June 10, 1958 G. V. PLANER ET AL 2,838,639

FILM RESISTOR SPIRALLISING

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Fig. 1

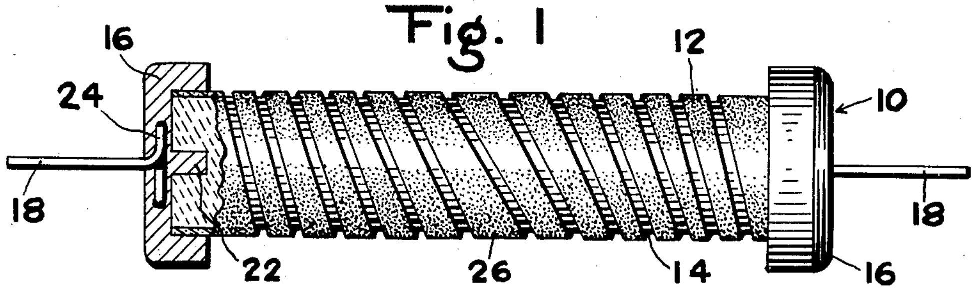

Fig. 2

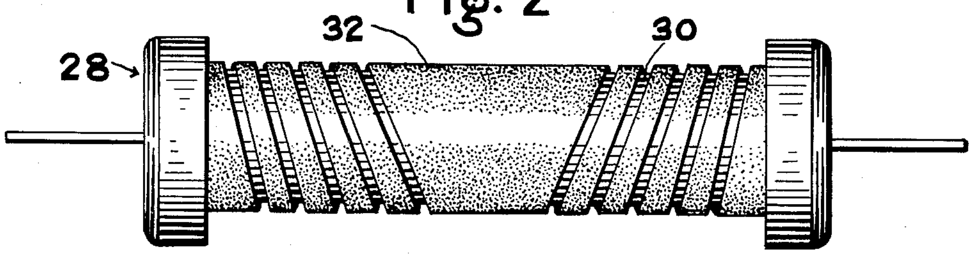

Fig. 3

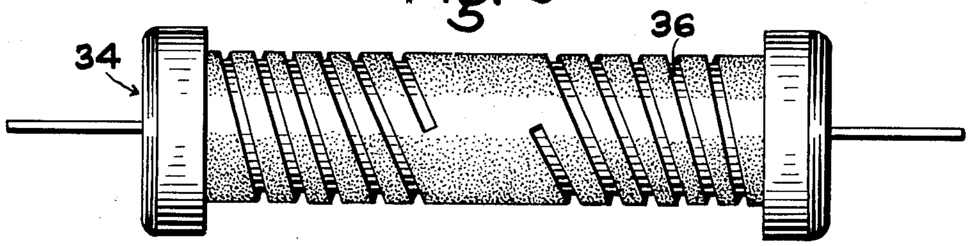

Fig. 4

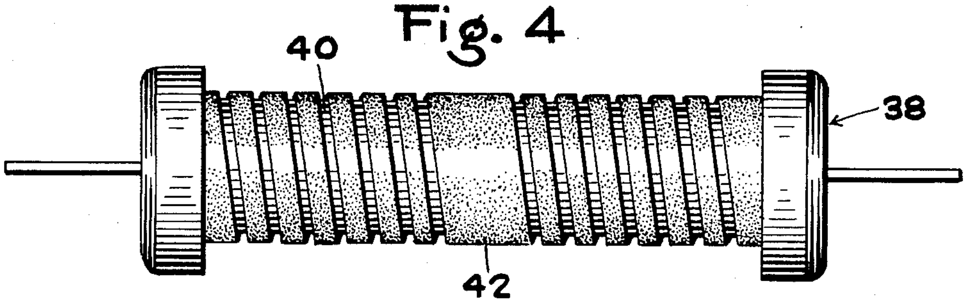

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Fig. 5

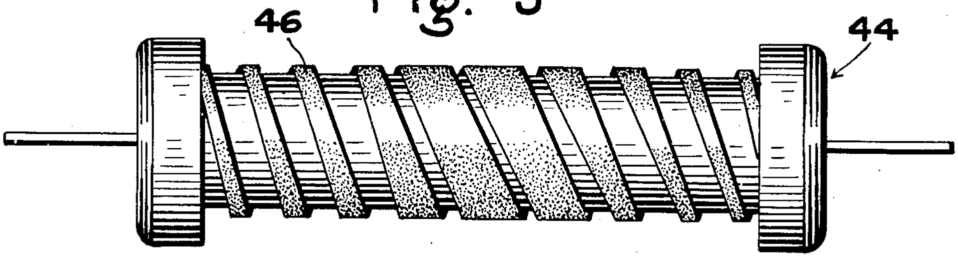


Fig. 6

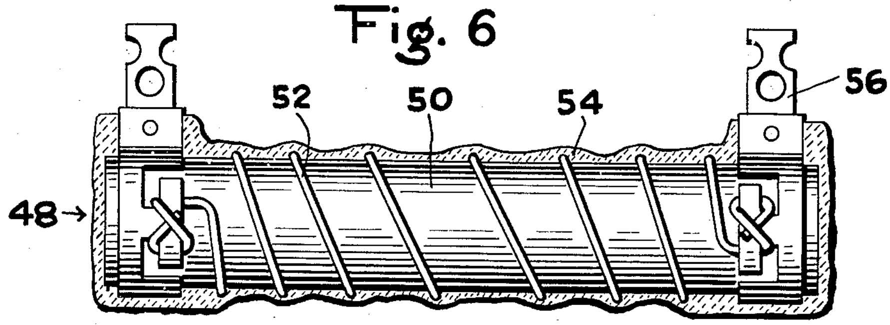


Fig. 7

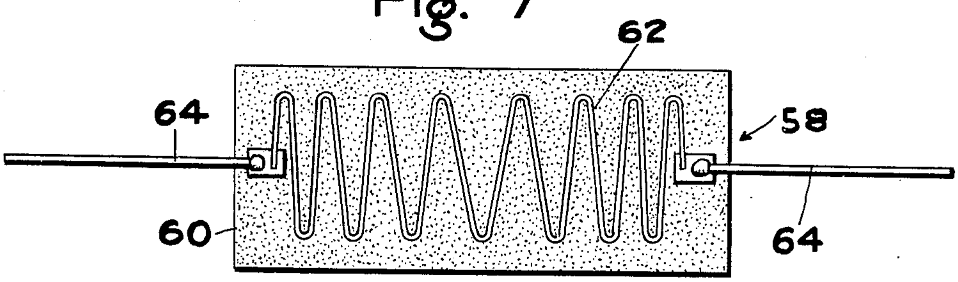
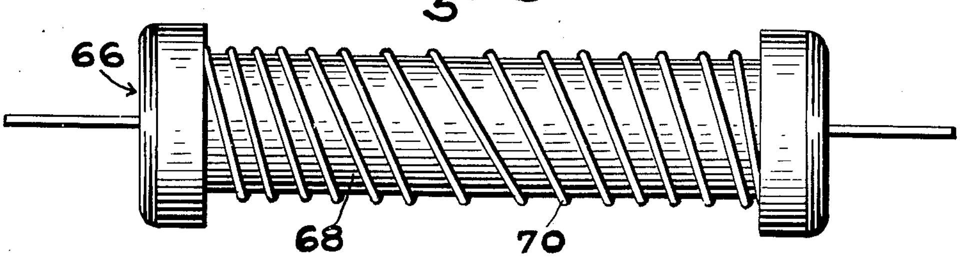


Fig. 8



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United States Patent Office

2,838,639

Patented June 10, 1958

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2,838,639

FILM RESISTOR SPIRALLISING

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Application February 10, 1954, Serial No. 409,464

2 Claims. (Cl. 201—63)

This invention relates to electrical resistors, and particularly relates to the dissipation of heat generated by the resistor in such fashion as to provide an even temperature distribution in the resistor.

There are various types of resistors to which this invention may be applied. Among such types are the resistors of the pyrolytic carbon type, in which the resistor element comprises a ceramic base which has been coated with a thin film of carbon by the thermal decomposition of a hydrocarbon or other carbon-containing gas. The invention may also be applied to resistors wherein a conducting material in the form of a wire or tape is coated with an insulating material and wound upon a ceramic base.

One of the most troublesome problems involved in these resistors, especially when they are to be used in electrical circuits where the wattage rating of the resistor element must be high, is the effective dissipation of heat equally along the whole length of the resistor. Where the dissipation of the heat is uneven and the temperature gradient along the surface of the resistor is high, there is a definitely detrimental effect on the electrical stability of the resistor.

It is, therefore, one object of this invention to provide an electrical resistor having an effective and even dissipation of heat.

A further object of this invention is to provide a resistor having good electrical stability.

Another object of this invention is to provide a resistor having superior wattage dissipation for a given hot spot temperature in the case of a protective coating which has a thermal point which must not be exceeded.

Another object of this invention is to provide an electrical resistor having a strong electrical stability over wide ranges of temperature.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a partly elevational and partly sectional longitudinal view of one embodiment of the invention,

Fig. 2 is a longitudinal elevational view of a second embodiment of the invention,

Fig. 3 is a longitudinal elevational view of a third embodiment of the invention,

Fig. 4 is a longitudinal elevational view of a fourth embodiment of the invention,

Fig. 5 is a longitudinal elevational view of a fifth embodiment of the invention,

Fig. 6 is a longitudinal elevational view of a sixth embodiment of the invention,

Fig. 7 is a longitudinal elevational view of a seventh embodiment of the invention, and

Fig. 8 is a longitudinal elevational view of an eighth embodiment of the invention.

Regarding, first, the carbon film type of resistors, the conventional methods for the production of carbon film

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resistors generally comprises the steps of first coating the ceramic base, usually in the form of a cylindrical rod, with carbon, and, thereafter, spirallising the rod, as by grinding away a helical groove around the rod. This results in the lengthening of the resistive path and hence in an increase in resistance value. To attain any given final resistance value R_f by this method, the rods are coated to give approximately a corresponding, lower initial value R_i and, thereafter, the spiral groove is cut, extending over either a part or the whole of the length of the resistance element, until the desired R_f value is attained. The spirallising process is normally carried out by means of an automatic grinding machine, the rod being rotated about its axis, while at the same time, a rotating grinding wheel is advanced at a constant speed along the length of the rod. Alternatively, the plane of the grinding wheel is sometimes rotated without advancing while the rotating rod is advanced in a direction parallel to its axis. The relative speed between the rod and the grinding wheel may be automatically controlled to attain a predetermined pitch for a given R_f value. After the spirallising process is completed, metal caps and metal or wire leads are applied to the units.

According to normal manufacturing practice, the spirallised portion of the resistor is generally varied between about 70 and 100% of the distance between the terminations, to allow for the spread of R_i values obtained in production, and in order to cover a wider range of R_f values for any given R_i value, any unspirallised portion being situated at one end of the resistor, i. e. adjacent to one of the terminations.

Since the dissipation of heat generated by the resistor in use is considerably greater at the ends, owing to conduction through the end-caps and leads, than in the center of the rods and, moreover, since more heat is naturally generated in the spirallised than in the unspirallised end portion, the temperature distribution along the surface is necessarily very uneven. The surface temperature in conventional resistors is found to be at a maximum in the middle of the resistor, falling off at either end, but particularly at the unspirallised portion at one end, in the case of resistors which are not fully spirallised.

In Fig. 1 an embodiment of the invention is shown wherein a ceramic rod **10** is coated with a thin film of carbon **12**, upon which has been ground a helical groove **14**. Metal end-caps **16** and leads **18** are provided at either end. The caps have an anchoring center flange **22** embedded in the ceramic rod while the wire leads **18** are provided with circular end portions **24**. It should be noted that the pitch of the groove **14** is varied along the length of the rod so as to be smallest at either end thereof while rising to a maximum at the center of the rod. In other words, the number of turns per unit length is at a maximum at the ends and a minimum in the center. Since the conducting track comprises the coated areas between the turns of the groove, it is seen that the width of the conducting track increases on approaching the center of the resistor, being greatest at **26**. This gradation in the pitch of the groove may be obtained by varying the relative speed between the rod and grinding wheel during the spirallising operation, that is, by making the relative speed lowest at the ends and raising it to a maximum in the center.

In production, up to as much as 30% or thereabouts of the effective length of the element has often to be left unspirallised. Accordingly, an alternative embodiment of this invention is illustrated in Fig. 2 and comprises a resistor **28**, spirallised as in the previous embodiment, with the spiral groove **30** having a minimum pitch at the ends, the unspirallised portion of the resistor being positioned at **32** the center of the rod, as opposed to being at one end, as in the conventional method. This may conveniently be carried out using a spirallising machine with two grinding wheels, starting at each end of the resistor and advancing towards the center. One of the wheels may be arranged to grind up to a fixed point shortly before reaching the center of the rod, while the other is advanced until the required R_f value is attained, the resistance of the element being measured throughout the spirallising operation. An additional advantage of this method is the resulting reduction in the inductance of the resistor, due to the opposing directions of the spirals at either end.

Alternatively, as illustrated in Fig. 3, the rods may be spirallised using only one grinding wheel. According to this method the rod **34** is first ground from one end with the groove **36** having a gradually increasing pitch, up to a point close to the center; the rod being then reversed in the machine and ground again from the other end until the correct resistance value is attained. If the direction of the rotation of the rod in the second grinding operation is opposite to that of the first operation there will result a resistor such as shown in Fig. 3 wherein the pitch of both parts of the groove is the same. However, if the direction of the second grinding operation is the same as the first, the pitch of one part of the groove will be opposite that of the second part, similar to Fig. 2.

Fig. 4 shows a modification of the resistor attained by the method used to obtain the resistor in Fig. 3. Here, the resistor **38** is ground first from one end and then from the other as is the resistor of Fig. 3. However, the interrupted groove **40** of resistor **38** has a constant pitch due to a constant relative speed between the resistor and the grinding wheel. This type of resistor, although it has an ungrooved area, as at **42**, in its center and, therefore, does provide for heat dissipation from the ends, is not as effective in reducing the temperature gradient along the rod as the resistors described above. It does have the advantage, however, of allowing the use of a normal type of spirallising machine.

Fig. 5 illustrates a resistor **44** having a helical resistor track which is obtained not by applying a coating to the insulating base and then grinding a helical groove, but by applying the conducting film to the insulator base in the form of a helical band **46**, the windings of which are spaced from each other and which increases in width on approaching the center of the element.

It is also within the scope of this invention to apply the conducting film by means of painting or spraying suspensions containing the finely divided conductor particles on the base and then subjecting such coating to a heat treatment. The insulating track in such a painted or sprayed resistor may be provided either by masking a helical track of the proper pitch configuration on the base during the painting or spraying process or by applying the coating over the entire surface and then grinding out the insulating groove as in the processes described above.

Fig. 6 illustrates the invention applied to a resistor **48** of the type comprising a ceramic body around which an uncoated conducting wire has been wound and an insulating coating such as vitreous enamel, thereafter applied over the whole assembly to anchor the wire in place. The ceramic body is illustrated in Fig. 6 by rod **50**, the wire is illustrated at **52** and the coating is illustrated at **54**. In this case, the wire is helically wound with a pitch which is greater at the center than at the ends. Since the wire turns generate heat during the flow of electrical current therethrough, the amount of heat generated at the ends of the resistor **48** is greater than in the center.

It is, further, possible to use resistors having shapes other than cylindrical, as for example, a resistor **58** comprising a flat plate **60**, of ceramic for example, having a carbon track **62** applied thereon such as illustrated in Fig. 7 as by printed circuit techniques. The meandering track **62** is designed so as to provide a greater amount of heat dissipation at the ends, resulting in maximum generation of heat in the vicinity of the end terminals **64**. In this case, heat is given off at the bends of the track as well as at the ends thereof. The amount of heat given off at the bends may be still further increased by making these bends of complex configuration. Such additional concentration of heat at the sides (longitudinal) is also very helpful inasmuch as the dissipation of heat at these sides is also more effective than from the center of the plate.

It is also possible to make the track **62** wider in the center and narrower at the ends and/or sides of the plate resulting in a maximum generation of heat where it is best dissipated.

The invention may also be applied to resistors wherein an insulation-coated wire or the like is wound on an insulation base. An example of this is illustrated in Fig. 8 which shows a resistor **66** comprising a ceramic rod **68** upon which is wound an insulation-coated wire **70**. This wire is wound upon the base in helical fashion wherein the pitch is smallest at the ends and greatest in the center. However, it is also within the scope of the invention to wind the wire in non-helical fashion or even in layers. In any event, however, the winding of the wire is effected in such a way that the amount of adjacent or superimposed wire turns is greater at the ends than in the center of the resistor. This insulation wire, in a meandering configuration, may also be used in place of the meandering carbon track on the flat plate of Fig. 6.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed in this invention is:

1. An electrical resistor comprising a generally elongated narrow base of electrically insulating material, a pair of electrically conducting tracks each having a plurality of turns around the base, one track extending toward the central portion of the base from adjacent one end, and the other track extending toward the central portion of the base from adjacent its opposite end, the tracks being joined together at said central portion and having their turns oriented in opposite directions.

2. An electrical resistor having an elongated electrically non-conductive support rod and an electrically conductive layer coated on the surface of the rod, said film being cut through by two spiral tracks each extending with gradually increasing pitch toward the center from adjacent opposite ends of the support, each track stopping short of the center and the turns of one track being directed oppositely to the turns of the other track.

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