July 24, 1951 G. R. FISH 2,561,355

ELECTRIC SIGNAL DEVICE

Filed May 20, 1947 3 Sheets-Sheet 1

Fig. 1

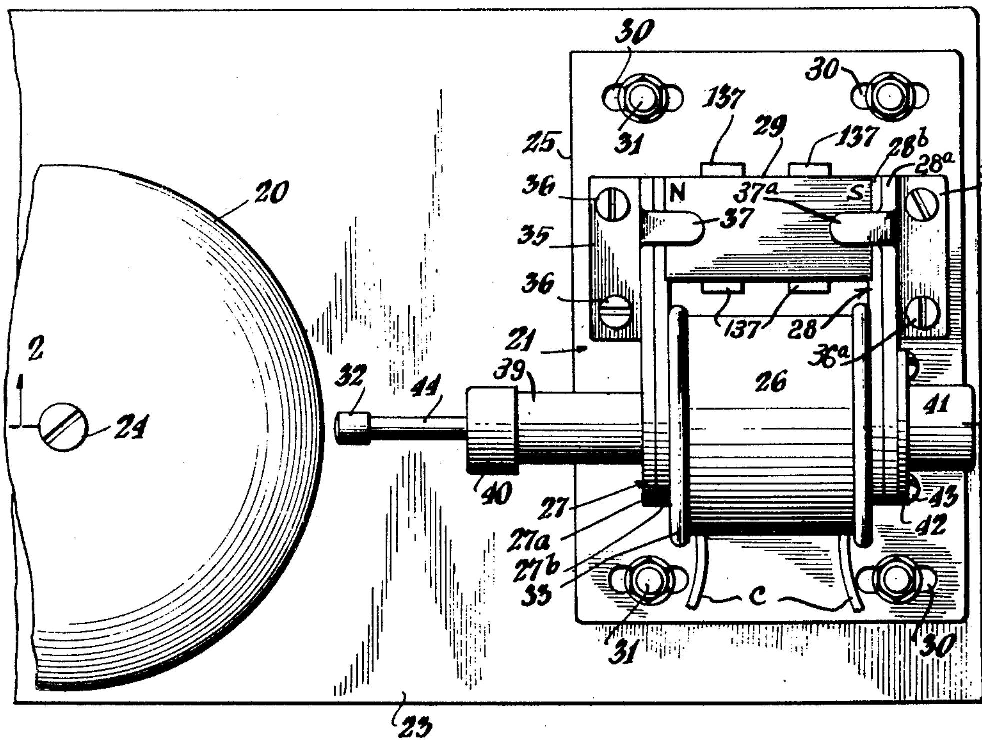

Fig. 2

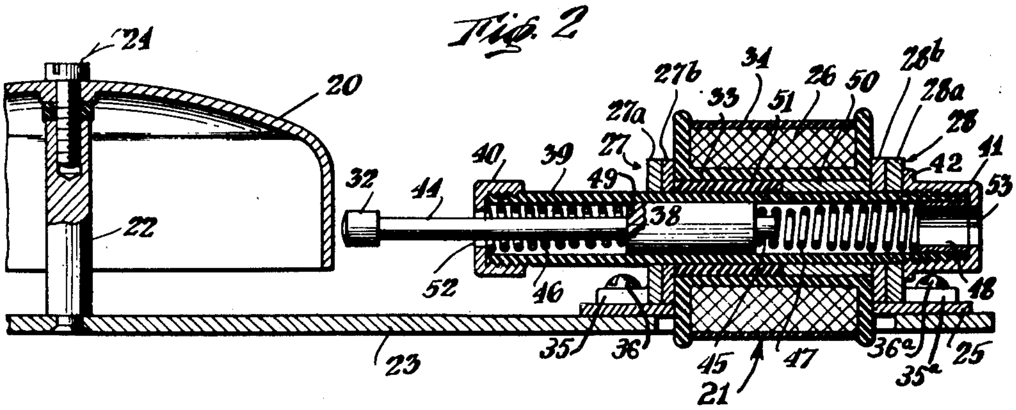

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Fig. 3

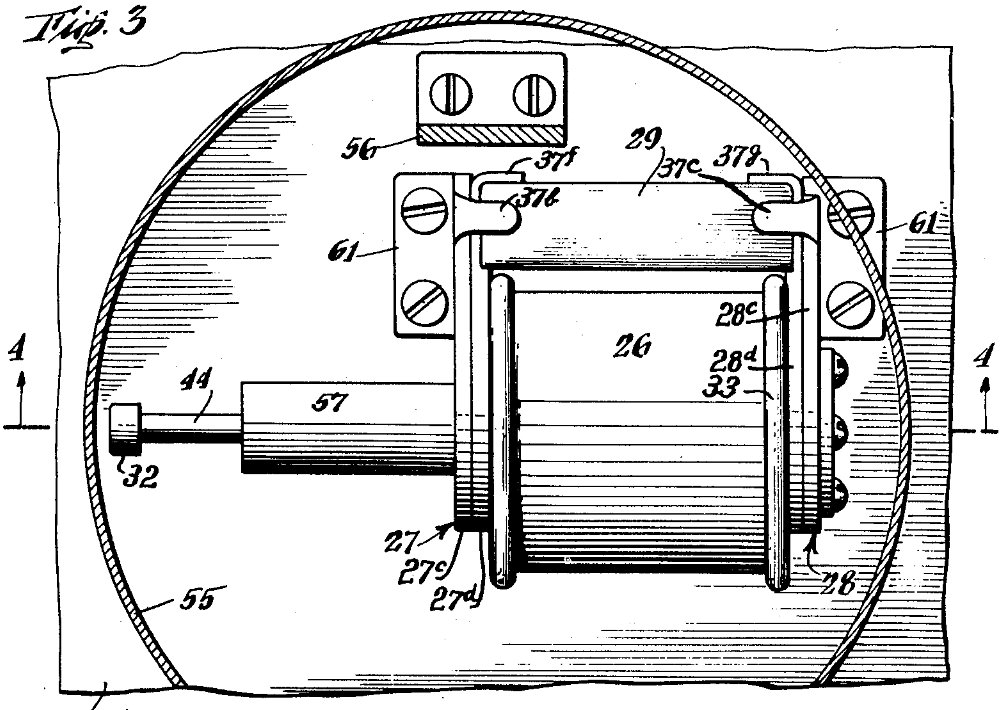

Fig. 4

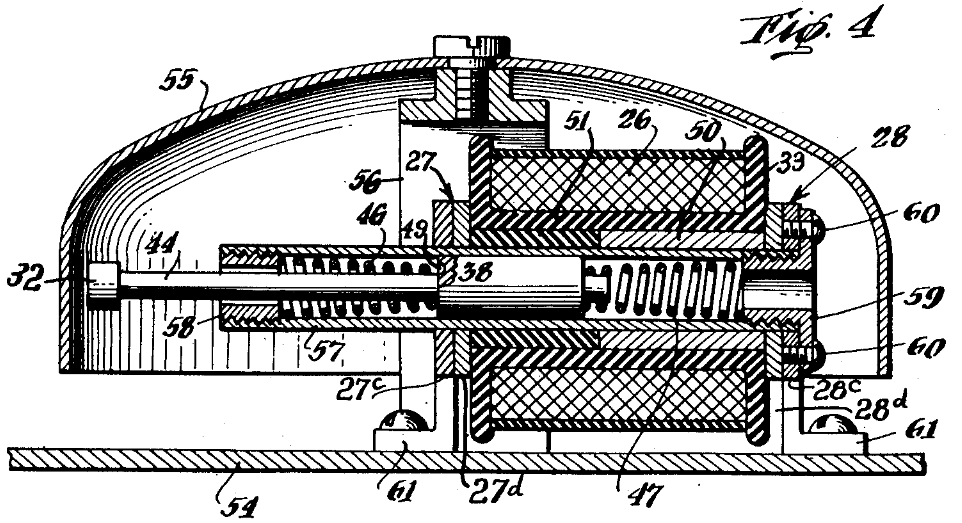

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Fig. 5

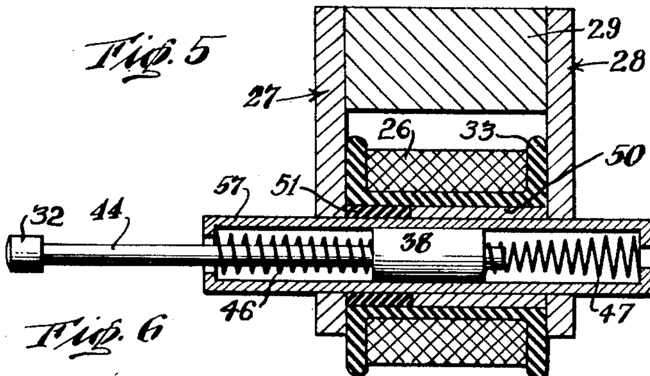


Fig. 6

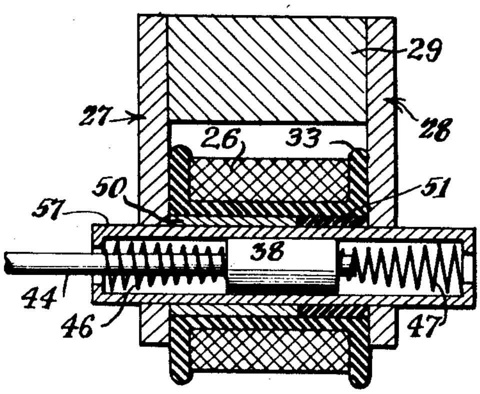


Fig. 7

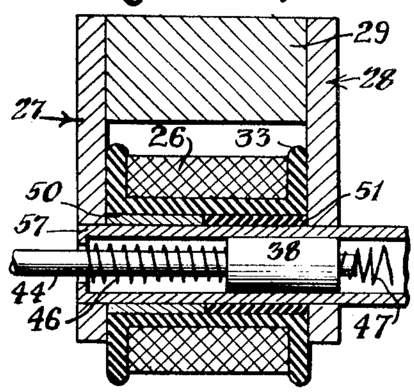


Fig. 8

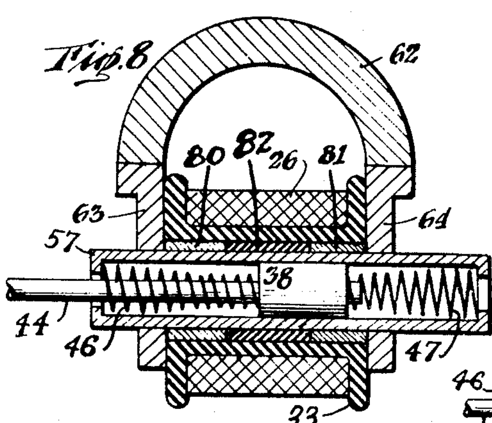


Fig. 11

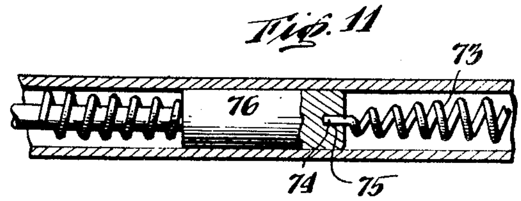


Fig. 10

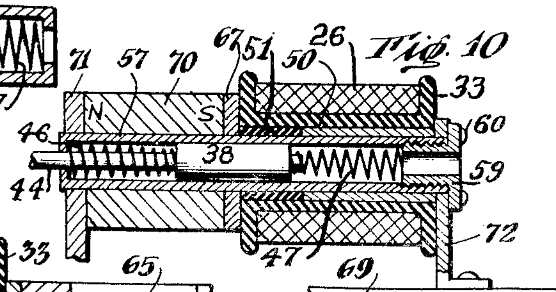
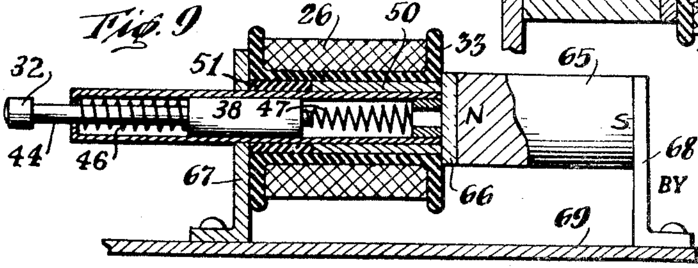


Fig. 9



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Patented July 24, 1951 2,561,355

UNITED STATES PATENT OFFICE

2,561,355

ELECTRIC SIGNAL DEVICE

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Application May 20, 1947, Serial No. 749,251

39 Claims. (Cl. 177—7)

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This invention relates to electric signal devices and particularly to electric bells, gongs and buzzers actuated from a source of alternating current energy.

An object of the invention is to improve electric signal devices.

Another object is to improve electromagnetically operated bells, buzzers and gongs.

A further object is to improve alternating current actuated electromagnetic signalling devices.

A still further object is to improve the efficiency of electro-magnetically actuated A. C. bells.

Further objects of the invention are to provide a practical and inexpensive signalling construction that will be strong and durable, compact and of dependable action, to provide an electrically actuated gong construction that will be economical to manufacture, capable of ready assembly, fool-proof in construction and action and more efficient in operation than prior bells and gongs.

Other objects of the invention will be apparent from the following description and accompanying drawings taken in connection with the appended claims.

In the accompanying drawings, in which are shown several of the various possible embodiments of this invention and in which similar reference characters refer to similar parts throughout:

Figure 1 is a top plan view of an electromagnetically actuated solenoid-type alternating current bell or gong embodying features of the present invention;

Figure 2 is a section on the line 2—2 of Figure 1 showing the construction and mounting of the solenoid armature or plunger, with the spring suspension or locating means therefor, and the construction of the stationary solenoid core;

Figure 3 is a plan view, partly in section, of a modified bell construction, wherein the solenoid is mounted inside the bell;

Figure 4 is a section on the line 4—4 of Figure 3, showing the internal construction of the solenoid;

Figure 5 is a sectional view, showing a modified mounting arrangement for the armature or plunger to obtain impact with the bell on the power stroke of the striker;

Figures 6 and 7 show further modifications in which the stationary core assembly has been rearranged to provide a gap in the magnetic circuit at the rear of the solenoid;

Figures 8, 9 and 10 illustrate further modifications utilizing permanent magnets of different

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construction or mounted in a different manner in relation to the solenoid; and

Figure 11 is a detail sectional view showing a modified spring mounting arrangement.

As conducive to a clearer understanding of certain features of this invention it might here be mentioned that many deficiencies have attended the operation of various types of electric signalling apparatus such as large and small electric bells or gongs and especially those constructed for actuation by alternating current. It will be appreciated that if alternating current of a frequency of 60 cycles per second, such as is generally available, is used to energize a simple electromagnet or solenoid without modification of its wave form the electromagnet will attract its armature 120 times per second. When the armature, vibrating at this frequency, is used to actuate the striker for the bell the best tone and volume output is not obtained. The strokes are too rapid to yield a good gong tone and the striker interrupts the free vibration of the gong produced by the preceding stroke too quickly.

Attempts have been made to improve the tone of A. C. bells by inserting a dry disc rectifier in the electric circuit to convert the current to a pulsating direct current of 60 pulses per second. This has resulted in an improvement in tone since the electromagnet armature is then impelled against the gong only 60 times per second but this is achieved at the cost of a considerable decrease in efficiency due to the fact that only one-half of the current wave is used. Also such rectifiers always have a certain amount of leakage in the reverse or blocking direction which disturbs the proper functioning of the electromagnet and cuts down the efficiency. These rectifiers are also subject to some change in characteristics during their operating life.

Another cause of low efficiency in A. C. bells has resulted from the fact that if a solenoid were used which was large enough to produce a pull of the required strength the weight of the armature or plunger became so great and the necessary stiffness of the supporting springs so high that the plunger would not respond satisfactorily and with sufficient amplitude to the magnetic impulses and a great deal of energy was consumed in overcoming the friction of the armature and springs on their supports.

A dominant aim of the present invention is to overcome these disadvantages and provide a solenoid actuated bell or gong for operation on alternating current in an efficient, reliable and economical manner. The invention also contemplates a mechanical construction and inter-relation of parts which is economical to produce on a quantity basis and simple and convenient to assemble.

In its preferred embodiment the invention utilizes a permanent magnet associated with the solenoid for increasing the effective pull of the solenoid when energized by alternating current and for decreasing the frequency of the vibration of the striker to one which will elicit greater volume and better tone of signal from the bell or gong. By use of a permanent magnet to modify the magnetic flux produced by the solenoid the change in pull on the plunger during a reversal in the alternating current is greater than can be obtained with the A. C. solenoid alone, whether alternating current or rectified alternating current is used, as a result of the square law relationship between flux and pull. The stronger the permanent magnet, the greater is the effectiveness of the current in the solenoid.

The construction of the solenoid is arranged to take the fullest advantage of the magnetic flux and makes possible the use of a smaller plunger with a solenoid of the most efficient size. Greater freedom of choice in the size of the plunger is also provided so that the most effective and powerful stroke can be obtained for the source of power used and the most pleasing tone can be produced in the gong.

The invention also makes possible greater economy of space than heretofore since a more compact solenoid and striker assembly is possible, so that the entire mechanism may be mounted within the limited space available under a gong.

Referring to the drawings, Figures 1 and 2 illustrate a solenoid actuated signalling device in the form of an electric gong and comprising a gong 20 mounted in any suitable manner, as by post 22 staked to base plate 23, the gong being secured to the post by a screw 24 through its crown portion at the center thereof. The gong is sounded by a striker 32 of an electromagnetic actuating mechanism 21 which may illustratively comprise a brass auxiliary base plate 25 upon which is mounted a solenoid comprising a winding 26, a core 38, and a permanent magnet 29 which, in this illustrative embodiment, coacts with the solenoid by way of iron end pieces 27 and 28 and other parts later described.

Auxiliary base plate 25 is provided with mounting slots 30 through which it is secured to the face of main base plate 23 by bolts 31, the slots enabling adjustment in the position of the mechanism in relation to the gong in order to obtain the preferred positioning of the striker 32 for obtaining the most desirable volume and quality of tone from the gong when the striker is actuated by the solenoid.

The solenoid comprises an insulated wire winding or coil 26 mounted on a suitable form 33 which may be a spool-like member of insulating material, such as Bakelite-impregnated fibre or the like. The coil may be covered with an insulating sheath 34 which may comprise a winding of insulating tape or a lacquer coating layer. The form 33 is mounted between the parallel iron end pieces 27 and 28 which preferably form part of the supporting structure for the solenoid.

Each end piece may be formed of a single piece of cast iron or soft steel but I have found it more, for facilitating assembly and mounting, convenient to make them each of two plates, as shown, mounted in face-to-face relation. For example, end piece 27 is composed of an outer plate 27a which has at its lower edge (Figure 2) an outwardly turned flange 35 provided with screw holes to secure it to the brass plate 25 by screws 36, and an inner plate 27b which, at one end portion thereof, rests flatwise against the left-hand end of the permanent magnet 29 as seen in Figure 1; the outer plate 27a has an inturned flange or tongue 37 which, as seen in Figure 1, extends over the top edge of the inner plate 27b and overlies the permanent magnet 29 to coact to hold these parts assembled. In like manner, end piece 28 is composed of an outer plate 28a which has at its lower edge an outwardly-turned flange 35a by which it is secured, through screws 36a, to the brass plate 25, and an inner plate 28b on which an end portion rests flatwise against the other end of the permanent magnet 29, a tongue-like flange 37a of the outer plate 28a overlying the inner plate 28b and also the permanent magnet 29, as shown in Figure 1.

Permanent magnet 29 may preferably comprise a single rectangular bar of magnetized material, such as Alnico, which is of the same length as coil form 33 and by the above-described arrangement is mounted alongside and parallel with solenoid 26 between end pieces 27 and 28, held by flanges 37 and 37a and by spaced pairs of elements 137—137 engaging opposed sides of the bar magnet 29 as shown in Figure 1. The magnet poles may be disposed in either direction in relation to the solenoid.

The solenoid is provided with a movable iron or soft steel core or plunger 38 which slides in a tube 39 extending through the central axial hole or channel in coil form 33 and through accommodating aligned apertures in end pieces 27 and 28. The tube 39 may be formed of any non-magnetic material of suitable low friction and anti-wearing properties, such as Bakelite impregnated fibre (as shown) or brass. The tube is provided with end caps 40 and 41 which are screwed onto external threads on the tube. Cap 41 may carry flanges 42 which enable it to be secured to end piece 28a by screws 43.

Steel plunger 38 is provided with a striker rod 44 of non-magnetic material such as high chrome stainless steel or Monel metal which extends from the end of plunger 38 axially outward through a central aperture in cap 40 and terminates in a tip or striker 32, which may be of slightly larger diameter than the main body of the rod, if desired. Tip 32 may be of the same material as the rod or of a harder material if desired. It is desirable that either the tip or the gong or both be of non-magnetic material to avoid or lessen risk of sticking due to magnetic attraction between the two. If the gong is of non-magnetic material the rod 44 can in some cases be paramagnetic material such as iron or steel if the rod does not pass through the gap in the magnetic circuit, which will be described later. The other end of plunger 38 is provided with a short, centrally-located projection 45 which may be turned out of the steel making up the body of the plunger. The plunger is positioned between a pair of coil springs 46 and 47.

Rear spring 47 is preferably a non-linear spring whose force increases with compression at a progressively increasing rate beyond a certain point in the plunger travel and for that purpose is sharply tapered. This compensates in great part for the variation from linearity of the magnetic force-distance curve, which is concave upwardly over the working range of the plunger. The resultant force of the spring and the magnet with no current flowing in the solenoid is thereby made to approach a linear relationship with distance traveled. This improves the timing of the plunger so that the time taken for strokes of different length, due to variations in A. C. line voltage for example, will be substantially a constant and the mechanical frequency of the plunger can be synchronized with the 60 cycle A. C. supply without changes in weighting or spring tension being required for differing line voltage. Likewise the energy stored in the gong from an impact of the striker will cause it to vibrate throughout the plunger stroke so that upon the next impact the phase of the gong vibration will have a considerable effect upon the rebound of the striker and affect its distance of travel. The compensation obtained by use of the non-linear spring also reduces variation in timing due to such variations in rebound from the gong. While a tapered non-linear spring is illustrated it is also possible to use a spring of constant turn diameter, or one with only slight taper to reduce side-wall friction and wear. In such springs non-linearity can be imparted by progressively increasing the spacing between turns along the length of the spring.

It is also contemplated that under some conditions front spring **46** may be given non-linear characteristics rather than, or in addition to, a non-linear characteristic in the rear spring. These arrangements, in which either the rear spring, the front spring, or both, are given non-linear characteristics are applicable not only to the mechanisms in which the "power stroke" draws the plunger away from the gong as in Figures 1 to 4, but also to those in which the "power stroke" drives the plunger toward the gong, as illustrated in Figures 5, 7, and 8, for example.

Wearing of the side walls of the tube and the turns of the coil spring and frictional resistance therebetween are avoided by forming springs **46** and **47** into tapered coils of a truncated conical form. The large base or end of each coil spring is substantially the diameter of the inside of tube **39** whereby the coil is fitted snugly within the tube and centered by it. The smaller end of coil spring **46** is slightly larger in diameter than rod **44**, which it surrounds, and fits in a circular channel or groove **49** in the end of plunger **38** surrounding the rod **44** at its point of attachment to the plunger. The smaller end of coil spring **47** fits closely around the base of projection **45**. Hence, it will be noted that the springs **46** and **47** are both definitely located and positioned at their ends while their turns intermediate of their ends are spaced from the tube **39**, and, in the case of spring **46**, from the striker rod **44**. This greatly diminishes the wear on the tube and the springs and prolongs the life of the gong mechanism.

The large end of spring **46** is seated against the inside of cap **40**, as shown. The large end of spring **47** may be similarly seated against cap **41**, but I prefer to use an additional tubular sleeve **48**, which may preferably be made of metal. The sleeve **48** rests against the inside of cap **41** and the spring **47** rests against the inner end of the sleeve. By varying the length of the sleeve used the adjustment and compression applied to springs **46** and **47** may be varied. A similar sleeve can be used within cap **40**, if required. Caps **40** and **41** are provided with apertures **52** and **53** to permit ingress and egress of air when the plunger is vibrated, but are not needed where a loosely fitting plunger is used.

As was already mentioned, one of the difficulties in operating A. C. bells in the past has been in obtaining sufficient amplitude of response in the plunger at the desired operating frequency. The present structure overcomes this disadvantage, increases the power and efficiency of the plunger stroke and the resulting signal obtained from the gong, and makes possible greater flexibility in the adjustment of plunger size and positioning to obtain the strongest and most pleasing signal. This structure embodies an improved arrangement of the magnetic circuit enabling a shorter and lighter plunger to be used without interfering with the plunger stroke and without cutting down the efficiency of the magnetic circuit.

As shown in Figure 2, that embodiment of the magnetic circuit includes a stationary core member in the form of an iron or steel sleeve **50** inside the solenoid winding **26**. The sleeve is conveniently mounted within the bore or channel of the tubular part of coil form **33** and surrounds plunger tube **39**, with one end in contact with iron end piece **28*b***. Sleeve **50**, being tubular, is of ring-shape or annular cross-section and its respective end faces are likewise annular in shape; as is better shown in Figure 2, its right-hand end annular face rests flatwise against a correspondingly shaped area of that part of end piece **28*b*** that, like its adjacent end piece **28*a***, surrounds the tube **39**, thus to make for good conduction of magnetic flux from one to the other; the other or left-hand annular end face as shown in Figure 2 provides a flux-guiding face that is coaxial with the solenoid winding **26** and with the bore of channel therein. Sleeve **50** extends only part of the distance through solenoid **26**, the rest of the distance to end piece **27*b*** being filled with a sleeve **51** of non-magnetic material such as plastic or brass. The relative lengths of sleeves **50** and **51** can be varied to provide a gap of any desired length in the magnetic path, measurable generally to or from the above-described flux-guiding face of the part **50**.

In the embodiment illustrated in Figures 1 and 2 the plunger **38** is held by springs **46** and **47** in a normal or rest position in which the left-hand end of plunger **38**, as seen in Figure 2, projects through end piece **27** and slightly beyond it. The right hand end of the plunger body terminates some distance to the left of the inner end of sleeve **50**.

The magnetic circuit in the form shown in Figure 2 extends from the left hand end of permanent magnet **29**, then through soft steel end piece **27**, then radially through or across a small "air" gap through the wall of tube **39** to the left hand end of plunger **38**, through the length of plunger **38**, then by way of a longer air gap from the right hand end of plunger **38** to the inner end of sleeve **50**, then through sleeve **50** to end piece **28** and back along the end piece to the right hand end of magnet **29**. End piece **27** and end piece **28** together with sleeve **50** thus comprise extensions of the poles of magnet **29**.

Magnetic flux is continuously present in the magnetic circuit as a result of the presence of the permanent magnet and is constantly bridging the air gap between the plunger **38** and the inner end of sleeve **50**. This permanently imposed flux is unidirectional. This magnetic flux tends to draw plunger **38** to the right, as viewed in Figure 2, to close the gap. Spring **47** resists this pull and the plunger assumes the rest position shown wherein spring **47** is held under a bias or compression by the magnetic pull. The adjustment is such that the striker 32 is spaced a short distance from the rim of the gong at this time.

In operation, the solenoid is energized by an alternating current signal through input conductors C—C which may extend through a push button or other switch device to an A. C. source, for example, a 60 cycle power line, or the secondary winding of a transformer connected to the A. C. power line. Since the solenoid winding 26 encircles the magnetic flux path the A. C. energization of the solenoid causes an alternating flux to be superimposed upon the steady or unidirectional flux produced by the magnet 29 first in an aiding, then in an opposing direction.

For the most efficient operation the magnetic effect of the solenoid at the peak of the alternating current cycle is made to be substantially less than that of the magnet 29. When the two magnetizing forces are opposing each other the net magnetic flux will fall to a relatively low value due to partial neutralization or opposition of the permanent magnet flux by the current-induced flux, and when the two are aiding each other the flux will reach a high value due to reinforcement of the permanent magnet flux by that of the solenoid.

The effect of the variation of the flux in the magnetic path across the gap between the plunger 38 and the end of sleeve 50 is to increase the attraction to pull the plunger further away from the gong when the two effects are aiding and to reduce the magnetic pull on the plunger when the effect of the solenoid opposes the magnet. The plunger, in moving inward, reduces the air gap and further compresses spring 47. On the opposite current half-cycle the compressed spring system drives the plunger against the gong and is aided by an additional spring force due to the partial neutralization of the permanent magnet flux by the current flux. By using a permanent magnet whose flux is large in relation to that produced by the current, the change in force on the plunger caused by the current aiding the magnet will be substantially equal to the change in the force in the opposite direction due to the current opposing the magnet. Upon rebound from the gong with the mass of the plunger and stiffness of the springs suitably adjusted, the plunger is again drawn to the right by the next peak in the magnetic flux cycle.

By use of the permanent magnet for biasing the solenoid the change in the pull applied to the plunger between the peak of an aiding half-cycle and the peak of an opposing half-cycle is greatly increased as a result of the square law relationship between flux and pull. From the equation for the pull (f) on the plunger of a solenoid:

$$f=0.0139\ B^2S \text{ pounds}$$

and its derivation

$$\frac{df}{db}=2B$$

where B is the flux density in the air gap and S is the cross section of the air gap, it will be seen that the force change produced by superimposing the permanent magnet flux on the alternating flux due to the solenoid is very much greater than the change that would be produced by the solenoid acting alone.

A relatively strong permanent magnet has the added advantage of being less subject to the demagnetizing effect of the A. C. current than would be a magnet having a flux more nearly equal to the A. C. flux.

The cross section of sleeve 50 can be made equal to that of the plunger so that the full flux carrying capacity of the plunger is used. In most cases it will be preferable to make the cross section of the sleeve greater than that of the plunger to compensate for leakage flux to the opposite steel end piece 27.

An advantage in the steel sleeve core construction resides in the fact that the plunger 38 can slide freely into the end of the sleeve and thus reduce the magnetic circuit to a minimum.

Another advantage of the sleeve construction may be availed of in some applications to obtain a more compact bell structure. In these embodiments the rear spring supporting the plunger is mounted entirely within the solenoid so that the actuating mechanism can be mounted in a limited space, such as beneath a small gong.

Figures 3 and 4 show a compact bell structure of this type. This comprises a non-magnetic base plate 54 (of brass, for example) upon which is mounted the small gong 55 by means of a bridge shaped bracket 56. The solenoid mechanism is generally similar to that of Figures 1 and 2 comprising solenoid 26, end pieces 27 and 28, permanent magnet 29 and plunger 38.

In this embodiment (Figures 3 and 4) the plunger tube 57 is formed of a non-magnetic metal, such as brass, and end caps 58 and 59 are externally threaded to screw into the ends of the tube. Cap 59 has a flange at its outer end which is secured to end piece 28 by screws 60. Tapered coil springs 46 and 47 abut the inner ends of caps 58 and 59. The solenoid is mounted on base plate 54 by flanges 61 on end pieces 27 and 28.

As in the form of Figures 1 and 2, the end pieces 27 and 28 may each comprise two plates, as shown, mounted in face-to-face relation. Thus end piece 27 may comprise an outer plate 27*c* and an inner plate 27*d*, and the end piece 28 may comprise an outer plate 28*c* and an inner plate 28*d*; as with the outer plates 27*a* and 28*a* of Figure 1, the outer plates 27*c* and 28*c* of Figure 3 may be provided with inturned tongue-like flanges 37*b* and 37*c*, respectively, overlying the respective inner plates 27*d* and 28*d* and also the respective ends of the upper face of the permanent magnet 29. As shown in Figure 3, inner plates 27*d* and 28*d* may be provided with inturned flanges 37*f* and 37*g*, respectively, that take against a side of the permanent magnet 29.

It will be noted that with this construction the plunger tube does not project from the rear of the solenoid and the solenoid is mounted within the limited space beneath the gong. The plunger nevertheless has ample freedom of movement and adequate space is available for springs of sufficient size to obtain the best operating frequency and amplitude.

In the solenoid mechanisms illustrated in Figures 1 to 4 the plunger 38 is so mounted in relation to the steel sleeve 50 as to provide the air gap in the magnetic circuit at the rear end of the plunger. This position is generally preferable as it permits use of the shortest striker rod and because variations in strength of the permanent magnet have less effect on the signal. Thus, with a weaker magnet the rest position of the striker will be closer to the gong because of less magnetic bias placed on the springs.

Other mounting positions can be used, if it appears expedient, as shown in Figures 5, 6 and 7. Figure 5 shows a modified mounting arrangement in which the rest position of plunger 38 is partly within the sleeve 50 and the main air gap is between the forward end of the plunger and the end piece 27. Striker rod 44 is of non-magnetic metal as well as plunger tube 57.

In operation of the mechanism of Figure 5 the striker is impinged against the bell on the "power" stroke of the plunger, that is, on the stroke in which the magnetizing force of the solenoid reinforces that of the permanent magnet. This insures a positive and definite action.

Figures 6 and 7 illustrate other modifications in which the sleeve 50 is mounted within the forward end of the solenoid in contact with end piece 27. In Figure 6 the main air gap is between the rear (right) end of the plunger 38 and end piece 28 and in Figure 7 the gap is between the front (left) end of the plunger and the inner end of the sleeve 50. These structures are of advantage where the mounting space requires the solenoid to be placed close to the bell as the forward end of tube 57 can be partly or entirely within the solenoid.

It is also contemplated that variations in the shape and mounting of the permanent magnet can be effected in order to make use of magnets of different size or length or to adapt the solenoid structure for mounting in spaces of different sizes and shapes.

Figure 8 illustrates the use of a horseshoe or semi-circular magnet 62. The ends of the magnet abut steel end pieces 63 and 64 which, in effect, comprise extensions of the magnet poles along the ends of the solenoid. This figure also illustrates another modification of the plunger and core arrangement in which a pair of iron or steel sleeves 80 and 81 are provided inside the solenoid winding, the sleeves extending inward from the ends where they are in contact with end pieces 63 and 64. Sleeves 80 and 81 are spaced apart by a non-magnetic sleeve 82, preferably formed of an insulating plastic material. Plunger 38 is normally at rest in a position within sleeve 81 and extending into the gap provided by sleeve 82. Upon energization of the solenoid in an aiding direction the plunger is drawn into the gap.

In Figure 9 a bar magnet 65 is mounted coaxial with the solenoid 26 at the rear (right) end of the coil form 33. The right hand or outermost end of the magnet is secured to a steel bracket 68 which is screwed to steel base plate 69. The forward end of the solenoid is provided with a steel end piece or bracket 67 also secured to the base plate. A steel piece 66 is interposed between the left hand end of magnet 65 and the steel sleeve 50 which extends into the coil. The magnetic circuit in this embodiment extends through the base plate 69 from end piece 67 to bracket 68. This structure permits mounting of the mechanism in a long narrow housing.

Figure 10 shows a further modification in which the permanent magnet 70 is in the form of a cylinder which is mounted with one end against a steel end piece 67 at the forward end of the solenoid and the plunger tube 57 projects through the central aperture of the magnet. Steel brackets 71 and 72 at the ends mount the structure on steel base plate 69 to complete the magnetic circuit through the plate.

Figure 11 shows a modified arrangement for centering the inner end of the rear spring. Tapered rear spring 73 has its inner end 74 formed into an axially extending tip which is received in an axial recess 75 in plunger 76. The recess takes the place of the projection 45 and permits use of a more sharply tapered spring.

While insulating sleeve 51 has been shown and described as a separate element it is contemplated that it may, if desired, be integral with the coil form 33.

Although the invention in its preferred embodiments contemplates a permanent magnet as an essential part of the structure, some of the features of the invention are also applicable to solenoid actuated signals and bells which do not embody a permanent magnet, such as those supplied with pulsating direct current obtained from a rectifier or current interrupter.

It will be seen that the present invention provides an improved electric signal construction as exemplified by an A. C. gong in which the objects and advantages mentioned are achieved in a practical embodiment capable of convenient manufacture by factory methods. The gong is capable of more efficient operation with greater strength of signal than prior structures and is more susceptible of ready adjustment of frequency response and tonal quality. The invention also permits use of a large solenoid without the necessity of correspondingly increasing the size and weight of the plunger.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. An alternating current signal device comprising, a solenoid winding, a pair of end pieces of paramagnetic material disposed at the ends of said winding, a permanent magnet adjacent said winding having its poles in contact with said end pieces, a plunger tube extending through the center of said winding and through at least one of said end pieces, a paramagnetic sleeve surrounding said tube, said sleeve being disposed within said winding with a first end thereof in contact with a first of said end pieces, the second end of said sleeve terminating within said winding whereby an air gap is provided between said second end and the second of said end pieces and said second sleeve end and second end piece comprise extension poles of said permanent magnet, a paramagnetic plunger in said tube, said plunger carrying a striker rod on one end thereof, said rod projecting from one end of said tube and terminating in a striking tip, an impact signal element, means mounting said element opposite said striking tip, and spring means positioning said plunger within said tube in a rest position wherein one end of said plunger is radially within one of said extension poles and the other end of said plunger is longitudinally spaced from the other of said extension poles and said striking tip is spaced from said impact signal element.

2. An alternating current signal device comprising, a solenoid winding, a pair of end pieces of paramagnetic material disposed at the ends of said winding, a permanent magnet adjacent said winding having its poles in contact with said end pieces, a plunger tube extending through the center of said winding and through at least one of said end pieces, a paramagnetic sleeve surrounding said tube, said sleeve being disposed within said winding with a first end thereof in contact with a first of said end pieces, the second end of said sleeve terminating within said winding whereby an air gap is provided between said second end and the second of said end pieces and said second sleeve end and second end pieces

comprise extension poles of said permanent magnet, a paramagnetic plunger in said tube, said plunger carrying a striker rod on one end thereof, said rod projecting from one end of said tube and terminating in a striking tip, a gong, means mounting said gong opposite said striking tip, and spring means positioning said plunger within said tube in a rest position wherein one end of said plunger is radially within one of said extension poles and the other end of said plunger is longitudinally spaced from the other of said extension poles and said striking tip is spaced from said gong.

3. In an alternating current solenoid operated signal mechanism, a solenoid winding, a pair of end pieces of paramagnetic material each at one end of said solenoid, said end pieces each comprising at least two overlapping members of which at least one has ears, means of paramagnetic material bridged across said end pieces exteriorly of said solenoid and engaged at its ends by said ears, means of non-magnetic material forming a channel through the center of said solenoid and extending coaxially therewith, a paramagnetic sleeve surrounding said channel and positioned in an annular space between said non-magnetic channel-forming means and said winding, one end of said sleeve being in contact with one of said end pieces and the other end of said sleeve being spaced from the other of said end pieces, whereby an air gap is provided within said solenoid of shorter length than said solenoid, and a plunger of magnetic material slidable in said channel and coacting with said air gap.

4. An alternating current striker-actuating mechanism for audible signals comprising, a solenoid winding having an internal coaxial bore, a tubular guide member extending through said bore and having a lesser diameter than said bore to provide therebetween an annular space, a pair of paramagnetic end pieces at the ends of said winding surrounding said guide member, an annular extension of paramagntic material extending from one of said end pieces toward the other of said end pieces and positioned in said annular space between said winding and said guide member, said extension terminating intermediate of the ends of said winding, a paramagnetic element bridging said end pieces outside said winding, a paramagnetic plunger within said tubular guide member and striking means connected thereto and projecting from said guide member.

5. An alternating current striker-actuating mechanism for audible signals comprising, an alternating current solenoid winding, a nonmagnetic tubular guide member extending through the central axis thereof, a pair of paramagnetic end pieces at the ends of said winding surrounding said guide member, an annular extension of paramagnetic material extending from one of said end pieces toward the other of said end pieces between said winding and said guide member, said extension surrounding said tabular guide member and terminating intermediate of the ends of said winding, a paramagnetic element bridging said end pieces outside said winding, a paramagnetic plunger within said tubular guide member and striking means connected thereto and projecting from said guide member, said annular extension having a cross-section at least as great as the cross-section of said plunger.

6. An alternating current striker-actuating mechanism for audible signals, comprising, a non-magnetic base, a coil form having a coaxial bore therein, an alternating current solenoid winding on said form, a non-magnetic tube extending into the bore of said form, a pair of plate-like paramagnetic end pieces disposed against the ends of said form and embracing said tube, said end pieces extending beyond the edges of said form, a permanent magnet bar outside said winding extending between said end pieces parallel to the axis of said form, means securing said end pieces to said base and holding said magnet between said end pieces, a paramagnetic sleeve inside said coil form surrounding said tube, said sleeve engaging one of said end pieces and being axially spaced from the other of said end pieces, a paramagnetic plunger in said tube and carrying striking means projecting from one end of said tube, and spring means within said tube for bringing said plunger to a rest position partially bridging the air gap between said sleeve and said other end piece.

7. An alternating current striker-actuating mechanism for audible signals, comprising, in combination, a base of non-magnetic material, a coil form, an alternating current solenoid winding on said form, a non-magnetic tube extending through the central axis of said form, a pair of plate-like paramagnetic end pieces disposed against the ends of said form and embracing said tube, said end pieces extending beyond the edges of said form, a bar magnet outside said winding extending between said end pieces parallel to the axis of said form, means securing said end pieces to said base and holding said magnet between said end pieces, a paramagnetic plunger in said tube and carrying striking means projecting from one end of said tube, a paramagnetic sleeve inside said coil form and extending part way from one of said end pieces toward the other end piece and leaving an air gap between it and the other end piece and spring means within said tube for bringing said plunger to a rest position partially bridging the air gap between said sleeve and said other end piece, shoulder means within the ends of said tube, said spring means comprising a pair of conically-shaped coil springs having their large bases disposed respectively against said shoulders and their small bases disposed respectively against the ends of said plunger, said plunger having centering means on the ends thereon for centering the ends of said springs with respect thereto.

8. An alternating current gong comprising, in combination, a base plate, a cup-shaped gong mounted on said base plate with its mouth facing said plate, and a solenoid-actuated striker mechanism nested beneath said gong, said mechanism comprising a coil form, a solenoid winding thereon, a non-magnetic tube extending through the axis thereof, a pair of plate-like steel end pieces disposed against the ends of said form and embracing said tube, a bar magnet alongside said form with its poles in engagement with said end pieces, a steel sleeve surrounding said tube within said form with one end thereof in engagement with one of said end pieces and the other end thereof terminating within said form and spaced from the other of said end pieces, a steel plunger slidable within said tube and a striker rod projecting from one end of said plunger and out of one end of said tube to a position spaced from the rim of said gong, shoulder means within the ends of said tube and a pair of coil springs within said tube having their ends disposed respectively against said shoulder means and the ends of said plunger, one end of said tube terminating sub-

stantially at that one of said end pieces with which said sleeve is in engagement and one of said springs being disposed predominantly radially within said sleeve, whereby said striker mechanism can be disposed beneath said gong.

9. In an alternating current striker-actuating mechanism for audible signals, a support member, a pair of steel end pieces mounted thereon in spaced relation with an axially aligned solenoid winding and tubular permanent magnet interposed therebetween, a plunger tube extending through said solenoid and magnet, a paramagnetic plunger within said tube, a striker rod on said plunger extending out of one end of said tube, and spring means positioning said plunger within said tube.

10. In an alternating current striker-actuating mechanism for audible signals, a support member, a pair of steel end pieces mounted thereon in spaced relation with an axially aligned solenoid winding and tubular permanent magnet interposed therebetween, a plunger tube extending through said solenoid and magnet, a paramagnetic plunger within said tube, a striker rod on said plunger extending out of one end of said tube, and spring means positioning said plunger within said tube, and a steel sleeve surrounding said tube within said winding with one end thereof adjacent an end of said magnet.

11. An alternating current striker mechanism comprising a tubular guide member slidably housing therein a reciprocable plunger and spring means for urging the plunger outwardly, an alternating current solenoid winding disposed around said guide member, a pair of end pieces of paramagnetic material disposed at the ends of said winding, a bar-type of permanent magnet adjacent and at one side of said winding and having its poles in contact with said end pieces, and an annular extension of paramagnetic material extending from one of said end pieces toward the other of said end pieces between said winding and said guide member, said extension terminating intermediate the ends of said winding and coacting to form an axially extending gap for flux produced by said solenoid winding and for flux from said permanent magnet, said plunger coacting with said flux.

12. In a device of the kind described the combination of a solenoid winding and a paramagnetic plunger reciprocably mounted therein, end pieces of para-magnetic material extending across the ends of the solenoid, a sleeve of para-magnetic material extending from one of said end pieces toward the other of said end pieces, around the said plunger and with its internal surface of greater diameter than said plunger and with its end spaced axially from the said other of said end pieces to form therebetween an axially extending gap, and spring means positioning said plunger within said solenoid with an end of the plunger axially spaced from one end of said gap, said end pieces being extended radially beyond said solenoid to receive and contact with the respective ends of a bar magnet.

13. In an alternating current reciprocating motor unit a solenoid winding having an axial bore and an internal non-magnetic sleeve received in said bore and partially closed at its ends, a permanent magnet in the form of an elongated bar with its longitudinal axis coincident with the axis of said sleeve and producing a unidirectional flux that extends axially along said bore, a soft iron core within said sleeve, a first resilient means interposed between the soft iron core and one end of the sleeve, the soft iron core being axially displaceable in said sleeve and being provided with an axial extension extending to the exterior of said sleeve, a second resilient means surrounding said extension and bearing against the other end of said sleeve and a portion of the said soft iron core nearest the end of said sleeve through which the extension projects, and holding means for fixing the permanent magnet bar positioning it coaxially of said bore and with a pole face extending transversely of the axis of the bore whereby its flux extends axially along the bore and energization of the winding of said solenoid by alternating current causes reciprocating movement of said axial displaceable core.

14. In an alternating current reciprocating motor unit a solenoid winding having an axial bore, a non-magnetic sleeve received in said bore, a paramagnetic plunger mounted for reciprocation within said sleeve, said plunger comprising a core having an extension projecting from one end of the sleeve, spring means between the ends of said plunger and the ends of said non-magnetic sleeve respectively, end pieces of paramagnetic material extending across the ends of the solenoid, said end pieces being extended radially beyond and to one longitudinal side of the solenoid, and a permanent magnet in the form of a straight bar extending along said side of said solenoid and having pole faces at its opposite ends, said magnet bar bridging between and being received between the said extended portions of said end pieces, and a sleeve of paramagnetic material extending from one of said end pieces into said bore and around said non-magnetic sleeve and terminating in spaced relation from the other of said end pieces and coacting therewith to form an axial gap into which said paramagnetic core extends.

15. An alternating current synchronously-responsive striker-actuated signalling mechanism comprising in combination an impact signal element, a solenoid winding defining an axially extending channel having a reciprocable paramagnetic plunger therein and having related thereto the spaced pole extensions of a permanent bar magnet for producing a unidirectional magnetic field in said channel of a strength to produce a magnetic effect substantially greater than that produced by said solenoid winding at the peak value of the alternating current cycle energizing it, said plunger having a striker rod projecting out of one end of said channel to strike said signal element, and spring means acting axially upon said reciprocable plunger and having a non-linear characteristic between force and deflection to make up in substantial measure for the non-linear relation between plunger displacement and magnetic force exerted by said unidirectional field on the plunger, said non-linear spring means yielding to the pull exerted on the plunger when in one half-cycle of energization of said winding the flux of the latter aids the flux of said permanent magnet whereby the plunger and striker move in one direction and said spring means overcoming the pull exerted on the plunger when in the other half-cycle the flux of the winding opposes the flux of said permanent magnet whereby said plunger and striker move in opposite direction, said non-linear spring means coacting, during de-energization of said winding, with the pull exerted by said permanent magnet flux alone to position said plunger within said channel relative to said pole extensions.

16. An alternating current striker-actuating

mechanism for audible signals comprising in combination a pair of paramagnetic end pieces mounted in spaced relation with an axially aligned solenoid winding, and permanent magnet means interposed therebetween, said solenoid winding defining a channel, a paramagnetic plunger within said channel, a striker rod on said plunger projecting outwardly from said winding through one of said end pieces, and spring means positioning said plunger in said channel, said permanent magnet means surrounding said channel and having an end in contact with one of said end pieces.

17. In an alternating current reciprocating motor unit, a solenoid winding having an axial bore and an internal non-magnetic sleeve received in said bore, a permanent bar magnet coaxially aligned with said bore endwise so that flux from an end thereof extends into said bore, a paramagnetic plunger reciprocably mounted within said sleeve for movement in reversible strokes to move one plunger end toward and away from said end of said coaxially aligned permanent bar magnet and having an axial extension extending to the exterior of said sleeve, the end of said sleeve through which said extension projects being provided with apertured retaining means, and spring means positioning said plunger within said sleeve.

18. An alternating current striker-actuating mechanism for audible signals comprising a solenoid winding defining an axially extending channel and producing when energized a magnetic field that extends along said channel, means comprising a permanent magnet for producing a unidirectional magnetic field in said channel, a paramagnetic plunger within said channel and having means guiding it for axial reciprocating movement along the axis of said channel, a striker rod on said plunger projecting out of one end of said channel, and non-linear spring means positioning said plunger axially within said channel.

19. In an alternating current solenoid operated signal mechanism a support member for a form to receive a solenoid winding, a form for a solenoid winding supported on said support member, a solenoid winding on said form, a pair of end pieces of paramagnetic material at the ends of said solenoid, a channel through the center of said solenoid, a sliding paramagnetic plunger in said channel, non-linear spring means positioning said plunger in said channel, a paramagnetic sleeve surrounding said channel inside said solenoid winding, one end of said sleeve being in contact with one of said end pieces and the other end of said sleeve being spaced from the other of said end pieces whereby an air gap is provided within said solenoid of shorter length than said solenoid.

20. A device of the character described comprising a solenoid winding having an axial bore, said solenoid winding when energized producing a magnetic flux that extends along said bore and in the direction of the axis thereof, permanently magnetized means producing a unidirectional continuous magnetic field and having a flux-guiding face that is positioned substantially coaxially with said bore and at a point lengthwise of the axis of said winding so that the flux of said unidirectional magnetic field extends along said bore and throughout at least a portion of the length of the axial path of flux produced by said winding, a paramagnetic plunger for axial conduction of flux produced by said winding and having an end coacting with said flux-guiding face for flow therebetween of flux from said unidirectional field, and means guiding said plunger for axial movement thereof lengthwise of the axis of said bore and in reversible strokes whereby said end of the plunger is movable toward and away from said flux-guiding face, said guiding means comprising means exerting axially directed yieldable force upon said plunger and coacting to position the plunger with said one end thereof spaced from said flux-guiding face and to hold it in such position against the axial pull exerted thereon by the flux of said unidirectional magnetic field alone.

21. A device as claimed in claim 20 in which said permanent magnet means comprises an elongated permanet bar magnet having means supporting it coaxially with said bore, said flux-guiding face comprising one end face of said bar magnet.

22. A device as claimed in claim 20 in which said plunger-guiding means comprises a tube coaxial with said bore and said permanently magnetized means comprises an elongated cylindrical permanent bar magnet having a surface of revolution of the same radius as one of the surfaces of said plunger-guiding tube, said bar magnet and said tube being interfitted one within the other, and said flux-guiding face comprising one end face of said cylindrical bar magnet.

23. A device as claimed in claim 20 in which said plunger-guiding means comprises a tube coaxial with said bore and projecting from one end of said solenoid winding, said permanently magnetized means comprising an elongated cylindrical permanent bar magnet interfitted with and carried by said tube, the end face of said cylindrical bar magnet that is remote from said winding being positioned adjacent the outer end of the projecting portion of said tube and said flux-guiding face comprising the other end face thereof.

24. A device as claimed in claim 20 in which said permanently magnetized means comprises a solid elongated permanent bar magnet, and means mounting it in coaxial alignment with said solenoid winding, said flux-guiding face comprising that end face of said bar magnet that is nearest the center of the axial dimension of said winding, the other end face thereof being external of said winding and axially spaced therefrom.

25. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent magnet having a sleeve-like pole piece element substantially coaxial with said winding and extending into said bore, said flux-guiding face comprising one of the annular end faces of said sleeve-like element and said guiding means comprising a member extending into said sleeve-like pole piece element.

26. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent magnet having means mounting it externally of said winding, said permanent magnet being provided with two pole pieces positioned in spaced relation along the axis of said winding, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field.

27. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent magnet having means mounting it

externally of said winding, said permanent magnet being provided with two pole pieces spaced along the axis of said winding, one of said pole pieces being in the form of a sleeve-like element extending into said bore, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial spcae therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field.

28. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent magnet external of said winding and provided with two pole pieces spaced apart along the axis of said winding, each of said pole pieces comprising a sleeve-like element of which one extends toward the other, said flux-guiding face comprising the inner end face of one of said sleeve-like elements and coacting with the other sleeve-like element to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field.

29. A device of the character described comprising a solenoid winding having an axial bore, said winding when energized producing a magnetic flux that extends along said bore and in the direction of the axis thereof, permanent-magnet means producing a unidirectional continuous magnetic field and having a flux-guiding face that is positioned substantially coaxially with said bore and at a point lengthwise of the axis of said winding so that the flux of said unidirectional magnetic field extends along said bore and throughout at least a portion of the length of the axial path of flux produced by said winding, a plunger of magnetic material within said bore, and means for guiding said plunger for movement substantially axially along said bore and in directions toward and away from said flux-guiding face, said guiding means comprising spring means operating upon said plunger to position the latter with one end spaced from said flux-guiding face and hold it in equilibrium against the axial pull exerted thereon by the magnetic field produced by said permanent-magnet means alone and adapted to yield when said equilibrium is upset by the pull exerted on said plunger by both said magnetic field and the magnetic flux produced by said winding, said spring-means having a non-linear relationship between force and deflection to substantially compensate for the non-linear relationship between the force exerted by said unidirectional magnetic field alone and the distance of travel of said plunger throughout at least a substantial portion of the working stroke of the plunger, whereby the resultant of the spring force and the pull of said unidirectional magnetic field alone, on said plunger, is substantially a linear function of said distance of plunger travel.

30. A device as claimed in claim 20 in which said permanent magnet means comprises an elongated permanent bar magnet and a pole piece having means supporting them with one pole face of said bar magnet and a face of said pole piece coaxial with said bore and in spaced relation along the axis of said winding and with the other pole face of said bar magnet in flux-conductive connection with said pole piece, said flux-guiding face toward and away from which said plunger is axially movable comprising one of said faces.

31. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent bar magnet having means mounting it externally along a side of said winding with its axis substantially parallel to the axis of said winding, said permanent magnet being provided with two pole pieces positioned in spaced relation along the axis of said winding, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field, said two pole pieces having parts that extend in spaced relation to said side of said winding and said permanent bar magnet mounting means comprising said pole piece parts and a support of non-magnetic material for said pole piece parts with means for securing said pole piece parts thereto in said spaced relation, said spaced pole piece parts having holding portions which are interfitted respectively with the two end portions of said permanent bar magnet and which are held against movement away from said end portions upon securing said pole piece parts in said spaced relation to said support.

32. A device as claimed in claim 20 provided with a plate-like support of non-magnetic material and in which said permanently magnetized means comprises a permanent magnet bar with one side thereof resting against said support externally of said winding, said permanent magnet being provided with two pole pieces positioned in spaced relation along the axis of said winding, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field, said pole pieces comprising plate-like parts that extend therefrom to said side of said winding, said plate-like parts having flange-like elements overlapping the opposite side of said permanent magnet bar, and means securing said plate-like parts to said plate-like support in said spaced relation and by said flange-like elements hold said bar magnet against said plate-like support.

33. A device as claimed in claim 20 provided with a plate-like support of non-magnetic material and in which said permanently magnetized means comprises a permanent magnet bar with its bottom side resting against said plate-like support, said permanent magnet being provided with two pole pieces positioned in spaced relation along the axis of said winding, at least one of said pole pieces being apertured substantially coaxially with said bore of said winding and said plunger-guiding means comprising a non-magnetic tube within said bore to carry said winding and slidably supporting said plunger therein, said tube extending through and interfitted with said apertured pole piece and having means supporting it from the other pole piece and for holding it against lengthwise movement, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field said pole pieces having plate-like portions which extend in spaced relation toward said permanent magnet bar and which are provided with flange-like means overlapping top portions of said permanent magnet bar, and means coacting to secure said plate-like portions in said spaced relation to said non-magnetic plate-like support and thereby maintain said flange-like elements in said overlapping relation to said permanent magnet bar and to form rigid spaced supports for said tube and winding.

34. A device as claimed in claim 20 provided with a plate-like support of non-magnetic material and in which said permanently magnetized means comprises a permanent magnet bar external of said winding and extending parallel thereto, said permanent magnet bar resting against said plate-like support and said support being provided with spaced upstanding parts between which said magnet bar is received and held against shift toward or away from said winding, said permanent magnet bar being provided with two pole pieces having plate-like portions in flatwise flux-conductive engagement with the respective ends of said magnet bar, said pole pieces being positioned in spaced relation along the axis of said winding, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field, and means securing said plate-like portions in spaced relation to said plate-like support and in engagement with the respective ends of said permanent magnet bar thereby to hold the latter against shift in a direction parallel to said winding, said plate-like portions having flange-like elements overlying said permanent magnet bar and holding it against shift in a direction away from said plate-like support.

35. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent magnet external of said winding and provided with two pole pieces spaced apart along the axis of said winding, each of said pole pieces comprising a sleeve-like part each received into an end of said bore of said winding and terminating internally thereof in axially spaced relation and a part external of said winding and each in flux-conductive connection with a pole of said external permanent magnet, said flux-guiding face comprising an inner end face of one of said sleeve-like parts and coacting with the other sleeve-like part to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field, and means of non-magnetic material axially aligning said two spaced pole pieces, the other end of said paramagnetic plunger extending into said other sleeve-like part for flow of permanent magnet flux radially therebetween and said plunger having a coaxial operator part that extends externally beyond one of said pole pieces.

36. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent bar magnet having means mounting it externally and at one side of said winding, said permanent bar magnet being provided with two pole pieces having portions that extend to the respective ends of said bar magnet, said two pole pieces being positioned in spaced relation along the axis of said winding, said flux-guiding face comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field, said permanent bar magnet mounting means comprising said pole piece portions and a support of non-magnetic material with means securing said pole piece portions thereto in said spaced relation, said spaced pole piece portions having means extending toward each other for engaging side portions of said bar magnet at the respective ends thereof and held in engagement therewith and against endwise separating movement therefrom upon securing said pole piece portions to said support.

37. A device as claimed in claim 20 in which said permanently magnetized means comprises a permanent solid-bar magnet with plane pole faces having means mounting it externally of said winding, said permanent bar magnet being provided with two pole pieces having parts that are in respective flux-conductive engagement with said pole faces, said two pole pieces being positioned in spaced relation along the axis of said winding, one of said pole pieces having a round coaxial aperture therein of greater diameter than that of said plunger and the other pole piece extending coaxially therewith into said bore from one end of said winding and terminating in axially spaced relation from the other pole piece, said flux-guiding face toward and away from which said plunger is movable comprising a surface of one of said pole pieces and coacting with the other pole piece to bridge the axial space therebetween with magnetic flux that comprises the aforesaid unidirectional magnetic field.

38. A device as claimed in claim 20 in which said permanently magnetized means comprises an elongated tubular permanent bar magnet and a pole piece having means supporting them in relation to said winding with one pole face of said tubular bar magnet and a face of said pole piece coaxial with said bore and in spaced relation along the axis of said winding, said flux-guiding face toward and away from which said plunger is movable comprising said face of said pole piece, a portion of said plunger extending into that portion of said tubular magnet adjacent said pole face and being radially spaced therefrom for reciprocating movement relative thereto, said pole piece having flux-conductive connection with the other pole face of said permanent tubular bar magnet.

39. A device as claimed in claim 20 in which said permanently magnetized means comprises a solid elongated permanent bar magnet and a pole piece having means supporting them in relation to said winding with one pole face of said bar magnet and a face of said pole piece coaxial with said bore and in spaced relation along the axis of said winding, said flux-guiding face toward and away from which said plunger is movable comprising said pole face of said bar magnet and said pole piece being apertured and receiving therein and radially spaced therefrom a portion of said plunger for reciprocating movement relative thereto, said pole piece having flux-conductive connection with the other pole face of said permanent bar magnet.

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