

## SYNCHRONOUS MOTORS REQUIREMENTS AND ADJUSTING PROCEDURES

### 1. GENERAL

- 1.01 This section covers apparatus requirements and adjusting procedures for synchronous motors with direct-connected exciters.
- 1.02 This section is reissued to incorporate material from the addendum in its proper location. In this process marginal arrows have been omitted.
- 1.03 Reference shall be made to Section 020-010-711 covering General Requirements and Definitions for additional information necessary for the proper application of the requirements listed herein.
- 1.04 Requirements are marked with an asterisk (\*) when to check for them would necessitate the dismantling or dismounting of apparatus or would affect the adjustment involved or other adjustments. No check need be made for these requirements unless the apparatus or part is made accessible for other reasons or its performance indicates that such a check is advisable.
- 1.05 Successful Commutation for the purpose of this section may be said to have been obtained if neither the brushes nor the commutator are injured in an acceptance test or in normal service to the extent that abnormal maintenance is required. The presence of some visible sparking is not necessarily evidence

of unsuccessful commutation.

### 2. REQUIREMENTS

#### 2.01 Lubrication

- (a) The bearings shall be adequately lubricated with one of the lubricating oils listed under Materials.
- (b) Oil in the bearings shall be kept at such a level that the gauges shall indicate  
Maximum  $3/4$  full  
Minimum  $1/2$  full  
Gauge by sight. The amount of lubricant used at any time shall not be such as to cause it to run or creep out of the bearing housing.
- (c) Oil gauges shall be free from leaks and glass gauges, where provided, shall be free from cracks.
- (d) Bearings shall have the lubricating oil replaced with fresh oil at least every two years.

#### 2.02 Speed

- (a) The speed of the motor under the voltage limits outlined below and under all conditions of temperature and load (no load to not exceeding full load) shall be the synchronous speed corres-

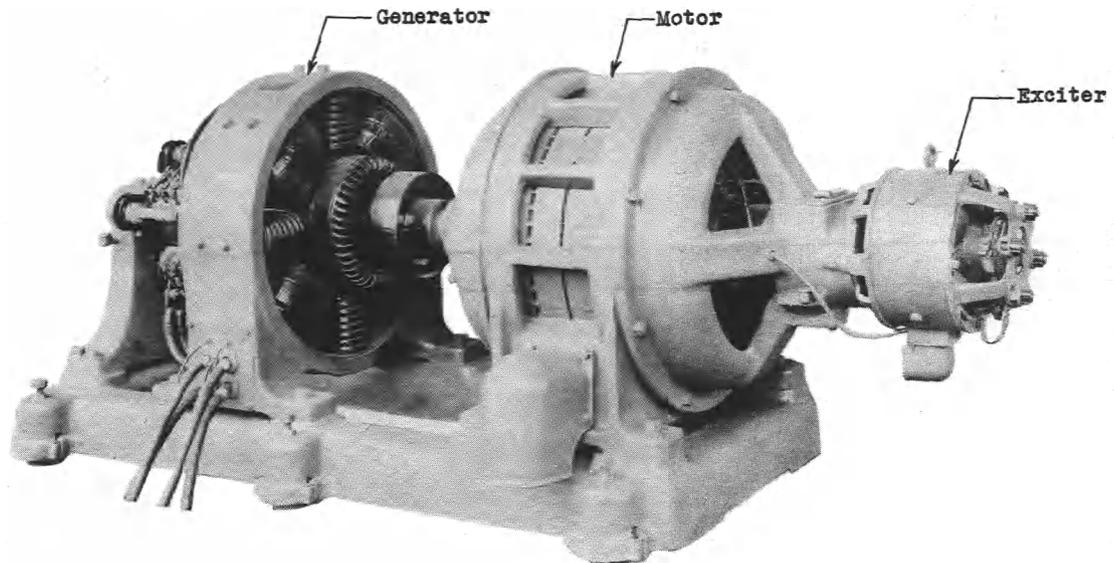


Fig. 1 - Motor - Generator Set - 50HP Synchronous Motor - 65 Volt 500 Amp. Gen.

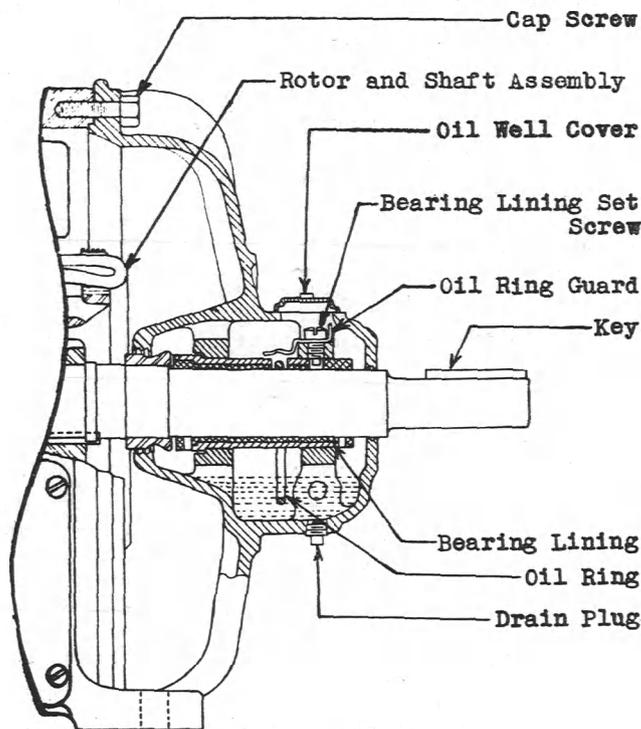


Fig. 2 - Bearing Assembly -  
Solid End Shield

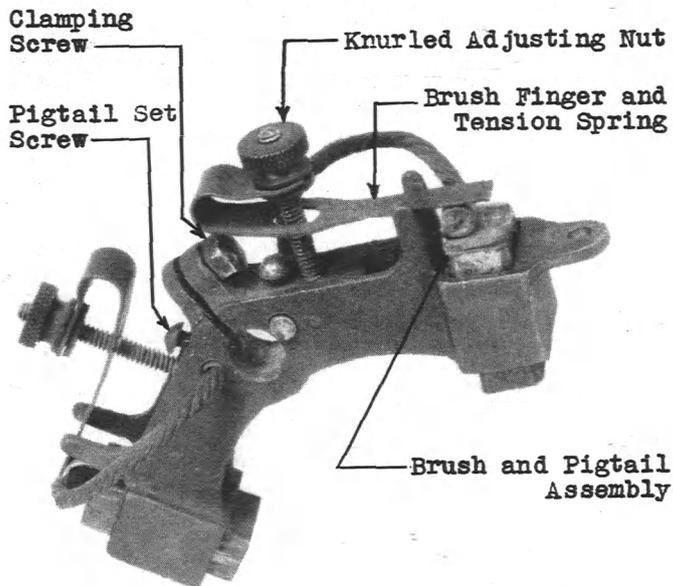


Fig. 3 - Brush Holder Assembly -  
Motor

ponding with the actual frequency of the power supply. For example a six pole motor on 60 cycle power supply should run at 1200 rpm. If the frequency is 1% high or low the speed will also be 1% high or low. Use speed indicator.

(b) Requirement (a) shall be met provided the service voltage remains within  $\pm 10\%$  of the nominal rating stamped on the motor nameplate and the frequency remains within  $\pm 2\%$  of nominal. Use voltmeter and a frequency meter or equivalent.

\*2.03 Bearings The bearing linings shall free from excessive wear. If the motor operates satisfactorily under all conditions of load and the other requirements of this section are met, the bearings may be considered to be in a satisfactory condition.

2.04 Air Gap The air gap at all points between the motor rotor and stator or between the exciter armature and pole faces shall be  
Minimum 0.010 inch  
Use feeler gauge.

2.05 Exciter End Shield The end shield of the exciter which supports the brush studs shall be set so that the marks on the end shield and frame are in line.

#### 2.06 Brush Holders

(a) Exciter brush holders shall have the edge nearest the commutator  
Maximum  $1/8$  inch  
Minimum  $1/32$  inch  
from the commutator. Use scale.

(b) Collector ring brush holders shall have the edge nearest the collector ring  
Maximum  $3/16$  inch  
Minimum  $1/8$  inch  
from the collector ring. Use scale.

#### 2.07 Brush Length

(a) All brushes shall have a length such that there will be  
Minimum  $1/16$  inch  
between the commutating surface and the rivet and washer which holds the pigtail.

(b) At the time of turnover, the wearing length of a brush shall be a minimum of  $1/2$  inch.

#### 2.08 Brush Fit

(a) Brushes shall not bind in their holders, neither shall they be loose enough to give poor commutation.

(b) Brushes shall be fitted so as to insure successful commutation.

(c) Replacement brushes shall be fitted over the entire arc of the brush and so that at least 3/4 of the entire contact surface of the brush bears on the commutator or collector ring. Gauge by sight.

#### 2.09 Brush Alignment

(a) Exciter brushes shall be so located in their holders that they will not override the end of the commutator or ride upon that part of the commutator used for connection to the armature conductors under any condition of normal operation.

(b) Collector ring brushes shall not override the edges of the collector rings under any normal operating condition.

2.10 Brush Spacing: The variation in the spacing of the exciter brushes around the circumference of the commutator shall not exceed 1/16 inch. If the exciter commutates successfully, it will not be necessary to check this requirement.

#### 2.11 Brush Pressure

(a) Brush pressure on the exciter commutator shall be  
 Maximum 2-1/2 pounds - 1134 grams  
 Minimum 1-1/2 pounds - 680 grams  
 per square inch of brush cross section.  
 Use spring balance or gram tension gauge.

(b) Brush pressure on the collector rings of the motor shall be  
 Maximum 3 pounds - 1361 grams  
 Minimum 2 pounds - 907 grams  
 per square inch of brush cross section.  
 Use spring balance or gram tension gauge.

(c) Brush pressure of all brushes on a given commutator or collector ring shall be as nearly uniform as possible.

#### 2.12 Commutator and Collector Ring Surfaces

(a) The surfaces of the commutator and collector rings shall be clean and free from scoring, pitting or other deformation of the surface or structure, save that caused by normal wear.

(b) The commutator shall have no high, low or loose segments, or flat spots.

(c) The mica of the exciter commutator shall not be undercut to exceed  
 Maximum 1/32 inch  
 Gauge by eye.

(d) Eccentricity shall not be such as to cause chattering of the brushes or excessive sparking.

2.13 Commutation: Without altering the position of the brushes, the exciter shall commutate successfully at any value

of current and voltage output required for excitation of the associated motor under nominal power service ( $\pm 10\%$  voltage,  $\pm 2\%$  frequency), under any condition of temperature (hot to cold) and at any exciter field rheostat setting within the limits outlined below.

2.14 Exciter Rheostat Setting: The exciter Rheostat shall be capable of adjusting the motor power factor to any point between the limits of 0.8 leading at full load with rated voltage and frequency as given on the motor nameplate, and unity power factor at 25% full load with any voltage and frequency within the nominal operating range.

#### 2.15 Freedom of Rotating Parts

(a) The motor rotor shall turn freely in its bearings. Gauge by feel.

(b) There shall be end play in each direction from the running position of the motor rotor. The end play shall not be sufficient to interfere with the proper operation of the motor.

2.16 Noise and Vibration: The noise and vibration of a motor under any normal operating condition shall not be excessive at any load from no load to full load. Gauge by sound and by feel.

2.17 Temperature: With a motor operating continuously within the limits of power factor and power service outlined herein, the temperature rise of the various parts above the adjacent room temperature (ambient temperature) within the limits of 10° and 40°C, shall not exceed the following

Commutator, Slip Rings and Brushes	65° C.
Bearings	40° C.
Frame and Windings	50° C.

Use Thermometer.

### 3. ADJUSTING PROCEDURES

#### 3.001 List of Tools, Gauges, Materials, and Test Apparatus

##### Tools

Screw-driver, 5" (regular) A. T. & T. Co.  
 Std. Dwg. 46-X-34  
 Wrenches, double end or single end, flat with the following openings, 5/16", 3/8", 1/2", 19/32", 11/16", 7/8", 1-1/16", 1-1/4", 1-7/16", and 1-5/8"  
 Wrench, Crescent adjustable, double end, flat 8", maximum opening 15/16".

##### Gauges

Gauge, Feeler, Starrett No. 66 or equivalent  
 Scale, 6 inch, steel

##### Materials

Cloth, KS-2423 or equivalent  
 Felt or equivalent

## SECTION 159-410-701

Lubricating Oil (one of the following)

Western Electric KS-2245  
Texas Regal Oil "B"  
Standard Renown Engine Oil  
Gulf Security Grade "A"  
Sinclair's Speed Engine and Dynamo Oil  
Squire's Royal Dynamo Oil  
Vacuum Oil "DTE" light

Measure, 1 qt. (funnel attached) or equivalent  
Pail or equivalent receptacle for oil  
Petroleum spirits  
Sealing compound KS-6824  
Sandpaper No. 1-1/2 or No. 2 and No. 00 or  
No. 0000

### Test Apparatus

Indicator, speed, Foxboro, Hasler or  
equivalent  
Spring balance 0-6 lbs; Gauge, gram tension  
0-1000, 79B gauge, or equivalent  
Thermometer, R1032, Detail 1  
Voltmeter, Weston a-c. model 528, 150-300  
volt scales  
Frequency meter, Frahm 20-80 cycles or  
equivalent

### 3.01 Lubrication (Rq.2.01)

(1) To add oil to an oil ring bearing pour the oil slowly into the bearing chamber until the proper level is indicated in the oil gauge. The oil should be added with the motor stopped. The oil should be added slowly to permit the level to rise in the gauge at the same rate as in the bearing chamber. If the oil does not rise in the gauge, it is an indication that the passage to the gauge is blocked and should be cleaned. A small bare copper wire will be found advantageous in cleaning the passage. Any of the oils listed under Materials are satisfactory for the lubrication of the motor. A quart measure with a funnel attached may be found very convenient for adding the oil.

(2) To replace the oil in a bearing remove the drain plug in the bottom of the bearing chamber and drain the old oil into a pail or other receptacle. Scrape off old compound, clean the drain plug and associated threads in the casting with petroleum spirits, coat with KS-6824 sealing compound and replace.

(3) If the oil ring is bent or damaged it should be replaced. If dirt or foreign matter should adhere to an oil ring it should be scraped clean and wiped with a cloth moistened with petroleum spirits. If a glass oil gauge is broken or cracked it should be replaced.

(4) If an oil gauge leaks, the oil should be drained from the bearing chamber into a pail or other receptacle as outlined above. If the leak occurs at the point where the gauge is screwed into

the machine casting the gauge should be removed, the screw threads on the gauge and in the casting scraped to remove old compound, cleaned with petroleum spirits, coated with KS-6824 sealing compound and the gauge replaced. After the gauge has been replaced clean the drain plug and the associated threads in a similar manner, coat the plug with KS-6824 sealing compound and replace.

### 3.02 Speed (Rq.2.02)

(1) If the motor speed is not substantially the same as called for on the nameplate examine the exciter switch to make sure it has closed and check the voltage of the exciter to make sure it has built up. Also check the voltage and frequency of the power service. On a large frequency controlled system the probability of the frequency varying more than the limit is negligible. On a small or uncontrolled system, if a frequency meter is not available, correct operation of a synchronous clock over a period of several minutes is an indication that the frequency is satisfactory. The synchronous clock operation may be checked with an ordinary watch or clock equipped with a second hand. If the power service is not correct replace any blown fuses or communicate with the Power Company to ascertain the cause of the trouble. See that the motor meets the requirements of freedom of rotation and temperature and make certain that the driven machine is in a satisfactory operating condition and is not overloaded. If these conditions are found to be satisfactory and the motor speed is still outside the specified limits, the matter should be referred to the supervisor who may wish to replace the motor.

### 3.03 Bearings (Rq.2.03)

(1) Replace any worn bearings.

### 3.04 Air-Gap (Rq.2.04)

(1) With the motor rotor or exciter armature in any position measure the air-gap between the rotor and stator and between the exciter armature and pole pieces with a feeler gauge. Particular care should be taken in measuring the air-gap in the lower half of the frame as this is where the maximum bearing wear will be most noticeable. Turn the rotor and armature approximately a 1/4 of a revolution and repeat.

Checks should be made with the rotor and armature in at least four different positions. See that there is no dirt or foreign matter lodged in the air gap. If the air-gap is less than the specified amount replace the bearing or bearing linings.

**3.05 Exciter End Shield (Rq.2.05)**

(1) To shift the exciter end shield loosen the cap screws holding the end shield and shift the end shield until the marks are in line, and then tighten the cap screws.

**3.06 Brush Holders (Rq.2.06)**

(1) To adjust the clearance between a brush holder and a commutator or a collector ring, loosen the brush holder clamping screw and turn the brush holder on its stud as required. After adjustment be sure the clamping screw is firmly tightened and refit the brushes. If the desired clearance cannot be obtained on the exciter in this manner, it will be necessary to loosen the nut holding the brush holder stud in the end shield and raise or lower the brush holder stud. Tighten the brush holder stud nut firmly.

**3.07 Brush Length (Rq.2.07)**

(1) Replace any short brushes, fit the new brushes and adjust the pressure as required.

**3.08 Brush Fit (Rq.2.08)**

(1) Remove the brushes from their holders and wipe them with a clean cloth. If there are any rough projections the edges of the brush may be smoothed with fine sandpaper before wiping. In replacing the brushes see that they are put back in the same holder and in the same position in the holder that they were originally.

(2) Where a brush requires a considerable amount of fitting cut a strip of sandpaper (No. 1-1/2 or No. 2) slightly wider than the width of the brush and approximately as long as the commutator or collector ring circumference. Remove the brushes on adjacent studs. Place the strip of sandpaper under the brush with the sanded side next to the brush and hold the sandpaper so that it will bear on approximately 180° of the commutator or collector ring surface. Draw the sandpaper back and forth under the brush until the brush has the same curvature as the commutator or collector ring. The final fitting or where only a small amount of fitting is required should be made in a similar manner with a piece of fine sandpaper (No. 00 or No. 0000). The final strokes should be made in the direction of rotation, raising the brush when drawing the paper back. After sanding, blow the dirt from the commutating surface and windings and wipe the surfaces and brushes with a clean dry cloth. In fitting a brush it is desirable to have the brush make contact over the entire arc of the brush and have as much of the contact surface

as possible bear on the commutator or collector ring. The amount of brush surface bearing on the commutator or collector ring can be estimated after a period of operation by noting the polish of the brush surface.

(3) If brushes are too loose in their holders they should be replaced.

**3.09 Brush Alignment (Rq.2.09)**

(1) Loosen the clamping screw and shift the position of the exciter brush holders on two adjacent studs until with the armature in the extreme position of end play toward the commutator end, the brushes just clear that part of the commutator used for connections. Shift the brush holders on the next two studs so as to cover the remaining space on the exciter commutator and not over-ride the edge of the commutator when the armature is in the extreme position of end play toward the coupling end. Tighten the clamping screw after each adjustment.

(2) Brush holders on the studs above the collector rings should be so mounted that the brushes ride as nearly as possible in the center of the collector rings with the machine in its normal running position. After any adjustment is made, the brush holder clearance should be checked.

**3.10 Brush Spacing (Rq.2.10)**

(1) To check the exciter brush spacing, place a piece of paper around the commutator and under the brushes and mark the points where the toes of the brushes make contact with the paper. Remove the paper from the commutator and measure the distance between the marks.

(2) To adjust the brush spacing loosen the brush holder clamping screw and rotate the brush holder arms on their stud or loosen the nuts holding the brush stud to the end shield and raise or lower this stud as required or use a combination of these adjustments. Tighten the stud nuts and clamping nuts after each adjustment.

(3) Any adjustment of the brush spacing will necessitate a check of the brush holder clearance and brush fit.

**3.11 Brush Pressure (Rq.2.11)**

(1) The exciter or collector ring brush pressure may be determined by looping a piece of cord under the brush finger as near the point where it touches the brush as possible. Exert a radial pull on this finger by means of a spring balance or gram tension gauge hooked into the looped cord. The reading of the balance just as the finger starts to

move away from the brush may be considered to be the total brush pressure. With brush holders on the lower part of the commutator it may be necessary to hold the brush against the commutator.

(2) The total pressure divided by the cross sectional area of the brush gives the pressure per square inch.

(3) The desired pressure may be obtained by increasing or decreasing the tension of the brush spring or brush finger. In adjusting the pressure it is highly desirable to make the pressure on all brushes on the same commutator approximately uniform.

### 3.12 Commutator and Collector Ring Surfaces (Rq.2.12)

### 3.13 Commutation (Rq.2.13)

(1) The commutator and collector ring surfaces should be cleaned as required by rubbing with a clean dry KS-2423 cloth or other hard non-linting cloth. If the surfaces become smutted and cannot be cleaned by wiping with a cloth, they should be smoothed with fine sandpaper. If the machine is to be left idle for a considerable length of time such as more than a week, the collector-ring brushes should be removed from their holders to prevent spotting or tarnishing the iron collector ring.

(2) Never allow a commutator to become more than slightly rough before endeavoring to correct with fine sandpaper.

Note: A bronze colored highly polished commutator is very desirable and should not be mistaken for a burned commutator. If a commutator presents this condition, is smooth, and commutation is satisfactory, it should be left alone.

(3) If a commutator becomes excessively rough or the commutation becomes unsatisfactory, the surface should be sanded. All brushes should be removed before sanding. Fold the sandpaper with sand side out on a wooden block shaped to fit the commutator. With the machine operating hold the sandpaper against the commutator, moving the paper with a lateral motion parallel to the commutator bars. After sanding clean the surfaces and coils and wipe with a clean dry cloth. Undercut the mica on the exciter commutator whenever the mica becomes flush with or extends beyond the commutator surface.

(4) If loose, high or low commutator segments appear on the exciter commutator, it will be necessary to remove

the exciter armature for repairs or replacement, in which case the matter should be referred to the supervisor.

(5) If a collector ring is dirty or the brushes spark, clean with a cloth moistened with petroleum spirits while the machine is not running. If the ring becomes exceedingly rough or develops enough eccentricity to interfere with proper operation the rings should be turned down or replaced.

### 3.14 Exciter Rheostat Setting (Rq.2.14)

(1) The rheostat is provided at the factory with a stop at the point where 0.8 P.f. leading at full load with rated voltage and frequency is obtained, so that it cannot be manipulated beyond that point. This stop should not be altered since to do so may permit overloading the field windings of the motor. By adjusting the rheostat to increase the resistance in the field circuit of the exciter the power factor may be reduced from .8 leading to as low as unity with 25% load on the motor at any voltage or frequency within the nominal operating range. If this cannot be done examine all field connections to the motor including the field switch and check the voltage and frequency of the power supply. If the desired power factor still cannot be obtained refer the matter to the supervisor.

### 3.15 Freedom of Rotating Parts (Rq.2.15)

### 3.16 Noise and Vibration (Rq.2.16)

(1) Where binding or excessive noise and vibration are present see that all holding down bolts and coupling bolts are drawn up firmly and that any keys are not loose in their keyways on the shaft. Vibration as referred to in this paragraph does not include the slow oscillations of the entire set which are more or less inherent in this type of set and which cannot always be overcome. Check the alignment of the motor with its associated driven machine and adjust as required. Level the set as required. If the motor is direct connected to its driven machine and mounted on a common sub-base with car spring cushions, adjust each car spring by loosening the lock nut on the adjusting screw and turning the screw in or out as required until all springs are carrying their share of the load. All lock nuts should be tightened firmly after completion of the adjustment.

(2) If the noise and vibration continues to be excessive after the above adjustments have been made, the trouble may be caused by worn bearings which should be replaced.

### 3.17 Temperature (Rq.2.17)

(1) The temperature of the bearings should be taken in one of the two ways outlined below with the machine run-

ning. One method for bearings having oil rings is to place the bulb of a thermometer in the lubricating oil of the bearing for at least five minutes if the oil well opening is large enough to permit this procedure. Care should be taken that the thermometer does not strike the shaft or interfere with the proper operation of the oil ring. This method is to be preferred, however, where the bearing construction makes this method impractical the second method may be used.

(2) The second method is to hold the bulb of the thermometer against the hottest spot on the outside of the bear-

ing housing as near as possible to where the bearing is located, covering that part of the bulb which is not in contact with the housing with a piece of felt or equivalent material and observe the highest temperature indicated.

(3) The windings and machine frame may be measured for temperature rise in a similar manner. If the temperature exceeds the specified limits see that the other requirements of this section are met. If the temperature still remains outside the prescribed limits, refer the matter to the supervisor as he may wish to replace the motor.