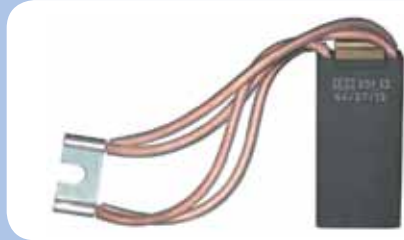


Carbon Brush & Holder Technical Handbook



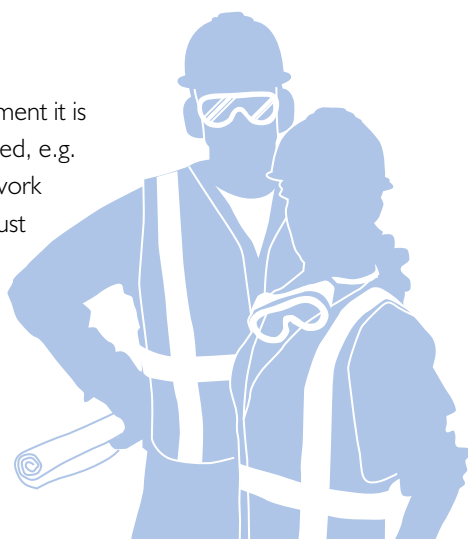
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Safety

NB when working on rotating electrical equipment it is essential that basic safety guidelines are observed, e.g. ensure equipment is fully isolated before any work commences. Eye protection and facemasks must be used when bedding brushes and blowing out machine enclosures.

Check with the site Health & Safety representative before conducting any work to ensure local safety procedures are complied with.



What is a Carbon Brush?

Rotating machines are used for the conversion of mechanical energy into electrical energy or vice versa. All electrical machines whether motors or generators using direct or alternating current, depend for their actions on the principles of electromagnetic induction.

Michael Faraday's fundamental discovery, that a conductor whilst being moved through a magnetic field becomes the seat of electromotive forces (emf) and furthermore the direction of the electromotive forces is at right angles to both the direction of motion and the direction of magnetic field.

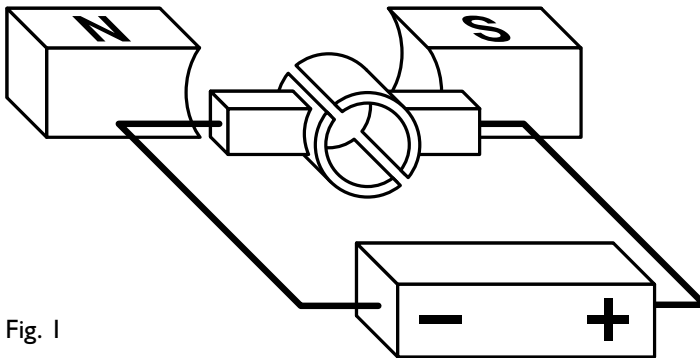


Fig. 1

The carbon brush is the integral part on the transfer of current in the rotating machine and although they differ in size, shape and technical composition carbon brushes and collectors all fulfil the same basic function. This is to transfer current from a moving device to a stationary point or vice versa within an electric circuit.

The Carbon Brush is fitted in a brush holder which is designed to hold it in the correct position and allow the brush to run on the surface of the commutator or slip ring (collector) to transfer that current at optimum performance.

Brush material grades

Electrographites - Commutation & Collection (Carbon partially transformed into graphite by heating to temperatures in the range 2200°C to 2800°C)

Biggest range of applications

- DC drives, & AC rings, etc.
- Current densities normally in the range 4 to 16Acm⁻²
- Surface speeds up to 50ms⁻¹

Metal graphites - Mainly collection except for low voltage applications

Copper -

- low voltage/collection of high current
- Current densities 12 to 30Acm⁻²
- Surface speeds up to 30ms⁻¹

Silver -

- low voltage with good signal integrity
- Current densities vary from almost zero to 30Acm⁻²
- Surface speeds up to 30ms⁻¹

Natural graphites - Collection

- TA exciters with steel sliprings
- Current densities up to 12Acm⁻²
- Surface speeds up to 80ms⁻¹

Resin bonded - Commutation

- High contact drop (poor commutation) or low current/temperature applications
- Current densities up to 8Acm⁻²
- Surface speeds up to 30ms⁻¹

Metal impregnated - Commutation

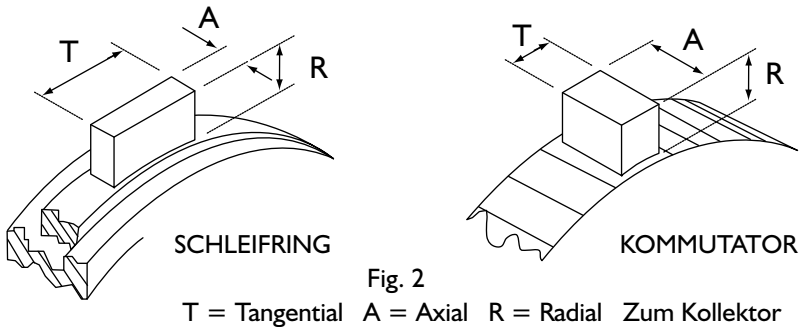
- High strength/ high current requirements
- Current densities up to 30A/cm²
- Surface speeds up to 40ms⁻¹

Hard carbon & carbon graphites - Commutation

- 'Older applications' or Difficult commutation
- Current densities up to 10Acm⁻²
- Surface speeds up to 30ms⁻¹

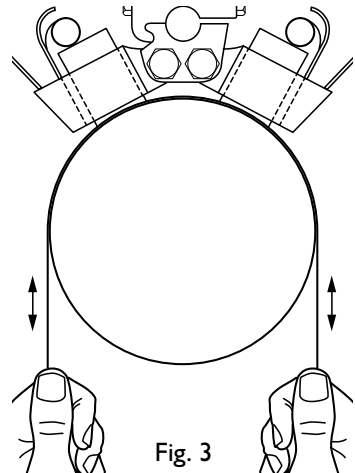
Understanding Brush Dimensions

Brushes usually fit on collectors as per arrangement below.



Bedding Brushes

New brushes must be bedded to fit the collector over their whole area of contact. Abrasive cloth is drawn between the brush and collector until the brush assumes the correct curvature. It is important that the abrasive cloth is 'wrapped' around the collector as much as possible to ensure the correct curvature is imparted on the brush face. For radial or trailing brushes draw the cloth only in the same direction as the rotation of the collector. For reaction brushes the cloth should be drawn against rotation. Alternatively a bedding stone held against the rotating collector may be used.



After bedding, the holders and brushes must be thoroughly cleaned. Brushing and then followed by thorough vacuum cleaning to remove all debris.

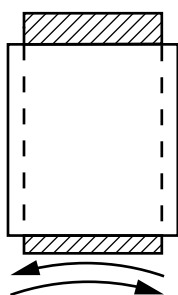
Clearance

After bedding and cleaning, check that the brushes are free to move easily in their boxes. Morgan Advanced Materials brushes & holders are all manufactured to either IEC 136 or DIN 4300 tolerances.

Brush Holders

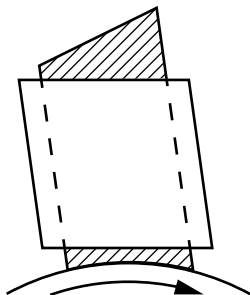
Brush holders may be divided into two broad classes; one in which the brush is rigidly attached to a swivel arm, and the other in which the brush is free to slide in a supporting box.

Slide-type holders are generally classified according to the angle at which the brush meets the collector. This may be:



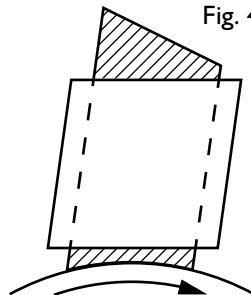
Radial

When the brush centre line is radial or normal to the collector surface.



Trailing

When the inclination of the brush centre line to the radial line is 'with' the rotation.



Reaction

When the inclination of the brush centre line to the radial line is 'against' the rotation.

Fig. 4

Fitting Brushes and Holders - General points

Clearance between Brush Holder and Collector

Set the holder so that the distance between its lower edge and the collector is approximately 2.5mm – If this distance is less than 2mm or more than 3mm re-set the holder, using the adjustment provided in the holder/clamp assembly, or by adjusting the brush arm.

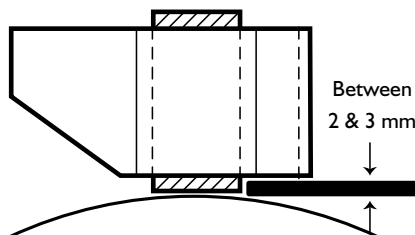


Fig. 5: Brush Box Clearance

Angle at which Brush meets collector

Care should be taken to set the brush holders at the angle for which they are designed.

There are different types of spring arrangements

Spring Pressure

Measurement of Brush Pressure

The pressure on all the brushes of a set should be the same. Periodically brushes and holders should be cleaned and the pressure checked by means of a spring balance (see figure 6) or a Morgan electronic.

Attach a spring balance to the tip of the finger and pull in a direction at right angles to the brush top until the finger just lifts from the top of the brush. The lifting point can be confirmed by just being able to slide the paper from beneath the brush face.

The applied pressure of most brush grades on industrial machines is generally between 180gcm^{-2} ($2.5\text{lb}\text{in}^{-2}$) and 210gcm^{-2} ($3\text{lb}\text{in}^{-2}$).

Certain (treated) grades can best run at slightly higher pressures $>210\text{gcm}^{-2}$ ($3\text{lb}\text{in}^{-2}$). With small brushes or on machines subject to vibration or with out of round collectors, it is advisable to use pressures up to 50% higher in the range of $210\text{--}280\text{gcm}^{-2}$ ($3\text{--}4\text{lb}\text{in}^{-2}$). The higher pressure enables improved contact and reduced electrical wear of the brushes.

On traction motors, and on some fractional horsepower machines, higher pressures of $280\text{--}490\text{gcm}^{-2}$ ($4\text{--}7\text{lb}\text{in}^{-2}$)

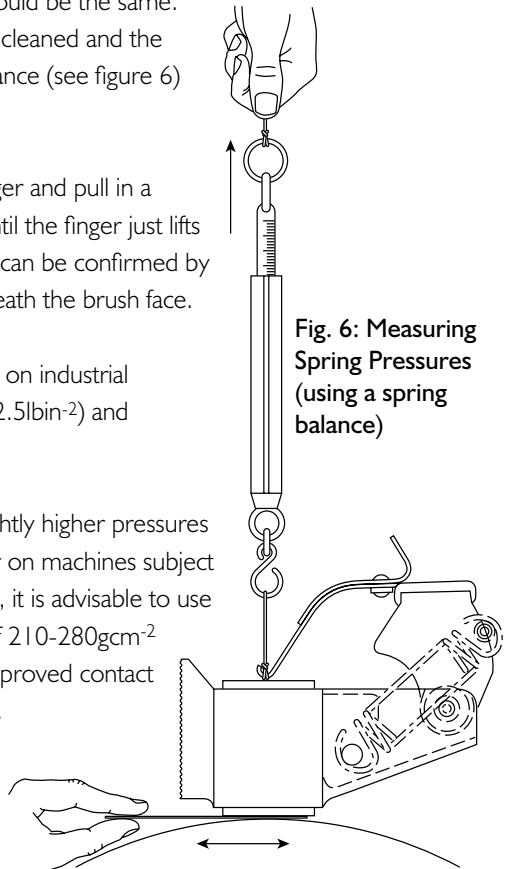


Fig. 6: Measuring Spring Pressures (using a spring balance)

Constant Force (CF) Springs

The characteristics of CF springs show the force is constant over a wide range of spring extensions, as the spring travels down the brush box the force remains constant until it has reached $0.8 \times \text{Dia of coil}$.

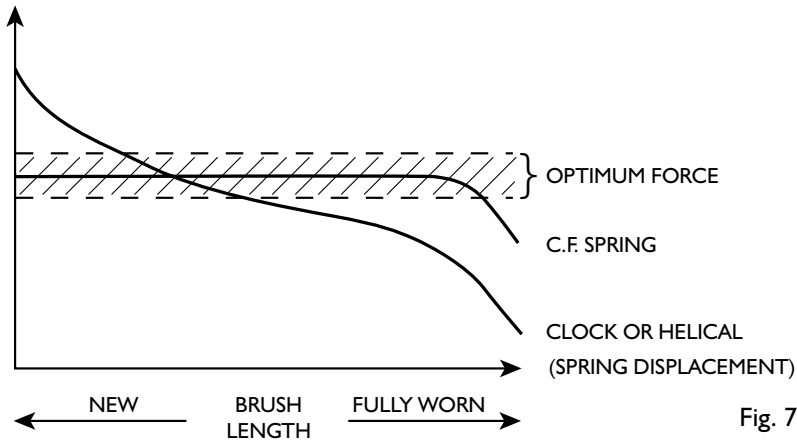


Fig. 7

Traction motors generally represent an arduous test of brushes and brush holders because of vibration and the shock loads that the motors can receive. C.F. spring brush holders have generally proved to offer advantages over conventional spring brush holders in the traction applications, and large production orders have subsequently been received.

Insulation

Although laboratory tests have shown that no appreciable current flows through the C.F. spring even if the brush flexible becomes disconnected, it is preferable to insulate the spring from the brush. This is achieved by fitting a non-conducting insert to the top of the brush where the spring bears upon it. Alternatively, Morgan Advanced Materials can provide fully-insulated spring assemblies.

Care and handling of the C.F. spring unit

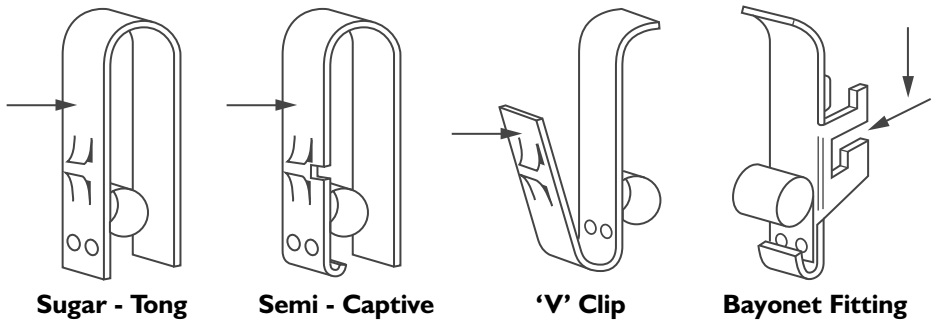


Fig. 8: Various spring types

1. To release the spring unit apply pressure on the latching side of the clip, as shown by arrow in fig 8. This will allow the clip to become free and rise out of the brush box under the tension between spring and brush.
2. When refitting, ensure that the spring clip is correctly placed in the brush guide and that the latching engages in the hole. Check by a slight pull on the clip to see that engagement is positive.
3. Check the Direction of the Brush top bevel as shown in fig 9.

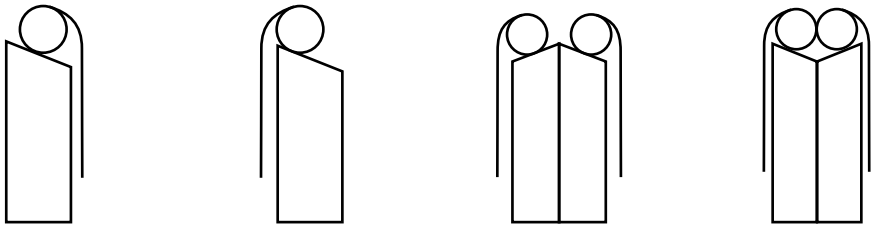


Fig. 9: Direction of brush top bevels

4. Check that the spring locates in the groove both circumferentially and axially when using square top brushes.

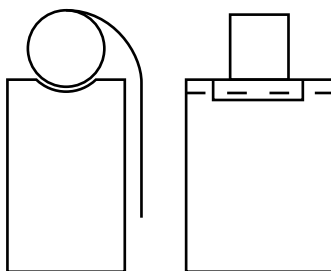


Fig. 10: Correct positioning of spring in top radius

5. Do not extend the spring by hand and allow it to recoil under its own force.

Commutators & Slip Rings (Collectors)

Collectors should be smooth and true. A collector which is in bad condition should be reground or turned. In general commutators with a TIR (Total Indicated Reading) of greater than $75\mu\text{m}$ (0.003") and/or to bar variance of $7.5\mu\text{m}$ (0.0003") needs to be reground or turned.

If it is impossible to regrind a worn collector, a collector grinding stone can be used to reduce flats, ridges, high mica and rough spots. In this way the performance of the machine may be improved sufficiently to allow continues operation.

Methods for reconditioning collector

A commutator or slip ring surface can be reconditioned in any one of seven ways, although other methods have been used in emergencies. The recognised and approved techniques are listed below in order of preference:

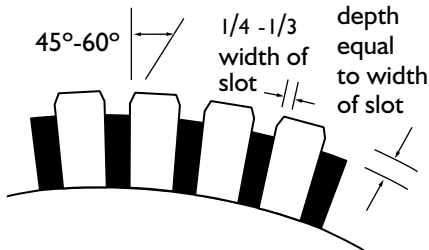
1. Turning with a diamond tipped tool
2. Turning with a tungsten carbide tipped tool
3. Grinding with a rotating wheel
4. Turning with a tool of normal high-speed steel
5. Grinding with a 'fixed' stone mounted in a toolrest
6. Grinding with a handstone
7. Scouring with abrasive cloth

Whichever of these methods is adopted, the collector should be trued whilst running at full speed in its own bearings if possible. This is especially important when the machine operates at high speed. Surface should be broken up with silicon carbide cloth before any machining is attempted, the depth of undercut on the micas must be checked and compared with the amount of material required to true the commutator up. If the undercuts will be removed completely by the turning operation then it is imperative that the micas are undercut before any turning is done; in this way the existing undercuts can be used as a guide for the undercutting tool.

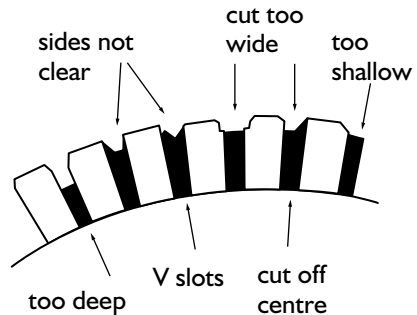
Mica Recessing

If the mica is sufficiently recessed the segment edges should be bevelled and any flakes of mica adhering to the edges of the segments should be carefully removed

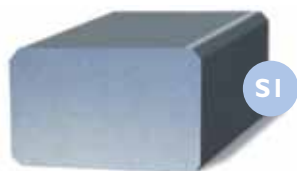
Recommended recessing and bevelling



Recessing faults

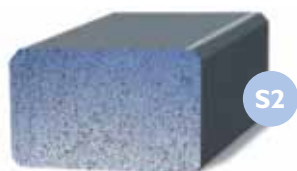


Surface appearance of brushes



Smooth Polished Surface (S1)

This indicates good performance. However, if the polish is mirror-like (glazed), high frequency chatter due to low current may be the cause. Check the side-faces of the brush for signs of vibration.



Open Textured Surface (S2)

This, again, indicates that brush performance is satisfactory. Actual appearance will depend on the type of grade.



Finely Lined Surface (S3)

Another satisfactory condition. Fine lines indicate the presence of dust in the atmosphere. This may be overcome by the use of filters or ducting the machine's air supply from another area.



Finely Serrated Surface (S4)

This is a further development of (S3) above. The causes are normally atmospheric contamination or lack of load current.



Heavy Serrated Surface (S5)

As (4) above, but problem is more severe or has been allowed to continue for longer.



Ghost Marked Surface (S6)

This may be associated with difficult commutation and can arise from incorrect neutral position, interpole problems or other causes of poor commutation.

**Burnt Edges (S7)**

Normally occurs on the trailing edge of the brush. Caused by poor commutation and heavy sparking.

**Pitted Surface (S8)**

Indicates heavy under-brush sparking as a result of current overload or brush instability.

**Laminated Surface (S9)**

This is an unusual condition caused by an armature winding fault giving rise to poor commutation.

**Double-bedded Surface (S10)**

This occurs as a result of brush tilting on a reversing machine, i.e. the brush beds itself in both directions of rotation. In itself this does not give any cause for concern.

**Copper Particles (S11)**

Copper pick-up from commutator surface can result from copper drag problems or heavy peak loads. Can cause further commutator wear.

**Chipped Edges (S12)**

Normally occurs on the leading (entering) edge of the brush. breakage can result from poor commutator profile, high micas and severe brush instability.

Patina



P1

Light Film (P1)

Over the entire commutator surface is one of the many normal conditions often seen on a well functioning machine. Film tone is dependent on the brush grade and current density.



P2

Patina Dark (P2)

Good condition. Film can be light to dark in colour but the important feature is that it is uniform and even. Normally, a good film will have a slightly polished appearance.



P3

Blotchy Film (P3)

This nonuniform filming condition is the most common appearance. The accumulated tolerances in the machine such as commutator roundness, brush contact pressure, unequal magnetic fields and chemical vapors all contribute to this type of film development.



P4

Slot Bar Filming (P4)

Repeating light and dark filming patterns related to the number of armature coils per slot. This pattern is dependent on the machine design and usually not a function of the brush grade.



P5

Streaking (P5)

Of only the film is not detrimental to the commutator. Brush and commutator life are not at risk in this condition. If metal transfer develops, this condition will progress into threading. This type of filming can be dependent on current density or brush grade.



P6

Bright Spots (P6)

Bright spots in the film suggest poor contact or overloading. The resultant under-brush sparking tends to destroy the patina and will eventually erode the commutator.



P7

Bar Burning (P7)

Is the erosion of the trailing edge of the commutator bar. Failed machine components, maladjusted electrical symmetry of the machine or a poor commutating brush can result in bar burning. If not corrected, this condition can cause severe commutator damage or a flashover.



P8

Slot Bar Burning (P8)

Results in commutator erosion of every second, third, or fourth bar depending on the winding design of the armature. Improper brush material, brush design or electrical adjustment of the machine can cause this condition. This condition severely damages the commutator and reduces brush life.



P9

Patina Streaked With Collector Wear (P9)

A streaky film with no commutator wear, tracks can vary in width and colour. Caused by atmospheric conditions (humidity, oil vapour or other gases) or insufficient load.



P10

Pitch Bar Burning (P10)

Results in commutator bars being eroded in a pattern related to 1/2 the number of brush arms, progressing into a pattern equal to the number of brush arms. This condition is caused by a cyclic mechanical or electrical disturbance such as an unbalanced armature, misaligned shafts, bent shaft, bad bearings, weak foundation, failed equalizers or a poor riser connection. If not corrected this condition will result in a flashover.



P11

Grooving (P11)

Is the uniform circumferential wear, the width of the brush, that is exhibited on the commutator. Excessive abrasive dust in the atmosphere or an abrasive brush can cause this condition. Extreme light spring pressure (below 1.5 psi) can also cause this condition. Proper brush applications and filtering the air on force ventilated motors can reduce the commutator wear.



P12

Copper Drag (P12)

Occurs when high energy transfers copper in a molten state. These particles become coated by contaminants from the surrounding environment or the brush treatment and do not oxidize properly to form the film on the commutator surface. These particles accumulate at the edge of the bar, eventually shorting across the insulating mica. This condition needs to be addressed immediately when discovered or serious damage may occur. Chamfering the commutator bar edges is necessary to stop the progression of this condition.

Chart of common difficulties on rotating electrical machines

SYMPTOMS														
M	Serration and grooving of collector													
L	Excessive collector wear-surface blackened													
K	Copper dragging													
J	Excessive collector wear or slip ring wear-bright surface													
I	Unequal brush wear													
H	Rapid brush wear- while commutation good													
G	Flexible burnt out or discoloured													
F	Brushes and brush holders too hot													
E	Collector-slip ring-too hot													
D	Sparking vicious and trailing around collector													
C	Green in sparks													
B	Sparking at entering edge													
A	Sparking at leaving edge													
PROBABLE CAUSE OF TROUBLE		A	B	C	D	E	F	G	H	I	J	K	L	M
1	Interpole field too strong		x	x										
2	Interpole field too weak	x		x								x		
3	Interpole air gap too small		x	x										
4	Interpole air gap too large	x		x								x		
5	Air gaps uneven (bearings worn?)	x	x							x				
6	Overload machine	x			x	x	x			x	x			
7	Vibration from external causes, i.e. Prime mover: Nearby forge hammer etc	x							x	x		x		x
8	Vibration from internal causes, i.e. out of balance, poor alignment etc	x							x	x		x		x
9	Quasi electrolytic wear of slip ring													
10	Oil and dirt on collector								x	x				x
11	Resistance between brushes and brush arms not uniform						x		x	x				
12	Grains of abrasive in brush contact face										x	x		x
13	Faults in armature winding or equaliser connections	x			x		x							
14	Mica proud	x		x	x								x	
15	Collector eccentric	x							x				x	x
16	Collector riser connections open circuited	x	x	x	x									
17	High or low collector segments	x		x									x	
18	Collector loose	x		x	x								x	
19	Flats on collector	x	x	x									x	
20	Spring pressure too low	x				x	x	x	x	x	x	x	x	x
21	Spring pressure too high					x	x		x		x	x		x
22	Spring pressure unequal	x						x	x		x		x	
23	Brush grade unsuitable for machine duty	x			x	x	x		x		x	x	x	x
24	Brush arc of contact excessive	x	x	x										
25	Brush arc of contact insufficient	x	x	x								x		
26	Brush flexible connection faulty							x		x				
27	Brush flexible too short or too stiff	x			x			x		x				
28	Imperfect brush bedding in	x	x		x					x				
29	Radial brush holders mounted at small reaction angle	x		x		x	x			x		x		x
30	Reaction type holder mounted trailing	x	x	x		x	x			x		x		x
31	Brush sticking or sluggish in brush holder	x	x			x		x	x	x			x	
32	Brushes too loose in brush holder(holders worn?)						x			x				
33	Terminal connections loose or dirty					x	x	x		x				
34	Brush holder mounted too far from collector									x				x
35	Incorrect brush position	x	x	x									x	
36	Unequal brush holder spacing or alignment	x	x	x	x			x		x				
37	Humidity of atmosphere low								x					x
38	Humidity of atmosphere excessive													x
39	Dusty atmosphere								x		x			x
40	Gas or acid fumes in atmosphere							x	x					x
41	Long periods of low or steady loads	x			x	x	x					x	x	

Note: Collector means slip ring or commutator

SYMPTOMS

Wear of slip ring on one polarity	N
Copper picking in brush face	O
Brush chatter	P
Collector surface streaky	Q
Collector has unsymmetrical burn marks	R
Collector has symmetrical burn marks	S
Collector has wavy pattern	T
Ghost marks on steel slip rings	U
Glazed contact surface of brush	V
Pitted contact surface of brush	W
Chipping of brush edges or brush breakage	X
Failure to develop a protective skin	Y
Insufficient voltage on self exciting machines	Z

N	O	P	Q	R	S	T	U	V	W	X	Y	Z	REMEDY	
	x				x				x				Weaken interpole by divert or by increase gap	1
	x				x								Strengthen interpole fields by reducing air gap	2
	x				x				x				Enlarge air gap to decrease effective interpole flux	3
	x				x								Reduce air gap to increase effective interpole gap	4
	x				x				x				Renew bearings and realign machine	5
	x					x			x				Reduce and limit load on machine	6
x	x	x			x	x	x	x		x	x	x	Locate and remove cause of vibration or mount machine on shock absorbers	7
x	x				x	x	x	x			x	x	Balance armature and check for bearing wear	8
x						x							Reverse the polarity of rings periodically	9
			x	x						x	x		Clean collector	10
					x				x		x		Clean and tighten the connections	11
										x			Re-bed and clean the brush face	12
					x	x			x		x		Locate and cure fault or consult manufacturer	13
	x	x		x					x	x	x	x	Recess mica, or use more abrasive brush	14
x	x		x	x		x					x		Turn or re grind preferably at near rated speed	15
					x							x	Re-solder connections	16
			x	x					x				Tighten collector, turn, or re-grind	17
	x	x	x	x		x				x			Tighten collector, re-mica if necessary, turn or re-grind	18
	x	x							x	x			Locate and remove cause of flattening, turn or re-grind	19
x	x	x	x	x	x				x	x	x	x	Adjust spring pressure to that recommended for brush grade	20
												x	Adjust spring pressure to that recommended for brush grade	21
	x	x	x	x		x			x	x			Adjust spring pressure uniformly to that recommended for brush grade	22
x		x			x				x	x	x	x	Select one of our alternative grades or ask for our recommendation	23
	x				x				x				Reduce the effective thickness of brush, preferably consult manufacturer	24
	x				x								Apply suitable circumferential stagger, preferably consult manufacturer	25
											x		Fit a new brush with a sound flexible connection	26
					x						x		Use brushes with flexible of correct length & flexibility	27
			x								x	x	Bed brushes by our recommended method	28
x		x		x	x				x	x	x	x	Adjust holders to a radial position, & correct distance from comm	29
x		x		x	x				x	x	x	x	Reverse holders or direction of rotation	30
	x		x	x	x				x			x	Check that brush size is correct, clean brushes and holders, remove any burrs	31
		x			x				x	x	x		Replace holders, or order brushes of correct dimension	32
		x										x	Clean terminals and terminal block. Tighten screws	33
x		x	x	x	x				x	x	x		Adjust holder to be 3mm from collector	34
	x				x				x			x	Adjust holders to correct position	35
	x				x				x				Correct spacing and alignment of holders	36
		x								x	x		Humidify the cooling air or draw air from normal humidity source	37
			x	x									Enclose machine or draw cooling air from normal humidity source	38
											x		Remove cause if possible or install filter	39
				x	x				x	x	x	x	Arrange clean air cooling	40
	x	x							x	x	x	x	Change brush grade, ask for recommendation	41

NOTES



We also offer a more detailed Carbon Brushes and Electrical Machines book and Training Courses.

If interested please contact the Customer Service team for a quotation.

For further information please contact

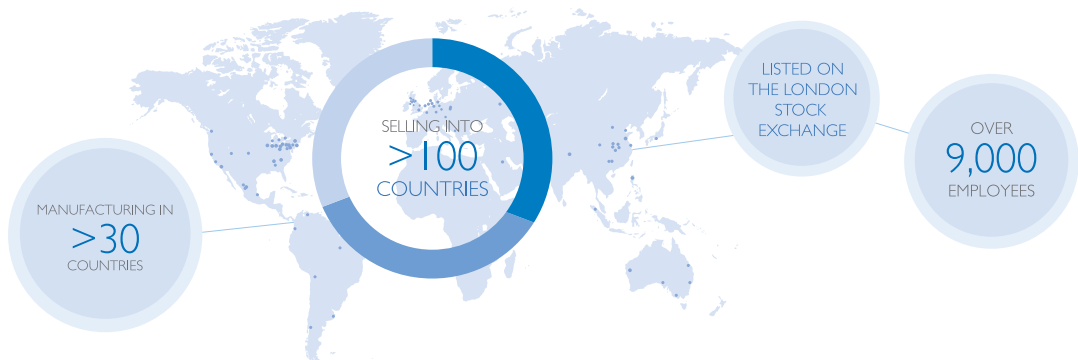
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ABOUT MORGAN ADVANCED MATERIALS



Morgan Advanced Materials is a global engineering company offering world-leading competencies in materials science, specialist manufacturing and applications engineering.

We focus our resources on the delivery of products that help our customers to solve technically challenging Problems, enabling them to address global trends such as energy demand, advances in healthcare and environmental sustainability.

What differentiates us?

- Advanced material science and processing capabilities
- Extensive applications engineering experience
- A strong history of innovation and reinvention
- Consistent and reliable performance
- A truly global footprint
- We find and invest in the best people

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