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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 14 MISSION

INABILITY TO DISCONNECT MAIN BUS A

ANOMALY REPORT 2

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

December 1971

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STATEMENT

During entry, the Apollo 14 spacecraft busses should have de-energized when the main bus-tie motor switches were switched to the "off" position. One motor switch did not transfer and main bus A remained energized until the battery bus-tie circuit breakers were opened after landing.

DISCUSSION

The motor switch consists of a dc motor, gear train, cams, power contact assembly, and motor control switch (fig. 1). These components are enclosed in a hermetically sealed container and are controlled by an external panel switch. When the panel switch (main bus-tie battery A/C) is placed to the "off" position, the motor will drive the gear train until the internal motor control switch shifts from the "off" position to the "on" position as shown in figure 2. At this point, power is removed from the motor.

The motor switch stalled at a position just before the transfer point of the internal motor control switch. The main power contacts were closed and the contact springs were applying their maximum load through the cams and the gear train to the motor (fig. 1). With the motor control contacts closed and the motor stalled, motor current increased to about 8 amperes (twice normal). Consequently, the motor windings fused open. Since the main power contacts were still closed, main bus A remained energized (figure 2).

An identical motor switch failure occurred during tests of the Apollo 15 command and service module at the launch site. Another motor switch on the Apollo 15 vehicle required 100 milliseconds to transfer; whereas, normal transfer time is 50 milliseconds. A motor current signature was taken for one switching cycle of the slow-operating switch and compared to a similar signature taken prior to delivery. The comparison revealed degraded and erratic contact resistance between the brushes and commutator. Figure 3 shows current signatures for a normal switch and one which operates slowly. In all three cases, the gear train, cams, internal control switch, and power contact assembly were completely normal.

Tracks of black deposits were found on the commutator, of the three motors (fig. 4). The deposits contained brush material (carbon and silver), organic silicone and bearing oil. Furthermore, the brush terminal pin seals which insulate the terminal pins from the bearing retainer plate (fig. 5) had reverted to a gummy state in all three motors.

The brush terminal pin seals were molded from silicone rubber by the switch manufacturer and the rubber was properly cured at room temperature. However, the seals were not subjected to a post-cure forced air bake at 185° F, as recommended by the rubber manufacturer to remove the residual rubber catalyst. If the residual catalyst is not removed, the rubber gradually reverts to a gummy state. Tests showed that when the reversion products from the seals were introduced on the surface of the commutator and the motor operated, deposit buildup and increased contact resistance occurred. When the reversion products were absent, neither deposit buildup nor increased contact resistance occurred.

A total of 13 motors have been examined for gummy terminal pin seals. Of these, all had gummy seals. Eleven had the commutator deposits and displayed longer-than-normal transfer times and abnormal motor current signatures. The remaining two which had no commutator deposits had normal motor current signatures and normal contact transfer times.

CONCLUSIONS

Residual catalyst caused the terminal pin seals to revert to a gummy state. Resulting reversion products then migrated to the motor commutator and caused brush degredation, increased and erratic commutator resistance, and reduced motor torque. The motor stalled when available motor torque was reduced below that required to drive through the maximum torque point of the switch.

CORRECTIVE ACTION

Motor operating current traces are useful in detecting switches which are developing high contact resistance; consequently, for Apollo 15, 16, and 17, and Skylab spacecraft, current traces will be taken for each motor switch. Any switch displaying degraded motor-commutator resistance will be replaced.

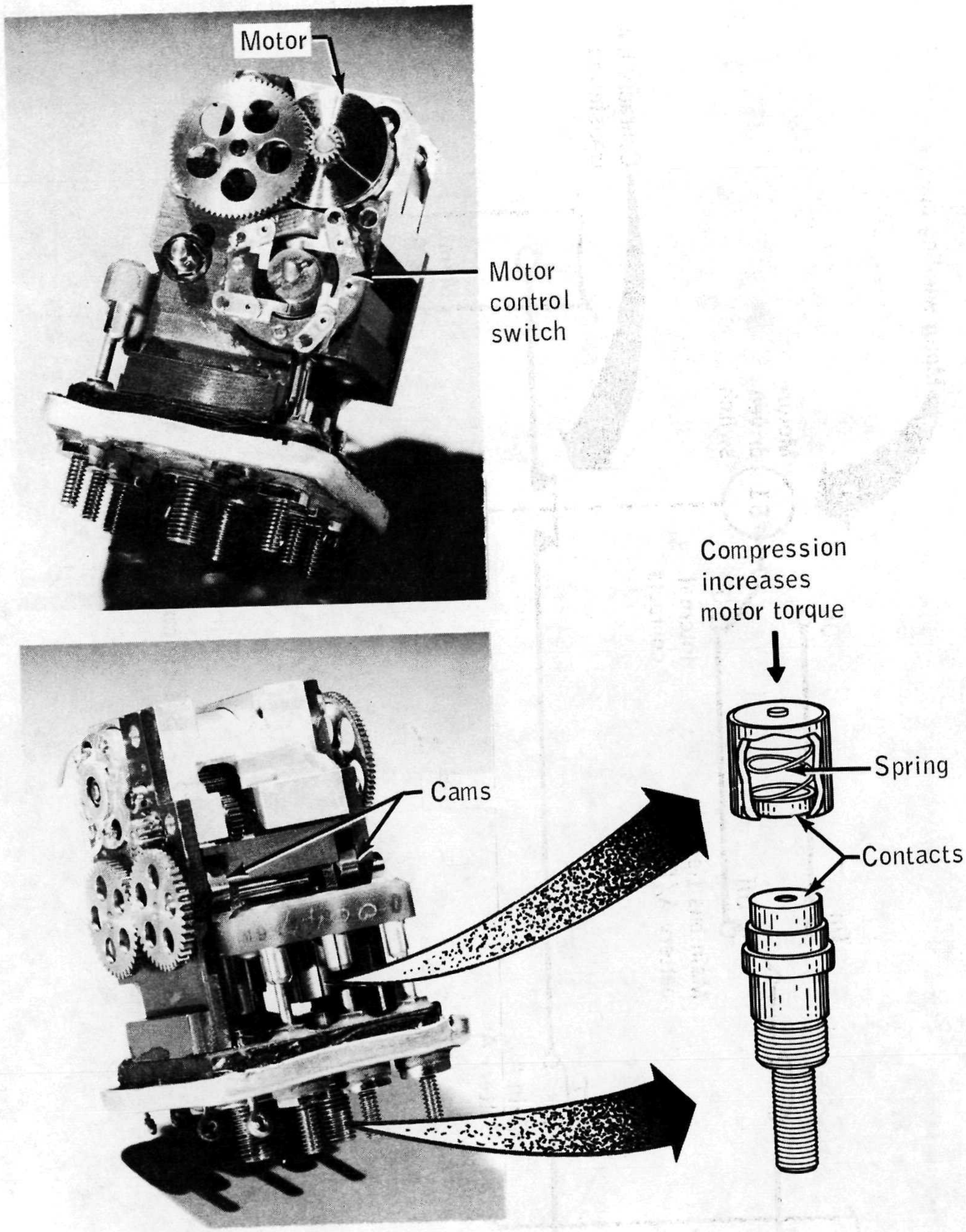

Figure 1.- Motor switch assembly.

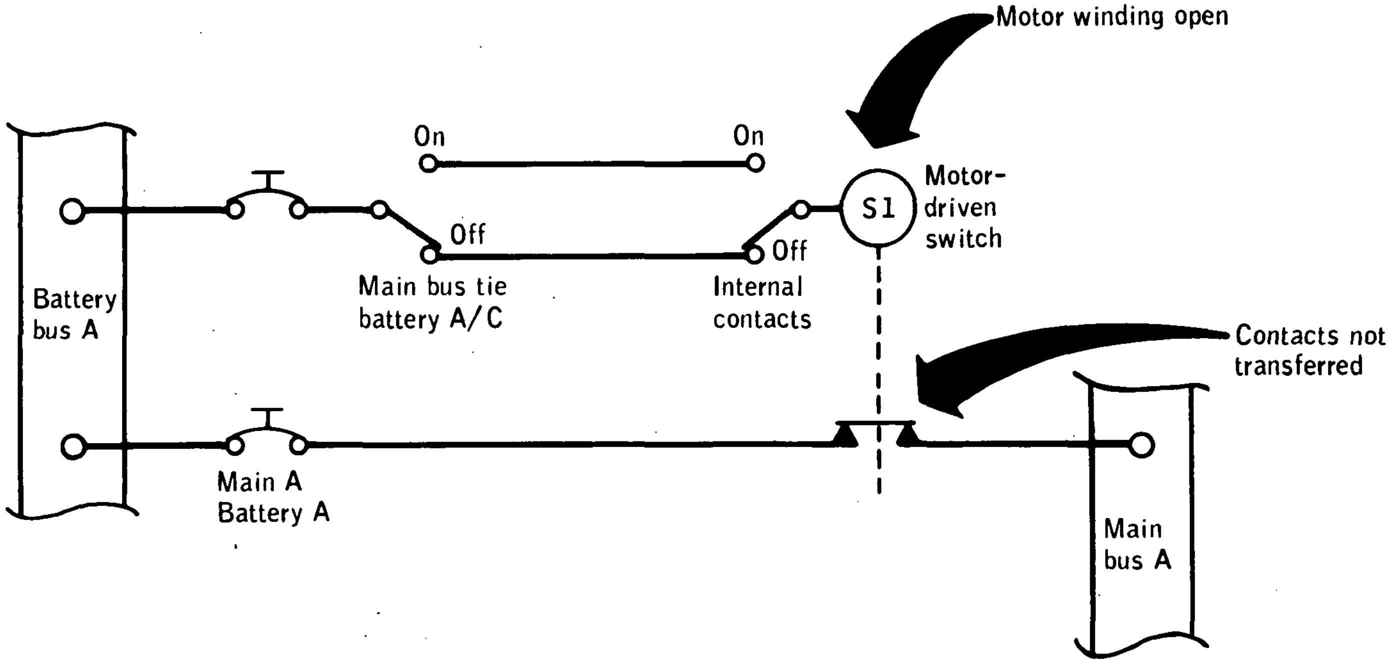

Figure 2.- Bus-tie circuitry.

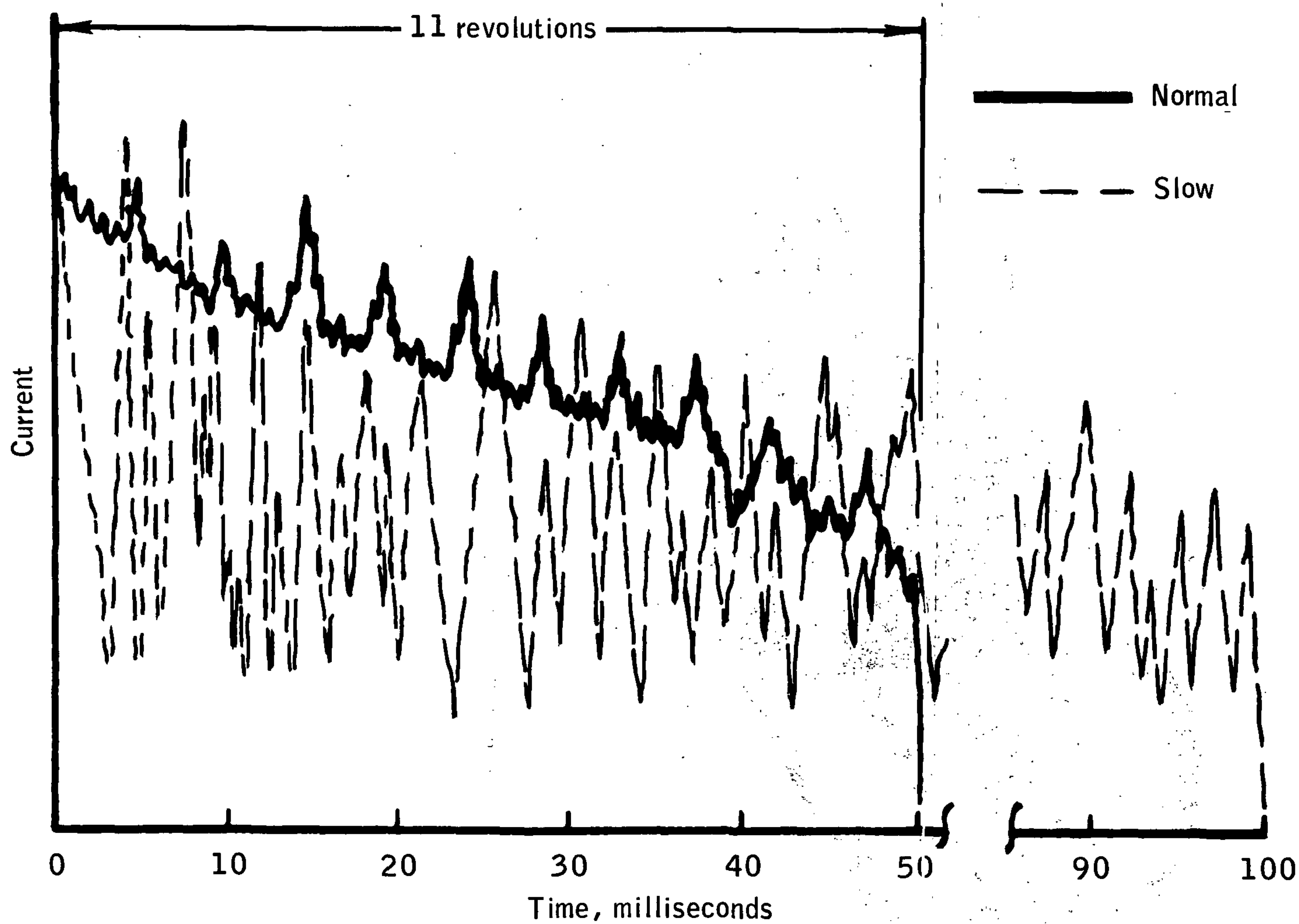

Figure 3.- Comparison of normal and slow motor traces.

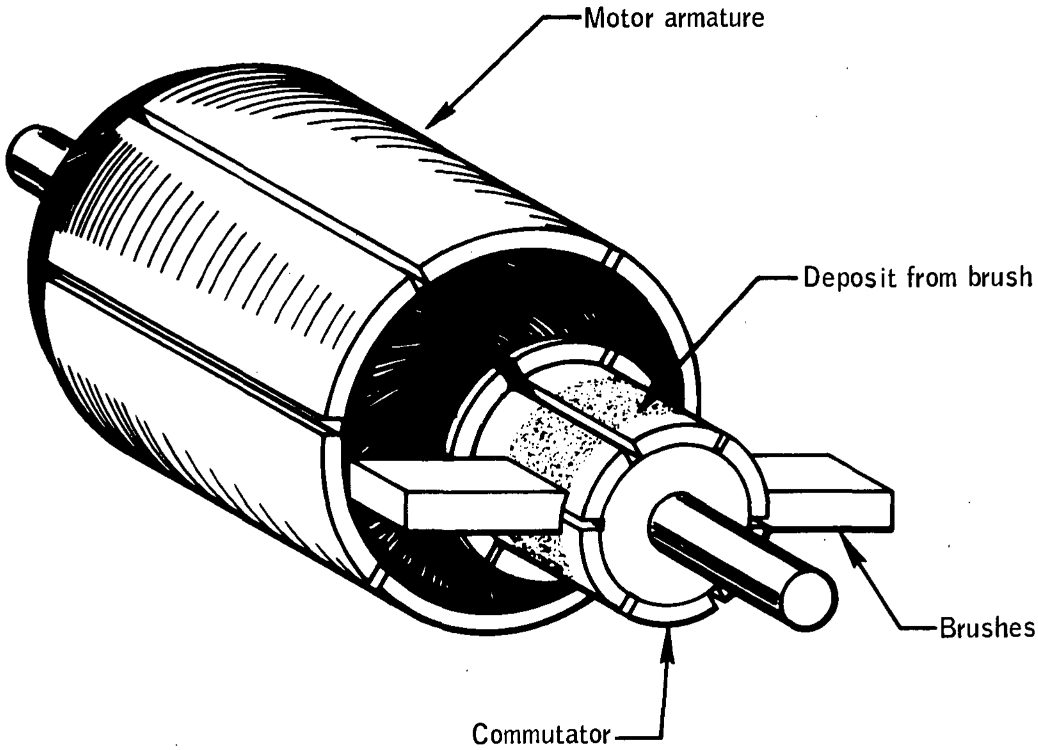

Figure 4.- Brush deposits on commutator.

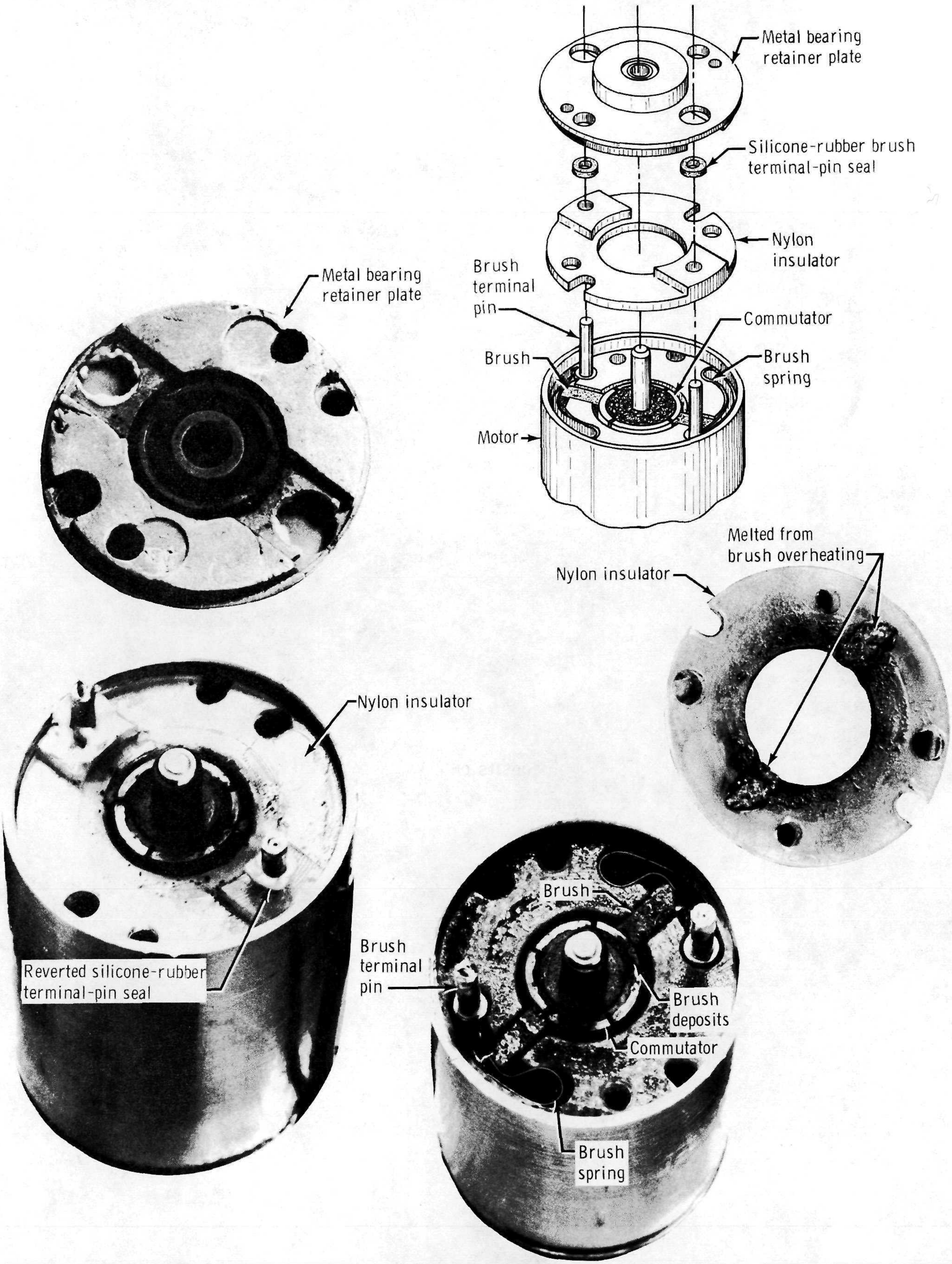

Figure 5. - Motor brush assembly.