Feb. 21, 1961 O. F. BOYKIN 2,972,726

ELECTRICAL RESISTOR

Filed Feb. 27, 1956 3 Sheets-Sheet 1

Fig. 1

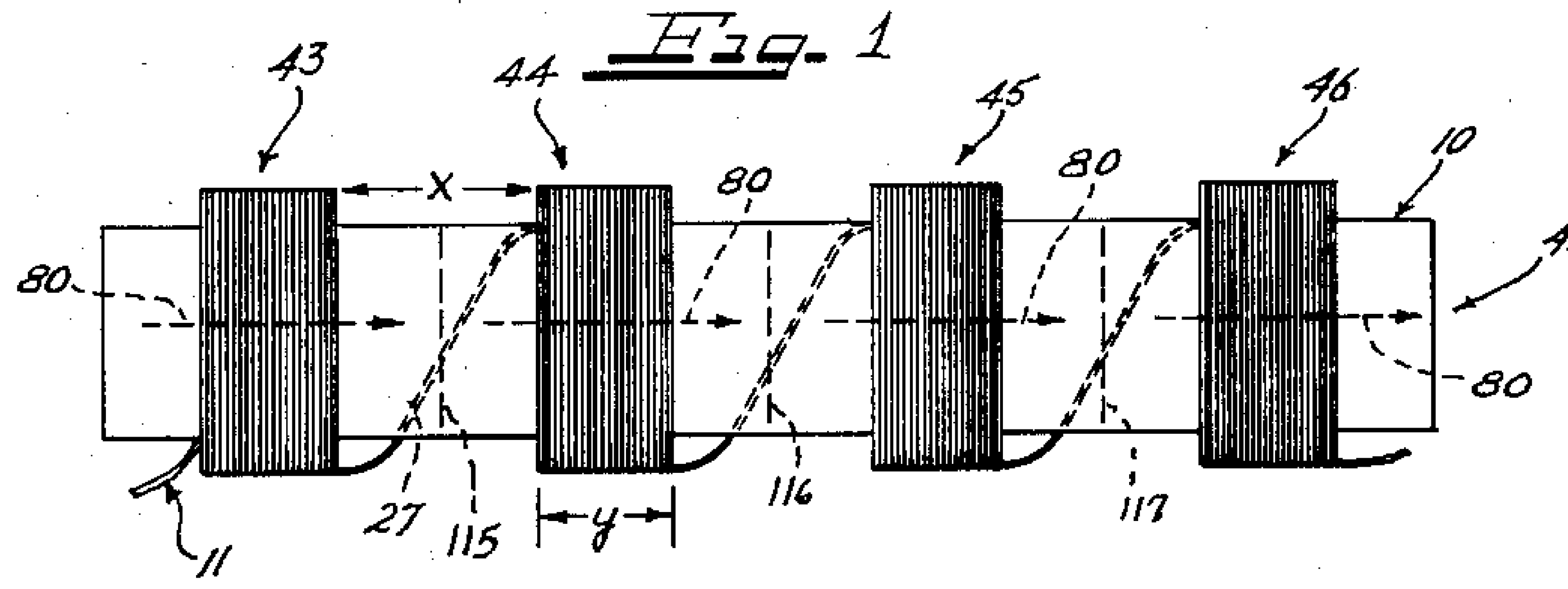

Fig. 3

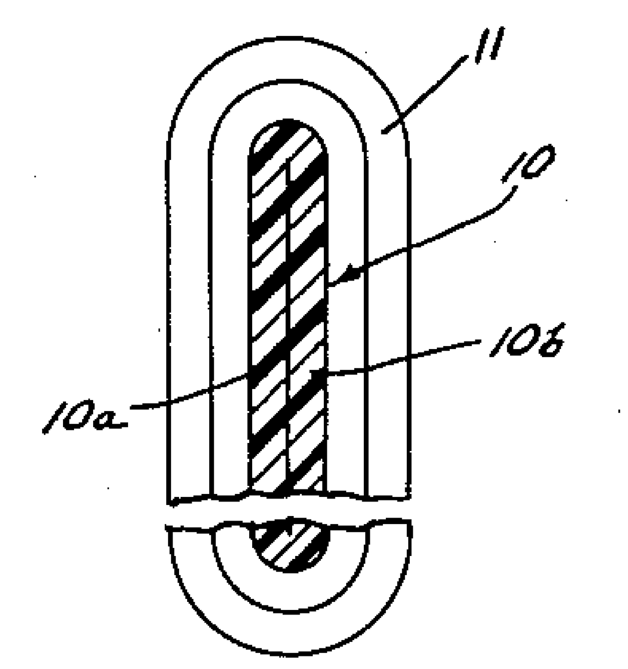

Fig. 2

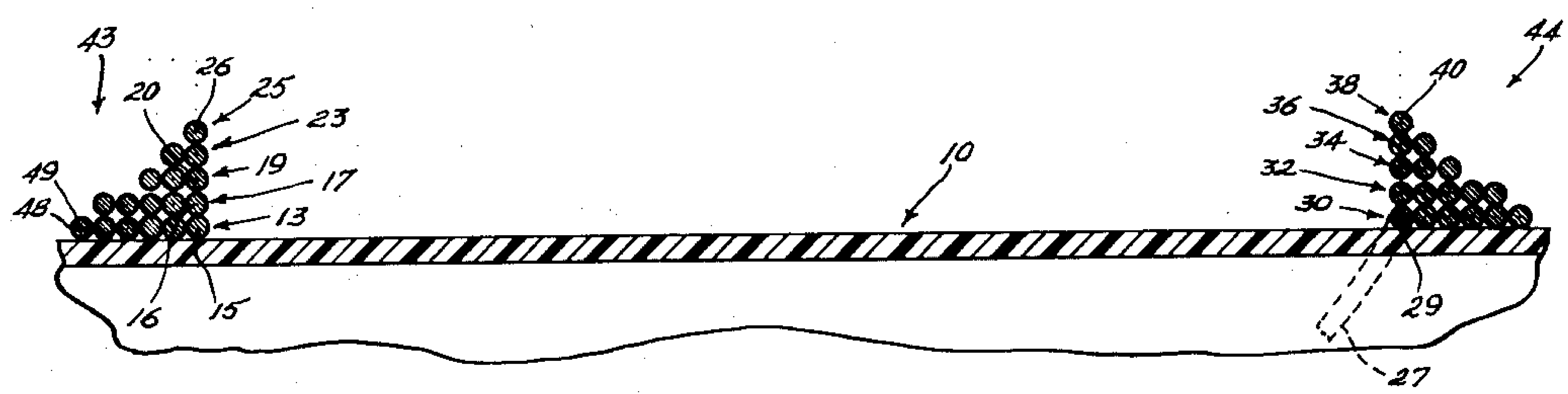

Fig. 4

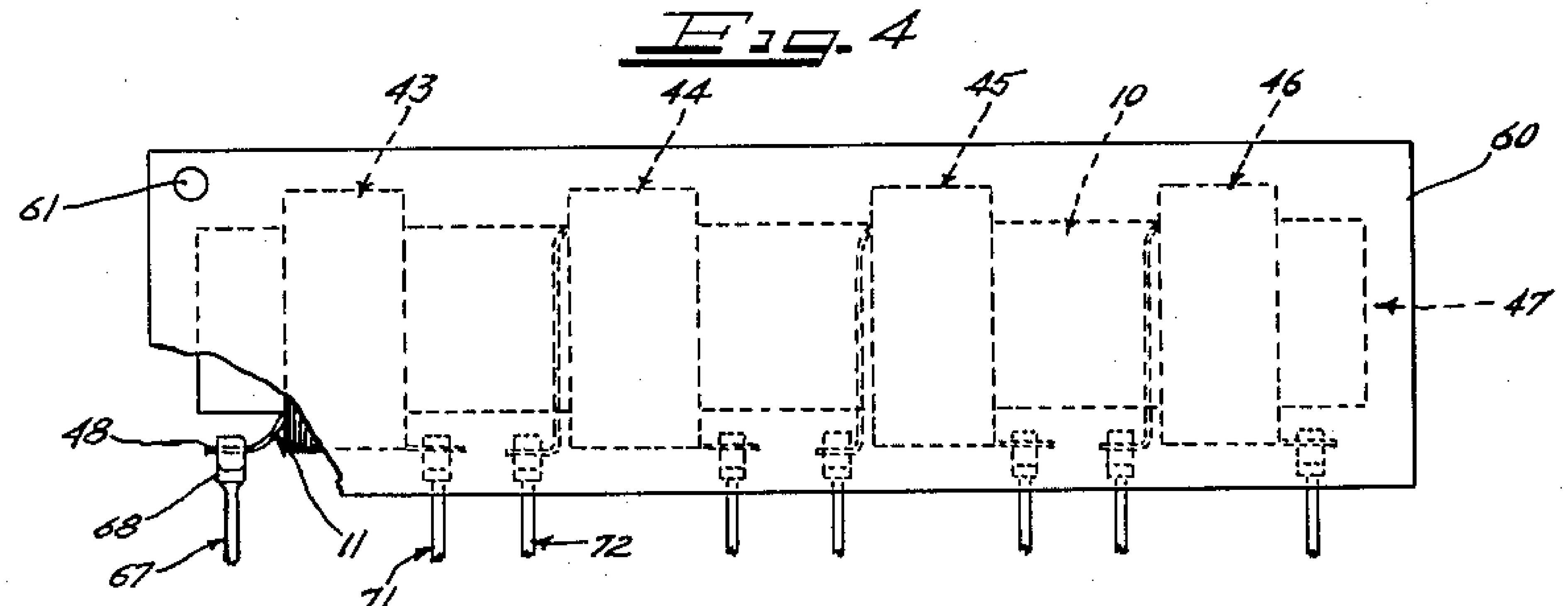

Fig. 5

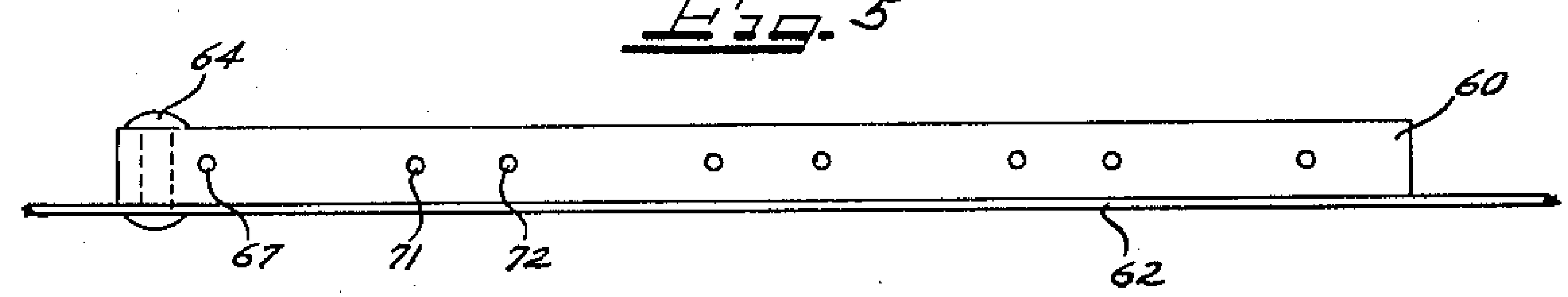

Fig. 6

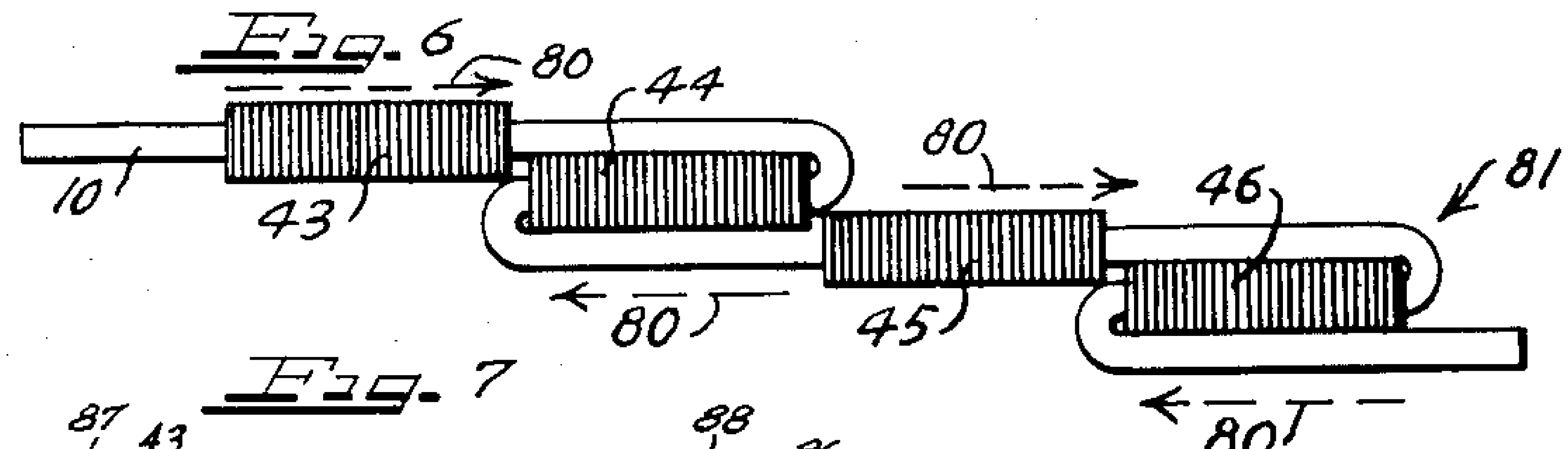

Fig. 7

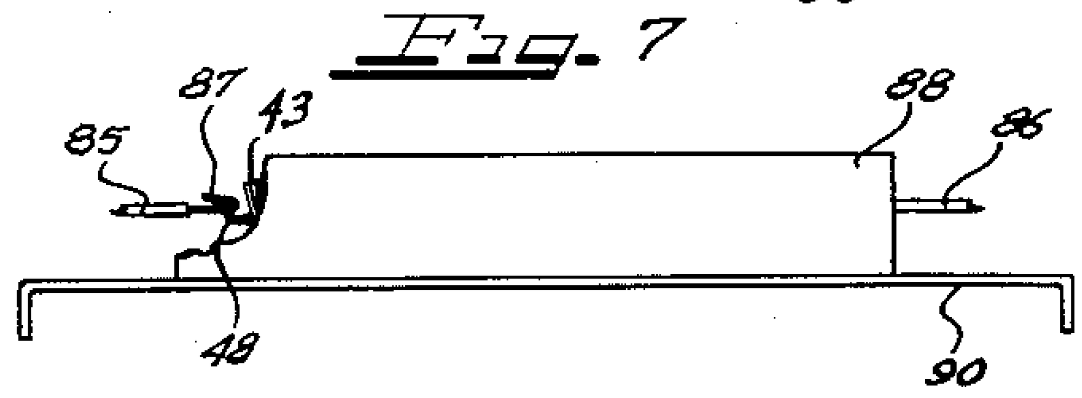

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Fig. 8

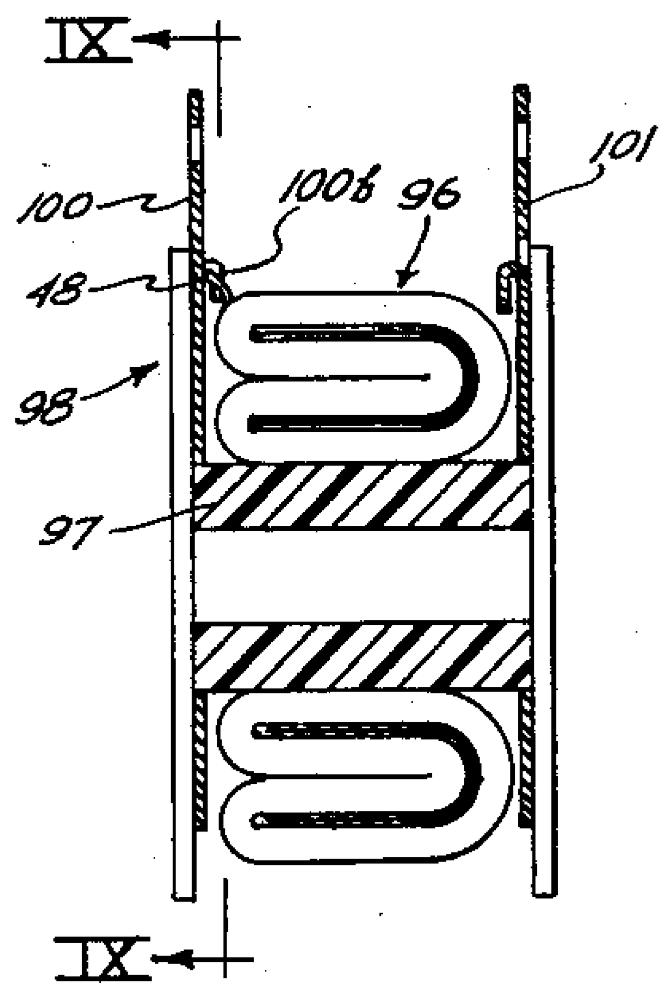


Fig. 9

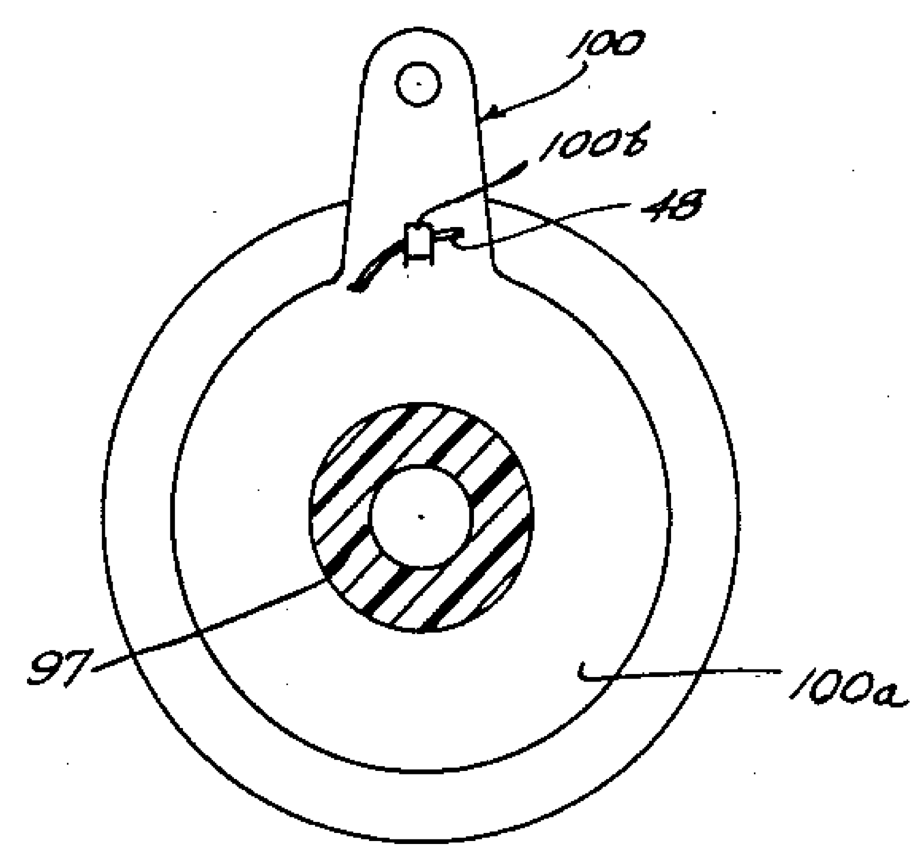


Fig. 8a

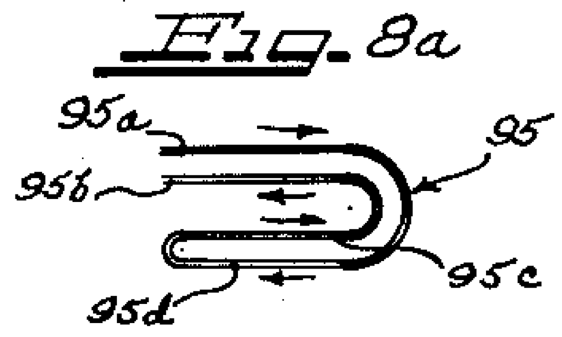


Fig. 10

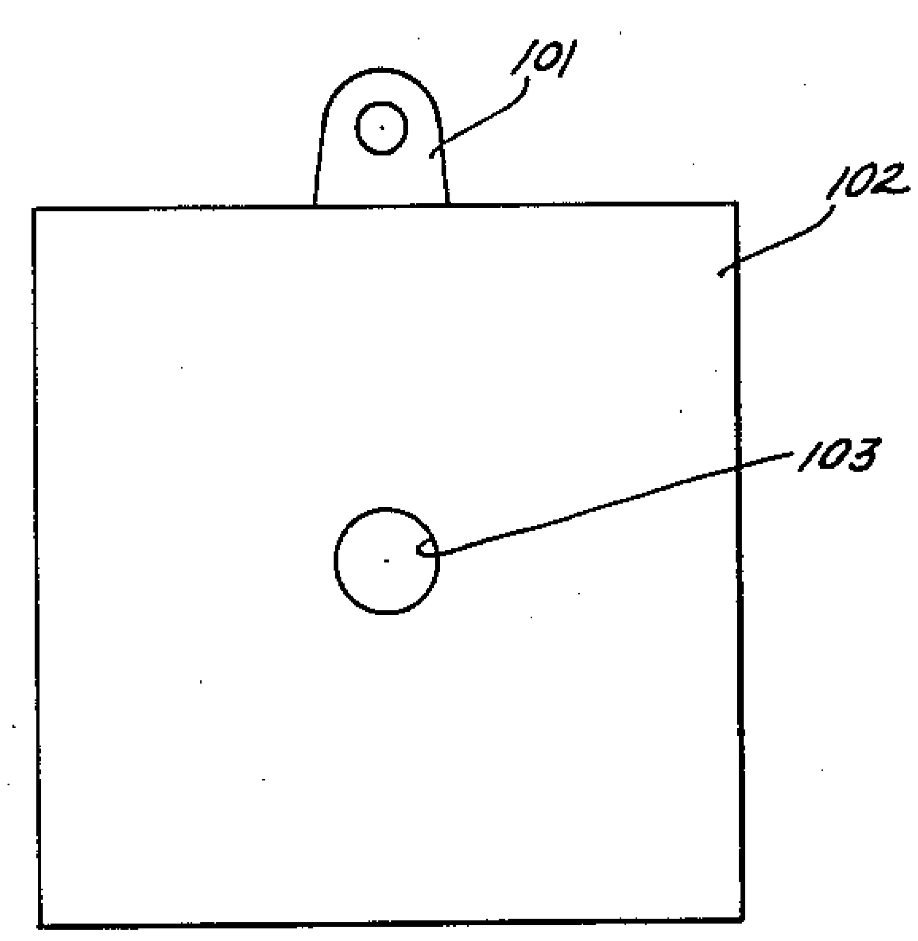


Fig. 11

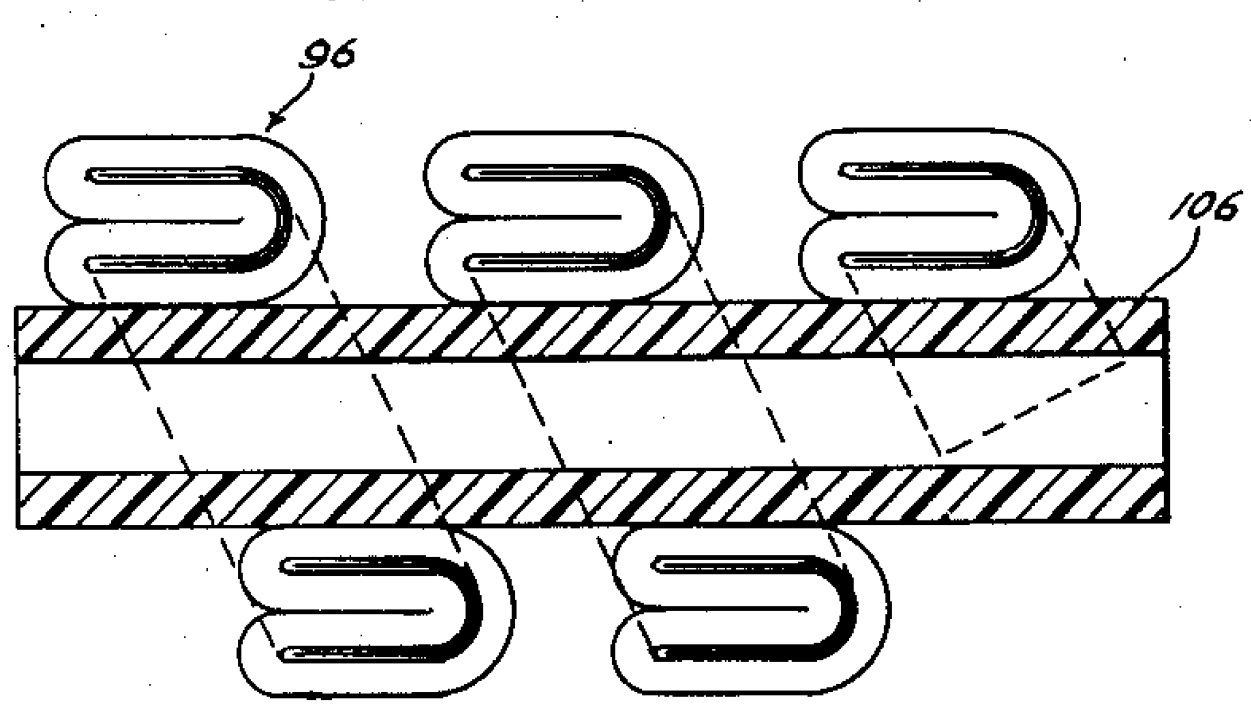
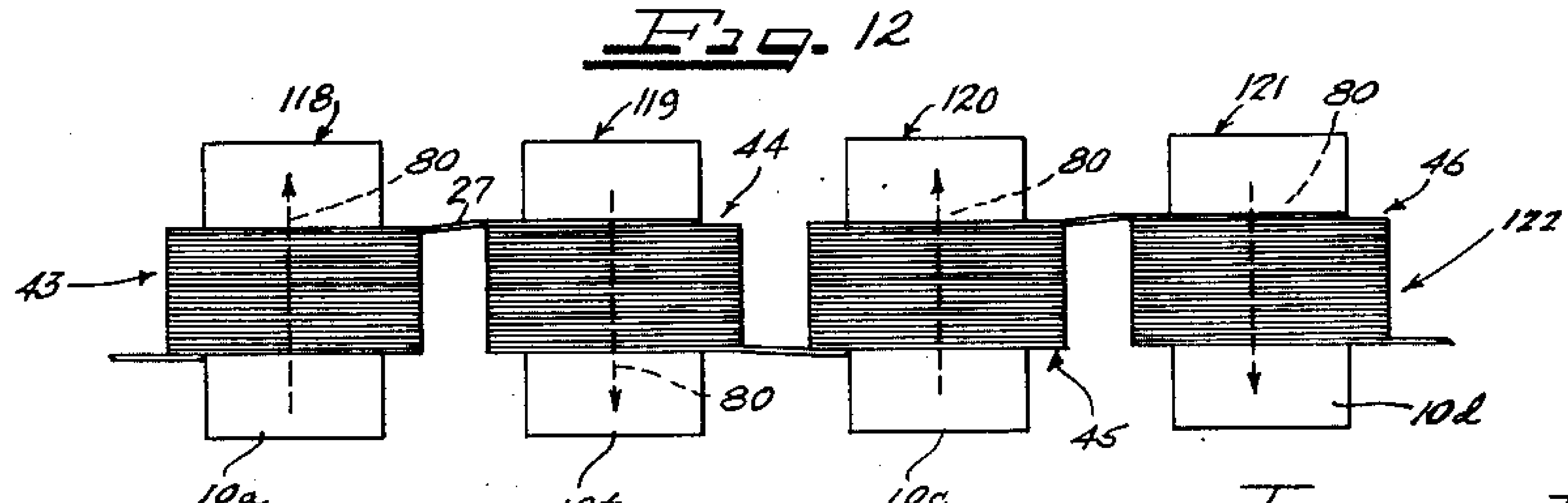


Fig. 12



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ELECTRICAL RESISTOR

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Fig. 14.

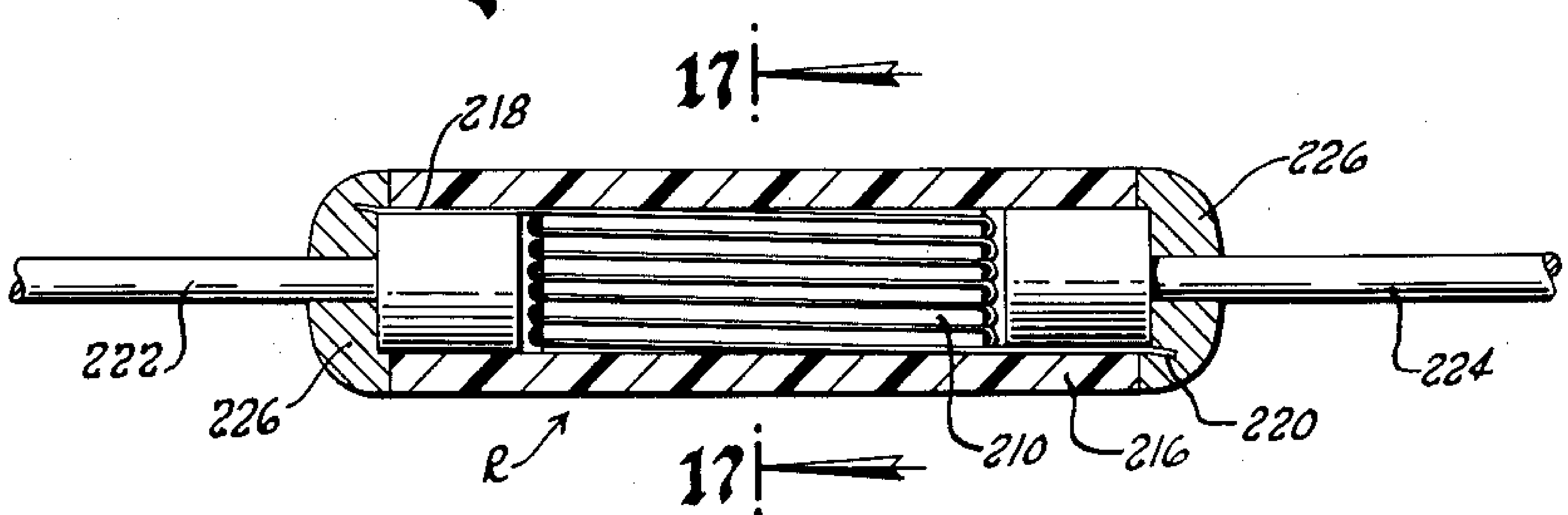


Fig. 15.

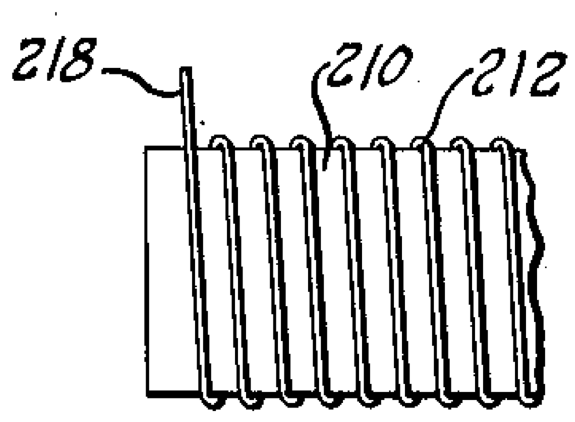


Fig. 16.

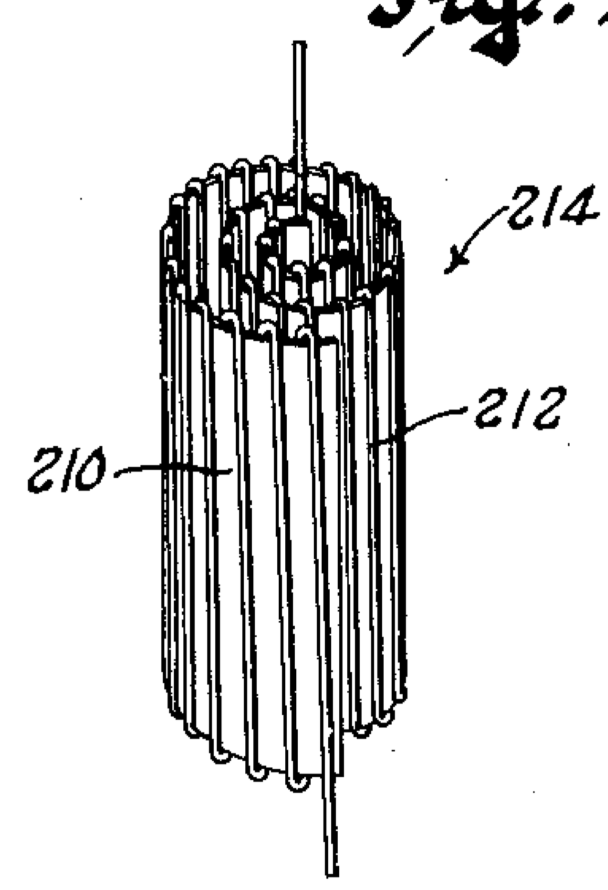


Fig. 17.

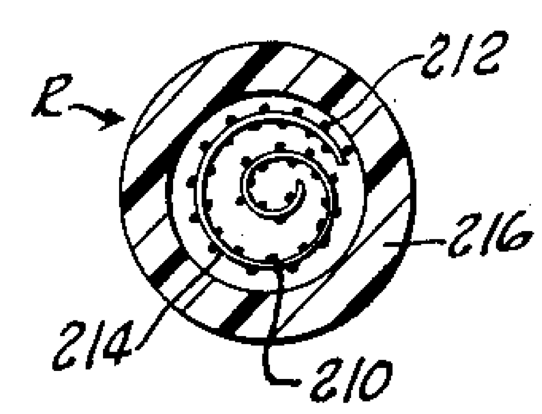


Fig. 18.

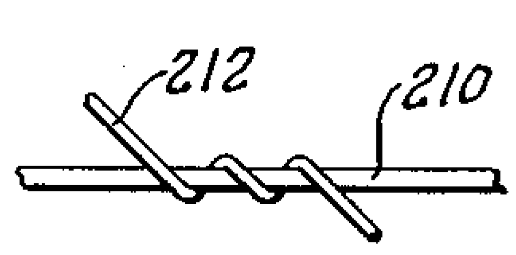


Fig. 20.

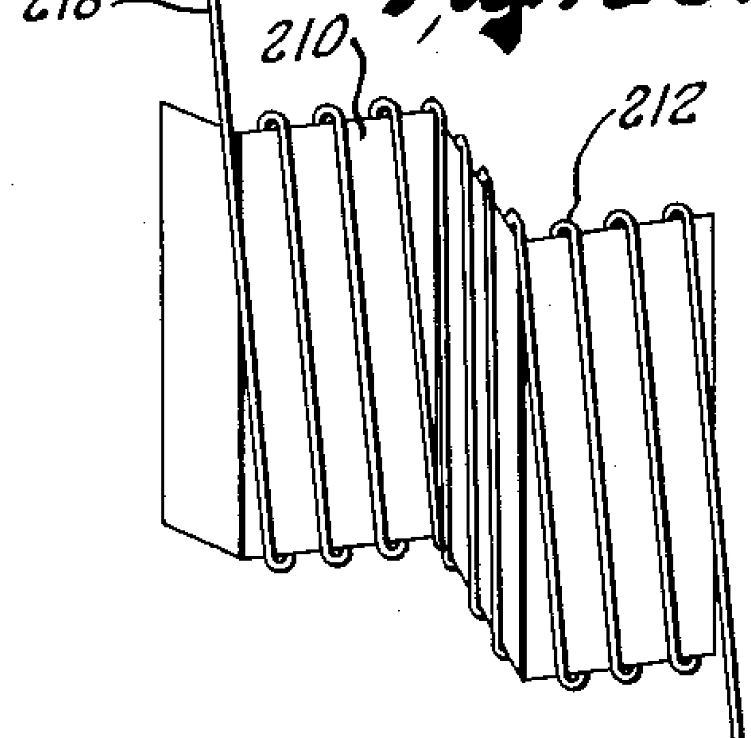


Fig. 19.

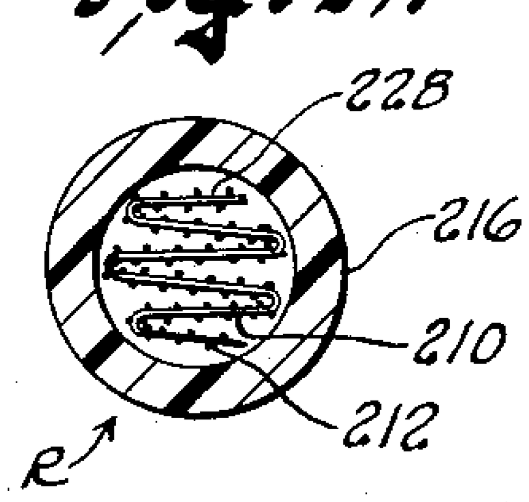
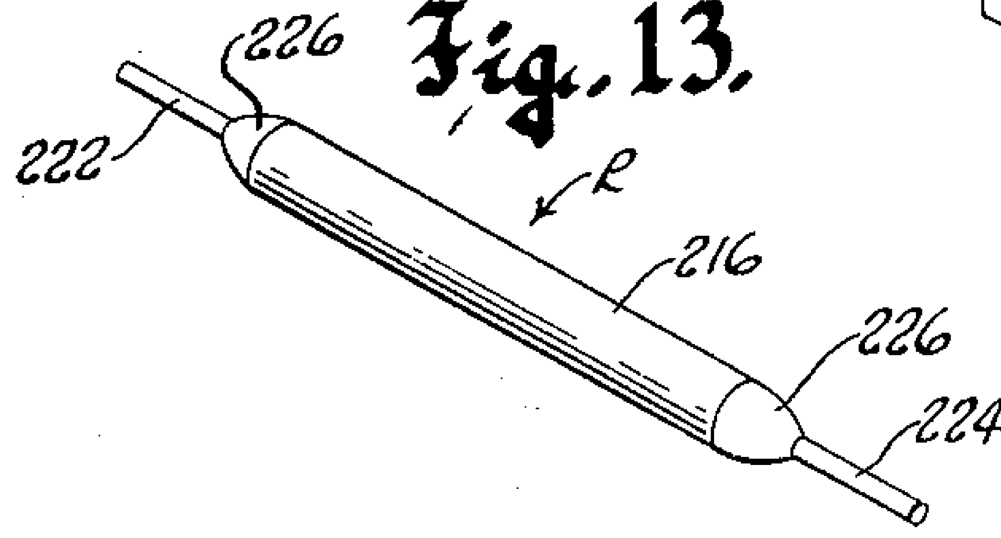


Fig. 13.



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United States Patent Office

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ELECTRICAL RESISTOR

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Filed Feb. 27, 1956, Ser. No. 567,765

21 Claims. (Cl. 338—297)

This invention relates to an electrical resistor, and particularly to a high precision wire-type resistor.

Precision resistors as heretofore constructed have been difficult to manufacture and hence have been quite expensive. Commonly, precision resistors have been wound on bobbins or spools in spaced reversely wound sections. The bobbins have cores of relatively small diameter and are rotated at high speed to wind the wire thereon so that the wire is subjected to relatively great tension. It has been found that the strains resulting from the winding operation cannot be economically fully relieved by heat treatment. Further the stretching of the wire during winding prevents accurate measurement of the wire as it is applied to the bobbin. The prior art spool or bobbin type resistors have also presented difficulties due to the differential expansion and contraction of the wire relative to the bobbin in operation, and additionally the bobbin type resistor has very definite space requirements which make it unsuitable or disadvantageous in many applications.

The present invention provides a precision type wire wound electrical resistor which can be readily adapted to different space requirements and configurations. The resistor will meet relatively stringent inductance requirements without the necessity for reverse winding as in the bobbin resistor, and may be made very cheaply and quickly without wire strain. In bobbin type wire wound resistors, design changes to minimize the inductive effect usually bring about an increase in capacitance. However, with the present invention, the resistor can be designed to combine minimum inductive with minimum capacitive effects.

Resistors according to the present invention can be designed to provide tolerances as low as required, for example .02%, and can be designed to withstand relatively great accelerations and shocks and great temperature changes such as encountered in rocket flight and the like. The resistors may be made in flat form for maximum heat transfer to flat mounting surfaces, or may be adapted to a wide variety of other mounting procedures.

It is therefore an important object of the present invention to provide a precision wire wound resistor eliminating the conventional bobbin.

It is a further object of the present invention to provide a novel resistance element in which the inductive effects associated with the element may be greatly reduced without the need for reverse winding of the wire.

A further object of this invention is to provide a novel electrical resistor which is simple and inexpensive to manufacture.

It is yet another object of the present invention to provide a resistance element which is readily adaptable to different space and mounting requirements.

A still further object of the present invention is to provide a resistor which can withstand extreme accelerations and shocks and great temperature changes without the danger of breakage of the fine resistance wire or other detrimental effects.

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It is a more specific object of the present invention to provide a novel and improved terminal connection for a resistance wire.

Other and further objects, features and advantages of this invention will become apparent from the following detailed description taken in connection with the accompanying drawings showing certain preferred embodiments, in which:

Figure 1 is a more or less diagrammatic elevational view of a resistance element comprising an embodiment of the present invention;

Figure 2 is a greatly enlarged longitudinal sectional view of a portion of the resistance element of Figure 1, and illustrating somewhat diagrammatically the manner in which the wire may be wound in multiple layers on its support;

Figure 3 is a cross sectional view through the element shown in Figure 1;

Figure 4 is a plan view of a resistance element of the type shown in Figure 1 embedded in an insulated casing with the successive sections of the resistance element of Figure 1 connected to individual terminals;

Figure 5 is an elevational view of the structure of Figure 4 and illustrating the resistor secured to a flat heat conductive mounting surface;

Figure 6 illustrates the resistance element of Figure 1 with the supporting tape thereof folded to dispose the sections of the elements in such a way that the magnetic fields of adjacent sections opposed one another;

Figure 7 is an elevational view illustrating the resistance element of Figure 6 secured within an insulating casing and mounted against a suitable heat conductive surface;

Figure 8 illustrates a resistance element of the type shown in Figure 1 folded about a longitudinal axis and then wound arcuately on a spool, the resistance element having a length such that the opposite ends thereof will be in spaced relation after the element is wound on the spool;

Figure 8*a* is a diagrammatic view of a single turn of resistance wire in the resistor configuration of Figure 8;

Figure 9 is a cross sectional view taken generally along the line IX—IX of Figure 8;

Figure 10 is an elevational view of the structure of Figure 8 embedded within an insulating housing;

Figure 11 represents a resistance element such as shown in Figure 1 folded on a longitudinal axis and wrapped helically on an insulating tube;

Figure 12 illustrates a modification of the resistance element shown in Figure 1, characterized by the fact that the tape or support upon which the winding sections are wound is severed between the sections and the sections are turned to dispose their magnetic axes in parallelism but with the magnetic fields of adjacent sections opposing one another;

Figure 13 is a perspective view of another form of resistor made in accordance with this invention;

Figure 14 is an enlarged longitudinal sectional view through the resistor of Figure 13;

Figure 15 is a fragmentary elevational view upon a larger scale of the resistance element shown in Figure 13;

Figure 16 is a perspective view of a resistance element, similar to that shown in Figure 15, wound into a spiral;

Figure 17 is a cross sectional view taken on the line XVII—XVII of Figure 14;

Figure 18 is a greatly enlarged top plan view of the resistance element shown in Figure 15;

Figure 19 is a view similar to Figure 17 showing a resistor constructed with a resistance element that is folded into pleats in accordion fashion; and

Figure 20 is a perspective view of a pleated resistance element of the type used in the resistor shown in Figure 19.

As shown on the drawings:

The present invention concerns high precision electrical resistors which are formed by lengths of resistance wire preferably of the order of .0006 inch to .010 inch in diameter. Wires of these sizes are commonly used for resistors of relatively small current ratings having resistance values from about .05 ohm to several megohms.

To form the resistance unit illustrated in Figures 1 to 3, a length of insulating material preferably in the form of a tube 10 is placed on a mandrel in such a manner that a resistance wire 11 may be helically wound onto the tube as by rotation of the mandrel, preferably without the wire coming into contact with the surface of the mandrel itself. As the wire is wound onto the tube 10 the wire may be waxed or otherwise suitably cemented to the tube, and when the winding operation is complete the unit is removed from the mandrel. The tube 10 with the wire thereon is then flattened so that the tube becomes a flat multi-ply tape and the convolutions of the winding are disposed in closely adjacent straight stretches. This flattened multi-ply tape provides a very satisfactory and convenient support for the wire.

By way of specific example, the tube 10 may be of polyethylene with the wall thickness for example of .002 inch. When the tube of polyethylene is flattened as indicated in Figure 3, it may form a tape having a width of 1¼ inches and a total thickness of .004 inch. Such a tape will be universally flexible and may be bent on any axis, and thus will accommodate a multiplicity of configurations as space or mounting requirements, inductive or capacitive limitations and the like may indicate.

Figure 2 illustrates, by way of example, the preferred manner in which the resistance wire 11 may be wound on the tube 10. In winding the resistance element illustrated in Figure 2, the wire may be wound in contiguous helical turns in a first layer 13 along the tube 10 from left to right with the last turn in this first layer designated by the reference numeral 15. The next turn 16 of the wire is wound generally in a second layer 17 on top of or outwardly of the first layer 13, but with the second layer 17 being laid down helically in the opposite direction from the first layer 13. The third layer indicated by the reference numeral 19 is wound from left to right as viewed in Figure 2 on top of the second layer 17 and has an end turn 20 which may be considered generally superposed on the end turns 15 and 16 of the preceding layers. The fourth layer indicated generally by the reference numeral 23 proceeds from right to left and the outer layer indicated by the reference numeral 25 proceeds from left to right and terminates in an end turn 26, for example.

The length of wire indicated at 27 in Figure 1 connects the turn 26 to a turn 29 in Figure 2 which is in a first layer 30. The layer 30 is wound helically in the direction from left to right just as layer 13. Successive layers are indicated at 32, 34, 36 and 38 and are wound in the same manner as layers 17, 19, 23 and 25, respectively. It will be noted that the first turn in layer 13 and the first turn 40 of the outer or fifth layer 38 will have a maximum difference in potential. However, the capacitive effect associated with these turns 15 and 40 is minimized by the proper selection of the spacing indicated generally at x in Figure 1 between these turns.

It will be appreciated that the advantage of winding the wire in multiple layers resides in the relative compactness of the resultant resistor element, particularly as reflected in the length of the tube or tape 10 required for a given resistance value. The desired capacitive limitation may be achieved by properly spacing the multilayer sections 43, 44, 45 and 46 shown in Figure 1, and by properly selecting the number of turns per section.

The resistance element of Figure 1 including the tube or tape 10 and the wire 11 wound thereon will hereafter be designated by the reference numeral 47. The section or pi indicated at 43 of element 47 has a right hand portion thereof represented in Figure 2 in the multiple layers 13, 17, 19, 23 and 25, while the pi 44 has its left hand side represented by the multiple layers 30, 32, 34, 36 and 38 in Figure 2. The conductive portion 48 of wire 11 has an insulating coating or covering thereon as indicated at 49 in Figure 2. The wire may be wound closely on the tube or tape 10 so that succeeding turns have their insulating coatings 49 in contact. The coatings will have the required thickness to properly insulate the turns of the wire taking into account the fact that the turns such as 16 and 20 will have a potential difference many times greater than the potential difference between successive turns such as 15 and 16, the difference in potential between the turns 16 and 20 being a function of the number of turns in the layers 17 and 19. By way of specific example, the layers may each have 350 turns, or the layers may be pyramided with the layers 17, 19, 23 and 25 having progressively fewer turns than layer 13. Resistors in accordance with the present invention generally have power ratings of the order of ½ watt.

Figures 4 and 5 illustrate the resistance element of Figure 1 embedded in an epoxy resin case 60. As illustrated in Figure 4, the case 60 may be provided with suitable mounting apertures such as 61 for fastening the case 60 in flat extended surface contact with a chassis surface 62 by means of suitable fastening means 64 as shown in Figure 5. The epoxy resin case is of a thickness to properly control the capacitive effect between the resistance element 47 and the chassis 62. This type of mounting gives very advantageous heat dissipation characteristics to the resistor, as well as providing a very compact assembly with the chassis. For example, the resistor may advantageously extend the entire length of the chassis in conforming contact therewith in certain applications.

A very advantageous manner of connecting to the resistance wire 11 is indicated in Figure 4 wherein a conductor 67 of circular cross section and of relatively large diameter as compared with the conductive portion 48 of wire 11 has a flattened end portion 68 bent into hook shape and mechanically clamped to the end of the conductive portion 48 of resistance wire 11. This method provides extended conductive contact between the terminal 67 and the wire 11 without requiring brazing or silver soldering of the parts which embrittles the wire.

The epoxy resin recommended for use in embedding the resistance element 47 requires no pressure molding or high temperature, and thus avoids danger of damage to the wire in the molding or forming of the case 60 about the resistance element. The resistor need not be in actual contact with the chassis 62 as indicated in Figure 5, since advantageous heat dissipation effects are achieved even where the resistor has a broad flat surface spaced from the flat surface of the chassis. The casing 60 may have a glass fiber mesh embedded therein for added strength and for reinforcement of the mounting holes 61, and under such circumstances the resistor may withstand extremely high accelerations and shocks. The epoxy case 60 occupies the entire space about the resistance element, or in other words the resistance element is encapsulated in the resin to eliminate air pockets adjacent the element. The case 60 thus prevents the formation of moisture near the resistance element, and the consequent possibilities of corrosion and the like.

The tube or tape 10 might also advantageously be formed of glass fiber or the like in such a way that upon forming of the case 60, the material of the casing would flow into the space between the plies corresponding to $10a$ and $10b$ in Figure 3 of the glass fiber and interlock the same. However, whether the tube or tape is of glass fiber or a plastic such as polyethylene, it provides a relatively soft pliable surface free from sharp edges on which to mount the relatively fine resistance wire **11**. Also relative expansion and contraction of the tube or tape and wire will not endanger the wire because the material of which the tube or tape is made will readily bend or constrict to accommodate relative contraction of the wire. This attribute of the tube or tape has the further advantage of enabling the resistance element to be bent or folded as needed to meet space requirements.

It will be understood that instead of having two terminals such as **71** and **72** between successive pies such as **43** and **44** in Figure 4, a single terminal may be connected to a conductor such as **27** extending between the pies, without cutting the conductor connecting successive pies as is done in Figure 4.

In Figure 1, if the spacing between successive pies such as **43** and **44** designated x, is equal to or greater than the longitudinal dimension y of the succeeding pi such as **44**, the resistance element **47** may be folded as illustrated in Figure 6. In Figure 1, the arrows **80** indicate the direction of the magnetic fields of the successive pies in their straight condition, and it will be observed that the magnetic fields are all in the same direction. Hence, they tend to add in the lengthwise direction, although of course they are relatively small because of the close spacing of the conductor portions on opposite sides of the tape as illustrated in Figure 3. To further reduce the inductive effect of the resistance element, the flattened tube or tape **10** may be folded as illustrated in Figure 6 to reverse the direction of the magnetic fields in alternate pies such as **44** and **46** relative to the pies **43** and **45**, thereby opposing the magnetic fields of adjacent pies as well as providing a longitudinally more compact resistance element which for convenience will be designated by the reference numeral **81**. It is to be understood that while for clarity Figure 6 shows the pies in more or less staggered or stepped relation, in actual practice they would be flattened to lie between closely spaced parallel planes. As with element **47** of Figure 1, a flexible flattened insulating tube could be slipped over the resistance element **81** of Figure 6 to form a flexible resistor.

As illustrated in Figure 7, the resistance element **81** could be embedded in an insulating case **88** of epoxy resin and the case **88** may be of a flat rectangular configuration for mounting in close proximity to a chassis **90** or the like for optimum heat dissipation. Terminals **85** and **86** may have flat end portions such as **87** crimped over and pressed against the resistor wire end portion **48** in the same manner as in Figure 4. The case **88** may have mounting holes extending therethrough as illustrated in Figure 4 at **61**, or the case **88** may be clamped to the chassis **90** or simply pressed thereagainst. The case may have a reinforcing skeleton of fiber glass or the like embedded therein for added strength as with the previously described embodiment.

Figures 8, 9 and 10 represent one manner in which the resistance element of Figures 1, 2 and 3, or Figure 6 may be formed for center hole mounting should such be desired. The element **47** or **81** is folded on a longitudinal axis into generally U or V cross section. The number of layers or the number of pies used on the element **47** or **81** may be selected in accordance with the size of the resistor to be formed. In the embodiment of Figure 8, each turn of wire such as indicated at **15** in Figure 2 is of an elongated loop form bent about a mid-point so that the opposite ends of the loop are folded toward each other to form four wire segments with the current flowing in successively opposite directions in the four segments to further neutralize the inductive effects of the wire as well as to render the resistance element more compact in width. By way of illustration, a single conductor turn **95** is illustrated in Figure $8a$ with arrows indicating the direction of current flow in the four successive segments $95a$, $95b$, $95c$ and $95d$ of the conductor **95**. A resistance element of the type shown at **47** or **81** with the tape folded on a longitudinal axis is designated by the reference numeral **96** and is illustrated in cross section and end elevation in Figure 8. The element **96** may be used as a resistor in straight form in the same manner as elements **47** and **81**, or may be disposed in a straight flattened flexible tube of insulating material as described in connection with the embodiments of Figures 1 and 6. Alternatively, the resistance element **96** may be wrapped arcuately about the core **97** of a spool **98** as illustrated in Figure 8. By way of illustration in Figures 8 and 9, terminal lugs **100** and **101** may have portions such as $100a$ in Figure 9 encircling the core **97**, and may have flat lugs such as $100b$ struck out and hooked to receive the respective ends of the resistance wire, such as **48** in Figure 9, for mechanically clinching the wire end portion **48** in the flat hook portion of the lug **100** in good electrical contact therewith.

Figure 10 indicates the manner in which the subassembly of Figures 8 and 9 would be embedded in an insulating case **102**, with the center mounting hole **103** extending through the spool **98** and through the case **102** and with the terminal lugs such as **101** projecting from the case **102**. By way of example, the case **102** may be in a cubical or other rectilinear form, and both the cases of Figure 7 and Figure 10 may be of epoxy resin.

Figure 11 illustrates an element of the type shown at **47** or **81** folded on a longitudinal axis as in Figure 8 with the resistance wire wound thereon as illustrated in Figures 1 to 3 and with the folded resistance element wrapped helically onto a cylindrical tube **106**. The final product may be identical to that shown in Figure 10, except that the casing **102** would be more elongated to accommodate the additional length of the tube **106**.

The resistance element **47** or **81** may of course be wrapped around a core such as **97** in Figure 8 without first folding the element on a longitudinal axis, and the element may be wrapped helically about a tube such as **106** in Figure 11 without first folding the element along a longitudinal axis. Any suitable means could be utilized to maintain the element **81** of Figure 6 in its folded condition as it is wrapped about the hub **97** or tube **106**, for example a flattened flexible tube of insulating material could be slipped over the element **81**, before it is wrapped into either of the arcuate configurations specified.

Each of the above mentioned modifications could, of course, be enclosed in a suitable insulating housing as illustrated in Figure 10, for example, or as illustrated in Figures 4 and 5, whichever is more suitable or advantageous. In each case, the casing is preferably of epoxy resin and fills the entire space adjacent the resistance element.

Figure 12 illustrates an embodiment wherein the resistance element **47** of Figure 1 is cut along severance lines such as indicated by the dotted lines **115**, **116** and **117** in Figure 1, and the resulting segments **118**, **119**, **120** and **121** with their respective tape portions $10a$, $10b$, $10c$ and $10d$ and pies **43**, **44**, **45** and **46** are turned through 90° in opposite directions to cause the magnetic axes of pies **43** and **45** to extend in the opposite direction from the magnetic axes of the pies **44** and **46**. The resulting element designated by the reference numeral **122** could be suitably secured to a flexible strip of insulating material as by stapling or cementing to form a flexible resistance element, or the resulting configuration could be embedded in an insulating casing in the manner illustrated in Figures 4 and 5. Alternatively, the segments **118** and **120** in Figure 1 could be maintained in the orientation illustrated in Figure 1 after severance along the lines **115**, **116** and **117**, and the segments **119** and **121** could be turned through 180° to direct the magnetic axes of the pies **44** and **46** in the longitudinal direction but in the opposite sense to the magnetic axis of the pies **43** and **45**. In this case, the magnetic axes would be directly in line and opposing rather than being offset and extending in opposite directions as in Figure 12. Here again, the resulting configuration could be secured to a flexible insulating tape, or embedded in an insulating casing as just mentioned.

Referring to the embodiment of Figures 13 to 18, there is provided an elongated flexible flat tape **210** of insulating, or non-conductive material, such as paper or the like. The elongated tape **210** has a width which is very much greater than the thickness of the tape as can be seen by comparing Figure 15 with Figure 18. An elongated resistance wire **212** is wound onto the flexible insulating tape **210**. The wire is wound into elongated loops and the successive loops of the winding defines what could be considered an elongated helical coil having elongated loops therein.

Insulated wire is employed and the wire may, if desired, be coated with wax, oil, or the like before being wound onto the insulating tape. A continuous process is used, and so, for example, the tape **210** may be drawn off a roll therefor (not shown) and the wire is formed and wound about the tape as the tape is being withdrawn. By this means a continuous length of resistance element, comprising the tape **210** and the wire **212** wound thereon is produced. In order to form a resistance unit of some desired resistance value, the circuit resistance of the resistance element so formed may be calibrated in lengths so that a partiuclar length of tape with a particular size resistance element wound thereon produces a desired, or particular, resistance.

After a segment of insulating tape with wire wound thereon has been cut to a desired length, that resistance element is preferably wound into a spiral **214** as shown in Figure 16, and the spiral **214** is inserted into a tubular insulating housing **216** formed of ceramic or the like. The spiral **214** has the ends **218** and **220** of the resistance wire **212** extending therefrom. The ends **218** and **220** of the resistance wire **212** are adapted to extend outwardly through the ends of the housing **216** and are connected mechanically or by soldering to terminals **222** and **224**. In the preferred embodiment disclosed, the resistor R is completed by the attachment of terminals **222** and **224** to the ends of the housing **216** by inserting said terminals into the housing **216**. The terminals **222** and **224** may be provided with enlarged terminal ends, calibrated to the inner diameter of the housing **216**, for engaging the leads **218** and **220** of the electrical resistance to provide good electrical contact between the ends of the resistance wire and the terminals. If desired, the terminals may be soldered to the housing, as generally indicated at **226**, to provide greater strength for the resistor and to seal the resistor unit against ingress of moisture or foreign material. Where porcelain housing and body members are used, the end portions thereof may be coated with copper or other metals to facilitate soldering. The unit when completed is also a very rugged unit in which the desired resistance value can be accurately maintained with a minimum of inductive effect.

In the construction shown in Figure 19, the resistor is in most respects similar to the resistor shown in Figures 14 and 17 except that the resistance element **228** in the housing is folded into pleats in accordion fashion rather than being wound in a spiral as shown in Figure 17. A perspective view of the accordion pleated resistance element of Figure 19 is also shown in Figure 20.

In all of the resistor units described herein, it will be noted that the resistance element comprises an elongated wire whose length can be accurately controlled to control the resistance value thereof, and the resistance element is formed with a flat flexible tape having the resistance wire wound thereon. A length of resistance element so constructed may be wound into a spiral, or pleated in accordion fashion in such a manner as to substantially neutralize the inductance effects in the resistance element. Where the resistance element is mounted in the housing **216**, as shown in Figures 14, 17 and 19, the housing may be filled fully or partially with a silicone varnish, a grease or like filling material to increase the resistance of the resistor unit to humidity and to hold the resistance element firmly in place in the housing.

In the embodiments of Figures 13 to 20, it will be noted that the resistance element of the resistor is formed so that segmental lengths of the tape **210**, with the resistance wire **212** wound thereon lie in stacked relation adjacent each other and the disposition of the loops of wire is such as to reduce reactive capacity effects of the resistor. In the case of the spiral, the stacked segments are adjacent arcs of the spiral, and in the case of the pleated resistance element, the stacked segments are the adjacent segments of the pleat.

It will be understood that the embodiments of Figures 13 to 20 could be formed on a flattened tube of insulating material just as in the embodiments of Figures 1 to 12. The embodiments of Figures 13 to 20 could have multiple layers as in Figure 2, or the embodiments of Figures 1 to 12 could comprise a tape of single thickness, or a flattened tube construction with a single layer winding.

The present application is a continuation-in-part of my copending application, Serial No. 458,384, filed September 27, 1954, now abandoned.

While numerous embodiments of the invention have been shown and described herein, it will be understood that they are illustrative only and not to be taken as a definition of the scope of the invention, reference being had for this purpose to the appended claims.

I claim as my invention:

1. An electrical resistor comprising tape means, electrical resistance means extending along said tape means, and said tape means having longitudinal segments thereof in a generally V configuration, with points of the resistance means representing the highest potential difference between the respective segments having the greatest spacial separation, and an insulating material disposed between said segments.

2. An electrical resistor comprising tape means, and a length of resistance wire wound on said tape means in spaced groups of turns with successive groups of turns spaced apart by a distance at least substantially equal to the length of the respective groups.

3. An electrical resistor comprising tape means, a length of resistance wire tightly wound on said tape means, and an insulating casing substantially completely occupying the space surrounding said tape means and wire to eliminate the effects of humidity on the wire, said wire having an insulating coating thereon to prevent short circuits between adjacent turns thereof and said tape means having a cross section of loop configuration.

4. The method of making a fixed precision type wire wound resistor which comprises forming a thin walled tube of highly pliable insulating material, with the tube having a precise predetermined perimeter, winding a length of resistance wire helically on said tube, flattening said tube together with the resistance wire wound thereon into a tape-like resistance element, and completely embedding the resistance element in a rigid insulating casing.

5. The method of making an electrical resistor which comprises, winding a length of resistance wire transversely about a length of highly pliable insulating material in groups of turns of substantially equal length with said groups spaced apart a distance greater than the length of one of said groups of turns, and folding said one group of turns toward an adjacent group of turns to reverse the

magnetic axis of said one group of turns with respect to the magnetic axis of said adjacent group of turns.

6. The method of making an electrical resistor which comprises, winding a length of resistance wire helically on a thin walled tube of highly flexible insulating material, flattening said tube and the resistance wire thereon to form a tape-like resistance element, and folding said resistance element on a longitudinal axis to reduce the transverse space requirements of the element.

7. The method of making an electrical resistor which comprises, winding a length of resistance wire helically on a thin walled tube of highly pliable insulating material, flattening said tube with the resistance wire thereon to form a tape-like resistance element, folding said resistance element on a longitudinal axis to reduce the transverse space requirements of the unit, and wrapping the thus folded element into an arcuate configuration.

8. The method of making an electrical resistor which comprises, placing a length of material in a generally open loop configuration, winding a length of an elongated resistance element helically on said length of material in spaced groups of turns, flattening said length of material and the resistance element thereon into a tape-like resistance unit, and severing said length of material between adjacent groups of turns and shifting the resultant segments of the resistance unit to cause successive groups of turns to have magnetic axes extending in opposite directions.

9. An electrical resistor comprising: a thin walled tube of pliable plastic insulating material; and a precise predetermined length of resistance wire wound upon said tube in spaced apart groups of turns, said groups of turns being substantially equal in length and adjacent groups of turns being spaced apart a distance greater than the length of one group.

10. An electrical resistor comprising: tape means, and a length of resistance wire wound on said tape means in spaced groups of turns, which groups are of substantially equal length and spaced apart along the length of the tape means a distance substantially no less than the length of one group of turns, said tape means with the spaced apart groups of turns thereon forming a resistance element which is divided into a plurality of longitudinally spaced apart segments, and said resistance element being folded upon itself about a longitudinal axis.

11. The electrical resistor of claim 10 further characterized by the fact that said folded resistance element is formed arcuately about a hollow core.

12. The electrical resistor of claim 11 further characterized by the fact that said folded and arcuately formed resistance element is encapsulated in a rigid casing of insulating material.

13. An electrical resistor comprising an insulating housing, an elongated resistance wire wound onto a flexible tape which in turn is rolled into a spiral so as to substantially neutralize the inductance effects in the resistance wire, and positioned in said housing, and the ends of said wire projecting in opposite directions from the spiral within said insulating housing.

14. An electrical resistor comprising an elongated tubular insulating housing, an elongated resistance wire wound onto a flexible tape which in turn is rolled into a spiral so as to neutralize the inductance effects in the resistance wire, and is positioned in said housing, so that the axis of the spiral is disposed parallel to the longitudinal axis of said housing, the ends of said wire projecting from the spiral, and terminals projecting in opposite directions beyond the housing and electrically connected to said ends of the wire.

15. An electrical resistor comprising: a coil support in the form of a length of tape-like insulating material folded upon itself on at least two transverse bend lines so that said coil support has at least one straight middle portion between said bend lines and two end portions, each overlying a part of the middle portion; a coil of resistance wire wound transversely upon the medial part of said middle portion of the support; and a coil of resistance wire wound transversely upon each of said two end portions of the coil support, each with one end thereof contiguous to one end of the coil on said middle portion of the said support and its other end contiguous to one end of said middle portion of the coil support so that said coils are endwise adjacent and their combined length substantially equals the length of said middle portion of the coil support; the winding direction of adjacent coils being opposite.

16. The method of making an electrical resistor having minimum inductance and capacitance which comprises: winding a precise length of resistance wire transversely about a tube of highly pliable insulating material in groups of turns of substantially equal length with the convolutions of all of the turns running in the same direction and with said groups of turns spaced apart a distance greater than the length of one of said groups of turns; flattening the tube of insulating material with the wire wound thereon to collapse the tube and give it the formation of a multi-ply tape and to dispose the convolutions of the turns in closely adjacent substantially straight stretches at opposite sides of said multi-ply tape; and folding the multi-ply tape about transverse bend lines upon itself to superimpose portions of the tape which have no windings thereon upon adjacent groups of turns in endwise juxtaposition but endwise reversed from their original relationship so that the magnetic fields of adjacent groups of turns oppose one another.

17. The method of making an electrical resistor having a minimum of inductance and capacitance which comprises: winding a plurality of endwise spaced apart coils of resistance wire upon an elongated flexible support, with all of the coils wound in the same direction; and folding the flexible support about transverse bend lines upon itself to superimpose portions of the support having no coils thereon upon adjacent coils and to dispose adjacent coils in endwise juxtaposition but endwise reversed from their original relationship so that the magnetic fields of adjacent coils oppose one another.

18. A resistor of the character described comprising: a resistance element consisting of a spirally rolled length of pliant electrically non-conductive tape with a length of resistance wire wound transversely on and cemented to the tape; a tubular container of insulating material enclosing said element; and terminals connected to the ends of the resistance wire and projecting to the exterior of the container.

19. For use in making resistors of the character described: a section of pliant electrically non-conductive tape; and a length of resistance wire transversely wound on and cemented to the tape; the wire-wound tape being folded on a longitudinal axis substantially in the middle thereof, and also being rolled lengthwise into a compact unit.

20. A method of making resistors consisting in: winding resistance wire transversely on and cementing the same to flexible electrically non-conductive tape; and forming the wire-wound tape lengthwise into a spiral roll suitable for insertion into a container.

21. A method of making resistors consisting in: winding resistance wire transversely on flexible electrically non-conductive tape in predetermined spaced windings and cementing the windings to the tape, so that the length of the wire-wound tape is an accurate measure of the resistance value of the amount of wire wound thereon; cutting the wire-wound tape to a length corresponding to the total resistance required; and rolling the thus cut length of wire-wound tape lengthwise into a compact spiral roll.

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