutator bars pass under it. This means it must hold back current flowing in the short-circuited coil without, at the same time, appreciably interfering with the flow of useful load current.

(3) It must operate with low friction to avoid power losses and excessive commutator wear.

When we consider that the surface with which the brush is in contact is built up of many commutator bars separated by open slots and running at speeds up to two miles per minute or more, we begin to

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FIG. 2. Motor field-form curves under brushes

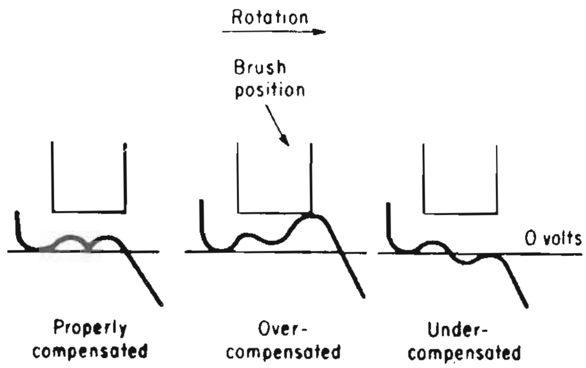
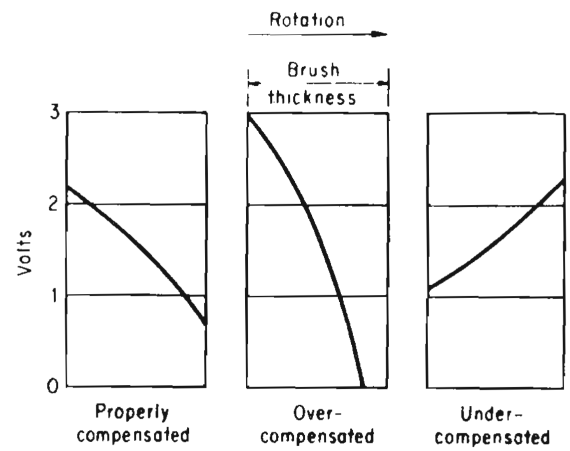


FIG. 3. Motor brush-drop curves



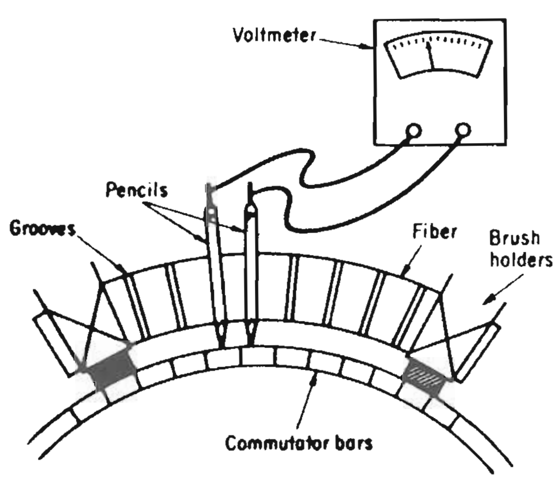
realize how difficult this job is, especially since the commutator is subject to distortion because of temperature changes and centrifugal forces and cannot be consistently maintained as a perfect cylinder.

Brushes used in the first few motors were built of copper. Before long, however, carbon brushes became standard because of their higher contact resistance, low friction against the commutator, and ability to withstand arcing.

The contact resistance or drop—the resistance offered to the flow of current between brush face and commutator surface—is normally expressed in ohms or voltage drop. It is effective in improving commutation because the load current impelled by high voltage must pass over the contact only once, while the circulating current in the short-circuited coil must pass over the contact twice and has only low voltage behind it.

Why are machines not designed so that interpoles and commutating windings take care of current reversal without any contact drop in the sliding member? This is not feasible because armature reaction varies with load and speed, and the self-inductance in the short-circuited coil cannot be eliminated by any practical design. Also, designers must make compromises to give satisfactory machine operation at minimum cost and size.

Most machines are designed so that the proper brush will give sat-



Field-Form Test

This test involves the measurement of voltages across successive commutator bars with the machine running at normal load. The readings may be taken readily using two graphite electrodes (soft lead pencils will do) insulated from each other, separated by the width of one commutator bar plus slot, and connected to a low-reading (5-volt) dc voltmeter. The pencils may be held in the hands and steadied by a piece of insulating paper (such as fiber) clamped to adjacent brush arms and cut to conform with the curvature of the armature, as shown in the sketch. Notches may be cut into the fiber to guide the pencils and insure proper separation. Readings are taken, moving the pencils around the armature between the two brushes, to provide a sufficient number of points to plot a curve such as is shown in Fig. 1, plotting voltage as the ordinate and position as the abscissa. The readings thus show the voltage between adjacent commutator bars at various points on the periphery with regard to the brush location.

isfactory commutation, good operating results, long commutator life, and reasonable brush life. But different machines have different brush requirements. That's why all manufacturers supply a number of different brush grades. Furthermore, operating conditions in industry are often not ideal; and proper machine inspection and maintenance are necesary if good operating conditions are to persist.

Sparking Causes and Cures

Following is a brief rundown of the more common causes of sparking, along with suggestions for their diagnosis and treatment.

Brush holders not equally spaced: This condition may appear as unequal sparking on different holders. It can be determined by counting the number of bars between holders or by putting a band of paper around the commutator, marking the positions of the brush toes, removing the paper, and measuring the distance between marks. *To correct, move the brush holders so that adjacent holders are all equally distant from one another.*

Brush holders off electrical neutral: Even though the holders are equally spaced, they may be out of their correct position and cause sparking which may be equally severe on all brushes of the same polarity. This fault can be detected by running a field form curve as described in an accompanying box. *The trouble may be corrected by shifting the brushes.*

Brush holders damaged or dirty: Any physical damage to the holder or an accumulation of dirt on its inside may interfere with the free motion of the brush in the holder and thus result in sparking. Since the commutator is seldom perfectly round or concentric, the brush must move in and out of its holder in order to maintain effective contact. Visual examination and testing the free action of the brush with the fingers are usually sufficient to reveal this condition. *Thorough cleaning or complete replacement will improve operation.*

Holders too far from commutator surface: If the holder is too far from the surface of the commutator, it fails to support or guide the brush properly. This may result in the brush cocking in the holder and binding, or in the brush vibrating and losing contact with the commutator. *The obvious remedy is to adjust the brush holders so that their nearest point is 1/16 in. to 1/8 in. from the commutator surface, depending on the type of machine.*

Wrong interpole strength: This may be caused by a flaw in the interpole winding such as a broken wire or short circuit, or by incorrect spacing of the pole face in relation to the armature (see above). *In either event, repair or correction may be facilitated through use of field form and brush drop curves (see test procedures described below and on the following page).*

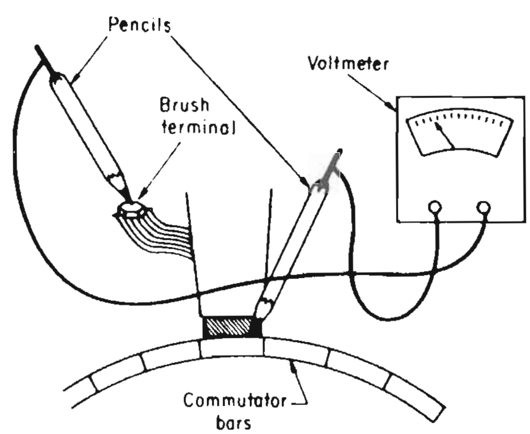
Overloads: Excessive overloads may result in severe sparking, especially if the interpoles have passed their saturation point and are, therefore, unable to increase their strength as required. If the machine has an ammeter, compare its load with the nameplate rating. *Make any load adjustments necessary.*

Underloads: Contrary to what might normally be expected, too little current flowing through the brush frequently causes difficulty. The friction apparently increases drastically at very light loads, resulting in brush vibration and very often in sparking. It sometimes becomes severe enough to break up the brushes or fray their shunts. *The remedy is to increase the load on the machine in some manner or replace it by a smaller unit. In some cases, however, the situation may be helped by changing to a high-resistance, higher quality graphite brush.*

The portion of such a curve under the brushes is the most significant, indicating the degree of compensation (correction for armature reaction). The compensation may be interpreted as shown by the three sketches of Fig. 2.

Brush Drop Test

By measuring the voltage from the brush terminal to various points on the commutator under the brush, we can plot a brush-drop curve. This curve illustrates the current distribution at the brush face and thus indicates the condition of the effective magnetic field. The same graphite electrode or pencil used for the field-form curve may be used for this test, as shown in sketch. The results are shown in Fig. 3 for proper compensation and for under- and over-compensated conditions.



Defective armature windings: Any defect in the windings may show up as sparking at the brushes. It will frequently also be apparent by one or more burned places on the commutator. Check for high-resistance connections where the risers are soldered or brazed to the commutator or for poor connections in one or more of the equalizers. Remember, though, that any other fault in the armature may also show up as sparking. *Where other tests verify an armature fault, the winding must be replaced.*

Incorrect spring pressure: Contact drop of a brush is influenced by the pressure with which it is forced against the commutator. If the pressure varies from brush to brush, those brushes carrying a higher pressure will have a lower contact drop and will tend to take more than their share of the current. This can sometimes be determined by checking the temperature of the brushes immediately after shutting down the machine. If this fault is suspected, check the spring pressure on each brush with a scale. *Adjust to the level recommended by the manufacturer.*

Poor undercutting of commutator: If the commutator has high mica or fins of mica that reach up to the brush surface, vibration and sparking may result. Similarly, any burrs of copper left as a result of the undercutting operation will cause trouble. In some locations and atmospheres, commutator slots may become filled with foreign material. This can cause the brushes to vibrate or cause ring fire by permitting current to leak through from one bar to the other. *Correction of these conditions is the solution to the problem.*

Foreign material on commutator surface: Any gummy or gritty material which sticks to the commutator surface may cause sparking. Oil may be beneficial in extremely small quantities but frequently causes gumming when used excessively. Careful examination of the commutator will usually disclose such conditions. *Thorough cleaning should be accomplished.*

Black commutator films: Abnormally dark commutators may result from sulfur, excessive humidity and other gaseous materials. This condition may cause selective action and result in sparking on the heavily-loaded brushes. *Solution of the problem may be difficult when commutator speeds are too high. A rather abrasive brush may be the answer. In other cases, frequent polishing of the commutator may be required.*

Brushes binding in holder: When brushes are not of the correct size or when brush hardware projects too far at some point, brushes may bind in their holders. Damage to holders may also cause binding. If the brushes are too tight in the holders, their proper motion will be restricted so that they cannot maintain contact with the commutator and sparking may result. If they are too small, they may wobble in the holders and thus tend to break contact with the commutator and bring about the same result. *The specific cause of binding should be determined and eliminated by repair or replacement.*

Restricted brush motion. Brush motion may be restricted because of shunt stiffness or by contact with some other member. Similarly, something may interfere with the motion of the spring itself or with the hammer by which the spring applies its pressure to the brush. *Mechanical adjustment will usually correct these conditions.*

Out-of-round commutator: The commutator may be out-of-round or eccentric because of improper finishing. As a consequence, the brush may not be able to follow the surface and maintain proper contact. Careful measurements, preferably made with the armature rotated in its own bearings, will usually disclose this defect.

High bars or flat spots: These conditions can usually be identified by careful examination of the commutator when it is not running. A high bar will usually be polished and followed by several bars which look rough and pitted or burned. The high bar will usually result in a flat spot because it lifts the brush off the commutator and the following bars may be burned so that their height is reduced. *To correct, the commutator should be ground or turned. If the trouble develops again, the commutator probably needs tightening by an expert.*

It is sometimes observed that commutators may be perfectly round when tested cold but develop a high bar in operating under conditions of speed and load. Consequently, the problem of loose bars is not always easy to diagnose.

Machine vibration: Vibration of the machine itself may cause brush sparking and eventually result in commutator damage. Such vibration may be caused by imbalance in the armature, by poor foundations or other mechanical faults. It can also result from defective bearings. *Pinpointing the cause of vibration will indicate the corrective course to follow.*

Summary

The following general order of procedure is suggested when unusual sparking is observed at the brushes:

1. Check holders for damage or dirt.
2. Check brushes for free movement within holders.
3. Check springs for freedom of action and adjust the pressure on each brush.
4. Examine commutator for indications of high mica, mica fins, or "slugged" slots.
5. Examine commutator for blackened, pitted, or burned segments or areas.
6. Check the commutator for roundness and for bar-to-bar deviations.
7. Examine risers at end of commutator for indications of poor contact.
8. Run the machine at its usual load and take data for a brush-drop or field-form curve, as explained herein.
9. Examine brushes visually and tactually for vibration. (A piece of insulating material held on top of the brush is a safe way to feel its action.)
10. Check the bearings for excessive vibration.

These tests may indicate the cause of the sparking and suggest the remedy. If they do not, or if available facilities do not permit correction of the indicated difficulty, the machine manufacturer should be consulted.