March 24, 1942. H. H. WERMINE 2,277,177

SHIELD FOR ELECTRICAL CONDUCTORS

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Fig. 1

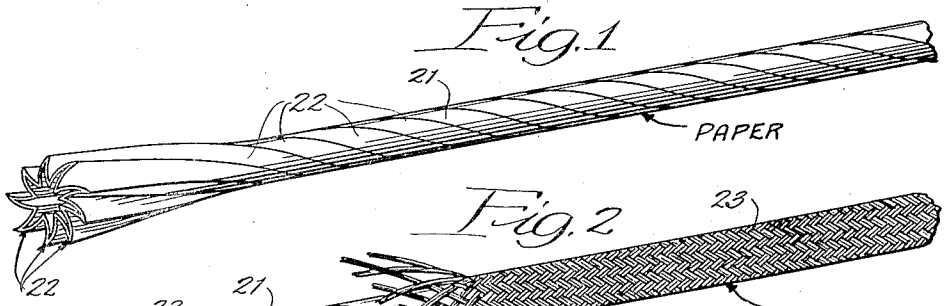


Fig. 2

Fig. 3

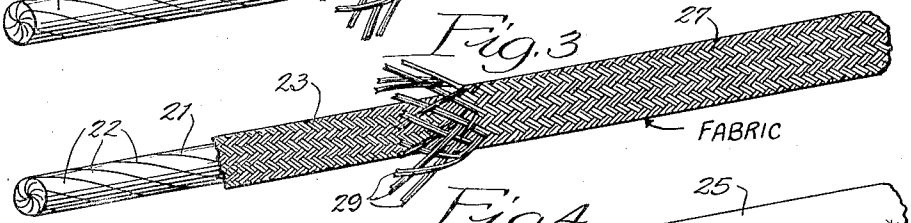


Fig. 4

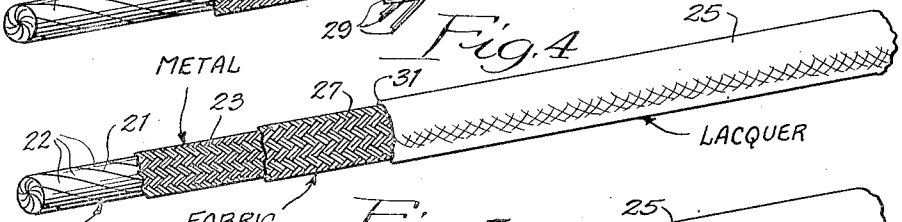


Fig. 5

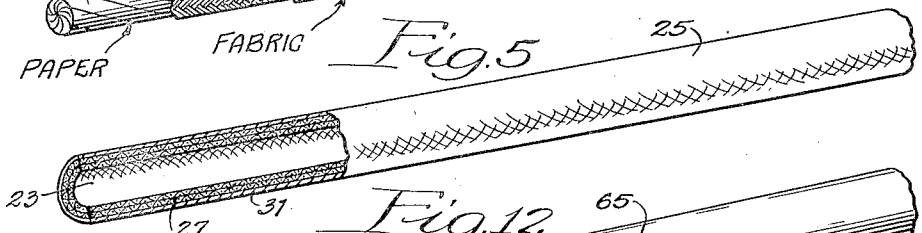


Fig. 12

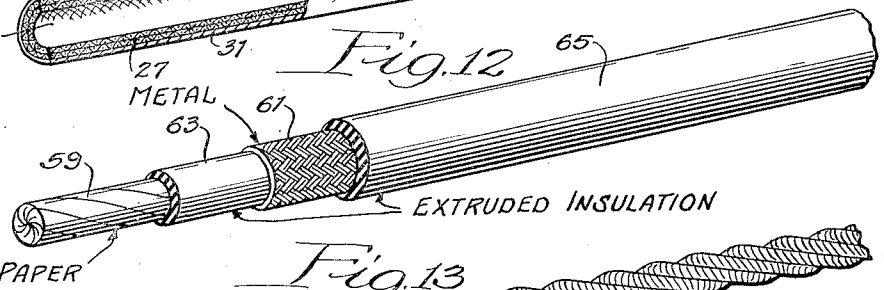
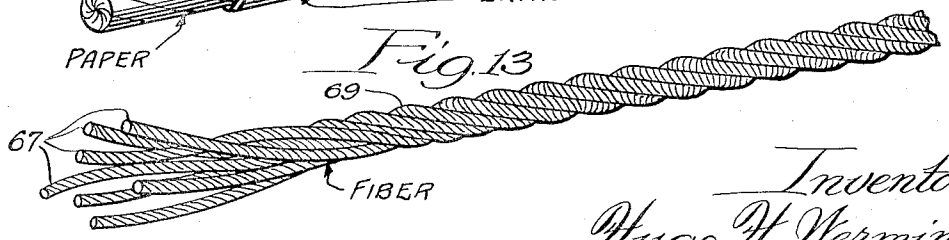


Fig. 13



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SHIELD FOR ELECTRICAL CONDUCTORS

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Fig. 6

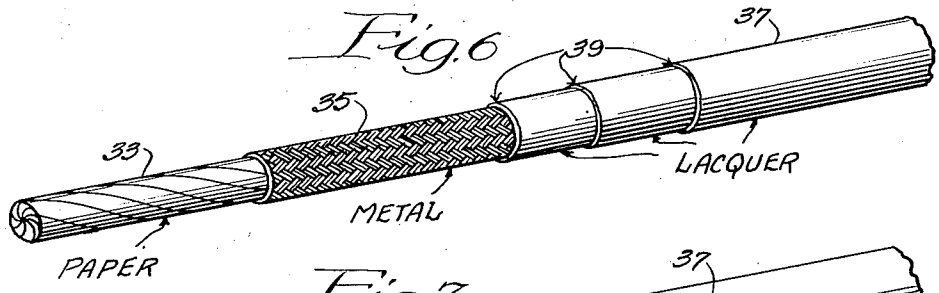


Fig. 7

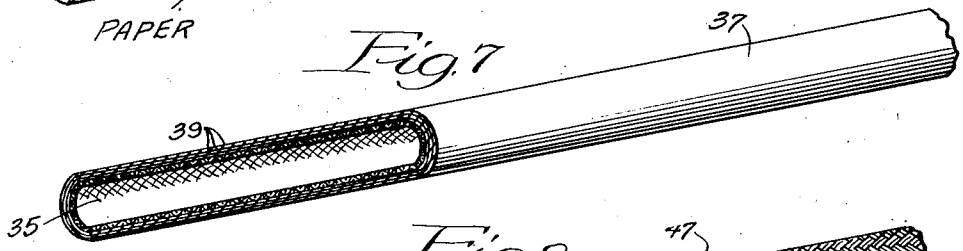


Fig. 8

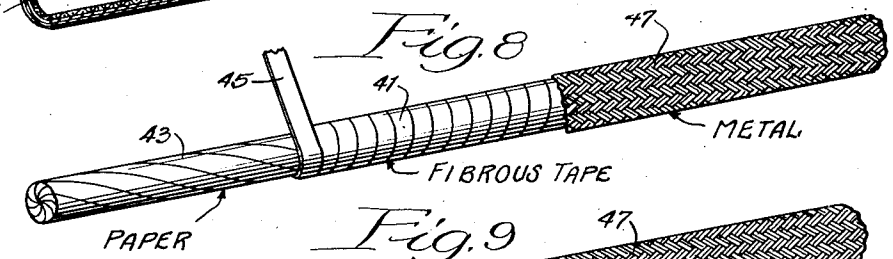


Fig. 9

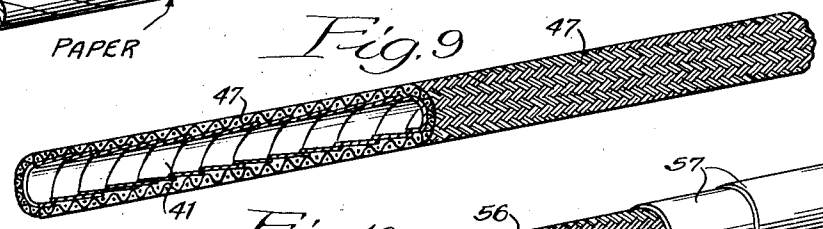


Fig. 10

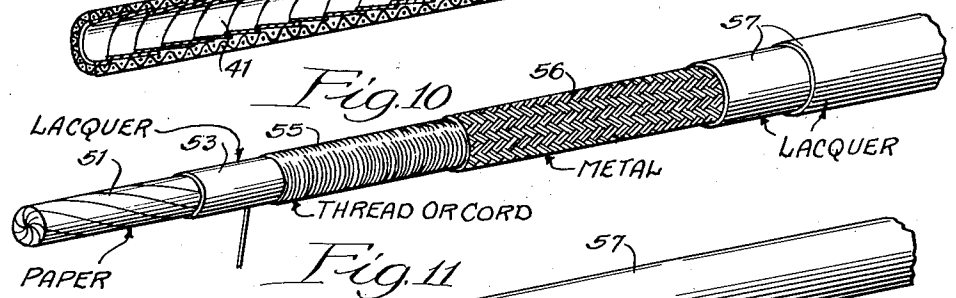
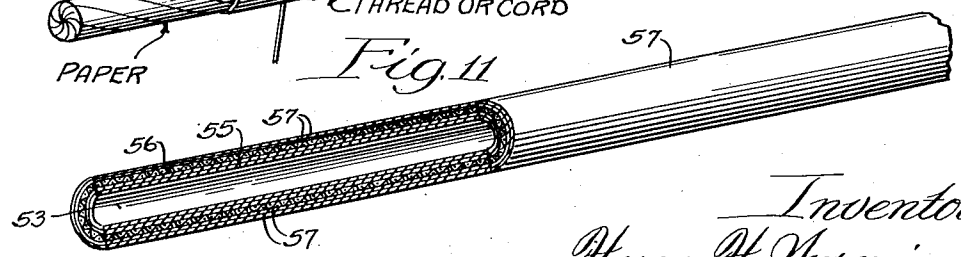


Fig. 11



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SHIELD FOR ELECTRICAL CONDUCTORS

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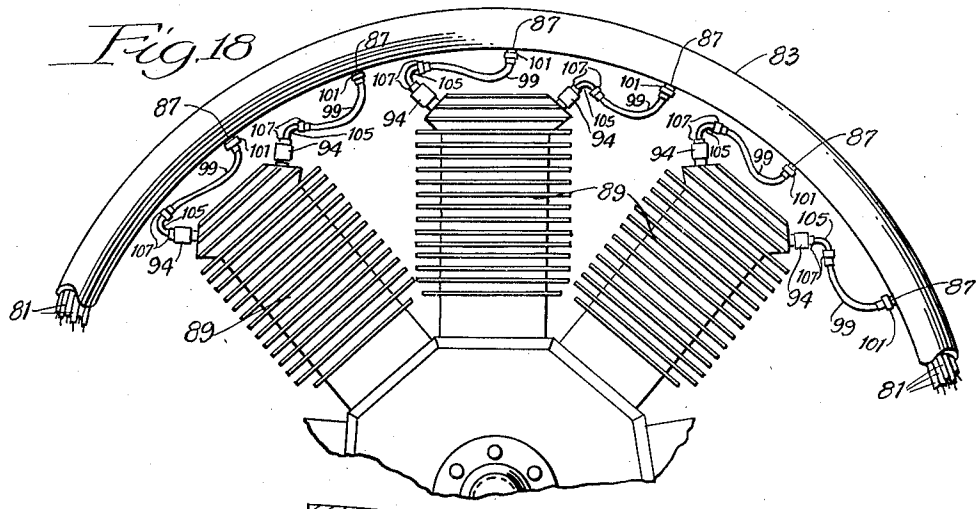
Fig. 18



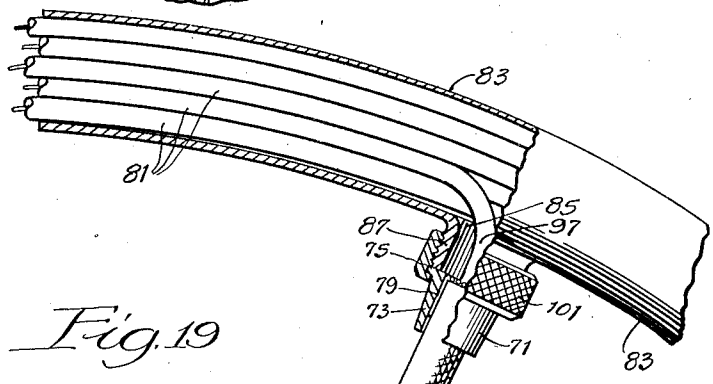


Fig. 19

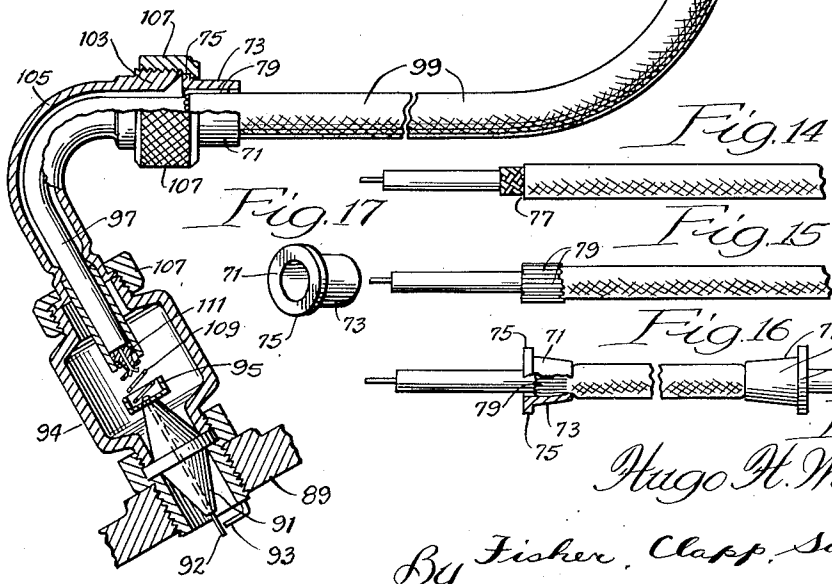


Fig. 14

Fig. 17

Fig. 15

Fig. 16

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UNITED STATES PATENT OFFICE

2,277,177

SHIELD FOR ELECTRICAL CONDUCTORS

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Application February 8, 1940, Serial No. 317,921

10 Claims. (Cl. 174—121)

My invention relates generally to electrical shielding means, and particularly to shields for electrical wires, cables and the like.

In certain apparatus, as, for example, airplane engines, it is necessary to shield various parts of the electrical equipment and wiring in order to minimize radio interference. However, the satisfactory accomplishment of this shielding has heretofore presented a most troublesome problem to the art, due in part to the necessity of providing a relatively large number of separate, flexible shields of widely varying lengths for those portions of the wiring which cannot conveniently be located within rigid shields, and in part to the difficulties experienced in applying the prior art shields to the wires or cables which are to be shielded. The principal object of the present invention, therefore, is to provide an improved, flexible shield for wires, cables and the like, and especially for those portions of wires and cables which must extend beyond rigid shields, which shall not only provide satisfactory shielding but which shall be much easier to use and apply than the shields heretofore known to the art.

Other objects of the invention include the provision of an improved, flexible, tubular shield which is at least temporarily self-sustaining and can be wound onto reels in relatively long lengths without collapsing or injury, thereby facilitating the storage and transportation of the product; the provision of an improved, flexible, tubular shield which can be readily manufactured at low cost by a continuous manufacturing process on existing machinery; and generally the provision of an improved flexible shield and method of making the same. The various novel features and advantages of the improved, flexible shield of the present invention will be made apparent in the following description and accompanying drawings of certain preferred embodiments thereof. In the drawings:

Figures 1 through 4 are perspective views illustrating three steps of one method of manufacturing the improved, flexible shield product of the present invention, a completed embodiment of the invention being illustrated in Figure 4;

Figure 5 is a perspective view, partially in section, showing the embodiment of the invention illustrated in Figure 4 ready for use;

Figures 6 through 11 are perspective views, generally similar to Figures 4 and 5, illustrating various other embodiments of the invention;

Figure 12 is a perspective view, similar to Figure 4, illustrating a second method of manufacturing the product of the present invention;

Figure 13 is a fragmentary perspective view illustrating a modified form of the removable core forming a part of the shield of the present invention;

Figures 14, 15, and 16 are fragmentary views illustrating one method of applying the shield of the present invention to a wire or cable;

Figure 17 is a perspective view of one type of terminal which may be used in connection with the shield of the present invention;

Figure 18 is a fragmentary, more or less diagrammatic view of an airplane engine, the ignition cables of which have been shielded by the use of the shield of the present invention; and

Figure 19 is an enlarged fragmentary view, partially in section, illustrating certain of the details of the shield applied to the ignition cables of the engine illustrated in Figure 13.

The flexible shield of the present invention is manufactured as a continuous cord and, while certain structural variations are contemplated, each of the several forms of the shield comprises basically a flexible, tubular conductor disposed about a flexible, cord-like core which is capable of being withdrawn from within the conductor in substantial lengths to provide a hollow shield and means for rendering the conductor self supporting when the core is removed so that the shield can be used. This last mentioned means may also include one or more sheath-like layers of insulating material which is disposed either inside or outside or on both sides of the flexible, tubular conductor and which may be bonded thereto. In the particular embodiment of the invention illustrated in Figures 4 and 5 of the drawings, the removable core element of the shield comprises a generally cylindrical cord **21** which may be formed by twisting together and compressing a plurality of sheets or strands **22** of paper, as illustrated generally in Figure 1. The flexible, tubular conductor comprises a metallic braid **23** disposed about and directly overlying the core **21**, and a multi-layer sheath **25** of insulating material overlies the tubular conductor **23**. During the manufacture of the product illustrated in Figures 4 and 5 it is contemplated that the core **21** shall be used as a form or mandrel and that the tubular conductor **23** shall be woven, as by braiding, directly thereon.

The insulating sheath **25** which overlies the flexible, tubular conductor **23** is of two-layer construction. The inner layer **27** constitutes a fabric sleeve which is formed, as by a braiding opera-

tion, from individual fibrous threads or strands **29** directly onto the conductor **23** after the conductor has been applied to the core **21**. The fabric sleeve **27** is impregnated, as by dipping or spraying, with an insulating lacquer or varnish to provide the outer layer **31** of the sheath and under ordinary manufacturing procedures, this impregnation will bond the fabric sleeve to the conductor **23**, thereby providing a relatively strong support for the conductor when the core **21** is removed.

The embodiment of the invention illustrated in Figures 6 and 7 differs from the embodiment of the invention just described in that the insulating sheath portion of the shield consists of a plurality of layers of similar material, preferably an insulating lacquer or varnish. The core **33** utilized in this form of the invention preferably comprises a flexible, cylindrical cord of suitable material similar to the core **21**. As in the previously described embodiment, the flexible, tubular conductor element of the shield comprises a multi-conductor, cylindrical sleeve **35** which is applied directly to the core **33** by a weaving operation, such as braiding. The insulating sheath **37** is applied to the formed tubular conductor **35** by successive dipping or spraying operations, the effect of which is to form a plurality of superimposed, thin, tubular layers **39** of lacquer, as illustrated in Figure 6.

The successive lacquer coatings or layers **39** may be applied conveniently by apparatus similar to that used for applying enamel or lacquer coatings to wire. The use of a plurality of thin lacquer coatings produces a very effective bonding together of the conductor **35**, and an insulating sheath for the shield of very considerable mechanical strength and very uniform dimensions. Lacquer sheaths may be produced in almost any desired color through the addition of suitable pigment to one or more of the lacquer coats. Additional advantages of the multi-layer lacquer sheath are its very low cost and extremely high insulating ability, both of which result from the use of lacquer alone in the formation of the constituent layers of the sheath. To assure easy removal of the core **21**, there must be no bond between the core and the conductor **35**.

In certain instances it may be desirable to utilize an insulating sleeve or layer inside the flexible, tubular conductor portion of the shield, and one embodiment of the invention having an insulating sleeve **41** in this position is illustrated in Figures 8 and 9. The core **43** utilized in this form of the invention is a flexible, cylindrical cord and may be of the same character as the cord **21** previously described. As distinguished from the two previously described embodiments, the first step in the manufacture of this form of the invention will consist in the application of the inner insulating sleeve **41** to the core **43**. The inner insulating sleeve or layer **41** may be of any convenient type and may comprise a wrapping of paper or fabric tape as illustrated at **45** in Figures 8 and 9; tests have shown that an insulation layer **41** which consists of a tape or thread wrapping, especially when that wrapping is impregnated with lacquer, will provide a shield possessing excellent mechanical strength in addition to good insulating ability. The lacquer impregnation assures good mechanical support of the conductor, and if the conductor is applied while the lacquer is still wet a good bond will be formed between the inner insulation layer **41** and the conductor.

Following the formation of the inner insulating sleeve **41**, the flexible, tubular conductor, which may comprise a woven metallic tube or sleeve **47** similar to the sleeves **23** and **35** of the previously described embodiments, will be formed over the inner sleeve **41**. The outer insulating sleeve or layer, if used, may then be applied to the flexible conductor **47**. For certain types of work an outer layer of insulation need not be used, although even in such instances it will be found desirable to impregnate the formed tubular conductor with an insulating lacquer or similar material in order to assure a self-supporting shield.

The embodiment of the invention illustrated in Figures 10 and 11 is provided with a sleeve or layer of insulation both inside and outside of the flexible, tubular conductor element. The core **51** is similar to the core **21** previously described. The inner insulating sleeve, as illustrated, is of multi-layer construction and comprises one or more coatings **53** of lacquer and a reinforcing layer which may comprise a thread or cord wrapping **55**. When a multi-layer inner sleeve of this type is used it is desirable that the reinforcing layer shall be bonded to the other layer or layers. The flexible, tubular conductor **56** used in this embodiment of the invention is preferably a woven sleeve similar to the tubular conductors **23**, **35**, and **47** used in the previously described embodiments. The outer insulating sleeve, as illustrated, comprises a plurality of thin layers **57** of lacquer similar to the insulating sleeve **37** of the embodiment illustrated in Figures 6 and 7. This construction produces a very strong shield which is fully self-supporting when the core is removed.

In addition to the several specific forms of the invention which have been described in the foregoing, there is at least one other form of the invention and one other manufacturing method which have been found to be particularly advantageous. A shield produced by this method is illustrated in Figure 12. This embodiment of the invention includes a generally cylindrical, flexible core **59** which may be similar to the core **21**, a flexible, tubular conductor **61**, preferably of the multi-strand, woven type which has been described in connection with the previously described embodiments, an inner sleeve or layer **63** of insulation, and an outer sleeve or layer **65** of insulation, both of which layers have been applied by an extrusion operation. The extrusion process produces a particularly good bond between the sheath insulation and the conductor, and excellent support for the conductor when the core is removed.

The first step in the manufacture of the extruded sleeve embodiment of the invention illustrated in Figure 12 will consist in the application of the inner insulating sleeve **63** to the core **59** by an extrusion operation. Following this, the flexible, tubular conductor **61** will be applied to the inner insulating sleeve **63**, and finally the outer layer **65** will be applied, also by extrusion, to the conductor **61**.

The extruded insulating sleeves **63** and **65** will usually be made of rubber, rubber compound, or rubber substitute, although various synthetic resins may be extruded. The extruded type insulation lends itself particularly well to quantity production and may be manufactured at low cost. However, the extrusion procedure will not yield insulation of as uniform thickness as the multi-

layer lacquer sleeve **37** or the impregnated fabric sleeve **25** described in the foregoing.

It will be understood that, if desired, either the inner sleeve **63** or the outer sleeve **65** may be omitted, and that an extruded type sleeve may be used for only one of the two insulating sleeves. Also, one or more of the extruded type sleeves may be utilized in connection with the fabric sleeve **27** of the Figure 4–Figure 5 embodiment or the taped and wound sleeves **41** and **55** of the Figures 8 and 9 and Figures 10 and 11 embodiments.

The shield product of the present invention may be made of any desired size, depending upon the use to which it is to be put. Standard ignition cable, for example, is about ¼ of an inch outside diameter, and if the shield is to be used for shielding cable of this type the removable core, which determines the dimensions of the passageway within the flexible, tubular conductor, should have a diameter just slightly in excess of ¼ of an inch.

Various flexible materials, such as multi-strand or single-strand paper or fiber cordage, may be used for the removable core element of the product. The core **21**, which is illustrated in Figure 1 and which consists of a plurality of compacted and twisted strands of paper **22**, has proven very satisfactory, and cores which consist of a plurality of twisted strands **67** of fiber cordage such as manila or hemp fiber as illustrated at **69** in Figure 13 have also been used with good results. Since the functions of the core are to provide a form or mandrel for use in the manufacture of the several layers of the shield and to provide a removable internal support for rendering the shield self-sustaining prior to its use, the material from which the core is made should be relatively inexpensive. To assure easy withdrawal of the core from within the shield proper, the core should be sufficiently hard to resist compression during the forming of the tubular conductor and the insulation. Waxing and twisting the constituent strands of the core or the application of talc or a lubricant between the core and the shield will also facilitate separation of the core and the shield and may permit the use of moderately soft cores. For maximum convenience in the manufacture and use of the product, it is very desirable that the core shall be flexible.

The flexible, tubular conductor used in the product of the present invention preferably comprises a large number of interwoven strands of relatively fine copper wire, and may be most conveniently applied by the use of a wire braiding machine. To assure effective shielding under adverse conditions, the individual metallic strands constituting the conductor should be sufficiently closely laid to cover not less than about 60% to 75% of the surface area of the underlying core or insulation layer. In a particularly satisfactory embodiment of the invention designed for use in the shielding of aircraft ignition cables, the tubular conductor was formed by braiding together 96 strands of No. 36 (A. W. G.) copper wire, the individual strands being tinned.

Various fibrous materials capable of being formed into threads, tape, or other fabric, as for example linen, cotton, silk, asbestos, glass, cellulose fiber, paper, etc., may be used in forming the woven or wrapped fabric sleeves such as are illustrated at **27**, **41**, and **55** in the drawings. For this reason, "fabric sleeve" and "fabric sheath" as used herein shall cover insulating sleeves or layers of any of the foregoing materials, whether applied by weaving, knitting, braiding, or wrapping, and whether in the form of thread, tape, woven or felted fabric, or otherwise.

Most of the insulating lacquers and varnishes and most of the extrudable insulating materials now in use for insulating purposes will be found satisfactory for use in manufacturing the insulating sleeves or layers forming a part of the product of the present invention. For this reason the term "lacquer" is intended to cover insulating lacquers and varnishes of the ordinary types, cellulose derivatives, such as ethyl cellulose and cellulose acetate, and various similar materials which are suitable for use as an insulation or insulation impregnating material, and the term "extruded insulation" is intended to cover various extrudable insulating materials such as natural or synthetic rubber, rubber compounds, extrudable resins, etc.

When it is desired to use the product of the present invention, a suitable length will be cut off and the core will be withdrawn, thereby providing a flexible, hollow shield which is sufficiently self-supporting that it can be conveniently handled. This hollow shield may then be slipped over the wire or cable which it is desired to shield. To facilitate the electrical connecting of the shield with the other elements of the shielding system, it is desirable that terminals shall be used in connection with the shield, and a particularly satisfactory terminal is illustrated at **71** in Figures 16 and 17. The terminal **71** comprises a generally cylindrical, tubular body portion **73** and an outwardly projecting flange **75** formed integrally with the body portion **73**. When this type of terminal is to be used, a suitable length of the hollow shield is first placed over the wire or cable which is to be shielded and an end portion of the outer insulation, if used, is removed, as illustrated at **77** in Figure 14. Next, the constituent strands of the flexible conductor element of the shield are unbraided and are bent back over the adjacent end of the shield, as illustrated at **79** in Figure 15. If the shield is provided with an internal insulating sleeve, the portion of the inner sleeve exposed by the bending back of the shield wires **79** is preferably removed. One of the terminals **71** is then slipped over the end of the shield so as to overly the exposed wires **79**, and the body portion **73** of the terminal is crimped so as to tightly engage the shield and the wire or cable located within the shield, as illustrated in Figure 16. A similar procedure is followed in applying the terminal at the other end of the shield.

The use of terminals of this type not only provides a good electrical connection to the tubular conductor portion of the shield, but in addition it securely fastens the shield in place upon the enclosed wire or cable so as to prevent relative movement therebetween. The terminal also provides a very neat appearing connection which may be conveniently fastened to cooperating elements of the shielding system.

A specific example of the use of the shield of the present invention is illustrated in Figures 18 and 19, which are fragmentary views of a portion of an airplane engine. In these views, the rigid, tubular ring which constitutes the main shield for the ignition cables **81** is illustrated at **83**. Circular openings **85** (Figure 19), which are defined by hollow, externally threaded bosses **87**, are provided at regularly spaced intervals along the internal periphery of the ring **83** to permit the ignition cables **81** to be connected to the spark

plugs of the engine. Each cylinder 89 of the engine illustrated in the drawings is provided with two spark plugs, each of which includes an insulator 91, a pair of electrodes 92 and 93, and a cylindrical shield 94 which completely surrounds the upper portion of the insulator 91 and the spark plug terminal 95 which is connected to the central electrode 92, as illustrated in Figure 19.

The portion 97 of each ignition cable 81 which extends between the main shield ring 83 and each of the individual spark plugs is enclosed within a section 99 of the shield of the present invention which is held in place by two of the terminals 71 which have been applied thereto as illustrated in Figures 14, 15, and 16. The innermost terminal 71 for each of the shield sections 99 is adapted to be seated against the adjacent threaded boss 87 and is securely held in this position by an internally threaded, annularly shaped clamping member 101, as illustrated in Figure 19. The clamping members 101 serve the further function of completing the electrical circuit from the main shield ring 83 to the conductor elements of each of the several flexible shields 99. Each of the outer terminals 71 is adapted to be seated against a second hollow boss 103 integrally attached to one end of a hollow, metallic adapter 105 which is mechanically and electrically connected at its other end to the cooperating plug shield 94. Each of the outer terminals 71 is held in place against one of the bosses 103 by a second internally threaded, annularly shaped, clamping member 107, and a spring terminal 109 is attached to the outer end of the conductor 111 of each of the ignition cable portions 97 for connecting that conductor to the associated spark plug terminal 95.

It will be apparent that the shield arrangement just described provides a complete electrical shield for the portions 97 of the ignition cables which extend between the main shield ring 83 and the adapters 105 for the spark plugs. By virtue of the inherent flexibility of the shield of the present invention, the spark plugs can be readily removed for examination or servicing. Also, replacement of individual cables or the complete ignition wiring may be readily accomplished. In this connection, it might be mentioned that in the ignition wiring systems heretofore used it has been found necessary to use cables which were fully shielded throughout their length, and to remove the shielding from all except the end portions of the cables which project from the rigid sheath during their installation. Obviously, this procedure was not only extremely wasteful, but in addition it sometimes resulted in injury to the cable insulation.

From the foregoing it will be seen that I have provided an improved, continuous cord product which can be readily converted into a hollow, self-supporting, flexible, tubular shield of any desired length. The product of the present invention can be readily manufactured at high speed and at low cost without the use of any special equipment. The completed product is completely self-sustaining, due to the presence of the removable core, and may be wound onto spools or reels for convenient storage and transportation. The product is at all times ready for use and waste is entirely eliminated due to the fact that the mechanical support provided for the conductor by the shield insulation permits easy removal of the core any reasonable length of the insulating sheath.

Actual tests have shown conclusively that the shield of the present invention constitutes a simple and at the same time highly satisfactory means for accomplishing the shielding of electrical conductors, and particularly for shielding the end portions of flexible conductors which project from a rigid sheath or shield and which must be shielded without loss of flexibility. It will be apparent to those skilled in the art that various modified forms of the present invention may be developed, and that some variation is possible in the particular structure of the invention. Accordingly, it is my desire that the accompanying claims shall be accorded the broadest reasonable construction consistent with the language appearing therein and the prior art.

I claim the following as my invention:

1. A continuous cord, comprising a flexible core, a flexible, tubular conductor disposed about said core, and a flexible sleeve of insulating material which includes a fabric sheath in contact with and bonded to said conductor, said core being capable of being withdrawn from within said conductor sleeve in substantial lengths to provide a flexible hollow shield, said sleeve serving to support and mechanically strengthen said conductor so as to render said shield self supporting when said core is removed therefrom.

2. A continuous cord comprising a flexible core, a flexible, tubular conductor disposed about said core, and a flexible sleeve which includes a plurality of superimposed layers of lacquer associated with, and bonded to, said conductor, said core being freely movable relative to said conductor and being capable of being withdrawn from within said conductor and sleeve in substantial lengths to provide a self supporting, flexible, hollow shield.

3. A continuous cord comprising a flexible core, a flexible, tubular conductor disposed about said core, and a flexible sleeve which includes at least one tubular layer of extruded insulation associated with, and bonded to, said conductor, said core being freely movable relative to said conductor and being capable of being withdrawn from within said conductor and sleeve in substantial lengths to provide a self supporting, flexible, hollow shield.

4. A continuous cord comprising a flexible, generally cylindrical core, a flexible, tubular conductor disposed about said core, a fabric sheath which is impregnated with an insulating lacquer overlying and bonded to said tubular conductor and means for preventing a bond between said core and conductor whereby said core is capable of being withdrawn from within said conductor and sheath in substantial lengths to provide a flexible, hollow shield, said impregnated sheath serving to mechanically strengthen said conductor and to render said shield self supporting when said core is removed therefrom.

5. A continuous cord comprising a flexible core, a flexible sleeve of insulating material overlying said core, a flexible, tubular conductor overlying said sleeve, and a second flexible sleeve of insulating material overlying said tubular conductor, said core being capable of being withdrawn from within said conductor and said insulating sleeves in substantial lengths to provide a flexible, hollow, insulated shield, said sleeves serving to mechanically strengthen said conductor and to render said shield self supporting when said core is removed therefrom.

6. A continuous cord comprising a flexible core, a flexible sleeve of insulating material overlying

said core, a flexible, tubular conductor of metallic braid construction overlying said sleeve, a second flexible sleeve of insulating material overlying said tubular conductor, at least one of said sleeves being bonded to said conductor, and means preventing a bond between said core and said inner sleeve whereby said core can be readily withdrawn from within said inner sheath in substantial lengths to provide a flexible shield, said sleeves serving to mechanically strengthen said conductor, and to render said shield self supporting when said core is removed therefrom.

7. A flexible sheath of the class described comprising a generally cylindrical, continuous, flexible core, a flexible, multistrand, braided conductor of tubular shape disposed about said core, and an insulating sleeve overlying and bonded to said conductor, the constituent strands of said conductor being sufficiently closely laid to enclose at least 60 to 75 percent of the surface area of said core, said core being capable of being withdrawn from within said tubular conductor in substantial lengths, said sleeve serving to mechanically strengthen said conductor so as to render said sheath self supporting when said core is removed therefrom.

8. A continuous cord comprising a continuous, flexible core, a flexible conductor of tubular form disposed about said core, and means including a flexible sleeve of non-metallic material in contact with and bonded to said conductor for mechanically strengthening said conductor so as to render said conductor self supporting independently of said core, said core being capable of being withdrawn from within said conductor and sleeve in substantial lengths to provide a self supporting, flexible, hollow shield.

9. A continuous cord comprising a continuous, flexible, generally cylindrical core, a flexible multi-strand braided conductor of tubular shape disposed about said core, and means including a flexible sleeve of insulating material in contact with and bonded to said conductor for mechanically strengthening said conductor so as to render said conductor self supporting independently of said core, said core being capable of being withdrawn from within said conductor and sleeve in substantial lengths to provide a self supporting, flexible, hollow shield.

10. A continuous cord, comprising a flexible, generally cylindrical core, a flexible tubular conductor of metallic braid construction disposed about said core, means including a flexible sleeve of insulating material which is bonded to said conductor for mechanically strengthening said conductor so as to render said conductor self supporting independently of said core, and means for preventing a bond between said core and said conductor and sleeve in order that substantial lengths of said core can be readily withdrawn from within said conductor and sleeve to provide a self supporting, flexible, hollow shield.

HUGO H. WERMINE.