Chapter 1

MAGSLIPS

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LIST OF ILLUSTRATIONS

Introduction

1. Magslips are one of a number of devices used for a.c. data transmission, and in B.S.1523, "Glossary of terms used in automatic controlling and regulating systems", it is laid down that the term SYNCHRO, which was originated in the United States for their a.c. data transmission units, shall be the generic name. Other similar devices used in different applications are known as Selsyns, Teletorque, Autosyn etc.

2. The name Magslip is given to the units used in a completely self aligning electrical system used for remote indication and control.

3. Magslips may be used to provide accurate direct remote indication or control of the position and movement of a light mechanism. Simultaneous indication or control at a number of points is readily achieved, and is effective over considerable distances. They may also be used with servo systems to control large mechanisms.

4. They are made in different sizes and for operation from various power supplies. The three nominal sizes are 1½ in., 2 in., and 3 in., (based on the stator lamination diameters and not on the actual external dimensions of the elements) and various voltages and frequencies are catered for (115V, 60 c.p.s.; 120V, 333 c.p.s.; 115V 400 c.p.s.; 20V, 1100 c.p.s.; 50V, 50 c.p.s.).

5. In general, applications of magslip elements may be grouped under five headings as follows:—

(1) Distant indication of position and movement.

(2) Operation as a synchronous link (equivalent to a shaft) between mechanisms for the transmission of a moderate amount of torque.

(3) Remote servo control of position, speed etc. of a mechanism.

(4) Summation of two or more mechanical movements.

(5) Analogue computation.

DESCRIPTION

General

6. A magslip is an electro-magnetic machine consisting of a stator and rotor similar to a small electric motor. A typical system would consist of a transmitter and receiver energized by alternating current, and the arrangement is such that any movement of the transmitter rotor is exactly reproduced on the receiver. This self synchronous characteristic gives rise to the term "Synchro".

The transmitter

7. A typical transmitter is shown in fig. 1. The stator has a body made up of internally slotted laminations with three sets of windings spaced 120° apart, and arranged in similar fashion to the stator windings of a 3 phase induction motor. This gives rise to the term "3 phase windings", but actually the voltages in them vary in magnitude, and are either in phase, or in complete anti-phase with each other, and with the supply voltage.

8. The rotors are of two types. One type is built up from laminations to make an H-shaped core carrying a single phase exciting winding, whilst the second type is built up from circular slotted type laminations, and carries up to three windings, depending on the particular application of the magslip. The 2 in. transmitter has an H-type rotor (*fig.* 2) and the 3 in. a circular type. Connections to the rotor are normally made by brushes and slip rings, but in some instances where the rotor is only ever called on to make one revolution, flexible connections are used. The rotor is carried on light ball bearings, and the mechanical drive to the rotor is through a hub pinned to the shaft. This hub has a

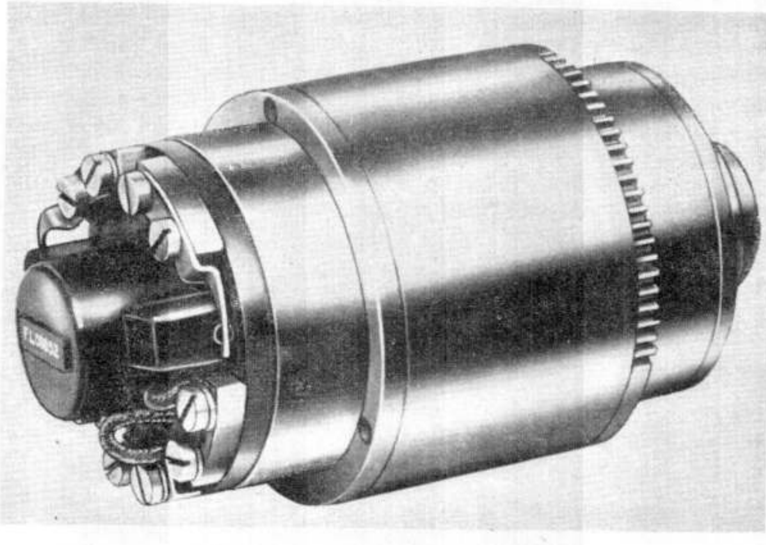

Fig. 1. Typical magslip transmitter

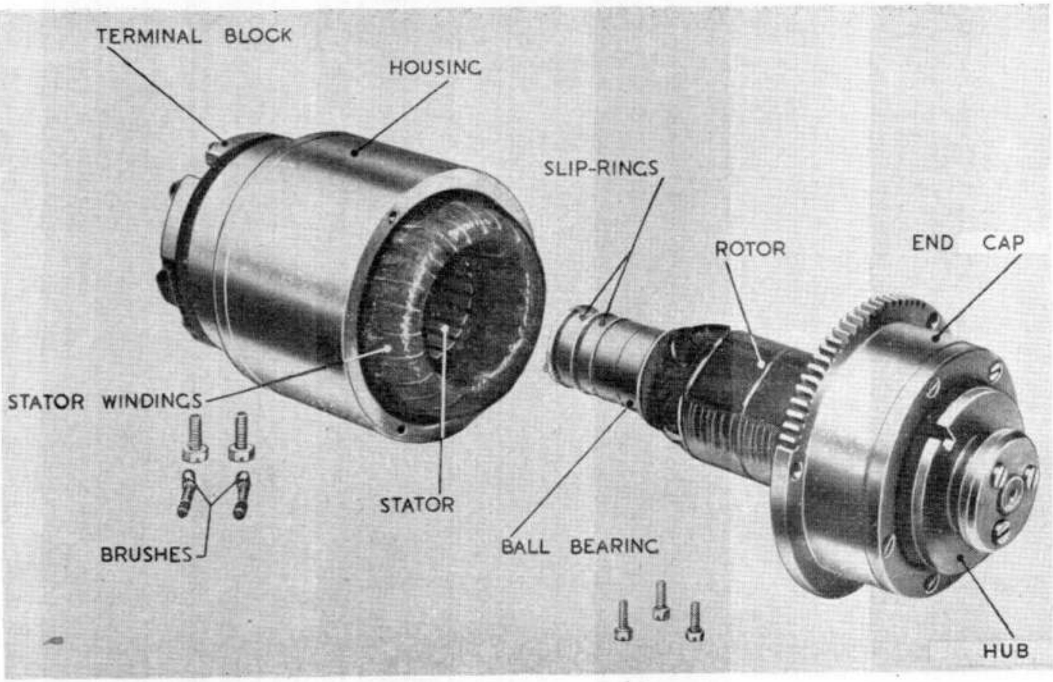

Fig. 2. Transmitter partly dismantled

slot in it so that the rotor can be locked when lining-up.

9. In the 3 in. transmitter with the circular type rotor, one winding is the exciting winding, whilst the second winding (which is short circuited on itself and wound at right angles to the exciting winding) is used to neutralize stray flux. Ideally, no current flows in it since it cuts no flux.

10. Due to assymmetries in the iron and variations in the air gap, together with slight winding variations, the main flux from the rotor may be distorted from its main axis. It can therefore be resolved into two components, one in line with the axis of the exciting coil and one at right angles to it. The component at right angles gives rise to a current in the neutralizing winding, which sets up a field to oppose this component and concentrate the main field on its axis.

11. Briefly, the neutralizing winding increases the reluctance of the magnetic path through the rotor in a direction at right angles to the exciting field. In the H-rotor the shape supplies this property. The reluctance in the direction of the exciting field is low, but at right angles to it, it is extremely high.

12. In the majority of transmitters the stator phase connections are brought out to terminals marked 1, 2 and 3, whilst the rotor connections are marked X and Y. An adjusting rack is incorporated at the driving end of the transmitter (*fig.* 2), so that the element

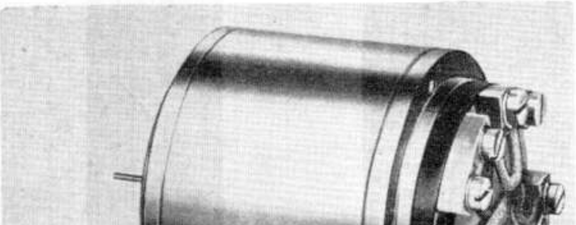

Fig. 3. Magslip receiver

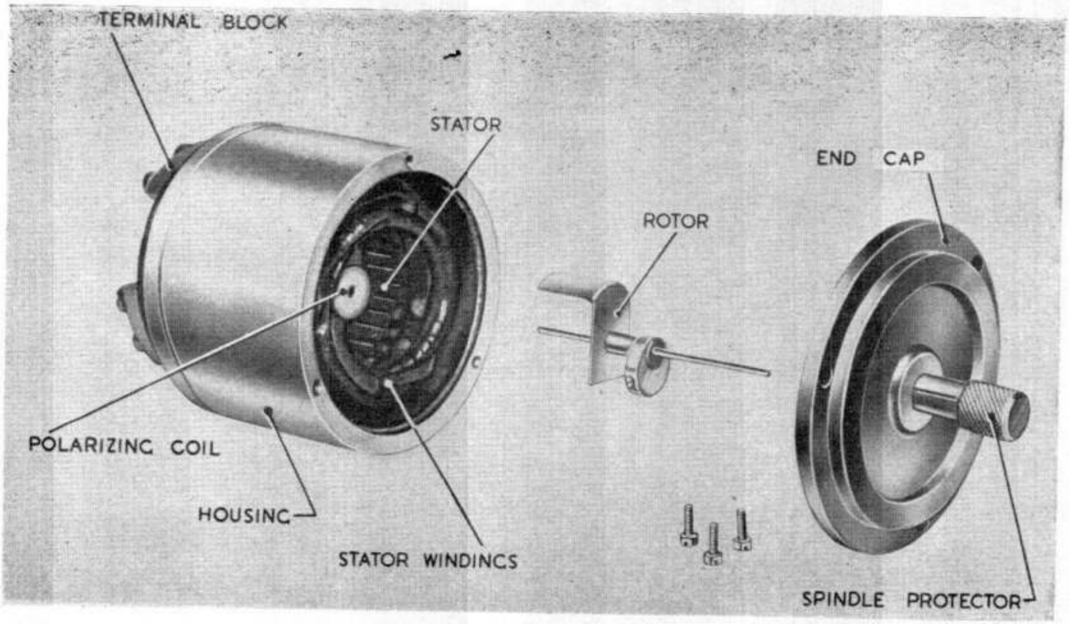

Fig. 4. Receiver partly dismantled

can be brought into exact coincidence by means of a pinion when lining-up.

The magslip receiver

13. The magslip receiver is an instrument used for remote indication only (*fig.* 3). It develops no measurable torque and is often supplied with built in scale and pointer. The stator windings are similar to those used in the transmitter. These windings are brought out to terminals 1, 2 and 3 (*fig.* 5), which in a system are connected to terminals, 1, 2 and 3, respectively of the transmitter.

14. The rotor is made of soft iron and revolves round a fixed polarizing winding. It is made as light as possible and moves with the least possible friction. Without the polarizing winding the rotor could line up in either of two positions 180 deg. apart. But the field set up by this winding gives the rotor the appropriate polarity corresponding to that of the stator field at the same instant, and it can thus only take up one position. The magnetic circuit is through the iron core of the polarizing winding, across an air gap to the rotor vane, across the air gap to the stator and back to the other end of the core. This method of polarizing the rotor has given rise to the term "magslip" since the flux is passed to the rotor through what may be called "magnetic slip-rings".

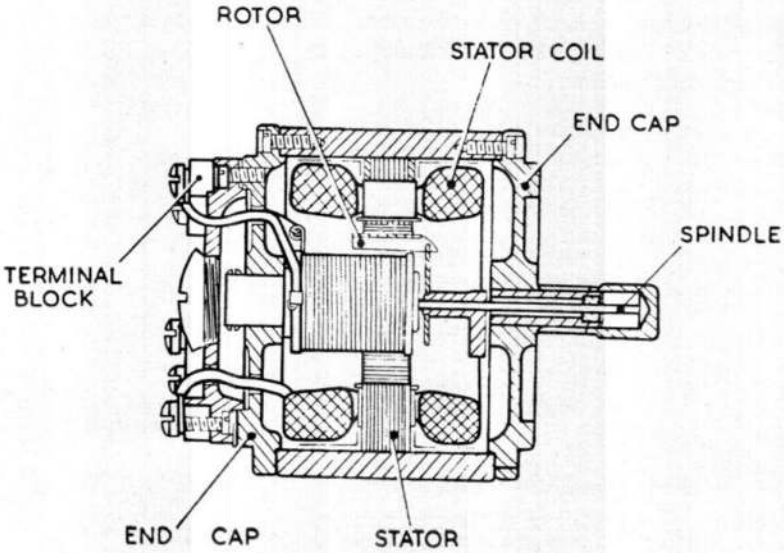

Fig. 5. Sectional diagram of receiver

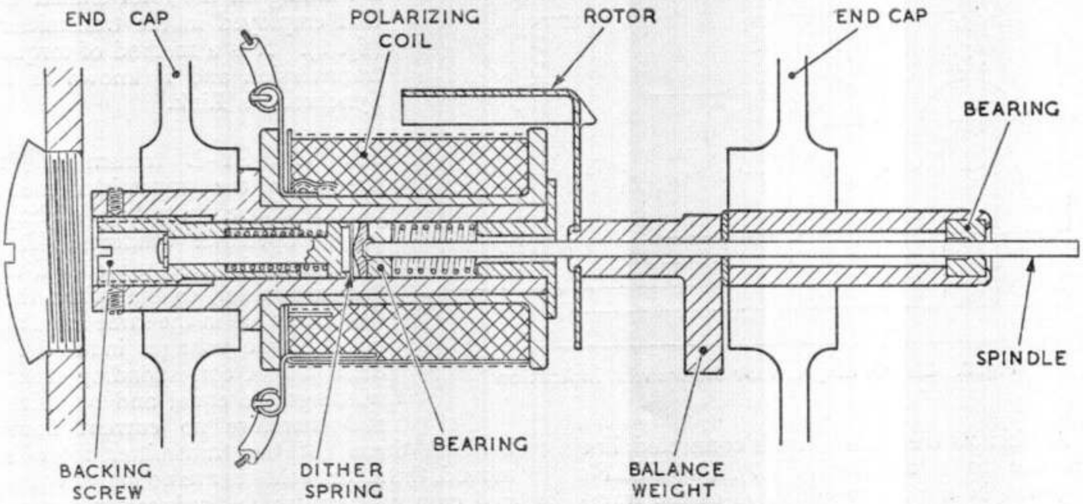

Fig. 6. Section of receiver rotor mechanism

15. The rotor spindle is carried in bronze bearing bushes (*fig.* 6) and in order to reduce static friction the spindle is given a small axial dither movement. The lower ends of the rotor spindle and bearing rest on a fibre cup and steel dither spring. The amount of dither can be adjusted by the adjusting screw. As the current in the polarizing coil alternates each side of zero, it pulls the rotor towards the coil and deflects the spring. The rotor will thus have an axial movement which in practice is about 0·002 in. at a frequency of 100 deflections per second. This facilitates accurate alignment of the rotor in the stator flux.

16. As has already been stated, the polarizing winding ensures that the receiver can line up in only one position, not two, but it does also give the receiver a small amount of torque. This becomes especially important when more than one receiver is paralleled from a single transmitter. The receiver provides very little reaction in the transmitter and if one pointer sticks the others are not affected.

The follow-through transmitter

17. Sometimes it is required to indicate the final result of two separate movements. In addition to the transmitter, what is known as a follow-through transmitter is then used. It is externally similar to the standard transmitter but has a three-phase, star-connected, distributed winding on the rotor, in addition to the 3 phase stator winding. It has six terminals, the rotor windings being brought out to those marked 1R, 2R and 3R, and the stator windings to those marked 1T, 2T and 3T.

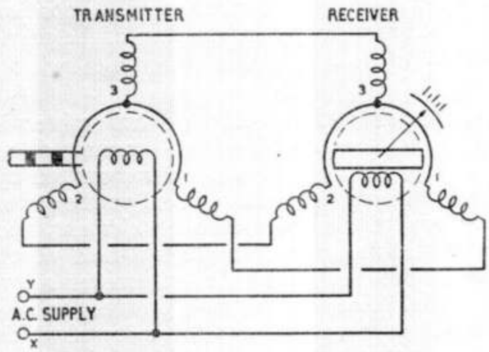

Fig. 7. Circuit diagram for single receiver

Principles of operation

18. If the rotor of the transmitter is excited with single-phase a.c., an alternating magnetic field is set up along the axis of the winding, and the flux, linking with the stator winding, induces E.M.F's in each of them by transformer action. These E.M.F's are in phase or in anti-phase with each other, and the magnitude of the E.M.F. in any stator winding depends upon the angle between its axis and the axis of the field, varying from a maximum when the winding is in line with this axis, to zero when it is at right angles. Thus if the rotor is moved, the axis of the field moves with it, and the E.M.F's induced in the stator winding change.

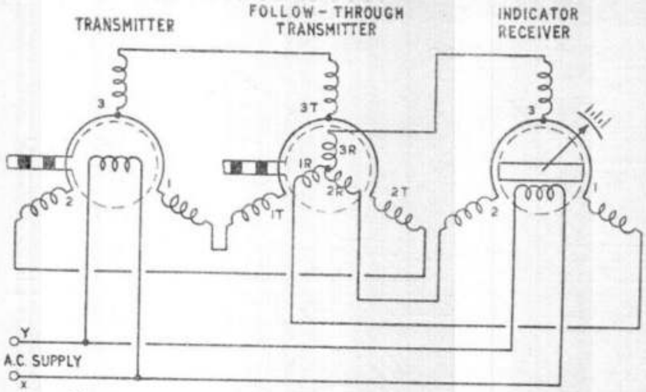

Fig. 8. Circuit diagram for differential indication

19. If now the transmitter is connected, line to line to a receiver (*fig.* 7), the E.M.F's induced in the stator windings of the transmitter cause current to flow in the stator of the receiver. The magnetic field set up by these currents is identical in its angular position to that in the transmitter rotor because the receiver and transmitter stator are identical. The receiver rotor now aligns itself with this field, and so the pointer of the receiver gives a true indication of the position of the transmitter rotor, and thus of the prime mover.

20. When a follow-through transmitter is employed, the elements are connected as shown (*fig.* 8). The voltages transmitted by the first transmitter, are received on the stator windings of the follow-through element, and the resultant current produces a field which follows the position of the transmitter rotor. This field induces voltage in the follow-through transmitter rotor, the value of which depends on the relative position of the stator field and the rotor, which is coupled to the second controlling position. These induced voltages are passed on to the indicator stator and the iron rotor of the receiver will line up with the field produced by the resulting current. Hence the rotor of the receiver has been turned through an angle corresponding to the sum (or difference) of the transmitter and the follow-through transmitter rotor movements.

Synchronous link

21. The torque available in the normal type of receiver just mentioned is only sufficient for pointer indication. If it is required to move a dial or potentiometer slider then SY–L transmitters and receivers must be used. The magnetic coupling is increased in this type of receiver by putting a winding on the rotor similar to that employed in the transmitter (*fig.* 9). It is a method of torque transmission and is known as a Synchronous Link.

22. The SY–L transmitter is similar to the transmitter mentioned above but has slightly lower impedance windings. The receiver is electrically identical to the transmitter, so that when the two rotors are in the same angular position, the voltages induced in each pair of corresponding stator windings are equal and opposite, and therefore no current flows between them. If the transmitter rotor is moved, the stator voltages are no longer equal and currents flow which produce torques on both rotors to pull them into alignment. If the transmitter rotor is held, and the receiver rotor is free to rotate, it will align itself with the transmitter rotor. The receiver has a damping flywheel on the rotor which prevents self-oscillation, especially when the power supply is first switched on.

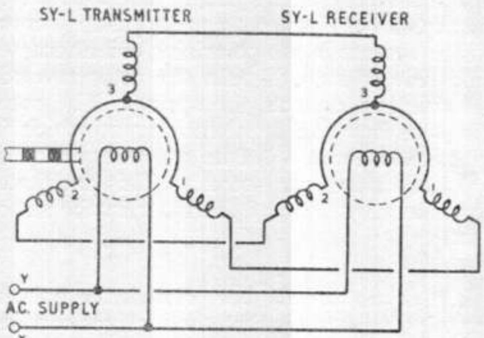

Fig. 9. Circuit diagram, synchronous link

POWER CONTROL

General

23. Magslip power transmission or control normally consists of a two or three element chain, or variations and combinations of these two systems, used for the operation of a power unit.

The coincidence transmitter

24. The coincidence transmitter or co-transmitter, as it is sometimes called, is used to indicate the position of a normal transmitter rotor by an electrical signal instead of a mechanical movement. It is therefore used extensively in electrical servo-mechanisms.

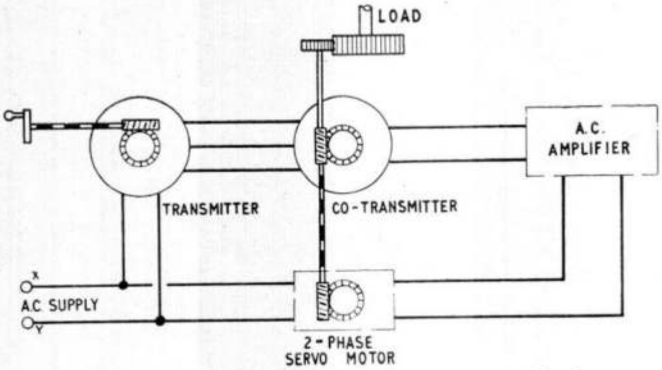

Fig. 11. Co-transmitter applied to a servo-mechanism

The co-transmitter comprises a normal stator and a cylindrical rotor, having a single winding which is not energized from the a.c. supply. No torque is produced in the rotor, and a voltage is induced in it by transformer action having a magnitude corresponding to its position with respect to the axis of the stator field. This voltage varies sinusoidally with angular displacement of the rotor, having a maximum value when the axis of the co-transmitter rotor winding is in line with the stator field axis, and being zero when it is at right angles. Thus the lining-up position of the co-transmitter is at right angles to the axis of the field. Fig. 10 shows how the co-transmitter rotor voltage varies with clockwise rotation of the transmitter rotor from the lining-up position, with the co-transmitter rotor remaining in the lining-up position. This voltage is frequently referred to as the " error signal " because it gives a measure of the misalignment between the transmitter and co-transmitter rotors. The error signal undergoes a phase reversal. On one side of zero it is in phase with the supply, and on the other in anti-phase with it. This is used to establish the direction of misalignment of the co-transmitter rotor with respect to the transmitter rotor.

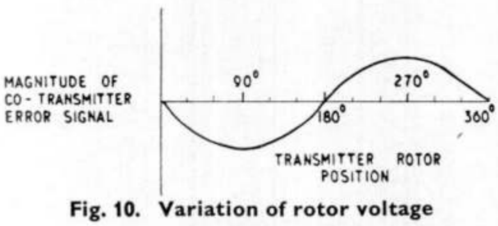

Fig. 10. Variation of rotor voltage (co-transmitter)

25. A typical application of the co-transmitter is shown in fig. 11. The transmitter stator windings are connected to the co-transmitter stator windings in the normal manner and the co-transmitter rotor is connected to the input terminals of an amplifier, in which the error signal is amplified (a follow-through transmitter can also be employed in the system). The output of the amplifier is connected to the control windings of the two phase servo motor, which has its reference winding connected to the supply. When the rotor of the co-transmitter is at right angles to the transmitter rotor, no output voltage is produced (*para.* 24). If now the transmitter rotor is turned, a voltage is induced in the co-transmitter rotor, which is in phase or in anti-phase to the supply, depending on the direction in which the transmitter rotor is turned. This voltage after amplification is fed on to the control winding of the servo motor, causing it to rotate, drive the load and also rotate the co-transmitter towards the " zero volts " position. Thus the load is rotated through an amount equal to the original movement of the transmitter rotor. When this has been accomplished no error signal is being put out by the co-transmitter and the system is at rest.

The hunter

26. A magslip element called a hunter (*fig.* 12) is used to measure the angular difference between two transmitters by comparing line voltages. The second transmitter is usually referred to as a " resetter ". The hunter has similar stator windings to the transmitter but its rotor also has three windings set at 120 deg. to each other. It has six terminals, the stator windings being brought out to those marked 1, 2 and 3 " Local " and rotor windings through flexible connections or brushes, to those marked 1, 2 and 3 " Distant ".

27. Hunter elements are normally fitted with a balanced operating arm of standard design (*fig.* 13). Taking a servo operated hydraulic mechanism as an example there would be a pilot valve directly operated by the hunter. The connection can be made using a flexible operating rod, screwed at one end and secured to the operating arm by a spring clip; thus enabling adjustments to be

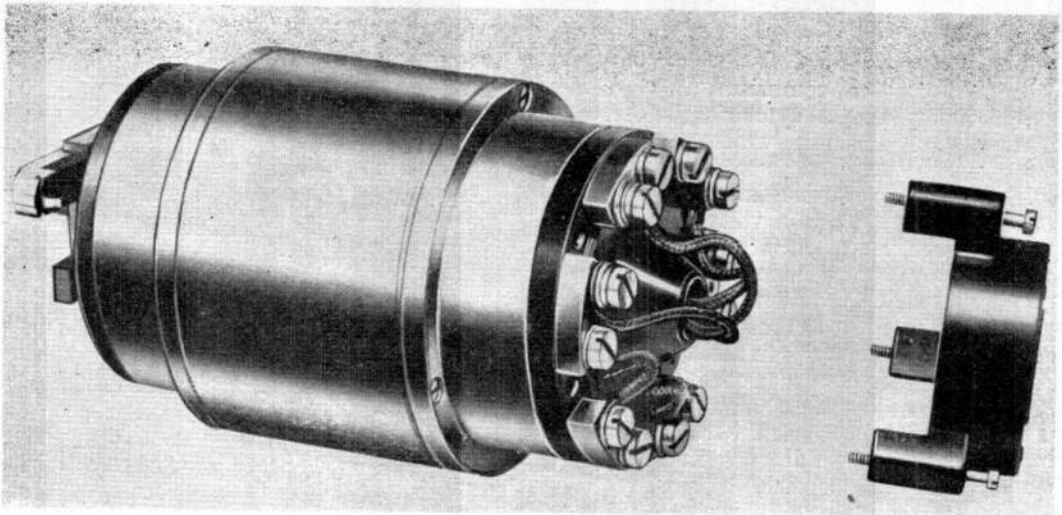

Fig. 12. Magslip hunter

carried out. Stops are provided to limit the rotation of the operating arm to about ten degrees either side of a central position, and are used to carry loading springs.

28. When energized, a free hunter will take up its zero position, if the positions of the transmitter and resetter correspond. Due to the small torque developed per degree of misalignment, good sensitivity and accuracy can only be obtained by keeping the mechanical load on the hunter element as small as possible, any attachments statically balanced, and the axis horizontal.

29. To ensure stable operation, it is essential that the hunter rotor should be capable of moving at a rate greater than that corresponding to the maximum acceleration of the power unit; the maximum rate at which the hunter rotor is moved is determined by its natural period of oscillation. Where this rate and accuracy is sufficient, the hunter is used in its free state, but when higher rates and

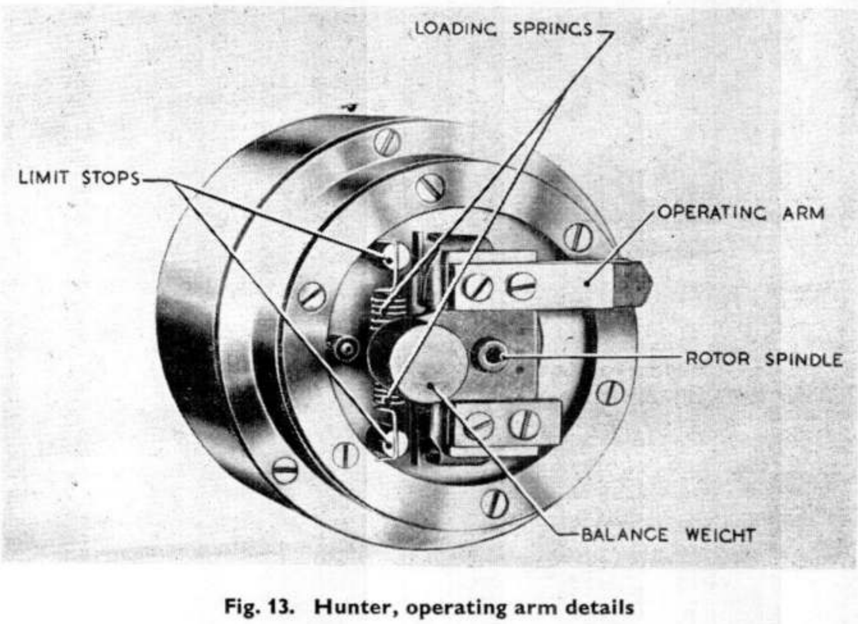

Fig. 13. Hunter, operating arm details

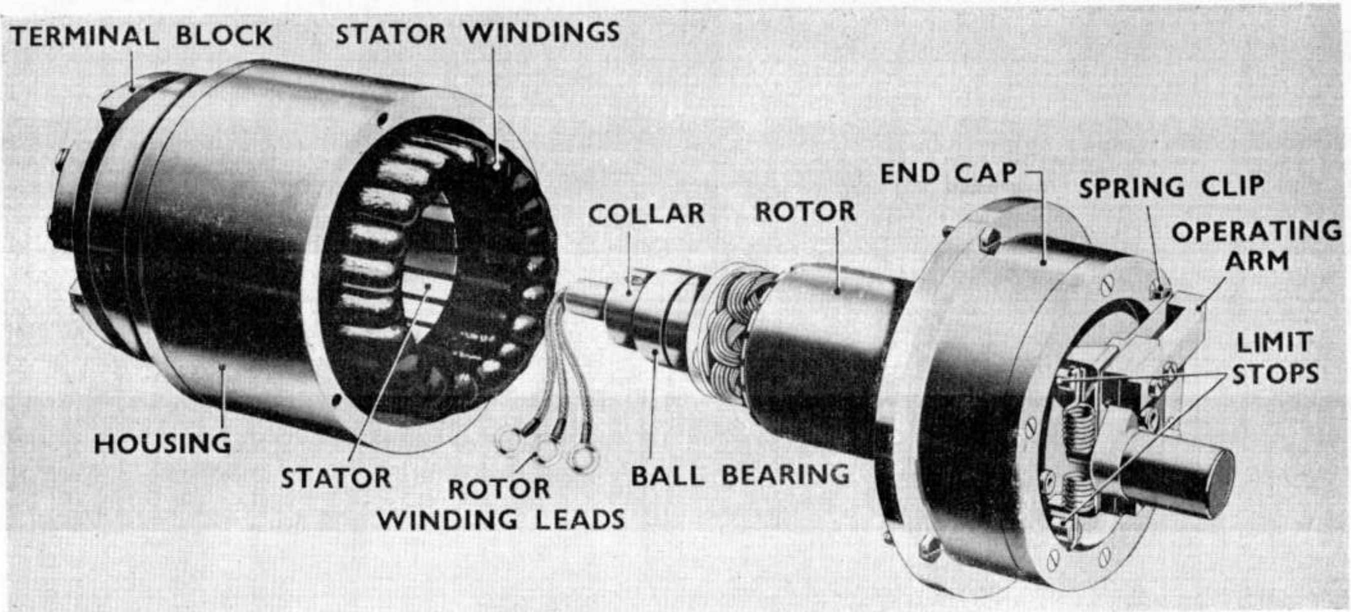

Fig. 14. Hunter partly dismantled

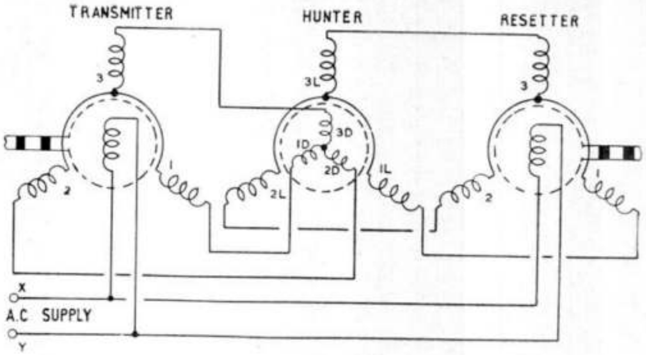

Fig. 15. Circuit diagram, three element chain

greater accuracy are needed, the periodic time is decreased by the addition of loading springs (*para.* 27), thus giving more stable operation. The spring loading must be kept to a minimum, consistent with stable operation, because it diminishes the rotor displacement for a given angle at the transmitter, and so reduces sensitivity and increases the operating lag. In the event of a power failure or, on switching off, the spring makes the hunter return to its central position and closes the valve.

The three-element chain

30. Fig. 15 shows the wiring arrangement in a system using a transmitter, hunter, and resetter and controlling a servo mechanism. It will be noted from the diagram that terminals having like numbers are connected together but that the internal connections from the terminals to the rotor windings of the hunter are reversed with respect to the stator. A decision has been made that resetting transmitters shall move in the opposite direction to the transmitter. Thus if the rotor of the transmitter is offset clockwise, then the rotor of the resetter will move an exactly equal amount anti-clockwise.

31. The voltages induced in the transmitter stator, cause corresponding currents to flow in the hunter rotor windings, and the hunter rotor produces a magnetic field. Similarly the voltages induced in the resetter stator, cause currents to flow in the hunter stator windings, and thus produce a second field in the hunter. The hunter rotor always tries to move into such a position that the axes of the two fields are coincident (minimum energy condition).

32. Applying the system as shown (*fig.* 15) to a hydraulic servo system, the transmitter is the initiating or master element. The hunter rotor is connected to the pilot valve of the servo-mechanism (*para.* 27) and the re-setter is connected by gear drive to the servo-mechanism itself, so that it must move with it.

33. The operation of the system may best be followed by referring to fig. 16, in which the axes of the respective magnetic fields and the positions of the rotors are seen diagrammatically. In each diagram the axis of the field due to the transmitter rotor is shown in the circle on the left, and the corresponding field set up by the hunter rotor is shown in the inner cycle of the central element. The field due to the resetter rotor is shown in the circle of the right hand element, and the corresponding field set up by the hunter stator is shown in the outer ring of the central element.

34. Fig. 16a corresponds to fig. 15 and shows all the elements in the central position, with the pilot valve closed, and the servo-mechanism at rest. In fig. 16b the transmitter rotor has been turned in a clockwise direction and the axis of its field has therefore advanced towards No. 1 stator winding. This causes the field in the hunter rotor to move through the same angle towards its No. 1. winding, but in the opposite direction due to the internal connections being reversed (*para.* 30). Misalignment of the hunter rotor and stator fields causes a torque to be set up on the rotor, which immediately rotates clockwise until both fields are once again in alignment. The rotor rotating rocks the operating arm (*para.* 27), thus opening the pilot valve and setting the servo-mechanism in motion (*fig.* 16c). The resetter rotor is moved by the servo-mechanism in the opposite direction to the original movement of the transmitter rotor (*fig.* 16d) and the field of the hunter stator is offset by the same amount. The hunter stator and rotor fields are now again out of alignment, a torque is set up, and the rotor begins to move back to its original position. When the resetter has turned through an angle exactly equal to the original rotation of the transmitter rotor, the hunter rotor has arrived back at its original position, the pilot valve is closed, and the servo-mechanism is at rest (*fig.* 16e).

35. The movements have been described as taking place in sequence but in practice the servo-mechanism begins to move immediately

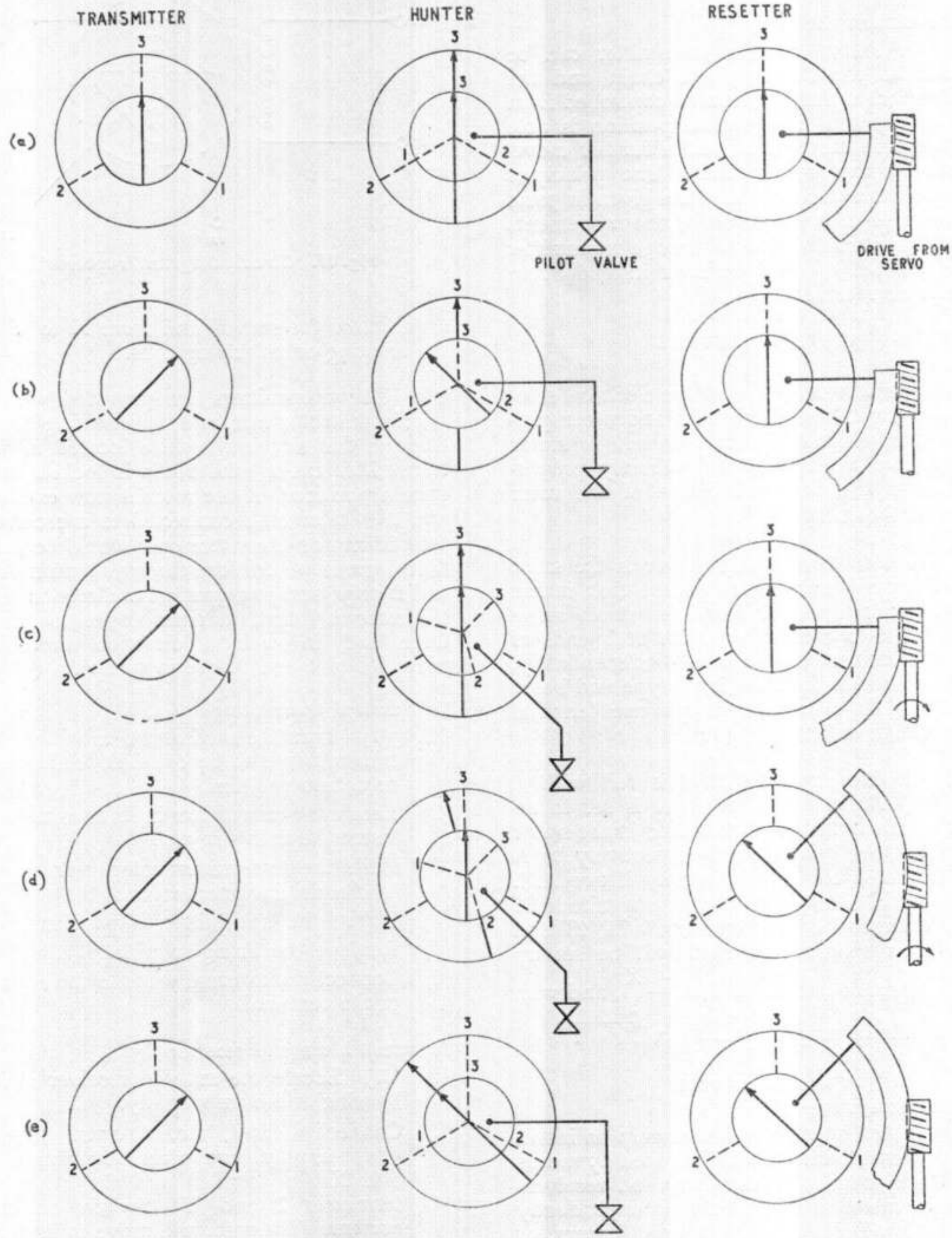

Fig. 16. Operation of three element chain

after the hunter rotor moves. The total rotation of the hunter rotor from its central position, is usually quite small, because little movement of the pilot valve is required for full output of the servo-mechanism.

Four-element chain

36. A follow through transmitter can be added to the three-element chain and the servo-mechanism can then be controlled from two positions. The second position is able to override the first or add a further movement to that of the first. The principles involved are the same as those given in para. 20, except that the result of the movements of transmitter and follow-through transmitter are now fed on to the hunter instead of an indicator receiver.

SPECIAL TYPES

The resolver

37. A resolver is used for the electrical solution of right-angled triangles and other purposes in electrical computation. A stator output voltage is obtained directly proportional to the sine and cosine of the rotor angular position.

38. The stator of the resolver is the same as a normal transmitter except that it has only two sets of windings set at an angle of 90 deg. to each other, with both ends of both windings brought out independently. The rotor is of the cylindrical type and has a similar pair of windings, but one terminal is common to both (*fig.* 17).

39. If one rotor winding is fed with a voltage A and the rotor shaft is set to an angle θ, then the voltage induced in the stator windings are proportional respectively to A sin θ and A cos θ. Conversely if two A.C. voltages of like phase and of magnitude X and Y are connected to terminals 1T, 2T and 3T, 4T respectively a field will be set up with its axis at an angle $\text{Tan}\ \frac{-1\,X}{Y}$, and with a magnitude proportional to $\sqrt{X^2+Y^2}$.

INSTALLATION

Indication system

40. In order to facilitate lining-up on installation, a method has been developed by means of which magslip transmitters and receivers may be installed and lined up independently of each other. A conventional datum, or zero position, for the rotor of each element has been adopted. When in this position, current of the same polarity will flow at the same time through the units from terminals

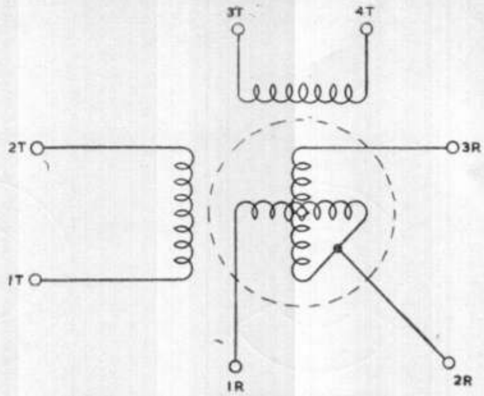

Fig. 17. Circuit diagram, resolver

1 and 2 of the stators and from X to Y of the exciting or polarizing coils.

41. The transmitters are provided with a slot in the rotor hub and by inserting a pin through this slot into a hole located in the transmitter casing, the rotor is locked in a certain position. If the rotor is now excited, and the stator coils connected to a receiver, the polarity on the stator coils would be such that current would flow through terminals 1 and 2 only, and in a particular direction (i.e. the rotor is locked at right angles to phase three and in such a direction that the polarities of 1 and X are in phase).

To install a transmitter

42. (1) Turn the mechanism to which the transmitter is to be coupled, to the zero or datum position.

(2) Locate the transmitter in its housing and insert the lining-up pin.

(3) Mesh the transmitter rotor gear wheel to the driving mechanism.

(4) Clamp the transmitter in position.

(5) Remove the lining-up pin.

(6) Connect the external wires to the appropriate terminals.

To install a magslip receiver

43. (1) Locate the magslip receiver in its housing and clamp tightly.

(2) Connect a 50V, a.c. 50 c.p.s., single-phase supply, one wire to terminals 1 and X (in parallel) and the other to terminals 2 and Y. Switch on the current. The rotor will move to its zero or datum position.

(3) Fit the indicator pointer to the magslip receiver and clamp it approximately in the zero position on the dial.

(4) Take off the 50V supply, connect up to the transmitter and switch on. Adjust the pointer exactly to zero by rotating the receiver stator. This may be done by hand, or where fitted, by the gear provided.

(5) Securely clamp the stator in position.

(6) Connect up the external leads to the appropriate terminals.

44. In systems using the follow-through transmitter, this transmitter must be aligned to its datum position, as explained for the transmitter, and after lining-up the first transmitter.

Power control (lining-up)

45. (1) With a.c. supplies and motor power " off ", set all transmissions and the controlled equipment to the zero or datum line.

(2) Mesh all transmitters and coincidence transmitters with lining-up pins in position, arranging adjusting pinions (where fitted) in the centre of stator racks as far as possible.

(3) Where the hunter is used, set the operating arm horizontal, and fit the operating rod from the sensitive valve of the hydraulic unit.

(4) With motor power only " on ", adjust the hunter arm screw on the sensitive valve stem until the motor stops. Check by deflecting the arm gently in each direction. Restore the controlled equipment to the zero or datum line.

(5) Check all electrical connections.

(6) Switch on the a.c. supply. The controlled equipment should remain steady in its zero position, but slight deflection can be rectified by turning the stator body of one of the transmitters by means of the rack and pinion.

(7) Check each transmission in turn against the controlled equipment for correct mechanical rotation.

46. The only connection changes allowed for reversal of rotation of a magslip element are as follows:—

(1)	For transmitters and follow-through supply transmitters	reverse connections to 1 and 2 (stator) and X and Y (rotor)
(2)	For follow-through transmitters	reverse connections to 1T and 2T (stator) and 1R and 2R (rotor)
(3)	For hunters	reverse connections to 1L and 2L (stator) and 1D and 2D (rotor)

These double reversals are necessary to preserve the conventional lining-up positions of magslip elements.

SERVICING

General

47. Very little servicing should be needed on these machines, as they are very robust, apart from the items mentioned in the following paragraphs.

Lubrication (all elements)

48. On assembly the bearings are lubricated with special oil, and no external provision is made for lubricating. If any further lubrication seems necessary then a new element should be fitted and the old one sent back to the appropriate repair depot.

Transmitters

49. The brushes should be inspected occasionally, to ensure that they are working freely, and all connections checked over.

Hunters

50. The dust cap may be removed to inspect the connections. No other servicing should be undertaken.

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