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Chapter 7

RAM AIR TURBINE, ROTAX, TYPE BAT 0102 (INCORPORATING GENERATOR, ROTAX, TYPE BA 1603 or BA 1604)

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LIST OF ILLUSTRATIONS

LEADING PARTICULARS

Ram air turbine, Type BAT0102
(*incorporating generator, Type BA*1603 *or BA*1604) **Ref. No. 5UA/7874**

Controlled output	15 *kVA*, 3-*phase*, 370 *c/s a.c.*
Output current	42 *amp.* (*line*)
Power factor	0·5–0·8 *lagging*
Rating	*Continuous*
Overload	30 *kVA*, 0·8 *p.f. for* 0·5 *sec.*
Controlled voltage (output)	185*V* (*line*)
Governed speed	7,400 *r.p.m.*
Voltage regulation	*Control unit, Type U*3703/1
Excitation current (on O/C)	7·5 *amp.*
Excitation current (on S/C)	19·5 *amp.*
Excitation current (at F.L.)	0·8 *p.f.*, 26·2 *amp.*
3-*phase tickler exciter maximum line voltage on O/C at* 8,000 *r.p.m.*	8·0 *volts*

LEADING PARTICULARS (*continued*)

Altitude	25,000–60,000 *ft.*
Ambient temperature	−60 *deg. C. to* +30 *deg. C.*
Brush length (new)	0·750 *in.*
Brush grade	*K.C.E.G.* 11, *P.E.G.* 11—*post Mod. Elect. A437*
Cooling	*self-cooled via turbine ram air*
Speed control (mechanical governor)	*via ram air turbine*
Direction of rotation (viewed from drive end)	*Anti-clockwise*
Overall dimensions—	
Length	25·000 *in.*
Height (over lug)	18·242 *in.*
Weight (complete unit)	88 *lb.*

Minimum air requirements for 15*kVA*, 0·8 *p.f.*—

ALTITUDE (1,000 *ft.*)	*MASS-FLOW* (*lb/sec.*)	*PRESSURE DROP ACROSS UNIT* (*lb/in²*)
25	7·5	0·50
35	5·3	0·48
50	3·1	0·46
60	2·3	0·46
65	2·1	0·46

At higher mass flow, pressure drops are reduced

Introduction

1. This is a 15 kVA, 0·5 to 0·8 power factor, 208V, 400 c/s, 3-phase 6-pole, self-excited ram air turbine a.c. generator designed to supply essential services with electrical power for emergency purposes in the event of main generator failure.

2. A permanent magnet a.c. generator, integral with the main generator, provides supply for control purposes and also ensures positive generation build-up. Speed control is effected by a mechanical governor which is directly coupled to the generator. The ram air turbine drives the generator via an integral mechanical governor designed to provide constant speed; the associated U3703/1 control unit ensures voltage control of the 15 kVA emergency supply to the flying control motors which form the major part of the emergency loading.

3. The original ram air turbine, Type BAT0101 (Ref. No. 5UA/6853, incorporating generator Type BA1601 or BA1602), became Type BAT0102 on the embodiment of Mod. Elec. A/410 (Rotax R.6191). This modification consists essentially of the following points:—

(1) The incorporation of a pre-loaded, double bearing ballrace in place of the original single bearing ballrace in the spider balancing assembly of the turbine, associated with the turbine hub balancing and blade assembly. This ensures positive ball loading of the bearing, and prevents "ball stick" on light loads.

(2) The incorporation of an anti-rotational locking device to prevent inadvertent rotation of the turbine in a clockwise direction due either to reverse air flow or manual handling. This could cause damage to the internal clutch mechanism due to excessive loading.

(3) Turbine component parts have been strengthened and modified to accommodate the new double-bearing ballrace and anti-rotational device; this has caused an increase of 8 lb. in the overall weight of the unit.

(4) The end shell has been modified by the incorporation of three equally-spaced cut-outs for access to the brushgear screws.

(5) Pinned locking studs have been incorporated in the BA1603 and BA1604 generators for securing the end shell and brushgear respectively, as shown in fig. 5.

DESCRIPTION

4. The complete ram air turbine assembly, with the generator mounted inside, is illustrated in fig. 2 and 3; a sectional view of the turbine is given in fig. 4. The generator is driven from the variable pitch turbine rotor blades, which are mounted on a hub balancing assembly and drive a forward mounted spinner assembly. The nose of the spinner incorporates an internally serrated spinner bridge drive to which is fitted the turbine drive shaft. The turbine drive shaft is directly coupled to the generator drive by an internally serrated coupling, thus providing a complete turbine generator drive assembly.

5. Variation in turbine speed due to varying conditions of generator load, aircraft forward speed, and altitude, is controlled by the turbine governor to provide a constant speed of 7,400 r.p.m.$\pm$1 per cent. This regulation of speed is accomplished through the pitch change mechanism of the blades, the governor, and governor bob weights which control the servo mechanism, to increase or decrease the turbine speed as required.

6. The blade angle is modified by a rotating thrust ring coupled via a bearing to an axially moving member, which is in turn connected via jackscrews and a gear train to the governor.

7. The governor body and weights revolve at half the turbine speed during steady state conditions, and are driven by the cage of a bevel differential gear. The input to the differential is driven at turbine speed from the coupling shaft between the turbine and the generator, the output being normally stationary but revolving when a blade angle change is necessitated.

8. The governor weights move a sleeve carrying a pair of friction surfaces, one of which faces a stationary surface and the other a surface rotating at turbine speed. During running at governed speed the friction faces controlled by the weights are normally poised between and apart from their mating surfaces and torque is not exerted on the governor output bevel gear. An increase in turbine speed gives a proportional increase in governor speed, the friction faces controlled by the bobweight change position so that one face is in contact with the stationary surface, and torque is then exerted on the output gear and the pitch change mechanism. Above a certain speed error the torque exerted is sufficient to turn the pitch change mechanism, and since this output movement tends to reduce the rotational speed of the bobweights, pitch changing is infinitely slow. For larger speed errors the rate of pitch changing is increased. The rate of pitch change is proportional to the turbine speed error from that speed at which the clutch just moves the pitch change mechanism.

9. The bobweights under the action of the clutches always tend to run at their nominal speed, and the movement of the pitch change mechanism under a given disturbance is directly related to the extra revolutions made by the turbine in running too fast for a period of time.

10. For underspeeding conditions the mode of operation is similar, but the controlled friction plate is in contact with the surface running at turbine speed.

11. By applying the thrust from the governor control springs via a ball race to the bobweights, a potential balancing problem is solved, and it also permits the spring setting to be modified whilst the governor is running. Limit stops are introduced so that in the event of the pitch change mechanism reaching the limit of its travel, unloading of the clutches occurs.

Generator

12. The generator fitted may be either a BA1603 or BA1604. These are electrically identical machines, but differ in that on the BA1604 the rotor poles are pinned. The generator is illustrated in fig. 1, and a sectional view appears in fig. 5. ▶

Rotor and stator

13. The machine comprises a main rotor assembly together with a permanent magnet rotor, built integral on a common shaft. The main stator assembly encircles the rotor, the permanent magnet rotor and the stator being located under the "overhang" of the alternator. The main and permanent magnet rotors are carried by two bearings, a roller bearing at the drive end, and a ball bearing at the slipring end. The shaft is

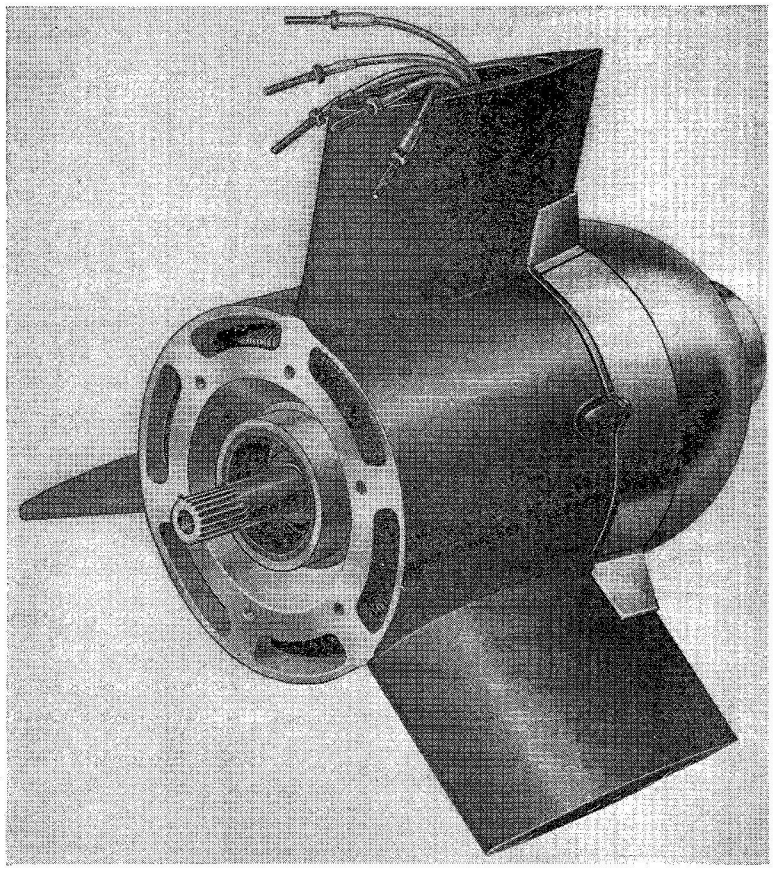

Fig. 1. General view of generator

extended beyond the slipring end bearing to which is fitted the slipring assembly. The opposite end of the rotor shaft is splined to suit the driving coupling, which is integral with the turbine differential drive.

Casing

14. An aluminium body casting, containing a steel liner at the drive end, supports the rotor assembly in a roller bearing fitted in the liner. The body casting also incorporates the stator, located in the main bore, and held in position by the end cover spigot, the flange of which is bolted to the end locating face of the casting.

End cover

15. The end cover, brushgear assembly, sliprings and support plate, are enclosed by an end shell assembly, which acts as the outlet for the ram air cooling, and also provides protection for the slipring end of the generator.

Brushgear

16. The brushgear assembly comprises two brush box plate assemblies, containing six brush boxes set at an angle in the direction of rotation, the complete assembly being held in position by the support plate assembly.

Support plate

17. An aluminium support plate, embodying a locating spigot, positions the ball bearing fitted in the end cover at the slipring end, and in addition positions and supports the brush gear assembly. The unit, therefore, consists in its essentials of an alternator with pilot exciter, a variable pitch turbine and a mechanical servo governor.

Operation

18. The a.c. generator rotates in an anti-clockwise direction viewed from the drive-end. The rotor forming a 6-pole electro-magnet rotated inside a stator induces an

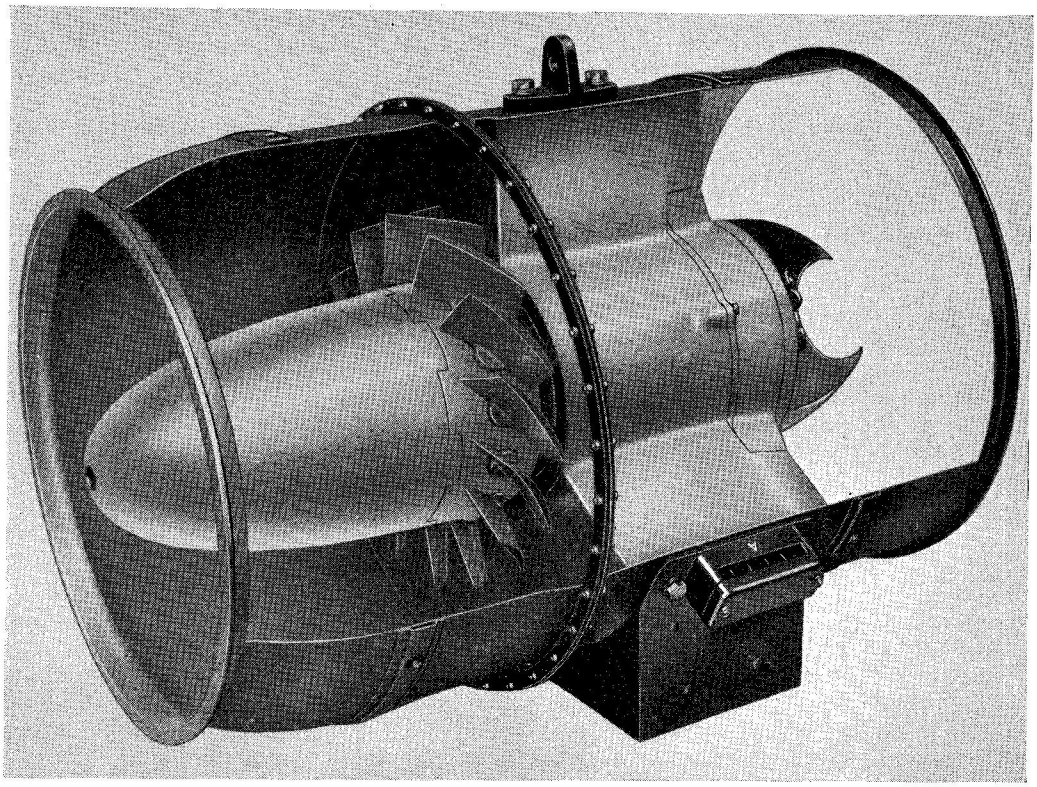

Fig. 2. Generator mounted in turbine (drive end)

alternating E.M.F. into the stator windings. Due to the stator windings being displaced by 120 deg. with respect to each other the induced E.M.F.s result in a 3-phase alternating current output of 185 volts (line) at 370 c/s, controlled at a governed speed of 7,400 r.p.m.

19. A permanent magnet a.c. exciter generator acts as a "tickler" exciter for the main rotor current, and is designed to provide extra excitation current only, during the running up of the generator, the maximum line voltage on open circuit at 8,000 r.p.m. being 8·0V. The output of the permanent magnet generator is also used to ensure positive generation build-up.

INSTALLATION

20. The a.c. generator is mounted concentrically inside a turbine outer casing by three support ribs which are an integral part of the generator body assembly, the ribs being secured to the casing from the outside by securing bolts and associated locking washers.

21. Electrical connections are brought out through two support ribs to external terminal blocks A and B respectively, displaced at 120 deg. on the outer casing. A support lug is provided which is secured to the top of the outer casing adjacent to the vertical support rib, as shown in fig. 2.

22. A rectangular plate is provided for mounting the turbine and generator, and is an integral part of the turbine outer casing; the unit is mounted via four 0·406 in. dia. holes whose centres form a rectangle 10·125 in. × 5·000 in.

SERVICING

23. Remove the end shell assembly from the generator prior to servicing the brush gear assembly; this will be found at the opposite end to the turbine governor and blades assembly.

24. Release three captive screws from inside the shell (*fig.* 5); the hexagon head of the

screw is slotted to facilitate removal by screwdriver, access being gained through the shell orifice to release the screws.

25. To gain access to the brushgear assembly remove the end shell assembly together with the captive screws. Check the brush spring pressure using a spring balance; the load should be 19 $\pm$ 3 oz. when the trigger is in line with the top of the brush box for each of the six springs.

26. Examine the brushes and remove any carbon deposit with a supply of clean dry compressed air. Check that the brushes are a sliding fit in their boxes and examine for carbon dust in the corners. Remove any carbon with a cloth moistened with lead-free gasoline. Check that the length of the brushes is such that they will continue to operate satisfactorily until the next overhaul period. The minimum permissible length for each brush is 0·343 in.

27. Release the three brushgear studs (*see fig.* 5) and remove the brushgear assembly. Ensure that the brush springs have been released and that the brushes are removed from their boxes. The brush lead and tag number is engraved adjacent to the corresponding brush box number. Brushes if satisfactory must be replaced in their correct positions.

28. The sliprings should be examined for scores or burns. If their condition is such that the efficiency is impaired, the machine must be removed for reconditioning or repair. The minimum permissible slipring diameter after reconditioning or repair, for continued satisfactory service, should not be less than 1·343 in. for both diameters.

29. Reassemble the brushgear assembly and tighten and secure the three mounting studs, using new locking washers. Replace the brushes in their correct positions in the brush boxes; adjust spring tension of levers to the value given in para. 25.

30. In the event of new brushes being introduced the generator should be driven at 3,000 r.p.m., and the main rotor current set to 12 amp. or a reduced value if sparking at the

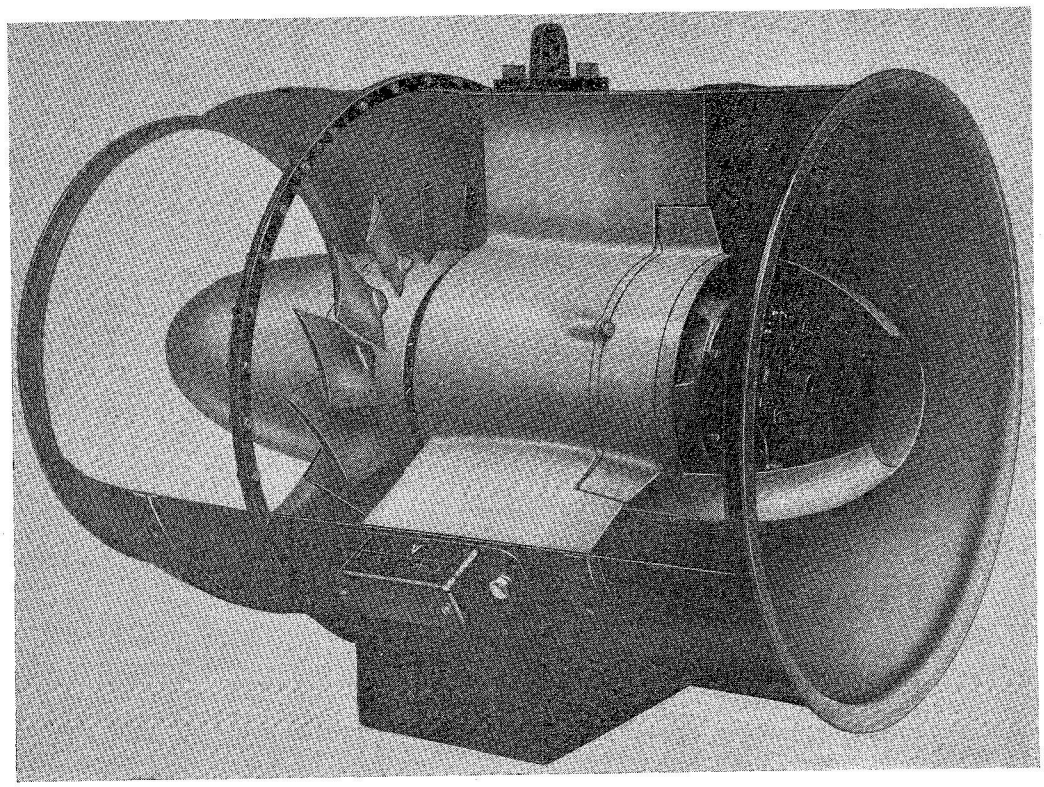

Fig. 3. Generator mounted in turbine (brushgear end)

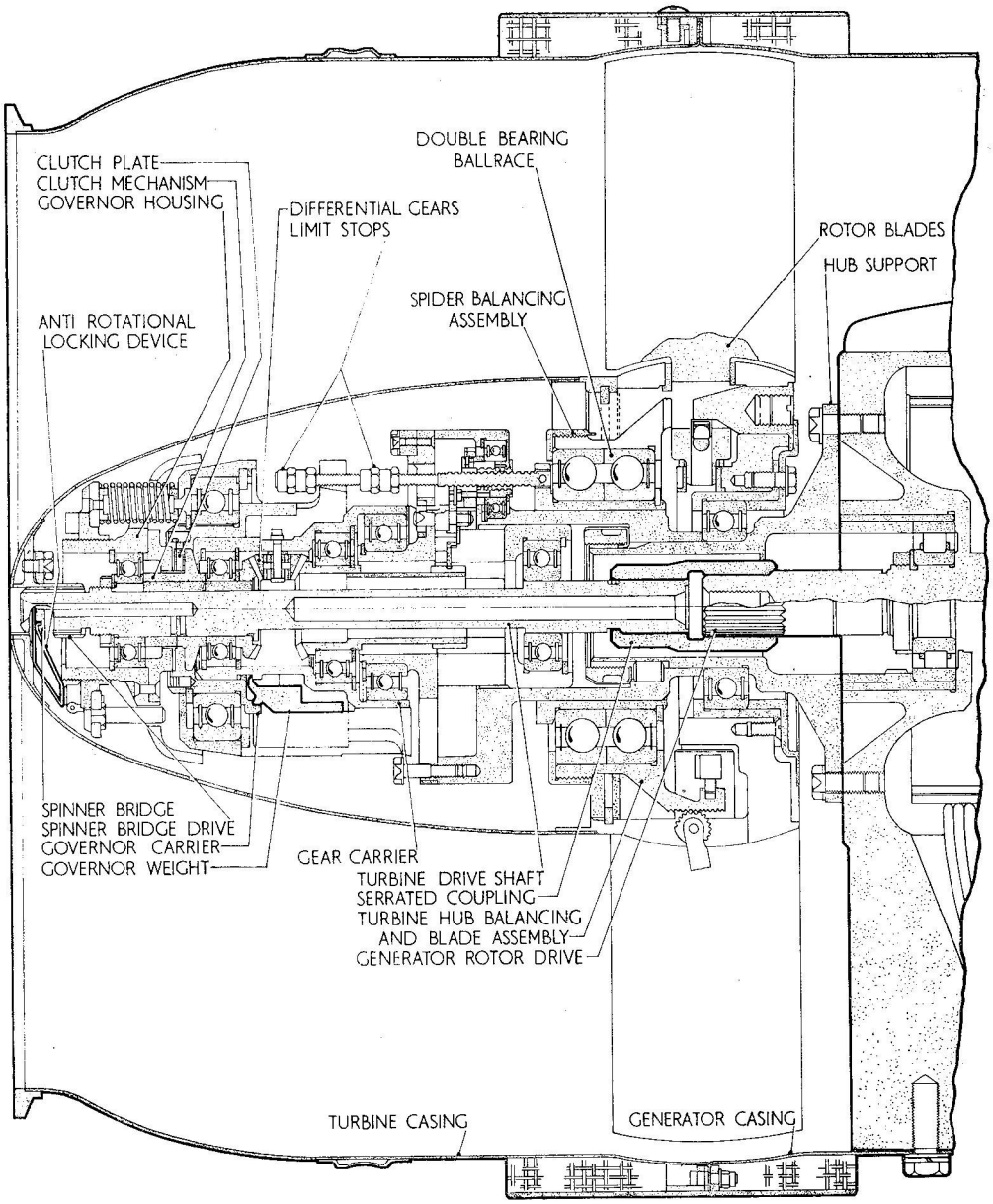

Fig. 4. Sectional view of ram air turbine

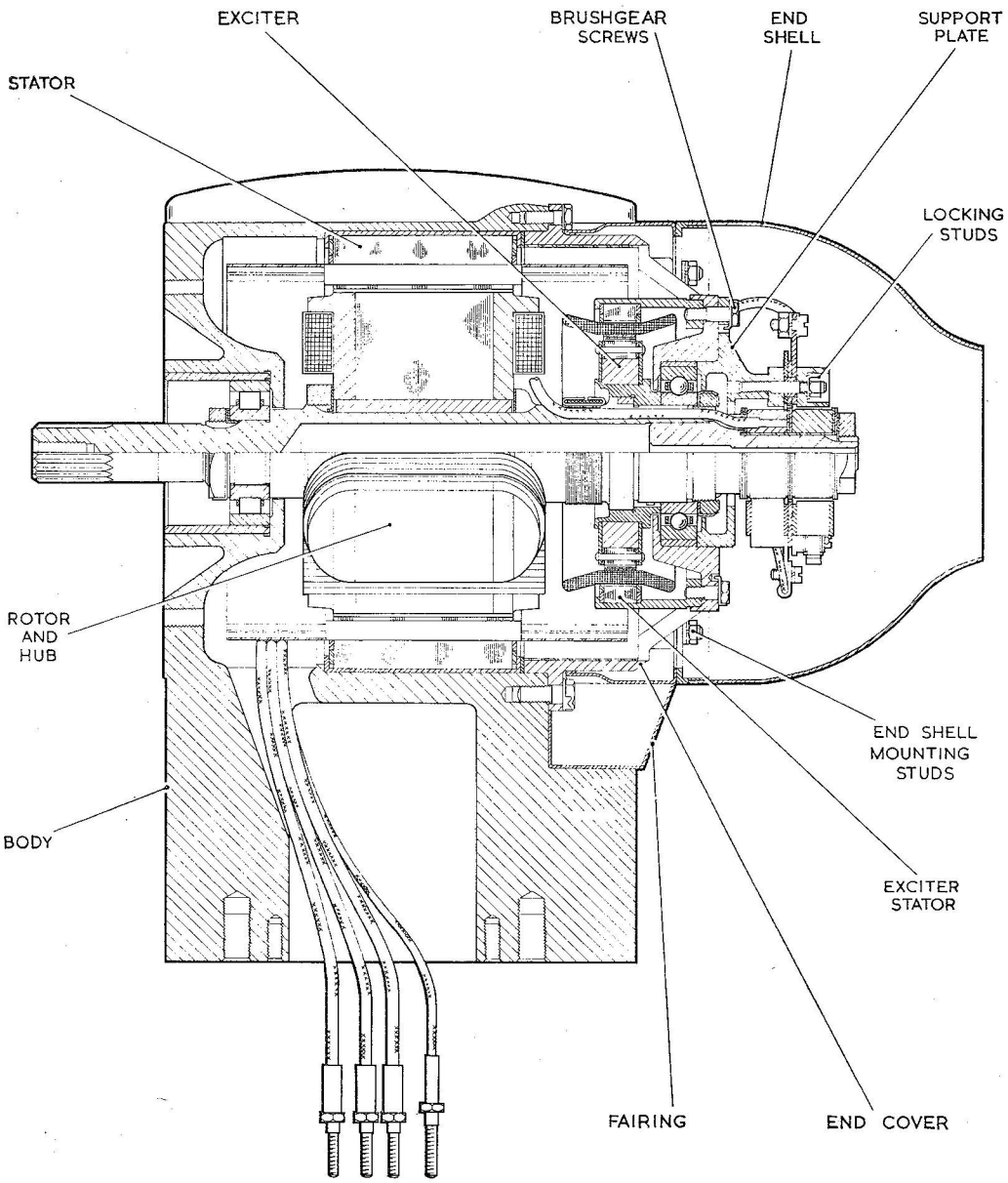

Fig. 5. Sectional view of generator

slip-rings occur. Each brush is to be bedded to at least 80 per cent of its contact area.

31. All electrical connections for brush gear and terminal box assemblies should be examined to ensure that they are secure and free from corrosion.

Lubrication

32. On assembly of the generator, the roller and ball bearings are packed with grease XG-275; this will require to be renewed only during assembly after repair.

Testing of generator

33. The generator should be coupled to a driving motor and driven in an anti-clockwise direction when viewed from the drive end. Blast air should be supplied to the air inlet at a head of 6 in. water gauge and a 24V d.c. supply connected to the rotor through a suitable regulating resistance. Care should be exercised to avoid breaking the rotor circuit when the excitation current exceeds 5 amp.

34. Prior to mounting, test the generator for freedom of rotating parts, by turning the rotor by hand without using a coupling.

Caution . . .

No attempt should be made to rotate the rotor in a clockwise direction. Damage to the anti-rotation ratchet will result should this be attempted.

35. *Phase rotation.*—When mounted and connected as specified, the phase sequence of the a.c. output must be red, white, blue, relative to the terminal markings.

36. *Open circuit test.*—With the machine driven at 8,000 r.p.m. and the output open circuited, set the line voltages to an average value of 208V by adjustment to the rotor current which should be between 7·2 and 8·8 amp.

37. *Short circuit test.*—The output should be short circuited through current transformer in each line, connected by short lengths of heavy current conductor. The generator should be driven at 8,000 r.p.m. and the rotor current increased until the average line current is 41·6 amp. The rotor current must lie between 14 and 15 amp. The machine should be maintained on short circuit for 15 min.

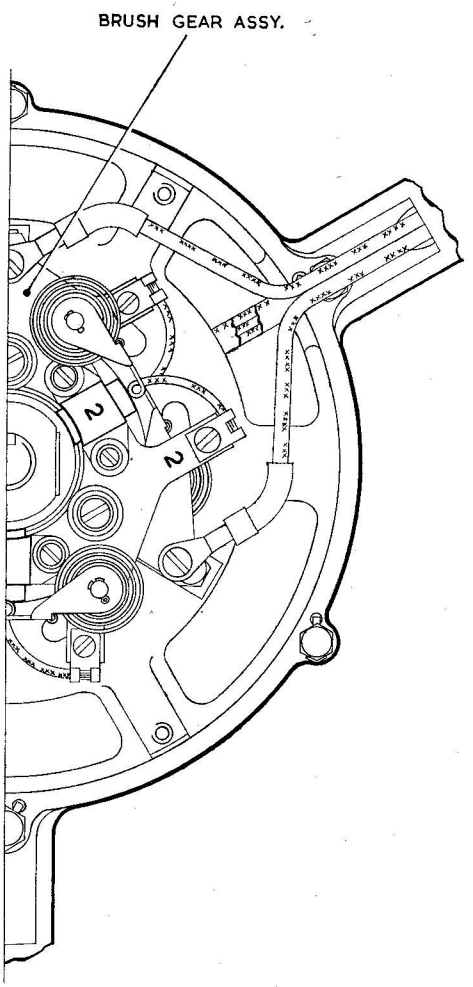

Fig. 6. Part view of brushgear assembly

38. *Insulation resistance test.*—The insulation resistance as measured by a 500V insulation resistance tester should not be less than 50,000 ohms.

(1) Between stator windings and the frame.

(2) Between rotor windings/brushgear and frame.

Exciter

39. *Short circuit test.*—(This test must be carried out first). With the machine

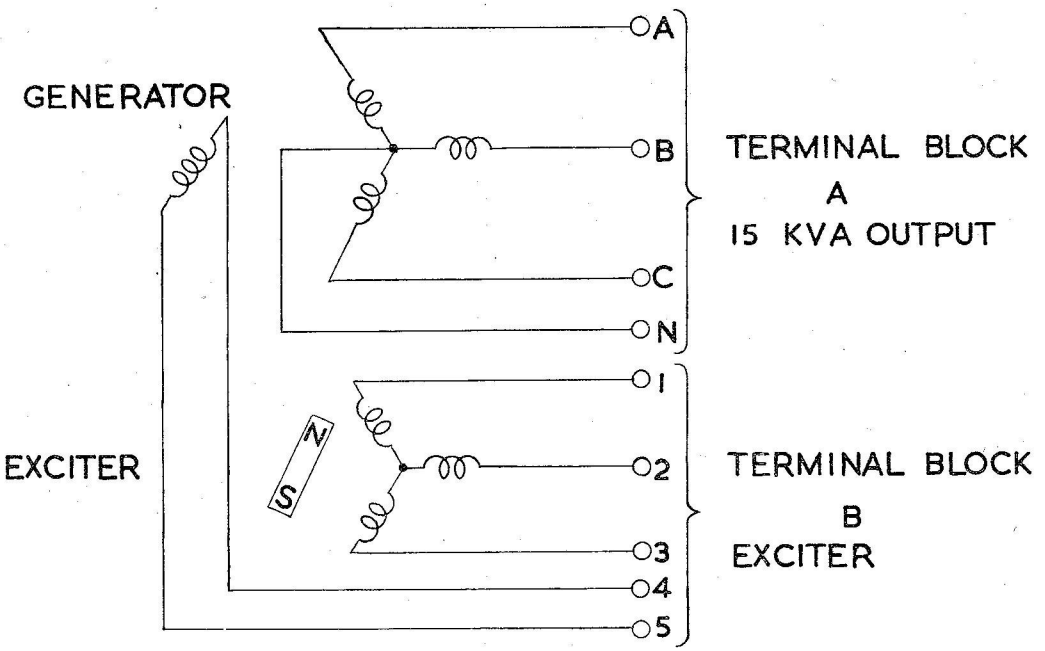

Fig. 7. Circuit diagram

stationary, the output terminals 1, 2 and 3 should be short-circuited through 50 amp. current transformers. The following procedure must then be quickly executed to prevent overheating:—

(*a*) Take speed up to 8,000 r.p.m.

(*b*) Read ammeters, the current should not be less than 25 amp.

(*c*) Reduce speed to zero and remove short-circuit.

40. *Open circuit test.*—With the machine driven at 8,000 r.p.m. and the output terminals open-circuited, the line voltage should lie between 7·5 and 8·25 volts.

41. *Insulation resistance test.*—The insulation resistance as measured with a 500V insulation resistance tester between all live parts and the frame should not be less than 50,000 ohms.