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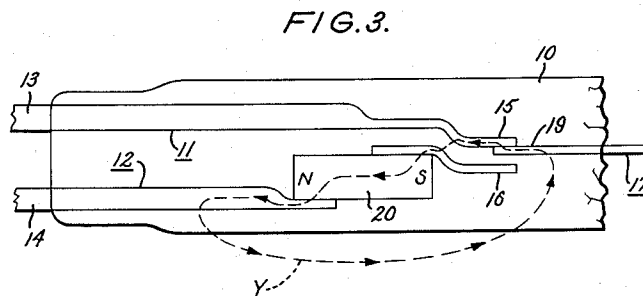
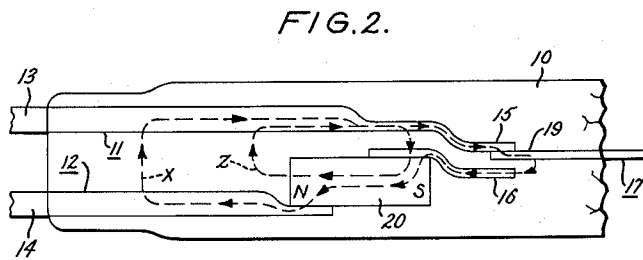
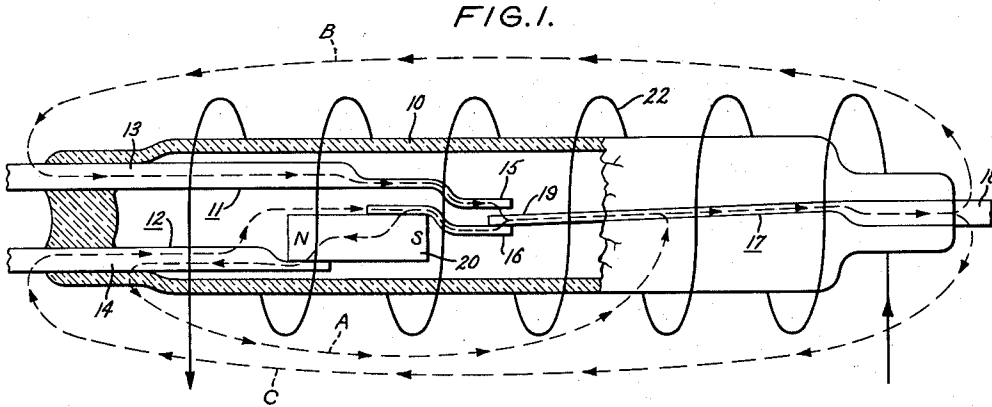
E. W. WERTS

3,117,202

MAGNETIC REED SWITCHES

Filed April 26, 1962

2 Sheets-Sheet 1



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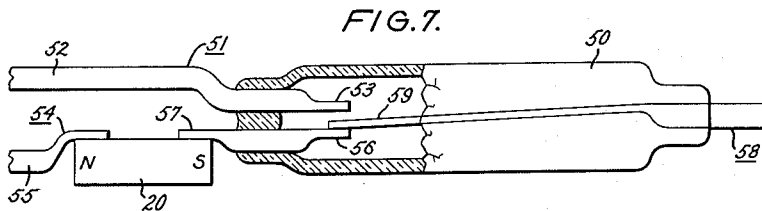
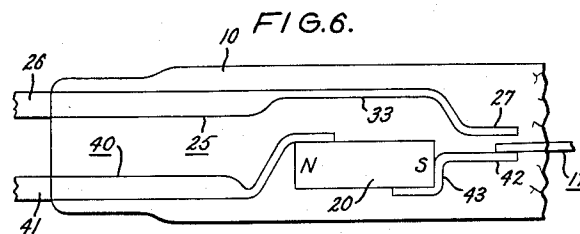
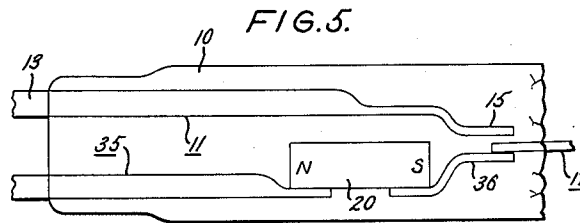
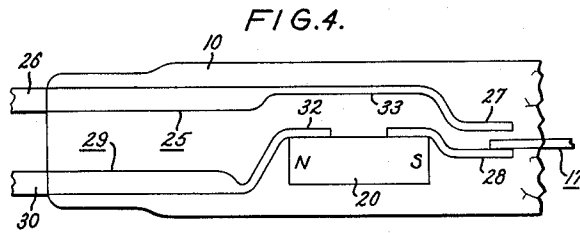
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MAGNETIC REED SWITCHES

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2 Sheets-Sheet 2



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3,117,202

MAGNETIC REED SWITCHES

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 Filed Apr. 26, 1962, Ser. No. 190,274
 13 Claims. (Cl. 200—87)

This invention relates to magnetic reed switches and has particular relation to sealed magnetic reed switches of the double throw type.

Double throw reed switches of previous design have included a sealed tube containing a pair of fixed contacts and a deflectable reed having a contact portion located between and overlapping the fixed contacts. A permanent magnet has been provided to control movement of the reed relative to the fixed contacts and a coil or other flux producing means has been located outside the tube to effect movement of the reed to a selected one of the fixed contacts for operating the switch. In switches of this type it is desirable that the switch include a minimum number of inexpensive parts arranged such that the switch is of minimum dimensions and of low cost construction. Also, such switches should exhibit good operating sensitivity so that a very small external magnetic field is capable of moving the reed to operate the switch. Further, it is very desirable that the switch design be such as to provide adequate contact closing and separating forces to assure positive operation of the switch and low resistance at the contacts, and to overcome any tendency for the reed to stick or weld to one of the fixed contacts. Previous designs of double throw reed switches have not been entirely satisfactory in that they have failed to incorporate one or more of the above desirable features.

It is therefore a primary object of the present invention to provide a novel and improved double throw magnetic reed switch of low cost and compact design.

It is another important object of the invention to provide a novel and improved sealed double throw magnetic reed switch having excellent operating sensitivity wherein the application of a very small magnetic field effects movement of the reed to operate the switch.

It is a further object of the invention to provide a novel and improved sealed double throw magnetic reed switch exhibiting substantial contact closing and separating forces to assure positive operation of the switch and low resistance at the contacts, and to overcome any tendency of the reed to stick or weld to the fixed contacts.

It is still another object of the invention to provide a novel and improved sealed double throw magnetic reed switch exhibiting low contact bounce and substantial contact separating forces which are provided in part by a spring force developed by the reed when in contact closing condition.

In carrying out the invention in one preferred form a sealed double throw magnetic reed switch is provided including a sealed glass tube which mounts at one end a pair of spaced electrodes of electrically and magnetically conductive material having terminal parts outside the tube and fixed contact parts within the tube in spaced relation. The tube also mounts at its other end an electrically and magnetically conductive deflectable reed having a terminal part outside the tube and extending between the fixed contact parts in overlapping relation therewith. When the reed is unstressed it assumes a neutral position wherein it is midway of the two fixed contacts, and when the reed is deflected to one of the contacts, it develops a spring force which urges the reed toward the other of the contacts. A permanent magnet is located on one of the electrodes for attracting the reed toward such one elec-

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trode. The magnet and reed are positioned in series in a first magnetic circuit which carries flux from the magnet which flows in the same direction through the reed and magnet. The reed and the other of the electrodes are included in series in a second magnetic circuit and the parts are arranged such that substantially zero resultant magnetic flux from the magnet passes between the reed and the contact part of the other electrode even when the reed engages such other electrode. In order to operate the switch suitable magnetic field producing means are located outside the tube to produce magnetic flux which flows through both of the first and second magnetic circuits to deflect the reed.

Other objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a view with parts broken away and with parts shown in section of a sealed reed switch constructed in accordance with the present invention and showing paths followed by operating magnetic fluxes produced by the permanent magnet and by the external flux producing means;

FIG. 2 is a view in side elevation of the switch with parts broken away showing two different paths for undesired magnetic flux produced by the permanent magnet;

FIG. 3 is a view in elevation similar to FIG. 2 showing a third path followed by undesired magnetic flux produced by the permanent magnet;

FIG. 4 is a view in elevation with parts broken away showing a switch of different construction than the switch of FIG. 1;

FIG. 5 is a view in elevation with parts broken away showing a switch of different construction than the switches of FIGS. 1 and 4;

FIG. 6 is a view in elevation with parts broken away showing a switch of different construction than the switches of FIGS. 1, 4 and 5, and

FIG. 7 is a view with parts broken away and with parts shown in section of a switch of different construction than the switches of FIGS. 1, 4, 5 and 6.

Referring now to the drawings there is illustrated in FIG. 1 a sealed reed switch of the double throw type constructed according to the teachings of the present invention. The switch includes a generally cylindrical elongated tube 10 preferably formed of glass and sealed at its opposite ends to support and enclose parts of the switch mechanism. At the left hand end of the tube 10 as viewed in FIG. 1 is mounted a pair of electrodes formed of electrically and magnetically conductive material, such as a nickel-iron alloy, and designated generally by the numerals 11 and 12. The electrodes 11 and 12 include respectively longitudinally extending spaced terminal parts 13 and 14 adjacent the inner wall of the tube 10 which are sealed to the tube 10 by any suitable glass to metal sealing process and which project outside of the tube. The electrodes also have contact parts 15 and 16 which are located within the tube in transversely spaced relation substantially centrally of the tube and which are more closely spaced than the terminal parts 13 and 14. The electrode 11 is preferably of integral one piece construction and includes a substantially cylindrical terminal part 13 adjacent the left hand end of the tube which terminates inside the tube in a flattened stepped part constituting the contact portion 15. The electrode 12 is preferably of two part construction as will presently appear.

An electrically and magnetically conductive reed 17 is supported by the tube 10 at its opposite end and includes a cylindrical terminal part 18 sealed to the tube and extending outside the tube and a flattened longitudinally

extending contact part 19 within the tube and extending between the contact parts 15 and 16 of the electrodes 11 and 12 and in overlapping relation with the contact parts 15 and 16. The reed 17 is deflectable into and out of engagement with the contact parts 15 and 16 of the electrodes 11 and 12, and in accord with the invention the reed 17, when unstressed, assumes a neutral position midway between the contact parts 15 and 16. When the reed 17 is deflected out of its neutral position to engage one of the contact parts 15 or 16 as shown, the reed develops a spring force which urges it away from the contact part with which it engages to provide a very effective contact separating force. The reed 17 is preferably formed of a nickel-iron alloy and is mounted by the tube 10 by a suitable glass to metal seal. Electrical connections are made to the terminal parts 13, 14 and 18, and when the reed engages the electrode 11, a first electrical circuit is completed, and when the reed engages the electrode 12, a second electrical circuit is completed.

In order to influence the position of the reed 17, the present invention provides a permanent magnet 20 which is included in a first magnetic circuit which also includes the reed 17. In the embodiment illustrated in FIG. 1 the magnet 20 is mounted on the electrode 12 and is located inside the tube 10 for attracting the reed 17 toward the contact part 16 of the electrode 12. The magnet 20 is preferably of cylindrical configuration having a high coercive force and may be formed of any suitable permanent magnetic material, such as alnico. The magnet 20 is positioned within the tube 10 so that when magnetized its north and south poles designated N and S, are spaced longitudinally of the tube and the magnet itself is spaced longitudinally of the reed 17 and is also spaced from the electrode 11. For this purpose the magnet 20 is mounted by the terminal part 14 of the two part electrode 12 at the upper surface of the flattened end of part 14 as by welding. The contact part 16 of the electrode 12 is mounted by the magnet 20 and for this purpose is welded to the upper surface of the magnet 20 which is adjacent the electrode 11. It is noted that the contact parts 15 and 16 are of generally conforming stepped formation and that the right hand ends thereof are located substantially equal distances from the inner wall of the tube 10.

As previously stated, the magnet 20 and the reed 17 are included in series in a first magnetic circuit, and this circuit provides a path for magnetic flux which emanates from the magnet 20 and which is designated by the dash lines A. As shown in FIG. 1 the flux A emanates from the north pole N of magnet 20, continues a short distance along the terminal part 14 of electrode 12, bends downwardly as viewed in FIG. 1 into the area outside tube 10, bends upwardly and returns to the reed 17 and passes through a portion thereof to the contact part 19, crosses the gap between the contact part 19 of reed 17 and the contact part 16 of electrode 12, extends along the contact part 16, and returns to the magnet 20 through the south pole S thereof. It is thus seen that the magnetic flux A from the magnet 20 traverses the reed 17 and the magnet 20 in the same direction which is essentially longitudinally of the tube 10, and operates to attract the contact part 19 of reed 17 toward the contact part 16 of the electrode 12. It can be appreciated that by varying the induction of the magnet 20, the degree of attraction of reed 17 to the contact part 16 may be varied. In the embodiment of FIG. 1 the induction of magnet 20 is relatively high so that the contact part 19 of reed 17 is normally in engagement with contact part 16 of electrode 12 to provide normally closed contacts.

In order to control operation of the switch, there is provided magnetic field producing means located externally of the tube 10 and illustrated in the form of a winding 22 having a number of turns surrounding the tube 10 and extending over substantially the entire length thereof. While the external field producing means is shown in the form of a winding, it is appreciated that other field pro-

ducing means, such as a permanent magnet, may be employed instead of the winding 22. Magnetic flux produced in response to energization of the winding 22 by current flowing in the winding in the direction of the arrows associated with the winding follows a number of paths. Energization of winding 22 produces magnetic flux designated by the dash lines B which traverses a second magnetic circuit including in series reed 17, an area external to the tube 10, terminal part 13 of electrode 11, contact part 15 of electrode 11, and the air gap between the contact parts 15 and 19.

Energization of winding 22 in the direction of the arrows associated therewith also produces magnetic flux designated by the dash lines C which traverses essentially the same magnetic circuit as is traversed by the flux A and which includes in series the reed 17, an area external to the tube 10, terminal part 14 of electrode 12, contact part 16 of electrode 12, and the gap between the contact parts 16 and 19. Inasmuch as the magnet 20 has a high coercive force, its inherent induction is not appreciably changed by the flux C. It is noted that the magnetic flux B produced by winding 22 exerts an attractive force between the contact part 15 of electrode 11 and the contact part 19 of reed 17, and that the magnetic flux C produced by winding 22 flows in the first magnetic circuit in the opposite direction with respect to the magnetic flux A produced by magnet 20. Thus, the flux C tends to nullify the attractive force exerted by magnet 20 and in cooperation with the flux B operates to move the reed 17 toward contact part 15 of electrode 11. Therefore, when the reed 17 is engaged with contact part 16 of electrode 12 as illustrated in FIG. 1, predetermined energization of winding 22 in the direction shown results in movement of the reed 17 out of engagement with contact part 16 of electrode 12 and into engagement with contact part 15 of electrode 11 thereby providing a switching action. Three forces thus contribute to a very effective separation of the normally closed contact parts 16 and 19, the three forces constituting the attractive force produced by flux B, the nullifying force produced by flux C, and the spring force developed by the reed in the normally closed condition. When the reed has been deflected into engagement with contact part 15 as described and the winding 22 is subsequently deenergized, the reed will return to engage the contact part 16 under action of its spring force and the attractive force of the magnet 20.

Magnetic flux emanating from the magnet 20 follows a number of different paths in addition to the path for the flux A previously described. It is found that flux from the magnet in these additional paths tends to adversely affect operation of the switch particularly when the reed engages contact part 15 of electrode 11 as shown in FIGS. 2 and 3, and it is therefore very desirable that the magnitude of these fluxes be minimized and their effects neutralized. As shown in FIG. 2 magnetic flux designated by the dash lines X emanates from magnet 20 and traverses a path which may be traced from the north pole N of magnet 20, through a portion of the terminal part 14 of electrode 12, the air space between the terminal parts 13 and 14 of electrodes 11 and 12, a portion of the terminal part 13 of electrode 11, the contact part 15 of electrode 11, a portion of the reed 17, a space between reed 17 and the contact part 16 of electrode 12 and a portion of the contact part 16 back to the south pole S of magnet 20.

It is observed that the magnetic flux X from magnet 20 flows in the same direction through the contact parts 15 and 19 as the flux B produced by energization of coil 22. This is undesirable in that the flux X tends to hold reed 17 in engagement with contact part 15 when the coil 22 has been energized to move the reed to such position as shown in FIG. 2, and results in a residual attraction of the reed 17 and the contact part 15 subsequent to deenergization of coil 22. As a consequence, the full spring force developed by the reed 17 when such

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is deflected to contact part 15 is not available for separating the reed 17 and the contact part 15 in the event of welding or sticking of these contacts. It is appreciated that the magnitude of the flux X can be varied by changing the spacing between and the form of the various parts of the electrodes 11 and 12 to vary the air gaps between the terminal parts 13 and 14 of the electrodes 11 and 12 comparatively large adjacent the left hand end of the tube 10, the flux X is minimized, and by reducing the spacing between the contact parts 15 and 16 adjacent the curved or stepped areas thereof, a portion of the flux X may be diverted from its illustrated path through this reduced spacing thereby further reducing the amount of the flux X which traverses the contact part 15 and the reed 17. The spacing between the terminal parts 13 and 14 of the electrodes is at least twice the spacing between the contact parts 15 and 16, and preferably about three times such spacing.

Magnetic flux designated by the dash lines Y in FIG. 3 is also produced by the magnet 20 and this flux traverses a path which may be traced from the north pole N of magnet 20 through a portion of the terminal part 14 of the electrode 12, an area external to the tube 10, a portion of the reed 17, the contact part 15 of electrode 11, the gap between the stepped areas of the contact parts 15 and 16, and back to the magnet 20 through the south pole S thereof. The flux Y adversely affects operation of the switch in that the flux Y traverses a portion of the second magnetic circuit including the contact parts 15 and 19 in opposition to the flux B produced by energization of coil 22. This serves to reduce the operating sensitivity of the switch inasmuch as a greater amount of the flux B is required to deflect the reed 17 to the contact part 15 of electrode 11 than would be required if the flux Y were absent. The magnitude of flux Y also can be varied by changing the air gap between the curved or stepped portions of the contact parts 15 and 16.

The magnet 20 also develops a magnetic flux designated by the dash lines Z shown in FIG. 2 and this flux traverses a path which may be traced from the north pole N of the magnet 20 through the air space between the left hand end of magnet 20 and the terminal part 13 of electrode 11, a portion of the electrode 11, and back to the south pole S of the magnet 20 through the air space between the electrode 11 and the contact part 16. The flux Z tends to reduce the operating sensitivity of the switch inasmuch as it traverses a portion of the electrode 11 in the same direction as the flux B produced by energization of the coil 22 thereby increasing the flux density in such portion of electrode 11. This increases the effective reluctance of the electrode 11 for the magnetic flux B and thereby requires a greater amount of the flux B to operate the switch than would be required if the flux Z were absent. It is noted that the flux Z traverses the space between the magnet 20 and the electrode 11 twice, and therefore the flux Z may be minimized by making such space as great as possible within the limitation of the overall dimensions of the switch.

Inasmuch as the fluxes X and Y traverse the contact parts 15 and 19 in opposing directions, the resultant of the fluxes X and Y which traverses the contact parts 15 and 19 may be reduced to essentially zero by equalizing the fluxes X and Y. In accord with the present invention the design of the switch is such that the fluxes X and Y are substantially equalized so that zero resultant flux from the magnet traverses contact parts 15 and 19 whereby the adverse effects resulting from the fluxes are substantially eliminated. By proper selection of the spacing between the contact parts 15 and 16 the magnitudes of the fluxes X and Y may be substantially equalized.

A very important feature of the switch is the variation in switch operating characteristics which may be obtained by changing the induction in the magnet 20 after the switch has been assembled. Such induction change is

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accomplished by first magnetizing the magnet 20 to saturation and then demagnetizing the magnet to the desired stable residual induction level. With the induction in the magnet 20 set at a level so that the reed 17 is normally deflected into engagement with the contact part 16, the reed 17 will be moved away from contact part 16 when the magnetic attraction between the contact parts 16 and 19 is reduced by action of the flux C resulting from energization of coil 22 in the direction shown to a point just slightly less than the spring force developed by the reed 17 when in its deflected position shown in FIG. 1.

With the induction in the magnet 20 set at a comparatively low level just sufficient to attract the reed 17 to the contact part 16, a gradual increase in the magnetic field generated by energization of coil 22 in the direction shown causes the reed 17 to eventually spring away from contact part 16 to an intermediate position between the contact parts 15 and 16. The reed 17 will not be moved to the contact part 15 because the low external field required to overcome the low attractive force of the magnet is insufficient to attract the reed to the contact part 15. The reed 17 will therefore remain in the intermediate position until the magnetic field from coil 22 is increased until the flux B is sufficient to attract the reed from its intermediate position to the contact part 15. The reed 17 will similarly assume an intermediate "off" position during its travel from the contact part 15 to the contact part 16 in response to a gradual decrease in the magnitude of the magnetic field produced by coil 22.

Increasing the residual induction in the magnet 20 operates to increase the attraction of the reed 17 to the contact part 16 which results in a higher contact pressure requiring a greater magnitude of flux from coil 22 to release the reed from the contact part 16. With the induction in the magnet 20 set at still higher levels, the strength of the external field from coil 22 required to release the reed from the contact part 16 is also sufficient to attract the reed to the contact part 15 in one continuous snap motion even though the external field is increased slowly. Similarly, the reed 17 will snap from the contact part 15 to the contact part 16 when the external field is gradually reduced. The snap action of the reed just described resulting from the high induction settings of the magnet 20 provides an improved contact action which prevents reclosing of the opened contacts and which provides a fast switching action. Also, the described snap action is obtainable throughout a wide range of settings of the magnet induction and changes in the induction within this range vary the contact pressure forces and the switch operating sensitivity.

A magnetic latching operation may also be obtained by setting the induction in the magnet 20 at a low level such that the attraction produced by the flux from the magnet is insufficient to deflect the reed 17 to the contact part 16 but is sufficient to hold the reed in engagement with the contact part 16 after it has been deflected thereto by energization of the winding 22. Thus, by energizing the winding 22 in the direction opposite to the direction of energization illustrated in FIG. 1, magnetic flux is produced thereby which flows in a direction to assist the flux A of magnet 20 and this resultant flux causes deflection of the reed into engagement with the contact part 16 where it is held by the flux A of the permanent magnet subsequent to deenergization of the winding 22. Thereafter, energization of coil 22 in the direction shown in FIG. 1 produces magnetic flux which opposes the flux A of magnet 20 to thereby release the reed 17 from the contact part 16. Increasing the strength of the external field in this same direction operates to deflect the reed to the contact part 15, but when this field is removed the reed 17 returns to its intermediate neutral position between the contact parts 15 and 16.

Polarized operation is also a feature of the switch inasmuch as when the reed 17 normally engages contact part 16, the reed 17 can be moved to the contact part 15 only by energization of coil 22 in a predetermined di-

rection which is the direction shown in FIG. 1. It is apparent that energization of coil 22 in the direction opposite to that shown in FIG. 1 produces a flux which aids the flux A of the magnet 20 and serves only to increase the attraction of the reed 17 to the contact part 16.

In FIG. 4 there is illustrated a switch having a different construction than the switch described in connection with FIGS. 1-3. The switch of FIG. 4 includes components which are identical in structure and configuration to components of the switch of FIGS. 1-3 and these similar components are designated by the same reference numerals. The switch of FIG. 4 includes the glass tube 10 containing an electrode 25 having a cylindrical terminal part 26 and a flattened contact part 27 spaced from the contact part 28 of two-part electrode 29 which also includes a cylindrical terminal part 30. A reed 17 extends from the opposite end of the tube between and in overlapping relation with the contact parts 27 and 28. The terminal part 30 of electrode 29 includes a flattened end portion 32 within the tube which is bent upwardly and outwardly and is secured to the upper surface of the magnet 20 as viewed in FIG. 4 to support the magnet. The contact part 28 is attached to the magnet at the upper surface thereof. To increase the spacing between the electrode 25 and the magnet 20 a portion 33 of the contact end of the electrode 25 is flattened over a distance which extends the full length of the magnet 20 and the flattened portion 33 is displaced upwardly from the lower surface of the terminal part 26 to be remote from the magnet 20.

A further modification is shown in FIG. 5 which is similar to the embodiment of FIGS. 1-3 with the exception that an electrode 35 is provided corresponding to the electrode 12 of FIGS. 1-3 and having a contact part 36 which is reversed from the position of the corresponding contact part 16 shown in FIGS. 1-3 to be secured to the magnet 20 at the lower surface thereof as viewed in FIG. 5. Parts of the device of FIG. 5 which are similar to parts of the device of FIGS. 1-3 are designated by the same reference numerals assigned to the parts of FIGS. 1-3.

FIG. 6 illustrates a still further modification of the invention. In FIG. 6 the electrode 25 has the same configuration as the electrode 25 of FIG. 4. An electrode 40 is provided and includes a terminal part 41 having the same configuration as the terminal part 30 of the electrode 29 of FIG. 4. However, in FIG. 6 the electrode 40 includes a contact part 42 which is connected to the lower surface of the magnet 20 as viewed in FIG. 6, and which includes a flat central section 43 which extends parallel to and in engagement with the end surface of the magnet.

In FIG. 7 a reed switch is illustrated which differs from the switches previously described and which includes a permanent magnet 20 located outside a cylindrical glass tube 50 which is of considerably smaller size than the corresponding tubes 10 of the switches of the previous embodiments. The switch of FIG. 7 includes a first fixed electrode 51 of electrically and magnetically conductive material supported by the tube 50 at the left hand end thereof as viewed in FIG. 7. The electrode 51 is of one piece construction including a terminal part 52 outside the tube 50 and a contact part 53 within the tube at the upper part thereof. A second fixed electrode 54 is provided at the left hand end of the tube 50 which is formed of electrically and magnetically conductive material and which is of two-part construction. The electrode 54 includes a terminal part 55 outside the tube 50 which is welded or otherwise fixed to the upper surface of the left hand part of the magnet 20 as viewed in FIG. 7, and includes also a contact part 56 having a portion 57 outside the tube which is secured to the upper surface of the right hand part of the magnet to support the magnet.

The contact parts 53 and 56 of the electrodes 51 and

54 are spaced transversely of the tube to cooperate with a deflectable reed 57 supported by the tube 50 at the right hand end thereof and having a contact part 58 extending between and overlapping the contact parts of the electrodes 51 and 54. The reed 58, when unstressed, assumes a neutral position midway between the contact parts 53 and 56. In the embodiment of FIG. 7 the induction of the magnet 20 is set relatively high so that the reed 58 is normally in engagement with contact part 56 of electrode 54. An external winding (not shown in FIG. 7) is provided to produce when energized magnetic flux to deflect the reed in the manner of the winding 22 of FIG. 1.

One advantage of locating the magnet 20 outside the tube 50 is that the diameter and length of the tube 50 can be materially reduced as compared to such dimensions of the tube 10 in the embodiments of FIGS. 1 and 4-6. Another advantage is that the magnet 20 can be secured in position after the tube 50 has been sealed thereby eliminating any possibility of damage to the magnet which might occur as a result of the high sealing temperature involved. It is observed that the overall lengths of the electrodes 51 and 54 are less than the lengths of the corresponding electrodes of the previous embodiments, and that the magnet 20 is positioned further from the contact part 53 of electrode 51 than in the previous embodiments. This arrangement is very desirable in that it minimizes the magnetic coupling between the magnet 20 and the contact part 53 to thereby minimize the magnitudes of the undesirable fluxes emanating from magnet 20 and corresponding to the fluxes X, Y and Z described in connection with FIGS. 2 and 3.

The operation of the switch of FIG. 7 and the paths for magnetic fluxes associated with such switch are essentially the same as for the switches of FIGS. 1 and 4-6, and need not be described. Suffice it to say that the magnet 20 and the reed 58 are in series in a first magnetic circuit which carries flux from the magnet which flows in the same direction through the reed and the magnet. Also, the reed 58 and the electrode 51 are in series in a second magnetic circuit and flux produced by the external winding (not shown) flows through both of these magnetic circuits to deflect the reed. The parts are arranged so that substantially zero resultant flux from the magnet passes between the reed 58 and the contact part 53 of electrode 51.

In assembling the various switches shown and described the permanent magnet 20 is in a demagnetized condition and after the switch is assembled, the magnet 20 is magnetized to a saturated condition and then is demagnetized to the desired stable residual induction level. The present invention provides a very desirable double throw sealed magnetic reed switch possessing a number of advantageous features. With the described arrangement, the contact separating force is provided in part by a spring force developed by the reed when it is deflected from its neutral unstressed intermediate position to a position wherein it engages one of the fixed contacts. Also, the parts are arranged so that magnetic fluxes produced by the permanent magnet and which adversely affect the operation of the switch are minimized and neutralized. This results in a reed switch having a very excellent operating sensitivity requiring a very small external magnetic field to operate the switch. Further, by varying the induction of the permanent magnet, a number of different modes of operation of the switch may be obtained as previously explained. It can be appreciated that the magnet 20 can be magnetized such that the polarity thereof is reversed from that shown so that the north pole N is at the right and the south pole S is at the left as viewed in the figures. When this is done, the direction of energization of the winding 22 must also be reversed to obtain the switching actions described.

Switches having the configuration of the switch of

FIG. 1 have been successfully constructed with the following approximate dimensions:

Length of tube 10.....inches	2.125
Outer diameter of tube 10.....do	.315
Length of magnet 20.....do	.375
Space between stepped portions of contact parts 15 and 16.....inch	.022
Spaces between reed 17 and contact parts 15 and 16 with reed in neutral position.....inch	.005

In typical applications of the switch of FIG. 1 the parts of the electrodes 11 and 12 outside the tube 10 have lengths of the order of .5 inch, and the length of the part of the reed 17 outside the tube is approximately .625 inch. However, these dimensions may be shortened to reduce considerably the overall length of the switch without adversely affecting the desirable operating characteristics of the switch.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A switch comprising a sealed tube, a pair of electrically and magnetically conductive electrodes mounted by said tube having terminal parts outside the tube and having contact parts within the tube in spaced relation, an electrically and magnetically conductive deflectable reed mounted in said tube and having a terminal part outside the tube, said reed extending longitudinally of the tube between and in overlapping relation with the contact parts of said electrodes for deflection into and out of engagement with the contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from said fixed contact parts, and a permanent magnet on a single one of said electrodes between the ends of said one electrode and spaced longitudinally from said reed and spaced from the other of said electrodes for attracting said reed toward the contact part of said one electrode, said magnet being positioned with its poles spaced longitudinally of said tube, said magnet, said reed and the contact part of said one electrode being in series in a magnetic circuit for magnetic flux from the magnet which flux traverses the magnet and the reed in the same direction substantially longitudinally of said tube, said reed when attracted to and engaging either of said contact parts developing a spring force which urges the reed away from the engaged contact part toward the other contact part.

2. A switch as defined in claim 1 wherein the magnet is in said tube.

3. A switch as defined in claim 1 wherein the magnet is outside said tube.

4. A switch as defined in claim 1 wherein said magnet has induction sufficient such that the reed is normally deflected out of said neutral position into engagement with the contact part of said one electrode to establish a spring bias on the reed acting to urge the reed toward the contact part of said other electrode.

5. A switch comprising a sealed tube, a first electrically and magnetically conductive electrode of integral construction mounted by said tube and having a terminal part outside said tube and a contact part within the tube, a second electrically and magnetically conductive electrode of two-part construction including a first terminal part having portions both inside and outside of said tube and including a second contact part within said tube spaced from said first part, a permanent magnet mounted on the portion of the first terminal part of said second electrode which is inside said tube and connected to and mounting the second contact part of said second elec-

trode, an electrically and magnetically conductive deflectable reed mounted by said tube and having a terminal part outside said tube, said reed extending longitudinally of said tube between and in overlapping relation with the contact parts of said electrodes for deflection into and out of engagement with said contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from said contact parts, said magnet being between the ends of said second electrode spaced longitudinally from said reed and being spaced from said first electrode with the poles of the magnet spaced longitudinally of said tube for attracting said reed toward the contact part of said second electrode, said reed when attracted to and engaging either of said contact parts developing a spring force which urges the reed away from the engaged contact part toward the other contact part, said magnet, said reed and the contact part of said second electrode being in series in a magnetic circuit for magnetic flux from the magnet which flux traverses the magnet and the reed in the same direction substantially longitudinally of said tube.

6. A switch as defined in claim 5 wherein the parts of said second electrode which are connected to said magnet are positioned on opposite sides of the magnet and are spaced transversely of said tube.

7. A switch as defined in claim 5 wherein the parts of said second electrode which are connected to said magnet are positioned on a common side of the magnet which is adjacent said first electrode.

8. A switch as defined in claim 5 wherein the parts of said second electrode which are connected to said magnet are positioned on a common side of the magnet which is remote from said first electrode.

9. A switch comprising an elongated sealed tube, a pair of electrically and magnetically conductive electrodes mounted by said tube in spaced relation at one end thereof, said electrodes having terminal parts outside the tube and having spaced contact parts within the tube, an electrically and magnetically conductive deflectable reed mounted by the tube at the other end thereof having a terminal part outside the tube, said reed extending longitudinally of the tube between and in overlapping relation with the contact parts of said electrodes for deflection into and out of engagement with said contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from said contact parts, said reed when deflected out of said neutral position to engage one of said contact parts developing a spring force which urges the reed away from the engaged contact part toward the other of said contact parts, a permanent magnet on a single one of said electrodes between the ends of said one electrode spaced longitudinally from said reed and spaced from the other of said electrodes for attracting said reed toward the contact part of said one electrode, said magnet being positioned with its poles spaced longitudinally of said tube, said magnet, the contact part of said one electrode and said reed being in series in a magnetic circuit for magnetic flux from the magnet which flux traverses the magnet and the reed in the same direction substantially longitudinally of said tube, the terminal parts of said electrodes being spaced transversely of the tube adjacent said one end of the tube by a distance which is at least twice the distance by which the contact parts of the electrodes are spaced.

10. A switch comprising an elongated sealed tube, a pair of electrically and magnetically conductive electrodes mounted by said tube in spaced relation at one end thereof, said electrodes having terminal parts outside the tube and having spaced contact parts within the tube, an electrically and magnetically conductive deflectable reed mounted by the tube at the other end thereof having a terminal part outside the tube, said reed extending longitudinally of the tube between and in overlapping relation with the contact parts of said electrodes for

deflection into and out of engagement with said contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from contact parts, said reed when deflected out of said neutral position to engage one of said contact parts developing a spring force which urges the reed away from the engaged contact part toward the other of said contact parts, a permanent magnet inside said tube on a single one of said electrodes between the ends of said one electrode and spaced longitudinally from said reed and spaced from the other of said electrodes for attracting said reed toward the contact part of said one electrode, said magnet being positioned with its poles spaced longitudinally of said tube, said magnet, the contact part of said one electrode and said reed being in series in a magnetic circuit for magnetic flux from the magnet, which flux traverses the magnet and the reed in the same direction substantially longitudinally of said tube.

11. A switch comprising a sealed tube, a first electrically and magnetically conductive electrode of integral construction mounted by said tube at one end of the tube and having a terminal part outside said tube and a contact part within the tube, a second electrically and magnetically conductive electrode of two-part construction including a first terminal part mounted by said tube at said one end of the tube and having portions both inside and outside of said tube and including a second contact part within said tube spaced from said first part, a permanent magnet mounted on the portion of the first terminal part of said second electrode which is inside said tube and connected to and mounting the second contact part of said second electrode, the terminal parts of said electrodes being spaced transversely of the tube adjacent said one end of the tube by a distance which is at least twice the distance by which the contact parts of the electrodes are spaced, an electrically and magnetically conductive deflectable reed mounted by said tube at the other end of the tube and having a terminal part outside said tube, said reed extending longitudinally of said tube between and in overlapping relation with the contact parts of said electrodes for reflection into and out of engagement with said contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from said contact parts, said magnet being between the ends of said second electrode spaced longitudinally from said reed and being spaced from said first electrode with the poles of the magnet spaced longitudinally of said tube for attracting said reed toward the contact part of said second electrode, said reed when attracted to and engaging either of the contact parts developing a spring force which urges the reed away from the engaged contact part toward the other contact part, said magnet, said reed and the contact part of said second electrode being in series in a magnetic circuit for flux from said magnet which flux traverses the magnet and the reed in the same direction substantially longitudinally of the tube.

12. A switch comprising a sealed tube, a first electrically and magnetically conductive electrode of integral construction mounted by said tube at one end thereof and having a terminal part outside said tube and a contact part within the tube, a second electrically and magnetically conductive electrode of two-part construction including a first terminal part mounted by said tube at said one end thereof and having portions both inside and outside of said tube and including a second contact part within said tube spaced from said first part, a permanent magnet mounted on the portion of the first terminal part of said second electrode which is inside said tube and connected to and mounting the second contact part of said second electrode, the portion of the first terminal part of said second electrode which mounts said magnet and the second contact part of said second electrode being positioned on opposite sides of said mag-

net, the portion of the first terminal part of said second electrode which mounts said magnet being positioned closer to the wall of said tube than the second contact part of said second electrode, the terminal parts of said electrodes being spaced transversely of the tube adjacent said one end of the tube by a distance which is at least twice the distance by which the contact parts of the electrodes are spaced, an electrically and magnetically conductive deflectable reed mounted by said tube at the other end thereof and having a terminal part outside said tube, said reed extending longitudinally of the tube between and in overlapping relation with the contact parts of said electrodes for deflection into and out of engagement with said contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from said contact parts, said magnet being between the ends of said second electrode spaced longitudinally from said reed and being spaced from said first electrode with the poles of the magnet being spaced longitudinally of said tube for attracting said reed toward the contact part of said second electrode, said reed when attracted to and engaging either of said contact parts developing a spring force which urges the reed away from the engaged contact part toward the other contact part, said magnet, said reed and the contact part of said second electrode being in series in a magnetic circuit for flux from said magnet which flux traverses the contact part of said second electrode and said reed in the same direction substantially longitudinally of the tube.

13. A switch comprising a sealed tube, a first electrically and magnetically conductive electrode of integral construction mounted by said tube at one end thereof and having a terminal part outside said tube and a contact part within said tube, a second electrically and magnetically conductive electrode of two-part construction including a first contact part mounted by said tube at said one end thereof and having portions both inside and outside of said tube and including a second terminal part outside said tube spaced from said first contact part, a permanent magnet mounted by the portion of the first contact part of the second electrode which is outside said tube and connected to and mounting the terminal part of said second electrode, and an electrically and magnetically conductive deflectable reed mounted by said tube at the other end thereof and having a terminal part outside said tube, said reed extending longitudinally of said tube between and in overlapping relation with the contact parts of said electrodes for deflection into and out of engagement with said contact parts, said reed when unstressed assuming a neutral position wherein it is midway between and spaced from said contact parts, said magnet being spaced longitudinally from said reed and being spaced from said first electrode with the poles of the magnet being spaced longitudinally of said tube for attracting said reed toward the contact part of said second electrode, said reed when attracted to and engaging either of the contact parts developing a spring force which urges the reed away from the engaged contact part toward the other contact part, said magnet, said reed and the contact part of said second electrode being in series in a magnetic circuit for flux from said magnet which flux traverses the magnet and reed in the same direction substantially longitudinally of the tube.

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