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[54] **HEATING DEVICE**
14 Claims, 8 Drawing Figs.

[52] U.S. Cl. **219/343,**
 219/339, 219/353, 219/553

[51] Int. Cl. **F24h 9/02**

[50] Field of Search 219/339,
 342, 343, 347, 353—357, 377, 552, 553

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ABSTRACT: A graphite resistance-type heating element having legs mounted on liquid cooled connector blocks is disposed in front of a graphite felt pad which, in turn, is mounted on a liquid cooled plate. The graphite felt absorbs heat and radiates it back toward its source and beyond. Consequently, the connector blocks, the plate and other components located behind the graphite felt remain relatively cool and need not be constructed from refractory materials.

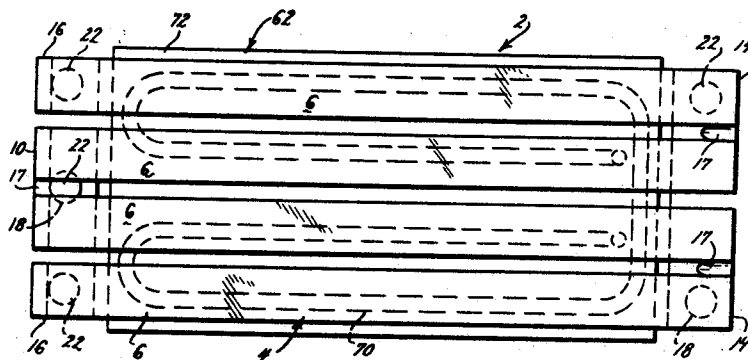


FIG. 1.

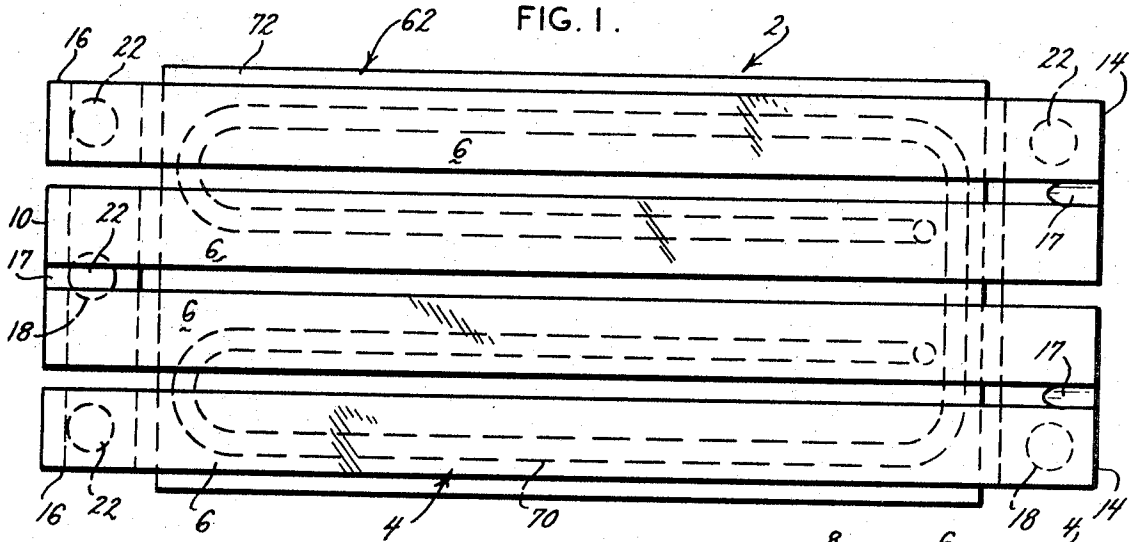


FIG. 2.

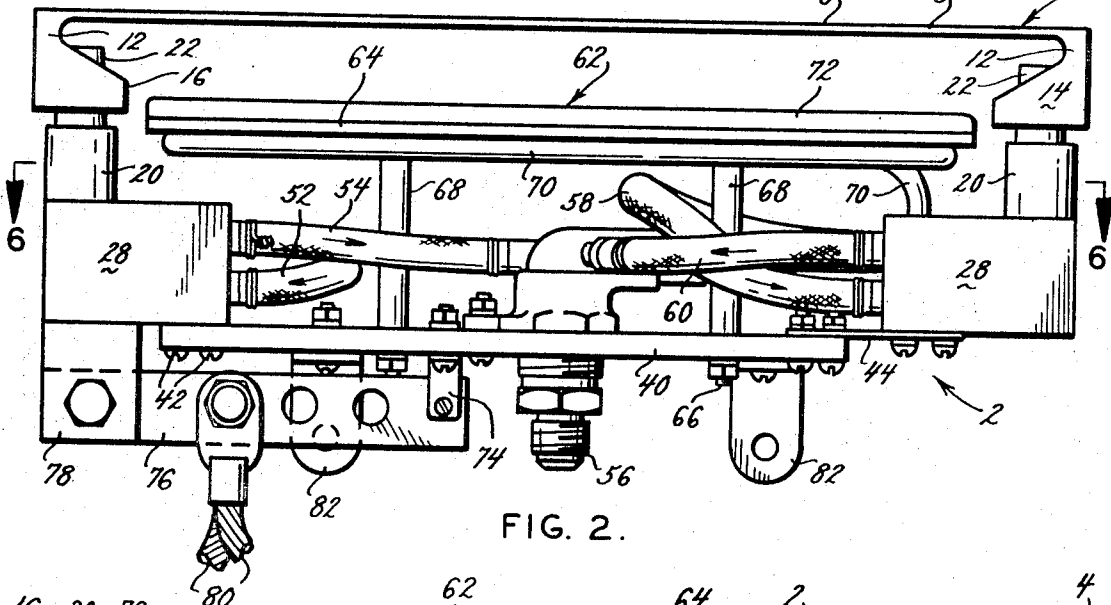
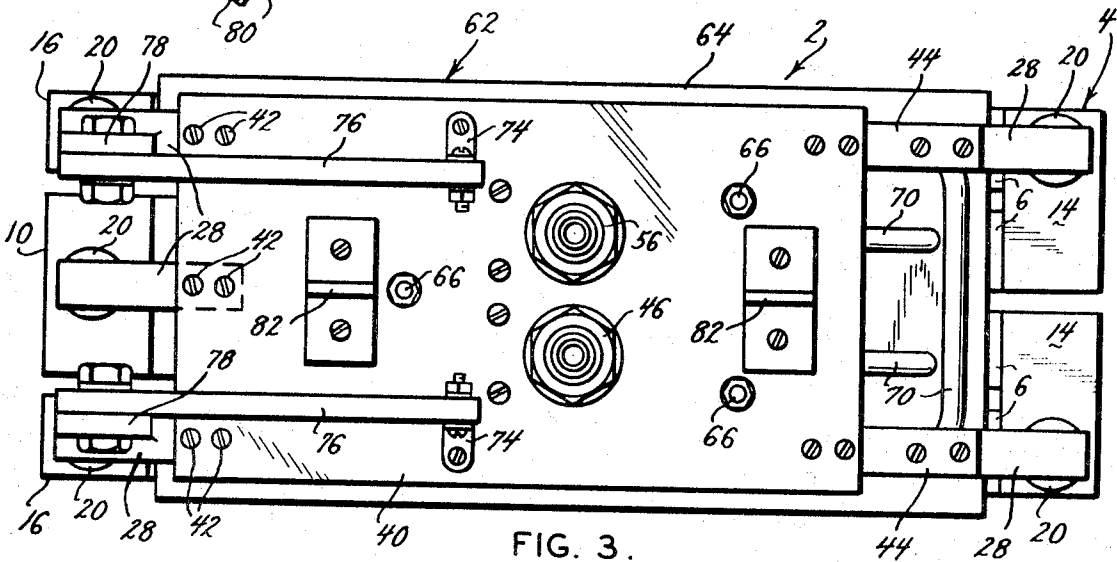
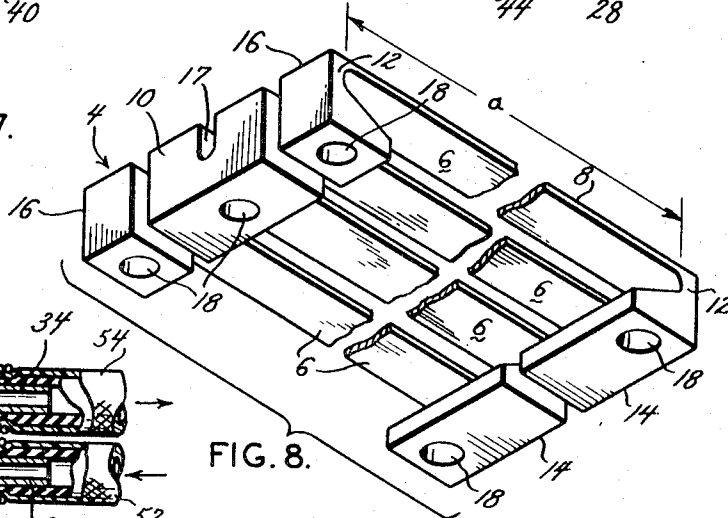
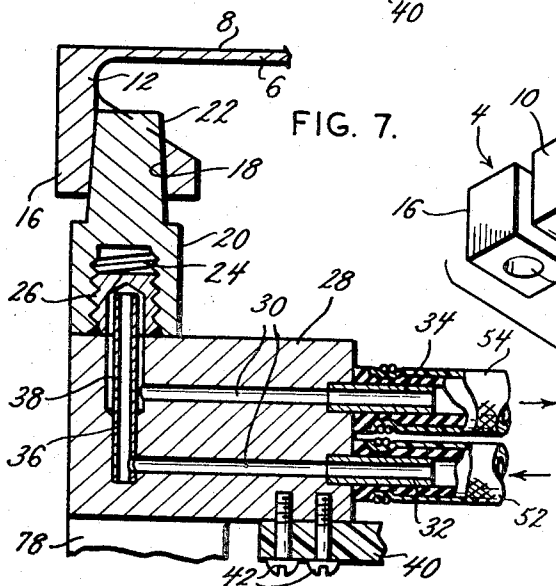
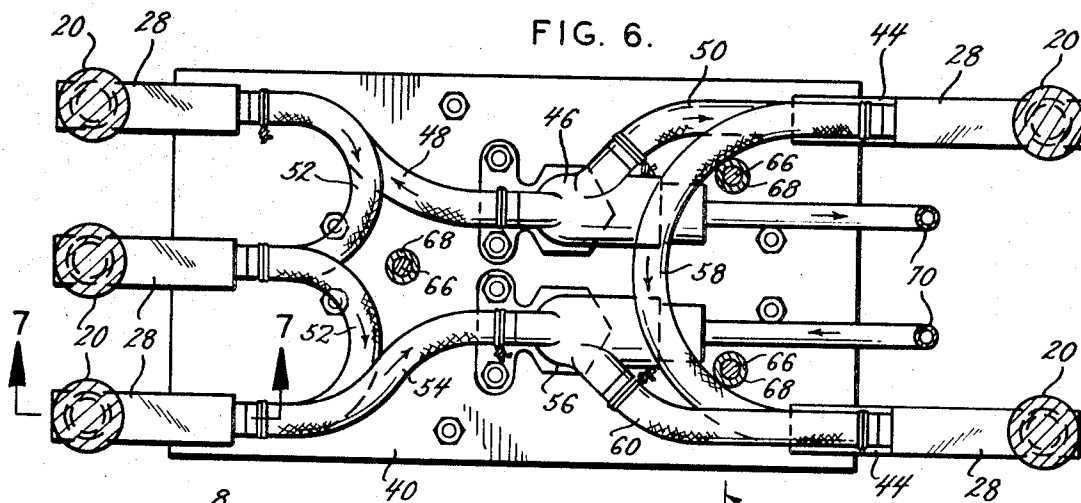
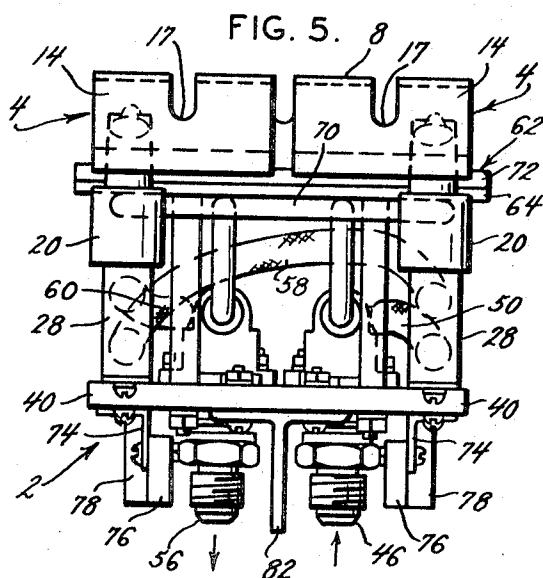
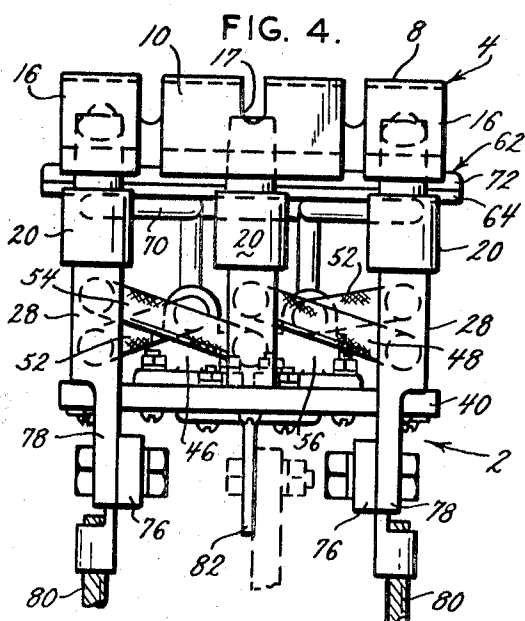


FIG. 3.





HEATING DEVICE

This invention relates in general to heating devices and, more particularly, to heating devices capable of generating extremely high temperatures and heat flux densities.

In certain industries, particularly the aerospace industry, it is necessary to test materials and structures at extremely high temperatures. Flame producing heating devices have been constructed for this purpose, but they are complicated and difficult to control. To overcome these problems radiant heating devices have been developed and perhaps the most common is the quartz lamp heater. These heaters utilize quartz lamps which are mounted in front of ceramic or plated reflectors aimed at the test specimen. A quartz lamp, however, is extremely expensive, and this coupled with the fact that they have a life span of approximately 2 hours at high temperatures, adds appreciably to the cost high temperature test procedures. Moreover, the test specimens when heated to such temperatures invariably effuse contaminants which adhere to the reflectors and create localized areas thereon which absorb heat from the lamp instead of reflecting it. This results in a substantial temperature differential across the reflector face and, of course, eventual destruction of the reflector. Furthermore, in actual practice quartz lamp heaters are limited to a maximum heat flux density of 100 to 120 Btu/ft.² sec.

Graphite heating elements are capable of producing a heat flux density of 500 Btu/ft.² sec. and have experienced limited use in high-temperature applications. Nevertheless, they have always been used in conjunction with reflective devices, and reflectors impose severe limitations as previously noted. Moreover, it is the accepted belief that graphite heaters can only operate across low-voltage high-current electrical energy sources and this, of course, requires heavy transformers and other expensive control equipment.

Furthermore, conventional radiant heaters, whether they be of the quartz lamp or graphite variety, make generous use of expensive refractory materials and this adds appreciably to the cost of the heater itself.

One of the principal objects of the present invention is to provide a novel heating device which is capable of producing extremely high temperatures and heat fluxes. Another object is to provide a heating device of the type stated which does not employ a reflector and, therefore, does not have the disadvantages associated with reflectors in high-temperature applications. A further object is to provide a heating device of the type stated which is constructed from inexpensive materials. Still another object is to provide a heating device which utilizes a graphite heating element, but does not require a low-voltage high-current power supply.

These and other objects and advantages will become apparent hereinafter.

The present invention is embodied in a heating device including a resistance type heating element disposed in front of a reradiating body having good insulating properties. The invention also consists in the parts and in the arrangements and combinations of parts hereinafter described and claimed. In the accompanying drawings which form part of the specification and wherein like numerals and letters refer to like parts wherever they occur:

FIG. 1 is a plan view of the forward side of a heating device constructed in accordance with and embodying the present invention;

FIG. 2 is a side elevational view of the heating device;

FIG. 3 is a plan view of the rear side of the heating device;

FIGS. 4 and 5 are end elevational views;

FIG. 6 is a sectional view taken along line 6-6 at FIG. 2;

FIG. 7 is a fragmentary sectional view taken along line 7-7 of FIG. 6; and

FIG. 8 is a perspective view of the graphite heating element forming part of the present invention.

Referring now in detail to the drawings, 2 designates a heating device including a resistance type heating element 4 formed from graphite in the configuration best illustrated in

FIG. 8. In particular, the heating element 4 consists of four relatively flat and thin heating strips 6 located in spaced and parallel relation and having coplanar radiating faces 8 which are presented forwardly toward the object to be heated. The strips 6 are dimensionally equal and the two innermost strips 6 are connected to each other through a common center leg 10 which extends rearwardly from the strips 6, leaving the uninterrupted radiating faces 8 extending entirely across the front of the heating element 4. The leg 10 integrally merges with the two inner strips 6 at narrow and contoured neck portions 12, and rearwardly from the neck portions 12 it flares inwardly toward the opposite end of the heater element 4. While the neck portions 12 are considerably thinner than the inwardly flared portion of the leg 10, they are still greater in cross-sectional area than the strips 6 and this is also true of a cross section of the leg 10 taken between the two neck portions 12, that is, at the location where the two innermost strips 6 are connected to each other through the leg 10. At the opposite end of the heater element 4 the two pairs of adjacent inner and outer strips 6 are similarly connected through common legs 14 which possess the same configuration as the leg 10. Finally, the two outermost strips 6 have individual legs 16 formed at their opposite ends and those legs also possess the same configuration as the leg 10 and indeed are located on each side of and in alignment with the leg 10. Accordingly, a generally serpentine electrical path exists through the heater element 4, that path extending from one of the individual legs 16 to the other individual leg 16 through the strips 6 and the common legs 10 and 14. Where two adjacent strips 6 are joined through the legs 10 or 14, the margins thereon are contoured as at 17 to prevent a concentration of current and a localized hot spot at any point along the serpentine path. Each of the legs 10, 14 and 16 are provided with a rearwardly opening tapered socket 18 having its axis perpendicular to the coplanar radiating faces 8.

The heating element 4 is supported on a plurality of mounting studs 20 (FIG. 7) having tapered nose portions 22 which project into the sockets 18 and frictionally engage the legs 10, 14 and 16 so that each strip 6 is secured at both of its ends. The studs 20 are further provided at their opposite ends with threaded bores 24 which receive hollow threaded studs 26 mounted on and forming part of connector blocks 28. The connector blocks 28 may be formed from any conventional metal capable of withstanding moderately high temperatures such as brass or steel, and each connector block 28 has a coolant channel 30 which commences at a tubular inlet 32 and terminates at an adjacent tubular outlet 34 in the block 28. Each channel 30 further includes a tube 36 set into its block 28 and extending into the hollow portion of the threaded stud 26 thereon for delivering the coolant medium to the stud 26, the return from the stud 26 being through a return passage 38 located concentrically about the tube 36.

The connector blocks 28 disposed behind the common leg 10 and the two individual legs 16 aligned therewith are fastened securely to a rigid dielectric mounting plate 40 by means of machine screws 42. The plate 40 is spaced away from the heater strips 6 and is formed from any dielectric material capable of withstanding moderately high temperatures in the neighborhood of 200° F., such as silicone phenolic board. The connector blocks 28 disposed at the opposite end of the heater element 4 are connected to the plate 40 by means of flexible connecting straps 44 which are free to shift longitudinally with respect to the plate 40 for a limited distance to compensate for thermal expansion of the heater element 4.

The mounting plate further carries a coolant inlet fitting 46 having supply hoses 48 and 50 leading therefrom in opposite directions (FIG. 6). The hose 48 connects with the tubular inlet 32 of the connector block 28 supporting one of the individual end legs 16 and the outlet 34 of that block 28 is connected through a connecting hose 52 with the inlet 32 of the adjacent connector block 28 located behind the common leg 10. Similarly, the outlet 34 of the connector block 28 at the

common leg 10 is connected to the inlet of the connecting block 28 supporting the other individual end leg 16, through another connecting hose 52, the outlet 34 of that block 28 being connected through a return hose 54 to an outlet fitting 56 disposed on the mounting plate 40 adjacent to the inlet fitting 46. At the opposite end of the plate 40, the supply hose 50 connects with the tubular inlet 32 on the block 28 supporting any of the common end legs 14, the outlet 34 of that block being connected through a connecting hose 58 to the inlet 32 of block 28 supporting the opposite common leg 14. The outlet 34 of that block 28 also communicates with the outlet fitting 56 through a return hose 60.

In addition to the blocks 28 and the fittings 46 and 56, the mounting plate 40 supports a reradiator assembly 62 including a support plate 64 which is fastened to the mounting plate 40 behind the heating strips 6 and is maintained in properly spaced relation to the plate 40 by means of three mounting bolts 66 and spacer sleeves 68. The support plate 64 is formed from any conventional metal capable of withstanding at least 200° F. such as copper, and on its backside, that is the side presented away from the strips 6, it is provided with a coolant coil 70 having ends which are turned downwardly toward the mounting plate 40 and connected with the inlet and outlet fittings 46 and 56, respectively. The opposite face of the support plate 64, that is the face presented toward the strips 6, is located approximately at the base of the legs 10, 14 and 16, and it is covered with a reradiator pad 72 which, as the name implies, has a high emissivity for reradiating most of the heat radiated to it by the heating element 4. The reradiator pad 72 should further be capable of withstanding extremely high temperatures in excess of 4,000° F. and should, in addition, be a good insulator to the passage of heat. Graphite felt approximately one-quarter inch thick is ideally suited for forming the pad 72, and that substance amounts to nothing more than carbon having a myriad of interstices throughout. Indeed, graphite felt comprises a conglomeration of carbon fibers formed into a flexible pad with the fibers spaced relatively far apart so that the pad has excellent insulating properties and weighs relatively little in comparison to its bulk. In short, graphite felt resembles conventional Fiberglas insulation, only the fibers are carbon instead of glass. Graphite felt is formed by transforming rayon fibers laid up into the desired weave or conglomeration into carbon fibers. It is inexpensive and can be obtained from the National Carbon Company, a division of Union Carbide. The reradiating pad 72 is secured to the plate 64 by any adhesive which is compatible with the two and capable of withstanding temperatures of about 200° F. Most weatherstrip cements are suitable for this purpose.

The dielectric mounting plate further mounts a pair of brackets 74 to which bus bars 76 are attached, the opposite ends of the bus bars 76 being bolted to tabs 78 projecting rearwardly from the two connector blocks 28 which support the individual legs 16 of the heater element 4. The bus bars 76 are also formed from a common metal such as copper or brass, and they, in turn, are connected to a pair of electrical leads or cables 80 leading directly from the mains or from a suitable power controller (not shown).

Finally, the dielectric mounting plate 40 has a pair of mounting brackets 82 projecting rearwardly from it for securing the entire heating device 2 to a suitable supporting structure.

In use, the heating device 2 and the object to be heated are both emplaced within an inert atmosphere with the radiating faces 8 of the former presented toward the latter. Nitrogen forms a suitable inert atmosphere for most test specimens. Next, a liquid coolant such as water is introduced into the inlet fitting 46, and that coolant flows through the connector blocks 28 supporting the legs 10 and 16 on the heating element 4 by way of the hoses 48, 52 and 54, as well as through the connector blocks 28 supporting the legs 14 by way of the hoses 50, 58 and 60. The coolant further flows through the coolant coil 70 on the support plate 64.

After the flow of coolant has been established, an electrical potential is impressed across the electrical leads 80, the voltage being dependent on the resistance offered by the heater element 4 as well as the temperature desired at the heating strips 6. When the strips 6 are 0.80 inches × 0.070 inches × 12.0 inches, the last dimension being between the inner margins of opposing neck portions 12 as designated by the dimension line *a* in FIG. 8, the heater element 4 will draw 540 amperes of current when 240 volts are impressed across it and the temperature of the strips 6 will rise to approximately 4,750° F. Under these conditions the radiant heat flux density from the heating device 2 to the object will amount to 300 Btu/ft.² sec. Much of the heat generated by the heater element 4 is radiated from the radiation faces 8 toward the object. Of course, the opposite faces of the strips 6 also radiate heat and that heat is absorbed by the reradiating pad 72. Since the reradiating pad 72 is a good heat insulator, very little of the absorbed heat passes through it to the plate 64 and the coolant passes through the coil 70 in the plate 64. Consequently a high-temperature differential exists across the pad 72, its outer surface being capable of attaining temperatures approaching that of the strips 6 themselves, while its interface with the plate 64 remains at approximately 200° F. due to the flow of coolant in the coil 70. Thus, neither the coil 70 nor the plate 64 need be fabricated from refractory metals. Indeed, most of the temperature differential is in that portion of the pad 72 immediately adjacent to the plate 64 and, consequently, the remainder of the pad 72 and particularly its surface exposed behind the strips 6 remains at a relatively high temperature. By reason of the high emissivity of the pad 72, over 80 percent of the heat absorbed by it is reradiated away from it toward the object being heated. Some of this heat is radiated through the spaces between the heating strips 6 directly to the object being heated, while the remainder is radiated back into the heating element 4, reducing its net heat loss. The efficiency is about the same as the reflectors used in conventional heating devices.

Should the object disintegrate as a result of the high temperatures and expel contaminants as they often do, those contaminants upon depositing on the reradiating pad 72 will merely burn away since the pad 72 normally reaches a temperature in excess of the object anyway. In other words, the contaminants will not create localized hot spots as they do on reflectors, and even if they did, those hot spots would not damage the pad 72 since it is capable of withstanding extremely high temperatures, as well as extreme temperature differentials. When the radiator pad 72 is formed from graphite felt it does not demand great handling care as is the case with reflectors having highly polished surfaces.

The coolant in the connector blocks 28 flows through the internal tube 36 and into the hollow threaded studs 26, dissipating enough heat from the mounting studs 20 to prevent them from melting. The coolant flow through the blocks 28 and threaded studs 26 thereon, as well as the insulative effect on the reradiator pad 72, further maintains the temperature of the various components behind the pad 72 at a level which is sufficiently low to permit the use of common structural materials in lieu of expensive refractory materials. While it is desirable that the pad 72 have a high emissivity, it is imperative that it have good insulating properties to prevent the destruction of the components behind it. In this connection, graphite felt at temperatures encountered in the heating device 2 has an average thermal conductivity of about 12 Btu-in./hr. ft.² F. Other substances having average thermal conductivities less than about 25 Btu-in./hr. ft.² F. would also be suitable for a pad 72 approximately one-quarter inch thick.

The disposition of the legs 10, 14 and 16 to the rear of the heater strips 6 instead of at the ends of and in the same plane with the strips 6 increases the radiating area of the heating element 4 and provides a more uniform temperature across the radiating faces 8. It further serves to reduce the temperature of the mounting studs 26. Inasmuch as the

legs 10, 14 and 16 are considerably greater in cross section than the strips 6, most of the heating is confined to the latter. Moreover, the contoured margins 17 and the contoured neck 12 prevent localized spots of excessive temperature due to excessive current concentration.

The mating tapered nose portions 22 on the mounting studs 20 and the tapered sockets 18 in the legs 10, 14 and 16 eliminate the need for graphite nuts and bolts. Accordingly, heater element 4 can be removed merely by tapping its legs 10, 14 and 16 away from the connector blocks 28. Another heater element 4 is installed merely by pressing its socket 18 lightly over the tapered nose portions 22 or the mounting studs 20.

The voltage control across the leads 80 can be maintained by a simple power controller such as an ignition power controller manufactured by Research, Inc., Minneapolis, Minn., and expensive transformers for the production of high currents and low voltages are not required. Furthermore, the response of the heating element 4 to thermal shock is such that full power can be reached in relatively large voltage increments without the necessity of a long warmup period as is the case with quartz lamp heating devices.

With the heating device 2 a heat flux density of approximately 300 Btu/ft.² sec. can be maintained for periods as long as 2 hours and this is considerably higher than similar heating devices of prior manufacture. The area for computing the foregoing quantity was that defined by the forward peripheral margin of the entire heating element 4, and is not merely the area of the radiating faces 8.

This invention is intended to cover all changes and modifications of the example of the invention herein chosen for purposes of the disclosure which do not constitute departures from the spirit and scope of the invention

We claim:

1. A heating device comprising mounting means including connector blocks having outwardly projecting tapered studs and coolant channels for distributing a coolant through them so that heat conducted to the blocks is dissipated into the coolant, a heat insulative reradiating pad mounted on and supported by the mounting means, an electrically conductive heating element including a strip positioned in front of the reradiating pad and legs extending from the strip toward the reradiating pad, the legs having reduced neck portions and extending inwardly behind the strip from the neck portions, the legs further having sockets extending generally perpendicular to the strips and receiving the tapered studs which frictionally engage the legs within the sockets.

2. A heating device comprising mounting means including connector blocks having outwardly projecting studs; a heat insulative reradiating pad mounted on and supported by the mounting means; an electrically conductive heating element including a plurality of spaced strips arranged in side-by-side relation in front of the reradiating pad, and legs on the ends of the strips and extending toward the reradiating pad, the legs having sockets which extend generally perpendicular to the strips and receive the studs such that the studs frictionally engage the legs within the sockets, each leg further having a reduced neck portion and extending inwardly behind at least one of the strips from the reduced neck portion; each pair of adjacent strips having a common leg only at one end of such pair of strips, the common legs supporting adjacent strips in side-by-side relation and electrically connecting them, whereby a generally serpentine electrical path exists through the heating element.

3. A heating device comprising mounting means including connector blocks which project outwardly and have coolant channels for distributing a liquid coolant through them, an electrically conductive heating element including at least one carbon strip engaged with and supported on the connector blocks only at its ends and being free of support and spaced from the mounting means intermediate its ends, the carbon strip being constructed to conduct an electrical current from end to end so that its temperature will rise with the passage of

current through it, and a heat insulative reradiating pad mounted on and supported by the mounting means, the reradiating pad being spaced from and positioned behind the carbon strip so that heat absorbed from the strip is radiated back toward and beyond the strip, the reradiating pad being further formed from a material capable of withstanding extremely high temperatures and having a myriad of interstices throughout so that it insulates the mounting means from the heat produced by the heating element.

4. A heating device comprising mounting means, an electrically conductive heating element including further least one carbon strip supported on the mounting means only at its ends and being free of support and spaced from the mounting means intermediate its ends, the carbon strip being constructed to conduct an electrical current from end to end so that its temperature will rise with the passage of current through it, and a heat insulative reradiating pad mounted on and supported by the mounting means, the reradiating pad being spaced from and positioned behind the carbon strip so that heat absorbed from the strip is radiated back toward and beyond the strip, the reradiating pad being further formed from carbon and having a myriad of interstices throughout so that it insulates the mounting means from the heat produced by the heating element.

5. A heating device comprising mounting means including a rigid supporting surface and a coolant channel in heat transfer relationship with the supporting surface for conveying heat away from the surface, an electrically conductive heating element including at least one carbon strip supported on the mounting means only at its ends and being free of support and spaced from the mounting means intermediate its ends, the carbon strip being constructed to conduct an electrical current from end to end so that its temperature will rise with the passage of current through it, and a heat insulative reradiating pad supported by and having one of its surfaces in contact with the rigid surface of the mounting means whereby heat from the pad is transferred to the coolant in the coolant channel, the opposite surface of the reradiating pad being presented toward and positioned behind the carbon strip so that the reradiating pad is spaced from the strip and heat absorbed from the strip is radiated back toward and beyond the strip, the reradiating pad being further formed from a material capable of withstanding extremely high temperatures and having a myriad of interstices throughout so that it insulates the mounting means from the heat produced by the heating element.

6. A heating device according to claim 24 wherein the heating element is carried by connecting blocks having coolant channels for conveying a coolant, whereby heat from the element is dissipated and the blocks are maintained relatively cool.

7. A heating device according to claim 4 wherein the supporting surface is on a plate, and the coolant channel in heat transfer relationship with the supporting surface is a coolant coil extending across the plate.

8. A heating device according to claim 3 wherein the heating element has tapered sockets at the ends of the strip; and wherein the connector blocks have tapered studs which fit into the tapered sockets and frictionally engage the heating element within the socket, the heating element being secured to the mounting means only by the frictional engagement between the studs and the heating element.

9. A heating device according to claim 3 wherein the heating element further includes carbon legs formed integral with the strip at the ends of the strip and extending toward the reradiating pad, the legs having reduced neck portions where they merge into the strip; and wherein the connector blocks engage the legs and support the heating element such that the strip is spaced from the reradiating pad.

10. A heating device according to claim 9 wherein the inwardly presented sides of the legs extend inwardly beneath the strip.

11. A heating device according to claim 10 wherein the out-

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wardly presented sides of the connector blocks are squared off so that two heating devices can be positioned close to each other.

12. A heating device according to claim 9 wherein the legs are provided with tapered sockets and the connector blocks are provided with tapered studs which fit into the tapered sockets; and wherein the heating element is held to the mounting means by the frictional engagement between the studs and the legs within the sockets.

13. A heating device according to claim 9 wherein the mounting means further comprises a plate presented toward but spaced from the backside of the strip, the plate having a coolant channel extending along it for distributing the liquid coolant along the plate, the reradiating pad extending across the plate and being interposed between the plate and the carbon strip for insulating the plate.

14. A heating device according to claim 4 wherein the pad is formed from carbon fibers.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,573,429 Dated April 6, 1971

Inventor(s) Frederick W. Brodbeck et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the ABSTRACT the word "rectory" is misspelled and should be "refractory".

In column 1, line 17 after the word "cost" insert the word "of".

In column 6, line 49, cancel the numeral "24" and substitute therefor "5".

Signed and sealed this 28th day of December 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents