United States Patent [19]

Quirk

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[54] **FAIL-SAFE ELECTRIC WATER HEATER**

[75] Inventor: **Virgil P. Quirk,** St. Marys, Pa.

[73] Assignee: **Stackpole Carbon Company,** St. Marys, Pa.

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Related U.S. Application Data

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[52] **U.S. Cl.** **219/311,** 219/345, 219/543, 338/308

[51] **Int. Cl.** **H05b 3/16,** F24h 1/18

[58] **Field of Search** 219/311, 345, 540; 338/308

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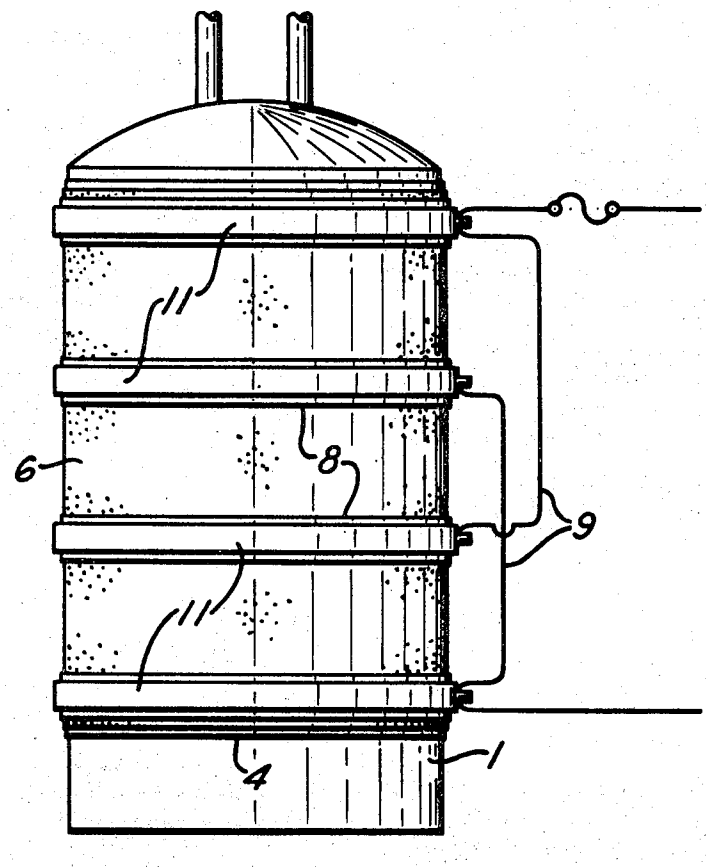
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Primary Examiner—J. V. Truke
Assistant Examiner—Kenneth Hairston
Attorney, Agent, or Firm—Brown, Murray, Flick & Peckham

[57] **ABSTRACT**

Adhering to an electric water heater is a porous layer of heat-fused insulating material powder covered by an adhering porous layer of heat-fused electric resistance powder having a negative temperature coefficient of resistivity. The pores of the two layers are filled with dielectric material. Electric terminals connected to the resistance layer are electrically connected with current-actuated circuit breaking means that will be operated by increased current flow through the resistance layer if that layer reaches a predetermined maximum temperature, whereby the water heater is fail safe.

6 Claims, 3 Drawing Figures



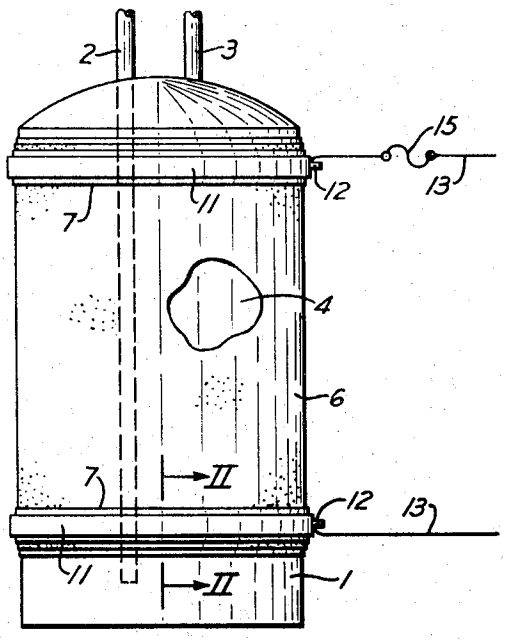


Fig. 1

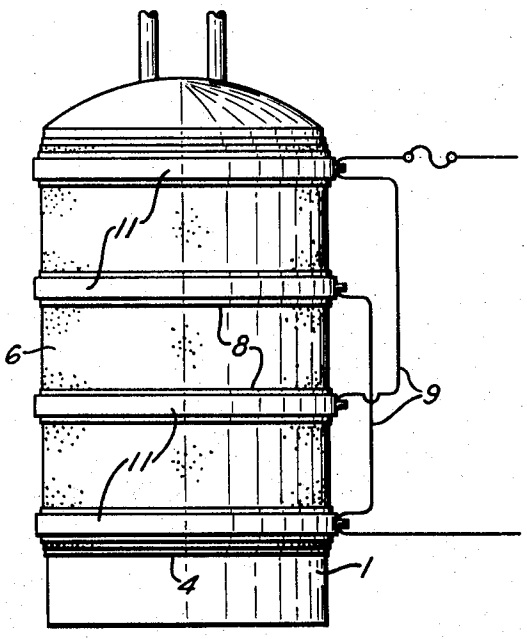


Fig. 3

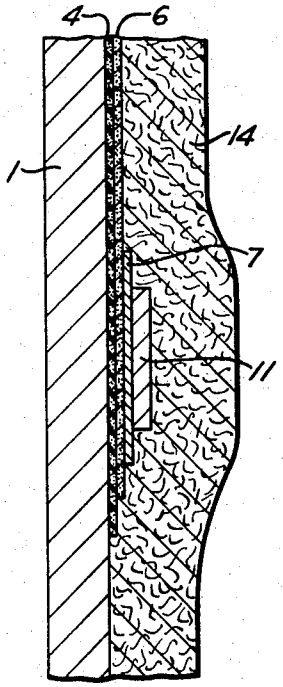


Fig. 2

FAIL-SAFE ELECTRIC WATER HEATER

This application is a division of my copending patent application, Ser. No. 256,757, now U.S. Pat. No. 3,791,863 filed May 25, 1972.

It is known that carbon or graphite particles dispersed in organic binders and carriers have been sprayed on substrates to form electrical resistance films, but such films are not stable electrically in heating applications, and particularly when the electrical load on the films exceeds 10 watts per square inch. It also has been proposed to spray tin oxide onto a vitreous coating on a water heater tank while the tank is in an oven, to thereby provide it with an electrical resistance film for heating water in the tank. A heater made in that manner suffers from minute faults in the vitreous coating and fissures and cracks in the resistance coating. These are caused by the heat treatment of the insulating coating on the tank at the time the resistance coating is applied, and by the subsequent cooling of the massive composite structure. Moreover, pin holes are formed in fired-on insulative coatings. These fissures, cracks and pin holes lead to electrical breakdown of the resistance coating or of the insulating coating or both. Also, the adherence between the coatings and between the insulating coating and the tank is faulty.

It is further known that fine particles or powdered materials have been deposited on the substrate by passing the particles through a high temperature flame, which can be either arc plasma or gas. For example, ceramic ferrite powder has been flame-sprayed on substrates to absorb X-rays or to make use of the electromagnetic properties of the ferrite. Piezoelectric material also has been flame-sprayed onto substrates. In these applications dense coatings are required in order to maintain the desired properties. On the other hand, the flame-spraying of electrical resistance material, and especially of ceramic ferrites, for electrical resistance purposes has not proved to be satisfactory because the resistance coatings, used either as electrical resistors or as heating elements, have tended to spall due to thermal cycling. That is, when such elements become heated the resistance coatings have expanded at a different rate than the insulative films beneath them and at a different rate than the substrates broken have borken away.

It is among the objects of this invention to provide an electric water heater which is fail-safe and which is heated by an adhering layer of heat-fused electrical resistance material powder connected in an electric circuit.

The invention is illustrated in the accompanying drawing, in which

FIG. 1 is a side view of an electric water heater without its thermal insulation;

FIG. 2 is an enlarged fragmentary vertical section taken on the line II—II of FIG. 1; and

FIG. 3 is a side view of a modification.

Referring to FIGS. 1 and 2 of the drawings, an electric water heater is shown that includes the usual metal tank 1, to which cold water is delivered and from which hot water is withdrawn through pipes 2 and 3, respectively, that enter the top of the tank. In accordance with this invention, finely powdered electrical insulating material is flame-sprayed onto the outside of the tank to form a thin coating or layer 4, generally between about 0.010 and 0.020 inch thick. Alumina powder, preferably between 100 and 250 mesh, is suitable for this purpose, but other dielectric materials such as steatite or mullite can be used, provided they are not reactive with the material that is to cover the insulation. The powdered material is fed in a carrier gas to a flame-spray gun or torch, either arc plasma or gas, to heat the powder and it is sprayed onto the tank all around its circumference for best results. The hot powder fuses together and to the metal tank. The height of the sleeve thus formed will depend on different circumstances. It can either extend the full height of the tank or only part way along it. Also, it may be located near the bottom, near the top or at the middle of the tank, depending upon what is found to be the best location for the particular application in mind.

Over the insulating layer a coating or very thin layer or film of electrical resistance material 6 is flame-sprayed. This film may be between 0.004 and 0.020 inch thick, preferably about 0.006. The longer the resistance sleeve, the thicker the film should be. It is preferred that a fine ceramic ferrite powder can be used for reasons that will be explained later, but other finely powdered resistive materials, such as metal oxides or metal carbides, can be used. Here again the powder may be between 100 and 250 mesh. The particles of the resistance material fuse together and to the underlying insulating layer when they strike the insulation.

I have discovered that the spalling problem can be solved by flame-spraying both layers in such a manner that they are porous. "Porous" as used herein means not more than about 93 percent of theoretical density, but more than about 60 percent of theoretical density because with greater porosity the coatings are not as continuous as they should be; they are more fibrous and subject to deterioration. Also, with greater porosity the particles of resistance material could be sprayed into the pores in the insulating layer and reach the metal tank. The porosity for any given thickness of coating can be controlled in several ways, such as by flame temperature, spray flame velocity, particle size and velocity, or distance of spray gun from the tank. The porous layers, due to their honeycomb structure, are flexible or "give" to some extent as compared with the flame-sprayed rigid dense coatings that have been required heretofore in other applications. As a result of this flexibility, the flame-sprayed layers can expand and contract relative to each other and the tank, due to temperature changes, sufficiently to avoid separating from each other or from the metal tank. Consequently, fissures or cracks are not formed that would lead to electrical breakdown.

In order to connect the resistance coating or sleeve into an electric circuit so that the water in the tank can be heated, terminals 7 are joined to the top and bottom areas of the coating. These terminals are formed by flame-spraying highly conductive metal powder or wire, such as copper, onto the resistance layer to form thin metal bands fused to it and extending around the tank. These terminals should be wide enough to make good and sufficient electrical contact with the resistance material. Terminals from three-fourths to one-half inch wide have been used satisfactorily. If the resistance sleeve extends very far along the tank, it may be desirable to flame-spray additional terminals 8 in the same manner between the end terminals and to electrically connect alternate terminals by wires 9 as shown in FIG. 3. In such a case the resistance film can be

made thinner than the long resistance sleeve shown in FIG. 1.

After the terminals have been formed in this manner, a further procedure is required in order to avoid a disadvantage that otherwise may result from the use of porous coatings. That is, unless something further is done to increase the electrical stability of the coatings, it is likely that there will be high voltage transient breakdown of the resistance layer because of moisture from the atmosphere entering the pores of the two layers. Therefore, to avoid this problem the two coatings are impregnated with a high dielectric material to fill their pores and thereby do away with all voids in the coatings. This material can be an epoxy or resin, such as Dow Corning R7 521 silicone resin. The impregnant does not interfere with the desired flexibility of the coatings. In order to impregnate the coatings with dielectric material, the coated tank may be preheated to about 150°F and then subjected to a vacuum of about 20 inches of water to remove the air from the pores. While still under vacuum, the tank is immersed in the liquid resin and then the vacuum is released and a pressure of about 80 psig is applied to fill the pores with the resin. After that the pressure is released, the unit is drained and resin on its surface is wiped off. Following this the resin or other dielectric is cured in the manner appropriate for the particular material used. This curing may be simply air curing or it may require considerable heat for several hours. If the porosity of the coatings were so low that the density of the coatings was more than about 93 percent of the theoretical density, the pores would be too small to be impregnated, so voids would be left in the coatings that could lead to electrical breakdown. Also, the coatings would be too rigid and not tolerant of expansion differentials.

Separate metal bands **11** are then clamped around the sprayed-on terminal bands **7**. The clamping bands are provided with means, such as screws **12**, for connecting them to the wires **13** of the electric circuit that is to supply the current for heating the resistance coating. The entire unit then is encased in thermal insulation **14**, shown only in FIG. **2**.

Such a water tank will have an extremely long life and it has the additional advantage that it does not have to be provided with any openings for the insertion of electric heating elements, since the heating element encircles the outside of the tank. One of the advantages of using ceramic ferrites over other resistance materials to form the heating element is that ferrites are a single phase material and therefore it heats uniformly throughout the mass. Because of that, the material has a uniform coefficient of expansion, which avoids possible strain in the material. It also is chemically inert at water heater temperatures.

A further big advantage is that ferrites have a negative coefficient of resistivity, which means that as the ferrite coating is allowed to be heated due to the water temperature increasing in the tank the electrical resistance of the coating decreases. The electric circuit for the tank is provided with a fuse **15** or circuit breaker that will open the circuit in case the current flow through the ferrite increases to a predetermined point. This much increase will not occur unless the temperature of the ferrite reaches an unsafe level due to a transient or permanent fault in the resistance coating causing an area of it to start to overheat. Consequently, this water heater is failsafe. Also, due to the same property of the ferrite when the coated heater is series connected as shown in FIG. **1**, it delivers the heat to the tank in the location where it is most needed. That is, as the water in the top of the tank reaches the desired temperature the upper part of the ferrite coating will become hotter than its lower part and the resistance of the upper part will decrease. According to Power Law ($P=I^2R$), the power is equal to the square of the current through the entire resistance coating, times the resistance of that layer. With resistance in series, the same current passes through the upper portion and the lower portion of the coating, and since the resistance of the upper portion is less, more power will be delivered to the lower portion to be conducted through the tank wall to the cold water, thus delivering the power to the coldest spot where needed.

As is well known, ceramic ferrites are ferromagnetic compounds containing Fe_2O_3; that is, one or more metal oxides in combination with Fe_2O_3. They are principally in two forms; a spinel crystal structure or a hexagonal crystal structure. Ceramic ferrites generally are made by dissolving hydrated ferric oxide in concentrated alkali solution, by fusing ferric oxide with alkali metal chloride, carbonate or hydroxide, or by heating ferric oxide in contact with metal oxides. Different ceramic ferrites have different electrical resistivity. Some typical values are as follows:

$NiFe_2O_4$	greater than 10^9 ohm cm.
$MgFe_2O_4$	10^6 ohm cm.
$Cu_{0.5}Zn_{0.5}Fe_2O_4$	10^5 ohm cm.
$Ni_{0.5}Zn_{0.5}Fe_2O_4$	10^3 ohm cm.
$Cu_{0.5}Li_{0.25}Fe_{2.25}O_4$	500 ohm cm.
$Mn_{0.66}Zn_{0.28}Fe_{0.06}Fe_2O_4$	150 ohm cm.
$Ni_{0.99}Fe_{0.01}Fe_2O_4$	30 ohm cm.
$Ni_{0.85}Fe_{0.15}Fe_2O_4$	5 ohm cm.

The method of making an electric water heater disclosed herein assures good heat transfer between the heating element and the metal wall of the tank, together with a resistance to thermo-mechanical spalling not experienced heretofore with firedon or vitreous typing coatings. Moreover, when the resistance material is a ceramic ferrite, a negative temperature coefficient of resistivity is present with the advantage that the heater can be controlled and made fail-safe. The difference in thermal expansion of the resistance coating and the metal tank is reduced by the fact that the resistance coating runs considerably hotter than the metal tank, which is in contact with the water.

The method explained herein can also be used for making other kinds of liquid heaters, such as laboratory flasks or beakers, baby bottle warmers, cups, and beverage and soup warmers. Where the substrate, such as a cup, is ceramic it is unnecessary to first apply an insulative coating. The resistance material can be flame-sprayed directly onto the substrate. Also when used as the heating source for a fluorescent light tube, the resistance material is flame-sprayed directly onto the glass tube.

The invention likewise is applicable to heating units that may be separate from the articles that they are designed to heat.

According to the provisions of the patent statutes, I have explained the principle of my invention and have illustrated and described what I now consider to represent its best embodiment. However, I desired to have it understood that, within the scope of the appended

claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A fail-safe electric water heater comprising a water tank, a porous layer of heat-fused insulating material powder on the tank and adhering thereto, a porous layer of heat-fused electrical resistance material powder covering the insulating layer and adhering thereto, said resistance material having a negative temperature coefficient of resistivity, electric terminals connected to said resistance layer, dielectric material filling the pores of said porous layers, and means for electrically connecting the terminals with current-actuated circuit breaking means that will be operated by increased current flow through the resistance layer if that layer reaches a predetermined maximum temperature.

2. A fail-safe water heater according to claim 1, in which said resistance layer is formed from ceramic ferrite powder fused together and to said insulating layer.

3. A fail-safe water heater according to claim 1, in which said terminals are formed from metal particles fused together and to said resistance layer.

4. A fail-safe water heater according to claim 3, in which said layers and terminals encircle the tank, and said connecting means include metal clamping bands encircling the tank in tight engagement with said terminals.

5. A fail-safe electric water heater according to claim 1, in which said electric terminals are spaced lengthwise of the tank.

6. A fail-safe electric water heater according to claim 1, in which said layers and terminals encircle the tank, and the terminals are spaced lengthwise of the tank.

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