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F. C. WALZ ET AL
MICROFILM ELECTRIC HEATERS

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2 Sheets-Sheet 1

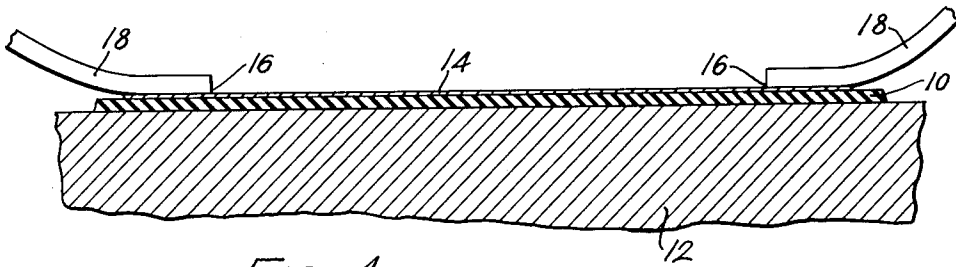


FIG. 1.

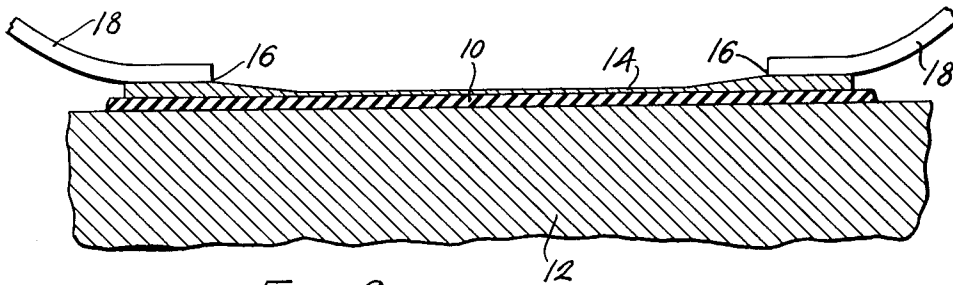


FIG. 2.

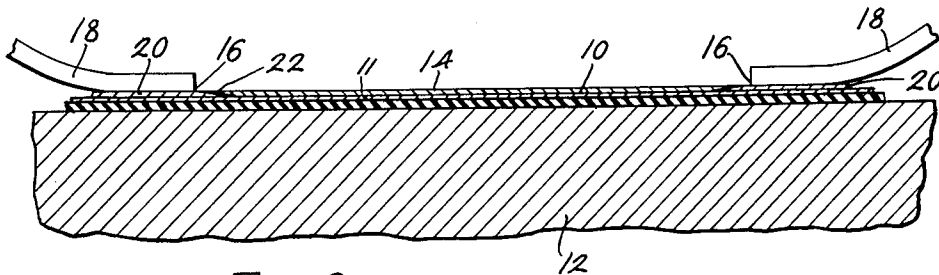


FIG. 3.

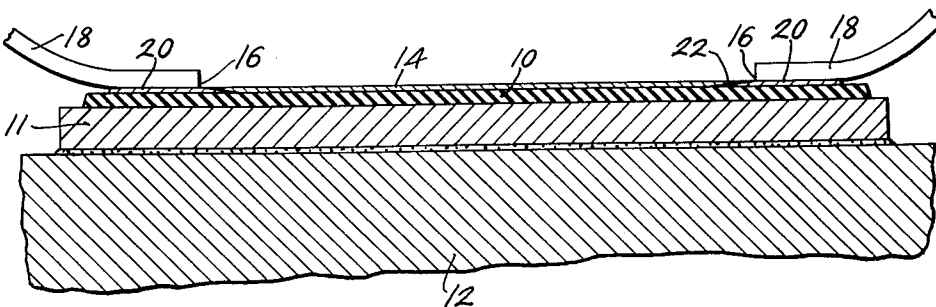


FIG. 4.

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MICROFILM ELECTRIC HEATERS

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2 Sheets-Sheet 2

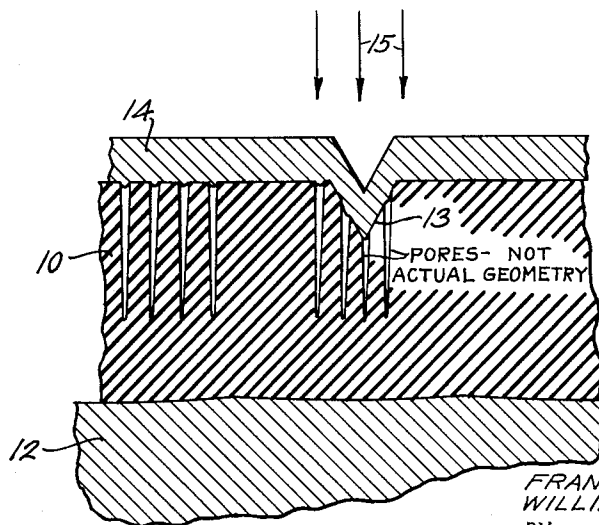
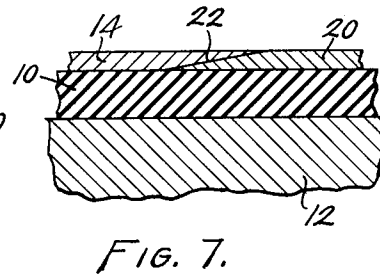
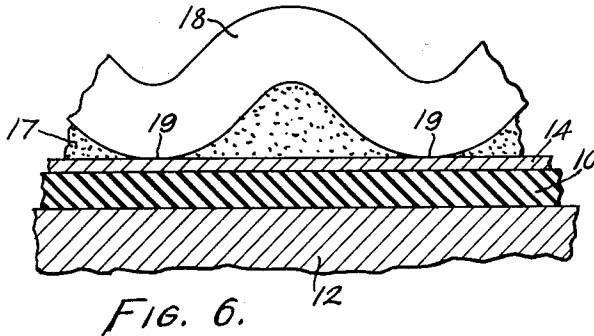
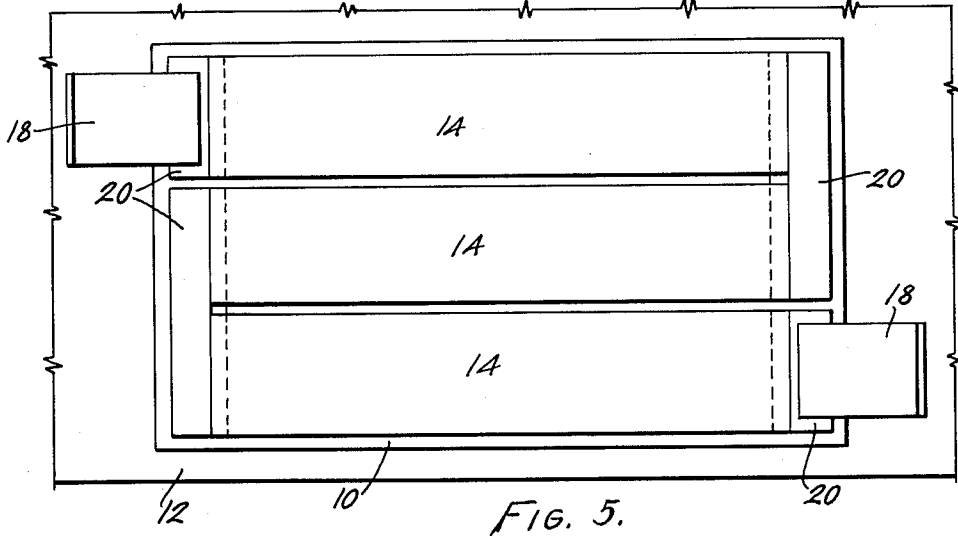


FIG. 8.

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MICROFILM ELECTRIC HEATERS

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14 Claims. (Cl. 219-19)

This invention relates to improved electric heaters and more particularly to electric heaters of the type comprising a microfilm of conductive material electrically insulated from but in thermal continuity with a heat sink or body to be heated.

Considerable difficulty has been experienced in the past in providing a film type heater with high current carrying ability, high heat transfer efficiency and one capable of extended operation without failure under these conditions.

It is an important object of this invention to provide an improved heater having heat transfer efficiencies over 90% and as high as 98%.

Another important object of the invention is to provide an improved heater capable of heating a body with a minimum time delay as compared with presently available heaters.

Another important object of the invention is to provide a heater having low thermal capacity with negligible temperature overshoot upon interruption of the power input to the heater. Such low thermal capacity further provides fast response time. These characteristics of the heater of the instant invention are important where the heater is used in automatic temperature control applications.

Another and further important object of the invention is to provide an improved heater capable of providing a predetermined uniform or varying surface distribution of power, having long life with increased transfer power densities and being economical of manufacture and use.

Another object of the invention is to provide an improved terminal means for effecting an improved efficiency in the transfer of electrical current into and out of a film type heater.

Another object of the invention is to provide an improved heater arrangement of the film type which substantially eliminates burn out of the heater film under the normal use for which the heater is designed.

Another object of the invention is to provide an improved terminal for a film type heater which will permit the passage of larger electrical currents into and out of the film without the usual localized failure.

A further object of the invention is to provide an improved means of interconnecting an electrical terminal to a heater film to avoid localized overheating and burnout.

A still further object of the invention is to provide an improved heater film arrangement having any predetermined dimensional variation in the heater film or material making up the film to provide any predetermined power density distribution therein while making it capable of handling maximum power densities without burnout.

In accordance with the invention, the improved electric heater comprises a base or film of electrically insulating and thermally conducting material, an electrical conducting heater film attached to the base and terminal means connected to the heater film for connecting same to a source of electrical power, wherein the thickness of the heater film at any given point therein is not less than one-half the thickness of the predominating thickness of the film. It may be further stated that the thickness of the heater film at any given point in the film is not less than that thickness which will withstand a local increase in power density due to a change in the

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direction of current flow or reduction in film thickness without burnout. This minimum thickness of the heater film at any given point may be controlled, in practice, conveniently by controlling the roughness of the insulating base or substrate on which the heater film is deposited, as will be more fully explained as the description progresses. A multiple point contact terminal is used to effect the ingress and egress of heavy currents into and out of the heater film while avoiding localized failure and burnout.

For a better understanding of the present invention together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims. As used throughout the specification the term "power density" refers to the electrical power dissipated as heat in an amount of heater film covering a unit area of substrate, "transfer power density" refers to the amount of power (in the form of heat) transferred through a unit area of the substrate and "current density" refers to the amount of current per unit of cross sectional area of the heater film or tab. The "predominating" thickness of the heater film has reference to the prevailing thickness of the heater film over a principal portion of a specified area of the heater film and where the "predominating" thickness corresponds to a predetermined thickness of the film, it may be defined as the "predominating predetermined" thickness.

In the drawings:

FIGURE 1 is an elevation in section, partly broken away to conserve space, of one embodiment of the improved heater of the invention showing the heater formed on a body to be heated;

FIGURE 2 is an elevation in section of another embodiment of the heater of the invention;

FIGURE 3 is an elevation in section of still another embodiment of the heater of the invention;

FIGURE 4 is an elevation in section of a heater, in accordance with the invention, formed directly on a metallic foil which may selectively be secured to a body to be heated by a thermally conductive adhesive or other suitable means;

FIGURE 5 is a plan view of one embodiment of the film of a heater according to the invention wherein the heater film in plan is of a zig-zag or an involute configuration and is particularly adapted for heating extensive surface areas;

FIGURE 6 is a section elevation to an enlarged scale of the junction between the terminal and a heater such as shown in FIGURES 1 through 4;

FIGURE 7 is a sectional elevation to an enlarged scale of the connection between the heater film and a tab of a heater as shown in FIGURES 3 and 4; and,

FIGURE 8 is a sectional view of a heater film and an insulating base, to a greatly magnified scale, showing one effect of imperfections in the surface of the base on a heater film deposited thereon.

The most efficient heating of a metallic body, electrically, is accomplished by using I^2R power development within the metallic body. Apart from the usually large I^2R power losses in an external electrical circuit, such heating would have an ideal efficiency of 100%. Because of high current requirements and attendant difficulties therefrom in insulation problems, most presently known heater arrangements fall far short of the ideal.

A heater arrangement with high voltage and low current requirements will substantially eliminate the external I^2R power losses and a heater with these requirements adapted to transfer heat efficiently into a heat sink

will be the virtual equivalent of generating the heat within the heat sink itself.

Primarily the thermal capacity of the heater element, the thermal capacity of the electrical insulator, the thermal contact with the heat sink and the external losses will determine the heat transfer efficiency of the system. It has been found that these requirements may be achieved to a large degree by the use of extremely thin metallic films as the heater or current carrying element. Such a film may conveniently be formed by hot filament vacuum deposition techniques and other like micro film deposition techniques well known to those skilled in the art.

Referring to the figures, FIGURE 1 shows an insulating base or substrate 10, formed directly on a body 12 to be heated. A metallic film 14 is formed on the base by means of a vacuum deposition and the like. The purpose of the base is to provide electrical insulation between film 14 and body 12 while providing efficient thermal conductance therebetween. To provide high heat transfer from film 14 to body 12, the thermal conductivity of base 10 should be as high as possible and its thickness should be as small as possible consistent with the insulation voltage requirements.

The electrically insulating thermally conducting base 10 may be formed, as on a heat sink, by electrolysis, plating, vacuum evaporation, vapor deposition, chemical deposition, flame spraying and the like. Base 10 must be of substantially uniform thickness, it must have relatively high voltage insulation and the contact thereof with the body to be heated must be sufficiently intimate to attain efficient thermal conduction across the junction therebetween. It is also important that the base 10 have adequate adherence to the body to be heated. It has been found that in a heater capable of meeting the objectives of the present invention, the thickness of the heater film at any given point therein must not be less than one-half that of the predominating film thickness. In practice, this requisite is met when the surface roughness of the insulating base, upon which the metallic heater film is deposited, is not greater than one-half the predominating thickness of the heater film. That these conditions are met is important to avoid localized increases in current density, due to reduction in heater film thickness and/or resulting from a change in the direction of current flow of such magnitude that the heat developed thereby causes the heater film to fail, resulting in burnouts.

Base 10 may conveniently be of any material having the requisite electrical and thermal properties, however, certain oxides, such as, aluminum and zirconium oxides, silicon monoxide, titanium dioxide and ceramics have been found to be highly satisfactory. The use of other base materials will depend on the effects of the combination of such material and the metal film attached thereto, the dielectric strength of the material and the thickness required to meet the electrical insulation requirements to support the voltage necessary to produce the required power density in the heater film.

In certain instances it may be desirable to use a base of multi-layer or sandwich configurations for improved results. For example, an aluminum oxide layer formed chemically upon an aluminum body to be heated may contain minute pores which reduce the effective electrical insulation characteristics of the base. It has been found that the vacuum deposition of a thin layer 11 of silicon monoxide upon the so formed aluminum oxide layer, FIGURE 3, seals the pores producing a substantially uniform continuous electrical insulation base.

The electrically conducting heater film 14 attached to base 10 must be electrically continuous. It must be of uniform thickness for uniform heat development or it may be of predetermined varying thickness for non-uniform heat development. Film 14 must adhere sufficiently and continuously to the base or substrate, and be devoid of air trapped therebetween, to resist spalling and

provide the necessary continuous thermal contact with the substrate.

The thickness of the heater film 14 is dictated by the specific conditions of operation. These are determined by power requirements, power density distributions desired and external mechanical loading conditions imposed on the heater film. In general the minimum thickness is that which is electrically continuous and not less, at any given point, than about one-half of the predominating thickness of the heater film. The maximum thickness of the film should be chosen such that its heat capacity is considered negligible when compared to the heat capacities of the electrically insulating substrate and the body to be heated.

Heater films found to meet the above requirements may be formed by any one or more of the methods used to form the insulating base 10.

The maximum power density which any film can develop without burnout is limited by the maximum power density that can be transmitted through the electrically insulating substrate to the body to be heated without causing the temperature of the heater film or substrate to exceed its melting point. For an ideal heater film the maximum power density would be the same at all points of the heater film. In actual practice, local concentration of current resulting from the surface roughness of the substrate, terminal contact, and change in direction of current flow within or into and out of the heater film will cause local increases in power density which may exceed the maximum power density transfer capacity of an insulating substrate and lead to the local destruction of the heater film.

For maximum efficiency, the heat conductance of base 10 should be as high as possible and, therefore, its thickness should be as small as is consistent with the electrical insulation requirements. The surface of the insulating base supporting the conducting heater film should have a low surface roughness so that the thermal capacity of the minimum thickness heater film which is operational is negligible compared with the thermal capacities of the base and body to be heated. It will be appreciated that if the surface roughness of the insulating substrate 10 is of a magnitude which requires a large predominating thickness in the heater film for the heater to be operational, the increased heater film thickness produces an increase in the thermal capacity thereof substantially increasing the response time of the heater system.

Attention is directed to FIGURE 8 in which is represented a heater in section, greatly magnified, showing the effect of a scratch, i.e., roughness, in the insulating base on a heater film deposited thereon. It will be seen that a scratch 13 in the base, even where the path from the deposition source to the scratch is normal to the surface will produce a film configuration requiring a marked change in the direction of current flow in passing through the film resulting in an increase in the local current density at the point of change. When scratches or roughness of the insulating base is of such configuration and depth that the thickness of a deposited heater film over a scratch or roughness is less than about one-half of the predominating heater film thickness it has been found that the amount of current that can be handled by the heater film without burnout is insufficient to render the resulting heater substantially operative for the intended purpose. A scratch or roughness in the base where the deposition path 15 is off the normal to the surface, on which the metal is deposited, causes a masking of a portion of the surface and results in a defect in the metallic heater film causing a point, line or area of reduced thickness in the film. Such defect produces a local increase of current density in the film and may, if the increase exceeds the capacity of the film, result in burnout. It is essential, in order to provide an operational heater, to avoid defects in the insulating substrate and heater film which will create a potential burnout.

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Conductive films formed in accordance with the above teaching on a compatible dielectric or electrically insulating base with high thermal conduction through the latter to a body to be heated, are capable of developing and efficiency transmitting very high power densities. A difficulty, encountered in the past, has been to lead large electrical currents, associated with such high power densities, into or out of a heater film without overheating and burning out the leading edge 16 thereof, FIGURE 1. Such failure is hereinafter referred to as "leading edge" burnout. The flow of current through a heater film can be substantially likened to a fluid flow through a conduit. Wherever there is a change in the direction of current flow in a heater film, the current appears to follow the shortest path producing an increase in the current density which produces an increase in local power density above that which can be transferred by the substrate without melting the heater film or substrate resulting in burnout or failure of the heater film.

The problem of leading high currents into and out of a heater film has been found to be solved in large part by the use of an improved design of the terminal 18, FIGURES 1 through 6, in intimate contact with the heater film. Terminals 18 shall have an electrical conductance many times that of a like area of the heater film. The terminal 18 may be attached to the heater film 14 in good electrical contact for lower power density operation, as in FIGURE 1, or the heater film 14 may be thickened at the extremities and terminal 18 attached thereto in good electrical contact for higher power density operation and greater current carrying capacity, as in FIGURE 2. Terminals 18 may be attached to tabs 20 in good electrical contact for improved current carrying capacity and reduced local heating as in FIGURE 3. Where the terminal is of the same metal as the element, i.e., film or tab, to which it is connected, it may conveniently be of greater thickness to provide the necessary current carrying capacity.

The contact of terminal 18 is preferably in the form having a plurality of small area contacts to provide multiple point electrical contact with the heater film. Referring to FIGURE 6, there is shown, in section, terminal 18 in multiple point electrical contact with the heater film 14. The contact surface of the terminal is involuted or knurled in a multi-dimensional pattern and secured to the heater film by a high temperature adhesive 17 and the like or mechanically such that the raised portions or points 19 only of the terminal are maintained in intimate electrical contact with the heater film while the adhesive serves to electrically insulate all but the points. The numerous small area contacts tend to lead current into and out of the heater film gradually and thus materially increases the current carrying capacity of the connection between the terminal and heater film without damage to the heater film or insulating film. Terminals providing small contact areas may conveniently be made of a metal screen on the order of 100 mesh, the mesh size depending on current requirements. The screen may be held in mechanical contact with the film but a more efficient contact is obtained by the use of a high temperature adhesive. Currents in excess of 200 amperes can easily be passed through a 3000 A. film with an aluminum screen terminal having 30 points bonded to the heater in this manner.

The heater embodiment shown in FIGURE 3 illustrates the use of a tab 20 interconnecting terminals 18 and heater film 14. The tab has an ohms-per-square unit resistance many times less than the heater film and is provided by either using a metal different from that of the heater film and having the requisite higher conductivity or by providing a tab of greater thickness than the heater film to have a greater current carrying capacity, as shown in FIGURE 2. Such tab will have negligible power developed therein per unit area compared with a like area of the heater film. The tabs 20 are formed on a previously formed electrically insulating base or substrate

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by vacuum deposition of the required metal while masking the source as will be understood by those skilled in the art, in a manner to produce a tapering edge 22, FIGURE 7 or a squared edge if sufficient skill is employed.

The heater film is then deposited on the base to provide good electrical contact with the edge of tab 20 be it tapered or squared. The junction between the tab 20 and the heater film 14 should be such as to produce a minimum change in the direction of the current flow when passing from the tab to the heater film or vice versa. While a true squared junction may be preferred, a tapered junction is satisfactory as long as the change in the direction of current flow resulting therefrom is not so abrupt as to cause localized overheating. The practice in the past has been either to provide a straight overlapping junction and/or to build up the junction in some manner. These junctions produce an objectionable abrupt change in the flow of current therethrough which results in leading edge burn out at the junction. A true butt-joint is difficult to achieve, in the present state of the art, without some degree of overlap, therefore, a tapered joint is to be preferred with the present state of the art. An electrical terminal 18 is then attached to tab 20 preferably in multiple point contact therewith.

FIGURE 4 illustrates an embodiment of the heater of this invention where the heater is formed upon a relatively thin foil 11, metallic or non-metallic, having an electrically insulating base 10 deposited thereon. The foil 11 is then attached to the body 12 to be heated by means of a high temperature, heat conducting adhesive or other means which will provide good thermal contact between the foil and the body.

FIGURE 5 illustrates the heater of the invention in zig-zag or involute configuration where the straight portions of the heater film are connected at their ends by means of a connecting tab 20. Thus a tab is provided at not only the ingress and egress of current into the heater as a whole but also at the ingress and egress of each straight portion of the heater. If the heater film 14 were continuous, the current would hug the "inside rail," as it were, resulting in an excessive current density and consequent localized overheating at this point with successive burnouts across the film until destruction of the film at the curves is complete. The provision of tabs "on the curves" allows straight line flow of the current into, through and out of the heater film 14 to avoid localized increases in current density in the heater film and to permit the current introduced or removed from the heater film to traverse the length thereof "turning the corners" with a minimum heating effect. It is of interest to note that the current passing through the heater film also may be likened to fluid flow and a roughness in the dielectric insulating base 10 sufficient to cause the aforementioned reduction in the thickness in the heater film and increased resistance to current flow therethrough will result in excessive heating and burnout at this point or points. A line of reduced thickness in the film normal to current flow is more susceptible to failure, however, a film deposited on a base meeting the minimum roughness requirement will withstand burnout even where the defects are predominately normal to current flow.

The heat transfer efficiency of the heater of the present invention may be expressed:

(1)

$$e = \frac{H_p T_p}{H_p T_p + H_d T_d + H_a T_a + H_h T_h + \text{losses} + H_t T_t}$$

Where: H_p , H_d , H_a , H_h and H_t are heat capacities of the body to be heated (plate) p , dielectric (base) d , air films a , heater film h , and terminals t , including tabs, respectively at temperatures T_p , T_d , T_a , T_h and T_t .

When the heat capacity of the dielectric b (insulating film), heater film h and terminals t are substantially less than that of the body or plate b to be heated, the magnitude of $H_d T_d$, $H_h T_h$ and $H_t T_t$ is negligible. Where

intimate attachment between elements of the heater system and heat sink p is accomplished, $HaTa$ ceases to be significant and is negligible compared to loss as in the heater and insulating film, then Equation 1 reduces to:

$$(2) \quad e = \frac{HpTp}{HpTp + L}$$

Where: L is the sum of the small losses.

Calculations in which the heat capacities are known and the temperatures are such that the radiation losses can be considered negligible, show the expected heat transfer efficiency to be 98% or better.

Efficiency may also be expressed:

$$(3) \quad e = \frac{WpCpdTp/dt}{EI}$$

Where: Wp is the weight of the body or plate b to be heated (it being assumed that the heater thermal capacity is negligible compared to that of the plate).

Cp is the specific heat of the plate;

dTp/dt is the rise rate of temperature of the plate; and

EI is the power input to the heater.

In operation, a heater constructed in accordance with the present invention and formed directly on a large heat sink (body to be heated) provided heat transfer efficiency of approximately 98%. Efficiencies of about 95% are likewise obtained with a heater film, dielectric combination on aluminum foil which is attached to the heat sink by a highly thermally conductive adhesive. Even when the adhesive layer is almost 0.001 of an inch in thickness, the efficiency remains above 90%.

If the thermally conductive bonding of the heater film and dielectric base to the heat sink is accomplished with sufficient uniformity, these efficiencies are maintained and the heater can be applied effectively to many general applications.

Because of the high efficiency of the substrate or base in transferring heat developed in the heater film to the heat sink, the temperature of the film is only several degrees higher than that of the heat sink. The resulting system, therefore, approaches the ideal and the power can be essentially considered as being developed directly in the heat sink.

For certain applications, dielectric liquids, such as phenolic epoxy resins, silicone resins and the like, may be sprayed on various metals and used as an electrically insulating base after curing. These liquid dielectrics may also be used to cover an oxide dielectric to provide a smoother surface, greater electrical insulation or to enhance adhesion of a vacuum evaporated metal heater film.

In each of the above cases, the heat transfer efficiency of a particular heater system will be altered in direct proportion to the change in the value of Hd in Equation 1.

A heater constructed in accordance with the invention will produce in excess of 200 kw. per square foot at voltages up to 440 volts and currents up to 100 amperes (depending on the area activated).

While there have been described what at present are considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention. It is aimed, therefore, in the appended claims to cover all such changes and modifications which fall within the true spirit and scope of the invention.

What is claimed is:

1. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conductive heater microfilm attached to said base and terminal means connected to said film for leading an electric current into and out of said microfilm, wherein the contact surface of said terminal means is provided with a plurality of raised portions arranged in a multi-dimensional pattern and is connected to said heater microfilm to provide multiple point electrical contact therewith and

each terminal means has an electrical conductance many times that of a like area of said heater microfilm.

2. An electric heater comprising a base of an electrically insulating material having a thickness to be essentially thermally conducting, said base including a coating of another electrically insulating material formed on said base of a thickness adapted to maintain the thermal conductivity of said base, a metallic electrically conductive metallic heater microfilm attached to said multilayer insulating base and terminal means connected to said microfilm for leading an electric current into and out of said microfilm, wherein the insulating base has a maximum surface roughness not to exceed about 50% of the predominating thickness of the heater microfilm and including tab means electrically interconnecting said heater microfilm and said terminal means, wherein the tab means has an electrical conductance many times that of a like area of the microfilm and the contact junction between the heater microfilm and said tab is such as to permit a transfer of current thereacross without a significant increase in localized current density.

3. An electric heater according to claim 2 wherein the insulating base is formed from a material selected from the group consisting of metal and non-metal oxides and the base coating is formed of another oxide.

4. In a micro film electric heater, a terminal means, the contact surface thereof having a plurality of raised portions arranged in a multi-dimensional pattern, said terminal means being adapted to be attached to a heater microfilm to provide multiple-point electrical contact therewith.

5. The device as set forth in claim 4, wherein the terminal means has an electrical conductance many times that of a like area of a heater microfilm with which it is to be used.

6. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conductive heater microfilm attached to said base and terminal means connected to said heater microfilm for leading an electric current into and out of said microfilm, wherein the thickness of said heater microfilm at any given point is not less than about one-half the thickness of the predominating thickness of said heater microfilm and wherein the contact surface of said terminal means is provided with a plurality of raised portions arranged in a multi-dimensional pattern and is connected to said heater microfilm to provide a high current carrying capacity multiple point electrical contact therewith.

7. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conductive heater microfilm attached to said base, terminal means for leading an electric current into and out of said microfilm, tab means electrically interconnecting said heater microfilm and said terminal means, wherein said tab means has an electrical conductance many times that of a like area of the microfilm and the contact junction between the heater microfilm and said tab is such as to permit a transfer of current thereacross without a significant increase in localized current density and wherein the thickness of the heater microfilm at any given point is not less than about one-half the thickness of the predominating thickness of the heater microfilm.

8. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conductive heater microfilm attached to said base, tab means having an electrical conductance many times that of a like area of said heater microfilm attached to the heater microfilm in electrical contact therewith and terminal means electrically connected to said tab for leading an electric current into and out of the heater microfilm wherein the contact surface of said terminal means is provided with a plurality of raised portions arranged in a multi-dimensional pattern and is connected to said tab means providing multiple point

electrical contact therewith and said terminal means having an electrical conductance many times greater than a like area of the heater microfilm.

9. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conducting heater microfilm of generally involuted configuration comprised of a plurality of substantially straight portions and tab portions, having an electrical conductance many times greater than a like area of the microfilm, electrically interconnecting said straight portions and attached to the free ends of the heater microfilm and terminal means connected to the tabs attached to a free end of the heater microfilm for leading an electrical current into and out of the heater microfilm, wherein the contact surface of the terminal means is provided with a plurality of raised portions arranged in a multi-dimensional pattern and is connected to said tab means by providing multiple point electrical contact therewith and said terminal means having an electrical conductance many times greater than a like area of the heater microfilm.

10. A heater according to claim 1 including tab means electrically interconnecting said heater microfilm and said terminal means, wherein the tab means has an electrical conductance many times a like area of the microfilm and the contact junction between the heater microfilm and said tab is such as to permit a transfer of current thereacross without a significant increase in localized current density.

11. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conductive heater microfilm attached to said base, terminal means connected to said heater microfilm for leading an electric current into and out of said microfilm, and tab means electrically interconnecting said heater microfilm and said terminal means, wherein the tab means has an electrical conductance many times that of a like area of the microfilm and the contact junction between the heater microfilm and said tab is such as to permit a transfer of current thereacross without a significant increase in localized current density and wherein the insulating base has a surface roughness not to exceed about 50% of the predominating thickness of the heater microfilm.

12. A heater as set forth in claim 11, wherein the con-

tact surface of said terminal means is provided with a plurality of raised portions arranged in a multi-dimensional pattern and is connected to said tab means to provide a high current carrying capacity multiple point electrical contact therewith.

13. A heater as set forth in claim 2, wherein the contact surface of said terminal means is provided with a plurality of raised portions arranged in a multi-dimensional pattern and is connected to said tab means to provide a high current carrying capacity multiple point electrical contact therewith.

14. An electric heater comprising a base which is electrically insulating and thermally conducting, a metallic electrically conducting heater microfilm of generally involuted configuration comprised of a plurality of substantially straight portions attached to said base, tab portions, having an electrical conductance many times greater than that of a like area of the microfilm, electrically interconnecting said straight portions and attached to the free ends of the heater microfilm and terminal means connected to the tabs attached to a free end of the heater microfilm for leading an electrical current into and out of the heater microfilm, wherein the thickness of the heater microfilm at any given point is not less than about one-half the thickness of the heater microfilm and the contact junction between the heater microfilm and said tabs is such as to permit a transfer of current thereacross without a significant increase in localized current density.

References Cited in the file of this patent

UNITED STATES PATENTS

1,422,130	Raynolds	July 11, 1922
2,569,773	Orr	Oct. 2, 1951
2,583,000	Lytle	Jan. 22, 1952
2,679,569	Hall	May 25, 1954
2,715,668	Booker et al.	Aug. 16, 1955
2,739,083	Brown et al.	Mar. 20, 1956
2,787,694	Farries	Apr. 2, 1957
2,795,682	Knoll	June 11, 1957
2,808,351	Colbert et al.	Oct. 1, 1957
2,921,257	Boicey	Jan. 12, 1959
2,939,807	Needham	June 7, 1960
2,977,450	Boicey	Mar. 28, 1961