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ELECTRICAL TRANSFORMER AND
PRIMARY WINDING THEREOF
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Fig. 1

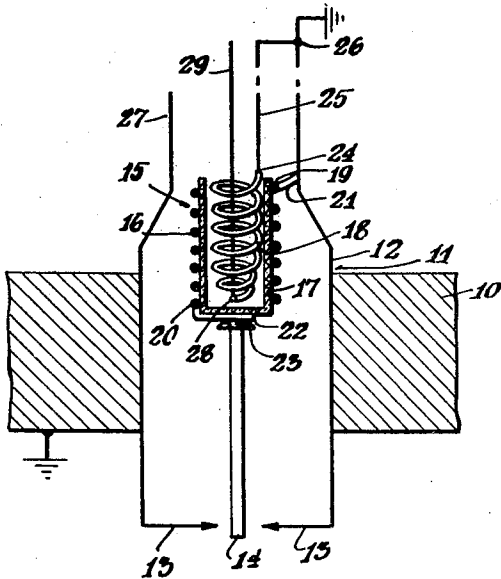


Fig. 2

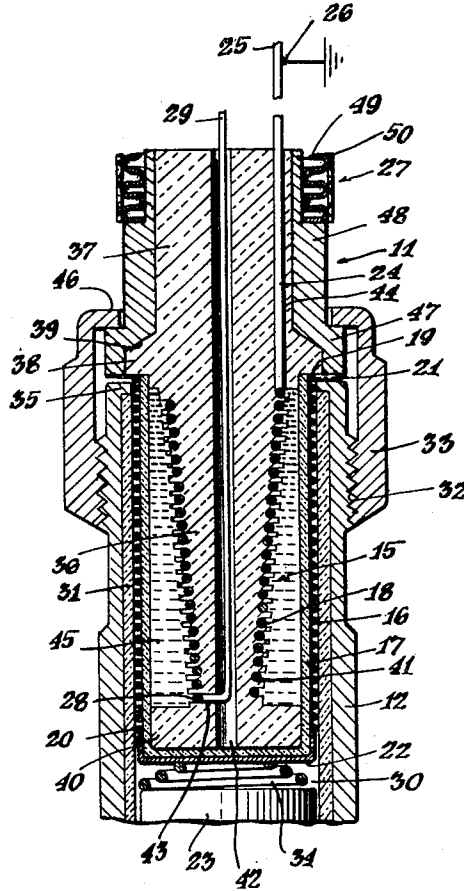
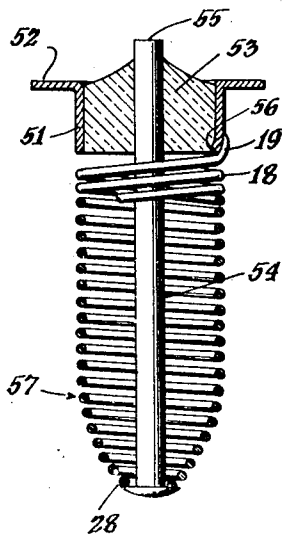


Fig. 3



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ELECTRICAL TRANSFORMER AND
PRIMARY WINDING THEREOFCleon F. Frey, Greenfield, Ind., assignor to P. R.
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Application December 5, 1944, Serial No. 566,734

2 Claims. (Cl. 175—359)

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The present invention relates to electrical transformers which may be employed for a variety of purposes, although more particularly designed for advantageous use in an ignition system of the type disclosed in the patent application of Alexander C. Wall for Ignition system and apparatus thereof, Serial No. 549,278, filed August 12, 1944.

A general object of the invention is the provision of such an electrical transformer (and the primary winding thereof) which by virtue of a novel construction of the primary winding and resultant structural features of the transformer, though simple and easily constructed and assembled, is exceptionally efficient, relatively free from capacity loading characteristics and is capable of an unusually long service life.

A more specific object of the invention is to provide such a transformer with telescoped windings of such character and in such fashion that the convolutions of the higher tension end of the primary winding are spaced from the convolutions of the high tension end of the secondary winding a greater distance than the spacing between the two windings at the low tension ends thereof whereby, when such transformer is used for example in an ignition system for production of fuel charge-igniting sparks of high frequency and voltage at spark plugs, there is an effective minimization of power losses, corona effects and capacity loading with an appreciable and highly desirable avoidance of voltage breakdown tendencies, and which effectively aids in the build-up of desirably high voltages at the spark plug gaps.

A further object of the invention is the provision in such transformer structure of a primary winding which is tapered at its higher tension end easily and effectively to attain desired increased spacing at the high tension end of a substantially cylindrical secondary winding, or the like, when two such windings are telescoped together with their opposed low tension ends arranged opposite each other.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts, which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in

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connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatical showing of a portion of an internal combustion engine cylinder and spark plug mounted therein, employed in an ignition system (only part of which is shown) an embodiment of the transformer of the present invention;

Fig. 2 is an enlarged longitudinal sectional view, with parts broken away, of a modified form of transformer of the invention and associated parts of a spark plug employable in such ignition system, etc.; and

Fig. 3 is an enlarged longitudinal view, with parts broken away and in section, of a further modification of the primary winding of the present invention which may be employed to advantage in the secondary winding structure and with associated spark plug parts shown by way of example in Fig. 2.

In the above identified Alexander C. Wall application it has been proposed to provide a certain specific ignition system for internal combustion engines which generates electrical energy of relatively low frequency and voltage, distributes that energy toward the spark plugs of the various cylinders, then converts the energy to a high frequency current and finally transforms the relatively low voltage high frequency energy to high frequency energy at relatively high voltage for supply to the spark plug gaps. That specific system has proven to be highly effective in minimizing power losses to produce strong effective sparks at the spark plug gaps and very satisfactory for use with aircraft engines where conditions due to extreme and rapid changes in altitude and the dictates of that particular service normally tend to cause a variety of ignition troubles; and particularly in view of the efficacy thereof in overcoming the normally serious problems of radio interference. It has been found in accordance with the present invention that the performance of such system may be further enhanced by the employment therein of transformer apparatus of the present invention, embodiments of which are shown in the drawing, in which like numerals identify like parts throughout.

In Fig. 1 is diagrammatically shown a portion of a typical circuit of such an ignition system. A portion 10 of a cylinder wall is fitted in the usual manner with a spark plug structure 11 comprising a shell or metallic casing 12, one or more spark plug electrodes 13—13 carried by casing 12 and a central spark plug electrode 14.

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The spark plug shell or casing 12 houses a transformer 15 of the present invention.

This transformer structure 15 may include an elongated substantially cylindrical secondary winding 16, preferably wound about the exterior of a substantially cylindrical elongated cup or vial 17 of suitable insulating material, preferably glass, of a minimum wall thickness for separation of a primary winding 18 from the secondary winding 16 at a minimum distance. The thin vial 17 preferably is made from heat-resistant glass having a low coefficient of expansion but other glass materials such as lead glass may be employed provided thin layers thereof are of such character as to withstand the high temperatures and voltages to which they are subjected in operation of the system, in which voltage stresses of the order of 2,000 to 3,000 volts per mil may be common and localized stresses may at times be as high as about 10,000 volts per mil.

The secondary winding 16 is arranged upon the glass cup 17 with the low tension end at 19 located adjacent the rim of the cup and the high tension end at 20 located adjacent the closed end or relatively flat bottom of the cup. Preferably the low tension end of the secondary winding 16 is anchored at 19 directly to the surface of the glass cup 17 by a body or smear of metallic material, such as a silver compound which may be adhered to the glass by firing, preferably tinned with solder to anchor the wire, and which may also be employed for anchorage of means 21 for grounding the low tension end of the secondary winding 16 to the spark plug shell 12. The high tension end of the winding 16 is preferably anchored in a similar manner to the relatively flat bottom of the cup 17 by means of another smear or body 22 of similar metallic material which, with or without other associate means, may be employed to provide for connecting contact with a head 23 of central electrode 14.

The primary winding 18 is, as shown, telescoped with the secondary winding 16, such as by being received or socketed within the glass cup 17. Its low tension end at 24 is connected to a return conductor 25 in turn preferably grounded, such as by connection at any suitable point as at 26 to a grounded shielding cable sheath 27. The relatively higher or medium tension end of the primary winding 18, at 28 opposite the high tension end 20 of the secondary winding 16, is connected to a supply conductor 29 to which is fed relatively low tension high frequency energy from any suitable source of supply not shown.

It will be noted in Fig. 1 that, in accordance with the present invention, the convolutions of the primary winding 18 at its higher tension end 28 are spaced farther from the convolutions of the secondary winding at its higher tension end at 20 than are the convolutions of the primary winding at its low tension end at 24 spaced from the convolutions of the secondary winding at its low tension end at 19. This may be attained by tapering the primary winding 18 at its higher tension end at 28, such as by making convolutions thereof of successively decreasing diameter.

As shown in the embodiment depicted in Fig. 2, the transformer secondary assembly including the vial 17 and the secondary winding 16 may be removably mounted in a chamber 30 of a conventional spark plug structure which may comprise a metallic casing or shell 12 lined with a sleeve 31 of suitable insulating material, such as a heat-stable ceramic or porcelain, and in which is suitably supported the central electrode 14 with

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its terminal button or head 23 exposed in the bottom of chamber 30. The metallic casing or shell 12 is provided with external threads 32 for demountable mounting thereto of anchoring means for a connecting cable, such as a sleeve nut 33.

With the secondary assembly seated in chamber 30 electrical connection between the terminal of the high tension end 20 comprising the silver solder smear 22 and the electrode button 23 may be accomplished by any suitable means, such as by a tapered helical spring 34 which may also provide a desired resilient mechanical support. The low tension end at 19 may be grounded to the casing 12 by means of a pigtail 21 clamped between an edge or intumed end flange 35 of casing 12 and cable-end structure by means of the anchoring sleeve nut 33. However, if desired, the transformer secondary assembly may be permanently mounted within the chamber 30 by a soldered connection at 21 between the terminal for the low tension end at 19 and the edge 35 of the casing 12, or by a body of solder bridging across between the spark plug casing or shell 12 and the anchorage smear at 19, or by any other suitable anchoring means that may readily occur to one skilled in the art.

The primary winding 18 is supported and constructed in a manner to be received or socketed in the glass cup 17 with convolutions of that winding at the low tension end 24 spaced by the glass cup from convolutions of the secondary winding 16 at a minimum distance to assure the attainment of efficient coupling. This primary winding construction may, as shown in Fig. 2, comprise a core of suitable heat-stable insulating material, preferably in the form of an elongated tapered or conical body 36 having a base portion 37, an intermediate flange 38 providing a shoulder 39, and an end centering flange 40. A helical groove 41 is provided on the tapered portion 36, in which the wire of the primary winding 18 is received and seated. The core 36—40 may be formed from any insulating materials which will withstand the high temperatures encountered at the spark plugs without giving off gases, which would tend to cause gas-filled voids within the transformer giving rise to corona effects during engine operation; such as inorganic materials, e. g., glass or a material formed of compressed mica particles and an inert filler or other materials such as heat-stable plastics or a thermosetting phenolic resin if subjected to a sufficient prebaking period, e. g., about twenty-four hours at about 150° C. The core 36—40 is provided with an axial bore 42 which near the end flange 40 communicates with the groove 41 by means of a hole 43 through which the higher tension end 28 of the primary winding 18 makes connection with the supply cable conductor 29 located in the axial bore. The low tension end 24 of the primary winding 18 may be threaded up through a longitudinally extending hole 44 in the base portion 37 of the core to serve as a terminal for connection to the circuit cable conductor 25.

With the primary assembly socketed into the glass cup 17 for magnetic coupling of convolutions of the primary winding 18 with convolutions of the secondary winding 16, this transformer structure preferably is thoroughly saturated or impregnated with a suitable insulating compound to eliminate all gas- or air-filled voids to avoid corona effect and attendant energy loss. Relatively high operating temperatures at the transformer spark plug unit must be taken into account and only such insulating compounds as

will effectively stand up under the rigid operating conditions should be employed. The entire transformer spark plug unit should be thoroughly saturated and impregnated with a suitable insulating compound such as a fluid polymerizing resin which will be transformed by heat into a heat-stable solid or semi-solid. Such material, if desired, may be filled with particles of refractory material such as ground glass, asbestos, mica, or the like. If the mechanical structure is such as to assure hermetic sealing of the parts within the encasing shell, a heat-stable non-polymerizing fluid may be employed. It has been found that various insulating fluids known in the industry are satisfactory for this purpose. A body of such impregnating compound is indicated at 45.

The primary assembly is held in assembled position socketed within the vial 17 and telescoped with the secondary winding 16 with both windings located within the chamber 30 in the spark plug shell or casing 12, preferably by means of the internally threaded sleeve nut 33 threadably engaged with the external threads 32. The sleeve nut 33 preferably has a flange 46 engaged behind a flange 47 on a metallic sleeve or ferrule 48, positioned about the core base portion 37, with an internal shoulder in the sleeve 48 bearing against the core shoulder 39, as shown in Fig. 2. The outward end of the sleeve 48 is thus forced toward the end edge 35 of the spark plug shell or casing 12 by the sleeve nut 33 when it is tightened up to clamp, if desired, the secondary terminal or pigtail 21 between shell end edge 35 and the core flange 38 and/or the end of the sleeve 48 to ground the low tension end 19 of the secondary winding 16 and to make good electrical connection between the spark plug casing or shell and the sleeve 48. Preferably the shielding sheath 27 is provided for the supply conductors 25 and 29, which may comprise a continuous metallic hose 49 of bellows construction and an overlying protective bronze braid 50 suitably anchored to the anchoring sleeve 48 such as by solder.

The transformer assembly of a typical embodiment of the invention for employment in such an ignition system is in overall dimensions about one inch long and about three-eighths of an inch in diameter, and has a turn-ratio of the order of 15 to 20:1 with the secondary winding having about 400 turns of fine wire, such as No. 40 or 42.

It has been found in the operation of such an ignition system that the electrical power supply unit, such as a standard magneto, may deliver current of approximately 1,000 cycles at a peak voltage of about 1,000 to 1,500 volts through the distributor at proper timing successively to the various supply circuits, each of which may include a condenser, a spark gap and the transformer primary winding 18 connected in series to provide an oscillatory circuit in which, with a total impulse energy of about 7 millijoules, a high frequency current at, say, 1,000 volts peak and approximately 1 to 2 megacycles will be caused to flow. With the employment of a transformer of the invention having a turn-ratio of the order of 15 to 20:1 and a secondary winding of about 400 turns, the peak voltage of the relatively high frequency energy can be stepped up to in excess of 20,000 volts, possibly about 40,000 volts. As a result high frequency sparks are created at the gaps between the spark plug electrodes 14 and 13—13, which efficiently fire charges of fuel even though the spark plug electrodes be fouled with carbon and/or oil. The close spacing between

the convolutions of the primary winding and the convolutions of the secondary winding at the low tension ends thereof assures efficient attainment and maintenance of the necessary coupling. The increased spacing at the higher tension ends such as by virtue of the tapering of the primary winding effectively minimizes capacity to avoid undesirable capacity loading. Further the increased spacing at the portions of the windings where potential difference is great tends to avoid voltage breakdown and reduces power losses and any tendencies to corona effect. This feature also helps build up the voltage at the spark plug electrodes.

Although these advantages are efficiently attained with an elongated primary winding which tapers throughout its length as suggested in Fig. 2, it has been found in tests that to a large degree their attainment is assured with a primary winding the convolutions of which are successively decreased in diameter, i. e., the winding is tapered, to the medium tension end from a point about two thirds the axial distance from the low tension end. Seemingly under the high frequency conditions of the ignition system, perhaps especially during sparking at the spark plug gaps when frequencies of the order of 200 megacycles are present, there is an appreciable non-uniformity of distribution of stress which concentrates the potential difference at the higher tension ends, i. e., at the bottom of the primary winding-receiving vial. Thus tapering about a third of the primary winding at its higher tension end appears to relieve the stresses sufficiently for all practical purposes, although a slightly better performance may be attained by a complete tapering of the primary winding.

Such a proposal is made in Fig. 3 wherein is shown a primary winding having only about a third thereof at its higher tension end tapered. That structure, by way of example, comprises a cylindrical collar 51 of metallic material provided with a laterally extending flange 52. A body 53 of suitable insulating material, such as glass preferably fused to the collar 51, supports and properly centers an axial conductor 54, an exposed end 55 of which is adapted to be connected to or to make contact with a supply conductor such as 29 shown in Fig. 1. Preferably the collar 51 is of such diameter as to be rather snugly received in the open mouth of the vial 17 and thus it is indented at 56 there to receive the end 19 of the winding 18, which is suitably anchored in position such as by solder. The higher tension end 55 of the winding at 28 is anchored to the conductor 54 in any suitable manner, such as by solder.

It will be noted from Fig. 3 that the convolutions of winding 18 from the low tension end at 19 to a point at 57 about two thirds the axial distance from 19 are of substantially equal diameter, but that therebeyond they are of successively decreasing diameter, which in tests of models of that structure such tapering has been found to be effective in the attainment of the results desired.

It is to be understood that to employ the primary assembly of Fig. 3 it may be placed or socketed in vial 17 so that winding 18 is telescoped with the secondary winding 16 on the vial. The flange 52 is to serve as the connector 21, such as by being clamped between end flange 35 of the spark plug shell 12 and ceramic sleeve 32, or by being anchored thereto by any suitable means such as by soldering, or clamped thereto by cable end structure when drawn up by sleeve nut 33;

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with a terminal end of supply conductor 29 pulled into secure contact with the end 55 of axial conductor 54, all as may be easily understood from an inspection of Fig. 11 of the above identified Alexander C. Wall patent application. Of course, it is to be understood that in such case the body 45 of insulating compound fills all voids within the vial 17, including the interior of the primary winding 18.

It will thus be seen that the objects set forth above are efficiently attained by the present invention and since certain changes may be made in the above construction and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A transformer adapted to fit into the barrel of a spark plug which comprises a cup shaped coil form of insulative material, the walls of the cup defining a cylindrical coil form of slightly less diameter than the inner surface of the spark plug barrel, a secondary winding on the outer surface of said coil form comprising a single row of turns of substantially uniform diameter, a plug having a cylindrical end portion fitting snugly against the inner surface of the coil form and a flange for engaging the rim of the cup shaped coil form whereby the plug is removably socketed in the cup, and a primary winding supported by said plug and extending into said coil form, said primary winding comprising a single row of turns, the part of the primary winding adjacent the high tension end of the secondary winding being

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of reduced diameter as compared to the part of the primary winding adjacent the low tension end of the secondary winding.

2. A transformer adapted to fit into the barrel of a spark plug which comprises a hollow cylindrical coil form of insulative material which is of slightly less diameter than the spark plug barrel, a secondary winding wound on the outer surface of said coil form comprising a single row of turns of substantially uniform diameter, a plug having spaced cylindrical end portions fitting snugly against the inner surface of said coil form whereby the plug is removably socketed within said coil form, said plug having a tapered portion intermediate said cylindrical end portions, and a primary winding comprising a single row of turns wound on the tapered portion of said plug so that the part of the primary winding adjacent the high tension end of the secondary winding is of reduced diameter as compared to the part of the primary winding adjacent the low tension end of the secondary winding.

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