July 23, 1963 C. L. FARRAND ET AL 3,098,990

PRECISION VOLTAGE RATIO TRANSFORMER

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Fig. 4

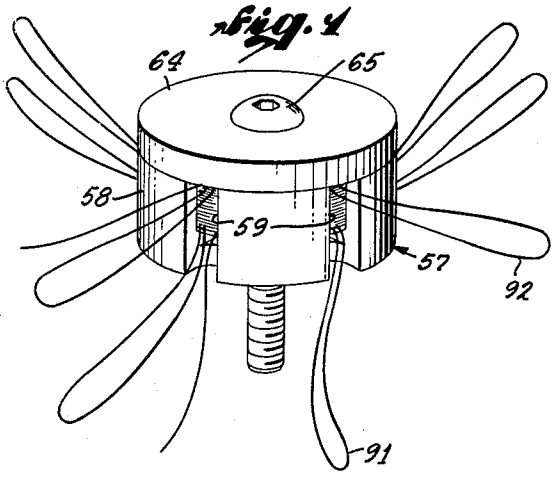


Fig. 2

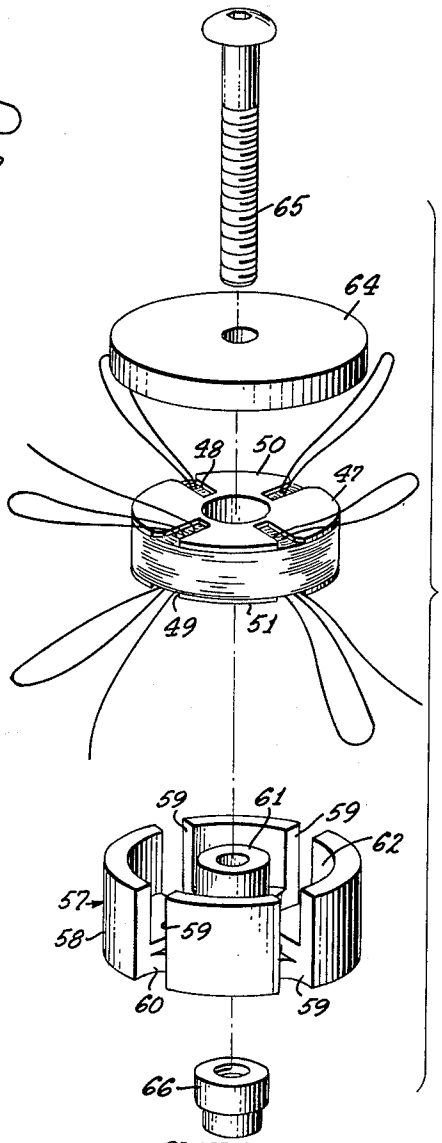
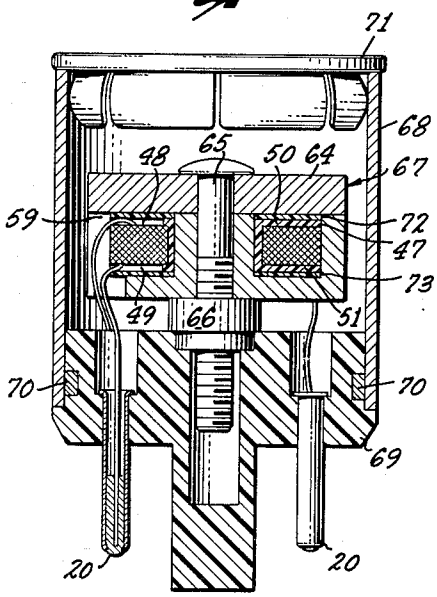


Fig. 3



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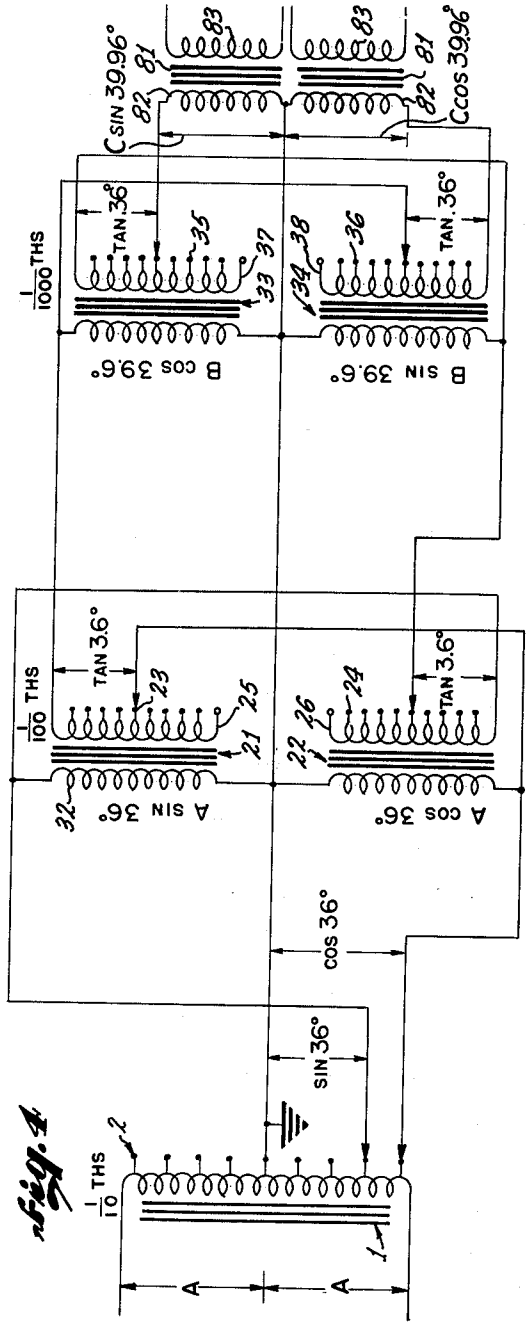


Fig. 4

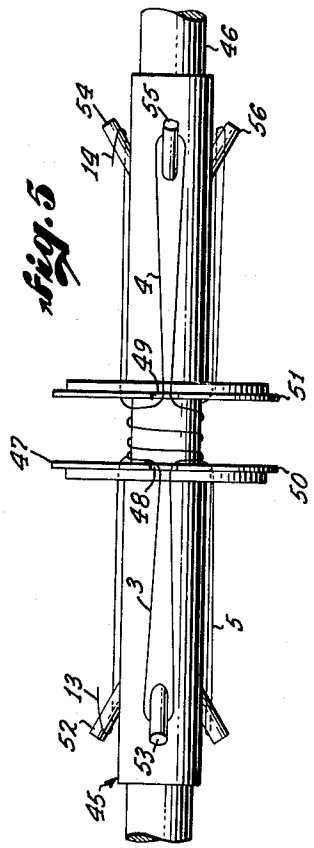


Fig. 5

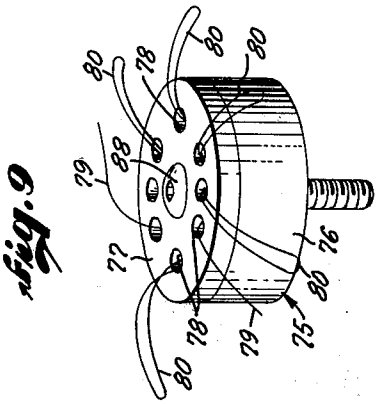


Fig. 9

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Fig. 8

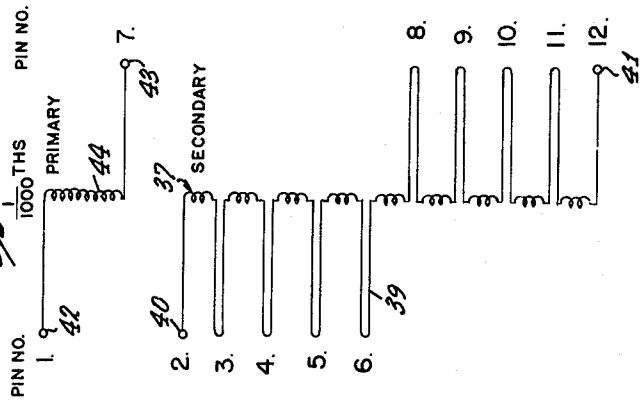


Fig. 7

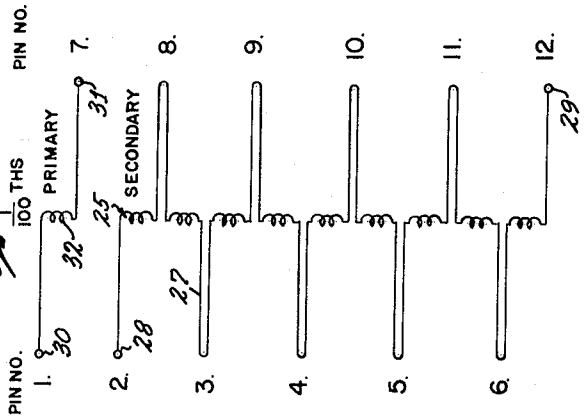


Fig. 6

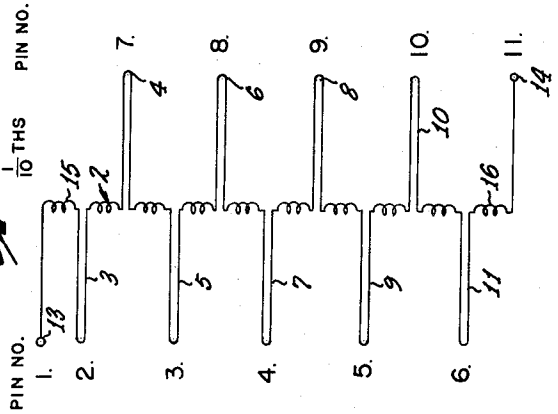


Fig. 11

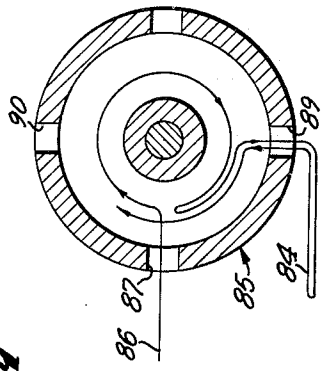
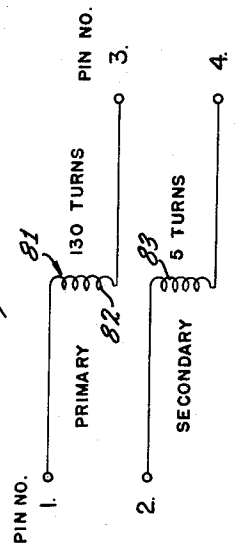


Fig. 10



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PRECISION VOLTAGE RATIO TRANSFORMER

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11 Claims. (Cl. 336—172)

This invention relates to precision transducers and more particularly to improvements in computing transformers of the type utilized in U.S. Patent 2,849,668, issued to R. W. Tripp on August 26, 1958.

An object of the invention is to provide an improved transformer having more precise ratios of voltages between its windings and wherein the transformer is of small size and can be made economically. The invention may be applied to inductive devices having turns represented by a whole number or by fractional turns.

A particular object of the invention is to provide a transformer structure which can be easily wound with any desired amount of fractional turns, thus permitting the use of fewer turns with high accuracy of voltages and reduced cost of winding.

A further object of the invention is to produce a transformer in which the voltage ratios are obtained by a modified type of core, but are unaffected by the assembly of the core.

These objects are accomplished in connection with a magnetic structure wherein the core is in the form of a cylindrical pot and cover with the winding completely enclosed in magnetic material. The core is constructed with one member apertured to permit the tapped turn to come out of the core at a point corresponding to the desired fraction of one turn, the other mating member preferably not being slotted, whereby its position will not affect the distribution of the flux in the magnetic legs between the slots.

A suitable magnetic material is powdered iron or oxides of iron, such as ferrite.

A further object is to provide a core construction which facilitates varying the effective number of turns of the winding.

Another object is to provide a wiring assembly to facilitate winding a bobbin with fractional turns, and/or an extra lead for varying the fractional part of a turn as described below.

In computing transformers, it is desirable that the ratio of voltages of the windings or sections of windings each to the other be precise.

According to the invention, the windings of the transformer are coupled by a common magnetic field and the leads of at least one of the windings are positioned to link with a fraction of the magnetic field, thus providing a voltage ratio corresponding to the ratio of the number of turns of the one winding plus the fraction to the turns of the other winding. Preferably, a plurality of taps are provided for interlinking with different fractions of the magnetic field. By the invention, any voltage ratio within the ratio of turns of any two windings including any fraction of one turn of one or both of the windings is produced.

More particularly, by the present invention the desired ratio of voltages between two windings is not limited to integral numbers of turns but can be secured, more precisely, by selecting each winding with an integral number of turns plus a fraction of a turn. The integral number of turns link with the total effective magnetic flux of the core and the effect of a fraction of a turn is obtained by bringing the end lead or tap, as the case may be, through an aperture, so positioned with respect to the aperture for the start of the winding that the turn links the desired fraction of the total effective magnetic flux.

Since it is not possible for all of the magnetic flux to interlink all of the turns, there is a certain amount of so-called leakage. In a magnetic core of the proportions shown, with the winding filling the entire enclosure, the resultant voltage is of the order of one one-thousandth ($\frac{1}{1000}$) less than would be expected by the ratio of turns of one winding to another. This observation applies in general to transformers of the prior art.

The present core construction, which is not limited to the number of slots shown, provides means of readily correcting for this lessened voltage by providing a disparity between the point at which the tap emerges from the winding and the point at which the tap emerges from the magnetic structure, the tap being led to a point in the path of the turn to emerge from the magnetic structure at a point which adds a fraction of a turn corresponding to the lessened voltage.

Further, the voltage ratios desired from windings are of various decimal values which can be obtained by selecting the proper number of turns and fraction or decimal part of a turn, adding the necessary fractional or decimal part of a turn to produce the desired voltage.

In some cases requiring great accuracy, changing the number of turns, and fractions, of one tap of a continuous winding having several taps, will affect the ratio of an adjacent section of the same winding. In accordance with this invention, this can be overcome by providing an extra tap near this point on the winding and by bringing it through another slot providing the exact proper voltage for this section of the winding.

In an alternative arrangement, one member is provided with apertures located away from the magnetic gap between the core members to permit bringing the taps of the winding out of the core, thus linking only the desired portion of the total magnetic flux.

While the invention is illustrated as applied to an autotransformer and to transformers having primary and secondary windings, in general, the invention is applicable to other types of inductive devices having one or more windings.

For further details of the invention reference may be made to the drawings, wherein

FIG. 1 is a perspective view of one form of the invention wherein the leads and taps are taken through apertures in the side wall of the magnetic structure.

FIG. 2 is an exploded perspective view of the form shown in FIG. 1.

FIG. 3 is a vertical, sectional view of a plug-in structure having pins and a casing enclosing the form shown in FIGS. 1 and 2, although it would serve as well for the form in FIG. 9.

FIG. 4 is a circuit diagram showing substantially the transformer circuit in the above mentioned patent.

FIG. 5 is a jig or fixture for winding the transformers or inductive devices.

FIGS. 6, 7 and 8 are diagrams illustrating the taps and leads for the nine steps in each of the transformers in the corresponding three stages in FIG. 4.

FIG. 9 is a perspective view of a modification wherein the loops and leads emerge through apertures in an end plate of the magnetic structure.

FIG. 10 is a wiring diagram for the output transformer of FIG. 4 which may be employed with the magnetic structure of FIGS. 1 and 2, and wherein the primary and secondary windings each have an integral number of turns.

FIG. 11 is a schematic sectional view showing how the tap can be brought out through the field member to provide a fractional turn of desired value.

Referring in detail to the drawing, in FIG. 4, transformer 1 has taps taken out as indicated at 2, providing nine steps in terms of $\frac{1}{10}$ of 360°, or 36°, the wiring diagram for this transformer being shown in FIG. 6. For

example, the autotransformer 1 has loop taps as indicated at 3 to 11 and terminals 13 and 14 which when brought out through appropriate apertures in the core will divide the winding into a fractional number of turns, reading from section 15 at the top, to 16 at the bottom, as follows: 2¼ turns, 10 turns, 13½ turns, 16½ turns, 19¼ turns, 19¼ turns, 16½ turns, 13½ turns, 10 turns, 2¼ turns for the bottom section 16. These loop taps 3 to 11 and terminals 13 and 14 are connected to pins, like pins 20 shown in FIG. 3, the pin numbers being shown in FIG. 6. In this example, taking pin No. 1 as 0 turn, the total number of turns available at the different pins is as follows, for FIG. 6:

Pin No.	No. of turns	Pin No.	No. of turns
1	0	7	12¼
2	2¼	8	42½
3	25¾	9	80¾
4	61½	10	110¾
5	97½	11	123
6	120¾		

Referring again to FIG. 4, each of the transformers indicated at 21, 22 has nine steps like 23, 24 for its secondary winding 25, 26, in terms of 3.6° or one-hundredths of 360°. The wiring diagram showing the loop taps and terminals for the secondary 25 is shown in FIG. 7, secondary 26 being similar. FIG. 7 shows the pin connections for the loop taps like 27, the secondary terminals 28 and 29, and the primary terminals 30 and 31 of primary winding 32. The number of turns available at these pins, for FIG. 7, is as follows, by way of example:

Pin No.	No. of turns	Pin No.	No. of turns
1	0 (Primary)	7	143
	0 (Secondary)	8	9¾
2	0	9	28½
3	19¼	10	46½
4	37½	11	64½
5	55½	12	83¼
6	73¾		

In FIG. 7, the sections of the secondary winding, reading from top to bottom, have the following number of turns, respectively: 9¾, 9½, 9¼, 9, 9, 9, 9¼, 9½.

Referring again to FIG. 4, each of the transformers indicated at 33, 34 has nine steps like 35, 36 for its secondary winding 37, 38 in terms of 0.36° or one-thousandth of 360°. The wiring diagram showing the loop taps and terminals for the secondary 37 is shown in FIG. 8, secondary 38 being similar. FIG. 8 shows the pin connections for the loop taps like 39, the secondary terminals 40 and 41, and the primary terminals 42 and 43 of primary winding 44. The number of turns available at these pins, by way of example, for FIG. 8 is as follows:

Pin No.	No. of turns	Pin No.	No. of turns
1	0 (Primary)	7	159
	0 (Secondary)	8	5
2	0	9	6
3	1	10	7
4	2	11	8
5	3	12	9
6	4		

Each of the nine sections of the secondary winding 37 in FIG. 8 has one turn.

Referring to FIG. 5, the winding assembly 45 may be employed for winding the transformers of FIGS. 6 to 8. The assembly 45 includes a shaft 46 which removably supports a bobbin 47 which as shown in FIG. 2 has radial slots like 48, 49 in its end plates 50 and 51, the slots in each end plate being four in number, 90° apart, whereby

the loop taps are positioned to be brought through apertures in the core corresponding to the number of turns or fraction thereof as given in the above examples in connection with FIGS. 6 to 8. The coil is thus conveniently wound on a bobbin having four slots which serves the purpose of positioning the taps in proximity to the correct apertures of the core which may be four, eight, ten or other desired number.

Shaft 46 on one side of bobbin 47 has a circular array of spaced pins like 52, 53 etc., spaced 90° apart opposite slots like 48 and at the other side of the bobbin is a similar series of four removable pins like 54, 55, 56, in position to receive the loop taps such as 3, 4 and 5 in the case of FIG. 6.

Referring to FIGS. 7 and 8, the primary 32 or 44 is wound nearest the core, with the secondary on top of the primary with Teflon tape between them.

FIG. 2 shows the bobbin 47 after it is wound with one of the windings of FIGS. 6 to 8. FIG. 2 also shows a magnetic core which completes the magnetic circuit for the winding. One magnetic member as shown at 57 has a cylindrical outer wall 58 having four radial slots like 59, at right angles to each other, an integral end plate 60 and an integral inner, hollow, cylindrical hub 61, providing an annular space 62 in which the bobbin 47 fits. The slots 59 provide exits through which the loop taps like 3 to 11 and terminals like 13 and 14 emerge. The end plate 64 in FIG. 2 fits on top of the No. 57 and completes the magnetic circuit, being held in position by the screw 65 and nut 66.

As shown in FIG. 3, the assembled winding and magnetic structure 67 may be mounted in a casing 68 having a base 69 carrying pins 20 in which the various terminals and loop taps are soldered. Base 69 closes one end of casing 68 and is fastened thereto by cement 70. The top of the casing has a cover 71, and the interior of the casing may be filled with a suitable sealing compound in which the device 67 is embedded. Insulating washers 72 and 73 keep the wire of the winding from touching the magnetic core.

In the form shown in FIG. 9, the transformer 75 has a magnetic core member having an imperforate side wall 76 and a removable magnetic end plate 77 held in position by a screw 88 and nut like 66. Plate 77 has apertures like 78 extending around the path of the winding and through which the leads or terminals like 79 and loop taps like 80 extend.

In FIG. 10, the transformer 81 has a primary 82 of 130 turns and a secondary 83 of 5 turns, these windings being connected to pins as shown, and provided with the magnetic structure of FIG. 1. Referring to FIG. 11, this illustrates how the loop tap 84, which is typical of any one of the loop taps shown in FIG. 1, may be brought out through an aperture in the field member 85, to add a desired fraction of a turn. The start of the winding 86 is shown as extending through an aperture 87 in the field member, the bobbin 47 of FIG. 2 being omitted in this schematic figure. The field member 85 is shown as having four apertures like 87 spaced 90° from each other. If the loop tap 84 were to emerge from aperture 87, the winding as shown being tapped at one turn, the winding would have effectively one turn. If as shown the loop tap 84 emerges from aperture 89, the winding as shown would have ¾ turn effective. If loop tap 84 were brought out through aperture 90, the winding would have 1¼ turns effective. Thus, the effective number of turns is not limited to the number of turns as determined by the points at which the taps like 84 are brought out from the winding itself.

Referring to FIG. 1, it will be apparent that a plurality of taps like 91 and 92 emerge from different layers of the winding through the same slot 59.

Various other modifications may be made in the invention without departing from the spirit of the following claims.

We claim:

1. An inductive device comprising a winding, a field member of magnetic material enclosing said winding and completing its magnetic circuit, said field member including an inner core member and forming an annular enclosure for said winding and having apertures spaced around the said field member, said winding having a tap extending through one of said apertures so that a fractional part of the total flux of said field member is interlinked by said tap.

2. An inductive device comprising a winding, a field member of magnetic material enclosing said winding and completing its magnetic circuit, said field member comprising members fitting together and forming an annular enclosure for said winding, one of said members surrounding said winding and having a periphery having circumferentially spaced apertures spaced at fractional intervals along the said periphery, said apertures opening out from said enclosure and respectively determining the fractional parts of a turn of the winding, another of said member being an inner core member, said winding having a plurality of taps each of a length sufficient to extend through one of said apertures, at least one of said taps extending through one of said apertures spaced around said member, the tap emerging from the winding in position so that a fractional part of the total flux of said field member is interlinked by said tap.

3. A precision transducer comprising a magnetic shell type transformer having a winding and providing accurate voltage ratios from fractional turns of the winding, said magnetic shell comprising inner and outer magnetic members spaced apart and providing an annular enclosure for the winding, said outer member having a periphery having apertures opening out from said enclosure and spaced at fractional intervals along its periphery, said winding having taps each having a length sufficient to emerge from a chosen one of said apertures, a plurality of said taps each extending through one of said apertures which is spaced along the said periphery so that a fractional part of the total flux of said magnetic shell is interlinked by said taps.

4. A precision transducer comprising a magnetic shell type transformer having a winding and providing accurate voltage ratios from fractional turns of the winding, said magnetic shell comprising inner and outer magnetic members spaced apart and providing an annular enclosure for the winding, said outer member having apertures opening out from said enclosure and spaced at predetermined positions along the periphery of said outer member, said winding having a tap having a length sufficient to emerge from one of said apertures, said tap extending through one of said apertures so that a fractional part of the total flux of said magnetic shell is interlinked by said tap.

5. A precision transducer comprising a magnetic shell type transformer having a winding and providing accurate voltage ratios from fractional turns of the winding, said magnetic shell comprising inner and outer magnetic members spaced apart and providing an annular enclosure for the winding, said outer member being cylindrical and having apertures opening out from said enclosure and accurately spaced at predetermined angles apart along the periphery of the outer member, said winding having taps each having a length sufficient to emerge from one of said apertures and a plurality of said taps each extending through one of said apertures so that a fractional part of the total flux of said magnetic shell is interlinked by the tap.

6. A precision magnetic shell type transformer having at least two windings and providing accurate voltage ratios corresponding to fractional turns of one of the windings, said magnetic shell including an inner core member and providing an annular enclosure for the windings with apertures opening out from said enclosure and spaced at predetermined positions around the said magnetic shell, said one winding having a tap emerging from one of said apertures and interlinking with a fractional part of substantially the total flux of said magnetic shell.

7. A precision magnetic shell type transformer having at least two windings and providing accurate voltage ratios corresponding to fractional turns of one of the windings, said magnetic shell including an inner core member and providing an annular enclosure for the windings with apertures opening out from said enclosure and spaced at predetermined positions around the said magnetic shell, said one winding having a plurality of taps emerging from a plurality of said apertures respectively, said taps interlinking with different fractional parts of substantially the total flux of the said magnetic shell.

8. A transformer comprising a winding having a hollow core of magnetic material substantially enclosing an annular space within which the winding is disposed, said core having a central portion extending through the center of the winding, said central portion merging with an outer portion having a plurality of apertures giving access between said space and the exterior of the core, said apertures being disposed in said outer portion at points circumferentially and regularly displaced lengthwise of the periphery of said winding, said points being located at positions corresponding to fractional portions of a turn of the winding, the winding including a plurality of taps extending through said apertures from fractional turns of said winding.

9. A transformer according to claim 8, said outer portion of said core comprising a magnetic shell member and a magnetic coverplate member fitting on said shell member, said apertures being arranged in one of said members.

10. A transformer according to claim 8, said outer portion of said core comprising a magnetic shell member and a magnetic coverplate member fitting on said shell member, said apertures being arranged in one of said members, said apertures being equally spaced in a circular array.

11. A transformer comprising a winding having a hollow field member of magnetic material substantially enclosing an annular space within which the winding is disposed, said winding having primary and secondary inductively related turns in said space, said field member having a central portion extending through the center of the winding, said central portion merging with an outer portion having a plurality of apertures giving access between said space and the exterior of the field member, said apertures being disposed in said outer portion at points circumferentially and regularly displaced lengthwise of the periphery of said winding, said points being located at positions corresponding to fractional portions of a turn of the winding, the winding having a number of turns and additionally having a tap extending through one of said apertures to form a fractional turn of said winding so that a fractional part of the total flux of said field member is interlinked by said tap, said tap providing a transformer voltage ratio corresponding to its said tap.

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