

Sept. 2, 1941.

T. AAMODT

2,254,589

PULSE DELAY RELAY

Filed Nov. 26, 1940

3 Sheets-Sheet 1

FIG. 1

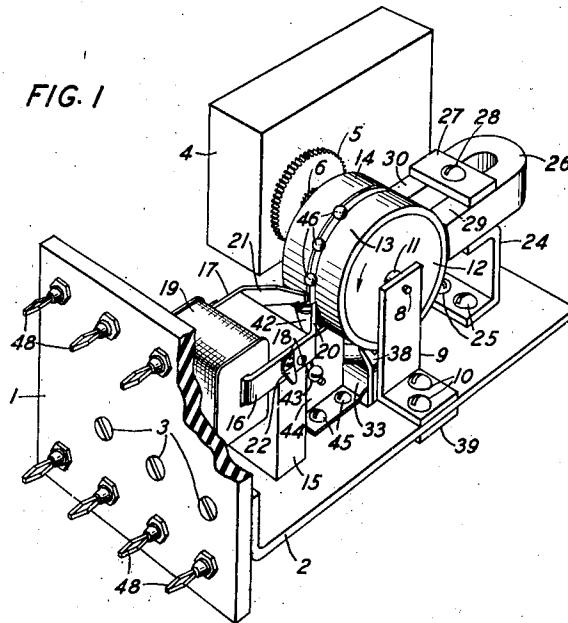


FIG. 2

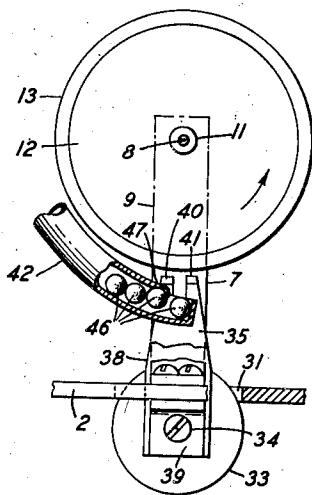
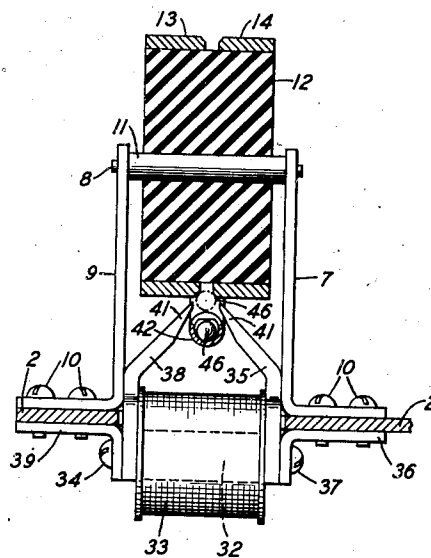


FIG. 3

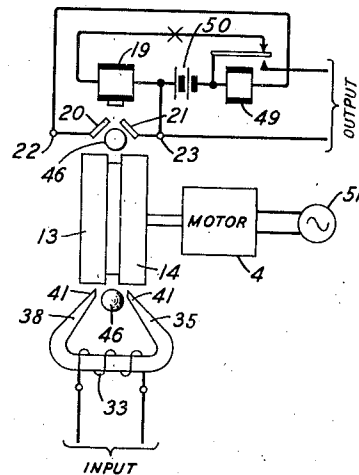
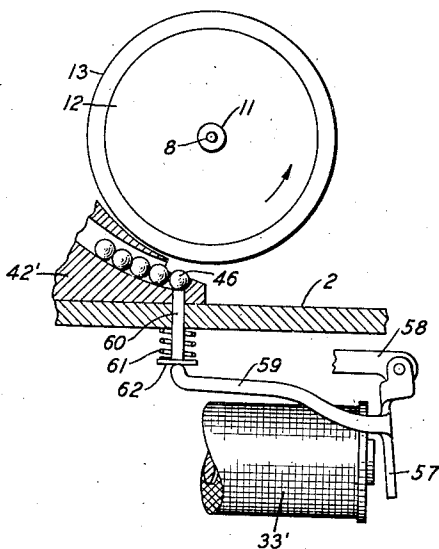
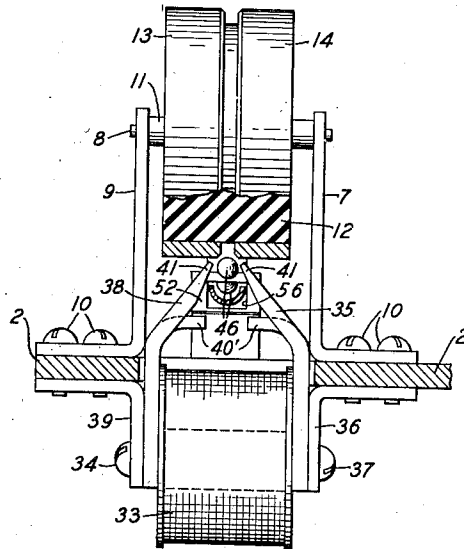
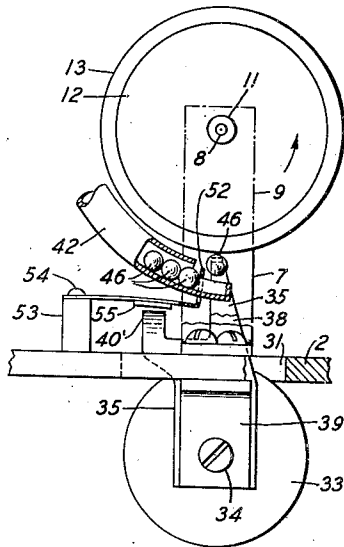


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PULSE DELAY RELAY

3 Sheets-Sheet 2



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3 Sheets-Sheet 3

FIG. 8

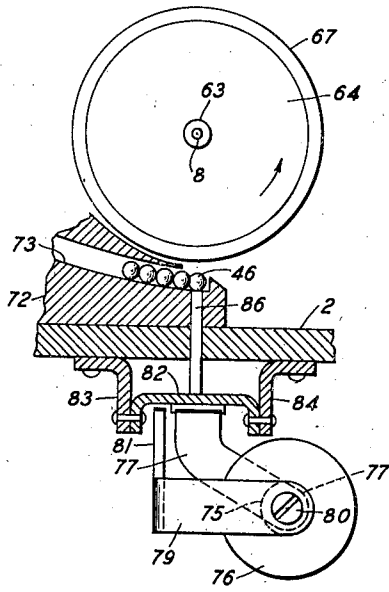
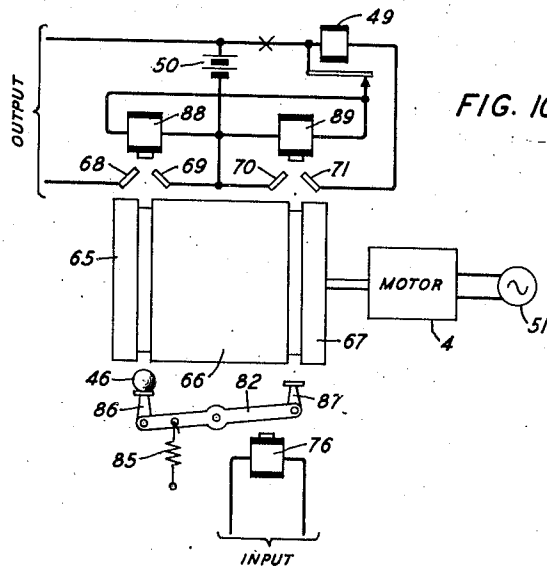
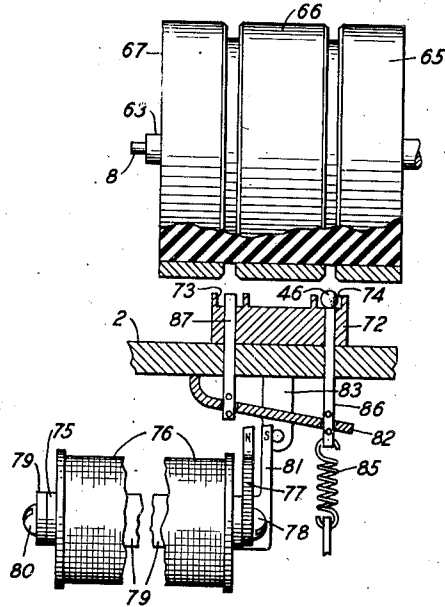


FIG. 9



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UNITED STATES PATENT OFFICE

2,254,589

PULSE DELAY RELAY

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Application November 26, 1940, Serial No. 367,201

10 Claims. (Cl. 200—97)

This invention relates to an electromagnetic device and more particularly to a relay of the type which closes its work circuit a predetermined interval after its energizing circuit is closed.

In my application Serial No. 304,486 filed November 15, 1939, I have disclosed a delay relay structure comprising an operating electromagnet having two fixed pole-pieces electrically insulated from each other and two rotatable annular pole-pieces mounted on a hub of insulating material and thereby electrically insulated from each other and insulated from the fixed pole-pieces by narrow air-gaps. The fixed pole-pieces are surrounded by the relay coil so that when the coil becomes energized the rotatable pole-pieces become oppositely polarized. The relay armature comprises a steel ball which is normally positioned by gravity against a back stop adjustably secured to an arcuate runway positioned beneath and concentric to the rotatable pole-pieces. The rotatable pole-pieces are rotatable at a slow speed by a suitable motor. In its operation when the coil becomes energized to magnetize the rotatable pole-pieces the ball armature is attracted from the runway into a bridging contact of the rotatable pole-pieces thus closing the motor circuit which then advances the rotatable pole-pieces at a slow speed until the ball armature becomes positioned opposite the air-gap between the fixed pole-pieces whereupon it is attracted into bridging contact with such fixed pole-pieces to close the relay work circuit and is attracted out of bridging engagement with the rotatable pole-pieces to open the motor circuit and to thereby arrest the further rotational movement of the rotatable pole-pieces. A time delay is thus measured from the time the coil becomes energized until the work circuit is closed which is dependent upon the original position of the ball armature on the runway and upon the rotational speed of the rotatable pole-pieces and the work circuit is then maintained so long as the coil remains energized.

It is sometimes desirable to receive a series of impulses such as a series of impulses dialed in a dial switching system and to retransmit the impulses after a suitable delay interval. While the relay structure hereinbefore described is capable of receiving successive impulses and retransmitting similarly spaced impulses, the spacing between the received impulses would have to be sufficient to enable the ball armature to return to its normal position upon the termination of

each impulse before it could be reattracted in response to a succeeding impulse.

It is therefore one object of the present invention to provide a relay of this general type which, in a simple and dependable manner, is capable of receiving closely spaced impulses and retransmitting such impulses after a predetermined delay interval.

It is a further object of the invention to provide a relay which is capable of retransmitting impulses after a predetermined relay interval which have the same per cent make and break periods as the received impulses.

In accordance with the present invention the proposed relay structure, in its broadest aspect, comprises two fixed pole-pieces electrically insulated from each other and two annular rotatable pole-pieces mounted on a hub of insulating material and thereby insulated from each other and also insulated from the fixed pole-pieces by narrow air-gaps. The rotatable pole-pieces are oppositely polarized by a fixed permanent magnet, the pole-pieces of which are separated from the rotatable pole-pieces by narrow air-gaps and such rotatable pole-pieces are continuously rotated at a slow speed through reduction gearing by a suitable motor. Located beneath the rotatable pole-pieces is an arcuate armature magazine tube which extends from a point immediately beneath the fixed pole-pieces to a point beneath the bottom of the rotatable pole-pieces which magazine tube is capable of holding a plurality of steel armature balls. An out-pulsing magnet coil normally energized over the back contact of an associated impulse repeating relay surrounds the fixed pole-pieces to oppositely polarize them. A magnet responsive to incoming impulses is positioned adjacent to the lower end of the armature magazine tube and is instrumental in response to each incoming impulse to move an armature ball from the lower end of the magazine tube into a position in which it is attracted into engagement with the rotatable pole-pieces.

As the pole-pieces continue their rotation each armature ball attracted into engagement therewith is carried to a position opposite the air-gap between the fixed pole-pieces in which position the magnetic flux set up by the coil surrounding such fixed pole-pieces overcomes the flux set up through the ball armature and the rotatable pole-pieces by the permanent magnet and the ball is therefore attracted into bridging engagement with the fixed pole-pieces to close the circuit of the associated impulse repeating

relay. This relay thereupon operates to close the out-pulsing circuit and to open the circuit of the magnet coil. The ball attracted to and bridging the fixed pole-pieces is then released into the upper end of the magazine tube. In this manner each incoming impulse moves a ball armature into engagement with the rotatable pole-pieces which, after a delay interval, will cause the retransmission of an impulse.

Having briefly described the invention and the method of its operation reference may now be had for a more complete understanding thereof to the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a relay constructed in accordance with the invention;

Fig. 2 is a side view partly in cross-section of the rotatable pole-pieces, armature magazine tube and impulse receiving magnet of the relay;

Fig. 3 is an end view partly in cross-section of the elements disclosed in Fig. 2;

Fig. 4 is a side view partly in cross-section of a modification of the armature magazine tube and the impulse receiving magnet of the relay;

Fig. 5 is an end view partly in cross-section of the elements disclosed in Fig. 4;

Fig. 6 is a side view partly in cross-section of a further modification of the armature magazine and the impulse receiving magnet of the relay;

Fig. 7 is a diagram illustrative of the application of the relay to an electrical circuit;

Fig. 8 illustrates a side view partly in cross-section of a further modification of the relay to enable a delay interval to be measured from the reception of an incoming impulse and a further delay interval to be measured from the termination of such impulse;

Fig. 9 is an end view partly in cross-section of the modified structure illustrated in Fig. 8; and

Fig. 10 is a diagram illustrative of the application of a relay modified as shown in Figs. 8 and 9 to an electrical circuit.

Referring first to the preferred embodiment of the invention illustrated in Figs. 1 to 3, inclusive, the impulse delay relay is provided with a base member 1 of insulating material having a supporting plate 2 secured thereto by screws 3. Suitably secured to the horizontal arm of the plate 2 is a motor assembly 4 which comprises a synchronous alternating current motor which may, for example, be of the type employed for driving electric clocks and a speed reduction gearing. The motor assembly is further geared through reduction gearing of which only gears 5 and 6 are disclosed to the shaft 8 which is journaled in two supports 7 and 9 secured to the plate 2 by screws 10.

Secured to the shaft 8 and positioned between the bearing supports 7 and 9 is a rotatable pole-piece assembly which comprises a metal hub portion 11, a web portion 12 of insulating material and two annular rings 13 and 14 of magnetic material supported in parallel spaced relationship on the periphery of the web portion 12. The rings 13 and 14 and the hub 11 may, if desired, be assembled in a suitable die and insulating material molded into the die to form the web 12 or the rings, hub and web portion may be separately made, machined and assembled together.

A rectangular block 15 of insulating material, such as hard rubber, is supported on the plate 2 between the base member 1 and the shaft sup-

ports 7 and 9. This block may be secured to the plate 2 by screws (not shown) extending upwardly through holes in the plate 2 into threaded holes in the lower end of the block. To the upper end of this block is secured the out-pulsing magnet assembly comprising two substantially U-shaped fixed pole-pieces 16 and 17 secured by their bases to the outer edges of the block 15 by screws 18 and a magnet coil 19. Two of the arms of the pole-pieces overlap each other, are insulated from each other by an interposed strip of insulating material and are both surrounded by the magnet coil 19. The other arms 20 and 21 extend toward each other with their ends separated by an air-gap. The ends of these pole-pieces are tapered to concentrate the flow of magnetic flux therethrough, also terminate adjacent to the peripheral surfaces of the rotatable pole-pieces 13 and 14, respectively, and are separated therefrom by narrow air-gaps.

Secured beneath the head of one of the screws 18 by which the pole-piece 16 is secured to the block 15 is a terminal lug 22. A similar terminal lug 23 is held under the head of one of the screws which secures the pole-piece 17 to the other end of the block 15. These terminal lugs serve as terminals for controlling the circuit of an associated impulse transmitting relay as will be later described. Since the pole-pieces 16 and 17 are insulated from each other by the block 15 and by the insulating strip separating the arms thereof positioned within the coil 19, there is normally no circuit path between the terminal lugs 22 and 23.

Positioned on the plate 2 on the side of the rotatable pole-pieces opposite to the out-pulsing magnet assembly is a channel-shaped bracket 24 of non-magnetic material. This bracket is secured to the plate 2 by screws 25 which extend through holes in its lower flange into threaded holes in the plate 2 and supports a permanent horseshoe magnet 26 on its upper flange. The magnet 26 is clamped to the upper flange of the bracket 24 by a clamping plate 27 of non-magnetic material and by the clamping screw 28 and is disposed with the ends of its pole-pieces 29 and 30 adjacent to but separated by narrow air-gaps from the rotatable pole-pieces 13 and 14, respectively. To reduce the air-gaps to a minimum and yet permit the pole-pieces 13 and 14 to rotate freely the ends of the pole-pieces of the magnet may be ground to be concentric with the peripheries of the rotatable pole-pieces.

The plate 2 is provided with a rectangular opening 31 therein directly beneath the rotatable pole-pieces 13 and 14 and between the shaft supports 7 and 9, as best disclosed in Fig. 2, through which the impulse receiving magnet assembly extends. This magnet assembly comprises a core 32 surrounded by a magnet coil 33 and having secured to one end thereof by a screw 34 a pole-piece 35 and a mounting bracket 36 and having secured to the other end thereof by a screw 37 a pole-piece 38 and a mounting bracket 39. The brackets 36 and 39 engage against the under face of the plate 2 with the upper portion of the coil 33 and the pole-pieces 35 and 38 extending upwardly through the hole 31 in the plate 2. The brackets 36 and 39 are secured to the plate 2 by the same screws 10 by which the shaft supports 7 and 9 are secured. The upper ends of the pole-pieces 35 and 38 are inclined toward each other and each is bifurcated as disclosed in Fig. 2 to form two tapering pole tips 40 and 41. The pole tips 41 of the two pole-pieces are slightly longer than the

pole tips 40 and extend almost into engagement with the rotatable pole-pieces 13 and 14.

Positioned adjacent to the rotatable pole-pieces 13 and 14 and extending from a point between the tips of the fixed pole-piece arms 20 and 21 to a point beneath the tips of pole-pieces 35 and 38 is a tubular ball armature magazine 42. This magazine is clamped by clamping screw 43 between two parallelly disposed L-shaped clamping plates 44 which are secured by screws 45 to the plate 2. The magazine is of sufficient length to hold a plurality of steel balls 46 which serve as armatures, the inner diameter of the magazine being sufficiently larger than the diameter of each ball so that the balls are able to roll freely therethrough. The lower end of the magazine is closed and the upper wall adjacent to such end closure is cut away to permit balls to be drawn from the magazine towards the pole tips 41 of the pole-pieces 35 and 38. The end of the upper wall adjacent to the opening therein is bent inwardly at 47 to form a barrier for a purpose to be presently described.

The base member 1 is provided with a plurality of plug terminals 48 which are insertable into a jack block (not shown) mounted on a relay rack by means of which the relay is supported on the rack and which afford connection terminals for the relay. One pair of such terminals is connected to terminals of magnet coil 33, another pair is connected to the terminals of motor 4, another pair is connected to the terminals of coil 19, and still another pair is connected to the terminal lugs 22 and 23.

The structure of the relay having been described, the operation thereof will not be discussed. It will be assumed that the relay is connected into a circuit with an impulse repeating relay 49 in the manner disclosed in the circuit diagram of Fig. 7 and that the circuit of out-pulsing magnet coil 19 is established by any appropriate switching means through such coil and over the normal contact of relay 49 in series with the battery 50 whereby the coil is energized to create a difference of magnetic polarity between the tips of the fixed pole-piece arms 20 and 21. It will also be assumed that the circuit of motor 4 is established by suitable switching means to a source of commercial power 51 to cause the rotation of the pole-pieces 13 and 14 at a slow speed.

When thereafter an incoming impulse is received through the winding of magnet coil 33 a flow of magnetic flux is created through the core 32, pole-piece 35, across the air-gaps between the pole tips 41 of the pole-pieces 35 and 38 and the steel armature ball 46 which is at the time resting against the end closure of the magazine 42, and thence to pole-piece 38 whereby the ball is attracted out of the magazine in an attempt to center itself between the pole tips 41. At the same time the flow of flux created between the shorter pole tips 40 of the pole-pieces 35 and 38 draws the next ball upwardly against the upper wall of the magazine where it is restrained by the inwardly bent barrier 47 from rolling down against the end closure of the magazine into the space formerly occupied by the ball which has now been attracted upwardly between the pole tips 41 thereby preventing more than one ball from being attracted upwardly out of the magazine in response to a single incoming impulse.

With the ball positioned between the pole tips 41 the magnetic field created by the permanent magnet 26 extends from the rotating pole-piece

13 across the air-gaps between the pole-pieces 13 and 14 and the ball 46, thence to the pole-piece 14, and thereafter when the magnet coil 33 deenergizes at the end of the impulse and the magnetic field created thereby and holding the ball between the pole-piece tips 41 ceases, the ball will be attracted into engagement with the rotating pole-pieces and will be carried thereby in a counter-clockwise direction toward the tips of the pole-piece arms 20 and 21.

When the impulse terminates and the coil 33 deenergizes the ball 46 which has been held by the pole tips 40 against the magazine barrier 47 is released and rolls down against the end closure of the magazine and the remaining balls in the magazine roll downwardly also. When a second impulse is received and the coil 33 is reenergized a second ball is in the same manner removed from the magazine and attracted into engagement with the rotating pole-pieces 13 and 14. Thus in response to successive incoming impulses a ball for each impulse will become attracted into engagement with the rotating pole-pieces and carried forwardly by the rotation thereof, the balls being spaced apart on said pole-pieces at intervals commensurate with the spacing of the terminations of the incoming impulses.

As soon as the first ball 46 attracted to the rotating pole-pieces 13 and 14 reaches a position between the pole tips of the pole-piece arms 20 and 21, which may occur after any desired delay interval as determined by the speed of the motor 4 and the ratio of the reduction gearing interposed between the rotor shaft of the motor and the shaft 8, which interval, for example, might be 1.5 seconds, the magnetic pull on the ball by the pole-piece arms 20 and 21 will be greater than the magnetic pull which is retaining the ball attracted to the rotating pole-pieces. The ball will therefore be attracted from the rotating pole-pieces into a bridging engagement between the fixed pole-piece arms 20 and 21 and, as illustrated in Fig. 7, will close the circuit of impulse repeating relay 49 extending from one terminal of battery 50 through the winding of relay 49, terminal lug 22, pole-piece arm 20, ball 46, pole-piece arm 21, terminal lug 23 to the other terminal of the battery. Relay 49 will thereupon operate to open the circuit of magnet coil 19 and to close an out-pulsing circuit. As soon as the circuit of magnet coil 19 is opened the ball 46 is released and drops into the upper end of the magazine 42 thereby opening the circuit of relay 49 which releases and opens the out-pulsing circuit. The out-pulsing circuit is thus closed only during the interval that relay 49 remains operated. Each successive ball carried by the rotating pole-pieces 13 and 14 similarly causes the transmission of an impulse over the out-pulsing circuit.

The impulse receiving magnet assembly may, if desired, be modified as shown in Figs. 4 and 5. In accordance with this modification the barrier 47 shown in Fig. 2 is omitted and a movable barrier 52 is provided in lieu thereof. This barrier comprises a leaf spring supported at one end on the member 53 secured to the supporting plate 2 by the screws 54, having an armature 55 cooperating with the pole tips 40' of the pole-pieces 35 and 38 secured thereto, and having its free end upturned and provided with an opening 56 therein through which the reduced end of the magazine 42 extends. Normally the upturned end of the barrier spring assumes such a posi-

tion that the ball armatures 46 are free to roll down the magazine into engagement with the end closure thereof. When an impulse causes the energization of the magnet coil 33 the first ball armature is lifted to a position between the pole tips 41 from which position it is attracted into engagement with the rotating pole-pieces 13 and 14 upon the termination of the incoming impulse. At the same time the armature 55 carried by the barrier spring 52 is attracted toward the pole tips 40' into the position disclosed in Fig. 4 thereby interposing the upper end of the outer portion of the barrier spring in the path of the second ball armature to prevent it from rolling to the end of the magazine where it might also be attracted by the pole tips 41 into a position in which it would also be attracted into engagement with the rotating pole-pieces. Upon the termination of the impulse, the magnet coil 33 becomes deenergized whereupon the barrier spring is restored to its normal position thereby releasing the ball armature restrained thereby which then rolls into a position against the end closure of the magazine.

As a still further modification, the receiving magnet assembly may, if desired, be constructed as disclosed in Fig. 6. In accordance with this modification the magnet 33' is supported in any desired manner beneath the mounting plate 2 and is provided with an armature 57 which is pivoted to the heel-piece 53 of the magnet and has an arm 59 engaging with the lower end of a plunger 60. The plunger extends upwardly through a hole in the plate 2 and a hole in the lower end of the magazine block 42' to a point directly beneath the ball armature 46 which at the time is positioned against the lower end closure of the magazine. Normally the plunger is maintained in the position disclosed by the coiled spring 61 interposed between the enlarged lower end portion 62 of the plunger and the lower side of the plate 2.

When the magnet coil 33' is energized in response to an incoming impulse, the armature of the magnet becomes attracted towards the end of the magnet core thereby moving the arm 59 to press the plunger 60 upwardly against the tension of the spring 61 thereby moving the first ball armature 46 from the magazine into a position in which such armature is attracted into engagement with the rotating pole-pieces 13 and 14. So long as the magnet coil 33' remains energized the next ball armature in the magazine is restrained by the plunger 60 from rolling down into the position against the end closure of the magazine. As soon, however, as the magnet 33' deenergizes upon the termination of the impulse the spring 61 withdraws the plunger 60 thereby permitting the restrained ball armature to roll into position against the end closure of the magazine and over the upper end of the plunger 60.

It may be desirable to retransmit impulses after a predetermined delay interval which will have the same length or make period and spacing or break period as the received impulses. In that case the relay might be modified as disclosed in Figs. 8 and 9 and employed in a circuit illustrated in Fig. 10. In accordance with this modification the rotatable pole-piece assembly comprises a hub 63, a web portion 64 of insulating material and three pole-piece rings 65, 66 and 67 positioned on the peripheral surface of the web portion 64 in spaced relationship. These rings are magnetized by a permanent magnet, similar to the magnet 26 disclosed in Fig. 1, but arranged

to magnetize the middle ring 66 with one polarity and to magnetize the two outer rings 65 and 67 with the opposite polarity.

Two out-pulsing magnet assemblies similar to the assembly of Fig. 1 are provided. One of these assemblies has a magnet coil 88 and pole-piece arms 68 and 69 corresponding to pole-piece arms 20 and 21 separated by narrow air-gaps from the adjacent portions of the rotatable pole-pieces 65 and 66 and the other assembly has a magnet coil 89 and pole-piece arms 70 and 71 separated by narrow air-gaps from the adjacent portions of the rotatable pole-pieces 66 and 67 as diagrammatically illustrated in Fig. 10. An armature ball magazine 72 is provided having two storage channels 73 and 74 extending from points directly beneath the pole tips of the pole-piece arms 68 and 69 and the pole tips of the pole-piece arms 70 and 71, respectively, to points directly beneath the rotatable pole-pieces and in alignment with the grooves between such pole-pieces. Each of these channels is capable of holding a plurality of steel armature balls 46.

The impulse receiving magnet assembly comprises a core 75 supporting a magnet coil 76 to one end of which core a pole-piece 77 is secured by screw 78 and to the other end of which core a pole-piece 79 is secured by the screw 80. The pole-piece 79 is bent at right angles to lie parallel to the core 75 and has an upwardly extending portion 81 so that the pole faces of the pole-piece 77 and the pole-piece extension 81 lie in the same plane and adjacent to each other. The magnet may be supported from the under-side of the supporting plate 2 in any desired manner. An armature 82 is pivoted between brackets 83 and 84 secured to the under-side of the plate 2 with one of its ends overlying the pole faces of the pole-pieces 77 and 79 and normally retracted therefrom by the tension of spring 85 secured to the opposite ends of the armature. Slidable in holes in the plate 2 and magazine block 72 are two plungers 86 and 87 which are so linked with the opposite ends of the armature that they are caused to slide toward and away from the bottom of the magazine channels 73 and 74 upon the rocking movement of the armature 82. The rocking movement of the armature 82 is limited in one direction by the pole-pieces 77 and 79 and in the other direction by the upturned end of the armature engaging against the under-side of the plate 2.

The circuit diagram of Fig. 10 discloses the impulse receiving magnet 76 deenergized and both out-pulsing magnets 88 and 89, with which the pairs of pole-piece arms 68, 69 and 70, 71 are respectively associated, in an energized condition. The circuits of the magnets 88 and 89 extend from battery 59 thence through the windings of such magnets in parallel and over the normal contact of relay 49 back to the battery 59.

When magnet 76 operates in response to an incoming impulse the armature 82 is attracted toward the pole-pieces 77 and 79 thereby elevating the plunger 86 to move a ball armature 46 from the magazine channel 74 into a position in which it is attracted to the rotating pole-pieces 65 and 66. At the same time the plunger 87 is withdrawn to permit a ball armature to roll into a position over its upper end and against the end closure of the magazine channel 73. When the impulse is terminated the coil of magnet 76 becomes deenergized and thereupon spring 85 restores the armature there-

by elevating the plunger 87 to move a ball armature 46 from the magazine channel 73 into a position in which it is attracted to the rotating pole-pieces 66 and 67. At the same time the plunger 86 is withdrawn to permit a ball armature to roll into a position over its upper end and against the end closure of the magazine 73. Thus at the beginning of an impulse a ball armature is delivered to the rotating pole-pieces 65 and 66 and upon the termination of the impulse a second ball armature is delivered to the rotating pole-pieces 66 and 67, the circumferential spacing of the two armatures on the rotating pole-piece assembly being indicative of the make period of the impulse. When thereafter the magnet 76 becomes reenergized at the beginning of the next impulse, another ball armature is delivered to the rotating pole-pieces 65 and 66. The circumferential spacing of the armature previously engaged with the pole-pieces 66 and 67 and this latter armature engaged with pole-pieces 65 and 66 indicates the break period between the two successive impulses. At the end of the second impulse magnet 76 again deenergizes to cause the delivery of another ball armature to the rotating pole-pieces 66 and 67 to determine the make period of such second impulse. Magnet 76 continues to function in this manner in response to other incoming impulses.

If it be assumed that the rotatable pole-piece assembly is driven by motor 4 at such a speed that any ball armature delivered to the pole-pieces 65 and 66 reaches a position opposite the fixed pole-piece arms 68 and 69 after the lapse of a 1.5 seconds delay interval then when such first armature reaches that position with magnet 88 energized to create a magnetic field between the tips of its pole-piece arms 68 and 69 the ball armature is attracted from the rotating pole-pieces 65 and 66 into a bridging engagement with the fixed pole-piece arms 68 and 69 thereby establishing the out-pulsing circuit including battery 50. When thereafter, that is, after an interval commensurate with the make period of the first received impulse, the ball armature engaged with the rotating pole-pieces 66 and 67 reaches a position opposite the pole-piece arm 70 and 71 now magnetized by the energization of the magnet coil 89, the armature is attracted from the rotating pole-pieces 66 and 67 into bridging engagement with the fixed pole-piece arms 70 and 71 thereby establishing an obvious circuit for relay 49. Relay 49 thereupon operates to open the circuit of magnets 88 and 89 which release the ball armatures held between their pole-pieces into the channels 73 and 74 of the magazine thereby opening the out-pulsing circuit and the circuit of relay 49. The out-pulsing circuit has thus been closed for an interval equal to the make period of the incoming impulse but after the 1.5 seconds delay.

When the next ball armature which was engaged with the rotating pole-pieces 65 and 66 at the beginning of the second incoming impulse reaches a position opposite the fixed pole-piece arms 68 and 69, since such pole-pieces have now been remagnetized upon the release of relay 49, it becomes attracted to such pole-pieces thereby closing the out-pulsing circuit. Since the period between the release of magnet 88 and the reclosure of the out-pulsing circuit has been determined by the engagement of ball armatures with the rotating pole-pieces upon the termination of

one impulse and the beginning of a succeeding impulse, the period during which the out-pulsing circuit is open is equal to the break period between incoming impulses. The out-pulsing circuit is again opened in response to the bridging of the pole-piece arms 70 and 71 by a ball armature engaged with the rotating pole-pieces 66 and 67 and the subsequent operation of relay 49 and the release of magnets 88 and 89. Other received impulses are restored and retransmitted in a similar manner.

What is claimed is:

1. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a first electromagnet operable in response to each impulse of an incoming impulse series to remove a ball from said magazine to a position in which it is attracted to said rings and moved away by the rotation of said rings, a second electromagnet operative after a delay interval determined by the speed of rotation of said rings to remove each ball from said rings, means controlled by each ball upon its removal to close an out-pulsing circuit and means operative following the closure of the out-pulsing circuit by each ball to deenergize said second electromagnet to return said ball to said magazine.

2. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a plunger associated with the lower end of said magazine with its upper end normally positioned beneath the lowermost ball in said magazine, a first electromagnet operable in response to each impulse of an incoming impulse series to elevate said plunger to remove a ball from said magazine to a position in which it is attracted to said rings and moved away by the rotation of said rings, a second electromagnet operative after a delay interval determined by the speed of rotation of said rings to remove each ball from said rings, means controlled by each ball upon its removal to close an out-pulsing circuit and means operative following the closure of the out-pulsing circuit by each ball to deenergize said second electromagnet to return said ball to said magazine.

3. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a first electromagnet operable in response to each impulse of an incoming impulse series to remove a ball from said magazine to a position in which it is attracted to said rings and moved away by the rotation of said rings, a second electromagnet operative after a delay interval determined by the speed of rotation of said rings to remove each ball from said rings, and a relay operable in response to the removal of each ball to close an outpulsing circuit and to deenergize said second electromagnet to return said ball to said magazine whereupon said relay is released to open said out-pulsing circuit and to reoperate said second electromagnet.

4. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a first electromagnet having a pair of pole-pieces positioned above the lower end of said magazine and adjacent to said rings and having its coil energizable in response to each impulse of an incoming impulse series to magnetize its pole-pieces whereby a ball is attracted from said magazine into a position in

which it is attracted to said rings and moved away by the rotation of said rings, a second electromagnet operative after a delay interval determined by the speed of rotation of said rings to remove each ball from said rings, means controlled by each ball upon its removal to close an out-pulsing circuit, and means operative following the closure of the out-pulsing circuit by each ball to deenergize said second electromagnet to return said ball to said magazine.

5. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a first electromagnet having a pair of pole-pieces positioned above the lower end of said magazine and adjacent to said rings and having its coil energizable in response to each impulse of an incoming impulse series to magnetize its pole-pieces whereby a ball is attracted from said magazine into a position in which it is attracted to said rings and moved away by the rotation of said rings, a second electromagnet having its pole-pieces insulated from each other and positioned adjacent to said rings at the upper end of said magazine and having its coil energizable to remove balls from said rings into bridging engagement with its pole-pieces after a delay interval determined by the speed of rotation of said rings, and means operative upon each bridging of said pole-pieces by a ball for causing the closure of an out-pulsing circuit and the deenergization of said second electromagnet to return said ball to said magazine.

6. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a barrier member associated with the lower end of said magazine, a first electromagnet having a first pair of pole-pieces positioned above the lower end of said magazine and adjacent to said rings, a second pair of pole-pieces cooperative with said barrier member, and a coil energizable in response to each impulse of an incoming impulse series to magnetize its pole-pieces whereby the lowermost ball is attracted from said magazine into a position in which it is attracted to said rings and moved away by the rotation of said rings and whereby the next and remaining balls are restrained by said barrier member from movement in said magazine, a second electromagnet having its pole-pieces insulated from each other and positioned adjacent to said rings at the upper end of said magazine and having its coil energizable to remove balls from said rings into bridging engagement with its pole-pieces after a delay interval determined by the speed of rotation of said rings, and means operative upon each bridging of said pole-pieces by a ball for causing the closure of an out-pulsing circuit and the deenergization of said second electromagnet to return said ball to said magazine.

7. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a down-turned barrier lip near the lower end of said magazine, a first electromagnet having a first pair of pole-pieces positioned above the lower end of said magazine and adjacent to said rings, a second pair of pole-pieces positioned above said barrier lip and a coil energizable in response to each impulse of an incoming impulse series to magnetize its pole-pieces whereby the lowermost ball is attracted from said magazine into a position in

which it is attracted to said rings and moved away by the rotation of said rings and whereby the next ball in said magazine is attracted into a position behind said barrier lip to restrict it and the remaining balls from movement in said magazine, a second electromagnet having its pole-pieces insulated from each other and positioned adjacent to said rings at the upper end of said magazine and having its coil energizable to remove balls from said rings into bridging engagement with its pole-pieces after a delay interval determined by the speed of rotation of said rings, and means operative upon each bridging of said pole-pieces by a ball for causing the closure of an out-pulsing circuit and the deenergization of said second electromagnet to return said ball to said magazine.

8. In a pulse delay relay, a pair of oppositely polarized rotatable pole-piece rings, a ball armature magazine associated therewith, a plurality of armature balls therein, a barrier spring movable to intercept said magazine immediately behind the lowermost ball therein and having an armature secured thereto, a first electromagnet having a first pair of pole-pieces positioned above the lower end of said magazine and adjacent to said rings, a second pair of pole-pieces cooperating with the armature of said barrier spring and a coil energizable in response to each impulse of an incoming impulse series to magnetize its pole-pieces whereby the lowermost ball is attracted from said magazine into a position in which it is attracted to said rings and moved away by the rotation of said rings and whereby said barrier spring is moved into its intercepting position to restrict the movement of the remaining balls within said magazine, a second electromagnet having its pole-pieces insulated from each other and positioned adjacent to said rings at the upper end of said magazine and having its coil energizable to remove balls from said rings into bridging engagement with its pole-pieces after a delay interval determined by the speed of rotation of said rings, and means operative upon each bridging of said pole-pieces by a ball for causing the closure of an out-pulsing circuit and the deenergization of said second electromagnet to return said ball to said magazine.

9. In a pulse delay relay, three parallelly disposed rotatable rings, means for magnetizing said rings to form two pairs of oppositely polarized pole-pieces, a ball armature magazine associated with each pair of said pole-pieces, a plurality of armature balls in each of said magazines, an electromagnet energizable in response to each impulse of an incoming impulse series to remove a ball from one of said magazines to a position in which it is attracted to one pair of said rotatable pole-pieces and operative upon the termination of each incoming impulse to remove a ball from the other of said magazines to a position in which it is attracted to the other pair of said rotatable pole-pieces, a second electromagnet operative to remove each ball from said first pair of pole-pieces, means controlled by each of said balls upon its removal to close an out-pulsing circuit, a third electromagnet operative to remove each ball from said second pair of pole-pieces, and means controlled by each of said latter balls upon its removal to cause the release of said second and third electromagnets whereby the out-pulsing circuit is opened and the balls

thus removed from the pole-pieces are returned to their respective magazines.

10. In a pulse delay relay, three parallelly disposed rotatable rings, means for magnetizing said rings to form two pairs of oppositely polarized pole-pieces, a ball armature magazine associated with each pair of said pole-pieces, a plurality of armature balls in each of said magazines, a plunger associated with the lower end of each of said magazines, an electromagnet energizable in response to each impulse of an incoming impulse series to elevate one of said plungers to remove a ball from one of said magazines to a position in which it is attracted to one pair of said rotatable pole-pieces, and operative upon the termination of each incoming impulse to elevate

the other of said plungers to remove a ball from the other of said magazines to a position in which it is attracted to the other pair of said rotatable pole-pieces, a second electromagnet operative to remove each ball from said first pair of pole-pieces, means controlled by each of said balls upon its removal to close an out-pulsing circuit, a third electromagnet operative to remove each ball from said second pair of pole-pieces, and means controlled by each of said latter balls upon its removal to cause the release of said second and third electromagnets whereby the out-pulsing circuit is opened and the balls thus removed from the pole-pieces are returned to their respective magazines.

THORALF AAMODT.