

March 1, 1966

P. F. VAN EECK
PARTICLE FILLED CONDUCTOR

3,238,355

Filed Dec. 10, 1962

2 Sheets-Sheet 1

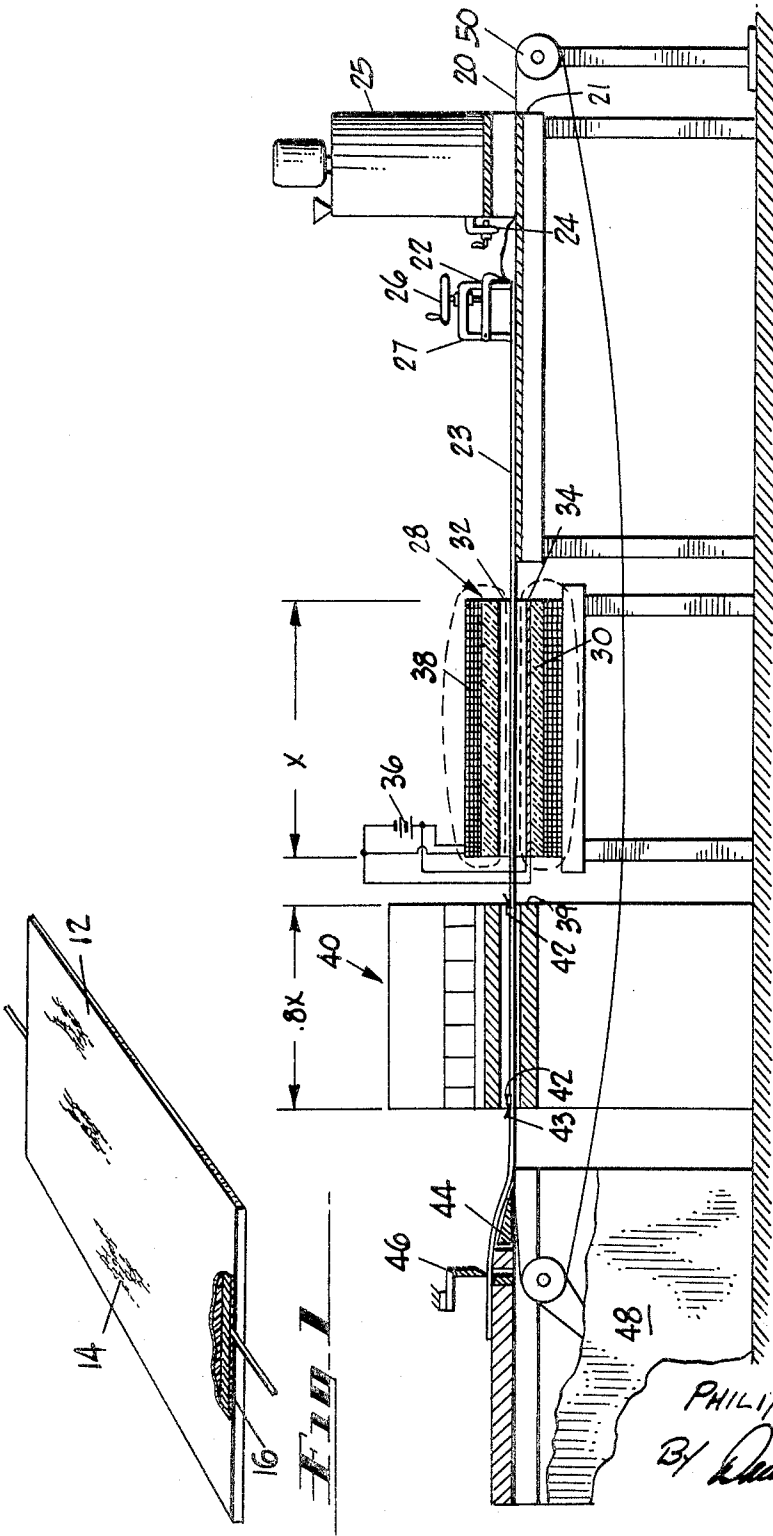


Fig. 1

INVENTOR
PHILIPPE F. VAN EECK
By *Donald E. Ryan*
AGENT

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2 Sheets-Sheet 2

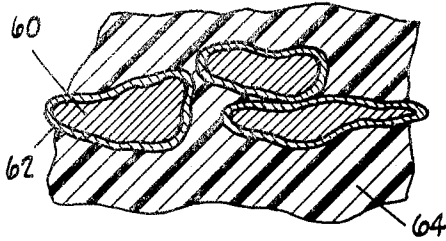


Fig. 3.

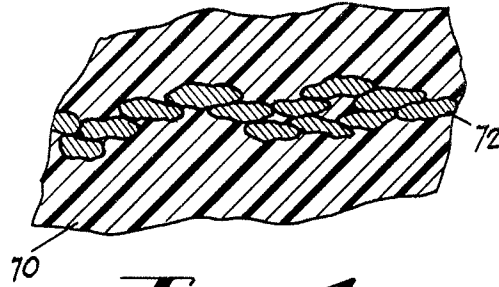


Fig. 4.

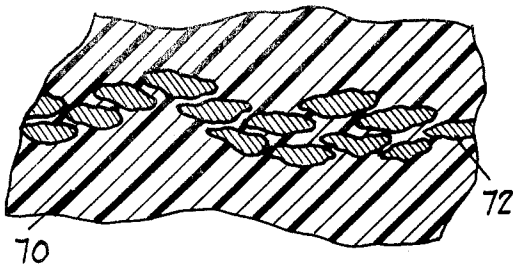


Fig. 5.

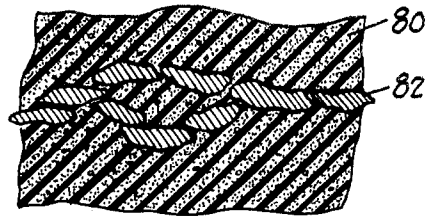


Fig. 6.

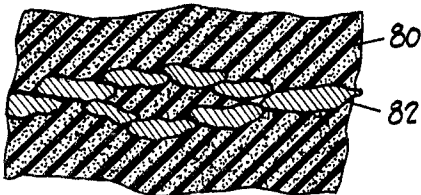


Fig. 7.

INVENTOR
PHILIPPE F. VAN EECK

BY *Donald H. Ryan*
AGENT

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PARTICLE FILLED CONDUCTOR

Philippe F. Van Eeck, Santa Monica, Calif., assignor to
Douglas Aircraft Company, Inc., Santa Monica, Calif.

Filed Dec. 10, 1962, Ser. No. 243,517

5 Claims. (Cl. 219-528)

This invention relates to electrical conductors and more specifically to those types of conductors comprising a non-electrically conductive material impregnated with magnetically oriented conductive particles. The invention also relates to a method of producing such electrical conductors.

There are many applications where a conductor is needed which has many of the properties of certain non-conductors. One of the most important of such needs arises in connection with electric heating panels or blankets which can be connected to a current source to heat a space, where such panels must have an attractive finish, a low conductivity in order not to burn persons who accidentally contact the panel, and other characteristics which are typical of many non-conducting materials. Such panels have been made by embedding heating wires of a resistive material, such as Nichrome, in a non-conducting matrix and providing external electrical leads to the wires. To allow the Nichrome wires to heat the surrounding matrix, they must be raised to a high temperature level and the material of the matrix immediately adjacent to the wires must be able to withstand such high temperatures. Many non-conducting materials, such as certain plastics with desirable properties including light weight, low cost, easy formability, flexibility, and attractive finish, will melt or otherwise deteriorate at high temperatures and cannot be used in connection with the highly concentrated conductors as defined by individual wires. The temperature of the Nichrome wire can be reduced if it is laid in a close zig-zag fashion so that the wires are close to all areas of the panel; however, if the panel is to yield considerable heat, the non-conducting material adjacent to each wire must still be able to withstand moderately high temperatures, higher than many otherwise suitable materials can withstand, and the cost of producing such a panel with closely spaced wires is considerable.

This invention provides conductors having the desired properties by adding conductive particles to a high resistance fluid or granular matrix material, usually with a resistance approaching infinity (i.e., non-conducting), orienting the particles into conductive chains by applying a magnetic field while the high resistance or non-conductive matrix material hardens, and providing electrical leads which make physical contact with the conductive particle webs.

By forming the matrix as a flat sheet or panel, with the magnetic field applied parallel to the plane of the panel, and providing conductive strips at opposite ends of the panel, a heater panel is obtained whose entire surface is heated upon the application of current.

Magnetic particles have been heretofore introduced into liquid plastic and oriented in a magnetic field. The structures created by these techniques have exhibited magnetic and resistive characteristics favorable for use as transformer and inductor cores and in other electrical apparatus, to minimize eddy current and hysteresis losses therein. However, these prior devices were not suitable for the present purposes, and in no instance have the magnetically oriented particle chains been provided with physical electrical connections between the particle chains and external electrical leads to enable direct application of currents thereto. As will be described in detail hereinafter, conductors with magnetically oriented par-

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ticles are not only useful as heating panels or blankets, but it has been discovered that by varying the contents and/or treatment of such conductors, additional useful properties are achieved which allow for the use of the conductors in many additional and varied applications.

In accordance with one aspect of the invention, during manufacture of the present conductors pressure is applied to the particle impregnated non-conductive base material or matrix as it is cured and solidifies. This results in a conductor having a resistance substantially lower than that of a similar conductor cured without such pressure. The need for a low resistance conductor arises when a conductor is used as a heating element or a heating blanket and considerable current must be directed therethrough to obtain a reasonably large heat output. In instances where a thin heating blanket is used so as to obtain a blanket of low cost, light weight, and other desirable characteristics, the resistance will normally be high and it is difficult to cause a large current to flow. The application of pressure to the non-conductive matrix before it solidifies results in the described conductor of much lower resistance, and such a conductor allows for the conduction of considerable current from a reasonably low voltage source.

In accordance with another aspect of the invention, the particles disposed in the matrix are constructed from small pieces of paramagnetic material which form cores, and these paramagnetic cores are coated with a highly conductive material. Such composite particles are utilized to obtain a conductor of lower resistance than can be obtained with uncoated particles.

In accordance with still another aspect of the invention, a non-conductive matrix with a much higher coefficient of expansion than that of the impregnating particles is used to obtain a heater blanket whose resistance increases greatly with the temperature of the conductor. When the resulting structure is used as a heater blanket, it is self temperature regulating in that, as temperature increases the heating currents decrease, and this eliminates any need for external control of the current source.

In accordance with a further aspect of the invention, a compressible base or matrix material is used, and a conductor is obtained whose resistance decreases with the application of pressure to the conductor. Such a conductor is useful as the measuring element of a pressure transducer used to measure the pressure of a chamber or the like. For this purpose, one side of the conductor is maintained rigid while the other side is exposed to the environment whose pressure is to be measured. An ohmmeter connected across the terminals of the conductor may then serve as a pressure indicating device.

The conductors of the various types described above are readily manufactured by adding paramagnetic particles to the highly resistive or non-conducting base material or matrix, magnetically orienting the particles to form conductive chains and providing external electrical leads which make physical electrical connection with the conductive particle chains.

A more complete understanding of the invention and of the aforementioned and additional features may be had by reference to the following description and claims taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a partially cutaway pictorial view, showing one embodiment of the present invention in the form of a conductive panel;

FIG. 2 is a partially diagrammatic, sectional view illustrating one means and system for producing the conductive panels of the present invention;

FIG. 3 is a greatly enlarged, fragmentary, sectional view of a low resistance conductor comprising particles having paramagnetic cores and highly conductive coatings;

FIG. 4 is an enlarged, fragmentary, sectional view of a self-temperature regulating conductor at a low temperature;

FIG. 5 is a sectional view similar to FIG. 4 but which shows the self-temperature regulating conductor of FIG. 4 at a high temperature;

FIG. 6 is an enlarged, fragmentary, sectional view of a pressure sensitive conductor under low pressure; and

FIG. 7 is a sectional view of the pressure sensitive conductor of FIG. 6 under high pressure.

Referring to FIG. 1, one form of the electrical conductor of the present invention includes a non-conductive matrix material 12 such as polyester, numerous paramagnetic particles 14 (shown greatly enlarged for clarity) such as iron particles which have been magnetically oriented to form interconnecting conducting chains, and electrical leads 16 for conducting electricity to the particle chains in the matrix. For some applications such as heating panels, it is desirable to form the matrix 12 as a sheet, this form being as shown in FIG. 1. Obviously, conductors may be constructed in other physical forms without departing from the spirit and scope of the invention.

The matrix 12 may be constructed from most available types of non-conducting or very high resistance materials which have the properties desired in the final conductor, such as attractive finish, light weight and the like. For easier production, it is desirable that the matrix be liquid or of low viscosity at temperatures of less than about 400° F. (unless the conductor is to be used at high temperatures). This allows the matrix to be formed to the desired shape and the particles to be magnetically oriented in the unhardened matrix material at relatively low production temperatures. Most of the presently known rubbers and plastics fulfill these requirements.

The paramagnetic particles 14 may be particles of almost any paramagnetic material; however, it is desirable that the material be capable of great influence by magnetic fields, i.e., ferromagnetic, so that the particles may be oriented to form conductive chains under the influence of a magnetic field of reasonable intensity. It is also important that these particles be electrically conductive. Accordingly, one very satisfactory material for the present purposes is iron or one of its alloys, inasmuch as such materials are of low cost, high magnetic permeability, and possess reasonably good electrical conductivity. In the event the conductor is to be exposed to a corrosive or other adverse environment, stainless steel particles constructed from stainless types of steel alloys may be used to prevent any possible corrosion blemishing on the material.

As will be pointed out in detail hereinafter, the particles 14 are oriented so that they physically touch one another to form conducting chains which interconnect and generally display a web-like structure. It is contemplated that one means of orienting the particles includes the application of a magnetic field to a mixture of the matrix material and the particles (or to the matrix material simultaneous with the addition of particles) while the non-conducting matrix material is in a fluid state. This allows the particles to move within the matrix material under the influence of the magnetic field. The influence of the magnetic field causes the particles to be attracted to one another, and to rotate and move until contact is established. Since the particles physically touch one another, they form conducting chains to create the desired conductive paths. The conducting particle chains are permanently established by solidification of the matrix while the particles are in physical conducting relationship to each other.

In order to use the conducting particle webs as direct conductors of electricity, physical electrical connections must be provided between the conductive particle chains or webs and external conductors or leads. These connections may be established through use of any good electrical conductor having a large surface area, the conductor with large surface area being embedded in the

matrix or disposed against a surface thereof and connected to the external leads. One method for disposing the conductors in contact with the particle chains includes the embedding of a length of wire material in the matrix. For matrixes formed into a sheet at least two alternate methods are, first, to embed a strip of wire screen or foil in the matrix or, secondly, to attach a strip of foil to the matrix by any suitable means such as an electrically conductive paste. In both of these latter instances, an electrical wire or other suitable type of lead is preliminarily connected to the strip or foil, as by welding or soldering.

A very important characteristic of plastics, rubbers, and many other non-conducting materials is the ease with which they may be formed into sheets or panels. There are important uses for electrically conductive sheets, especially as heater panels or blankets. Such sheets may be formed by applying a magnetic field parallel to the plane of the sheet while the matrix or particle impregnated material is solidifying. The composite sheets will thus be made to conduct in directions parallel to the surface thereof and, if conducting strips are placed along opposite edges of the sheet, electricity may be directed through the sheet, producing heat which radiates therefrom to warm the atmosphere surrounding the sheet. Since the conducting chains are produced to extend through the entire area of the sheet, the entire sheet becomes warm and may be used to warm an area without being more than a few degrees warmer than that area.

The resistance of the conductors described hereinbefore tends to be relatively high. This resistance may be lowered by applying pressure to the matrix after the particles have been magnetically oriented and during a time when the material of the matrix is plastic or deformable. Application of pressure serves to compress the matrix material and to move the particles into more intimate contact with each other. Thin sheets suitable for use as wall paper may thus be produced by coating a sheet of paper material or the like with a mixture containing 50% of a dispersion of neoprene in toluene, 40% iron powder and 10% graphite (the graphite being employed to lower resistance further, as will be explained hereinafter), all quantities by volume; then drying the sheet while in a strong magnetic field having a direction parallel to the plane of the paper; placing foil strips with wire leads near opposite edges of the sheet; placing a second sheet on top of the first; and vulcanizing the sandwich thus formed. A one foot square sheet of wallpaper having a thickness of 0.010 inch which was thus produced, without appreciable pressure having been applied, exhibited a resistance between ends of approximately 2000 ohms. By vulcanizing a similar sandwich under pressure of approximately 2000 lb./in.², a similar sheet having a thickness of 0.002 inch was obtained which exhibited a resistance of approximately 14 ohms. A noticeable lowering of resistance is usually obtained by applying pressures of at least about 50 lb./in.². Very great decreases in resistance are usually obtained by applying pressures of at least about 500 lb./in.².

A method of producing particle filled conductors is shown in FIG. 2, which illustrates an intermittent production line for producing conductive panels. The typically illustrated line type apparatus includes a conveyor belt 20 which advances the materials through various stages of the process. The conveyor belt 20 first moves over the top of a table 21 to allow the belt to be precisely positioned below a spreading knife 22 supported above the upper exposed surface of the belt. The belt 20 moves under a dispensing nozzle 24 connected to a suitable container such as a tank 25 which supplies a paste containing the constituents of the final conducting material, such as a dispersion of neoprene in toluene, iron powder, and graphite. The belt 20 further carries this mixture to the spreading knife 22 which spreads the paste into a sheet of uniform thickness as indicated generally at 23. The thickness of the sheet 23 may be controlled by adjusting a

thickness wheel 26 to move the knife 22 relative to the surface of the belt 20, the knife 22 and the wheel adjusting mechanism being carried by a bracket 27 disposed over the belt and mounted on a side of the table 21.

A layer of paste indicated at 23 is thereafter carried on the belt 20 into an oven indicated generally at 28 which supplies heat which helps to cure the neoprene, and which is also equipped to supply the magnetic field required to orient the paramagnetic particles. The oven 28 is provided with insulation walls 30 which define a rectangular oven chamber 32 through which the belt 20 and the sheet 23 pass. A heating plate 34 positioned in the bottom of the chamber 32 carries current from a current supply 36 and produces most of the heat necessary to cure the neoprene. A magnet coil 38, also connected to the current supply 36, produces a magnetic field along the length of the chamber 32 and also adds some additional heat. Thus, while the neoprene is being cured, the iron particles are maintained in an oriented chain-like condition. Before the sheet 23 on the conveyor belt 20 is fully cured, it is moved between platens 39 of a suitable press 40. Foil strips 42 with wire leads 43 are placed on the sheet at each end of the press 40 and the platens 39 of the press are then forced together to apply pressure to the sheet while curing is completed.

After the pressure is applied to the sheet, the platens 39 are separated and the conveyor belt 20 moves the sheet 23 to a stripped knife 44 which separates the sheet from the conveyor belt 20. The sheet then moves under a cutter 46 which is suitably supported above the sheet 23 and which is operated to cut the sheet along the lines situated just before the first foil strip and just after the second foil strip. The end product is a conductive panel with wire leads at opposite edges.

The process, as carried out by the equipment illustrated diagrammatically in FIG. 2, is intermittent, that is, the conveyor belt 20 does not run continuously, but for a short period every few minutes. This intermittent action allows pressure to be applied by a simple press 40, the sheet 23 being rapidly moved from a center portion of the oven 28, where the magnetic field is horizontal, to the press 40 for final curing. As shown, the oven 28 is about 20% longer than the press 40 or the final panel inasmuch as the magnetic field in the oven is distorted and not of the desired horizontal nature at the ends of the oven and for about 10% of the length thereof adjacent each end. The portions of sheet lying in these regions have particle webs which do not extend parallel to the plane of the sheet and therefore do not conduct well along the plane of the sheet. Accordingly, after being cut off from the balance of the sheets, these ends are discarded. In this connection, it is to be understood that advanced techniques are more elaborate equipment may obviate the present need to discard portions of the sheets without departing from the spirit and scope of the invention. When the conveyor belt is moved, it is moved a distance sufficient to carry the sheet portion lying at the center of the oven 28 to a point at the center of the press 40. The belt 20 may be driven by suitable machinery (not shown) disposed in the cabinet 48, over rollers, one of which is shown at 50, and through the path of the processes described hereinbefore.

Though panels of fairly low resistance can be obtained by means of the above process, panels of even lower resistance can be obtained by vibrating the paramagnetic particles while they are being aligned by the magnetic field, such vibrating preferably starting while the matrix material is in its most fluid condition. The vibration of particles allows them to come into closer contact by pushing through any film of matrix material which separates them.

One way of vibrating the particles is by placing a mechanical buzzer similar to a large doorbell buzzer on the oven 28. A better way is to send alternating currents through the panel as by placing electrical probes adjacent

to opposite sides of the panel. The currents are preferably of a high frequency on the order of ten thousand cycles per second, because the tiny particles can vibrate at this rate and the rapid vibration allows the particles to move into close contact. A high voltage on the order of ten thousand volts for panels having a length of several feet is generally required to provide sufficient electrostatic forces to cause vibration. The high voltage also increases conductivity if applied after the matrix is at least partially solidified, by causing arcing between particles, which turns some matrix materials into carbon and provides a conductive path between adjacent particles. In order to prevent overheating, the current is generally applied as a series of several bursts, each burst lasting a fraction of a second.

The basic ingredients of the particle filled conductors are a matrix material and paramagnetic particles, and, if pressure is applied to such a combination during curing, a conductor of moderate electrical resistance is obtained. The resistance of the conductor may be lowered even further by adding a powdered material which produces a lower contact resistance between adjacent paramagnetic particles. Materials suitable for this purpose are powdered graphite, aluminum, silver and the like. A one foot square, 0.025 inch thick panel that was constructed using approximately 50% iron powder and 50% of a dispersion of neoprene in toluene by volume, had a resistance of approximately 10,000 ohms. A similar panel constructed using approximately 40% iron, 10% graphite, and 50% of a dispersion of neoprene in toluene by volume, had a resistance in the order of 100 ohms. The use of ½% silver powder in place of 10% graphite resulted in about the same reduction of resistance.

The resistance of a conductor made in accordance with the present invention is maintained at a low level through use of paramagnetic particles composed of materials having high electrical conductivity, and especially of those materials having low contact resistance. In general, particles composed of the most conductive metallic materials such as copper and silver are most desired, but these materials are not magnetic. However, such particles may be magnetically oriented to form conducting chains if they are combined, alloyed or coated onto magnetic material. FIG. 3 shows particles of a magnetic material such as iron 60, coated with a highly conductive material 62 such as silver and embedded in a matrix material 64. If the coating 62 is made relatively thin, most of any current will flow through the iron core 60. However, the thin silver coating serves to lower the resistance of the particle chain by reducing the contact resistance below that normally encountered with uncoated iron particles, inasmuch as the contact resistance of adjacent silver shells is low. The large area of contact of the silver coating 62 with the iron core 60 provides a silver-iron interface of low resistance. The relatively large cross-sections of the iron cores allows the cores to conduct current easily. Particles of iron coated with copper and silver may be used to achieve a lowering of resistance to 1% of the value obtained for uncoated iron particles.

In accordance with a further aspect of the invention, a conductor is produced whose resistance increases greatly with temperature by the use of a matrix material having a high coefficient of expansion together with paramagnetic particles having a low coefficient of expansion. Such a conductor is useful as a self-regulating heating panel which tends to maintain a predetermined temperature in a manner similar to that of a heater with thermostatic controls. A sectional view of a panel of this type is shown in its cold state in FIG. 4 and in its hot state in FIG. 5. When current is applied across the panel and the panel is heated, the thermal expansion of a matrix 70 moves paramagnetic particles 72 in a direction to separate at least a portion of the particles and to interrupt the flow of current along paths defined by the

conductive chains of particles. For this purpose, many matrix materials such as silicone, epoxy, rubber and the like have sufficiently high coefficients of expansion, while materials such as polyesters do not. Examples of magnetic particles having low coefficients of expansion are iron, nickel, chromium and stainless steel.

The use of simply a base material and paramagnetic particles (no contact resistance lowering particles such as graphite) results in a panel having a fairly high resistance, and the resistance vs. temperature characteristics display a sudden and large increase in resistance when a predetermined temperature is exceeded. The temperature at which the resistance suddenly increases may be regulated by applying pressure to the panel while it is hardening. A panel may be constructed of 50% iron powder and 50% silicone by volume, which has a resistance of approximately 10,000 ohms at temperatures below 90° F., and whose resistance rapidly increases to over 10 megohms at 95° F. A sheet with these characteristics is useful to control the temperature of a chamber, for example, or as an element of a heat sensitive relay. A conductor with a lower cold resistance may be obtained by using particles having a core of paramagnetic material such as iron and coated with a good conductor such as silver, and such a conductor displays the same sharp increase in resistance at a certain temperature as do conductors which employ uncoated particles.

The addition of graphite powder to a temperature sensitive panel which contains uncoated magnetic particles results in a panel with lower resistance, and with a reduced rate of resistance change. For small percentages of graphite such as 5% of the total volume, the resistance still increases rapidly at a certain temperature, but not as rapidly or to such a high value as without graphite. The addition of graphite amounting to about 15% of the total volume of the sheet results in a sheet whose resistance vs. temperature characteristic is approximately a straight line function, the slope of the line becoming smaller with increasing amounts of graphite.

The use of a compressible material such as foam rubber as the non-conductive base material results in a conductor whose resistance decreases with application of pressure. As may be seen in the representation of FIG. 6, which shows such a conductor under no pressure, and FIG. 7, which shows the same conductor under pressure, the compression of a matrix material serves to move paramagnetic particles closer together and into better contact with each other, thereby lowering the resistance of the conducting chains. Pressure sensitive conductors may be made containing, for example, 50% iron, 10% graphite, and 40% polyurethane foam by volume, no pressure being applied during curing. The free spaces within many types of foam are airtight and conductors using such foams are useful as sensing elements of devices used to measure the pressure within a chamber. Through use of a light foam rubber which is very easily compressed, a conductor is obtained which serves as a sensing element to measure slight pressure changes and is useful in connection with an electrical barometer.

Compressible sheets made in accordance with this invention are also useful in connection with such applications as microphones, the change in resistance with pressure allowing the material to be used in a manner similar to that of a carbon button in a carbon microphone. Still further, the pressure sensitive material changes dimensions when it is subjected to a magnetic field, and is useful as the movable member of a loudspeaker or ultrasonic generator.

Conductors made from a compressible matrix not only change resistance with pressure, but also change resistance with temperature, if the matrix material has a coefficient of expansion different from that of the para-

magnetic particles. A thermistor (temperature sensitive resistor), whose resistance at any given temperature is adjustable, is obtained by providing a simple adjustable pressure applying mechanism such as a screw, which can act on the matrix.

It may thus be seen that the present particle-filled conductors may be made in a variety of shapes and sizes and may exhibit a large number of different and varying characteristics, depending primarily upon the types of material employed in the base or matrix and the types of particles employed, as well as the material of the particles. Furthermore, such conductors may be constructed to exhibit various characteristics depending upon action or work performed on the matrix material or the particles during fabrication or thereafter.

Having thus described the invention and the several embodiments thereof, it is desired to emphasize the fact that many further modifications may be resorted to in a manner limited only by a just interpretation of the following claims.

I claim:

1. A particle filled conductor comprising:

a high resistance, substantially solid, matrix material; electrically conductive particles situated within said matrix material and arranged in electrically conductive paths, said paths having the form of multiple interconnected chains forming a web-like structure; at least two electrical leads, said leads being disposed in physical electrical contact with said particles at spaced locations; and

said electrically conductive particles comprised of paramagnetic cores coated with a non-magnetic metal of high conductivity.

2. A heating blanket comprising:

a compressed non-conductive matrix material in the form of a sheet, said material being a curable material which, before curing, is viscous at temperatures of less than approximately 400° F.;

electrically conductive particles within said base material and positioned in contact with each other; electrically conductive strips positioned in physical contact with a plurality of said paramagnetic particles; and

said electrically conductive particles comprising paramagnetic cores coated with a non-magnetic metal of high conductivity.

3. A particle filled conductor comprising:

a high resistance matrix material;

electrically conductive particles distributed throughout said matrix material and arranged in numerous interconnected chains;

said electrically conductive particles comprise paramagnetic cores coated with a non-magnetic metal of high conductivity; and

graphite amounting to about 15% or more of the volume of said conductor dispersed in said conductor, whereby the electrical resistance of said conductor varies substantially linearly with temperature over at least limited temperature ranges.

4. A particle filled conductor comprising:

a high resistance matrix material;

first particles of electrically conductive paramagnetic material disposed in said matrix material and arranged in numerous interconnected chains; and

second particles of metal having substantially lesser paramagnetivity and greater electrical conductivity than said first particles, said second particles dispersed in said matrix in random orientation.

5. A particle filled conductor comprising:

a matrix of high electrical resistance material formed in a sheet configuration having first and second opposite edges;

electrically conductive particles disposed in said matrix in multiple electrically conductive chains, forming

conductive paths between said first and second opposite edges;
 second particles of metal having a lesser paramagnetivity and greater electrical conductivity than said electrically conductive particles, said second particles being randomly dispersed in said matrix; and
 first and second strip-like electrical conductors disposed along each of said first and second opposite edges.

References Cited by the Examiner

UNITED STATES PATENTS

942,555	12/1909	Hankin	338—224	15
1,723,872	8/1929	Longer	338—223 X	
2,067,393	1/1937	Habann	338—223 X	
2,472,214	6/1949	Hurvitz	338—114	
2,559,077	7/1951	Johnson et al.	219—543	

2,589,766	3/1952	Bernstein	252—62.5
2,683,673	7/1954	Silversher	219—549 X
2,688,070	8/1954	Freedlander	219—528
2,707,223	4/1955	Hollmann	338—32
2,717,946	9/1955	Peck	252—512 X
2,741,692	4/1956	Luke	219—528
2,796,505	6/1957	Bocciarelli	388—329 X
2,861,163	11/1958	Asakawa	388—324 X
2,862,097	11/1958	Negromanti	219—499
2,899,657	8/1959	Quade et al.	388—223 X
2,942,330	6/1960	Luke	29—155.5
2,951,817	9/1960	Myers	388—36 X
2,962,680	11/1960	Sidaris	388—9
2,978,665	4/1961	Vernet et al.	388—223
2,990,607	7/1961	Negromanti	29—155.5
3,031,344	4/1962	Sher et al.	117—227 X
3,056,750	10/1962	Pass	252—512

RICHARD M. WOOD, *Primary Examiner.*