Nov. 18, 1952 W. H. BUSSEY 2,618,755

ELECTROMAGNETIC IMPULSE GENERATOR

Filed March 28, 1951

Fig. 1.

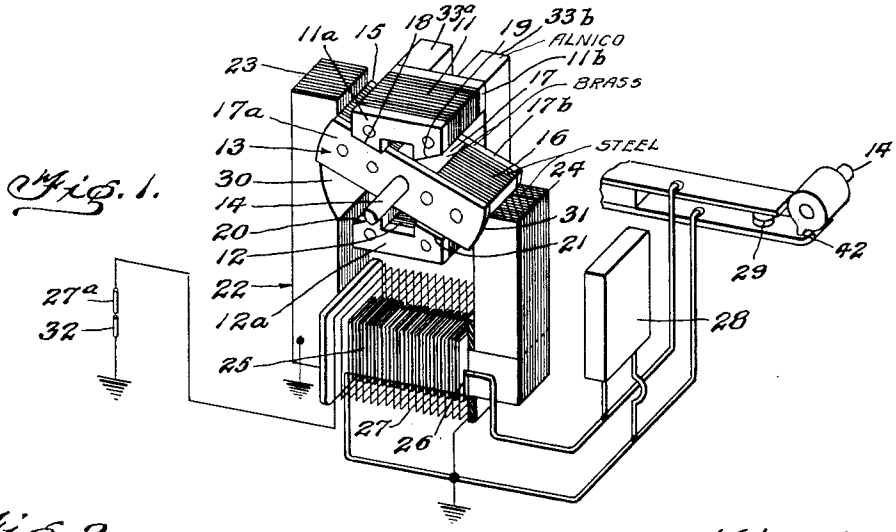


Fig. 2.

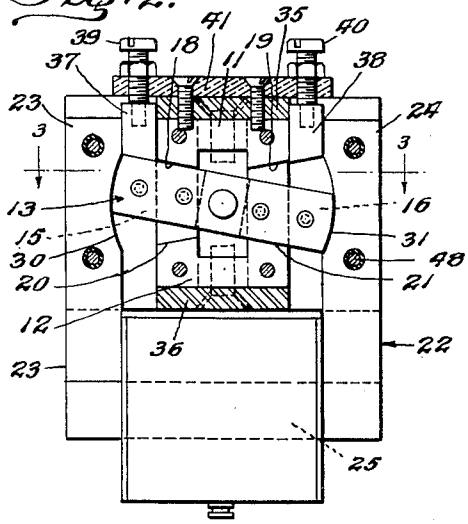


Fig. 4.

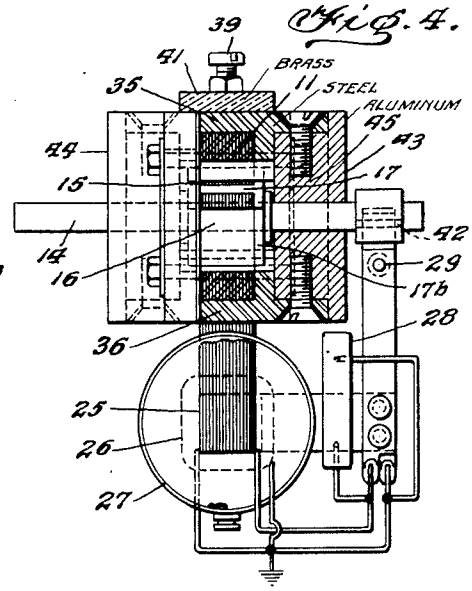
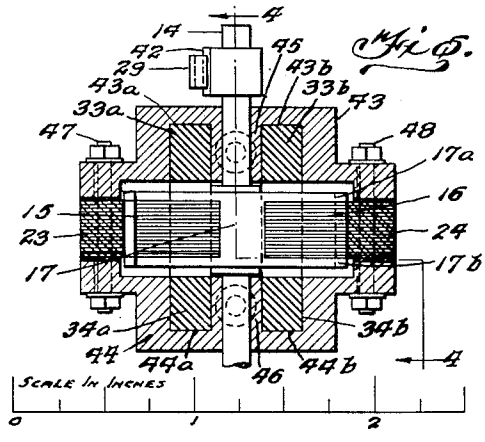


Fig. 3.



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Patented Nov. 18, 1952

2,618,755

UNITED STATES PATENT OFFICE

2,618,755

ELECTROMAGNETIC IMPULSE GENERATOR

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Application March 28, 1951, Serial No. 217,975

10 Claims. (Cl. 310—36)

1

This invention relates to an electromagnetic impulse generator.

It is an object of this invention to provide a device capable of generating an electrical impulse of brief duration and high peak power sufficient for ignition purposes.

Another object of this invention is to convert a small energy input into an electrical output pulse of relatively high peak power and brief duration of a preferred embodiment.

A further object of this invention is to provide an electromagnetic impulse generator which is capable of generating a high peak power electrical impulse in response to a small angular movement of an armature.

It is also an object of this invention to provide a magnetic impulse generator of small size and rugged construction, yet capable of relatively high peak power output.

Other and further objects of the invention will be apparent during the course of the following description.

In the drawings:

Figure 1 is a schematic view illustrating broadly the construction of my electromagnetic impulse generator, with portions thereof removed to better illustrate the operation thereof, along with the associated external electrical circuit;

Fig. 2 is a longitudinal view, partly cut away, showing the structural details of the electromagnetic portion of my invention;

Fig. 3 is a tranverse sectional view along the line 3—3 of Fig. 2, and

Fig. 4 is a vertical view, partly in section, along the line 4—4 of Fig. 3.

In accordance with the present invention there is provided an electromagnetic device for converting angular movement imparted to a shaft into a rapid change of magnetic flux to generate an electrical impulse. A pair of fixedly positioned, spaced, opposed magnetic pole shoes 11 and 12 are polarized north and south, respectively, to create a magnetic field between them. Rotatively positioned between the poles 11 and 12 is a movable armature, generally indicated at 13. The armature is mounted for rotation on shaft 14, and consists of spaced, separate ferromagnetic arms 15 and 16, and a central portion 17 of a material, such as brass, having high magnetic reluctance and high electrical conductivity separating the arms 15 and 16. The north pole shoe 11 is formed with spaced outwardly and upwardly inclined faces 18, 19 at each side interposed in the paths of movement of armature arms 15, 16. Similarly, south pole

2

shoe 12 is formed with spaced outwardly and downwardly inclined faces 20, 21 interposed in the paths of movement of magnetic arms 15 and 16 at the opposite side thereof. Stops (not shown in Figure 1) are preferably provided to limit movement of armature 13 in either extreme of movement so that neither magnetic arm 15 or 16 directly contacts either inclined face of either magnet pole shoe. A fixed generally U-shaped, laminated external core 22 of readily magnetizable material is formed with spaced upstanding legs 23, 24 closely adjacent the armature at either end thereof. An interconnecting portion 25 of the core is surrounded by a primary winding 26 and a secondary winding 27. One side of both the primary and secondary windings is grounded to the core, the other side of the secondary winding leading to an ignition electrode 27a or other output load. A condenser 28 and a switch 29 are connected across the pirmary winding.

In the operation of this device, the armature 13 in one extreme position is positioned with the upper face of one magnetic arm 15 closely spaced from the sloping face 18 of the north pole shoe 11 and with the end thereof closely spaced from the adjacent arcuate inner face 30 of core leg 23. Also, in this position of armature 13, the lower face of the other magnetic arm 16 is closely spaced from the sloping face 21 of the south pole shoe 12 and the end thereof is spaced closely from the adjacent arcuate inner face 31 of core leg 24. In this rest position of the armature, the static magnetic flux from north to south is caused to flow from pole shoe 11 across the small air gap between face 18 and magnetic arm 15, along the laminations of arm 15 to the end thereof and across the small air gap to face 30 of core leg 23, downwardly along the laminations of core leg 23, across the interconnecting portion 25 of the core, upwardly along the laminations of core leg 24, across the air gap between arcuate face 31 of core leg 24 to the end of magnetic arm 16, along the laminations of magnetic arm 16 and across the small air gap between the lower face of magnetic arm 16 and the adjacent sloping face 21 of pole shoe 12. Since the central portion 17 of the armature is of non-magnetic material it opposes the flow of magnetic flux, which is thereby induced to follow the path of least magnetic reluctance across the small air gaps, as described. Thus, the armature is divided magnetically into two distinct and separate parts 15 and 16 to cause the flux to flow through the external core member 22.

In response to counter-clockwise rotation of shaft 14, the armature is moved angularly about its axis 14 to its opposite extreme limit of movement. During the movement of the armature, the magnetic flux, which is changing because of the armature movement, is caused to follow an external path through the external core 22, rather than across the central armature portion 17 because the non-magnetic, electrically conductive form of the latter opposes the occurrence of a change of flux through itself. In this opposite extreme position of the armature the static magnetic flux flows from the north pole shoe 11 across the small air gap between sloping face 19 of the north pole shoe and the adjacent upper face of magnetic arm 16, through arm 16, across the small air gap between the end of arm 16 and the adjacent curved inner face 31 of core leg 24, downwardly through core leg 24, across the interconnecting core portion 25, upwardly through core leg 23, across the small air gap between arcuate inner face 30 on the core leg 23 and the end of magnetic arm 15, through the magnetic arm 15 and across the small air gap between the lower face of magnetic arm 15 and the adjacent sloping face 20 of the south pole shoe 12. Thus, it will be seen that a relatively small limited angular movement of armature 13 has effected a complete reversal of the flux through magnetic core 22. This flux reversal is made use of to create an impulse of electrical energy for ignition or other purposes.

As is well understood, a change of magnetic flux in a core surrounded by a loop of wire forming part of a closed electrical circuit will induce a voltage therein. During the closed position of normally closed switch 29 the primary winding 26, which surrounds core portion 25, is part of a closed circuit, so that a change in the flux through the core at that time will induce a voltage in winding 26. The induced voltage in primary 26 is a maximum when the rate of change of flux through the core is greatest, i. e., when the flux is changing instantaneously from a finite value in one direction to a finite value in the opposite direction, thus flux reversal being effected by the angular movement of the magnetic armature, as described. The current in the primary winding lags the induced voltage therein because of the natural inductance of the winding, so that peak primary current will lag somewhat the induced primary voltage. Preferably, switch 29 should be opened at about peak primary current. When this occurs, an extremely abrupt change takes place in the flux linking the turns of the primary winding 26, giving rise to a rapid oscillatory exchange of energy between the primary winding and the condenser 28 to induce in the secondary winding 27 a voltage sufficient for spark ignition at ignition electrode 27*a*.

In the operation of my improved magnetic impulse generator it has a toggle-like action because of its unique construction. In either extreme position of armature 13 there are relatively large magnetic forces holding it in that position, so that the extreme limits of movement of the armature are stable positions. As the armature is moved away from either extreme position these magnetic forces decrease rapidly as the magnetic arms 15 and 16 each approach positions midway between the magnetic north and south poles. This midway position is one of unstable equilibrium since the net magnetic force pulling on the armature is zero because the air gaps between each magnetic arm 15, 16 and the north and south poles are equal in length, and so present paths of equal reluctance to magnetic flux. As soon as the armature has moved beyond this neutral position, however, the magnetic forces acting against the armature become unbalanced, and as the armature approaches its other extreme position the unbalance of these forces is progressively increased. The net result is that the armature moves through its neutral position of unstable equilibrium very rapidly with a snap action due to the action of the magnetic forces in the device. This is a very important advantage of the present invention since the maximum rate of change of flux through the external core 22 depends upon the speed at which armature 13 moves through its neutral position. The peak current induced in the primary winding is, of course, proportional to the maximum rate of change of flux in the core 22, so that the rapid, toggle-like movement of armature 13 serves to compress the time in which the energy which causes armature movement is converted into an electrical impulse. Thereby, a small input of mechanical energy is converted to electrical energy acting in such a brief interval that the instantaneous electrical power output is great.

It will be readily apparent that the snap action movement of armature 13, which is inherent in the above-described construction of the magnetic system, may be further accentuated by any suitable mechanical means interposed between shaft 14 and the driving means therefor, such as a spring, for storing the mechanical input energy up to a point at which it discharges this energy rapidly to impart a swift angular movement to shaft 14, which in turn is accelerated by the action of the magnetic system, as described.

A preferred embodiment of the above described device is shown in Figs. 2 to 4, which present a specific construction by which the purposes and advantages of the invention may advantageously be carried out. As shown in these figures, the spaced, opposed pole shoes 11 and 12 are magnetically polarized north and south, respectively, preferably by small Alnico bar magnets 33*a*, 33*b*, 34*a*, and 34*b* which straddle the pole shoes. Steel plates 35 and 36 straddle the magnets 33*a*, 33*b*, 34*a* and 34*b* at the top and bottom thereof and serve as mounting plates for the respective pole shoes 11 and 12. Preferably the pole shoes 11, 12 are laminated in form to render them inherently susceptible to undergo rapid flux changes. The pole shoe laminations are held in assembled relation by soft steel side plates 11*a*, 11*b* and 12*a*, 12*b*, respectively. The armature 13 includes separate arms 15 and 16, which are also laminated for the same purpose, on either side of a central non-magnetic portion 17 of brass. The laminated arms 15 and 16 are held in assembled relation on the armature by spaced brass side members 17*a* and 17*b* disposed on opposite sides of the arms 15 an 16 and interconnected with the central portion 17. By virtue of this construction of the armature 13, the magnetic flux is caused to travel along the laminations of the separate arms 15 and 16. In the static flux condition, i. e., when the armature is at rest, the high magnetic reluctance of the brass center member 17, which separates arms 15 and 16, serves to effectively oppose the flow of flux through itself. In the dynamic flux condition, i. e., when the armature is in motion to thereby cause a changing flux, the high electrical conductivity of the central brass section 17 effectively prevents flux from chang-

ing through it. Similarly the brass side pieces 17a and 17b on the armature oppose the flow of flux in both the static and dynamic conditions thereof, so that under all conditions the flux, whether static or changing, is directed along the laminations of the separate armature arms 15 and 16 and along the external path formed by the laminations of the fixedly positioned external core member 22. The soft steel side pieces 11a, 11b, 12a, 12b on the pole shoes 11, 12 because of their solid construction cooperate with the brass side pieces 17a, 17b on the armature to prevent flux change from occurring external to the armature in a plane normal to the axis of the armature shaft 14 by confining such changing flux to flow along the laminations of the armature and the pole shoes. These side pieces on the pole shoes also conduct magnetic flux from the bar magnets to polarize the laminations of the pole shoes.

Thus, it will be seen that this arrangement provides a divided magnetic structure of the movable armature 13. The flux change is caused to occur only in the laminated pole shoes, the laminated arms of the armature, and the laminated external core 22, all of which laminated portions have the inherent characteristic that they permit rapid flux changes. There is no flux change in the bar magnets 33a, 33b, 34a, 34b themselves.

Also, it is to be noted that the movable portion of the device is merely the relatively low mass armature 13. The magnets, magnet pole shoes, and the external core 22 are all fixed. The relatively small mass of armature 13 because of its smaller inertia is conductive to a rapid flux change and therefore to a large peak amplitude of the generated pulse.

Limit stops 37 and 38 are disposed at either end of the north pole shoe 12 to limit upward movement of the armature in either direction. These stops are of non-magnetic material, such as Bakelite, and are adjustable by screws 39, 40 extending through the brass housing top 41 to obtain the desired cross spacing between the magnetic pole shoes and the armature in either extreme position of the latter. The magnetic pole shoe mounting plate 35 is supported by housing top 41 by means of a plurality of screws extending therethrough.

The external core 22 is here shown in the form of three separate segments 23, 24 and 25. Each of these segments is laminated to provide a good path for rapidly changing magnetic flux. At their lower ends the upstanding core legs 23 and 24 have their laminations of magnetic material spaced so that the interconnecting core portion 25, which is provided at each end with spaced laminations, may have its laminations snugly interleave with those of the upstanding core legs 23, 24 to be supported from the core legs in that manner. The arcuate inner faces 30 and 31 of the upstanding core legs 23 and 24 are both formed concentric with the axis of rotation 14 of armature 13. The adjacent end faces of the magnetic arms 15 and 16 and the mounting portions 17a and 17b of the armature are also shaped arcuately and are disposed at equal radial distances from the rotary axis of shaft 14, slightly shorter than the radial distances from arcuate faces 30, 31 to the rotary axis. By virtue of this construction the respective air gaps between the ends of arms 15, 16 and the adjacent core legs 23, 24 is maintained equal in every position of armature 13.

The core segment 25 which interconnects core legs 23 and 24 carries a unitary coil assembly which includes a plurality of turns of wire forming the primary winding 26 and a plurality of turns of wire forming the secondary winding 27 surrounding the primary. Since the coil assembly is carried by the external core member, it in no way limits the movement or size of armature 13, as is common in the prior art construction of the "balanced armature" type of electromagnetic impulse generator, so that the flux capacity of the movable armature is completely independent of the coil assembly in my invention.

The switch 29 for opening the circuit of the primary winding is preferably mounted adjacent the free end of the shaft 14 at the rear of the magnetic toggle. A cam 42 is mounted on the rotary shaft at this end to engage switch 29 to open the contacts thereof at a predetermined position of the rotary shaft 14. For optimum results the cam 42 should be so positioned on shaft 14 that switch 29 is opened at the instant when the current in the primary winding is at a maximum, somewhat after the armature has passed through the unstable center position.

The housing for the magnetic system includes spaced aluminum side pieces 43 and 44. As best seen in Fig. 3 each of these side pieces includes spaced recesses 43a and 43b, and 44a and 44b, respectively, for snugly receiving the bar magnets 33a and 33b, and 34a and 34b, respectively. An inwardly protruding central portion 45 and 46 is provided on each of the respective side pieces. Each of these central portions is provided with a central hole which forms a bearing for shaft 14. These inwardly protruding central portions 45 and 46 also serve to separate the bar magnets 33a and 33b, and 34a and 34b, respectively. In addition, as best seen in Fig. 4, the inwardly protruding central portions 45 and 46 of the side pieces 43 and 44 are interconnected with the steel magnet pole shoe mounting plates 35 and 36 by screws extending through the latter end threadedly received in the central portions 45 and 46, so that the mounting plates 35 and 36 are supported by the side pieces 43 and 44 in this manner. At each extremity the side pieces 43 and 44 support upstanding core legs 23 and 24 by means of bolts 47, 48 extending therethrough.

In one practical form, the impulse generator according to the foregoing construction, including the coils, switch and condenser, occupies a space of less than 1¾ inches by 1¾ inches by 2½ inches.

With the foregoing novel construction of my impulse generator there is produced between the ignition electrodes 27a and 32 a spark of a voltage of about 15,000 volts capable of producing a spark sufficient for ignition purposes. For applications of my impulse generator where the impulse voltage is desired to be of a lower value the secondary winding 27 may be omitted and the ignition electrodes 27a and 32 connected directly across the terminals of switch 29.

While a specific embodiment of my invention has been described herein it is to be understood that various changes from the described embodiment may be resorted to without departing from the spirit and scope of the invention.

I claim:

1. An impulse generator comprising spaced, oppositely polarized magnet pole shoes, a pair of magnetic arms providing separate magnetic flux paths, said magnetic arms being concurrently movable between oppositely polarized pole shoes to be positioned respectively at either extreme

of movement adjacent oppositely polarized pole shoes, a magnetic core magnetically linked through said magnetic arms with said pole shoes to provide a path for magnetic flux whose direction and amount is responsive to the position of said magnetic arm, and means responsive to changing magnetic flux in said core to generate a current.

2. An impulse generator comprising fixedly positioned, spaced, oppositely polarized magnet pole shoes, a pair of magnetic arms separated by a non-magnetic portion to provide separate paths for magnetic flux, said magnetic arms being movable concurrently between oppositely polarized pole shoes to be positioned respectively at either extreme of movement adjacent oppositely polarized pole shoes, a fixedly positioned core member of magnetic material formed with spaced portions positioned respectively closely adjacent the magnetic arms in all positions thereof, and means responsive to changing magnetic flux in said core to generate a current.

3. An impulse generator comprising spaced, oppositely polarized magnet pole shoes, a pair of magnetic arms providing separate magnetic flux paths, said magnetic arms being concurrently movable angularly between oppositely polarized pole shoes to be positioned respectively at either extreme of movement adjacent oppositely polarized pole shoes, said pole shoes being formed with inclined faces positioned respectively to lie closely adjacent separate respective magnetic arms in either extreme of movement thereof, a magnetic core formed with spaced portions positioned closely adjacent the magnetic arms in all positions thereof and formed with a portion magnetically interconnecting said spaced portions, and coil means looped around said magnetic core and responsive to changing magnetic flux therein to generate a current.

4. An impulse generator comprising a pair of spaced, oppositely polarized magnet pole shoes, a pair of spaced magnetic arms providing separate magnetic flux paths, said magnetic arms being movable in unison angularly between the pole shoes to be positioned respectively in either extreme of movement closely adjacent oppositely polarized magnet pole shoes, said pole shoes being formed with inclined faces positioned respectively to extend closely adjacent separate respective magnetic arms in either extreme of movement thereof, a magnetic core formed with spaced portions respectively closely spaced from the magnetic arms in all angular positions thereof, said core also being formed with a portion magnetically interconnecting said spaced portions, said magnetic arms and said core forming a closed path for magnetic flux between the oppositely polarized magnet pole shoes, the direction and amount of the magnetic flux through the core being responsive to the respective positions of the magnetic arms with respect to the opositely polarized magnet pole shoes, and coil means looped around said magnetic core and responsive to changing magnetic flux therein to generate a current.

5. An impulse generator comprising spaced, oppositely polarized magnet pole shoes, a pair of spaced, oppositely extending magnetic arms, a member of non-magnetic material of good electrical conductivity interconnecting said magnetic arms to separate said arms to provide a divided magnetic armature structure, said magnetic arms being angularly movable between the pole shoes to be positioned in either extreme of movement closely adjacent oppositely polarized magnet pole shoes, a magnetic core formed with spaced portions respectively positioned closely adjacent the magnetic arms in all angular positions thereof, and means responsive to a changing flux through said core to generate a current.

6. An impulse generator comprising spaced, fixedly positioned, oppositely polarized magnet pole shoes, a pair of oppositely extending magnetic arms interconnected by a portion of non-magnetic material of good electrical conductivity to provide a divided magnetic armature structure, said armature being angularly movable between the pole shoes to respectively position said arms in either extreme of movement of the armature closely adjacent oppositely polarized magnet pole shoes, said pole shoes being formed with inclined faces positioned respectively to extend closely adjacent separate respective magnetic arms in either extreme of movement thereof, a magnetic core formed with spaced portions respectively fixedly positioned closely adjacent the free ends of the magnetic arms in all angular positions thereof, and means responsive to a changing flux through said core to generate a current.

7. An impulse generator comprising spaced, fixedly positioned, oppositely polarized magnet pole shoes, a pair of magnetic arms mounted on opposite sides of a common axis for unitary angular movement in opposite directions between the pole shoes, said magnetic arms being interconnected by a non-magnetic portion of high electrical conductivity to provide separate magnetic flux paths and having extreme limits of movement closely adjacent oppositely polarized magnet pole shoes, said pole shoes being formed with inclined faces positioned respectively to extend lengthwise of separate respective magnetic arms closely adjacent thereto in either extreme limit of movement thereof, a magnetic core formed with fixedly positioned spaced portions respectively disposed closely adjacent the separate magnetic arms in all angular positions thereof, and means responsive to changing flux through said core to generate a current.

8. An impulse generator comprising spaced, fixedly positioned, oppositely polarized magnet pole shoes of laminated magnetic material, a pair of laminated magnetic arms extending in opposite directions from a common axis and mounted for unitary movement in opposite directions angularly about said axis between the pole shoes, said magnetic arms being interconnected by a non-magnetic portion of highly conductive material to separate said arms magnetically to provide a divided magnetic movable armature, said arms having extreme limits of movement closely adjacent oppositely polarized pole shoes, said pole shoes being formed with inclined faces positioned to extend respectively lengthwise of the laminations of separate respective magnetic arms closely adjacent thereto in either extreme limit of movement thereof, a laminated magnetic core formed with fixedly positioned spaced portions closely adjacent the free ends of the magnetic arms in all angular positions thereof, and means responsive to a changing flux through said core to generate a current.

9. An impulse generator comprising a pair of spaced, fixedly positioned, oppositely polarized magnet pole shoes, a pair of spaced magnetic arms mounted on opposite sides of a common axis for unitary angular movement in opposite directions between the pole shoes, said magnetic arms

being interconnected by a non-magnetic portion to provide separate magnetic flux paths through the respective arms and having extreme limits of movement closely adjacent oppositely polarized magnet pole shoes, said pole shoes being formed with inclined faces positioned respectively to extend lengthwise of separate respective magnetic arms closely adjacent thereto in either extreme limit of movement thereof, a fixedly positioned magnetic core formed with spaced portions having arcuate faces concentric with the respective arcs of movement of the extremities of the magnetic arms remote from said common axis thereof to be closely spaced from said magnetic arm extremities in all angular positions thereof, said core also being formed with a portion magnetically interconnecting said spaced portions, said magnetic arms and said core forming a closed path for magnetic flux between the oppositely polarized magnet pole shoes, the direction and amount of the magnetic flux through the core being responsive to the positions of the respective magnetic arms relative to the magnet pole shoes, and coil means surrounding said magnetic core and responsive to changing magnetic flux therein to produce a current.

10. An impulse generator comprising a pair of spaced, fixedly positioned, oppositely polarized, laminated magnet pole shoes, pairs of solid side pieces on each of said pole shoes formed of magnetic material, a pair of spaced laminated magnetic arms mounted on opposite sides of a common axis for unitary angular movement about said axis in opposite directions between the pole shoes, said magnetic arms being interconnected by a non-magnetic portion of high electrical conductivity to provide separate magnetic flux paths through the respective arms, each of said magnetic arms being provided with side pieces of non-magnetic material of high electrical conductivity to confine the magnetic flux to flow along the laminations of the arms, said oppositely polarized magnet pole shoes being positioned on opposite sides of said axis to be interposed in the paths of angular movement of both magnetic arms, said magnet pole shoes each being formed with a pair of spaced inclined surfaces inclining inwardly toward said axis and interposed respectively in the paths of movement of the separate magnetic arms in opposite movements thereof, stop means for limiting angular movement of said magnetic arms in either direction to position said arms in either limiting position thereof to have their respective laminations extend respectively lengthwise of the laminations of the pole shoes closely adjacent the inclined surfaces of oppositely polarized magnet pole shoes, a fixedly positioned magnetic core formed with spaced portions having arcuate faces concentric with the respective arcs of movement of the extremities of the magnetic arms remote from said common axis thereof to be closely spaced from said magnetic arm extremities in all angular positions thereof, said core also being formed with a portion magnetically interconnecting said spaced portions, said magnetic arms and said core forming a closed path for magnetic flux between the oppositely polarized magnet pole shoes, the direction and amount of the magnetic flux through the core being responsive to the positions of the respective magnetic arms relative to the magnet pole shoes, and coil means surrounding said magnetic core and responsive to changing magnetic flux therein to produce a current.

WILLIAM H. BUSSEY.

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