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MAINTENANCE CONCERNS

Increasing Brush Life & Motor Performance with Good Maintenance Practices

Abstract - Successful long-term operation of dc motors and generators, like any piece of industrial equipment, needs maintenance. Scheduled periodic visual inspections and the recording of this data is valuable information when reviewing that machines' performance. These written inspection reports will perform much better than the memory of the maintenance technician or supervisor when questioning the performance history of a certain piece of equipment. A generic inspection record format is included along with guidelines to help make decisions on the health status of these motors. This paper will expand on 10 major items of concern for successful long-term operation of dc machines.

INTRODUCTION

The major areas of concern for successful long-term operation of dc motors that will be discussed are:

- Keep motor relatively clean, both inside and out
- Provide good quantity of ventilating air
- Provide good quality of ventilating air
- Provide good quality power
- Keep vibration to a minimum
- Maintain a good commutator condition
- Adjust quantity or grade of brush to be suitable for the application
- Inspect brushes regularly to obtain a wear history
- Do not use silicone sealant to make the motor watertight
- Do not over lubricate and remember to remove the grease drain plug during regreasing

KEEP EQUIPMENT CLEAN

Keeping both the outside and inside of dc motors relatively clean does have its benefits. Motors dissipate some of their heat through the outside surfaces of the frame. Accumulation of dirt can lessen the efficiency of this process and make the motor operate hotter than it would otherwise.

Occasionally blowing out and vacuuming motor interiors are good practices to eliminate excessive buildup of carbon dust (which is conductive and could lead to flashovers) and other particle contamination. Dry dirt or dust should first be vacuumed with the use of a soft bristle brush so that large accumulations can be easily loosened. Oily dirt makes the cleaning process more difficult because of the sticky nature and resistance to being vacuumed or blown loose. In these cases, a cloth dampened with solvent can be used to remove this oily buildup. Solvent cleaning by means of a soaking or flooding method is definitely not recommended. More harm than good can result by this method since conductive contamination can wick into small insulation cracks and actually be driven deeper into the windings with the help of capillary attraction. Solvent cleaning of individual motor parts like brush holders or springs can be done outside the motors without any harm. However, flood type solvent cleaning of commutators or varnish insulated coils should not be performed.

Large motors that have open type commutator risers should have those areas flushed with high velocity, clean, dry air stream to blow out carbon dust and stop possible comm. damage from creepage current flowing through the accumulations of this dirt. Megger reading have been known to change from 0.5 to 20 megohms just by performing this procedure alone. Realize though that inadequate cleaning can sometimes lead to uneven distribution of dirt and possible vibration caused by excessive unbalance. Blown dirt can sometimes settle in previously cleaned areas. It is therefore a good idea to go over some areas twice to ensure a thorough job. Fiberglass band construction is used on some larger motor and generator commutators. It is strongly recommended that liquid solvents not be used for cleaning these types of commutators.

Commutators can also benefit from blowing out particles that have lodged in the undercut area between individual commutator bars. This process is called AIR CURING and involves directing clean pressurized air towards the commutator as it revolves. Caution must be used in directing the air through a non-metallic hose while increasing the motor voltage in 10% increments and wearing appropriate safety equipment. If dirt still remains in the undercut area and sparking is resulting, then mechanically cleaning out each slot

may be necessary followed again by the AIR CURE process. Cleaning the film off the commutator surface should be done with a medium soft white abrasive stone called a SEATER STONE. These are available from many suppliers of electrical motor repair parts.

Remember that constant cleaning of the commutator film should not be necessary and that the commutator when in use should not look like a shiny new penny. It should look like a penny that's been lying outside for 6 months and has a nice chocolate brown oxidized color.

PROVIDE GOOD QUANTITY OF VENTILATING AIR

Motors of recent manufacture require much more ventilating air than the same rating made a few years ago. Motor manufacturers are always in the race of trying to reduce costs and reduce weight while supplying the most horsepower in the smallest package. Heat produced from the internal motor losses has not lessened so the ventilating air requirements are greater.

Motors that are force ventilated have their air requirements listed on the motor nameplate in CFM and inches of water pressure. These are the minimum values for the proper volume of air and the pressure required to force that much air through the motor. Air flow should not be reduced unless the actual operating load is substantially less than the nameplate rating. Small motors approximately 500 hp or less, usually need to have their air temperature rise limited to 30 degrees C while motors larger than 500 hp should have their air rise limited to 25 degrees C. Air rise for separately ventilated motors is the difference between the temperature of the exhaust air and the inlet air.

Blower ventilated motors also need a good supply of cool air and should not be mounted in such a manner that the blower is recirculating a large portion of its already heated exhaust air. The same air rises as stated above still apply and can be an indicator for blowers that are running backwards or dirty blower wheels or dirty filters that restrict air flow.

Blowers that supply cooling air for motors are usually of the type that can fool you into thinking that they are operating properly when they are actually running backwards. These blowers are actually air pumps and will pump air even though they're going the wrong direction. When running the wrong direction the air flow is only about 1/3 of the required amount. If the dc motor is operated under this reduced air flow condition, shortened insulation life is sure to result or even a total roast-out.

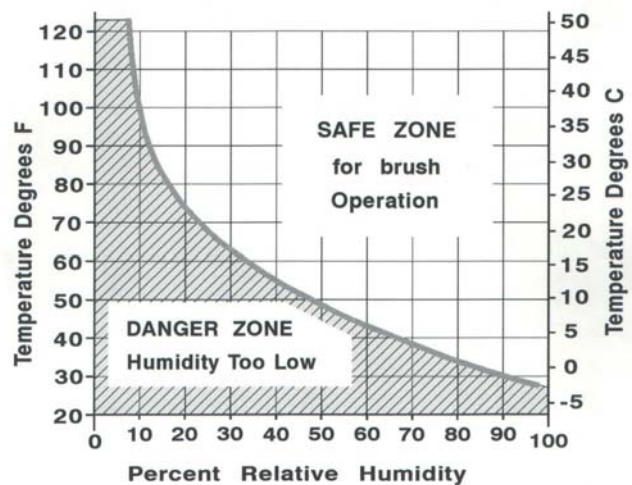
Enclosed motors like TENV or TEFC also need a good supply of free ambient air to properly dissipate their heat. Special considerations need to be made when motors are

mounted within a confined space or within another air restricting enclosure.

PROVIDE GOOD QUALITY VENTILATING AIR

Cooling air for ventilated motors must be clean, contaminant free with a relative humidity between 40% and 99% and be in the temperature range of 10 to 40 degrees C. To avoid condensation in the machine, the dew point of the air should be lower than the minimum surface temperature of any upstream air cooler. For good brush life the air absolute humidity should have at least 2 grains of water per cubic foot of dry air. See Fig. 1.

HUMIDITY and Brush Life



The curved line represents 2 grains of water per cubic foot of dry air or 4.6 grams per cubic meter.

Fig. 1

Filters are sometimes used to keep out dirt, cement dust, sand or sawdust, which can restrict cooling passages within the motor and cause over temperature. These filters can range from multiple layers of expanded metal, fiberglass material or self-charging electrostatic material. Regardless the type, they need to be inspected regularly and cleaned as necessary to insure proper air flow through the motor. Abrasive dusts, which can cause short brush life, commutator grooving or eroded insulation, also need to be eliminated or filtered out of the ventilating air.

Chemically contaminated air can have an extreme effect on machine performance and service life. Since copper is a reactive metal, severe chemical contamination can actually

cause a scale to build up on the commutator where the brushes don't contact. The buildup can be severe enough to short adjacent commutator bars causing sparking and possibly flashover. These chemical vapors can also cause high friction and uneven films to develop on the commutator, which reduces brush life. Relocation of blower inlets to obtain fresh outside air or charcoal filters can be used to improve air quality.

Analysis of industrial environments for corrosive agents is usually done by subjecting a copper or silver environmental test coupon in the immediate area of concern. After exposure for 1 to 3 months, the coupon can be analyzed for corrosion rates, and the result returned in written report form. Major motor OEM's have shown through field experience that **annual** corrosion rates of motor cooling air need to be **0.5 microns or less** for satisfactory brush and commutator operation. The cost of this analysis is usually \$200 to \$250 per coupon and needs to be done by specialists in the field of air filtration or air quality.

Motors operating in outdoor or damp moist environments should have space heaters or have their fields energized at 50% voltage. This should be done so the resulting heat can protect against condensation when the motor is not operating.

PROVIDE GOOD QUALITY POWER

Most motors are operated on adjustable voltage SCR power supplies, which have become quite reliable in the past few years. However, SCR operation results in increased motor heating and degraded commutation. These negative effects result from the ac components of voltage and current superimposed on the dc values.

The common types of SCR power supplies are usually identified by letter codes: A, C, D, E and K with the lower letters in the alphabet having the lower magnitudes of ripple current. This means that a motor rated and designed for a D power supply could be used with a C power supply but not an E, unless external inductance is added to the armature circuit to reduce the amount of ripple current.

As mentioned earlier, these SCR power supplies are quite reliable but do occasionally fail. This causes unbalanced or totally missing pulses during operation, which increases the amount of current ripple and could be the cause for increased motor sparking. This is mentioned because the brushes or motor itself are usually the first objects of suspicion when increased sparking is observed.

Some SCR systems and dc motors have differences in their complete power system circuit that cause voltage spikes. When such spikes are over 10 volts peak to peak they usually cause motor bearing to fail prematurely. These voltage spikes can only be seen or measured with an oscilloscope. The exact cause of this phenomenon is still not fully understood today and the only cure has been to add a shaft grounding brush to the motor. This does not eliminate the voltage but rather shunts it to ground through the grounding brush instead of going through the motor bearings where it causes a fluted pattern on the bearing raceways and rolling elements. A silver

graphite or copper graphite brush grade is usually used for these shaft grounding brushes.

VIBRATION KEPT TO A MINIMUM

Most new motors generally have less than 0.0015 in. of vibration for the motor itself as required by NEMA. Once the motor is mounted and coupled to the driven equipment, operating vibration for machines operating less than 2000 RPM should be limited to 0.002 in. displacement or 0.08 in./sec. velocity for long-term trouble free operation. Higher speeds would require less displacement.

Two problem areas with vibration once the motor is mounted are proper key lengths and coupling misalignment. Motors when new are balanced with a full length, half height key. When couplings are added, the key length needs to be 1/2 the full length motor keyway plus 1/2 of the coupling bore length to preserve the original balance. See Fig. 2 for proper key length calculation.

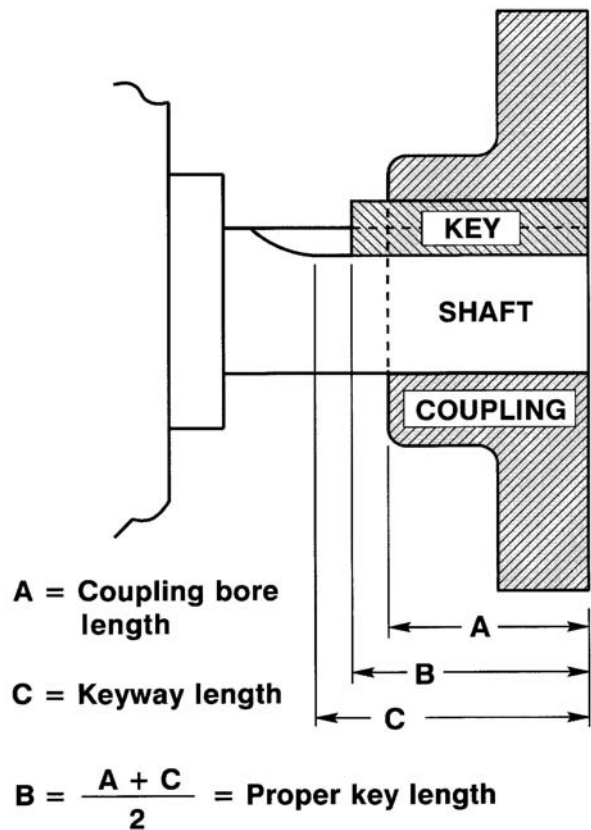


Fig. 2 KEY LENGTH CALCULATION

Many flexible couplings can tolerate large amounts of misalignment and still transmit their rated torque according to the coupling manufacturer's specifications. However, as far as the effects of this misalignment on the motor bearings, brushes and commutator, misalignment should also be limited to 0.002 in.

MINIMAL COMMUTATOR RUNOUT

To understand the importance of minimal commutator runout we first need to understand that brushes are stationary and they conduct current to a revolving commutator surface. The commutator surface is also never perfectly round and is usually traveling at a rate of 40 MPH (3,500 FPM). Also, larger dc motors greater than 50 hp, typically get about 200,000 miles or more brush life.

Brush life depends on the commutator surface being as smooth and true as possible. This insures good contact can be maintained between the brush and the commutator. When a commutator surface is excessively rough and brushes start

to bounce, then sparking (current being conducted through air) occurs. This damaging arcing process continues with each revolution. See **Table I** for commutator situation indicators. Unfortunately, commutators do not possess any self-healing properties. They need the help of some kind of resurfacing tool to bring them back to good health or acceptable runout.

TABLE I

COMMUTATOR SITUATION INDICATORS

Situation	Runout (TIR)	Bar-Bar Variance	Undercut Depth
New	Less Than 0.0015	Less Than 0.0002	0.050 or more
In Service	Less Than 0.003	Less Than 0.0003	0.020 or more
Needs Repair	More Than 0.003	More Than 0.0003	0.010 or less

TIR = Total Indicator Runout. Above values are in inches

Tabulations are listed at the end of this paper showing new and minimum commutator diameters for the more common makes and frame sizes of dc motors. Commutators can be turned or trued many times before they are at their minimum recommended diameters. A typical commutator could possibly last more than 20 years if properly maintained.

Sparking can have different causes other than excessive commutator runout. There are many other mechanical and electrical causes but for motors that have been in service for a few years, the condition of the commutator can be easily checked with a feeler stick. A feeler stick is an insulating material, usually about 12 inches long and 1/4" to 5/16" in diameter and sharpened like a pencil. This stick can then be placed on top of the brush, while the motor is running, to feel the commutator condition as it revolves. One can easily tell what feels acceptable and what it not. **NOTE: Please use whatever personal or company safety guidelines necessary to prevent injury from live electrical and rotating parts.**

NUMBER & GRADE OF BRUSH SUITABLE FOR THE APPLICATION

The quantity, grade and size of brush chosen by the motor manufacturer are based on the nameplate rating. In the case of a 200 hp motor, rated for continuous duty, the OEM selects brushes figuring this motor is to be used at or near the full load nameplate rating.

Unfortunately, many motors once installed and running in their application, are operating far below their nameplate rating. A 200 hp motor might be operating at only a 90 hp load. At first thought you might think this is better for the motor and will extend its life. You might also think that it may extend its thermal life since it's running much cooler. However, the current density in the brushes needs to be examined for optimum brush and commutator life. See **Fig. 4** for proper equations.

The most common brush grades used today for industrial size motors are electrographitics, EG abbreviated. In general, most EG's have a maximum current density of about 80 amps per square inch (APSI). However, they all have a "preferred operating range" and this is usually in the 40 to 80 APSI. Continuous operation below the 40 APSI point will usually start a destructive commutator condition called threading. This condition occurs because there is not enough current flow in the brushes and enough heat to establish a good commutator film. Threading on a motor commutator appears initially as fine grooves and looks like machined threads of a screw. This happens because small copper particles become trapped in the brush face. These trapped particles are work hardened and machine fine grooves just like a lathe tool.

The commutator film forms through an electro-chemical process. The electro portion of the process means that it needs the proper value of current, which for EG grades is in the range of 40 to 80 APSI. The chemical portion of this film forming process is the chemical reaction of the copper commutator bar, the carbon brush, the chemical treatments in the brush, the temperature of the commutator and brush and the environment that surrounds the commutator and brush. Chemical contamination of the environment surrounding the copper commutator can disturb the way the copper is oxidized and can drastically change the appearance of the film. As previously mentioned, even simple humidity is important for good brush life.

For motors running continuously at light loads, insuring good film formation on the commutator may be as simple as changing the brush to a graphite grade. Graphite brush grades operate successfully at lower APSI. In general, graphite grades have a good operating range of 10 to 50 APSI. Short time overloads or acceleration currents also need to be taken into consideration but most brush grades can be overloaded to twice their rated continuous APSI for 2 to 3 minutes. Large motors running at extremely light loads might need a combination of reducing the number of brushes per brush stud and changing the brush grade.

The above maximums and preferred operating ranges are stated in average numbers. If your problems are current density related, please consult your brush supplier for specifics on the grade that you are using. Be sure to have your specific motor application and operating data available for discussion.

To calculate the BRUSH CURRENT DENSITY or APSI (amps per square inch) you must know or measure the operating current in amps, the number of brushes, the brush thickness (T) and brush width (W). Brush T x W = cross sectional area. Dimensions are in inches.

$$\text{CURRENT DENSITY (DC MOTOR)} = \frac{\text{AMPS}}{\frac{1}{2} \# \text{ BR} \times \text{T} \times \text{W}} \quad (1)$$

$$\text{CURRENT DENSITY (SLIP RING)} = \frac{\text{AMPS}}{\# \text{ BR} \times \text{T} \times \text{W}} \quad (2)$$

Example: 100 HP DC Motor rated 500 Volts, 163 Amps and has 8 brushes .625 Thick x 1.25 Wide.

$$\text{CURRENT DENSITY} = \frac{163}{\frac{1}{2} (8) \times .625 \times 1.25} = 52.16 \text{ APSI}$$

Fig. 4 CALCULATING BRUSH CURRENT DENSITY

INSPECT BRUSHES REGULARLY TO OBTAIN A WEAR HISTORY

Brushes for industrial size motors usually last a few thousand hours when operating conditions are properly controlled. Inspecting brushes and recording their lengths and or dates changed can yield valuable information when evaluating suspected motor or brush problems.

Fewer maintenance people are typical these days and the probability of one individual inspecting the same motor each time is slim. Hence, answering the question; How long do the brushes last? would only be a guess if not for good inspection and maintenance records. Comparing brush wear to commutator runout or machine vibration would show definite wear histories if the information was available.

Some industries or processes do not have the luxury of frequent brush inspections or regularly scheduled shut-downs. In such instances brushes are probably changed before they are fully worn out. This fail safe method is sometimes necessary to eliminate the possibility of costly motor damage or unscheduled stops in production. However, if regular inspection can be made, here are some rules of thumb to know when brushes are worn out:

Brushes need to be replaced when the spring has run out of travel and no longer sufficiently pushes the brush towards the commutator surface. This can sometimes be overlooked since the brush itself looks as though there is still wear length available. Brushes also need to be changed before any hardware like clips, rivets or shunt material makes contact with the commutator or slip ring.

If wear bands are crimped on the brush shunts, these can be an indicator for brush replacement when this band approaches the top of the brush holder.

Many OEM motor manufactures list the minimum brush length in the Instruction Book or maintenance manual that comes with the motor.

If wear lines are shown on the brush, replacement is needed before the last wear line is reached.

Brushes need to be replaced if past history shows that the minimum brush length will arrive before the next scheduled shutdown or maintenance inspection.

Brushes are the most expendable item in dc machines and their replacement is usually far less expensive than the repair of the commutator, lost production and overtime maintenance efforts.

Figs. 5 and 6 are examples of Inspection forms, which are quite detailed but may serve as a starting point for you to create a form tailored to your needs.

DO NOT USE SILICONE SEALANT TO MAKE THE MOTOR WATERTIGHT

The use of silicone near dc motors will cause rapid brush wear. Just a few parts per million can cause wear to be 10 times normal. Most motor OEM's warn that silicone vapors interfere with commutation and high brush wear may result. Silicone vapors may originate from sealing compounds, electrical insulation, bearing grease and other ingredients to certain manufacturing processes. These sources must be eliminated if good overall motor performance is expected.

There are a few theories of how and why silicone vapors cause the rapid brush wear and most are not widely accepted or always understood. One should just rely on the testimony of many who have witnessed silicone's effect on brushes, both in the test lab and in customer's plants, and follow their recommendation not to use it. Even some well cured silicone insulations, when heated, will continue to give off enough vapors to cause problems.

Low cost, wide availability and overall good performance in other applications make silicone caulking very tempting for sealing motor covers to make them watertight or sealing ventilating ducts to make them leak free. Sealants for these kinds of motor use needs to be restricted to non-silicone products. Urethanes, polyurethanes or elastomeric adhesive sealants are recommended for use around brush type motors.

DO NOT OVER LUBRICATE AND REMOVE THE GREASE DRAIN PLUG DURING REGREASING

Many times while making brush inspections, one may notice an accumulation of grease around the inner bearing cap and the commutator end shaft. This is usually caused by a greasing program where someone is adding a few pumps of grease to the motor's lubrication fitting every couple of weeks but never removes the grease drain plug during this process. Once the grease cavity is full, and since the grease does not actually get used up, the grease gun will force the grease to extrude between the small running clearance between the shaft and inner bearing cap. This is not the procedure recommended by motor OEM's .

Bearing manufacturers and motor OEM's usually recommend regreasing at much longer time intervals and actually purging the grease cavity of the old grease by pumping in a large volume of new grease. Removal of the grease drain plug during this procedure is necessary so that excess grease will not enter the motor and possibly contaminate the commutator surface or motor insulation. Allowing the drain plug to remain open during the first 10 or 15 minutes of motor operation will help in expelling grease that has overfilled the area between the inner and outer races.

Most OEM's base their relubrication interval on the type of duty the motor is subjected to. Some bearing manufacturers have gotten a little more scientific with charts that show relubrication intervals in hours based on bearing size, type and the average RPM. Bearings rarely fail from under lubrication but more frequently fail from over lubrication, overload, misalignment, contaminants or faulty installation procedures.

Some motors have shielded or sealed bearing which are said to be "Lubed for Life". This usually means lubed for the life of the bearing, which is typically many thousands of hours or millions of revolutions. Shielded bearings can still benefit from packing the grease cavity in an attempt to help keep out water or contaminants.

CONCLUSION

Visually inspecting and recording the information as suggested above will serve well to diagnose motor problems or ascertain good operating health of dc motors in your plant. Also, in the case of new construction or retrofits, designing room around the motor to easily make these inspections will ultimately mean more complete reports, easier brush changes and happier technicians.

Customer & Location			
Application or Service		Date :	
Motor Manufacturer		HP =	
Model # & Frame size			
Serial #	NAMEPLATE RATING	ACTUAL OPERATING VALUE	
Armature Volts			
Armature Amps			
CCW or CW RPM			
Field Volts			
Field Amps			
Brush size (T x W x L)			
Brush quantity (Full set / in use)			
Min. recommended brush length			
Previous known brush life		Br. Part # =	
Present brush grade DO NOT MIX			
Calculated Current Density			← Nameplate vs Actual
Commutator Runout (TIR)			.003 Maximum
Comm. Profile recently taken ?		Printout attached ?	
Ambient Temperature			
Air inlet & Air exhaust temp.			
Filter appearance / last changed			
Relative Humidity (average)			
Measured Spring Force (lbs)		Calculated Brush Pressure	PSI
Sparking during operation			
Vibration measurements H V A			Drive End
Vibration measurements H V A			Comm End
Motor duty cycle HRS / DAY/WK		Has it recently changed ?	
Silicone caulking in use			
Measured armature endplay			
Commutator appearance : Grooved, Threaded, film color Dull, Shiny, Burned pattern			
	Date last Turned or resurfaced = :		
Brush appearance : Arcing evidence, burnt, fully seated Shunts : frayed / burnt / corroded			
Brush holder condition		Radial, Stubbing, Trailing ?	
Brush holder height above comm		.07" preferred, .10 Maximum	
Equal brush spacing within .05"		Approx. Comm. Dia. =	
Excessive grease inside motor			
Operating atmosphere dusty, oily			
Recent environmental changes			
COMMENTS : Feeler Stick Feel Unusual wear pattern, Failure history			
RECOMMENDATIONS:			

H V A = Horizontal, Vertical and Axial

Fig. 5 Motor and Commutator Inspection Form / Brush Analysis Questionnaire

Customer & Location			
Application or Service		Date :	
Motor Manufacturer		HP =	
Model # & Frame size			
Serial #	NAMEPLATE RATING	ACTUAL OPERATING VALUE	
Armature Volts			
Armature Amps			
CCW or CW RPM			
Field Volts			
Field Amps			
Brush size (T x W x L)			
Brush quantity (Full set / in use)			
Min. recommended brush length			
Previous known brush life		Br. Part # =	
Present brush grade DO NOT MIX			
Calculated Current Density			← Nameplate vs Actual
Slip Ring Runout (TIR)			.003 Maximum
S.R. Profile recently taken ?		Printout attached ?	
Ambient Temperature			
Air inlet & Air exhaust temp.			
Filter appearance / last changed			
Relative Humidity (average)			
Measured Spring Force (lbs)		Calculated Brush Pressure	PSI
Sparking during operation			
Vibration measurements H V A			Drive End
Vibration measurements H V A			Comm End
Motor duty cycle HRS / DAY/WK		Has it recently changed ?	
Silicone caulking in use			
Measured armature endplay			
Slip Ring appearance : Grooved, Threaded, film color Dull, Shiny, Burned pattern		Slip Ring Material =	
Brush appearance : Arcing evidence, burnt, fully seated Shunts : frayed / burnt / corroded			
Brush holder condition		Radial, Stubbing, Trailing ?	
Brush holder height above S Ring		.09" preferred, .12" Maximum	
Slip Ring Material & Diameter		FPM =	
Excessive grease inside motor			
Operating atmosphere dusty, oily			
Recent environmental changes			
COMMENTS : Feeler Stick Feel Unusual wear pattern, Failure history			
RECOMMENDATIONS:			

H V A = Horizontal, Vertical and Axial

Fig. 6 Motor and **Slip Ring** Inspection Form / Brush Analysis Questionnaire

GE Motor Commutator Diameters

Frame Designation	New Diameter (inches)	New Diameter (mm)	Minimum Dia. (inches)	Minimum Dia. (mm)
CD140AT	3.50	88.9	3.32	84.3
CD180AT	2.76	70.1	2.62	66.5
CD210AT	4.50	114.3	4.27	108.5
CD250AT	5.00	127.0	4.75	120.7
CD2512/13	5.30	134.6	5.02	127.5
CD280AT	5.78	146.8	5.49	139.4
CD2812/13	5.96	151.4	5.66	143.8
CD320AT	6.50	165.1	6.17	156.7
CD360AT	7.50	190.5	7.13	181.1
CD400AT	8.32	211.3	7.92	201.2
CD500AT	10.25	260.4	9.75	244.7
CD580	10.75	273.1	10.25	260.4
CD680	12.50	317.5	12.00	304.8
CD4300	11.50	292.1	11.00	279.4
CD4400	13.00	330.2	12.30	312.4
CD4500	15.00	381.0	14.25	362.0
CD4600	18.00	457.2	17.10	434.3
CD4700	22.00	558.8	20.90	530.9
CD5000	14.50	368.3	13.88	352.6
CD6000	11.50	292.1	11.00	279.4
CD6100	13.00	330.2	12.30	312.4
CD6200	15.00	381.0	14.25	362.0
CD6700	19.50	495.3	18.50	469.9
CD6800	22.00	558.8	21.00	533.4
CD6900	22.00	558.8	21.00	533.4
CD9000	22.00	558.8	21.00	533.4
MD802	6.38	162.1	6.00	152.4
MD803	7.12	180.8	6.75	171.5
MD804	7.88	200.2	7.50	190.5
MD806	7.88	200.2	7.50	190.5
MD808	9.00	228.6	8.50	215.9
MD810	10.00	254.0	9.44	239.8
MD812	11.25	285.8	10.62	269.7
MD814	12.50	317.5	11.88	301.8
MD816	14.50	368.3	13.75	349.3
MD818	16.00	406.4	15.25	387.4
MD820	17.00	431.8	16.25	412.8
MD822	19.50	495.3	18.62	472.9
MD824	19.50	495.3	18.62	472.9
MD828	22.00	558.8	21.12	536.4

Fiberglass bound commutators have reached their minimum diameter when there is not enough copper above the bands to allow undercutting without cutting these bands.

Reliance Motor Commutator Diameters

Frame Designation	New Diameter (inches)	New Diameter (mm)	Minimum Dia. (inches)	Minimum Dia. (mm)
DB&DC180ATZ	3.01	76.5	2.62	66.5
B&C180ATZ	4.12	104.8	3.66	93.0
B210ATZ	4.38	111.1	3.93	99.8
C210ATZ	5.03	127.8	4.59	116.6
DC210ATZ	3.01	76.5	2.62	66.5
B250ATZ	5.00	127.0	4.56	115.9
C250ATZ	5.78	146.8	5.34	135.6
B280ATZ	5.50	139.7	5.06	128.6
C280ATZ	6.53	165.9	6.09	154.7
B320ATZ	6.75	171.4	6.13	155.7
C320ATZ	7.53	191.3	7.09	180.1
B360ATZ	7.50	190.5	6.88	174.6
C360ATZ	8.70	221.0	8.26	209.8
B400ATZ	8.94	227.0	8.32	211.3
C400ATZ	9.55	242.6	9.06	230.0
B500ATZ	11.31	287.3	10.69	271.5
B580ATZ	13.75	349.2	13.00	330.2
B680ATZ	15.50	393.7	14.75	374.6
B840ATZ	17.75	450.8	17.00	431.8

Baldor Motor Commutator Diameters

Frame Designation	New Diameter (inches)	New Diameter (mm)	Minimum Dia. (inches)	Minimum Dia. (mm)
180	2.75	69.85	2.51	63.75
210	4.50	114.3	4.29	108.9
250	5.00	127.0	4.72	119.9
280	5.75	146.0	5.45	138.4
320	6.50	165.1	6.20	157.5
360	7.50	190.5	7.21	183.1
400	8.25	209.6	7.90	200.7
500	10.25	260.4	9.72	246.9