April 26, 1966 C. J. GANCI 3,248,679

METAL ALLOY RESISTORS

Filed Dec. 11, 1962

Fig. 1.

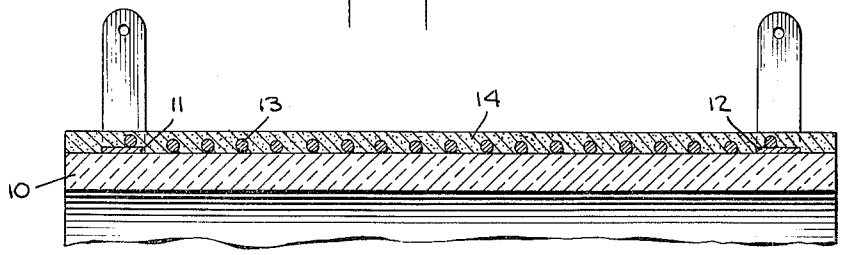


Fig. 2.

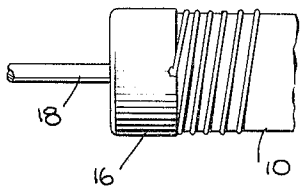


Fig. 3.

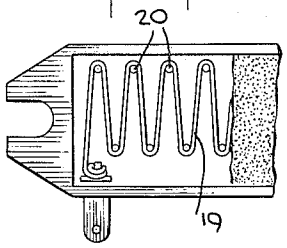


Fig. 4.

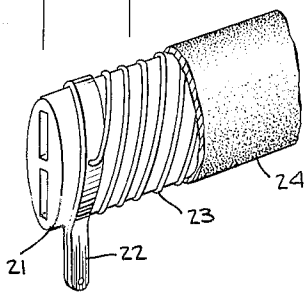


Fig. 5.

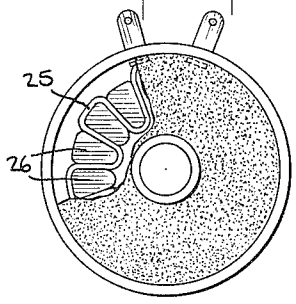
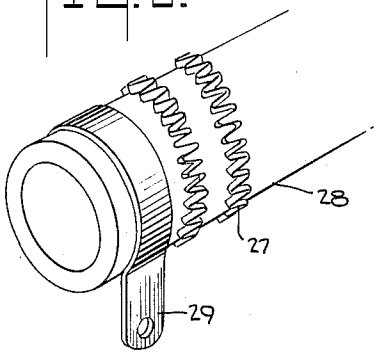


Fig. 6.



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3,248,679

Patented Apr. 26, 1966

3,248,679

METAL ALLOY RESISTORS

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Filed Dec. 11, 1962, Ser. No. 243,888
3 Claims. (Cl. 338—264)

This invention relates to electrical resistors and particularly to the composition of the metal alloy forming the element.

The invention is particularly directed to electrical resistors with wound resistive elements on a ceramic base and covered by a vitreous enamel coating. For good thermal and physical shock qualities, the base of the resistor should have a low coefficient of expansion and the coefficient of expansion of the coating should be slightly lower than that of the base. For high quality, high precision, reliable resistors it is also desirable that the resistance element have certain characteristics and meet certain standards.

Some of these are that the temperature coefficient of resistance should be zero or nearly zero so that the resistor may be subjected to high temperatures in operation without a material or, if possible, any change in resistance value of the resistive element due to temperature rise; and that the alloy should have a ductility and high tensile strength in order to form fine, strong wire or ribbon. The resistance value of the element should remain substantially constant over sustained periods of high heats so as to have a stable electrical load life.

A particularly desirable feature is to have the low coefficient of expansion of the base and the linear coefficient of thermal expansion of the element approximately the same. Heretofore the coefficients of expansion of the resistive elements have been approximately twice that of the base. The coefficient of expansion of the base has been 6 to 9×10^{-6} inches per inch per degree centigrade, while that of the resistive elements has been 15 to 18×10^{-6} inches per inch per degree centigrade.

When the coefficient of expansion of the wire is substantially greater than the coefficient of expansion of the base, difficulties are encountered during the formation of the protective coating. The resistor is subjected to high temperatures, the wire expands and loosens which causes the wires to pull, bunch or swim, possibly causing shorting of the turns which may result in rejections for resistance values creating hot spots and resulting in unreliability.

Also, the different and lower coefficient of expansion of the coating further aggravates these difficulties.

An object of this invention is to provide an electrical resistor having a base with a low coefficient of expansion and a resistive element of substantially the same coefficient of expansion as the base.

Another object of the invention is to provide a resistance element that has a low temperature coefficient of resistivity and a comparatively low temperature coefficient of expansion that is ductile and has a high tensile strength.

Other and further objects will be apparent from the description taken in connection with the drawings, in which

FIG. 1 illustrates a wire wound tubular resistor with tab type terminals;

FIG. 2 illustrates a wire wound tubular resistor with axial leads;

FIG. 3 illustrates a plaque type of resistor;

FIG. 4 illustrates a strip type of resistor;

FIG. 5 illustrates a disc type of resistor; and

FIG. 6 illustrates a tubular base with a crinkled ribbon type of resistive element.

The base **10** may be made of ceramic or other insulating material for supporting the terminals **11** and **12** and the resistor element **13**. The base **10** has a cylindrical

shape and the resistance wire is helically wound on the base and soldered or welded to the terminals **11** and **12**. A coating **14** may encase the wire and terminal to protect the wire from physical injury and corrosion. A vitreous enamel coating is illustrated, but other types of coatings, such as cements, Teflon, silicone and the like, may be used depending upon the particular characteristics desired.

The base **10** may be composed of various types of ceramics, such as steatite, alumina, modified talc, fosterite compositions, zircon compositions and other known ceramics. The linear coefficient of thermal expansion of steatite is 7×10^{-6} to 8.5×10^{-6}, fosterite is 10 to 10.5×10^{-6} or less, zircon is 5 to 7.5×10^{-6} and alumina is 7 to 8.5×10^{-6} inches per inch per degree centigrade. Illustrative compositions of these ceramics are set forth as follows:

Table I

	Percent
Zircon:	
Zr_5O_4 (zircon)	65
Plastic clay	15
Calcium zirconium silicate	20
Steatite:	
Talc	94
Clay	4
Barium titanate	2
Fosterite:	
Talc	75
Clay	4
Barium titanate	2
MgO	19
Alumina:	
Al_2O_3 (alumina)	95
SiO_2	.63
CaO, MgO	.63
Clay	3.75

The metal of the terminals **11** and **12** has a coefficient of expansion approximately the same as the ceramic base **10** and may be an alloy, such as a nickel-iron alloy having a range of coefficients from very low to 16×10^{-6} inches per inch per degree centigrade. Alloys having coefficients of expansion in the range of 6 to 10×10^{-6} are selected to match the coefficients of expansion of the foregoing ceramic bases. Thus the terminals will have substantially the same or the same coefficient of expansion as the base.

The particular resistive element of this invention comprises a titanium alloy including vanadium and aluminum. Various compositions are set forth as follows:

Table II

	A	B	C
	Percent	*Percent*	*Percent*
Vanadium	13	14	4
Chromium	11	11	
Aluminum	3	3.5	6
Hydrogen	Very low	Low	Very low
Titanium	73	71.5	90

The linear coefficients of expansion for these alloys are approximately 9.5 to 10×10^{-6} inches per inch per degree centigrade. These alloys have a specific resistance of about 900 ohms per circular mil foot and a temperature coefficient of resistivity of less than 100 parts per million. The alloys have good ductility and tensile strength and may be formed into small diameter wires or thin ribbons. The wires are easily wound on the base in conventional manner and secured to the base by conventional means, such as welding.

Various types of well-known coatings may be used to encase the resistive element and terminals as illustrated. Vitreous enamel coatings should have coefficients of ex-

pansion less than the coefficients of expansion of the base material in order to avoid crazing of the enamel. The coefficients of expansion are in the range of 5 to 9×10^{-6} inches per inch per degree centigrade. Cement, plastic and other types of coatings may be used.

In FIG. 2 the invention is illustrated in connection with an axial type of resistor having end cap **16** mounted on the base **10** with the axial leads **18**. In FIG. 3 the wire element is wound in a non-inductive manner on a plaque type of base fragmentarily shown. The wire element **19** is formed on the posts **20** and embedded in a vitreous enamel or cement coating. In FIG. 4 a resistor with an elliptical base **21** is partially illustrated with the tab type of terminal **22** and a wire wound resistive element **23**. A vitreous enamel coating is illustrated at **24**. FIG. 5 illustrates a radial type of resistor with the resistive element **25** intertwined in bosses **26**.

In FIG. 6 a tubular base resistor is illustrated with a crinkled ribbon type of resistive element **27** formed on the base **28** and attached to terminals **29**. In referring to a wire type of resistive element, the ribbon form is included in the meaning of this term. The titanium alloy forms a tough ribbon wire which retains its shape and is easily wound on the base.

A preferred form of the base to match coefficients of expansion of the base and the resistance element is a beryllium oxide base of 99 to 100% beryllium oxide. This produces an electrical resistor of greater reliability and higher wattage for a given size. The beryllium oxide base has a very good heat conductivity for conducting the heat of the resistive element.

In addition to the resistive element and the base having substantially the same coefficient of expansion, the terminals may be also made of the metal alloy that has a coefficient of expansion substantially equal to that of the base. The coatings may be any of the well-known coatings as previously mentioned, and if a vitreous enamel coating is used the coefficient of expansion should be slightly less than that of the beryllia base.

I claim:

1. An electrical resistor comprising an insulating core of ceramic composition having a coefficient of expansion between 5 to 10.5×10^{-6} inches per inch per degree centigrade, metal terminals mounted on said core having a coefficient of expansion substantially equal to said core, and a helically formed elongated resistive element of titanium alloy including vanadium and aluminum on said core and in engagement with said metal terminals, said element having a coefficient of expansion of 9.5 to 10×10^{-6} inches per inch per degree centigrade.

2. An electrical resistor as set forth in claim **1** wherein the titanium metal alloy comprises 11% chromium, 14% vanadium, 3.5% aluminum and the balance titanium.

3. An electrical resistor as set forth in claim **1** wherein the titanium metal alloy comprises 4% vanadium, 6% aluminum and 90% titanium.

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