June 26, 1962 W. A. GAMMEL, SR 3,041,562

IGNITION COIL

Filed Sept. 10, 1958

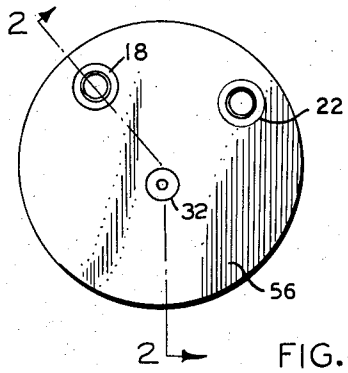


FIG.1

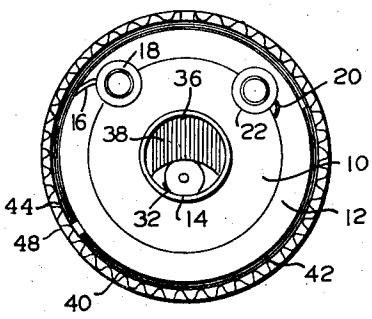


FIG.4

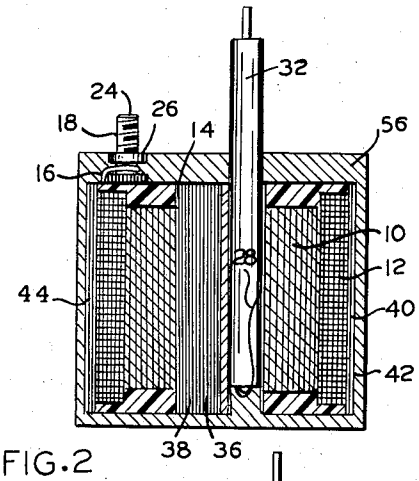


FIG.2

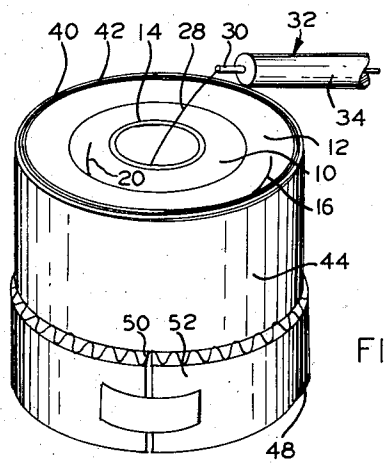


FIG.3

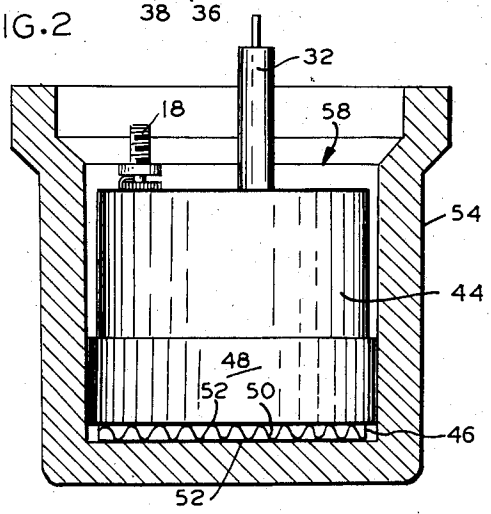


FIG.5

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IGNITION COIL

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This invention relates to ignition coils and more particularly to improvements in ignition coils for the high voltage systems of internal combustion engines.

It has been common practice to enclose ignition coils within a metal container filled with a potting compound. Such enclosed ignition coils are not only expensive to assemble but have considerably greater size and weight than the ignition coil itself.

Accordingly, an object of the present invention is to provide an improved ignition coil of rugged and compact construction which is more economical to manufacture than conventional coils.

Another object is to provide a substantially void-free, insulated ignition coil from which heat is rapidly dissipated.

A further object is to support and hold the high tension cable of an ignition coil with the same resin used to insulate the coil.

Still another object is to provide means for positioning the ignition coil in a casting mold, which means subsequently become an integral part of the ignition coil.

These and other objects and advantages of the invention will be more fully apparent from the following description and accompanying drawing in which:

FIGURE 1 is an end view of an ignition coil embodying the present invention;

FIGURE 2 is a sectional view taken substantially on the line 2—2 of FIGURE 1;

FIGURE 3 is a perspective view of the coil windings and the high tension cable showing the connection of the high tension cable to the secondary winding;

FIGURE 4 is an end view of the ignition coil before being impregnated and encapsulated; and

FIGURE 5 is a side view of the ignition coil in a mold just prior to the impregnating and encapsulating process.

In accordance with this invention, all parts of the ignition coil are enclosed, supported, insulated and mechanically protected by an impregnating and encapsulating resin casting. The parts of the ignition coil are temporarily positioned in a casting mold by means which subsequently become a permanent part of the ignition coil. A single casting of thermosetting resin is then applied to provide an impregnated and encapsulated ignition coil in which the coil parts are embedded in a substantially void-free mass with only the coil terminals and the high-voltage cable extending from the smooth outer surfaces.

Referring now to the drawing, the ignition coil comprises an inner secondary winding 10 and an outer primary winding 12 wound on a tube 14 of paper, cardboard or the like. As is well understood, secondary winding 10 consists of many layers of relatively fine wire, while primary winding 12 consists of relatively coarse wire. In accordance with usual practice, the windings have sheets of paper or other insulating material between adjacent layers of wire with the sheets extending beyond the end turns of the layers. The windings 10 and 12 are preferably of equal length and, as the primary winding 12 requires less paper extending beyond its end turns for insulating purposes, its wire layers may be longer than those of the secondary winding 10.

The outer end of the primary winding 12 is connected by lead 16 to terminal 18. The inner end of primary winding 12 and the outer end of secondary winding 10 are connected by lead 20 to terminal 22. Terminals 18 and

22 are identical in construction and comprise a threaded portion 24 and a grooved enlarged portion 26 which may be knurled. The inner end of secondary winding 10 is connected to lead 28 which extends into the bore of tube 14. Lead 28 is secured as by soldering or welding to conductor 30 of high tension cable 32 which has a sheath 34 of neoprene or other suitable insulating material. If desired, the free end of high tension cable 32 may be provided with a suitable terminal such as disclosed in U.S. Patent No. 2,745,075.

After being attached to lead 28, cable 32 is inserted in the bore of tube 14. Also disposed within the bore of tube 14 is an inner core 36 which consists of suitable magnetic material such as silicon steel or soft iron. Inner core 36 may consist of wires but is shown as consisting of rectangular elongated strips 38 of metal which substantially fill the space within tube 14 not occupied by cable 32. If desired, small strips or wires of magnetic material may be inserted into the spaces which are free of magnetic material. However, this is not essential and it is more convenient for production purposes to employ uniform strips of core material.

Disposed around the coil windings is an outer core 40 of suitable magnetic material consisting of curved laminations 42. Each lamination 42 may have any desired angular extent around the windings but preferably two laminations are matched together to form one layer surrounding the outside of the windings. At least two layers of laminations are preferably used with the laminations 42 nested together to form two groups, each comprising half of the outer core 40 and the two groups fitted together around the windings. The outer core 40 may be maintained in position in any suitable manner such as by wrapper 44 of paper.

Attached to the bottom ends of the coil windings 10 and 12, as seen in FIGURE 5, and closing one end of tube 14 is a flat plate 46 of corrugated insulation sheet stock, such as paper. Plate 46 which maintains the inner core strips 38 in position may be secured, if desired, to windings 10 and 12 by any suitable means such as with tape and may have any desired shape. Plate 46 is shown as having a circular shape and substantially covering the bottom ends of the windings 10 and 12. Encircling the outer core 40 is a strip 48 of corrugated paper whose ends may be secured together by tape. Strip 48 may have a greater width, if desired, and may be disposed anywhere along the length of wrapper 44. Plate 46 and strip 48 each include a corrugated element 50 and a binder sheet 52 secured on one or both sides of the corrugated element 50.

After the ignition coil construction so far described has been assembled and tested, it may be disposed in a mold 54 as seen in FIGURE 5 with the terminal and cable end at the top. If plate 46 has not been attached to the coil, it will be placed first into the mold. The inner surfaces of the mold 54 may be coated with a releasing agent such as silicone grease to facilitate removal of the ignition coil after being impregnated and encapsulated. It will be noted that plate 46 spaces the bottom of windings 10 and 12 and the inner core 36 from the bottom wall of the mold 54, while strip 48 centers the outer core 40 and the windings 10 and 12 in the mold 54. It is not essential that plate 46 and strip 48 have good dielectric properties, as they absorb the casting resin to a considerable extent to become an integral part of the outer coating of the ignition coil.

The ignition coil assembly and mold 54 then are placed in a closed chamber (not shown) and subjected to heat and vacuum to remove air and moisture from the coil. A liquid thermosetting resin 56 is next poured into the mold 54 to fill the mold to the level 58 near the top of

the mold and a positive pressure is applied to the closed chamber to force the casting resin **56** into all interstices and recesses. The corrugations of plate **46** and strip **48** permit access of the casting resin to all parts of the ignition coil. After the ignition coil has been heated in place to cure the resin, it may be removed from the mold and subjected to final tests.

Casting resins which have been found to be satisfactory include polyester and epoxy resin compositions and mixtures thereof containing finely divided mineral fillers such as silica, alumina, slate, glass fibers and mica, and a modifier such as trimer acid or a cashew nut shell oil to increase the normal flexibility and resiliency of the resin. A catalyst is added to the resin in sufficient amount to cause the resin composition to cure. An accelerator to facilitate the cure also may be used.

A preferred epoxy resin base is the diglycidal ether of bisphenol A having an epoxide equivalent of approximately 180 to 220. This epoxy resin is commercially available under the trademarks "ERL–2774" from the Bakelite Company, "Araladite 6020" from the Ciba Company, "Epi-Rez 510" from Jones-Dabney and "Epon 828" from the Shell Chemical Company. Epoxy resin compositions which have been found to be suitable for the practice of this invention comprise by weight 100 parts of epoxy resin, 50 to 200 parts silica fine enough to pass a 325 mesh screen, 0 to 25 parts milled glass fibers two to three mils in diameter and approximately one thirty-second inch long, and either 25 to 100 parts trimer acid or 10 to 30 parts of a phenol derivative of cashew nut shell oil sold by the Irvington Varnish and Insulation Division of Minnesota Mining and Manufacturing Company under the trademark, "Cardolite NC–513."

The following examples in which the parts given are by weight are illustrative of resin compositions employed in the practice of this invention:

Example 1

100 parts epoxy resin
120 parts 325 mesh silica
20 parts "Cardolite NC–513" oil
25 parts "Epon Z" curing agent (sold by Shell Chemical Co.)

Example 2

100 parts epoxy resin
150 parts 325 mesh silica
50 parts trimer acid
½ part 2,4,6-tri(dimethyl aminomethyl)phenol

Example 3

100 parts epoxy resin
80 parts 325 mesh silica
20 parts 1/32" milled glass fibers
20 parts "Cardolite NC–513" oil
25 parts menthane diamine

Example 4

100 parts epoxy resin
200 parts 325 mesh silica
20 parts "Cardolite NC–513" oil
120 parts hexachloroendomethylene-tetrahydrophthalic anhydride

Example 5

100 parts epoxy resin
120 parts 325 mesh silica
10 parts 1/32" milled glass fibers
10 parts "Carbolite NC–513" oil
20 parts maleic anhydride
20 parts pyromellitic dianhydride

Example 6

100 parts polyester resin (such as H. H. Robertson Resin No. 124E–50)
50 parts 325 mesh silica
5 parts 1/32" milled glass fibers
1 part cumene hydroperoxide

Resin compositions of the type described above have characteristics which are particularly useful in encapsulating ignition coils. They provide a smooth outer coating of minimum thickness and an interior impregnation substantially free of any voids or air spaces so that moisture cannot enter the windings and corona cannot be generated. The resin compositions have adequate toughness and mechanical strength to support the parts of the coil yet have adequate resiliency and flexibility to withstand both mechanical and thermal shock. Positioning of the high voltage cable **32** in the bore of tube **14** insures a good bond between the casting resin **56** and the cable sheath **34** to completely seal the electrical connection which is a valuable safeguard against ignition failure.

Since the casting resin **56** has good thermal conductivity and surrounds and penetrates windings **10** and **12**, the ignition coil has excellent heat dissipation properties permitting a substantial reduction in material in comparison to conventional ignition coils of the same output. Thus it is possible to make the ignition coil assembly more compact than conventional ignition coils in addition to avoiding the expense of additional parts such as the case, internal insulators, and high voltage terminal. Although epoxy and polyester resins are more expensive than certain of the potting compounds commonly used in insulating conventional ignition coils, the overall cost of the epoxy or polyester resin composition may be less because these compositions include a large proportion of inexpensive fillers and modifiers. Furthermore, coils constructed in accordance with this invention require considerably smaller quantities of casting resin than of potting compound employed in conventional ignition coils.

As one example of a coil embodying the present invention, the parts making an ignition coil as illustrated in the drawing had the following dimensions:

Inner core **36** had 40 strips of No. 29 gauge silicon steel. Each strip **38** was 1¾ inches long and ⅜ inch wide.

Secondary winding **10** was 1⅜ inches long with tube **14** being 11/16 inch in diameter and the outer diameter being about 1½ inches. The secondary winding had about twenty-four thousand turns of A.W.G. 40 copper wire.

Primary winding **12** had an outer diameter of 2 inches and had about 240 turns of A.W.G. 21 copper wire.

Two layers of metal each formed of two No. 29 gauge laminations **42** were used for the outer core **40**.

Disregarding the projecting ends of terminals **18** and **22**, the completed ignition coil had a length of 2 inches and a diameter of approximately 2¼ inches. The weight of the coil was approximately 15 ounces.

By comparison with the above, the inner core of a conventional coil with the same windings would require 44 strips of No. 29 gauge silicon steel, each 3⅛ inches long and ⅜ inch wide. This is substantially 100 percent more iron than used in the new coil. The conventional coil weighed 25 ounces or about 66 percent more than the new coil. The conventional coil had a length of 4¼ inches and a diameter of 2¼ inches, being about 100 percent larger.

While the invention has been illustrated and described in its preferred embodiment and has included certain details, it should be understood that the invention is not to be limited to the precise details herein illustrated and described since the same may be carried out in other ways falling within the scope of the invention as claimed. What is claimed is:

1. An ignition coil for use with an internal combustion engine comprising in combination: an electrical coil assembly including a tube of insulating material, a high-voltage secondary winding about said tube having layers of wires alternating with layers of insulating sheets, said sheets extending beyond both ends of the wire layers, and a low-voltage primary winding about the secondary winding; a magnetic core for said coil assembly disposed

within said tube; said core, tube and windings being substantially equal in length and coextensive; a flexible insulated high-tension cable having a substantial portion at one end extending into said tube; the innermost extremity of said cable being stripped of insulation and in permanent electric contact with said secondary winding; a single, solid casting of thermosetting resin substantially filling all interstices and recesses in said coil assembly and core and completely surrounding said coil assembly and core to form a substantially void-free assembly; said casting forming a fluid-tight bond with said cable and mechanically supporting said one end of said cable; the other end of said cable extending from said casting; and said casting resin having a high dielectric strength, high resistance to both mechanical and thermal shock, good heat transfer characteristics and good bonding properties.

2. An ignition coil according to claim 1, wherein said

casting resin comprises a first material selected from the group of epoxy resin and polyester resin; a second material comprising a cashew nut shell oil product; and a third material chosen from the group of silica, alumina, slate, mica, glass fibers, and mixtures thereof.

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