There's more to it than "JUST" changing brushes!

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FOREWORD

There is a lot more to it!

Modern centrifuges and power tools utilize high torque, high speed motors demanding quick acceleration, fast dynamic braking, electronic speed control and are most always used at the maximum designed speed which promotes maximum wear.

Usually by the time someone decides the brushes "just" need changing, excessive damage has already occurred and a simple brush change is not the most advantageous thing to do. Even machines with brush change indicators have no device to tell how many changes have occurred previously or the condition of the associated parts.

Yes, the new brushes made it run, but for how long? What else could you have done this time to insure economy, longevity, customer satisfaction and earn an honest profit?

Apparently most electronics courses concentrate on circuits that entertain display faces and skip over the electromechanical devices that perform work. As a result, few electronics technicians, BMETs, mechanics or repair types were/are taught the principles of troubleshooting and repair of electric motors or generators.

Many regard the repair of motors as a dirty, degrading and ho hum chore and are unaware of the subtleties even after much need and exposure.

Many motors are considered expendable or irreparable; manufacturers do not offer repair parts, even for the larger expensive units for several reasons. First, many motors are designed and built with close tolerance - parts are not easily interchanged and must be hand or machine fitted.

Second, field service personnel do not have training or facilities to effect proper repairs. Third, hourly charges and location logistics necessitate a one-time service call. Fourth, some small replacement motors are economical and some customers are leery of rebuilt motors, since their previous experience with them was not satisfactory.

The rising cost of new motors and the sophistication of electronic controls require multi-talented service technicians to sell and perform competent repairs that provide an acceptable, economical and profitable alternative.

Although machine shop practice, electric motor theory, application, rewinding and commutator replacement is beyond the scope of this text, a modest investment in special tools and the careful study of this guide will fill a void and provide a means to help insure that your efforts have quality results.

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ELECTRIC MOTORS

Electric motors are those electromechanical devices which convert electrical energy into mechanical turning force to perform work and make up the greatest number of prime movers used today.

Motors are available in many types and sizes to provide vast selections for specific applications.

Three basic groupings of motors are determined by the form of applied electrical power, i.e. alternating current (induction) motors, direct current motors and the universal motor which operates on A.C. or D.C.

The operating principles are nearly the same for all electric motors. The AC-DC series wound (universal) motor, because of its popular use in home appliances, tools and laboratory centrifuges, will be the example motor and focus of this text.

A universal motor produces a high starting torque, high speed, is easily controlled over a wide speed range and delivers more horsepower per pound than any other single-phase A.C. powered motor. It delivers more starting torque than any A.C. or D.C. motor of equivalent size and is the only motor capable of speeds over 3600 RPM from single-phase A.C. power.

Universal motors are generally produced in 2 pole 2 brush configurations. Four pole 4 brush designs reduce individual brush current and cogging in a given horsepower size and can develop more horsepower for a given physical size.

Universal motors with centered brushes are bidirectional, whereas offset brushes, to gain brush life and efficiency, denote a motor that is unidirectional and should not be reversed.

Universal motors should not be free run (without load) at full design voltage. Theoretically maximum speed is limited only by friction, windage, commutation or subsequent motor failure.

Note: Other motor types and applications may not have the same parts described later. The information and methods, however, are applicable to any motor rebuild or use.

Universal motor life is usually determined by a nominal wear of the commutator, bearings and a few sets of brushes. Motor life can be extended by commutator refinishing, new bearings, brushes and cleaning. Continued use will ultimately require replacement or total rebuilding that may include new commutator (rebaring), armature/field rewinding, etc.

A matter of economy: Small motors such as the Clay-Adams Readacrit(tm) are best replaced when the commutator or bearings are well worn; whereas the I.E.C. CL's armature can be rebuilt.

Since many manufacturers do not offer new or old motor components for sale, medium and

large motors can be economically rebuilt several times vs. new motor purchase. Rebuilding is of course limited to those shops having the expertise, resources, tools or sublets to perform the work.

ELECTRIC MOTOR BRUSHES

The motor brush must: carry the load current into and away from the armature; act as a low friction bearing on the commutator surface without any applied lubricant at surface speeds in excess of 8000 ft/min; control within safe limits the short circuit current in the armature; resist the destructive action of very high current densities which are frequently characteristic of the commutation cycle; keep sparking to a minimum; have low mechanical and electrical losses; have good thermal and refractory properteries; be a good conductor; lubricate and have quiet operation.

Brushes are made from four basic material groups: 1. Carbon/carbon graphite - brush use restricted to low speed fractional horsepower motors or motors with flush mica commutators. 2. Electro graphic - very popular brush. Used to solve commutation problems and gives long life at high speed. 3. Graphite - this brush is used in high speed motors, reduces noise and sparking, but provides a limited life. Frequent inspection, motor cleaning and brush change are required. 4. Metal graphite - These copper plated or filled brushes allow very high current densities at low voltages. Commonly used in automobile starter motors.

Various formulations permit optimum selection of characteristics, i.e. surface speed, lubricity, abrasion, polishing, friction, strength, noise, current density and oriented resistance for specific motor applications. Compensation can even be made for environmental conditions such as high or low humidity, altitude, temperature, fumes, dust and electrolytic erosion.

Brush Shunts: (brush leads) are usually made of fine, braided copper wire and are very flexible. Some brushes have no shunt but rely on the brush holder or spring arm to provide electrical contact.

Brush Terminals: Stamped from copper or brass in various forms such as disks, spades, rings or "U" shapes.

Brush Springs: Three basic types: 1. Coil spring which is wound around the shunt. This spring is inexpensive and common but loses pressure as the brush wears. 2. Roll spring which is expensive but exerts constant pressure throughout brush life. 3. Lever arm or reaction spring which is usually found in brush carrier assemblies. The pressure is adjustable and nearly constant.

Current Density: Measured in amperes/Cm^2 is determined by material resistance and cross section area.

Dynamic Current Density: This is the actual current that the brush can pass to the commutator in a running motor and, in addition to resistance and cross section, depends on pressure of the brush to

commutator and/or brush holder, condition of conductive film on commutator, commutator bar width and finish, shunt wire size, humidity, altitude, temperature, fumes, dust and surface speed.

Brush Wear Factors: The types of motors, frequency of starts and stops and all previous statements regarding formulations and current densities affect brush life in a good motor. Causes of brush failure or premature wear will be discussed in troubleshooting and repair sections. Average brush life is 200-5000 hours depending on motor type and application.

It is apparent by reading the preceeding information that brush selection and replacement is exacting and technical. Most always the O.E.M. recommended part or exact replacement should be used. The manufacturer did, after all, pay for the engineering and testing for optimum performance.

CHANGING BRUSHES IN A GOOD MOTOR

The title says it all. Brushes should be changed only in good motors as part of regular PMs or when the length is one-half of new. If a motor is bad, new brushes won't fix the problem but will probably make it worse.

Removing the Brushes. Rotate the armature by hand, pushing the output shaft side-to-side, in and out. Listen and feel; good bearings will be free of excessive noise, free play or irregular drag.

Examine the brushes in a good motor; the brushes will show no excessive wear, the face will be shiny without grooves or edge bevels. Also the spring shunt lead and holder must be free of burns or blueing. If not, the motor needs repair, not just brushes. But before any brush replacement, clean and blow out the motor, especially around the brush holders.

Replacing the Brushes. Using the proper brush, insert so the face bevel or radius makes maximum contact with the commutator. If the commutator has a slight groove in it, slightly chamfer the side edges of the brush face with a file to assure maximum contact. The brush should move freely but not loosely in the holder. The brush face edge should register with the commutator bar edges. When putting the brush into the holder, make sure tabs, if any, are positioned properly into the holder recess. Be sure the shunt wire is not wound up. Install the brush cap, making certain it screws freely and seats fully.

Brushes must be run in at 1/4 speed for 1/2 hour to fully seat. Note that maximum acceleration, speed and braking cannot be achieved until the brushes are in 100% contact with the commutator and a good electrographitic surface film is established. If there is no speed control, operate the on-off switch allowing a few seconds on and then coast as many times as required to obtain a 100% shiny brush face. If the commutator is visible, a fine, even spark line along the entire length of the trailing edge of the brush indicates proper seating. Brush removal and examination is the preferred method to confirm seating. Be careful to retain correct brush orientation.

In any case, be sure the rest of the motor is in responsible repair before merely changing brushes.

ESSENTIAL TOOLS FOR ELECTRIC MOTOR REPAIRS

In addition to a good selection of hand tools, i.e. sockets, box and Allen wrenches, nut drivers, screwdrivers, pliers, files, etc., the following tools are suggested to perform successful electric motor overhauls.

1. a. Metal lathe, 6 in. swing, 18 in. bed or larger
   b. Armature lathe with undercutter - Trucut TUC-B-15 accurate chuck and collets
2. Electric mica undercutter with asst. blades
3. Live center for lathe tail stock
4. Arbor Press, 3 ton - Snap-on CG100
5. Growler - Crown TC 2501
6. Dial indicator - .001 in. resolution
7. Verier Dial Caliper - 0-6 in.
8. Air compressor with blow gun
9. a. Mechanical tachometer - Jaquets #2301
   b. Electronic tachometer/stroboscope
10. a. V.O.M. - Simpson 260
    b. D.V.M. - Fluke 77
11. AMP Clamp and temperature adaptor for V.O.M.
12. Soldering iron, 150 watts/soldering gun 200-260 watts
13. Powerstat/Auto-transformer, 10-15 amp.

14. Gear/Pulley pullers, 2 & 3 jaw, several sizes
15. Bearing separator - Kukko 17 #TGP-17
16. Bearing installer kit, Kukko, #TBI-10
17. Dead blow hammer - Compocast
18. Commutator file/scraper - Curved draw cut
19. Prick punch/automatic center punch
20. Small stainless steel wire brush
21. Adjustable parallel hand reamers - as required
22. V blocks
23. Machinist's level
24. Tap and die set, threading file
25. Spring scale, 0-16 oz.
26. 3-cornered hand scraper
27. Flat hardwood paddle
28. Dust mask, goggles, gloves
29. Hacksaw blade handle - Snap-on HS-5
30. Small motor commutator resurfacer - Ideal S80-12

EXTRA: Balancing ways - HIPOT Tester

TOOLS TO FABRICATE

Bearing installer/remover mandrels - as required
Bearing puller cushions
Mica cutters (undercutters), - several widths
Polishing/cleaning stone paddles
Sandpaper paddles
Bearing pullers
Motor holder - padded V block with clamp
Ring nut spanners

CONSUMABLE SUPPLIES

Assortment of 400-1500 grit sandpapers
Mylar backed 600-1200 grit flexible sandpaper

Electric motor cleaner (spray)
Electric motor insulator varnish (spray)
Woven insulator tubing
Shrink tubing
IEC 1710 oil & 1709 grease, EP 80/90 lube, syringe
Hi-temp leaded solder - flux
Fish paper
Brush seators/commutator cleaners, Ideal TI-23-002
Flexible abrasive/commutator cleaner polisher, Ideal 9-82-001, 8-82-002
Beartex(tm) ScotchBrite(tm) pads, GRN-GRY

TROUBLESHOOTING FOR "LOOSE"

"LOOSE": Something loose is the most common and frequent failure condition of electrical and mechanical equipment. Not always the origin of problems as sometimes thought, most loose conditions are caused by and then create additional failure situations.

Loose conditions range from totally open, broken or disconnected to intermittent, not firmly connected or a high resistance connection.

The usual causes of something becoming loose are the result of time acting in conjunction with improper tightening, workmanship, design, materials, vibration, temperature, lack of lubrication, corrosion and or normal wear.

Loose conditions can be located by visual inspection, listening for noise, feeling or hand manipulation. For example: a. electrical power connections -

discolored/corroded; b. bad bearings - noisy; c. loose fastener can be tightened. Ideally loose conditions are best found before subsequent failures and complete inspections to prevent failure should be routine to any service company.

TROUBLESHOOTING INTERNAL MOTOR PROBLEMS

Always remove and inspect the brushes first.

Most internal problems with motors cause brush problems. The six major failures of brushes result in: charring; grooving; side beveling; breakage; rapid wearing or a burned/blued spring, shunt lead or brush holder. However, merely changing the brushes may repeat, aggravate or compound a problem.

Brush problems indicate or cause commutator failure. Conversely, a bad commutator ruins brushes.

However, a brush that looks good doesn't mean the motor is good.

After the brushes are removed, rotate the armature by hand and inspect each commutator bar and look for signs of deep grooving [more than .010"], out of round, erosion, thrown solder, burning or arcing. Spin the armature by hand; listen and feel for a loose armature, noisy bearings or irregular drag. Smell and inspect the field windings for signs of overheating. Most of these problems are interrelated and indicative of additional problems, either internal or external, that lead to motor failure. If any of the above conditions are found, the motor must be torn down and repaired.

The following is a guide of what to look for to troubleshoot, repair, reassemble and install any motor. It is organized around the component motor parts and includes the most common failures encountered. The problems listed include normal failures, misuse, improper repairs and improper manufacture.

<u>Commutators</u>

Used beyond normal life, high mica, out of round, carbon build up, non-conductive surface, oily, deep grooving, rough surface, twisted bars, shorted, open, turned down too far, off center, cut into wired end or riser, not undercut, thrown solder.

<u>Brushes</u>

Worn, axial position, type, seating, chipped, tight in holder, loose, broken, new installed over pieces of old, missing.

<u>Brush Springs</u>

Annealed, pressure high or low, compressed, adjustment, broken, bent, missing.

<u>Brush Shunt Leads</u>

Too short, long, hung up, wound up, shorted, loose, open.

Brush Terminals

Position, loose, type.

Brush Holders

Set screws tight or loose, axial position, too near to or far from commutator, brush wear switch impedes brush, cracked or carbon arc track insulation, burned, loose, shorted, open, connections, melted, wiring, dirty, stripped.

Brush Caps

Loose, cracked, shorted, missing, stripped.

Brush Carriers

Brush spring pressure, cracked or burned insulators/pieces, axial and radial position, arc track, loose, connections, melted, wiring, dirty.

Insulators

Disk or papers missing, shorted, burned.

Armatures

Open; shorted; unbalanced; rubbing on pole faces, brush carrier, etc.; shaft bent, upset, scored, worn splines, keys missing, worn bearing surfaces, loose, stripped threads, centers distorted, centrifugal short, dirty.

Armature Fans

Bent, loose, broken, missing, misaligned, loose balance weights, dirty.

Field Coils

Shorted, open, connections, loose, dirty pole faces, short to tie rod, centrifugal short, axial position, wiring, burned, wear, dirty.

Ball Bearings

Type, orientation, siezed, worn, loose in housing or in shaft, dry, pre-load, installation, dirty, end play.

Sleeve Bearings

Dry, wrong lubricant, scored, tight, loose, orientation, no wick hole, wicks installation, dirty, worn, end play.

Greasers/Oilers

Missing, dry, lubricant type, broken, wicks, stripped.

Thrust Bearings/Washers

Missing, too tight or loose, broken, lubrication, type, end play.

End Bells/Housings

Axial position, cocked, enlarged bearing bores, deformed, cracked, dirty, loose, overtight, restricted air vents/apertures.

Tie Rods

Loose, overtightened, broken, missing, size, twisted, stretched, stripped.

Wiring

Missing strain relief or grommet, broken, loose, chafed, open, shorted, position, incorrect, insulation, burned.

Thermal/Current Protectors

Open, shorted, position.

Lubrication

Lack of, too much, type.

Hardware

Loose, stripped, missing, too tight, incorrect, wrong order of assembly, too much or absence of locking products, size.

Motor Attachments

Loose, alignment, missing parts, open, shorted, stripped threads.

Miscellaneous

Reassembled as received - incorrectly, incorrect assembly of any kind, bad "new" parts, dirt. All electrical and mechanical connections should be tight. Check for poor solder joints. Discolored electrical connections indicate high resistance and should be corrected.

Installation

Incorrect installation or failure of associated parts including all external motor problems.

Some of the conditions listed above may not be evident during testing but will lead to premature motor failure.

The problems and failures in this section are referred to through the text. Attention to the items on the preceeding list will expedite repair, insure good performance and long motor life.

TROUBLESHOOTING OTHER MOTOR TYPES

D.C. Motors: All troubleshooting and repair information regarding universal motors apply. Exception - speed is regulated by design.

A.C. Induction Motors: Commutation, brushes and overspeed problems; excepting slip rings, do not apply to A.C. motors. Most other universal motor problems are applicable plus the following additions concerning parts usually found only in A.C. motors.

1. Defective or hung up starting switch.

2. Defective start/run capacitor, wrong values.

3. Open start winding.

4. Defective start/potential relay.

5. Motor internal/external thermal/current circuit breaker.

6. Wired wrong for applied voltage.

7. Wired wrong for desired rotation.

8. Open input power phase/phases.

9. Stepped rotor laminations causes noise.

10. Loose/broken shading coil.

11. Wrong applications, i.e. internal or external cooling, start loading, duty cycle.

Permanent Magnet Motors: Essentially the same as D.C. motors without field coils. The magnets may become demagnetized, broken or loose.

The preceeding information can serve as a checklist, useful during all phases of motor service, i.e. before removal from equipment, actual repairing, installation and performance testing.

Utilization of this information will extend the useful service life of motors and associated equipment. Attention to detail is essential, especially with centrifuges, since the user has a selection of different loads (rotors) and the units are frequently run at maximum speed.

It is always prudent, albeit necessary, to check and correct any condition that would be detrimental to motors, equipment and personnel.

Note: a. Do not try to start a siezed or hard to turn motor.

B. Do not spin motor by hand to start; sudden start-up of motor may cause injury.

TROUBLESHOOTING: EXTERNAL PROBLEMS THAT CONTRIBUTE TO OR CAUSE MOTOR FAILURES:

Problems external to the motor are categorized into four groups: A. Improper loading/application; B. poor maintenance; C. failure after repair and D. random failure.

Many of the following external problems can be obviated by good maintenance/repair practices and user in-service training. Note: Some problems listed fall under more than one grouping.

1. Loading: Alignment, too heavy, seized, position, wrong speed, unbalanced, not level, misapplication, loose belt, tightness, aerodynamics, no load overspeed.

2. Motor Mountings: Loose, cracked, broken, missing, misaligned, twisted.

3. Speed Control/Modulator: Defective, miscalibrated.

4. Tachometer or Feedback Circuits: Miscalibrated, tach gen magnet loose or missing, open, shorted tach gen coil, exciter lamp open in tach sensor, controls defective.

5. Restricted Ventilation: Crushed ducting, external fan seized or reversed, limited air

space, cooling water off or restricted, plugged filters.

6. Ambient Conditions: Too hot, cold, dry, wet, dirty, vibration or contaminated.

7. Excessive Acceleration, Sustaining or Braking Current: Miscalibration/setting, wrong brake resistors, operator error (see loading).

8. Wiring: Incorrect to motor, intermittent, size.

9. Wrong Power: AC or DC, high or low source, speed control, diodes, filter capacitors, relays.

10. Brush Change: Motor run at full load or high speed before complete brush seating and formed conductive surface on commutator, old brush assembly pieces inside motor.

11. Improper Manufacture or Repairs: Wrong, missing, loose or improperly installed parts, attention to detail, mishandling.

A FEW MOTOR AND GENERAL SERVICE TIPS

Three-phase (single voltage) A.C. motors can be reversed by transposing any two leads (this fixes a lot of pumps).

Check motor ground (case to equipment) after installation - few exceptions.

Motor start capacitors. Common failure of this non-polarized electrolytic are loose

terminal (rivets) or leakage indicated by a bulge in the pressure relief membrane (round hole) or actual liquid leakage.

Oil filled run capacitors. Almost always test open when failed. They have an internal fuse link. Replace if leaking oil and only with correct value.

All analog meters. Always de-static the meter before calibration.

Solenoids. Coil shorting most always caused by incomplete closing of the magnetic gap. Adjust the mechanism to allow total, even closure of the armature to the pole pieces.

Snap rings/Tru-Arcs. Install with flat side facing out of a bore or towards the end of a shaft.

Pozidrive screws. Do not confuse with Phillips screws. Pozidrives are identified with a cross, stamped 45 degrees to the slots. Use the correct tool. This fastener is becoming popular (in Europe since 1967).

Analog V.O.M. vs. D.V.M.. a. V.O.M. is better to use for power troubleshooting as the D.V.M. may register a voltage with one lead open. The V.O.M. allows a better "view" to noise and analog functions. b. A D.V.M. is more useful for accurate calibrations and measurement; have both.

A.C. amp clamp. Much safer, faster to use than a volt meter for general location of shorts, opens, high currents and equipment power draw. A must to test motors and resistive loads.

Make a short open wired (insulated) 3-conductor plug and socket adaptor for 110V A.C. and one for single-phase 220V A.C. interface betweeen A.C. outlet and equipment plug, amp clamp around the "hot" lead to measure.

Note: During use, keep amp clamp away from strong magnetic fields, i.e. large open transformers, saturable reactors, magnets, etc.

Wire end terminals. To secure terminals to chassis, frames, terminal studs, etc., place an external star washer between the terminal and the article to be fastened to. Then install the screw or nut. A better electrical connection is formed by penetration and prevents the longer lever (terminal) from loosening the smaller screw or nut.

Cleaning stainless steel. To clean and shine up stainless steel, use Pow'R Kleen(tm) Hand Cleaner by Woodbine Chemical Co. Use straight out of the can; wipe on and wipe off using paper toweling.

REMOVING ELECTRIC MOTORS

Always commence by disconnecting the equipment being serviced from its power sources before motor removal. Some equipment has 110V AC control voltages with 220/440V AC mains power; be sure both circuits are off. Disconnect or turn off all plugs, circuit

breakers, mains switches, etc., and tag or tape them over to prevent accidental turn on by other personnel while the equipment is down or is being serviced.

Before disconnecting, identify and mark with wire marking tape all individual motor lead wires or terminal ends and their corresponding connection points to map the connections during subsequent motor installation.

When removing motors, look for, note and if possible, correct any discrepancies found with motor mountings, drives, silencers, ducts, etc. Be careful not to bump or set the motor down on sensitive tachometer generators, encoders, etc. Some motors are quite heavy, be sure to get a good grip and lift properly. Refer to other sections of this text regarding problems that can be found.

BALL BEARINGS

Ball bearings have low friction, are suitable for high speed, accommodate thrust loads, can be adjusted to control end play and require little maintenance. Ordinarily ball bearings are more expensive and noisier than sleeve bearings and being made of steel, are subject to rust. When changing ball bearings in high speed motors, exact replacement is required.

In addition to being dimensionally correct, class type, whether the races are open, shielded, externally shielded or sealed and type of lubricant should be considered before change. Some ball bearings are produced with a "low side" inner race, i.e. the width of the inner race is narrower than the outer race (generally one side only). Be sure to note the orientation of "low side," shields, seals, etc. when removing or replacing ball bearings.

Ball bearings should never have the races struck or hard pressed in opposition; this cannot be avoided in most removal procedures, therefore, bearings that have been removed should be replaced.

Ball Bearing Removal

1. Always use a puller cushion between the motor shaft and bearing puller jack screws to prevent distortion of the shaft end or center. Fabricate and size puller cushions of aluminum with male and female ends to accommodate various shaft or jack screw configurations and to assist alignment during the pulling operation.

2. Use bearing separators with caution when working near armature commutators.

3. Use a brass punch or hammer if you must strike a motor shaft for bearing removal.

Ball Bearing Installation

1. Shaft bearing surfaces should be free of high spots or burrs and lightly oiled before bearing installation (remove high spots with a fine smoothing file).

2. Always use properly sized bearing installation tools to press inner races of

ball bearings onto shafts or outer races into bores.

3. Support the inner race when inserting a shaft into ball bearings.

4. Do not violate bearing shields or seals.

5. Because of lubricant hardening or overgreasing, some ball bearings may have to be "run in" to achieve free and quiet operation.

6. If the bearing outer race has spun or is loose in its housing or bushing, it can be secured using LocTite(tm) "Quick Metal." Use sparingly and immediately assemble the motor since this material sets up fast and can prevent preload action.

7. If the housing is too clapped out replacement may be necessary. "Quick Metal" can make up a lot of space, but concentricity of the bearing to the housing must be retained.

8. Inner races of ball bearings can be heated to expand for easier shaft mounting.

9. Bearing housings can also be heated to assist installation of bearings.

Ball Bearing Preloading

The outer races of ball bearings in electric motors are preloaded axially to control end play and to minimize noise. Most motors utilize finger, wave or bellville spring washers to exert the preload and are shimmed to compress to one-half their unloaded height when installed in motors. Threaded bearing retainers are also used to adjust preload.

Replace worn or weak spring washers as part of bearing replacement.

Note. The preload washers are usually at the output end of the motor.

Sleeve Bearings

Usually made of porous bronze, sleeve bearings are low in cost, quiet, have good radial load ratings and do not rust. They must be closely fitted, aligned (excepting self-aligning types), must not be allowed to run dry and are limited to about 5000 RPM.

Lubrication. Most sleeve bearings are oil impregnated (self lubricating) and/or may receive additional lubrication from oil saturated felt washers, wicks or reservoirs alone or in combination. Electric motor oils are usually light weight, non-detergent oils with additives to reduce friction and scuffing. EP 80/90 weight oil can be used in small amounts if low temperature is not a consideration. The grease used in some I.E.C. centrifuges has a low melting point and requires annual clean out and replacement to insure long bearing life. Lubricants can dry out with time, during storage or because of use; always add a drop or two of oil to any motor, new or in service, as a routine practice. Do not over-lubricate or contaminate the brushes or commutator with

oil. Store new sleeve bearings in EP 80/90 oil; blot off excess prior to installation.

Sleeve Bearing Removal and Replacement

Sleeve bearings should be pressed out or pressed in using a mandrel closely fitted to the bore and length of the bearing. The shoulder of the mandrel should be flat and the body sufficiently small in diameter to easily go through the bearing housing bore.

Fabricate mandrels of steel to fit each size of bearing encountered.

Preheating cast iron bearing housings (motor end bells) to 140-160 degrees F will reduce the force required for pressing and subsequent bearing distortion. Preheating can be accomplished with hot water or an oven (wear protective gloves when handling). Use a bearing press to keep perfect alignment during installation. Check wick orientation (if any). Install the bearing to its proper depth as noted during removal of the old bearing.

After sleeve bearings are pressed in they must be sized or fitted to the motor shaft. This is best accomplished using adjustable parallel hand reamers. Take very shallow cuts checking frequently to produce a smooth, snug fit to the shaft. Small upsets on the bearing ends can be scraped off. Be sure the bearing surface of the shaft is polished before fitting. Use light oil to assist fitting. During final assembly of the motor, the end bells may have to be tapped in whatever direction needed to produce the least rotational drag of the armature. Run in will correct slight drag but do not run the motor if the drag is excessive; find and correct the problem.

Thrust Washer Bearings

A bit of end play is inherent in motors which use sleeve bearings. Thrust washers and end bearings are used to control and adjust the end play and are position dependent. Thrust washers are made of fiber, steel or phenolic. They may have some lubricating properties and are often used in mixed combinations. Some gear motors or motors used on end, such as in centrifuges, may use a single ball or phenolic filled fiber "Arguto" plug on the bottom end to take the load. Other motors have a ball bearing on the lower end and a sleeve bearing on the upper end.

Be sure end play is sufficient for easy rotation but not loose enough to cause brush run off of the commutator.

Motors used horizontally may have flanged sleeve bearings and/or thrust washers to control end play.

MOTOR DISASSEMBLY

1. Always have paper and pencil handy to write down or draw the order, location, orientation and number of the motor parts.

2. Have a padded work area or "V" block to hold and protect the motor.

3. Remove the brushes (if accessible).

4. Index by scribing the motor case pieces to indicate rotational alignment (indexing) when reassembling (not many motor cases are pinned).

5. Remove shaft attachments; tachometer generators, drive couplings, etc.

6. Separate the case, end bells, etc.; be careful not to strain or pinch wires, lose parts, damage fans or upset mating surfaces.

7. Remove the armature by pulling or pushing the shaft. Do not pull on the fan; be careful not to damage armature or field windings.

8. Blow out/off all the motor components with compressed air. Wear protective eye wear and a dust face mask. This should be done out-of-doors or in a hood. If necessary, clean the parts with electric motor cleaner.

9. Refer to other sections of this text for additional instruction regarding bearing removal and troubleshooting.

10. Inspect all the motor parts for signs of wear or any other discrepancies.

Armature and Field Coil Testing

Armature shorts and opens are best found using a growler. Field windings can be tested individually with an autotransformer and an amp clamp.

Compare current draw at same voltage settings, the coil pulling the most current is likely to be shorted.

Note. Some field coils are not easily separated from their housings or form part of the motor housing themselves.

If new armatures or field coils are not available or desirable, find and use a competent small motor rewinding shop and sublet armatures and field rewinding and commutator replacement. This work requires specialized machinery, operations and skills not common to most repair facilities. Note: High speed armatures should be balanced after rewinding or commutator replacement.

TURNING/TRUEING OF COMMUTATORS

The performance and most important factor of any motor utilizing brushes is the ability to commutate the external circuits to the internal circuits. Satisfactory commutation offers reasonable service life without excessive sparking, burning or ablation to the commutator or brushes.

To insure good commutation conditions the commutator must be concentric, a good conductor, smooth, intrinsically sound and properly undercut.

Roughness of the commutator surface ablates the brushes and generates excessive heat.

Out of round commutators induce "brush bounce" that wears the sides of the brushes, lowers current density, causes arcing,

burning and consequent erosion as the brushes are lifted off or lose pressure to the commutator.

Commutator trueing is best accomplished by turning the commutator in a lathe. This procedure is performed to refinish used and new commutators by removing the least amount of copper to achieve concentricity or bars free of burns, pocks or edge erosion.

Armature Inspections:

Blow out the armature, especially the core slots and wiring, with compressed air.

Note: This procedure should be performed out-of-doors or in a hood. Protective eyewear and a dust face mask are required.

If the armature is greasy, clean with electric motor cleaning solvent and dry.

Visually inspect the commutator; if it has loose or missing bars, thrown solder, burned or open wires, is generally worn more than 0.080" (2 mm) per 1" (25.4 mm) of the original diameter or tests shorted to shaft or between windings, the commutator should be replaced and/or the armature rewound and turning is not recommended.

Discretion must be used so that adequate bar height/width and undercutting room is left after turning.

The armature must be straight, the bearing surfaces smooth and concentric and of proper diameter, and the centers, if any, (tapered hole in either/both ends) free of upsets, burns, gouges or foreign material.

If the armature is bent or the bearing surfaces ruined, it may have to be discarded.

Note: Specialty machine and service shops can straighten, build up, re-spline and reslot armature shafts that would normally be scrapped. Time permitting and if you can find and utilize this service, the repair investment may yet be more economical than a new replacement unit.

Note: A. Aramture Shafts are usually made of soft steels and are easily machined, bent or upset. b. The Centers will be used to support the armature in the lathe. Burrs in the center can be removed by carefully scraping using a 3-cornered scraper or correctly angled hand taper reamer. c. A simple bend of a long armature shaft can be removed by supporting the shaft in a lathe chuck and striking the core with a dead blow, composition hammer opposite the bend. The shaft must run out less than .001. d. Shaft surfaces that run in sleeve bearings can be polished in the lathe at high speed using 600-1500 grit sandpaper being careful not to reduce or distort the diameter appreciably.

Set-up in Lathe:

The armature may be supported on the lathe centers, collets, well fitted sleeve bearings or in special bronze jawed adjustable tailstock chucks. When possible, mount the commutator end into a live center at the

tailstock. This procedure increases accuracy and eliminates the cramped work space between the headstock chuck and the armature windings.

If the armature is centerless ground or the center is opposite the commutator end, use an appropriate bushing or chuck in the tailstock. Circumstances may require mounting the commutator end into the headstock and will require extreme care during the turning operation because of the cramped quarters. Do not mar, upset or otherwise damage bearing surfaces of the armature when chucking.

After installation, tighten the chuck and apply adequate axial pressure with the tailstock to the live center (or tighten the tailstock chuck) to inhibit chatter while turning. Use a dial indicator to check the centering of the armature bearing surfaces with respect to the lathe center or chuck. The run out should be less than .001". (It may be necessary to rechuck the armature in 45 degree rotational steps or shim the chuck jaws/center to obtain this tolerance.)

Never trust the accuracy of your set-up; especially 3-jawed chucks and armature centers. Find and correct alignment and centering problems before proceeding.

Wrap the armature windings tightly with Kraft paper secured with masking tape to keep copper chips and debris out of the windings.

Note: In addition to standard safety practices, clean protective eyewear is required while turning.

Cutting Tools: Copper, like brass and some plastics, is tenacious when being turned or drilled and requires a scraping action rather than gouging.

Cutting tools for copper should be ground with a front clearance angle of 12 degrees, side clearance of 14 degrees, a top rake of negative 0-3 degrees and a side rake of 20 degrees. These are true angles. If your tool holder has a built-in angle, you must compensate. A diamond shaped tool or one with a sharp point will suffice, but the point should be rounded slightly to promote overlapping cuts without threading. Grind or purchase tools for left and right cutting. The tool should be mounted and positioned to cut just below the center line of the work piece. The tool edge must be very sharp and free of burrs. Hone with a fine stone.

Turning Speeds: The surface speed to turn copper is generally 500-600 ft. per minute. Lead feed should be slow; .003-.010" per revolution. The depth of cut should not exceed .005" during any part of commutator turning as the tool may twist the segments cutting deeper on one side than the other. Final or finish cut depth should be .001". Do not use cutting fluids when turning armatures. Chattered or turned over edges are caused by interrupted surfaces, improperly dressed tools (too large radius, too much relief, improper rake, dullness), high speed or lack of rigidity of the tool or workpiece.

Set the carriage stop to limit tool entry into the riser or wired end of the commutator, but be sure the width of cut from the end of the commutator to the wired end accommodates the brush with as much extra space as possible. If the commutator was previously turned, turn only to that step (unless correcting improper turning). Do not cut on the back traverse after a cut; back out the tool to prevent threading. Repeat light cutting passes until all traces of burns, erosion and low spots of the copper are eliminated.

Remember, remove the least amount of the commutator to achieve this end. Recheck for concentricity and usable commutator diameter.

Practice turning discarded armatures to validate lathe set-up, tool configuration and to gain experience.

Blow out the commutator with compressed air. Use a magnifying glass to examine the commutator, especially near the wired end, and remove all copper chips, turned over copper, burned mica and carbon from the mica slots (that is if a slot still exists after turning). A dental pick is useful in removing stubborn chips. Hacksaw blades, as described for undercutting, should be used to clean out all the slots to obtain a clean mica surface. Be careful not to scratch the bar faces or disturb the windings.

Polish the commutator after turning using 600-1500 grit sandpaper regardless of subsequent undercutting. The sandpaper may be backed on a wooden paddle. Turn at relatively high speed, drawing the sanding medium over the commutator against the direction of rotation using moderate and even pressure to avoid clogging and heating to achieve a smooth finish.

Note: The sanding medium should be the full width of the turned portion of the commutator. Cut the sandpaper to the required width; do not use folded sandpaper.

Blow out the commutator and again check for copper chips, shorts and burrs. Recheck the commutator and bearing surface concentricity (should be less than .001" run out).

If the mica slots (undercuts) are deeper than the slot width, undercutting will not be necessary.

Chamfering the commutator bars can now be performed in the lathe set up. Please note: Chamfering is not required and is difficult to perform on small commutators, but smooth, even edge breaking of the commutator bars will greatly enhance commutation (see chamfering).

Growl test the armature for shorts (usually a copper chip in the commutator at this point). Recheck the finish of the commutator, rework as required. The armature is now ready for further assembly.

If the commutator has been turned into the mica or the slot depth is too shallow, undercutting to some degree must be performed as described in the following chapter.

Note: The slots in new commutators are 2-4 times deeper than the slot width which allows several light turnings if the motor is serviced before extreme wear occurs.

UNDERCUTTING MICA OF COMMUTATORS

Mica is the mineral used to insulate the commutator bars from each other and from the armature shaft. Some new motors use thermo-set or high tech plastics for the same purpose. The term "mica" pertains to all materials.

Undercutting is the process of cutting down the mica insulation to form a slot between the commutator bars. This procedure is carried out after commutator turning, preliminary polishing and concentricity checks, to allow even wear of the bars. Even the smallest amount of mica left in the slots can cause poor commutation. Undercutting is part of routine commutator maintenance to clean out brush deposits and to insure adequate slot depth.

The depth of the undercut slot should be the same as or greater than the width, and centered between the bars.

Two forms of slots are used; square bottom ("U") slots or 40-60 degree "Vee" slots. The "U" slot is more common and easier to make, but the "Vee" slot is preferred for low speed motors as brush deposits are easily thrown out.

Electric rotary undercutters offer the fastest, most economical method of undercutting for shops with a medium to heavy workload. Although dedicated electric undercutters and lathes are perhaps the best tools for the job, inexpensive alternatives will work as well.

1. For small motors, an adaptor can be made to mount small rotary undercutter blades to a Replacement Parts Industries motor (pt. no. CAM024). With the addition of a rigid, vertically adjustable bracket, this cutter can be attached to a lathe cross feed to give the same results as a dedicated tool. Limit the speed to 8000 RPM (free running) with an adjustable autotransformer. The adjustable bracket should permit mounting the motor behind the work piece with the blade centered above the work and facing the operator. Rotary blades (saws) are available in several diameters and widths with a 1/8" bore.

2. Grinding the set off new sabre saw blades or hacksaw blade pieces (4-5" long) make excellent undercutting saws. Grind several thicknesses and tooth numbers to accommodate different slot widths. Wrap one end with tape to form a handle or install in a blade holder. The teeth should point towards the handle. Be sure to grind some blades to cut "Vee" slots and some with a sharp point or hook on the end. These will be useful to remove copper chips, especially near the

wired end of the commutator or mica fins and debris from the slots.

Note: Some motors will have a balance disk or other attachment that may impede the operations as described. Interference may also indicate a commutator has been turned down too far and must be replaced. If the disk is to be removed, be sure to scribe its position to the armature shaft to permit exact relocation when reinstalled. These disks are attached to the armature by set screws, press fit or weld.

"U" Slot Formation:

1. Using powered rotary blade undercutter and lathe:

Remove the tool post and place the armature, less bearings, into the lathe with the commutator end center into the tail stock center. (If the armature shaft is centerless ground, use an appropriate bushing or chuck in the tail stock.) Safety tip: Unplug the lathe as rotation of the armature for undercutting will be done by hand. Wrap masking tape around the windings and the wired end of the commutator. This will serve as protection and a traverse guide during undercutting. Full armature protection as described when turning is desirable. Rotate and position a commutator mica slot at top dead center. Measure and select a sharp cutter blade of the same width as/or slightly narrower than the slot and firmly attach the blade to the cutter shaft. Be sure the blade teeth point the same direction as rotation of cutter motor. With the cross feed, carriage and vertical adjustment, position the cutter blade directly above and close to the top mica slot. Check for parallel and centering and set the carriage stop to prevent the blade traversing into the armature windings. (The undercutting should stop just short of the wired end of the commutator bars.) Lower the cutter blade until it just touches the commutator. Move the carriage so the cutter blade completely clears the outside end of the commutator. Now, lower the cutter blade the same distance as the width of the mica slot to be cut. Be certain all adjustments are locked, rigid and the carriage has some drag.

Note: In addition to standard safety practices, clean protective eyewear and a dust face mask are required before continuation of this procedure.

During the course of undercutting, be sure not to bump or turn the armature or cross feed since irreparable damage to the commutator or windings will occur.

Start the cutter motor; traverse the carriage slowly and carefully by hand into the mica making sure not to saw the copper bars or cut too deep. Reposition if necessary.

If all is correct, continue to carefully traverse and guide the cutter across the mica. Stop short of the wired end of the commutator bars. Reset the carriage stop if necessary. If a step exists because of turning, slow the traversing rate and advance carefully into the step far enough to

complete a slot in the main surface of the commutator. Avoid cutting into commutator risers or the wired end. Carefully traverse the cutter back and completely off the end of the commutator.

Note: If the cutter resaws measurably deeper on the return, reset the depth of cut or correct a lathe discrepancy.

Rotate the armature into proper position to cut the next slot and continue the foregoing until all slots are undercut. The two cutting passes should be sufficient to form the slots. After undercutting, blow off the amrature with compressed air. Every slot should be closely inspected with the aid of a magnifying glass and all feather edge mica, copper chips or shorts removed with a knife blade or suitable tool. Test for shorts by growling the armature. If OK, the commutator bars are ready to chamfer.

Develop a smooth rhythmic technique of undercutting. Be careful not to linger or go too fast. Optimum traverse speed and guidance depend on good eye, ear and hand coordination. This will prevent chatter, overheating, motor overloading, premature blade dulling, accidents and will produce the best results. Listen to the "sing" of the sawing while viewing the operation. A change in pitch or motor speed will alert to a change in cutting speed, type of material being cut, overloading, chatter, etc. As in turning, practice undercutting on discarded commutators to gain competence.

2. "U" slot formation by hand:

"U" slot formation can be performed by using hacksaw blades as previously described. Wrap the wired end of the commutator and windings with tape for protection. Place the armature into a lathe or clamp into a V block for support. Select a blade of the proper width and carefully saw into the mica using firm, even pressure keeping the blade parallel and vertical to the commutator. Being careful not to scratch the bar faces, saw to the desired depth.

"Vee" Slot Formation:

1. "Vee" slot formation with an electric undercutter is performed basically the same as forming "U" slots. The blades, known as "vee" slot milling cutters, are made in one thickness only - .045" with cutting angles of 40-, 50- and 60-degrees. For small commutators the 40-degree cutter is preferred. Very accurate centering and depth control is mandatory to prevent excessive copper loss and subsequent reduction in commutator bar width. Although chamfering is not required after slotting, rough edges, if found, should be removed by light scraping or sanding. Operations, inspections and warnings described previously should be adhered to.

2. "Vee" slots can be formed using slotting files, but these are usually found only with 60-degree angles.

Chamfering:

Turning, polishing and undercutting produce rough, hardened or turned over edges on the commutator bars. This condition will not permit even wear of the bars and may act as scrapers against the brushes. A light 45-degree chamfer will remove these rough edges and can be accomplished using a scraper, fine smooth cut square file or 600-1500 grit flexible sandpaper formed around a square metal block. On small commutators the latter is the best choice. Using the lathe or V blocks to hold the armature, draw the cutting tool or sanding medium through the slot away from the windings. A light touch, practice and sharp tools will produce symmetrical chamfers without appreciable loss of commutator bar width. Simple edge breaking of the commutator bars in small motors will greatly improve performance and extend brush life.

Note: "Vee" slotting, if performed accurately, obviates the chamfer process. After chamfering, blow out the slots with compressed air. Examine the slots using a magnifying glass, especially near the wired end of the bars. Locate and remove any copper chips, shorts, mica fins or other debris.

The commutator is now ready for final polishing.

Final Polishing of Commutator:

A smooth finish of the commutator can be obtained using 600-1500 grit flexible sandpaper or a very fine flexible polisher. Turn at a relatively high speed in a lathe, drawing the sanding medium over the commutator against the direction of rotation. Use a light and even pressure to avoid clogging, heating and to produce the best result.

Note: The sanding medium should be the full width of the commutator.

Blow out the commutator and windings with compressed air and inspect for debris. Be certain a slight chamfer still exists on all bars. Rechamfer if necessary, recheck concentricity of commutator and growl armature before further assembly.

MOTOR ASSEMBLY

The normal procedure is to reverse the order of disassembly.

1. Repair or replace all parts or wiring as required.

2. Brush holder and other motor leads should be well insulated, dressed away from moving parts, free of frays or discoloration. Brush holder leads must have a good connection to the holder. Note. Leads which have a spring or circular spring clip to the holder should be soldered using a hot iron, acid core solder and cleaned afterward to insure a good connection.

3. Test fit individual parts before final assembly.

4. Refer to your notes to assure correct number, order, location and orientation of the parts.

5. Refer to other sections of this text for details and specific information regarding troubleshooting and methods of assembly.

6. Lubricate sleeve bearings.

7. Tighten the motor case (housing) pieces evenly to avoid binding. The case should be indexed and fully seated.

8. Use thread locking compounds on tachometer generator posts, couplings or other mechanical hardware.

9. Rotate the motor shaft by hand; it should turn evenly, smoothly and without excessive or irregular drag.

10. Install the brushes (except in motors in which the brushes must be installed prior to case assembly).

11. "Hi Pot" test all motor connections to ground or measure with an ohmmeter to find high resistance connections, shorts or opens.

12. Correct any discrepancy before electrical dynamic testing.

MOTOR TESTING

Safety

1. Do not wear loose ties, clothing, jewelry or long hair when testing motors.

2. Do not place your fingers into any motor aperture during testing.

3. Be sure the motor case is grounded.

4. Temporary electrical connectors and jumper wires pose electrical safety hazards; be especially alert to exposure.

5. Be sure to firmly secure the motor before start up. The reactive torque will spin the motor if full rated power is applied.

UNIVERSAL MOTOR TESTING

Set Up. Mount and lightly clamp the motor into a padded V block or motor holder. Motors utilizing sleeve bearings which are normally used in a vertical position should be tested vertically. Do not impede the air flow through the motor.

Know the direction of motor rotation; example: Sorvall motors CW, I.E.C. CCW as viewed from shaft end. Locate, identify and connect the appropriate armature and field coil leads in series (if not connected internally). Connect the motor power leads to the output of an autotransformer (VARIAC(tm) powerstat) rated 7-10 amperes at 100V AC. Connect an amp clamp around the output high side of the autotransformer to monitor motor current. Throughout the testing, monitor the ammeter for improper or excessive current draw. Motor testing and brush seating will require only 25-40% of the autotransformer power setting. Normally, do not exceed 50% power to an unloaded series motor. Never exceed rated motor current

(usually the same as acceleration current). This set-up will run up to 220V motors.

Starting from zero, advance the autotransformer setting. The motor should start rotation by 30% power. Proper phasing of the motor armature and field will produce a maximum RPM in the proper direction at a given voltage. Improper phasing of a field coil will result in poor or no rotation, hum and high current. Reversible motors should run equally well in either direction.

If the motors fails to start properly, shut off the power, locate and correct the problem.

Run the motor at low speed; if loud brush "clicking: is noted, a commutator bar edge may be turned up or a brush is installed improperly and must be corrected before proceeding. Also note if commutator runs true.

Seating Brushes. Run the motor between 300-1500 RPM. Run a brush seating stone near the leading edge of the brushes for a few seconds; the motor will speed up and the current will diminish. Repeat the stoning process every 3-5 minutes until the motor no longer speeds up or the current changes appreciably. Some speed variations are normal because of power fluctuations.

Turn down the power as required to maintain the suggested speed setting. Examine the brushes to verify complete seating. Vacuum or lightly blow the stone dust off the commutator. Do not blow the dust into the bearings. Continue to run the motor at a moderate speed for one-half hour to detect problems, run in the bearings and form a conductive film on the commutator. The commutator will darken slightly. This procedure will allow the motor to be used at full load immediately after installation.

To apply stone through small apertures of motors, glue small pieces of stone to ice cream sticks. Flexible abrasives can be used to remove excess commutator film or to polish commutators in running motors.

Field/Carrier Alignment. To realign slipped field coils or brush carriers, lock the armature externally, momentarily apply full power to the motor, observe the current and then turn off. In some equipment the locked armature test is used to adjust the maximum current draw of the motor. Rotate the field coils/carrier by small increments and test again to obtain the rated motor current at its rated voltage. Lock down the fields/carrier after correct setting is obtained.

DC Motors. Running in DC motors is the same as in universal motors but a full wave bridge rectifier must be installed between the motor and the autotransformer. These motors can be run at full power setting.

AC Motors. Always apply rated voltage for testing but immediately shut down if the motor fails to start or runs poorly.

MOTOR INSTALLATION

Make sure all power is disconnected from the equipment and that any discrepancies noted during motor removal or at this time are corrected. (Please refer to the pertinent sections of this text.)

Be certain all manufacturers' motor and control circuit retrofits have been incorporated before operation.

Check the motor current under full load to be sure that it does not exceed manufacturers' specifications.

Always perform a complete operational and functional test before leaving the job site.

Conduct an in-service if you suspect that the problem was caused by improper use of the equipment. Before leaving the job site, always turn the motor speed control to zero if the equipment is not in use.

LABORATORY CENTRIFUGE USE INFORMATION

Rotor:

A rotor or head is the rotating part of a centrifuge which holds the tubes, bottles or bags containing the media to be centrifuged. It is constructed of very strong materials such as aluminum alloy, steel, stainless steel, titanium or bronze. Anti-corrosive protection is provided by anodizing, lacquering or plating.

Rotors are fabricated in several configurations such as anglehead, horizontal (swinging bucket), air shielded (swinging bucket with enclosure, vertical or sieve.

The rotor accessories are trunion rings, shields, multicarriers, buckets, lids, adaptors and cushions. The rotor load consists of the above accessories and includes the tubes, bottles, caps, bags, and media.

The media capacity, speeds RPM and RCF vary with size, application and design. Capacities of .1 cc to 6 liters and speeds to 200,000 RPM are commonplace.

Balance:

Proper balance is necessary for good separation, long machine life and prevention of accidents.

No less than two (2) samples should be spun in any kind of multi-place rotor and these samples must be loaded opposite each other.

For optimum performance and safety, the rotor load should be balanced within .1 gram, both statically and dynamically (rotationally) from side to opposite side. When using multicarriers, correct symmetry must be observed through the rotor's center of rotation and through the carrier's pivotal axis. Almost all accessories for horizontal or swinging bucket rotors are marked with their manufactured weight in grams. If not marked, weigh the accessories and use matched sets opposite each other. Include all accessories. Some rotors have buckets/carriers especially matched at the factory to be used only with each other. These will have a position number stamped on the rotor and the bucket/carrier. Match the numbers and have like numbers facing each other. Media of matched density-quantity must be loaded opposite of each other.

NOTE: If you are spinning high density materials (greater than 1.2 gm/ml), the maximum speeds must be reduced to prevent over stressing the rotor. When spinning glass tubes, the correct rubber cushion must be properly installed. These cushions protect the glass from breaking by distributing the force to the entire bottom of the tube. This is true for many plastic tubes as well. Conical base tubes require a thicker cushion which can also be used to add height within the shield or carrier. Tubes and bottles should not protrude excessively from the shield or carrier. Consult the manufacturer's recommendations for sizing of glass and plastic ware to the rotor and accessories.

Use only cushions manufactured for your specific application. The use of other devices (such as Vacutainer plugs and cotton) can compress excessively under stress, changing rotational balance. A rotor may weigh equally and be balanced but the mass is not always distributed at the same radius.

All positions in open horizontal rotors must have buckets, carriers, trunions and shields in place. In some cases even a load of media must be used. This is done to give the rotor proper stress loading and to prevent air turbulance which causes vibration. This condition is much like running out of balance.

Some large capacity, horizontal air shielded rotors must have empty buckets removed prior to spinning. A loaded bucket insures proper swing-out that might not be achieved when empty. In other units, loaded or empty buckets must be in place to prevent rotor arm distortion. Consult manufacturer's recommendations regarding rotor use and loading.

When using rubber adaptors, dust them with talcum powder to allow easy insertion and removal. If using capped and/or sealed tubes, be sure all sealing gaskets and/or "O" rings are in good condition. This is especially important if spinning in a vacuum or with vertical rotors. Again, strict adherence to manufacturer's guidelines is mandatory.

Lubrication:

All horizontal rotors with moving parts must have lubrication between load bearing surfaces. This is necessary to allow even swing-out when rotation starts and even swing-down at the end of a run. Lubrication also keeps vibration down and separation at a maximum.

Load bearing surfaces (pivot points) should be clean and free of corrosion. Proper lubricant should be used sparingly and in accordance with manufacturers'

specifications. General purpose horizontal rotors can be lubricated with light stopcock grease or GE Versilube (tm). In addition, lightly lubricate the spindle nose to allow easy separation of the rotor from the drive. Ultra speed horizontal rotors use special molybdenum liquid lubricant because of extreme pressures. Extra care must be exercised when using these rotors. ALWAYS RELUBRICATE AFTER CLEANING.

Cleaning:

All rotors and accessories must be kept clean, dry and free of media debris. Special attention should be given to anglehead, multicarrier and shield bores. In addition to sanitary reasons, this must be done to retain the manufactured balance weight and to prevent corrosion.

Cleaning should always be accomplished immediately after a spin. Wash with a solution of warm water and mild detergent. Of course use proper agents if the spill is radioactive or needs biological decontamination. Dry all parts thoroughly after cleaning.

An end bristled brush or plastic scraper may be of help, but avoid using metal tools on the rotor. A violated surface condition can promote corrosion and possibly weaken the rotor. All rotor parts and accessories should be kept clean and have no dents, dings, cracks, bends or corrosion. If you are suspicious - call for a manufacturer's inspection.

Installation of Rotor:

Before starting a centrifuge be sure rotor and associated parts are seated and/or locked down properly - i.e. rotor to drive key in spindle, trunions in cradles, caps and lids, anglehead covers, air shield covers, etc. Be sure of particular maximum speeds for given machine and rotor, never exceed this maximum. When installing a rotor use extreme care not to bend or jar the drive spindle. Do not let the rotor fall onto the spindle; gently lower into place. If there is a lower horizontal drive key, (of the spindle nose to rotor) purposely have the key misaligned then, using the supplied tool, hold the rotor stationary and turn the spindle until the key locks in. This maneuver is applicable to IEC models B-20, B-20A, B-35 and B-60. Other models may have a vertical drive key. If so, be sure it is in place and the set screw or locknut is secure. If the drive has drive pins or teeth, be sure the drive is engaged to the rotor properly. Listen or feel for two "clicks" or points of contact to engagement. If a rotor becomes stuck onto a spindle, do not use excessive force to pull it off. When removing a rotor be sure to pull in a straight up direction. To free up a stuck spindle, try spraying a penetrating lubricant such as WD-40 into the stuck area, allowing the lubricant to soak in and then try again. If this is not successful, use a proper rotor "puller" to remove. In the case of a direct drive tapered spindle, a stuck spindle may be removed by pulling up on one side of the rotor (firmly) and with the heel of the other hand striking down on the opposite side. NOTE: Do not use this procedure with

flexible or floating shaft drives. If a cold rotor is stuck onto a tapered spindle, merely allow the rotor to warm up. This can be accomplished by turning off the machine and opening the chamber door. Try removal after the rotor has reached ambient temperature.

In any case, after the rotor is removed, clean and lubricate the mating parts. If a galling condition or burr exists, remove it with fine sand paper and test for a good smooth fit. Always visually inspect rotors and drives before use; if questionable, do not operate.

Operation:

When starting a centrifuge stay near it until set speed is attained. If excessive continued vibration is encountered, shut the machine down and correct the problem, usually an unbalanced load. Do not exceed the maximum rated speed.

All rotors have a "critical speed" (maximum precession) that occurs as a vibration between 200 & 2000 RPM. This vibration should disappear as the rotor increases or decreases speed past the critical point. Avoid selecting an operating speed within the critical speed area. When starting a run be sure the rotor does not surpass the selected speed. Be aware of normal operating noises. If abnormal speeds or sounds are encountered, shut the machine down and have the problem corrected. Consult the manufacturer's recommendation regarding maximum speeds for the rotor and associated accessories. Excessive speed, in addition to an accident situation, causes extreme wear and over heating of the drive and motor. Always remove the rotor before moving or transporting the centrifuge. The heavy mass of the rotor will bend or break the drive shaft or ruin the drive bearings. The drive shafts are strong but should not be abused. Removal of a rotor from the drive must be done carefully. Rotors are usually very heavy and removal of accessories first is very helpful. Get a good grip with both hands on the rotor, pull straight up and set down gently. Get assistance if necessary.

Refrigerated Centrifuges:

When using refrigerated centrifuges do not allow excessive ice and water build-up to form inside the chamber. This condition becomes a thermal blanket causing efficiency loss of the cooling system and unregulated rotor temperatures. In addition, a rotor accident could occur if a piece of ice comes loose and strikes a moving rotor load. To remove ice from the chamber, merely turn the centrifuge off, open the door, allow the chamber to warm up, sponge out the water and dry with a clean cloth. Periodically clean the refrigeration condenser with a brush to remove dirt and lint and be sure nothing impedes the airflow. Continued use with an iced up chamber and dirty condenser will waste energy and will decrease compressor life. When installing refrigerated centrifuges, provide 8" of air space between adjacent walls or other equipment. Position to avoid intake of heated exhaust air from other appliances or heat vents.

Safety:

In addition to the previous information, the following is advised:

1. Be sure the centrifuge is level. The rotor will seek a perpendicular attitude to the earth's gravity and can cause a failure of the drive.

2. Be sure the centrifuge is in good operating condition.

3. Never open the lid or chamber door while the rotor is turning. The air inrush could upset the rotor and overload the drive and motor. In addition, debris going in or out of the chamber could result in an accident.

4. Do not stop any rotor by hand. Even a slow moving rotor develops a lot of hard force. Smooth anglehead rotors can actually fling out razor sharp plating.

5. Do not bypass any safety features or interlocks of any kind.

6. If a rotor accident occurs, the safest place is a position below the rotor level.

In closing, proper knowledge and handling of centrifuges and rotors will result in long life and good separations in an accident-free environment.

CENTRIFUGE MAINTENANCE

The following maintenance program must be carried out by user:

1. Keep the machine clean
2. Be aware of proper operation
3. Be aware of normal noises and vibrations - correct or stop use if different from normal
4. Keep all external screws and hardware tight
5. Lubricate motor (some older models)
6. Check brushes frequently
7. Run brushes in at low speed when renewed
8. Never defeat safety devices
9. Do not obstruct cooling vents
10. Keep chambers dry
11. Keep rotor trunions lubed
12. Do not use damaged rotors
13. Do not operate with damaged spindle
14. Be sure rotors can be fully seated on spindle
15. Replace all parts in correct order when R/R brushes, motors and drives
16. Be sure centrifuge is level and feet are down
17. Discontinue use of machine if it becomes noisy, vibrates excessively or does not seem to perform in any mode as it should
18. Never use an extension cord

CENTRIFUGE PREVENTIVE MAINTENANCE LIST

PM, or preventive maintenance, is a term used to describe labor and parts-changing performed in an effort to reduce or prevent a

mechanical or electrical failure which could cause machine or instrument failure or cause a machine or instrument to become unsafe to use. The following is a list of work performed by Sienco Instrumentation Service Co. that we feel is as comprehensive as possible. Parts that have failed or are questionable are replaced at the time of PM.

1. Clean condensers
2. Check upper-drive, complete
3. Check chamber and clean
4. Pull on all wire connections and check solder joints
5. Tighten all screws, electrical and mechanical
6. Lubricate fans, door hinges, fans - if applicable
7. Check all plugs and sockets
8. Check all large capacitors and lytics
9. Set timer and control knobs
10. Check machine level before operating
11. Check for correct voltage tapping
12. De-static tachometer indicator
13. Check tachometer output
14. Calibrate temperature indicator
15. Calibrate speed control
16. Calibrate tachometer indicator
17. Set acceleration current
18. Check brake operation
19. Check lower coupling, if applicable
20. Check motor completely, including armature; blow out dust with compressed air
21. Check power cords
22. Complete operational test
23. Complete functional test
24. Set overspeed relay or circuits
25. Check rotor balance

26. Check timer time out
27. Check all controls
28. Check all indicators
29. Check all safety devices, including interlocks
30. Check refrigeration and clean condenser
31. Check grounds
32. Clean outside of machine
33. Renew all paint, plastic and rubber parts with a product such as Armor All (tm)
34. Check lid latch mechanisms
35. Check all parts for wear and abuse, including brushes
36. Check and replace missing or damaged parts
37. If changed, run in and totally seat brushes
38. Perform total lubrication as required, i.e. hinges, latches, motors, moving parts
39. Check centrifuge rotor:
    a. inspect for corrosion
    b. clean and lubricate all threaded parts used in rotor
    c. check and replace any defective "O" rings used in rotor cover
    d. check rotor decal and clean if applicable
40. Perform total operation and functional test before leaving site
41. Check for "LOOSE" by all definitions

F eel
I nspect
T ighten
C lean
A align

L ubricate

SOME COMMON FAILURES AND FIXES IN POPULAR CENTRIFUGES

Although many of the following solutions do not require actual motor repair, thorough examination and remedial service of the motor and drive is advised. Always consult the manufacturers' service manual for specific calibration and adjustment procedures to be performed when repairs are completed.

Symptoms and causes are listed after the makes and models of various centrifuges.

<u>All Makes/Most Models</u>

1. <u>Lower speeds than normal, air rush noise, chamber warms</u>. a. Chamber cover lid or door loose or misaligned. b. Hinges/latches misaligned or loose. <u>Note</u>: Refrigerated models get excessive ice build-up.

2. <u>Higher speeds than normal; product warms up</u> (non-refrigerated models). Air vents restricted or closed.

<u>All Makes and Models of Ultra Centrifuges</u>

1. <u>Loss of vacuum shuts down machine, all functions OK with test rotor</u>. Leaky sample holders or tubes, check for telltale traces.

<u>DuPont/Sorvall</u>

RC2, 2b, 3

1. Overspeeds, doesn't shut down. a. Tachometer generator magnet loose, weak or missing. b. Open in tachometer generator circuits (orange wires). c. Defective or misadjusted overspeed relay.

2. Rotor won't start, no relay click when start switch depressed. a. Open or intermittent in timer, stop switch, start switch, overspeed relay or temperature control. b. Timer not on. c. Chamber temperature not within 5 degrees C of set point.

3. Relays click, rotor nudges but won't run when start switch is depressed. a. Speed control bad or fuse blown. b. Brush wear circuit breaker open.

4. Centrifuge shuts down before top speed is attained, but can be restarted when rotor speed is low. Bad or miscalibrated overspeed relay.

5. Motor noisy. Top speed low or slow to attain. Leaky or open 80 MFD 450 VDC electrolytic (always check during PM).

6. Rotor runs much faster than set speed. a. 3 MFD lytic in speed control (old style). b. Tach generator magnet weak or loose. c. Calibration. d. Leaky SCR in speed control.

RC 2, 2b, 5, 5b

1. Motor runs away, rotor doesn't spin. Broken rubber bond under spindle nose or broken lower coupling.

2. Rotor wobbles during start-up. Rubber bond under spindle nose cracked.

3. Spindle drive pins worn or bent. Rotor installed improperly, usually without rotor cover.

RC 3b

1. Lower coupling broken, square spindle nose twisted. Failure of modulator P.C.B., loose solder joints to filter caps (C 4,5,6,7,8,9; always check that RC 3bs have latest retrofit P.C.B.s before attempting repairs of any sort, especially motor/drive repair or replacement).

2. Brush arcing, poor brush wear or motor won't run. Brush leads from motor bent over brush caps, brush hung up in holder, holder charred.

RC 5, 5b

1. Motor and refrigeration won't start. Lamps in temperature indicator burned out.

2. Motor gets very hot, excessive brush wear. a. Crushed air ducts to motor silencer or plugged vents. b. Rubber baffle (doughnut in silencer around motor) missing or out of place (always check as part of PM).

All RCs

1. High brush wear or won't get to maximum speed. Readjust acceleration current: RC 2 - 12 amps; RC 2b, 5, 5b - 18 amps; RC 3 - 16 amps.

2. Rubber debris in chamber or under boot seal. a. Failure of rubber bonded parts in gyro drive assembly (check closely for cracks; when renewing spindle nose rubber parts, be sure cavity and bearing shaft end have no abnormal wear). b. Gyro cover seal boot not properly installed.

3. Noisy acceleration and pronounced motor modulation. a. Loose or worn lower coupling. b. Worn drive or motor splines (check by rotating spindle back and forth).

GLCs

1. Motor won't run or cuts out after long use. Loose spring wire connection to brush holder.

Note: Sorvall rotors run clockwise.

Damon/IEC

B20, B20A

1. Motor speeds up during acceleration. Loose drive belt.

2. High brush wear, frequent upper drive failure. Brake used at speeds above 10k RPM (provide label "DO NOT USE BRAKE ABOVE 10K RPM").

3. Upper drive shaft twisted or broken. Rotor not installed into drive key.

4. Motor won't drive until speed control is advanced to 1/4 turn or more. a. Carbon build-up on tach generator (in units with solid state control). b. Speed control.

Old Models

1. Motor runs backwards. Correct motor wiring (should run counterclockwise).

2. Motor oily and smokes. a. Unit has been tipped or overfilled with oil. b. Oil flinger on armature missing

3. Rotor cannot get to, or goes beyond maximum rated speed. a. Brush holder assembly loose and out of proper position. b. Brake lever (if any) not indexed properly.

4. User feels tingle or gets a shock when installing/removing rotors. Motor ground wire to frame loose or missing.

Most Floor Models

1. Rotor can't get to maximum rated speed. a. Field coil has turned (loose); best repaired in shop. b. Reset acceleration current.

PRJ, PR6, B-20

1. Rotor speed changes as compressor cycles. Install .01 400 volt mylar capacitor across coil of refrigeration relay.

CU, CRU 5000, PR, DPR 6000

1. Motor won't run, excessive brush wear. High drag of brush in holder with wear indicator switch.

PR 6000, DPR 6000

1. Irratic speed and temperature indicator. a. Lamp out, loose, misaligned in tach generator circuit (PR 6000). b. Moisture on tach generator P.C.B. (after correction, seal periphery of bell housing with R.T.V.).

UV

1. Arcing and short brush life. a. Shunt wound up when installing brushes (unwind 3 turns before installing). b. Operator advancing speed control too fast (all older models with Variacs or reostats).

PR6, B-20

1. Motor nums, won't get to speed. Shorted diode in power bridge.

Centra 7, 7R

1. Motor runs backwards in machine. Install rotor.

2. Wear on side of brush, short brush life. a. Needs current limiter retrofit kit. b. Has short stack motor. c. Limit RIA rotor to 2600 RPM. d. Tachometer indication wrong.

HN, HN-S, HN-SII

1. Black dust under machine, noisy, won't get to speed. Too many brush changes without blowing out or repairing motor.

MB

1. Top cover gets too warm and crit clay packing melts. a. Cover vent, air channel, filter or screen restricted. b. Rear vent too close to wall, etc. c. Unit being used in direct sunlight or box.

CL, CH

1. Sleeve bearings wear out prematurely. Hole for lubrication wick was not drilled through bearing.

Note: IEC rotors turn counter clockwise.

Beckman

TJ-6

1. Drive motor stops after several runs; can be restarted later. Thermo switch in motor defective (if all else OK).

J21-b

Arcing, high brush wear or no run. Brush lead bent over brush cap.

MSE Mistral 3000 Series

1. Motor sounds like it has bearing noise or ringing pulses louder than normal. Inverter P.C.B. misadjusted.

GENERAL INFORMATION ABOUT CENTRIFUGES

1. Rotors almost always turn opposite the rotor/lid nut or screw tightening direction.

2. If rotor won't get to set speed but all seems OK, check maximum allowable speed of set-up.

3. Close temperature control at low speeds with relatively warm temperature settings are not feasible because rotor speed (heat from air friction) provides thermal feedback.

4. Timers that work on the bench may fail when installed because knob or shaft is rubbing on control panel.

5. If you did a good job but user complains of noise, have user check all rotor parts for tightness (especially covers) and lube trunions, if any.

6. If brushes squeak at low speeds (starting or stopping), the brush may not be seated or have a hard spot. Run in further or replace.

7. Speed control knobs on non-feedback controlled motors are marked for reference or percent of power and are not indicative of a particular speed, especially if the rotor load is changed.

8. If refrigerated centrifuge doesn't get cold enough or has irratic temperature control, check for ice build-up in chamber. Defrost and dry the chamber. Check and clear condenser.

9. Loud or prolonged hissing or low frostline in a refrigerated centrifuse chamber may indicate a low refrigerant charge.

10. To calibrate a tachometer, measure the actual speed with a test tachometer, adjust tachometer indicator to actual speed, set speed dial to indicated speed and adjust speed control to match indicated speed. Analog indicators must be de-staticized before any calibrations. (Consult mfg. of equipment for specific adjustments.)

11. Grey or white powder in a centrifuge chamber is the result of broken glass swirling inside the chamber.

12. Noise generated in direct drive motors is transmitted to all rotor parts.

LAST WORDS

Good workmanship is the sum of the whole. Now, do you really <u>just</u> want to change the brushes?

TOOLS AND MATERIALS REFERRED TO IN THIS TEXT MAY BE OBTAINED FROM THE FOLLOWING SOURCES

1. Sienco Instrument Service Co., Denver, CO
   Shaft cushions, specialized bearing and rotor pullers, centrifuge parts
   Lubricants
2. Replacement Parts Industries, Chatsworth, CA
   Motors, brushes - catalogued parts
3. Snap On Tools Corp., Nationwide
   Pullers, presses, hand and power tools
4. Brownell Electro, Inc., Nationwide
   Most all tools and equipment for motor rebuilding
5. Grainger, Nationwide
   Tools, motors, test equipment

6. Ideal Industries, Inc., Sycamore, IL
   Saws, armature tools and surfacing supplies

Precision measuring tools can be purchased at machine tool dealers. Flexible sandpapers are available at model hobby shops, automotive paint or woodworking stores.

Addendum. Heat generated by loose or high resistance electrical connections break down insulation and erode or anneal metals.

REFERENCES

To learn more about motors and control the following texts are recommended.

1. Electro-Craft Corp.: DC Motors, Speed Control and Servo Systems, Hopkins, MN, 1973.

2. Bodine Electrical Co.: Small Motor, Gearmotor and Control, Chicago, 1986.

3. Anderson, E.P.: Audels Electric Motor Guide, Theo. Audel & Co., New York, 1948.

4. Fasco Industries, Inc.: Fasco Facts, St. Louis, 1989.

Further information:

1. Davidson, G.D.: Tool Grinding & Sharpening Handbook, Sterling, NY, 1989.

2. LeGrand, R. (ed.): American Machinists Handbook, New York, McGraw-Hill, 1955.

3. Sheeler, P.: Centrifugation in Biology and Medical Science, New York, John Wiley & Sons, 1989.

4. Graingers Catalog, reference section, 1989.

5. Holden, H.A., Inc.: Brushes, Minneapolis, Holden, Inc., 1988.

6. Beckman Instruments: A Centrifuge Primer, Palo Alto, 1976.

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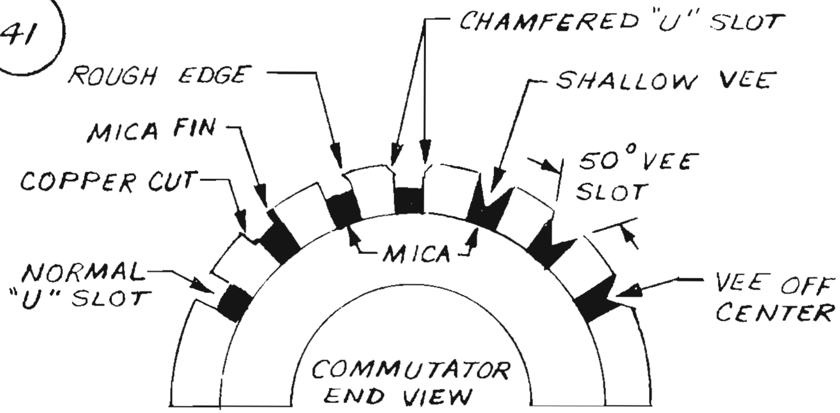

UNDERCUT EXAMPLES

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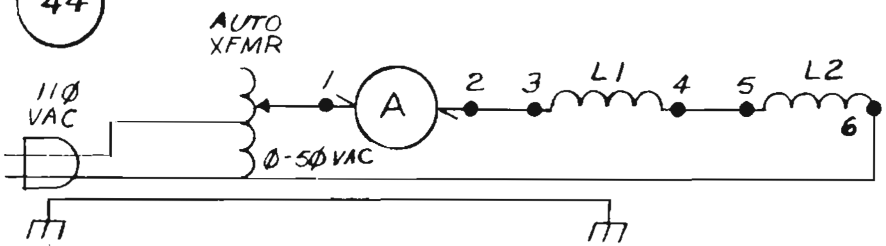

SERIES MOTOR TEST CIRCUIT

TO REVERSE — INTERCHANGE 3 & 6 OR 1 & 2. BE SURE L1 & L2 ARE PHASED PROPERLY IF NOT INTERNALLY CONNECTED.

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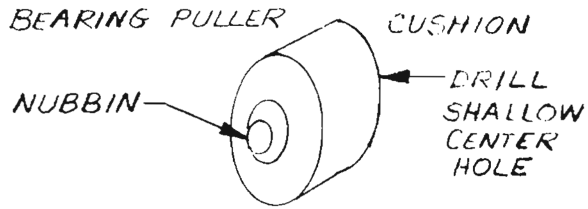

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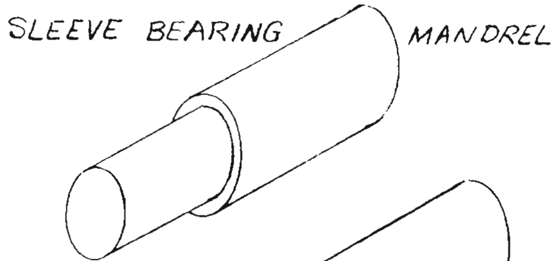

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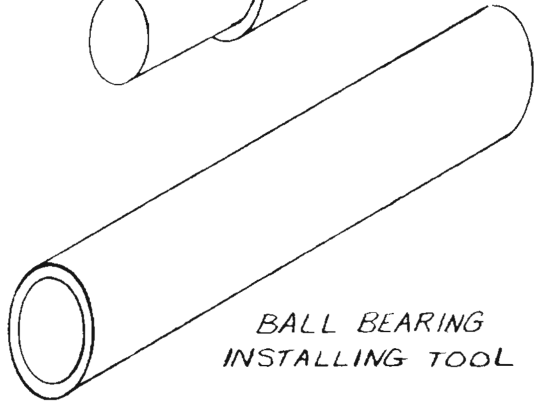

BALL BEARING INSTALLING TOOL

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HACKSAW BLADE UNDERCUTTER

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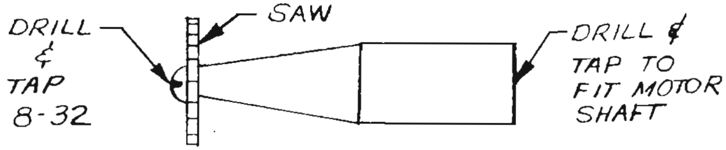
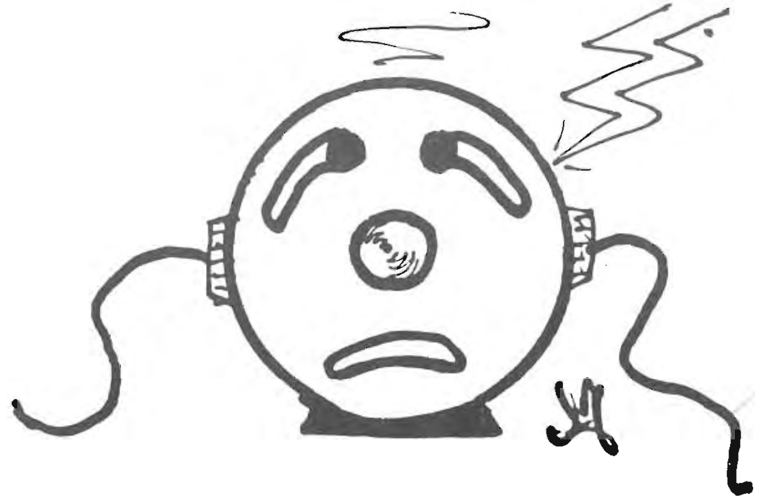
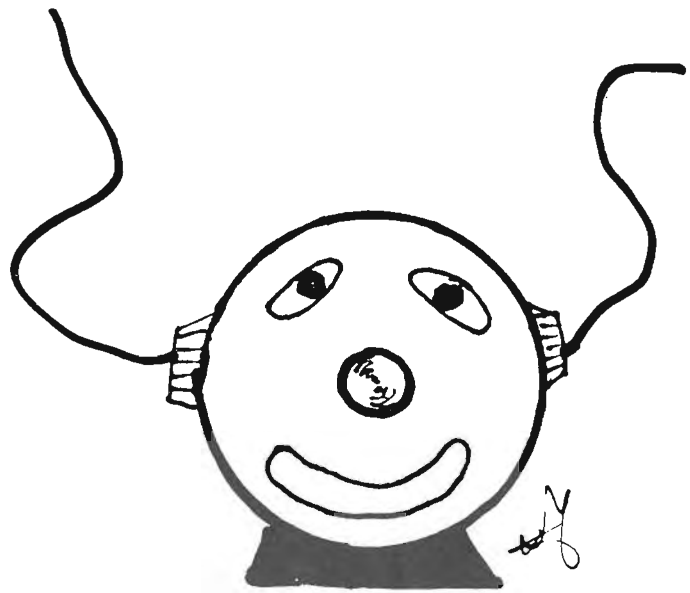


UNDERCUTTER ADAPTER FOR CAM Ø24 MOTOR





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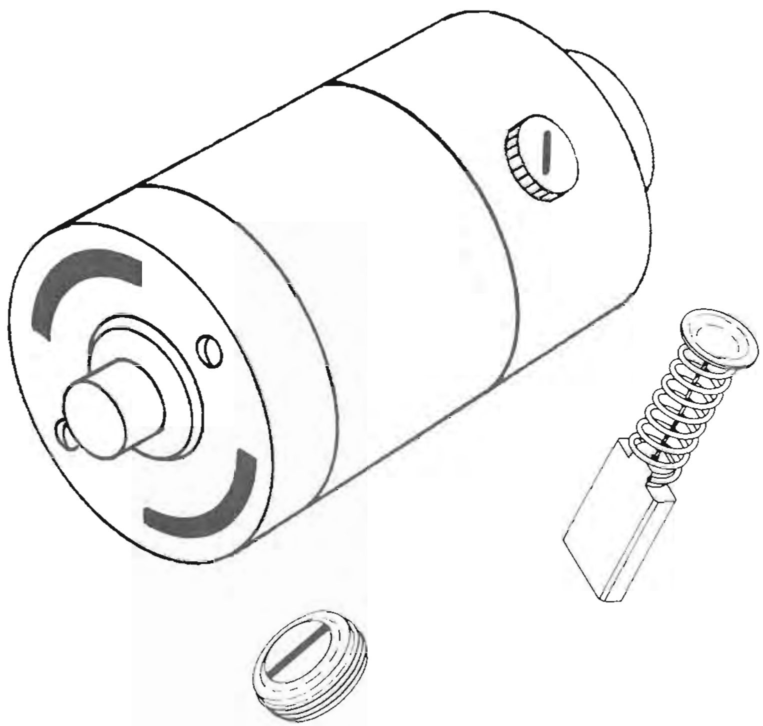
There's more to it than "JUST" changing brushes!



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