June 12, 1928.

1,673,681

A. W. HULL ET AL

TELEMETRIC SYSTEM

Filed Sept. 24, 1924

2 Sheets-Sheet 1

Fig. 1.

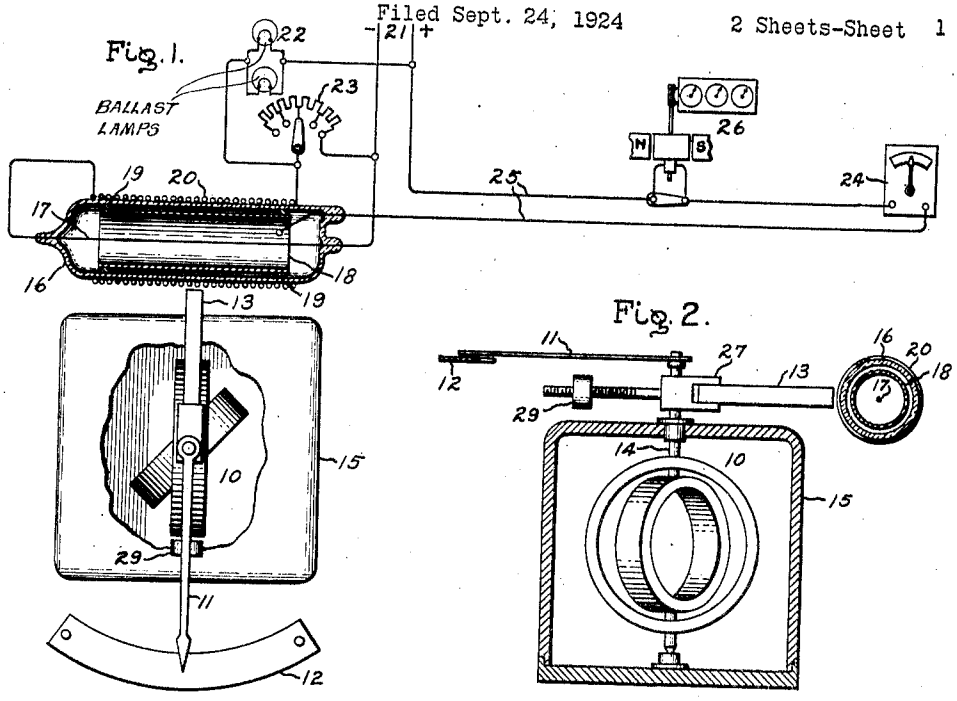


Fig. 2.

Fig. 3.

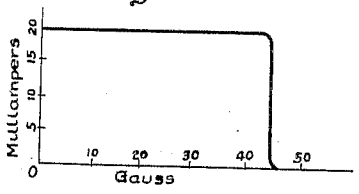


Fig. 4.

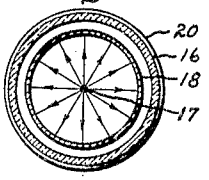
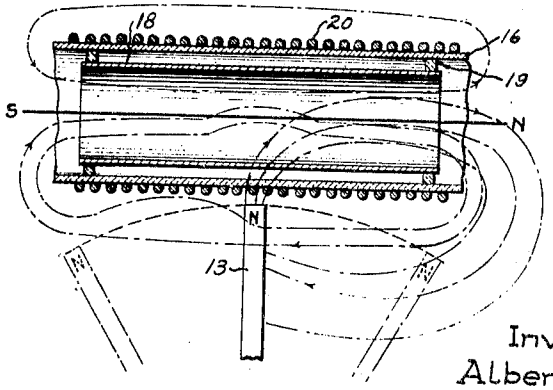


Fig. 5.



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Fig. 6.

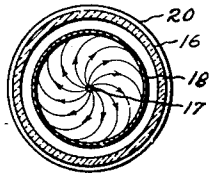


Fig. 7.

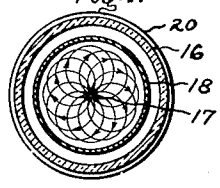


Fig. 8.

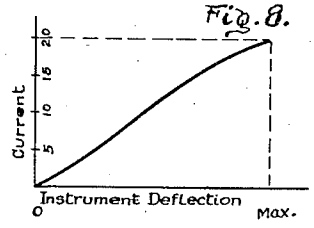


Fig. 9.

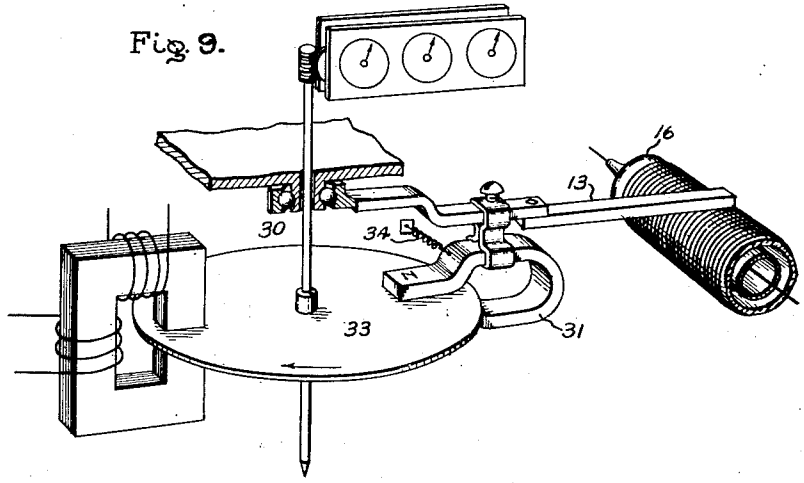
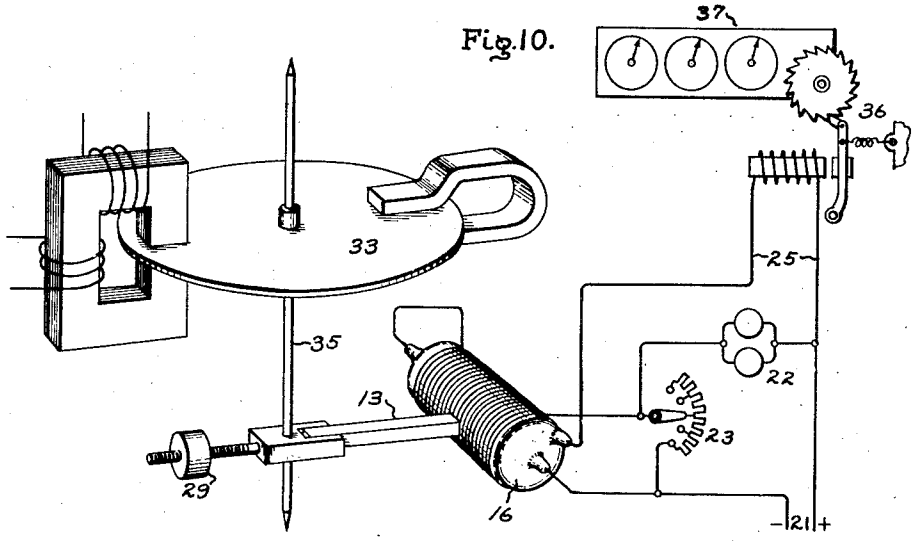


Fig. 10.



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1,673,681

UNITED STATES PATENT OFFICE.

ALBERT W. HULL, OF SCHENECTADY, NEW YORK, AND BYRON W. ST. CLAIR, OF LYNN, MASSACHUSETTS, ASSIGNORS TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

TELEMETRIC SYSTEM.

Application filed September 24, 1924. Serial No. 739,746.

Our invention relates to a telemetric system such as those used for transmitting the indications of an instrument or meter to a distant point over an electric circuit.

Our invention has for its object such a system capable of operating over very long lines of high resistance and, if necessary, high reactance, without impairment of accuracy. A further object of our invention is to provide in such a system a highly sensitive transmitter which may be operated directly by a delicate measuring instrument without affecting the accuracy thereof. Other advantages of our improved telemetric system will be pointed out hereinafter.

In carrying our invention into effect, we prefer to use as a part of the transmitter, an electron discharge device. One electron discharge device suitable for this purpose is known as the magnetron. The magnetron is a special type of kenotron generally made with a straight axial filament and a cylindrical anode symmetrically arranged with respect to the filament and enclosed in an evacuated chamber. If the filament or cathode of the magnetron is heated, an electron discharge will be given off therefrom and if an external circuit be established between the cathode and anode, including a source of electromotive force, the electrons will flow from the cathode to the anode and permit a current to flow in the external circuit which is proportional to the number of electrons which reach the anode. The natural flow of electrons in the magnetron is radially from the cathode to the anode, but it is known that if the tube be placed in a magnetic field which is parallel to the axis of the tube, the electrons are caused to take spiral paths in passing from the cathode to the anode and that if this field be made sufficiently strong, the electrons will be turned back before reaching the cylindrical anode and under these conditions, the external current will cease to flow. For convenience, that strength of the magnetic field which is just sufficient to turn back the electrons under a given set of conditions, will be hereinafter referred to as the cut-off point. This behavior of the magnetron has heretofore been utilized to measure the strength of a magnetic field. See pages 279 to 292 of the Physical Review No. 3, September, 1923, for a description of such utilization, by Albert W. Hull, one of the present applicants.

In the present application, we prefer to use a magnetron provided with a magnetic field and adjust the conditions so that the magnetron is normally near its cut-off point and then we provide means operated by the meter or instrument, the indications of which are to be transmitted, to upset this adjustment in such a way that the resultant current or current impulses in the external circuit is proportional to the meter indications. At one or more distant points in the external circuit, we provide a relay, an electrical measuring instrument or meter or both such devices by means of which the transmitted indications are reproduced in a well known manner.

The features of our invention which we believe to be novel and patentable will be pointed out in the claims appended hereto. For a better understanding of our invention, reference is made in the following description to the accompanying drawings, Fig. 1 of which shows a preferred arrangement of the apparatus and the circuit connections therefor; Fig. 2 shows a view of the transmitter taken at right angles to Fig. 1; Fig. 3 is a curve indicating the manner in which the discharge current varies with changes in the magnetic field through the magnetron; Fig. 4 represents a cross section of the tube indicative of a normal electron discharge; Fig. 5 is a schematic illustration of the flux modifications in different portions of the magnetron as influenced by the transmitting instrument; Figs. 6 and 7 represent cross sections taken at different portions of the magnetron of Fig. 5 indicative of the resulting electron discharge; Fig. 8 is a curve showing how the anode current varies with the instrument deflection; Fig. 9 shows an application of our invention for transmitting a current which is proportional to the speed of an integrating type meter; and Fig. 10 represents the application of our invention for sending current impulses to a distant point.

Referring now to the drawings, we have shown in Figs. 1 and 2 a measuring instrument 10, represented as of an electrical type, although it might be of any other type. The moving part of the instrument is pro-

vided with a needle 11 which cooperates with the stationary scale 12, and a small permanent magnet 13 secured to the shaft 14 and extending in a radial direction therefrom. When the instrument is of the electrical type, the permanent magnet 13 should be placed some distance away from the instrument coils or the latter should be shielded from the permanent magnet as by a magnetic shield 15.

The magnetron tube consists of a sealed glass container 16 which is highly evacuated and contains an axial filament 17 and a cylindrical anode 18 concentrically arranged with respect to the filament 17 and the walls of the tube. The anode is held in position by suitable supports 19. Wound about the tube is a magnetizing solenoid 20 which is utilized to produce a magnetic field in the tube parallel to its axis.

Any wiring arrangement may be used which provides for the proper heating of the filament 17, the proper magnetization of the solenoid 20 and an external circuit connected between the filament 17 and the anode 18 which contains a source of potential and the receiving device or devices. One such arrangement is shown in Fig. 1 where the filament 17 and the solenoid coil 20 are connected in series across a direct current source 21 through a bank of lamps 22. An adjustable resistance 23 is shunted across the filament and solenoid circuit. The purpose of the lamps is to make the system more nearly independent of voltage fluctuations such as might be present where the source 21 is an ordinary lighting or exciter circuit. This feature will be more fully explained hereinafter. The source 21, the transmission lines 25, and the distant receiving instrument represented at 24 are contained in the external circuit between the filament cathode 17 and the anode 18, as illustrated.

In Fig. 3 we have represented a curve showing how the effective electron discharge, which corresponds to the current in the external circuit for a given anode diameter and voltage, varies with changes in the magnetic field through the tube parallel to its axis. Up to a field strength of about 41 gauss, no change occurs in the number of electrons discharged from the filament which reach the anode. The manner in which the electrons flow from cathode to anode when there is no magnetic field in the tube is represented in Fig. 4. As the magnetic field increases in strength, the path of the electrons becomes more and more spiral. At a field strength of about 40 gauss, the path is as represented in Fig. 6 where the electrons strike the anode at a very small angle to the surface of the anode. When the field is increased to about 44 gauss, the electrons are completely turned back before reaching the anode and as a consequence, the current in the external circuit falls very abruptly to zero with a slight change in the magnetic field.

It will now be evident that by a very slight change in the magnetization of the tube, it may be changed from the condition represented in Fig. 6 to that represented in Fig. 7 and that one part of the tube can very readily be made to have the condition represented in Fig. 6, while another part has the condition represented in Fig. 7. We utilize this behavior of the tube when subjected to a magnetic field to provide a very sensitive telemetric transmitter by causing the instrument 10, in deflecting, to vary the magnetic field in the tube over the small range necessary to vary the current in the external circuit from a maximum to a minimum under the conditions specified. One way in which this may be accomplished is by providing the instrument shaft 14 with a small permanent magnet arranged adjacent the tube so that the shaft, in turning, will move one end of the magnet along the tube from one end to the other as represented in Figs. 1 and 5.

Thus, in Fig. 5 let us assume that the normal strength of the magnetic field through the tube is adjusted to about the cut-off point. Then, when the north end of the permanent magnet is brought opposite the south end of the solenoid of the tube, the permanent magnet will assist the solenoid in producing magnetic flux through the tube and the whole tube will be in the condition represented in Fig. 7. This corresponds to zero instrument deflection and zero current in the external circuit. Now if the magnet be swung to the central position represented in full lines, it will assist the right half of the solenoid in producing flux through the tube but will repel the flux in the other half of the tube in general as represented by the flux lines. Consequently, the right half of the tube will be in the cut-off condition represented in Fig. 7 and the left half of the tube will be in the condition represented in Fig. 6 and will allow current to flow in the external circuit. But since only one half of the tube is effective, only one half the current corresponding to the full capacity of the tube will be allowed to flow. This corresponds to one half full scale deflection of the instrument. As the magnet 13 swings toward the right or north pole end of the tube, more and more of the tube will become effective to pass current and the current in the external circuit will increase to a maximum when the north end of the magnet stands adjacent the north end of the solenoid. Then, the permanent magnet will oppose the flux of the solenoid and decrease the flux in the tube throughout the total length thereof to below the cut-off point, as represented by the condition shown in Fig.

6. This corresponds to full scale deflection of the instrument 10 and the maximum current in the external circuit, or 20 milliamperes in the case represented in Fig. 3. We may plot the current flowing in the external circuit against instrument deflection, as shown in Fig. 8, and we may measure this current flowing in the external circuit by an ordinary milliammeter constituting the receiving instrument, which will have a scale calibrated in the units of the transmitting instrument scale 12. The curve represented in Fig. 8 may not be exactly a straight line, but this is immaterial since it will always be the same and can be taken into consideration in calibrating the instrument 24.

Since the anode current is small and is only slightly affected by moderate resistance in the external circuit, it follows that we may use long high resistance circuits such as telephone lines for the transmission lines 25 and if desired, we may connect more than one receiving device in series in this circuit, as indicated at 26 where an integrating type meter is represented.

The weight of the magnet 13 of the transmitting instrument is preferably balanced against the weight of the pointer 11 and an adjustable counterweight 29, if that is necessary, and the length of the arc through which the magnet swings may be adjusted by moving the magnet in its holder 27 toward or away from the shaft 14. The relative effect of the permanent magnet 13 upon the field of the tube 16 may be adjusted by moving the tube toward or away from the shaft 14. Due to the fact that only a very slight change in the magnetization of the tube is required by this device, the permanent magnet may be made very small and its pull on the field of the solenoid made insignificant with respect to the torque of the instrument 10. An electron tube of this character can be made so sensitive to changes in magnetic field that it will respond to changes in field produced by the earth's magnetic field when the tube is rotated with respect thereto.

When the filament 17 is connected in series with the magnitizing solenoid 20, as represented in Fig. 1, the current in this circuit is fixed once for all to give the correct filament temperature by the use of one or more standard 110 volt lamps 22 connected in multiple in the circuit. The number of turns of the solenoid is then adjusted so that this current produces approximately the correct magnetic field corresponding to the condition represented in Fig. 6. A final adjustment of the field strength may be had by means of high resistance 23. The resistance of the field coil and filament is made comparatively small as compared to that of the lamps in order to obtain the beneficial effect of the lamps in maintaining a substantially constant current in this circuit, irrespective of ordinary voltage fluctuations of the source 21. It is known that in the standard gas-filled tungsten lamp the variation of resistance with temperature and the cooling effect of the gas cooperate in such a way that the current through the lamp is accurately proportional to the square root of the voltage at its terminals over a wide range of voltage. By connecting such lamps in this circuit as described, the current therein is maintained sufficiently constant for the purpose at hand when an ordinary 220 volt, direct current exciter bus is utilized as the source 21. If a very constant source of potential is available, the lamps will not be necessary.

Fig. 9 represents the application of our invention for transmitting a current proportional to the speed of an integrating type meter 30. In this case, a permanent damping magnet 31 is pivoted on an axis of the meter and cooperates with the meter disc 33 which is made of conducting material. The pull on the pivoted magnet 31 by reason of the rotating disc 33 is resisted by a spring 34 and the turning of the magnets on its axis away from a zero torque position is therefore proportional to the meter speed. This is utilized to swing the small permanent magnet 13 which is attached to the magnet 31 along the axis of the magnetron tube 16 for controlling the magnetic field of the magnetron in the manner previously described. In this modification, the permanent magnet 13 swings over the top of the tube instead of along its side and has the effect of producing a straighter deflection-current curve than that shown in Fig. 8.

In Fig. 10 we have represented the use of our invention as taking the place of a contact making device for sending current impulses to a distant point. In the ordinary contact making meter, the contacting device produces friction and often times trouble arises due to the fact that the contacts wear out or burn away. These objections are overcome by the use of the present invention as illustrated in Fig. 10. Here the meter shaft 35 is provided with a small permanent magnet 13 which influences the magnetron tube 16 every time the magnet rotates past the tube. The tube is adjusted so that normally no current flows in the external circuit 25, but as the magnet passes the tube, the field of the tube is disturbed in such a manner as to allow a current impulse to flow in the external circuit and which operates the ratchet relay 36, which is arranged to notch up the registering device 37 for each such current impulse. The register 37, which may be located at a distant point, will therefore give the integrations of the meter disc 33, while all contacts are avoided and no appreciable load is added to the meter.

In accordance with the provisions of the patent statutes, we have described the principle of operation of our invention, together with the apparatus which we now consider to represent the best embodiment thereof, but we desire to have it understood that the apparatus shown and described is only illustrative and that the invention may be carried out by other means.

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

1. Apparatus for producing a secondary motion indicative of a primary motion comprising a rotary movable indicating member, a stationary magnetron tube located in close proximity to said indicating member but having no electrical connection therewith, said tube having its magnetic field adjusted to about the cut-off point, means responsive to the movement of said indicating member for altering the field of said tube through the cut-off point, and an external circuit containing a source of supply and an electric measuring device connected in the anode circuit of said tube, said electric measuring device being calibrated to reproduce the indications of said indicating member in response to the anode current of said tube.

2. A telemetric system comprising a movable measuring device, electro-responsive means located at a distant point for reproducing the reading of said device, a stationary magnetron tube located in close proximity to said measuring device, said tube having its magnetic field adjusted to about the cut off point, magnetic means carried by said measuring device for directly altering the field of said tube through the cut off point when said measuring device is moved through its measuring range, and an external circuit including a source of supply and said electro-responsive means connected in the anode circuit of said tube, said system being adjusted so that the current in the external circuit is proportional to the measurement of said device.

3. In a telemetric system, a measuring device, a telemetric transmitter associated with said device comprising a magnetron tube having its magnetic field adjusted to just above the cut off point, a permanent magnet located in close proximity to said tube and arranged to be moved by said measuring device to decrease the magnetic field of said tube to below the cut off point.

4. In a telemetric system, a measuring device, a telemetric transmitter associated with said device comprising a magnetron tube having its magnetic field throughout its effective length adjusted to just about the cut off point, a permanent magnet associated with said tube and arranged to be moved from one end of the tube to the other by said measuring device to progressively alter the magnetic field of said tube through the cut off point.

5. In a telemetric system, a measuring device, a telemetric transmitter therefor comprising a magnetron tube having its field throughout its effective length adjusted to about the cut off point and a permanent magnet connected to the measuring device so as to have one end of the magnet moved from one end of the magnetron tube to the other as the measuring device is operated to progressively alter the field of said tube from above to below the cut off point.

6. A telemetric system comprising a measuring device having a rotatable element, a magnetron tube, a source of supply for heating the filament of said tube and energizing its field, said tube being adjusted to have its effective electron discharge responsive to very slight changes in its magnetic field, a small permanent magnet on the rotatable element of said measuring device arranged to swing adjacent the tube when the shaft is turned and to progressively alter the magnetization through said tube so that the effective electron discharge thereof will be proportional to the position of said shaft, an external circuit including said source of supply connected between the filament and anode of said tube and an electric measuring instrument in said circuit calibrated to indicate the position of said movable element.

In witness whereof, ALBERT W. HULL has hereunto set his hand this 4th day of September, 1924, and BYRON W ST. CLAIR has hereunto set his hand this 15th day of Sept., 1924.

ALBERT W. HULL.
BYRON W. ST. CLAIR.