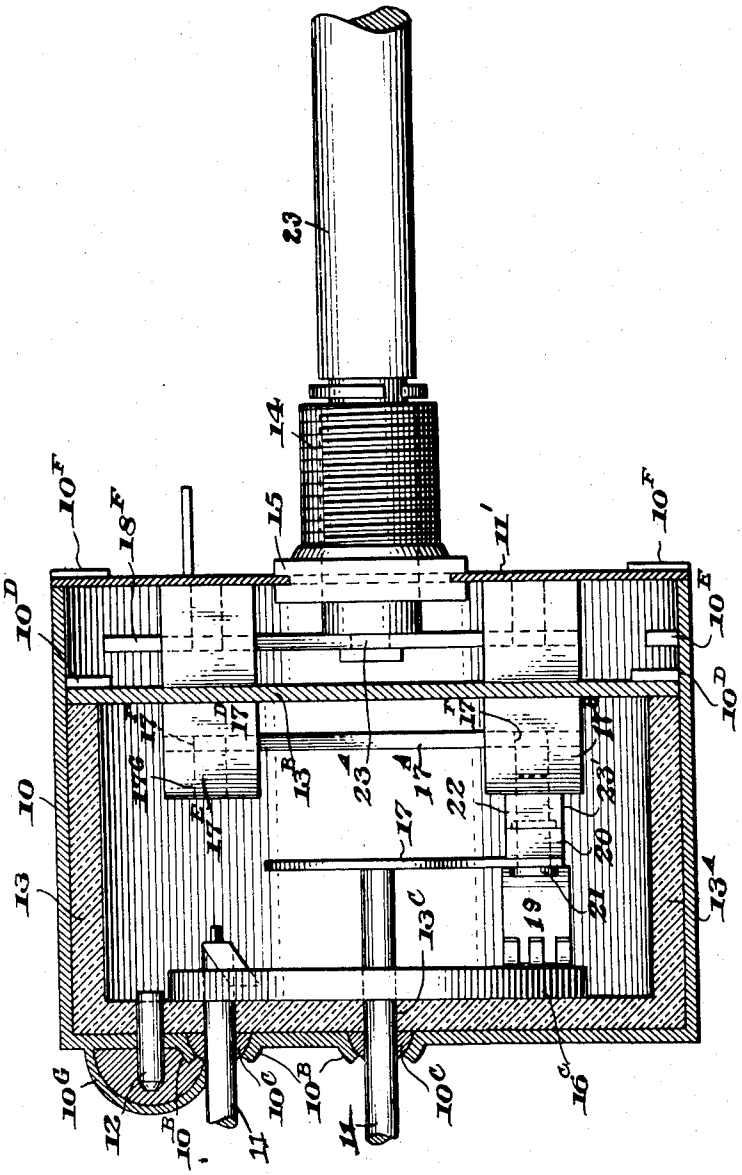
July 17, 1951 Z. HOF 2,561,116

VARIABLE RESISTOR

Filed Aug. 7, 1947 2 Sheets-Sheet 1

Fig. 1.



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VARIABLE RESISTOR

Filed Aug. 7, 1947 2 Sheets-Sheet 2

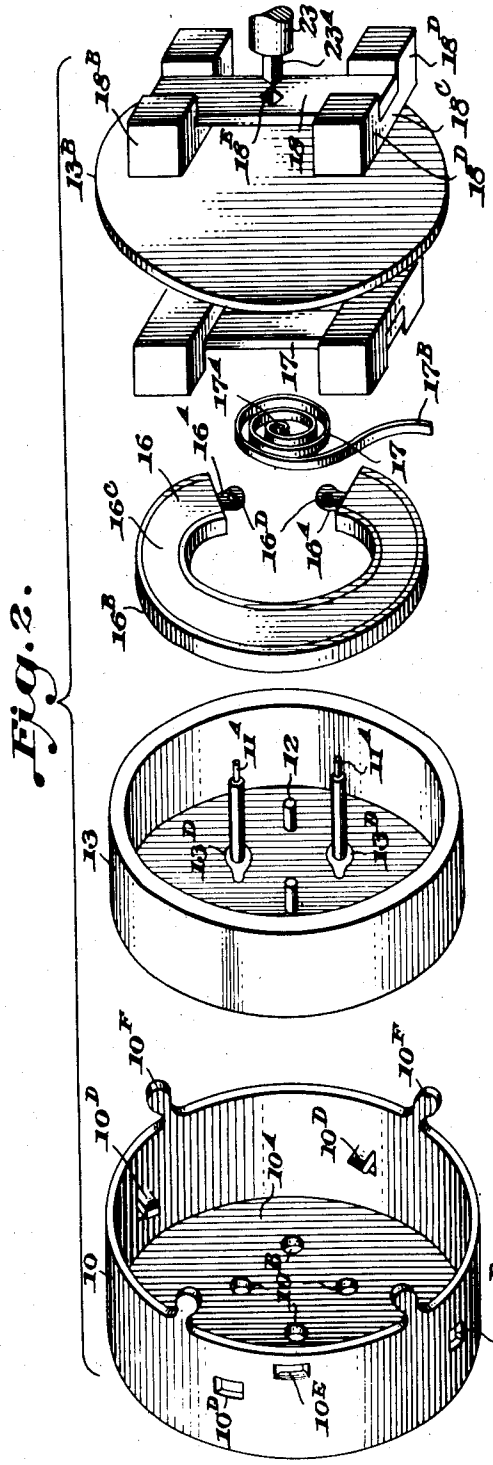


Fig. 2.

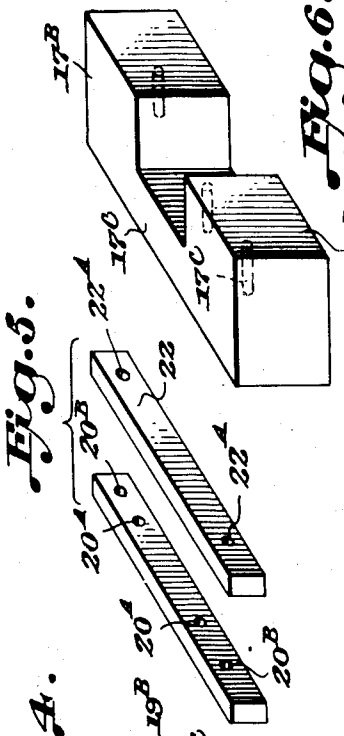


Fig. 5.

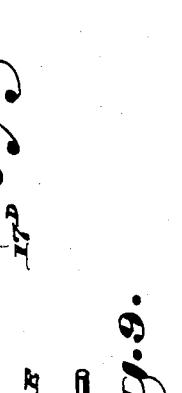


Fig. 6.



Fig. 4.



Fig. 9.



Fig. 8.



Fig. 3.

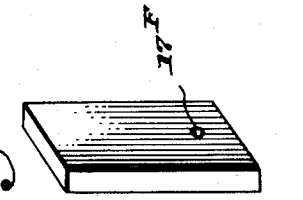


Fig. 7.

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Patented July 17, 1951

2,561,116

UNITED STATES PATENT OFFICE

2,561,116

VARIABLE RESISTOR

Zygmunt Hof, Jerusalem, Palestine

Application August 7, 1947, Serial No. 767,193

1 Claim. (Cl. 201—55)

1

My invention relates to improvements in radio equipment, and more particularly concerns an improved and substantially noise-proof volume control adapted for such generalized purposes.

An object of my invention is to provide a volume control assembly for service in electronic equipment, which is tightly sealed against substantially all ingress of foreign matter, either solid or liquid, while at the same time permitting ready, certain and accurate modulation of volume, which is readily assembled, employs a minimum number of moving parts, together with a minimum number of parts of specialized design, is of low first cost as well as low maintenance and operation cost; and, small, unitary, compact, sturdy, is reliable and highly efficient, with low magnetic and electrical losses, and requires minimum iron content.

All these as well as many other thoroughly practical objects and advantages attend upon the practice of my invention, some of which will in part be obvious and in part more fully pointed out hereinafter during the course of the following description.

My invention accordingly resides in the several parts, elements and features of construction, as well as in the combination of each of the same with one or more of the others, the scope of the application of all of which will more fully be pointed out in the claim at the end of the specification.

In the drawings, wherein I disclose one embodiment of my invention which I prefer at present, and throughout the several views of which like reference characters denote like parts,

Figure 1 is a view, partly in side elevation and partly in section, of my new construction, while

Figure 2 is an exploded view, in side elevation, with parts disposed in such manner as to disclose most readily the manner and mode of assembly.

Figures 3–9 inclusive show the details of the components of the construction shown in Fig. 2.

As conducive to a more thorough understanding of my invention it may be noted at this point that throughout the field of electronics and particularly in those instances where audio-frequency signals are processed, volume control failure has long represented a point of particular vulnerability. Such controls have required replacement with distressing rapidity, usually long before other elements of the assembly require servicing.

After considerable study, I reached the conclusion that these disadvantages stemmed in large measure from an accumulation of dirt, from the action of humidity, and from a combination of these two factors. This damage is brought about principally in the inner shell, comprising an essential part of the usual volume control. The net result is summed up in a noisy action, frequently accompanied by blurred and indistinct audible output.

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My studies disclosed that these two destructive elements enter the inner shell through adhesion and suction. This effect is of course accumulative and over a protracted period of time as measured on an absolute basis. It appears that moisture, grease and dust combine to form a film, having abrasive qualities. This film is migratory in nature, and forming at the exterior, at the outside edge of the control shaft, moves inwardly of the casing, much akin to liquid poured on a glass rod. Pressure differences between the air exteriorly and interiorly of the casing contribute to this action. This results from the enclosure serving as a temperature insulation, and temperature differences build up between the exterior and interior bodies of air. Under Charles's law, then, a pressure difference is likewise established, conducing to the inward migration of the abrasive film. That this is so is demonstrated, I believe, by the fact that the major part of the accumulation of dirt will be found on the sliding metallic hub in the center of the casing, adjacent the shaft.

Having reached these general conclusions, I thereupon directed my attention to the problem of preventing access of this dirt and accumulation of debris to the essential mechanism of the volume control. I reached the conclusion that the only practical manner of completely eliminating ingress of undesirable elements would be through entirely enclosing the working parts of the mechanism, and operating them through an indirect, mechanically separate connection. I decided upon a magnetic inductive coupling as a practical embodiment of such inventive concept.

An important object of my invention is, therefore, to eliminate and avoid in substantial measure the defects and disadvantages heretofore existing in the prior art, and at the same time to provide a noiseless volume control for use in electronic equipment, particularly household radios and the like, which, while embodying the combination of two entirely new principles of vacuum-tight sealing and magnetic coupling, retain style, type and dimensioning of parts as nearly consistent with heretofore conventional

equipment as is possible, thereby involving a minimum of change-over and use of specialized parts.

And now having reference more particularly to the embodiment of my invention disclosed in exploded Figure 2 and in the assembled Figure 1, I provide an outer casing 10 of conventional configuration, formed in the preferred instance of suitable metal. In the present embodiment this casing has a diameter of one and one-half inches, its depth being determined by the size of the coupling magnets later to be described. Casing 10 is open at one end and has a closed bottom 10A. Buckles 10B are struck outwardly from the bottom 10A for cooperation with air-tight seals in the inner envelope. These buckles and seals combine to serve for sealed passage of the terminal studs or metal rods 11 and for the exhaust stem 12, each of which extends through the outer metal casing 10 and through the snugly received interior glass envelope indicated generally at 13 and later to be described.

It will be observed that the casing 10 must be sufficiently strong to carry the inner glass envelope 13, vacuum tight in nature, together with the contents of the latter. I provide clamps 10D struck inwardly from the casing 10 intermediate its depth, for firmly gripping and clamping the envelope 13 in fixed relation relative to the casing 10. Moreover, I provide a stop 10E struck inwardly from the casing 10 intermediate its length and in the path of that one of the coupling magnets, later to be described, which is located exteriorly of the glass envelope 13, but within the casing 10. I position the stop 10D in such manner that it arrests the rotary movement of the outer coupling magnet so that the slidable contact member within the envelope 13 and later to be described, stops exactly at the terminals of the cooperating resistance strip which likewise will later be described, and the exact construction of which will be pointed out hereinafter.

Inasmuch as the single stop 10E serves to limit accurately the motion of the outer magnet in nicely determined manner and for the purpose which I have already pointed out hereinbefore, then the dimensioning of the stop 10E represents a simple but nice emperical matter so that blocking of the outer coupling magnet in either direction of travel will position the sliding contact exactly over the resistance strip.

Finally, clamping fingers 10F disposed about the periphery of the rim of the casing 10 serve to clamp firmly about the lid 11 which seats over and closes the casing 10. In the typical instance here undergoing description, lid 11 has an outer diameter of about one and one-half inches and constitutes an annulus having an inner bore of about $\frac{7}{8}$ inches in diameter. I make lid 11 fast to volume control mounting 14 (Figure 2) through clamping ring 15.

It is now in order to consider further the inner glass envelope 13 disclosed in both figures of the drawings. Envelope 13 fits tightly into the outer metal casing 10, so as to be accurately oriented therein and secured against motion relative thereto. This envelope may be envisioned as comprising two parts, constituting a bottom cup-shaped part 13A and a top disk 13B, sealed and flowed together as by melting after the assembly therein of the component elements of the volume control. I mold the metal rods or terminal studs 11 into the envelope 13 at 13C after they have been passed through the outer casing 10 at 10B. These rods 11 are left protruding on either side of the casing 13 to serve as terminals for the resistance element and for the sliding contact later to be described.

The exhaust stem 12, already described with reference to Figure 1 as extending through the outer casing 10, is now seen to extend in the manner shown in exploded view in Figure 2, through and into the glass or vitreous envelope 13 through the bottom wall 13A thereof. This stem serves to permit the evacuation of, and to hermetically seal the interior of the envelope 13 after all parts have been assembled therein.

It is of course apparent from the foregoing that the mechanical dimensioning of the container 13 and the several parts contained therein are dependent almost solely on the strength of the various materials available from which to construct these elements. Thus, the thickness of the bottom part 13A of the envelope 13 is dependent upon the unit strength of the glass or other vitreous material from which it is formed. The same is true of the gauge used for the construction of the exhaust stem 12, as well as the gauge and internal diameter of the metal rods 11, 11. The length of metal rod protruding exteriorly of the envelope 13 and casing 10 is simply an arbitrary matter of choice. If desired, they may terminate in soldering lugs. Interiorly, the rods, adapted for cooperation with the resistor element 16, terminate in reduced shoulders 11A, 11A, for snug reception, in the preferred instance by soldered connection, with the end lugs 16A, 16A of the resistor 16. That terminal rod 11 which cooperates with the contact connection spiral 17 may or may not have reduced shoulder portion, as desired. More will be said about the resistor element 16 and the connecting spiral 17 at a later point herein.

Returning for the moment to a discussion of the top or cover disk 13B which is sealed by flowing together the glass or other vitreous material from which the container 13 and top 13B are formed along the rims thereof, this material, whatever may be the choice, must satisfy two basic requirements. This top disk 13B must have absolutely smooth and plane surface, and at the same time must be as thin as possible, consistent with the requisite strength which it must have. This is because the magnets 17, 18 which cooperate in achieving the coupling effect on which my invention relies, must slide against the top disk 13B on opposite sides thereof with the least possible contact friction and without oiling or interposition of other lubricant. Thus, the disk surface must be absolutely smooth in order to minimize friction and abrasion of the magnets themselves. Moreover, for reducing frictional resistance, the magnet faces themselves must have maximum smoothness.

Returning at this time to a consideration of the resistor element 16 within the inner glass envelope 13, it is to be noted that the resistant strip illustrated is of the so-called composition type control wherein a "Bakelite" or other synthetic resin form 16B is employed, on which the resistance belt 16C is deposited. The end lugs 16A are molded in the Bakelite, in firm contact with the composition material. The entire contact is in the form of a flat annulus comprising a nearly complete circle, but open at the ends thereof through a slight angular extent. The end lugs 16A have holes therein 16D cooperating with the studs 11A shouldered on the ends of the terminal rods 11. After assembly, I find it better practice

to solder the end lugs 16D on the corresponding studs 11A. It is of course apparent that one conventional control may be substituted for another, and that conveniently a wire-wound resistance strip (not shown) may be employed in entirely similar manner. For communication equipment controls which are constructed with an assembly of fixed resistors, calculated in steps conforming to the required attenuation, and connected to contact studs which are arranged on circular strips and over which a contact finger glides the conventional construction may be employed within a larger glass envelope and casing, containing the resistor assembly, and the circular contact strips taking the place of the resistance belt 16C.

Overriding and cooperating with the resistor 16 is a contact finger or the like generally indicated as a frictional sliding contact member 19 shown in Figure 1 and in greater detail in the exploded view comprising Figure 2. The sliding contact member, the details of which vary depending upon whether the conventional type molded resistance is employed or the equally conventional wire-wound resistant strip, is likewise conventional in style. It is adapted to be carried from the inner magnet 17 which as will be seen, is disposed within the glass envelope 13. It is of course essential that for proper operation of the volume control, the contact element 19 must remain electrically remote from the magnet 17 and must be fully insulated therefrom. To this end, the contact member 19, here shown roughly of U-shape, with spring-like contact fingers 19A bent inwardly from one extremity of the U so as to conform closely to the top surface of the deposited, conductive resistance belt 16C of the resistance strip 16, is made fast to an insulating strip 20, here disclosed as of elongated rectangular shape, in any suitable manner. In the present embodiment rivets 21, 21, seating through holes 19B, 19B punched through the outer leg of the U-shaped, contact element 19, are passed through inner holes 20A, 20A punched in the insulating strip 20. To provide insulation against the heads of the rivets 21, 21, a second insulating strip 22 identical in external dimensions with the insulating strip 20 already described is likewise provided, closely contiguous to strip 20 and connected therewith in suitable manner, as by pins 23' extending through holes 22A, 22A in insulating strip 22 and seated in outer holes 20B, 20B of insulating strip 20.

Inasmuch as there is no physical contact between the rivets 21 it makes no difference of what material the pins 23', 23' are formed. They may be of a hard, insulating synthetic plastic, or of metal. The electric connection for the contact pin 19 is through the metal rod 11 to which is made fast the inner end 17A of contact spiral 17, and thence through the elongated terminal 17B thereof made fast in suitable manner to contact finger 19 as by soldering, welding or the like, to the upstruck finger 19C provided at the top outer extremity of the rightmost leg (Figure 4) of the contact finger.

It has been stated that the contact finger 19 is mechanically carried by the inner magnet 17. It is desirable at this time, therefore, to consider the configuration of this magnet. In reality, the coupling magnet 17 comprises two magnets disposed one at each end of a connecting bar 17A. The connecting bar 17A is rectangular in section and has a length somewhat short of that of the internal diameter of the glass envelope 13. Snugly received in each end of the bar 17A are

the coupling magnet elements 17B. One of these is shown at the top and the other at the bottom of Figure 2 near the right end thereof. Each magnet 17B is of substantially U-shape, the yoke portion 19C thereof being of comparatively small thickness, while the end pieces 17D are of massive cross-section. Conveniently, each magnet 17B is made fast to its corresponding extremity of the bar 17A by suitable means such as pin 17E seating through hole 17F of bar 17A and into corresponding hole 17G in the yoke portion 17C of the respective magnets 17B. To prevent disturbance of the flux stream, the pin 17E preferably should be formed of para-magnetic material.

Stated in other words, the magnet 17 consists of two equal magnet elements 17B interconnected by bar 17A conforming to the inner, U-shape of the magnets 17B. Center pin 17E serves to make the bar and magnet elements fast to each other. It will be noted that the bar 17A is disposed freely within the envelope 13. Its sole function is to coordinate the motion of the magnets 17B, 17B. These latter are thereupon, upon final assembly, locked into phase with the outer magnet 18, and are carried in space, clear of the side walls of the envelope 13.

In assembly, the three terminal rods 11 are molded into the bottom 13A of the casing 13, while the exhaust stem 12 is likewise sealed therein. The resistance strip 16 is thereupon nested within the container 13 against the bottom thereof so that the lugs 16A are seated over the studs 11A of the terminals 11 and are soldered or otherwise seated in position. It is to be noted that it is unnecessary for the terminal rods to protrude any considerable distance into the casing 13, to fulfil their desired objective. On the contrary, and for economy in space, it is desirable that they project into the envelope 13 the smallest possible distance. The spiral 17 is made fast at 17A to the third terminal rod 11 as by soldering or the like while the finger 17B thereof is made fast at 19C to the U-shaped contact element 19, the fingers 19A of which bear against the composition resistance surface 16C. The flexibility of the spiral 17 prevents interference of the latter with the contact finger 19 as the latter is assembled by rivets 21 against insulating strip 20, the latter being made fast by pins 23' to the insulating strip 22. Finally, these elements are assembled by pins 23' to the lower magnet 17B which in turn is made fast to one end of the bar 17A by pin 17E. It is of course possible to assemble the contact 19 on the magnet 17B before this contact is made fast to spiral 17. The mode of assembly is optional in this respect. When the mechanism is finally assembled within the envelope 13, the cover disk 13B is applied and sealed thereagainst. The glass envelope 13 is then ready for exhaustion sealing through the exhaust tube 12.

The glass envelope 13 is thereupon placed in casing 10 and clamped into position by clamps or the like 10D. The terminal rods 11 project exteriorly thereof at 10B, which serve as buckles for the reception of air-tight seals 13D for the envelope 13. The buckles 10B cooperate in insuring proper positioning of the envelope 13 within the casing 10.

Closely overlying and cooperating with the cover disk 13B, and within the confines of the outer casing 10, at the right or open end thereof, is the second magnet 18. This is much like the magnet 17 already described. It constitutes an elongated bar member 18A of rectangular section,

Fast at each end thereto in desired conventional manner are U-shaped magnet elements 18B, 18B, each having a central yoke portion 18C made fast to the bar 18 and terminating in massive leg elements 18D projecting outwardly towards and into contact with the cover disk 13B of the glass envelope 13. By rectangular or square-sectioned opening 18E disposed centrally of bar 18A, magnet 18 is made fast to the similarly sectioned, shouldered studs 23A provided on the end of the volume control shaft 23. This magnet 18, when brought within the container or casing 10 into contact with the outer surface of the cover disk 13, attracts and brings into step therewith the corresponding magnet element 17B of the magnet assembly 17. Magnet 17 is thus carried free in space. In this manner, the working heads 17D and 18D of the respective magnet assemblies 17, 18 come into positive contact with the respective surfaces of the disk 13B. Rotation of the outer magnet assembly 18 is accompanied by corresponding rotation of the inner magnetic assembly 17.

Outer magnet assembly is limited as to its extent of rotation, falling short of a full 360° amplitude by means of cooperation of a stop 10E struck inwardly from casing 10 and a corresponding stop 18F (top right of Figure 1) comprising an extension of the magnet bar 18A and intercepting the stop 10E. In this manner, and by proper dimensioning of the width of the stop 10E, it is insured that in either direction of rotation of the magnet assembly 18, the contact element 19 will reach a limit position corresponding to the limit of travel of the contact fingers on the resistance strip 16.

The mounting of the magnet assembly 18 on the volume control shaft 23 is center to center so that the magnet assembly rotates together with the shaft 23. The two magnets 18B, 18B fast to the end of the bar 18A rotate in a circle on the exterior of the glass envelope 13. Inasmuch as the paired magnet elements 17B, 18B are exactly opposite each other, with the disk 13B interposed therebetween, they are linked by the magnetic force and the magnet elements 17B follow the rotation of the magnet elements 18B. The movement of the volume control shaft is transmitted solely through this magnetic coupling without physical connection to the sliding contact 19, fast to one of the inner magnets 17B.

It can be readily computed from the theoretical standpoint that the minimum magnetic force required to link the corresponding magnets 17B, 18B together during rotation is a composite of that required to overcome the friction of the magnets 17B on the disk 13B, the friction of the contact spring 19A on the resistance strip 16, the force necessary to overcome the resistance of the spiral 17, and that required to overcome the system inertia. It can best be determined experimentally. While the foregoing determined the theoretical minimum magnetic force required, in actual practice I find it advantageous to provide a substantial margin of safety, and to provide for a substantially greater magnetic force to minimize the time and phase lag with which the inner magnets 17B follow the movements of the outer magnets 18A. In other words, backlash should be kept to a minimum value. In dimensioning the magnets in the initial design, the determining factors comprise not only the thickness of the air gap constituted by the glass or other vitreous wall 13B interposed between cooperating magnet elements, but as well, the size and shape of the magnets and the magnetic properties of the materials from which they are formed. Keeping in mind that the dimensioning of the volume control depends principally on the size of the magnets, these must be maintained reasonably small, and advantage taken of all favorable magnetic and electric qualities inherent in the several elements.

Moreover, keeping in mind that the magnetic flux between opposed faces of the magnets is proportional to the area of such faces, it is apparent that each magnet element 17B, 18B should be kept as short as is consistent with the passage of sufficient flux to overcome the reluctance of the air gap. For highest magnetic efficiency I find it advantageous to concentrate the largest contact area at the outer perimeter of the magnet elements, to provide for greater turning movement or level action, and to provide a pole separation just sufficient to avoid excessive losses through flux leakage. The reconciliation of these various objectives is a question of expediency in design. Thus, whether special dies be provided for the formation of the magnets or whether compromise should be relied upon through the utilization of the most nearly suitable standard design depends upon the particular manufacturing technique and marketing problems. The position of the magnet poles should be such that the greatest possible change of flux is effected through the motion of one magnet. That is to say, the north and south poles of each magnet must lie on the same circle of rotation for maximum transfer of motion between the magnets. This is but another way of saying that all parts of the magnets should be symmetrical with respect to each other.

The choice of the magnetic material of conventional composition and merchantable availability depends on the magnetic force which is required. This is determined by experiment, the size and shape which can be imparted to the magnets, and on the manufacturing process itself employed in producing the magnet elements.

It is of course to be understood that the particular mode of securing the magnet elements to the bars, as well as the mode of securing the insulating strips thereto, through the use of pins, is solely by way of illustration and that other conventional modes of connection may be employed which perhaps may prove more satisfactory in working with a particular magnetic material. In every instance, however, it is essential that the faces of the magnets which slide on the polished surfaces of the vitreous element 13B must be ground absolutely flush and must have a high polish.

In the design of the top disk 13B it should be kept in mind that inasmuch as this latter forms a magnetic separation between the coupling magnets and defines an air gap in the magnetic path, this disk, as has already been suggested, must be maintained at the smallest possible thickness commensurate with requisite mechanical strength. For the smaller the air gap between the cooperating magnet elements, the greater is the effective magnetic force therebetween. Thus, with given magnetic force requirement for the desired magnetic action, then the smaller the air gap (the thinner the glass disk) the smaller is the flux requirement for passage across the high reluctance air gap and the smaller will be the dimensions of the magnet elements required. Inasmuch as the dimensions

of the magnet elements control the dimensions of both the inner envelope 13 and the outer case 10, it is apparent that the size of the complete volume control is substantially affected by even slight reduction in the thickness of the glass disk 13B. In designing this glass disk it should be noted that while it is exposed on both sides to the pressure of the coupling magnets sliding thereover, these pressures are substantially equal and opposed to each other, and substantially cancel out. A slight unbalanced pressure is also exerted from within the envelope 13 through the reaction of the sliding contact 19 pressing against one of the inner magnet elements 17B. The disk must have sufficient rigidity to withstand not only these two pressure factors, but as well, the external atmospheric pressure.

The material of which the disk is made must be such that no structural strains occur therein either before or after it has been secured to the bottom cup portion of the envelope 13. This is essential to avoid warping of the surface of the disk, which must be kept absolutely flat.

It is at once apparent from the foregoing that my new construction is substantially foolproof, and in all practical respects completely avoids the difficulties and disadvantages heretofore discussed and which presented almost insurmountable difficulties to the prior art. The inner envelope 13 is completely sealed, so that all ingress of dirt, moisture or the like, is effectively prevented. Completely and hermetically sealed, the casing and its contents are immune against rust. Physically separate from the exterior, the contents of the envelope 13 are entirely free from ingress of any injurious ingredients by way of the operating shaft. Inasmuch as the inner magnet 17 floats in space except for its sliding contact against the face disk of the envelope 13, and since the contact fingers slide only against the resistance element, the number of moving parts are effectively reduced to a minimum. Only moderate wear occurs. Moreover, nice adjustment of the traverse of the contact fingers over the resistance element is achieved in the ingenious manner heretofore discussed. Accurate, sensitive response is achieved, with but a minimum departure from hitherto known construction and with substantially no increase in the overall dimensions of the volume control unit. Thus, the latter is enabled to be replaced with minimum change in an electronic assembly in which such volume control is employed. All these as well as many other highly practical advantages are achieved by the practice of my invention.

Since it is apparent from the foregoing that many embodiments of my invention will readily occur to those skilled in the art once the basic principles thereof are disclosed, and since it is further apparent that many modifications of the present embodiment will likewise suggest themselves, all falling within the sphere and scope of my invention, I intend the foregoing disclosure to be considered as merely illustrative and not by way of limitation.

I claim:

As a new article of manufacture, a radio volume control comprising an outer casing, a sealed envelope snug therein, and carrying a resistance and a cooperating sliding contact therefor, and having a nicely finished cover disc, and cooperating magnets disposed one on each side of said cover disc, said magnets being of generally similar physical and magnetic dimensions and characteristics, and each comprising an elongated central bar of comparatively small mass and cross-section and like magnetic elements disposed one at each end of each said bar of cross-sectional area and of mass which are substantial compared to those of the cooperating bar so as to impart substantial moment of inertia thereto, the outer magnet being disposed flush against the cover disc, means disposed centrally of the elongated bar of said outer magnet and projecting normally therefrom whereby said outer magnet may be quickly and accurately adjusted to any selected position relative to said resistance and sliding contact, manually and at the will of the operator, the said means comprising a rotatable shaft on which said outer magnet is carried, and including means for manually rotating said shaft, and the inner magnet being attracted flush against the cover disc by the outer magnet and carried freely, rotating in locked step with the outer magnet, said inner magnet being operably connected in magnetic sense with said sliding contact, but electrically insulated therefrom, so as to accurately and quickly position said sliding contact relative to said resistance in exact conformity with the manually-adjusted instantaneous position of the outer magnet, electric terminals for said resistance and said sliding contact extending exteriorally through said sealed envelope, a spiral of electrically conducting metal interconnecting one said terminal and said sliding contact and made fast to each of them in fixed and non-movable manner, and a stop provided in the outer casing for limiting the motion of the outer magnet so that the sliding contact remains always in contact with the resistance.

ZYGMUNT HOF.

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