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Schladitz

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[54] **POROUS ELECTRIC HEATING ELEMENT**

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[51] **Int. Cl.** **H01c 3/00**

[58] **Field of Search** .... 338/208, 210, 211, 308, 338/320, 333, 204; 219/381, 552; 117/98 F, 107.2 R; 174/110 F

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[57] **ABSTRACT**

An electric heating element for gases or liquids is formed from a porous body on whose inner surfaces is deposited a metal compound. The body or skeleton has low or negligible conductivity initially and may be made of layers of fabric or of foam material. It is heated by direct through flow of current and the metal compound is passed through in vapour form and is thermally decomposed to be deposited on the inner surfaces. The current and hence the resistance of the element can be continually monitored and the process arrested when the desired value is attained.

4 Claims, 4 Drawing Figures

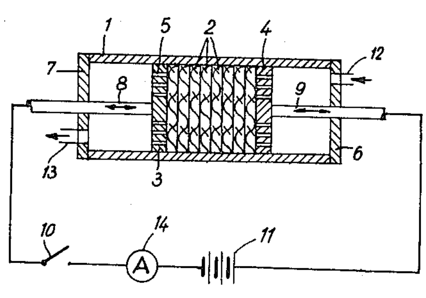


FIG.1

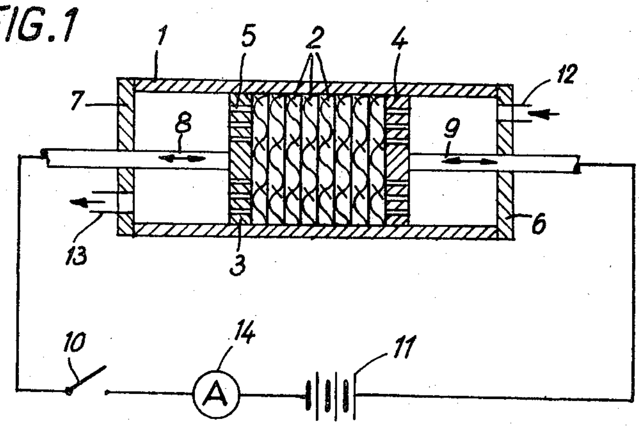


FIG.2

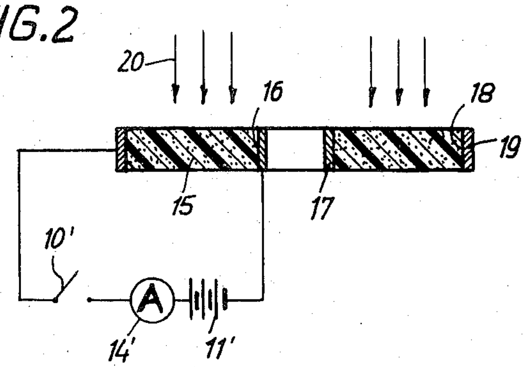
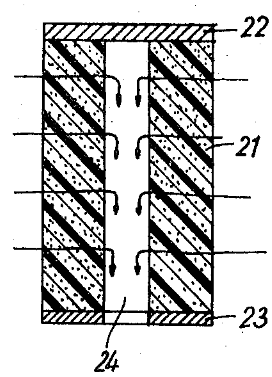


FIG.3



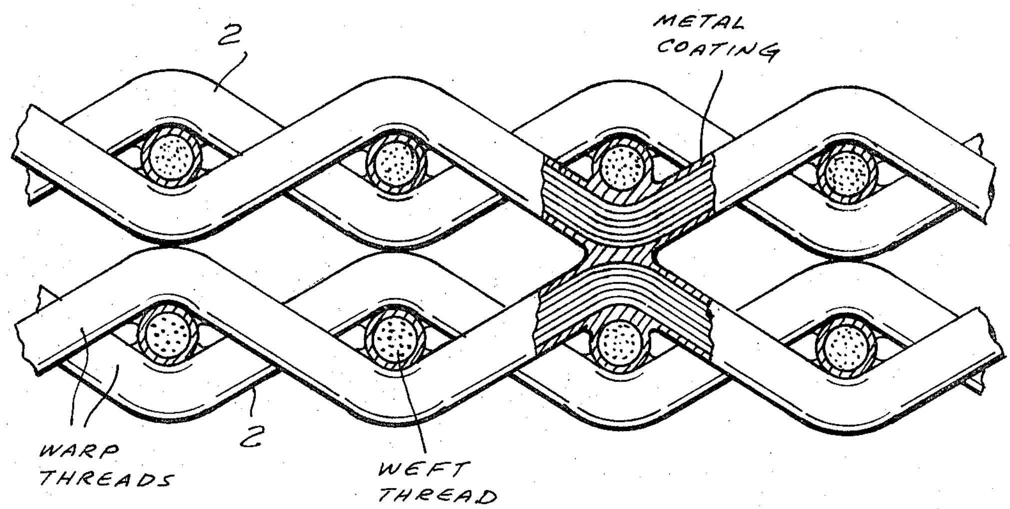


FIG. 4

POROUS ELECTRIC HEATING ELEMENT

This invention relates to porous, electrically conductive bodies and methods of making the same. It is particularly concerned with electric heating elements for the rapid heating of gases, liquids, vapours or aerosols and for vaporising liquid fuels.

A known body of this type consists of a plurality of elongated felted together electrically conductive parts which are metallically connected to one another at their point of contact. These parts may consist of hairs, needles, small rods or whiskers with a diameter of less than 10 μm, or of leaf-shaped particles of less than 1 μm thick. The porous body is manufactured from these elongated parts or particles by the latter first being formed into a loose accumulation of material which is compressed to the desired porosity. The individual particles are then connected metallically to one another at their points of contact, for example by metallisation from the gaseous phase. With this known porous body, intended preferably to serve as an electric heating element, a certain difficulty exists in achieving a substantially even pore size and thus a regular passage of the medium to be heated. Therefore, the medium which is to be heated endeavours to find the path of minimum flow resistance, so that individual portions of the heating element become more intensely permeated than others. This can lead on the one hand to minimal and on the other to excessive heating of the medium. In the latter case, the medium may be thermally decomposed, and when heating liquid hydrocarbons, in which excessive heat can result in cracking, the products of cracking may possibly clog the pores. An irregular permeation of the medium to be heated can under certain circumstances also result in destruction of the heating element, since the particles from which the heating element is formed are, as mentioned, very thin in order to create a very large internal surface area in the heating element. These have to be cooled by the through-flowing medium, since they would otherwise burn through. If, then, a part of the heating element is not or is inadequately traversed, then this part is subject to the risk of overheating and early destruction of the heating element. Another drawback is that since the manufacture of this known heating element is based on metallic or metallised particles, the electrical resistance of the completed heating element can be substantially varied only by changing the dimensions of the heating element. Also, with very small heating elements, such as are required for example for the evaporation of liquid fuels, the resistance is very low and for a given electric voltage, an undesirably high current strength results. Finally, the industrial production of heating elements from loose particles poses considerable difficulties.

It is an object of this invention to provide a porous electrically conductive body which offers a substantially regular passage to the medium to be treated, the electrical conductivity of which can be varied within wide limits during manufacture, and the manufacture of which is simple as compared with the known heating element.

According to one aspect of the present invention there is provided a porous, electrically conductive body comprising a preformed skeleton of electrically non-conductive or weakly conductive material, the inside surface of which is metal-coated by metallic products

of decomposition of a thermally decomposable metal compound.

The skeleton may be a plurality of layers of fabric, which may consist of glass, quartz and particularly carbon fibres, and which generally has a very even resistance to flow. The skeleton may alternatively be an open pore foam body, preferably made from carbon or polyamide foam, which can nowadays be manufactured with a very regular pore size. Thus, when using these starting materials, a substantially regular through-flow of medium to be treated can be guaranteed. It will be readily appreciated that a skeleton can easily be manufactured in the desired dimensions of the finished body, from these starting materials, by cutting, stamping or other known methods. If a foam substance is used, the skeleton can be produced to the desired size by foaming it into an appropriate mould. The resultant skeleton is then heated to a temperature required for decomposition of the metal compound and the latter, present in vapour form, can flow through it until such time as sufficient metal has been deposited on the inner surface of the skeleton to achieve the desired electrical conductivity. In this way, it is possible by simple means to produce a body of virtually any desired electrical conductivity.

The heating of the skeleton necessary to decompose the metal compound becomes particularly simple if the skeleton has a low initial electrical conductivity, since then the skeleton can be heated by the direct through-flow of current. In the case of a fabric consisting of electrically non-conductive fibres, such as glass or quartz fibres, this initial conductivity can be achieved by a weak pre-metallising of the fabric, preferably likewise by the depositing of metal from the gaseous phase.

The body according to the invention can preferably be used as an electric heating element, in which case the skeleton is provided with contacts for connection to a current source. These contacts can be connected to the metallised skeleton by depositing of metal during thermal decomposition of the metal compound. The body according to the invention can however also be used as a hot and cold electrode for electrochemical processes, fuel cells or collectors.

When used as an electric heating element, the body may take the form of a ring which is provided with one contact on the inner periphery and another on the outer periphery. This form of embodiment is particularly apposite if the skeleton is formed by a foam substance. On the other hand, the body may also take the frm of a column, the end faces of which are provided with contacts. This column can be formed by a foam substance or by placing a plurality of fabric discs or plates one on top of another. This column can take the form of a hollow cylinder and the medium to be heated can pass through it from the outside inwardly or from the inside outwardly.

In a method of manufacturing the body according to the invention when the skeleton consists of a plurality of layers of a fabric discs or plates of the desired dimensions are stamped or cut from a fabric, laid one on top of another in a required quantity and are pressed together by electrodes engaging at the ends of the pile so laid, the pile is heated by direct through-flow of current to a temperature necessary to decompose the metal compound, and the metal compound is then passed through the pile in vapour form until such time as sufficient metal giving the desired electrical conductivity has been deposited on the inner surfaces of the discs or plates.

In another method according to the invention, when the skeleton consists of an open pore foam body, a foam body is cut to the desired dimensions from a block of foam material, and is then heated by direct through-flow of current to the temperature necessary to decompose the metal compound and the vaporised metal compound is then passed through the body until sufficient metal giving the desired electrical conductivity has been deposited on the inner surface of the foam body.

Instead of cutting the foam body which is to form the skeleton from a block, the foam body can also be produced by foaming the material in a mould corresponding to the final form of the porous body.

With both methods, the electrical resistance of the pile or of the foam body can be constantly measured and, when the desired value is attained, the supply of metal compound and of current can be stopped.

For the metal compound, a carbonyl of the metals iron, chromium, nickel, tungsten, molybdenum, or a mixture of such carbonyls, is preferably used. It is known that metal carbonyls have the property that above a certain temperature, they decompose into metal and carbon monoxide, the metals being deposited in finely crystalline form and in the atomic state on the inner surface of the skeleton, so forming a rigidly adhering coating. The longer the metal carbonyl vapour flows through the skeleton, the thicker the deposit of metal will naturally be, and the higher will be the electrical conductivity. Other useful metal compounds are for example metal-acetyl-acetonates, such as platinumacetyl-acetonate, dicumene chromium or dibenzene chromium, platinum carbonyl chlorides et al.

Some examples of methods of producing the body according to the invention will now be described with reference to the accompanying drawing, in which:

FIG. 1 is a diagram of apparatus for forming a porous, electrically conductive body from layers of fabric,

FIG. 2 is a diagram of apparatus for forming a porous, electrically conductive body from a block of foamed material,

FIG. 3 is a longitudinal section through a heating element according to the invention, and

FIG. 4 is an enlarged fragmentary view of two adjoining discs each comprising a layer of fabric with the applied metal coating.

EXAMPLE 1 (FIG. 1)

Located side by side in a tube 1 made from an electrically non-conductive material or coated on the inside with an electrically non-conductive material, there are a plurality of discs 2 which have been cut from a premetallised glass-fibre fabric. The individual fibres are for example 5 microns thick. The discs 2 are located between two longitudinally displaceable electrodes 3 and 4 each of which consist of a gas permeable material or are provided with through ducts 5 and by which the discs are pressed against one another in intimate contact. A pressure of less than 1 kp/sq.cm is normally sufficient for this. The ends of the tube 1 are closed by covers 6 and 7, through which the connections 8 and 9 of the electrodes 3, 4 pass in fluid tight fashion. The electrodes can be connected to a current source 11 through a switch 10. Provided in the cover 6 is a connection 12 for the supply of metal carbonyl vapour, and in the cover 7 there is a connection 13 for the discharge of the carbon monoxide resulting from the decomposition of the carbonyl, and any non-decomposed carbonyl vapour. In operation, the discs 2 are pressed together by the electrodes 3, 4. Then the switch 10 is closed, so that the discs 2 are heated by the direct through-flow of current until they have reached the desired temperature at which decomposition of the metal carbonyl to be used occurs. In the case of nickel carbonyl, this temperature is between 100° and 160°C. The carbonyl vapour is then supplied to the connection 12, flows through the electrode 4 and the discs 2 and is decomposed in the region of the discs 2, the metal atoms released being deposited on the individual fibres of the discs 2 and forming a cohesive metal coating. The carbon monoxide and non-decomposed carbonyl flow through the electrode 3 and are carried off at the outlet connection 13. The ammeter 14 indicates the current strength and thus the electrical resistance of the column formed by the discs 2. Once the desired electrical conductivity of this column is reached, the flow of carbonyl is shut off and the switch 10 is opened. The metal coating may vary in thickness from 0.1 to several microns. The metal coating connects the individual discs 2 into one cohesive but still porous body which can now be removed from the tube 1. The electrodes 3, 4 are connected to this body by the deposited metal, so that it constitutes a ready-to-use heating element.

EXAMPLE 2 (FIG. 2)

In this example, the skeleton used is a foam body 15 in the form of a ring, consisting for example of a carbon foam produced from foamed synthetic resins by carburisation. Such a foam is characterised by a very low specific weight, a high pore volume and a regular pore size. A contact ring 17 is provided on the inside periphery 16 of the ring 15 while a contact ring 19 is provided on the outside periphery 18. The contact rings 17 and 19 can be connected to a current source 11' by a switch 10'. Upon closing the switch 10', the foam body 15 is heated to the desired temperature by the direct through-flow of current, whereupon a metal carbonyl vapour is passed through the foam body 15 in the direction of the arrow 20. The vapour decomposes inside the body 15, so that metal atoms are deposited on its inner surface. The ammeter 14' can be used to monitor the electrical resistance of the body 15. When the desired electrical conductivity is achieved, the switch 10' is opened and the supply of carbonyl vapour discontinued. The contact rings 17 and 19 are, in this method, connected rigidly to the foam body 15 by the metallisation treatment and can therefore be used for connecting the completed heating element to a current source.

The method illustrated in FIG. 1 can also be used for manufacturing a heating element consisting of a foam body.

FIG. 3 shows a longitudinal section through a heating element according to the invention, which can be used for example for vaporising liquid fuel, and which can find application in internal combustion engines or oil burners. This heating element consists of a column 21 manufactured by the method illustrated in FIG. 1 from layers of fabric or a foam body having the form of a hollow cylinder and provided on its end faces with contacts 22, 23. The liquid fuel passes through this body from outside over the entire length of the hollow cylinder and is carried away in vapour form through the central hole 24. In principle, the through-flow may also take place from the inside outwardly.

I claim:

1. An electric heating element comprising an electrically conductive porous body the pores of which forming passages for a fluid to be heated, said porous body consisting of a plurality of layers of a fabric made of fibers selected from the group consisting of glass, quartz and carbon fibers, said layers being arranged regularly one upon each other and being connected to each other in an electrically conductive manner by a metal deposition produced by decomposition of a thermally decomposable metal compound, said metal deposition forming at the same time a metal coating on the fibers of the fabric forming said layers, and electrodes in contact with spaced apart portions of the skeleton formed by said interconnected layers.

2. An element according to claim 1, in the form of a ring-like electric heating element, wherein the electrodes are provided on the inner and outer peripheries thereof.

3. An element according to claim 1, in the form of a column-like electric heating element, wherein the electrodes are provided on the end faces thereof.

4. A body according to claim 3, wherein the column has a longitudinal bore through its center.

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