Chapter 2

'M' TYPE TRANSMISSION

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LIST OF ILLUSTRATIONS

Introduction

1. The "M" type transmitter and receiver are step by step instruments used for the transmission of movement indication from one position to another. The system is fed from a 24V, d.c. supply and the information is transmitted in the form of angular movement. The transmitter, which is either turned by hand, or is geared to a mechanism whose movement it is desired to transmit, is connected by three line wires to the star-connected field windings of an "M" type motor embodied in the receiver.

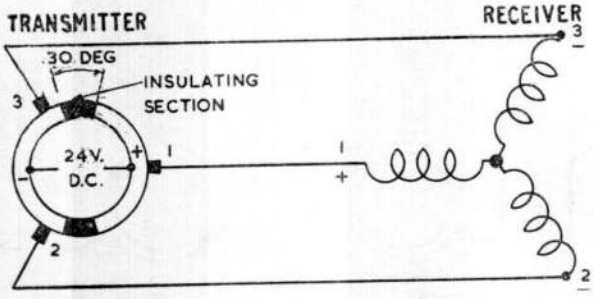


Fig. 1. Simple 'M' type system

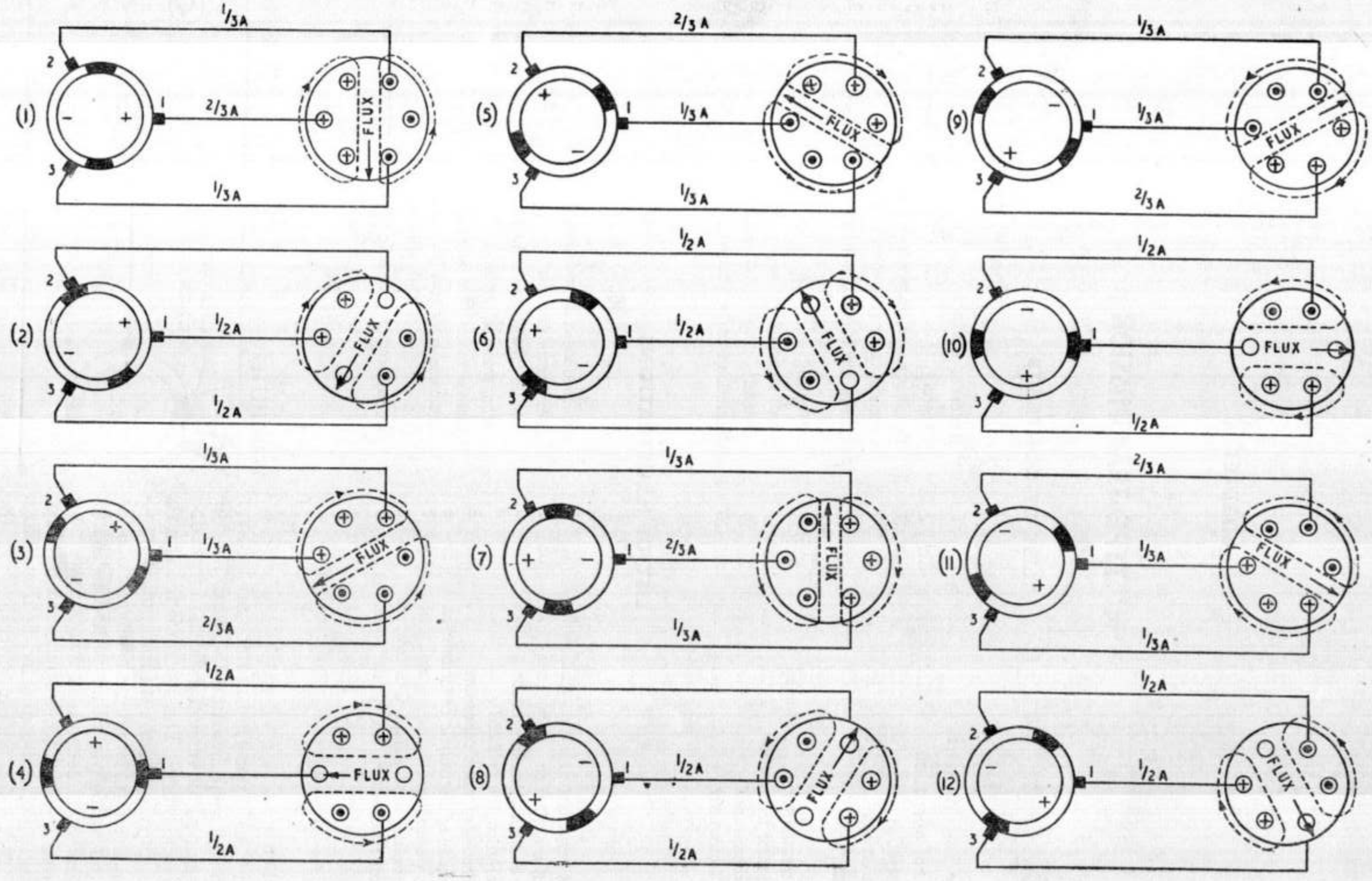


Fig. 2. Sequence of energization

PRINCIPLES OF OPERATION

2. The transmitter in an " M " type system is essentially a double-pole rotary switch. The simplest type of " M " type system is shown in fig. 1. Three star connected phase coils corresponding to a receiver are connected by three line wires to the transmitter. This simple transmitter is merely a drum switch with two insulating sections (each of 30 deg.) spaced at 180 deg. The two halves thus formed are fed from a supply of 24V, d.c., one positively and one negatively, and the line wires connected to the receiver are equally spaced round the drum at 120 deg.

3. If now the drum is rotated, the sequence of energization being fed to the receiver stator will change every 30 deg. Thus in one complete revolution of the transmitter the stator energization will change twelve times. The magnetic field set up produces a torque on the iron rotor tending to pull its magnetic axis into line with the field. It will be seen, therefore, that as the energization changes twelve times in one revolution, so the rotor of the receiver will take up twelve successive positions per revolution. These positions are known as " steps " and hence the term " step by step " transmission. Fig. 2 shows the complete sequence of energization through the twelve steps from transmitter to receiver.

4. Following on from this we can see (*fig.* 3) that the actual sequence consists of alternate three line and two line energization. Assuming a resistance of 20 ohms for each field winding, then at step 1, as shown in fig. 3, the total resistance of the field is 30 ohms. If the supply voltage is assumed to be 20V, d.c. the total field current will be $\frac{2}{3}$ amp. Thus line 1 will be carrying $\frac{2}{3}$ amp., and lines 2 and 3, $\frac{1}{3}$ amp. each (*fig.* 2). Moving on to the next step, line 2 is neutral and 1 and 3 are in series. The total field resistance is now 40 ohms and therefore lines 1 and and 3 carry $\frac{1}{2}$ amp. each. On the third step lines 1 and 2 are positive and line 3 negative, and thus fields 1 and 2 carry $\frac{1}{3}$ amp. and field 3, $\frac{2}{3}$ amp. It will thus be seen, that the current in each field coil rises from zero to a maximum positive, falls to a maximum negative and returns to zero in twelve small steps. Fig. 4 shows the variation of current in any field coil. The small steps in the current are useful in that they help to reduce the inductive effect of the fields upon one another.

5. The resultant current distribution throughout the stator due to this rise and fall of current in each winding is such as to produce a rotating field (*fig.* 2), and the rotor follows the field.

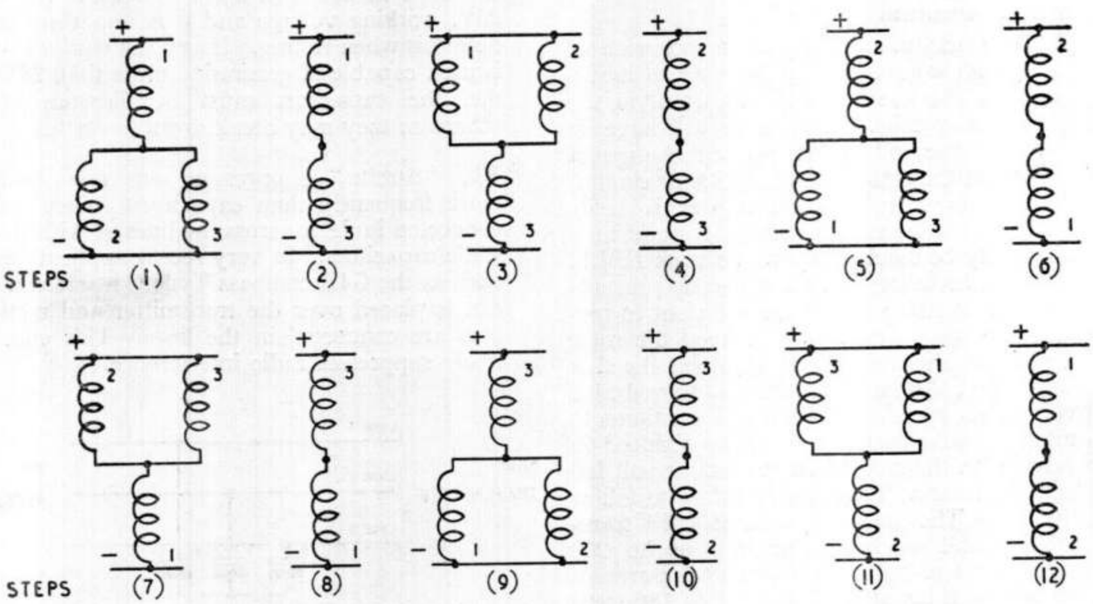


Fig. 3. Three line and two line energization

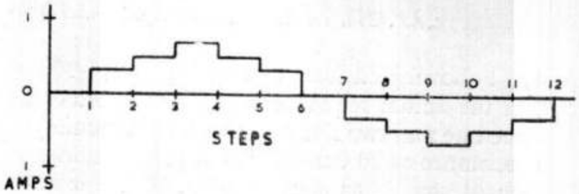


Fig. 4. Current variation in a field coil

6. It will be seen later that there are two general types of rotors used, one of laminated construction and the other a permanent magnet. The permanent magnet type gives increased torque.

7. The simple receiver (*para.* 3) is a two-pole type but there are four-pole types. The use of a four-pole winding makes the receiver rotate in 15 deg. steps and it thus becomes a 24 step receiver. If a 12 step transmitter drives a 24 step receiver there is a 2:1 ratio between the movement of the transmitter and that of the receiver rotor.

8. Any "M" type transmitter can be used with any "M" type receiver, and the principle advantage of an "M" type system is that it provides power amplification with relatively high efficiency. The principal disadvantage is that it is not self-aligning and once a receiver gets out of step it must be manually re-aligned.

Speed of operation

9. The maximum speed of transmission of the system is governed by the effect of inductance on the rise and fall of current in the motor stator coils. Inductance will have its greatest effect when the rate of change of current in the stator coils is at its maximum; this occurs when the transmitter is being turned at its maximum speed. A point may ultimately be reached where the back E.M.F. of self inductance in the stator coils prevents the current rising to a value sufficient to provide the torque necessary to keep the rotor turning at the high speed at which the flux is rotating. If the transmitter is turned at a very high speed, the flux will continue to rotate at that speed but will be reduced in value with the result that the torque will fall and the rotor will eventually refuse to follow the flux. The present system of "M" transmission will work satisfactorily up to 200 steps per sec. but for all practical purposes normal working speed is limited to 180 steps per sec.

Spark suppression

10. In addition to limiting the speed of transmission, inductance has another unwelcome effect on the transmission in that it increases wear and tear on the transmitter. Each pair of stator windings is connected between two line wires and so the back E.M.F. of self induction in the coils will be carried via the line wires back to the transmitter, and will be apparent in the form of a spark between contacts, or between brushes and drum or commutator. To reduce this effect capacitors or "Atmite" suppressors are connected in circuit.

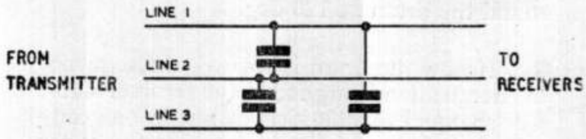


Fig. 5. Delta connection of static capacitors

11. Capacitors used are of two types, electrolytic and static. Static capacitors are connected in delta (*fig.* 5) across the lines but it is essential that electrolytic capacitors be connected in star (*fig.* 6). All positive terminals must be connected to lines and negative terminals to a common point, otherwise damage will result.

12. The two types of elctrolytic capacitor used are of 500 μF and 80 μF. The static capacitor in use is of 2 μF. They are all of 25V. working voltage and it is important to note this when testing. If any test equipment is used capable of generating more than 25V. d.c. the capacitors must be disconnected otherwise they may break down to earth.

13. "Atmite" suppressors are now used more frequently than capacitors. They are connected in delta across the lines as with the static capacitors. In very recent applications such as the G4B compass Type C a screening can is placed over the transmitter and rectifiers are connected in the lines. This effectively suppresses radio interference.

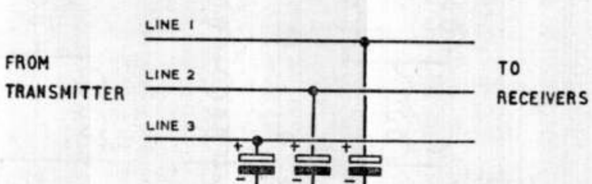


Fig. 6. Star connection of electrolytic capacitors

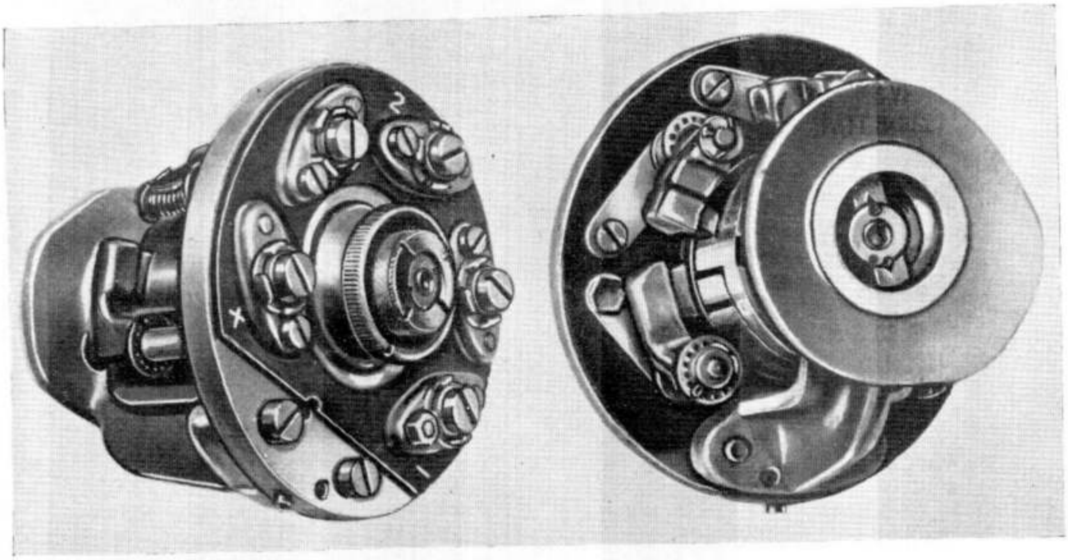


Fig. 7. Drum type transmitter

TRANSMITTERS

General

14. There are four main types, namely, the drum, commutator, cam and bottle.

The drum transmitter

15. This type of transmitter is widely used by the Admiralty but has not many applications in aircraft. However, it serves to illustrate the system very well and is shown in fig. 7 for that purpose. The drum is built up of copper, phosphor bronze or monel metal segments of suitable shape, and mounted on a shaft supported in bearings. Bearing upon the drum are five suitably spaced Morganite brushes; two of them connected to the positive and negative supply of a 24V, d.c. system and the other three connected to the line wires linking the receivers with the transmitter. When the transmitter drum is revolved the three line wires are connected in sequence to the positive and negative supply giving an "M" type output the same as shown in fig. 2. The segments on the drum are separated by small insulated islands, upon which the line brushes bear in certain positions of the transmitter drum. Without these islands it would be possible for the line brushes to cause a short circuit between the positive and negative segments of the drum as it revolved. The total number of combinations of impulses, or steps, as they are called, transmitted for each revolution of the drum varies with the type of transmitter and may be either 12 or 24 steps.

16. A type of drum transmitter used in the G4B compass is shown in fig. 8. It is a 12 step type.

The commutator transmitter

17. Commutator type transmitters are of two types, internal and external. Due to weight and size considerations however, those

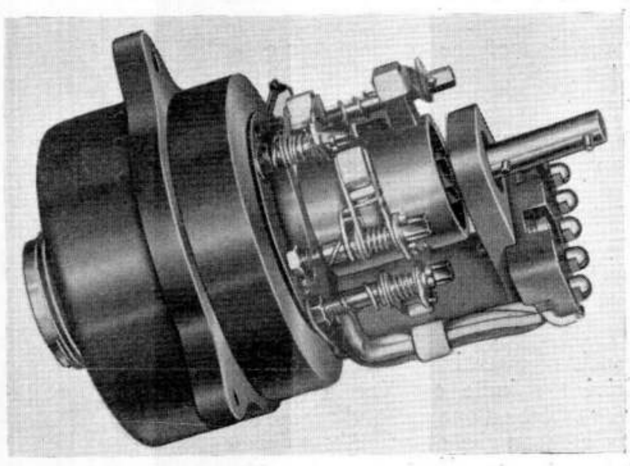


Fig. 8. Drum transmitter used in Type G4B compass

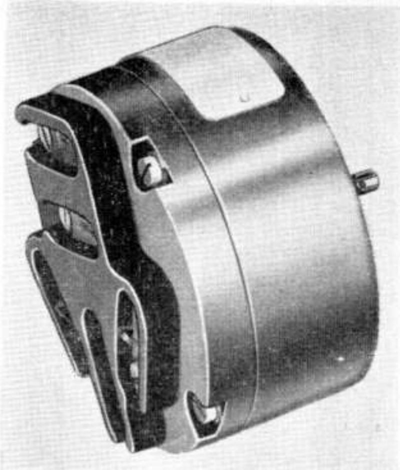


Fig. 9. Commutator transmitter

used in aircraft are invariably of the internal type. In this type (*fig.* 9) a face plate commutator rotates against the brushes held in the moulded terminal plate (*fig.* 10). The outer ring on the commutator face plate is fed through a brush from the negative supply and the innermost ring through another brush from the positive supply. It will be seen (*fig.* 10) that the ring between the supply rings is divided into four by insulating islands, and the segments so formed are connected by wire connections, one to the positive ring, its neighbour to the negative ring and so on, so that there is a definite positive, negative sequence round the divided ring. The line brushes 1, 2 and 3 bear on it and so, as the commutator rotates the lines are charged positively for a period, and then negatively, with a neutral point wherever a brush passes over one of the insulating islands. One complete revolution of the commutator gives 24 steps.

18. The shaft carrying the face plate commutator rotates in a ball bearing at the shaft end and a plain bearing at the other. The leads from all brushes pass straight through the end plate and are connected to terminals mounted on it.

The cam transmitter

19. The cam transmitter (*fig.* 11) consists essentially of a central driving spindle carrying a driving gear wheel on one end and an operating cam on the other. Six pairs of contacts are uniformly spaced concentrically with the spindle, and their inner contacts are permanently energized, positive and negative, in succession round the spindle. Diametrically opposite contacts are connected together, and the transmission lines are connected to these three pairs. By rotating the driving gear wheel the cam is made to make and break the pairs of contacts, setting up a standard "M" type sequence. A change or step takes place every 30 deg. thus making it a 12 step transmitter. A full description of this particular transmitter is given in A.P.1275B, Vol. 1, Sect. 1, Chap. 5.

The bottle transmitter

20. This transmitter (*fig.* 12) is so called because each of its three finger switches is enclosed in an evacuated glass envelope (bottle) to eliminate arcing and oxidation of the contacts (*fig.* 13). They surround a shaft driven by an "M" type repeater motor. Projecting into each bottle from a flexible sealing diaphragm is a contact arm working between the fixed contacts. Projecting the other way from the same diaphragm is an operating arm. The shaft from the motor carries a cam, operating spring loaded rocker arms, which in turn move the contact arms between the fixed contacts. One of these contacts is supplied positively and the other negatively, and the line wires are connected to the contact arm through the sealing diaphragm.

21. Thus, when the motor turns the cam the line wires are energized in an "M" type sequence. The cam is cut so that the output sequence is exactly the same as that supplied to the "M" type driving motor.

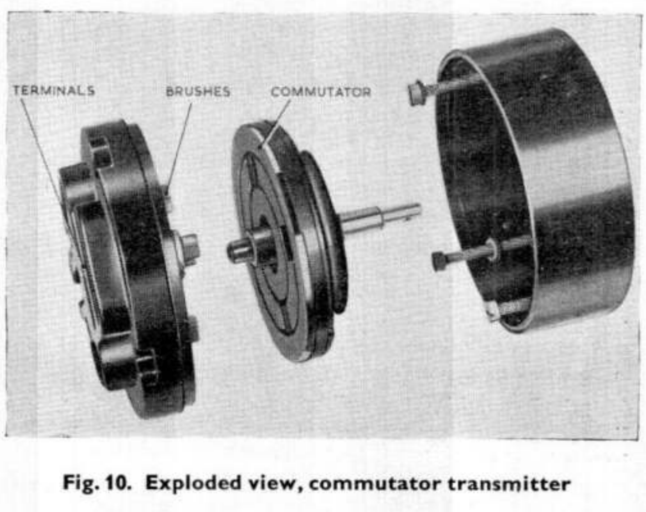


Fig. 10. Exploded view, commutator transmitter

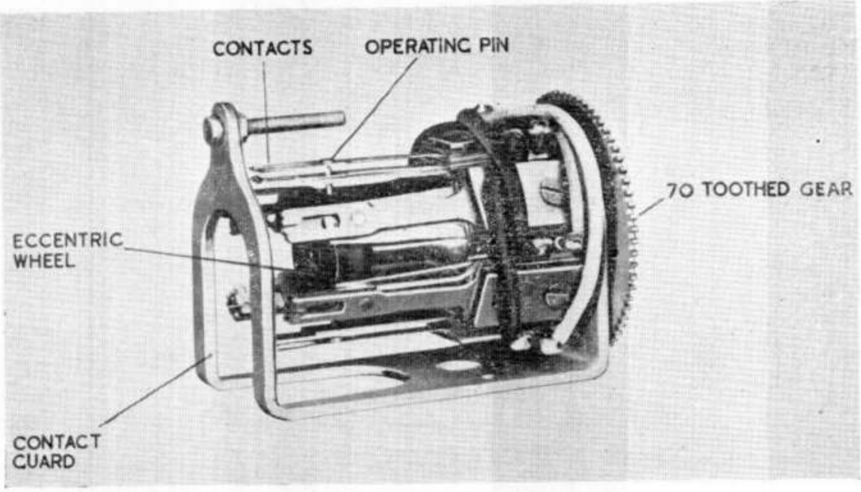


Fig. 11. Cam transmitter

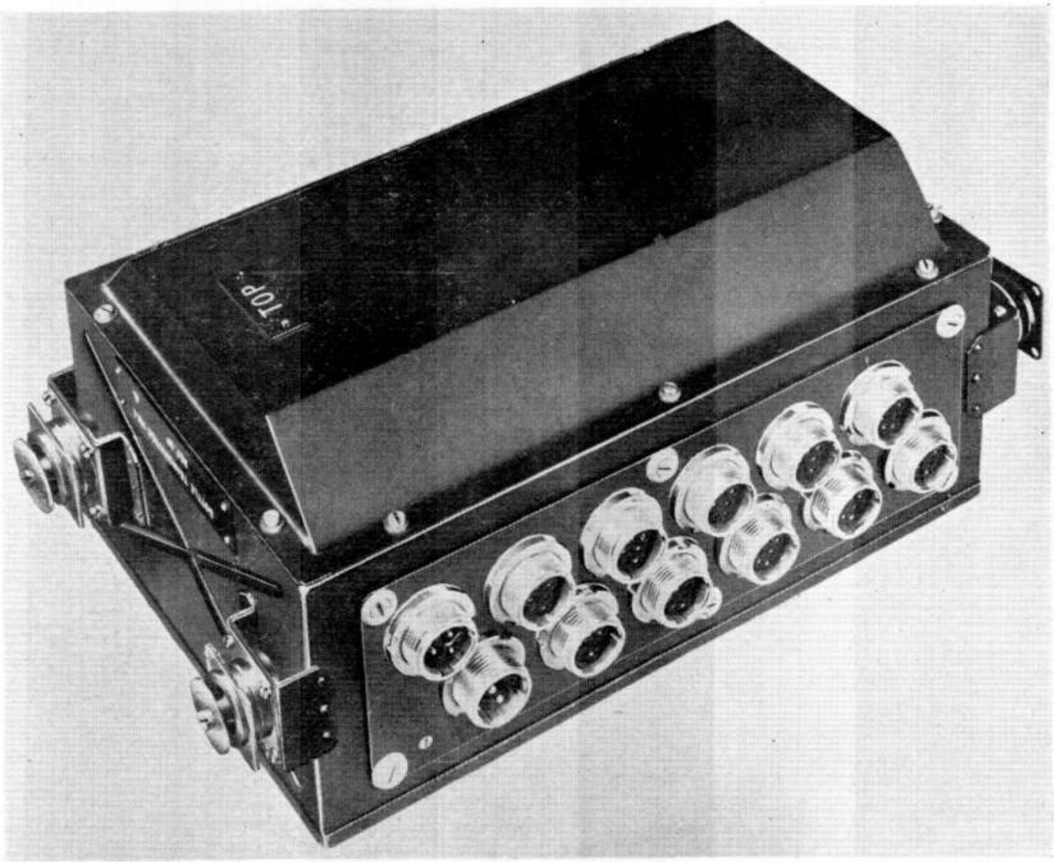
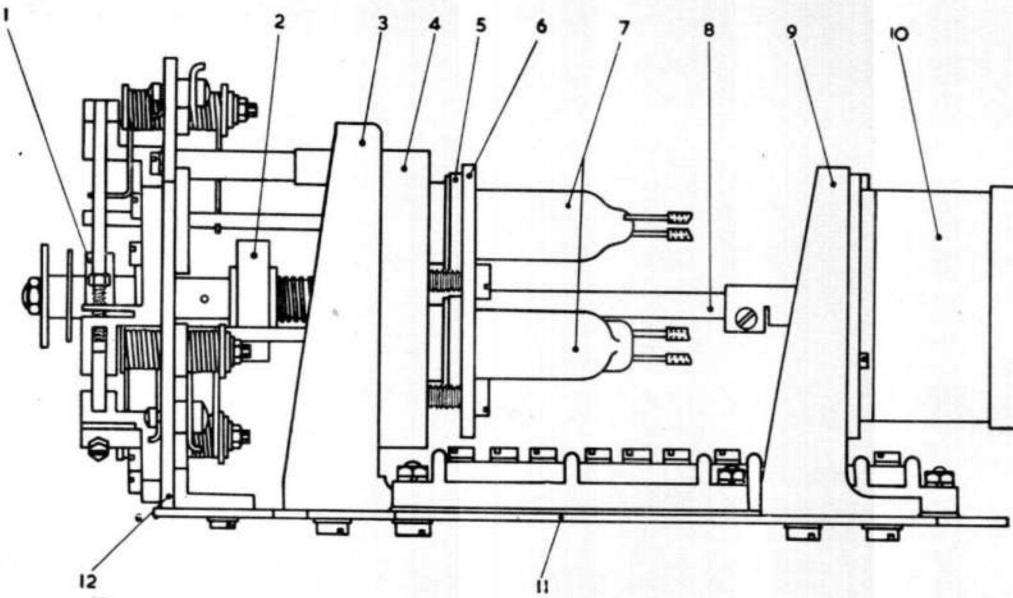


Fig. 12. General view, bottle transmitter



1 CAM
2 DAMPING WEIGHT
3 BOTTLE SUPPORT BRACKET
4 BOTTLE SUPPORT
5 BOTTLE CLAMP RING
6 BOTTLE CLAMPING PLATE
7 VACUUM CONTACT TUBES (BOTTLES)
8 CAMSHAFT ASSEMBLY
9 MOTOR SUPPORT BRACKET
10 REPEATER MOTOR
11 BASE PLATE
12 MOTION PLATE

Fig. 13. Arrangement of motor and transmitter mechanism

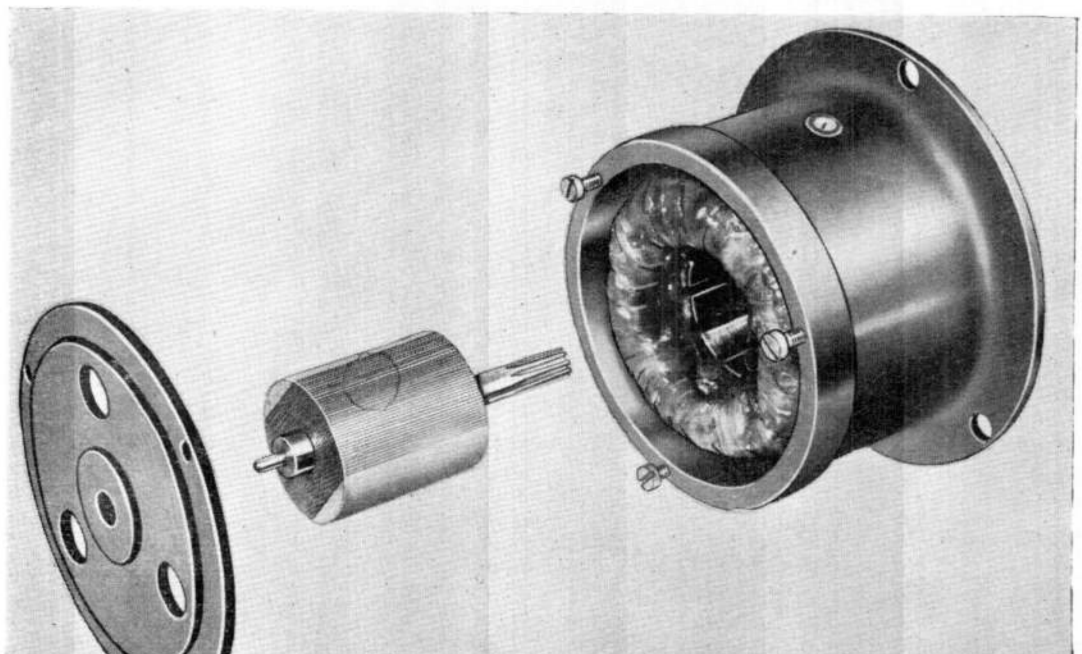


Fig. 14. Receiver motor (two pole laminated rotor)

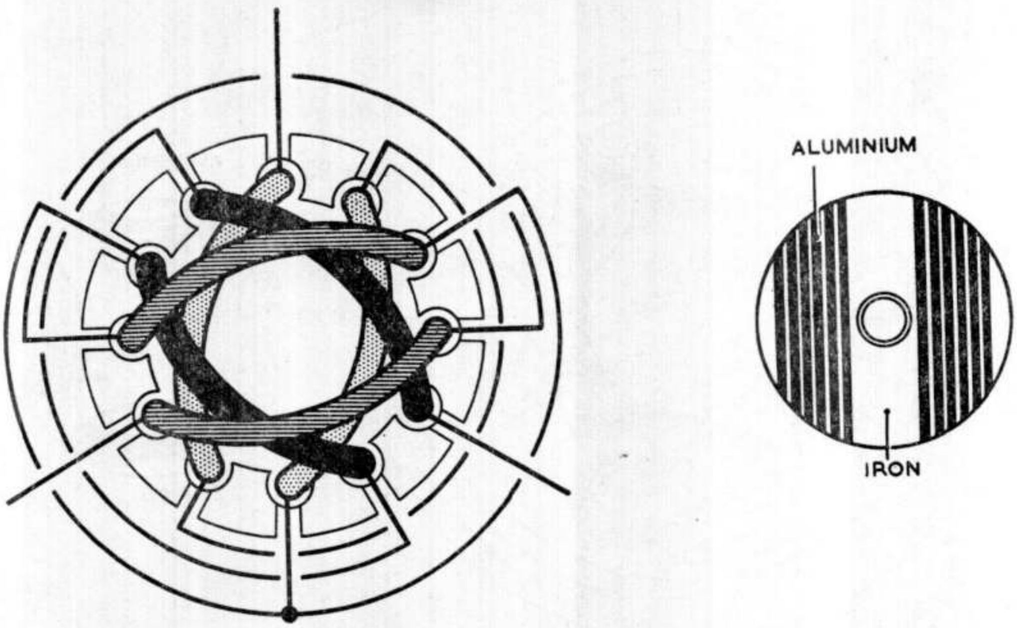


Fig. 15. Stator and rotor (two pole motor)

22. With all the other types of transmitters one big disadvantage is that as they become more loaded (i.e. more repeater motors are fed from them) sparking between contacts gets very much worse. So in applications where one transmitter has to feed several "M" motors a bottle transmitter can be used as a relay. The output from the initial transmitter is fed into the bottle transmitter and then relayed to the repeater motors. The transmitter will supply a maximum of ten Type "A" repeater motors. A full explanation of the bottle transmitter is contained in A.P.1275B, Vol. 1, Sect. 1, Chap. 16.

RECEIVER MOTORS

General

23. Several types of receiver motor are used and they can be divided into two main classes. Those with permanent magnet rotors and those with laminated iron rotors.

Receiver motor (laminated rotor)

24. The stator is of laminated silicon iron, with a three phase winding wound on it and mounted in a light alloy case. A further breakdown in types of motor occurs here for there are four pole and two pole motors. Some stators are therefore wound four pole and some two pole. Fig. 14 shows a two pole motor.

25. The stator winding for a two pole motor is shown in fig. 15. The motor has six coils arranged in three pairs. Each pair of coils is wound across a diameter of the stator (pole pitch is 180 deg.) and the coils are in series. The "starts" of each pair are 120 deg. apart on the stator and are joined to the line wires, whilst the "finishes" are connected to a common point, but not brought out. Thus the stator winding is exactly similar to that of a star connected three phase winding.

26. The stator winding for a four pole motor is shown in fig. 16, and is really equivalent to two, two-pole motors joined in series. Each coil is wound across 90 deg. of the stator, and each line has four coils in series, two pairs instead of one pair as in the case of the two pole motor. Energization of the fields is in the same sequence as for a two pole motor but owing to the 90 deg. pole pitch each step gives a rotor movement of 15 deg. instead of 30 deg.

27. In both four pole and two pole types the rotors are cylindrical, made up of iron and aluminium laminations and carried on a shaft running in ball bearings. The laminations are placed so as to lead the flux caused by the current in the stator windings, in the correct direction. In the two pole rotor this merely means that the laminations run parallel to the shaft (*fig.* 15) but with the four pole motor they have to be bent to form the poles (*fig.* 16).

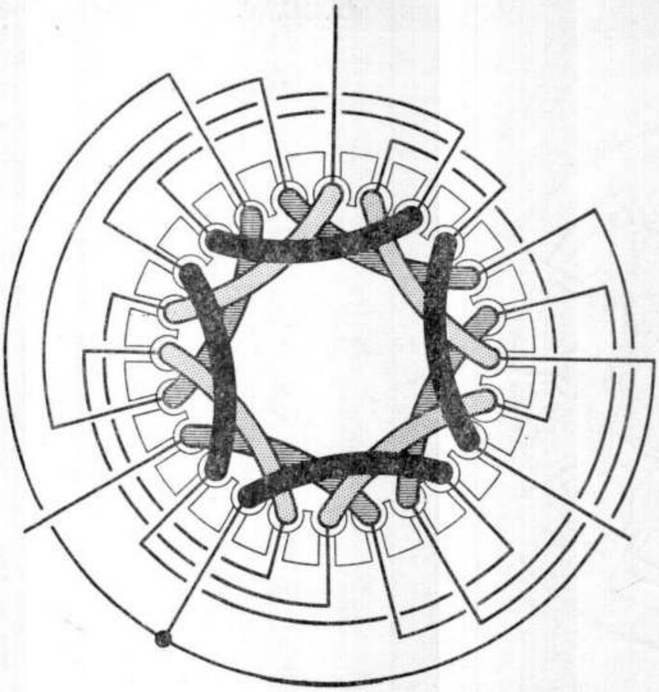
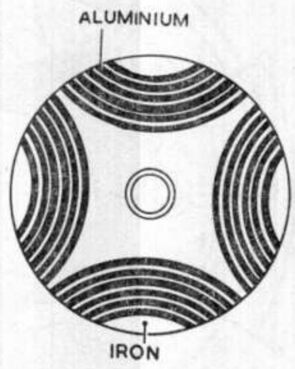



Fig. 16. Stator and rotor (four pole motor)

28. The reluctance of a magnetic path through the rotor is a minimum when the flux is in line with the laminations, and a maximum when the flux is at right angles to them. As a result of this construction the rotor will always turn to offer the path of least reluctance to the stator flux and thus follow the rotating magnetic field. The aluminium laminations act as conductance of low resistance in the rotor and eddy currents flow in them whenever the rotor is moving in the stator magnetic field. The effect of these eddy currents is to produce magnetic poles in the rotor which interact with the main flux and assist to turn the rotor laminations into line with the main flux. In this way the general effect of these laminations is to provide additional torque and to make the motor more positive in action. They also tend to prevent lag or over run of the rotor on the magnetic field. It should be noted that with this type of rotor being non-polarized it is possible for it to align itself in either of two positions 180 deg. apart.

29. The air gap between rotor and stator in all types of "M" motors is kept to a minimum in order to cut down the possibility of the rotor oscillating.

Receiver motor (permanent magnet type)

30. The rotor of the permanent magnet type of receiver (*fig.* 17) is made from an aluminium-nickel alloy. The permanent magnet rotor provides a higher torque, thereby increasing the stepping speed, and being polarized it can line-up in one position only.

31. The weight of the receivers used on aircraft has been considerably reduced by using aluminium alloy cases and it is anticipated that it might be still further decreased in the future by reducing the overall size. It is hoped that it might be possible to make them of the same size as the standard Synchro now in service.

LINING UP THE TRANSMISSION

32. The main disadvantage of an "M" type transmission system is that it is not self-aligning and therefore requires lining up before use. Also in the event of failure of power, all receivers get out of line. With Admiralty transmission systems a standard convention has been adopted. Under this convention a transmitter is said to be in its lining up position when it is feeding line 1 positively, and lines 2 and 3 negatively, or alternatively, line 1 negatively and lines 2 and 3 positively. Either of these represents the same position of the magnetic flux in the receiver motor although the direction of the flux is reversed. It will be seen (*table* 1) that a lining up position occurs twice in every 12 steps, on steps 1 and 7. The method for lining up the transmission under the Admiralty convention is to first put the transmitter to the lining up position and then set the rotors of the receiver motors to a predetermined lining up position when all rotors will occupy the same position relative to their stators.

TABLE 1

	STEP											
Lines	1	2	3	4	5	6	7	8	9	10	11	12
1	+	+	+	0	–	–	–	–	–	0	+	+
2	–	0	+	+	+	+	+	0	–	–	–	–
3	–	–	–	–	–	0	+	+	+	+	+	0

33. The lines from transmitters to receivers should be connected in sequence throughout the installation, all lines 1 being connected together, lines 2, lines 3 and so on.

34. With the various systems of "M" type transmission used in aircraft and using the types of transmitters already described no standard convention has been adopted. It is not possible therefore to give any standard method for lining-up all systems used in aircraft. Reference must be made to the appropriate chapter describing the complete piece of equipment using a particular transmission.

SERVICING

Common faults

35. (1) A broken line wire will cause the receiver rotor to oscillate or stop.

(2) Two line wires short circuited will blow a transmitter supply fuse as in some positions there will be a dead short between positive and negative.

(3) If two line wires are interchanged the direction of rotation of the receiver rotor will be reversed.

36. If the Admiralty convention for lining up is adopted then the lining up position is line 1 positive, lines 2 and 3 negative and if it is required to reverse rotation of the receiver (*para.* 35, *sub-para.* 3) then lines 2 and 3 are interchanged. They still remain negative and therefore the lining up position is unaffected.

General

37. All instruments should be worked frequently.

38. The drums or commutators of transmitters should acquire a fine polish when in good condition and should only require cleaning with soft rag. If serious pitting has occurred due to excessive sparking, then transmitters must be renewed.

Insulation test

39. The all-in reading of an "M" type system including transmitters, receivers and interconnecting wiring should not be less than ½ Megohm to earth. When tests are made any capacitors must be disconnected.

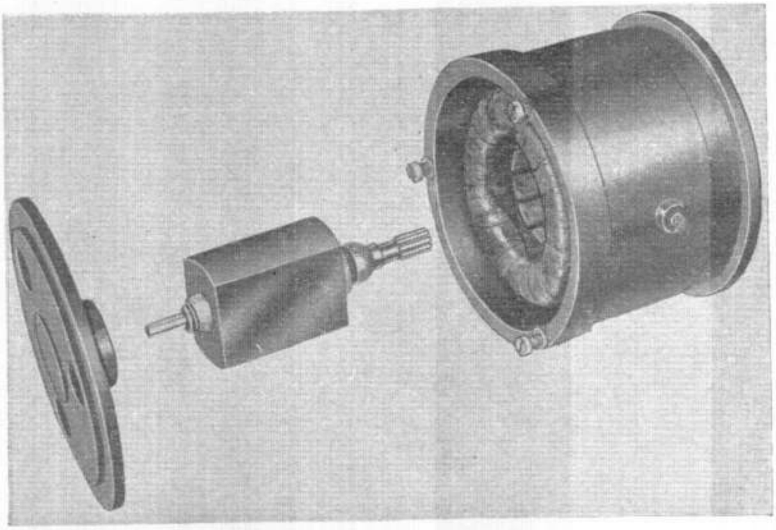


Fig. 17. Receiver motor (two pole permanent magnet rotor)

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