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IGNITION INTERFERENCE SUPPRESSION

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FIG. 1.

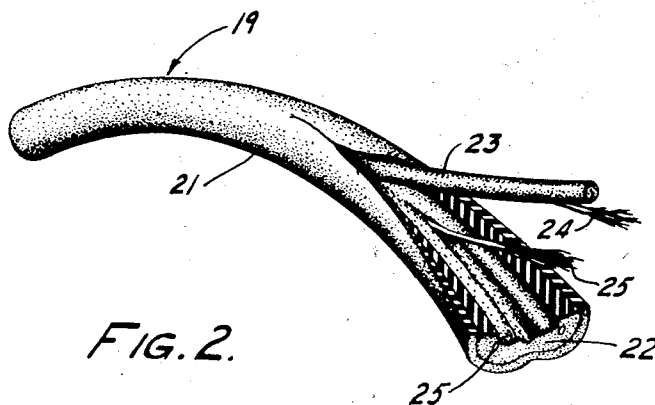
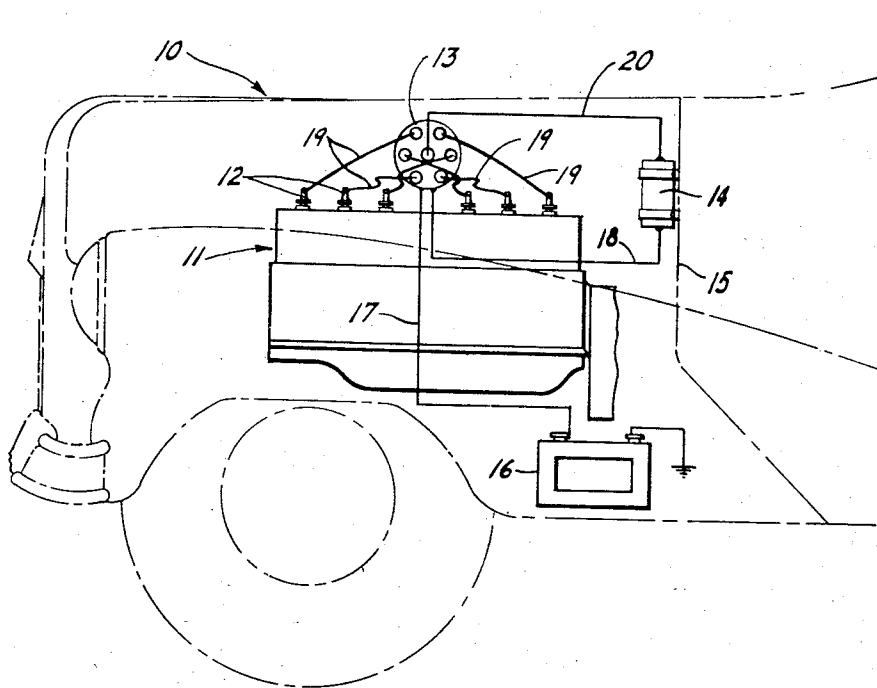
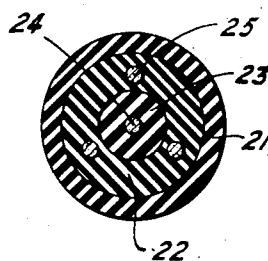


FIG. 2.

FIG. 3.



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IGNITION INTERFERENCE SUPPRESSION

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The invention hereinafter described and claimed relates to improvements in ignition systems for internal combustion engines and, particularly, to novel and improved high voltage cables or conductors, of special utility in such systems. In general, the invention is concerned with the damping-out, or suppression, of oscillations commonly generated in and radiated from the ignition systems of internal combustion engines of the type used, for example, in automobiles or other vehicles.

It has been known that spark plug cables and other high voltage leads, even when used with ignition interference suppressors, radiate oscillations coming within the very high frequency band ranging, for example, up to 300 megacycles and higher, and that such radiated "noise" results in interference with radio reception in nearby high frequency apparatus. It is recognized that the solution to this problem of radiated noise does not lie in complete shielding of the ignition system, since, for one thing, the expense involved in such shielding is prohibitive. With the increasingly wide use of frequency modulation, facsimile, television, and other high frequency services, this problem has become acute, and much effort has been expended upon attempts to find a solution thereto, particularly a solution which does not involve complex or expensive apparatus and is of such nature as to be readily applicable to the ignition systems of vehicles now in use without interfering with the normal functions of such systems. To aid in appreciating the magnitude of the problem, it is here recorded that engineering groups representing several affected industries have established boards of inquiry and devoted intensive effort to the problem. However, as far as applicant is aware, until the advent of the present invention no satisfactory solution was found.

The ignition interference suppressors now in common use in vehicles provided with radio apparatus adapted for reception in the standard broadcast bands (see Patent No. 1,904,149, to A. A. Leonard, issued April 18, 1933, and assigned to the assignee of the present invention), while extremely effective at standard broadcast frequencies, leave much to be desired in the suppression of radiations in the high frequency portion of the spectrum.

Experiments have been directed to the provision of cables of distributed resistance. However, heretofore, the particular utility of uniformly distributed resistance in the suppression of very high frequency radiations has not only

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been unrecognized, but it has not been realized that the selection of a particular resistance range represents an important factor, when it is desired to suppress radiations covering the radio frequency band and extending well upwardly within the very high frequency portion of the spectrum.

Further to facilitate a full understanding of this invention, it should be understood that distributed capacity exists between each spark plug lead and adjacent metal such, for example, as the engine block. Conductors of ordinary type have substantial inductance, and the result is that each spark plug wire forms a resonant circuit which is subjected to shock excitation by the spark discharges. By placing lumped resistors in these resonant circuits, at the spark plug terminals in accordance with prior practice, it is possible, in effect, to damp or reduce the amplitude of current flowing in the resonant circuits. This expedient, while satisfactory at lower frequencies where the whole structure provides a single resonant circuit for each ignition wire, fails at higher frequencies since small portions of each conductor form parts of independent resonant circuits which are undamped. By the use of distributed resistance, each of these small individual resonant circuits is damped and the effect of the aforesaid shock excitation is substantially nullified.

In another aspect of the invention, I have found that materials known prior to my invention are lacking in certain physical characteristics essential to realization of suppressors which have the necessary constancy in resistance value per unit of length, and the required mechanical strength.

While it is to be understood that, in the broad aspect, my invention is not limited to the use of conductive rubber, such material has certain advantages and is readily available. However, I have discovered that when attempts are made to use conductive rubber leads having the electrical characteristics specified hereinafter and using previously known techniques in the manufacture of the conducting material, the resultant leads are lacking in sufficient tensile strength. This characteristic is so marked that, even if handled with sufficient care to permit their application to ignition systems, the leads stretch under their own weight, with the result that the resistance varies so markedly as to render them entirely unsatisfactory for commercial purposes.

With the foregoing premises in mind, it is the primary object of the present invention to over-

come the aforesaid difficulties and disadvantages by the provision of simple and inexpensive apparatus which is not only substantially completely effective to eliminate high frequency noise radiations normally generated by the ignition systems of internal combustion engines, but which apparatus further is of such type that the resistance value of the individual leads remains substantially constant under all normal stresses encountered in applying said apparatus and throughout an extended period of useful life.

With more particularity, the invention has as an object the provision of improved non-radiating leads, the resistance of which is of a value having peculiar applicability to the problems involved, and which leads are of relatively large diameter (hence of very low inductance) and are adapted to replace the usual cables leading from the spark plugs to the distributor and from the distributor to the ignition coil. This apparatus not only serves as the requisite conductors, but further is highly effective to damp-out the aforesaid very high frequency oscillations. It is a feature of the invention that such improved apparatus has also proven effective to suppress lower frequency radiation which would otherwise interfere with reception in standard broadcast radio apparatus which may be carried by the vehicle.

To the foregoing general ends, and in the preferred embodiment, the invention utilizes, for the leads and cables aforesaid, non-metallic conductors of uniformly distributed resistance and preferably of conductive rubber; the conductors having physical and electrical characteristics which render them peculiarly adapted to accomplish the purposes aforesaid.

In addition to the above-mentioned experiments, attempts have been made, prior to this invention, to utilize distributed resistance as conducting leads in ignition systems to effect suppression at relatively low frequencies, but, even in such restricted portion of the frequency spectrum, results were unsatisfactory since, in order to obtain sufficient resistance, it was frequently necessary to coil the conductor. This expedient introduced inductive effects which deleteriously affected the operation of the apparatus. Certain other prior experiments have attempted the use of extremely high resistance materials in order to avoid coiling of the conductor, but this has also resulted unsatisfactorily in that the spark failed to bridge the gap in the spark plugs, with resultant failure of the ignition system. The significance of the proper resistance values—as being capable of giving excellent suppression throughout the entire frequency spectrum, up to and including the very high frequency portion thereof—was not recognized prior to the present invention and, in fact, distributed resistance was thought to be no better than lumped resistors, at the high frequencies.

I have discovered that distributed resistance is most effective for the purpose; that, as brought out hereinafter, the total distributed resistance of each circuit—between the ignition coil and each spark plug—should preferably be in the region of from about 10,000 to approximately 30,000 ohms; and that, if conductive rubber is to be employed, a solution could be found to the problem of resistance variations occurring as a result of the inherent physical weakness of the conductors. Resistance values in the stated region almost completely eliminate objectionable radiation in the very high frequency band, and further result in satisfactory suppression of the

lower frequencies which would interfere with radio apparatus carried by the vehicle. Such values do not interfere with normal operation of the ignition system.

It is of importance that the leads or conductors be substantially non-inductive, and that they have resistance per unit of length of such value as to provide the total resistance required to accomplish the purposes of the invention.

The objects and advantages set forth above, together with others brought out hereinafter, will be clearly understood from a consideration of the following detailed description in the light of the accompanying drawing, in which:

Figure 1 is a fragmentary, diagrammatic representation of an automobile provided with the apparatus of the present invention;

Figure 2 is a perspective illustration, approximately twice full size, showing a section of conductor incorporating constructional principles of this invention; and,

Figure 3 is a sectional view showing, on a greatly enlarged scale, a cross section of the conductor illustrated in Figure 2.

While for the purposes of illustration, the invention is shown and described as embodied in an automobile, it will be understood that the concepts thereof are applicable wherever it is desired to suppress deleterious radiations of the kind involved herein. However, it will be recognized that the breadth of the present invention is commensurate with the scope of the appended claims.

Now with particular reference to the drawings, there is shown in Figure 1 and designated by the reference character 10 an automobile provided with an engine represented, generally, by the reference numeral 11, said engine being provided with a plurality of spark plugs 12 and a distributor 13. The usual ignition coil, indicated at 14, is shown as secured to the forward surface of the fire wall 15, and a storage battery 16 is included in series circuit with the breaker points in said distributor and the ignition coil, it being understood that the coil includes the usual primary and secondary windings (not shown) associated with the storage battery and the distributor, respectively. It will be further understood that in accordance with the usual practice one side of each of said windings may be grounded to the automobile frame structure by suitable connections, not illustrated. The distributor, per se, is of known type and since it forms a part of the present invention only insofar as it cooperates with the novel elements of the apparatus, detailed description of said distributor is not necessary herein. However, as mentioned above, the distributor is provided with the usual breaker points through which the current flows from the battery toward the ignition coil, through the conductors indicated at 17 and 18.

In particular accordance with the present invention, a non-inductive lead or cable 19, of uniformly distributed resistance and preferably of conductive rubber, connects each spark plug 12 with the distributor 13 and, similarly, a cable or center lead 20 of similar material is provided between said distributor 13 and the secondary winding of the ignition coil 14. If desired, the conductors leading to the closer plugs may be installed with a loop or bend therein, as appears in Figure 1, in order to make it possible to utilize leads of equal length. In such instance, of course, all of the leads will have equal resistance value, per unit of length.

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The manner in which the several leads are connected to the spark plugs is not shown in detail herein, but such connections may conveniently comprise any of several connectors now in common use.

While, in the broader aspect, and as indicated above, the leads may take one of several available forms within the purview of the invention, as shown in Figures 2 and 3 it is preferred that these leads be of conductive rubber and that they include an insulating sheath 22, of suitable plastic material or of rubber, and an inner natural or synthetic rubber core 23, rendered conductive by the inclusion of finely comminuted particles of graphite, carbon black, combinations of the two, or the like. A detailed specification of the constituents which comprise this inner core is not of importance, except as regards its electrical characteristics and, accordingly, further and more detailed illustration of the physical construction of the core element is not necessary herein. As later appears, a cover or jacket (21) may be used if desired. As will be appreciated, the outer cover or jacket is of a type to withstand abrasion, and to be substantially unaffected by engine fuels and lubricants.

After extensive tests, and having discovered that conductors of uniformly distributed resistance are satisfactory for the suppression of very high frequency noise impulses, it was found that excellent results were obtained by the use of conductors having distributed resistance per unit of length of such value that the total distributed resistance of each circuit—between the ignition coil and each spark plug—came within the region of about 10,000 ohms to about 30,000 ohms. That is, in the form illustrated, the distributed resistance of the center lead 20 and of each of the cables 19 with which said center lead is normally in circuit, is of such value that the total resistance lies within the specified range, said resistance being substantially uniformly distributed throughout the circuit. I have found that if the total distributed resistance falls much below 10,000 ohms, the suppression, at high frequencies, is inadequate, while, on the other hand, if the total distributed resistance is much greater than 30,000 ohms, the ignition system will fail to function properly.

While, as above set forth, my invention is concerned with the provision of ignition systems including novel, non-radiating leads having the properties characteristic of the invention, in another important aspect my invention is concerned with the provision of the conducting cable, per se, both in extended lengths and as embodied in individual leads adapted for application to ignition systems. In this connection, it is to be borne in mind that in present day ignition systems the leads connecting the distributor with the individual spark plugs vary rather considerably in length—the leads now in common use being from about fourteen inches to upwardly of three feet—and this presents a problem in selecting conducting cable having a resistance value per unit of length such that the total resistance in circuit with each spark plug falls within the preferred range. It is also to be recognized that there is a rather wide variation in length in the distributor center leads employed in practice, some ignition systems, in fact, having no center lead. In the event that no center lead is used, that is in automobiles in which the ignition coil is directly associated with the distributor, the uniformly distributed resistance of

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each spark plug lead should fall within the range of from about 10,000 to about 30,000 ohms. On the other hand, if a center lead be used and this be of substantial length, a considerable portion of the distributed resistance may be in the center lead. In any event, there should be, in the circuit between the coil and each plug, resistance of from 10,000 to 30,000 ohms, substantially uniformly distributed throughout the length of said circuit.

Furthermore, it is desirable that the resistance per unit of length be so chosen that the conducting cable is applicable to a wide variety of ignition systems regardless of the aforesaid variations in lead length. As above indicated, I have found that the total distributed resistance in circuit between the ignition coil and each plug may vary in a ratio of about three to one and, since the variation in lead length is also of the order of three to one, it is evident that, in the broader aspect of the invention, a nine-to-one variation in resistance per unit of length is contemplated.

Bearing the above factors in mind, the following examples serve to demonstrate the absolute values, in terms of resistance per unit of length, which come within the broad teaching of the invention.

Assuming that the length of cable in circuit with each plug is of the order of fourteen inches, and that the maximum contemplated total resistance is selected, i. e., 30,000 ohms, it is seen that a resistance per unit of length may be of the order of 26,000 ohms per foot.

On the other hand, if the length of cable in circuit with the plug reaches forty-two inches, and the minimum value of total resistance is selected, i. e., 10,000 ohms, it is seen that the resistance per unit of length may be about one-ninth that specified in the foregoing example, or in the neighborhood of 2,800 ohms per foot.

However, as above indicated, it is desirable that a single resistance value per unit of length be selected, this value to be such that the cable is applicable to the ignition systems now encountered in practice. In this aspect of the invention, I have found that conducting cable having resistance per unit of length equal to from about 7,000 ohms per foot to about 10,000 ohms per foot, meets the requirements regarding the preferred range of total resistance, when applied to the majority of ignition systems encountered in practice. For example, if conducting cable is selected having a resistance value per unit of length equal to 8,570 ohms, leads fourteen inches in length will have a total distributed resistance of approximately 10,000 ohms, and forty-two inch circuits will have a total distributed resistance very closely approximating 30,000 ohms.

It is understood, of course, that all of the resistance values referred to herein have reference to the resistance of the conductive core member. Also, the term "conductive rubber," as used herein, should be understood to have a connotation sufficiently broad to contemplate the use of a variety of related synthetic materials such, for example, as polyethylene, and the like.

Considering now another aspect of the invention having to do with the difficulties inherent in the physical structure of prior types of conductive rubber—particularly with respect to the stretchability of such types—the invention provides novel means, the inclusion of which results in a conductor capable of withstanding very substantial tensile loads without appreciably af-

fecting its physical characteristics or electrical resistance.

To this end, the invention contemplates inclusion, in the composite cable, of a number of thread-like elements of small diameter which are tightly bonded to the cable structure during the manufacture thereof, and effectively resist stretching loads. In one type, the conductive rubber core (which is preferably made by an extrusion process) has extruded therewith a number of synthetic plastic threads of small diameter, which threads are indicated at 24 in the drawing. The composite conductor thus formed, including its strengthening threads, is then covered by extruding around it the insulating rubber or plastic sheath 22. Additionally, although not necessarily, the core thus formed may be extruded a third time, this time being covered with the jacket 21.

The aforesaid threads 24 are preferably composed of a suitable synthetic resinous fiber, such, for example, as polyvinyl or vinyl chloride or, alternatively, the fibers may be of cotton or nylon. It will be understood that other materials, such as glass threads or linen cord, may be employed for the purpose. While the resultant cable or lead is found to give satisfactory results, a still better embodiment may be obtained by including a second set of strengthening threads of similar material, these threads being represented at 25 and shown as lying within the confines of the sheath 22. In general, it can be seen that a central strain-resistant strand is extruded with the conducting core, and the additional strands 25 may be disposed as shown, or may be located between the layers which comprise the composite conductor, or may be included in the insulating cover or jacket. It is to be noted that the strands are of non-conductive material, thus making it possible to apply connectors and fittings thereto without the necessity of insulating the strands from either the connectors, or the conducting core.

Conducting cable fabricated in accordance with the foregoing has tensile strength ample to meet all normal stresses encountered either in applying the apparatus or throughout its useful life. In the embodiment illustrated and described, the conducting core has an average diameter of 0.08", and the overall diameter of the composite conducting cable is such as to be consistent with that of the fittings commonly used in ignition systems. The relatively large diameter of the conductive core is important in that it results in a low inductance per unit of length. Such a cable not only provides adequate conductance to accommodate the spark discharges, but is found to resist a forty-pound tensile stress, without deleterious change in its electrical characteristics.

Tests have indicated that use of the apparatus of the present invention results in a very great reduction in radiated high frequency noise impulses (measured in microvolts per meter), as compared with the reduction obtained by the use of the best suppressors hitherto available. In the frequency range of from thirty to four hundred megacycles, for example, which range includes most of the frequency modulation, television and facsimile apparatus presently in use, the noise reduction across the range averages better than five times the reduction achievable with

the aforesaid available suppressors. As indicated hereinabove, the suppression in the low frequency end of the spectrum is comparable to that realized by the use of said suppressors.

I claim:

1. In an electric ignition system having spark-producing elements including a coil and a spark plug, said elements normally generating oscillations ranging well upwardly within the high frequency portion of the radio frequency spectrum, means for substantially eliminating such oscillations consisting of a non-radiating high-voltage non-metallic conducting lead in series circuit with the coil and spark plug, said conducting lead being substantially non-inductive and having a total resistance of at least 10,000 ohms, said resistance being distributed substantially uniformly throughout the length of said lead.

2. In an electric ignition system having spark-producing elements including a coil and a spark plug, said elements normally generating oscillations ranging well upwardly within the high frequency portion of the radio frequency spectrum, means for substantially eliminating such oscillations consisting of a non-radiating high-voltage non-metallic conducting lead in series circuit with the coil and spark plug, said conducting lead being substantially non-inductive and having a total resistance lying in the region of from 10,000 ohms to 30,000 ohms, said resistance being distributed substantially uniformly throughout the length of said lead.

3. In an electric ignition system having spark-producing elements including a coil and a spark plug, said elements normally generating oscillations ranging well upwardly within the high frequency portion of the radio frequency spectrum, means for substantially eliminating such oscillations consisting of a non-radiating high-voltage non-metallic conducting lead interconnecting the coil and spark plug, said conducting lead being substantially non-inductive and having a total resistance lying in the region of from 10,000 ohms to 30,000 ohms, said resistance being distributed substantially uniformly throughout the length of said lead.

4. Apparatus in accordance with claim 2, and in which said lead comprises conductive rubber.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
443,565	Bremer	Dec. 30, 1890
1,577,981	Otto	Mar. 23, 1926
1,698,704	Middleton et al.	Jan. 8, 1929
1,888,762	Geer	Nov. 22, 1932
1,960,317	Rabazzana	May 29, 1934
2,165,738	Van Hoffen	July 11, 1939
2,304,210	Scott et al.	Dec. 8, 1942
2,322,773	Peters	June 29, 1943
2,397,082	Barker	Mar. 26, 1946
2,434,793	Feaster	Jan. 20, 1948

FOREIGN PATENTS

Number	Country	Date
464,278	Great Britain	Apr. 12, 1937
490,546	Great Britain	Aug. 17, 1938
114,246	Australia	Feb. 11, 1943