Oct. 16, 1962 N. E. PEDERSEN 3,059,086

RADIANT HEATER AND METHOD OF OPERATING THE SAME

Filed May 28, 1959 2 Sheets-Sheet 1

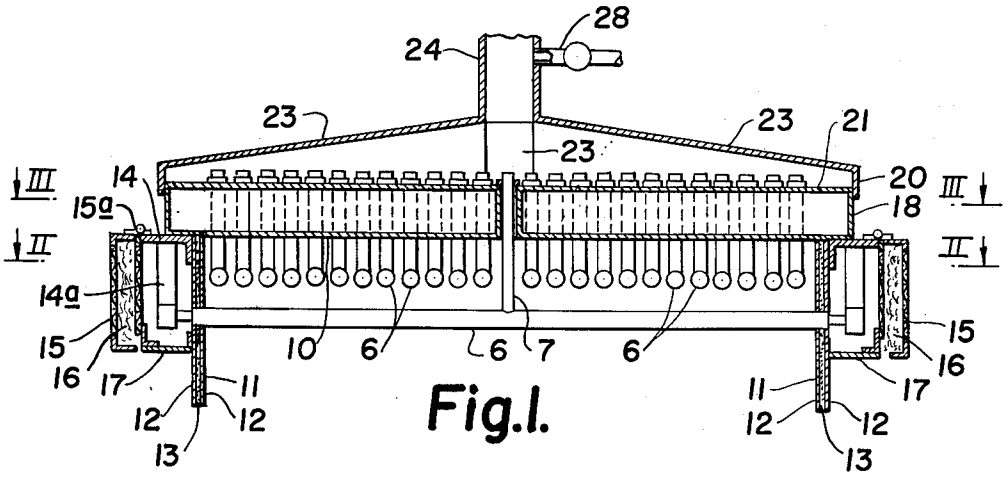



Fig.1.

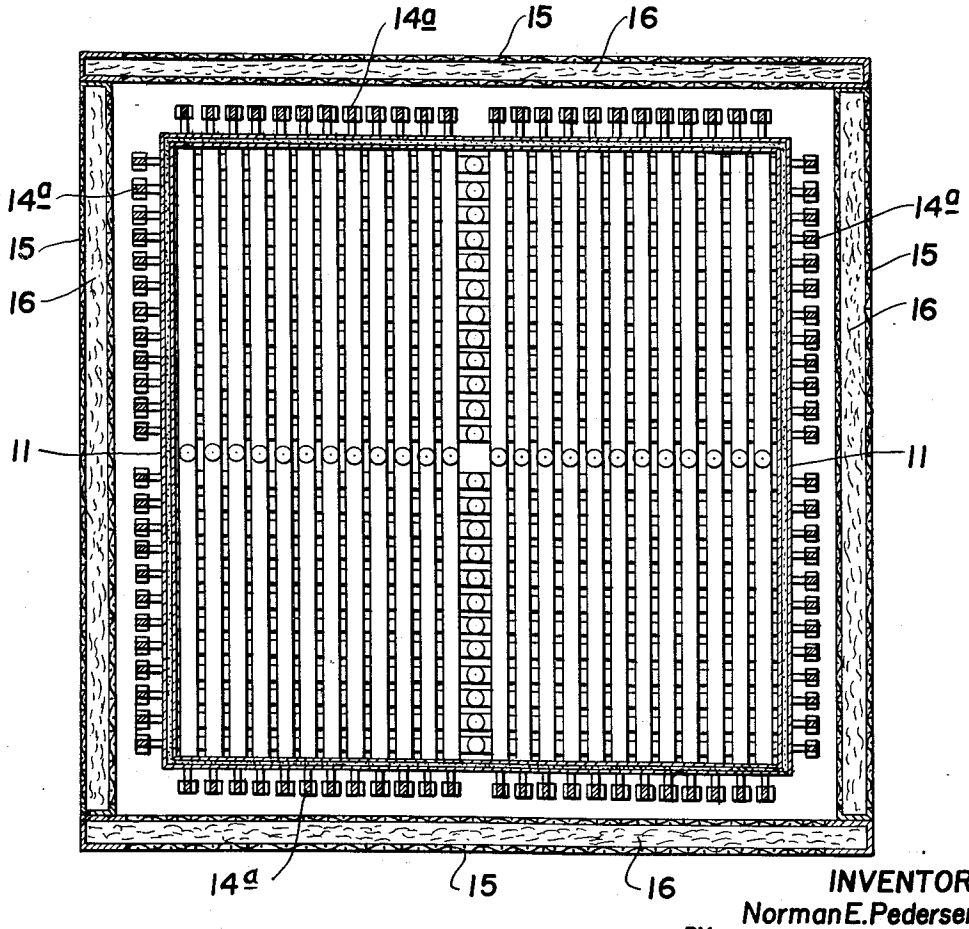



Fig.2.

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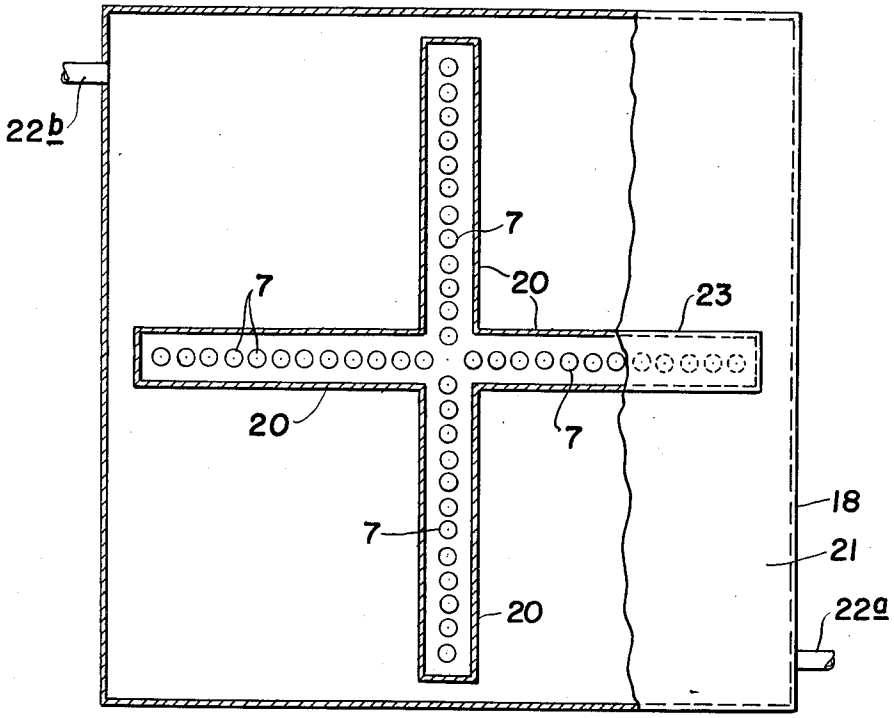



Fig.3.

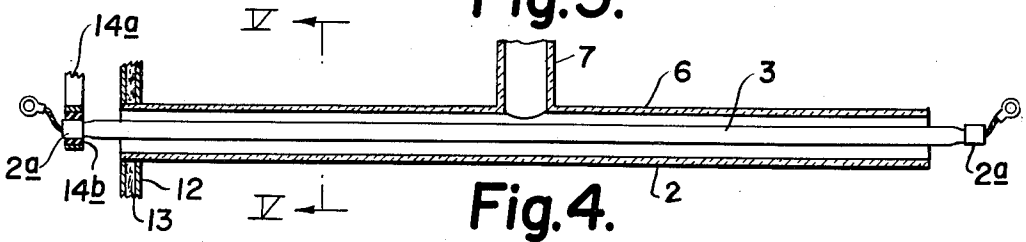



Fig.4.

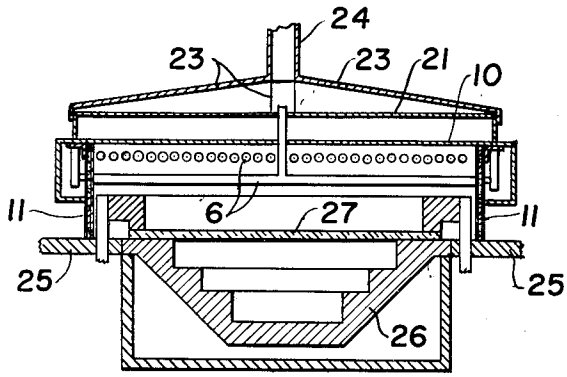



Fig.6.

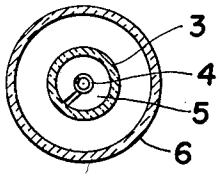



Fig.5.

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United States Patent Office 3,059,086 Patented Oct. 16, 1962



3,059,086

# RADIANT HEATER AND METHOD OF OPERATING THE SAME

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Filed May 28, 1959, Ser. No. 816,460
12 Claims. (Cl. 219—35)

This invention relates to radiant electric heaters and the method of operating the same, and more particularly to radiant electrical heaters for industrial applications where relatively high temperatures, rapid generation of heat, or close control of temperature with fast response to control is required.

In many industrial applications there is need for infra-red radiant heaters capable of operating at high temperatures, or for rapid transfer of heat from a heat source to a product being processed, as well as for close control of temperature coupled with rapid response to control or monitoring means where increase or decrease in temperature is called for.

Infra-red electric heat radiating elements, particularly those having incandescent filaments inside quartz tubes, will respond almost instantly to any variation in the applied voltage, and since infra-red radiation travels at the speed of light, there is little time lag in the response of such heaters to a demand for increased or decreased heat by the work piece, or in response to any programming control. Temperatures can be controlled within very close tolerances.

These heaters, however, are subject to severe temperature restrictions, and their use has been limited to low temperature applications. For example, one well known heater of the type above referred to comprises a tube of fused quartz, roughly about ⅜ of an inch in diameter through which passes a closely coiled wire filament that is held out of contact with the inside of the tube by spacer disks at intervals along the filament. Although capable of a high energy output, their use is confined to operations where the temperature does not exceed 1000° F. This is because the quartz tube, while being highly transparent to infra-red radiation, is in close proximity to the hot filament and will become highly heated. Above 1800° F. devitrification of the fused quartz will increase rapidly, and although the softening temperature of the quartz is around 3000° F., the tubes will begin to sag or bend with sustained operation at a much lower temperature. Consequently these elements are now operated under conditions where the maximum temperature of the quartz is below 1800° F., and the temperature of the ambient air considerably lower.

The present invention has for its principal object to provide a heater and method by which such heating elements can be operated for sustained periods of time in applications requiring much higher temperatures, or in environments providing a much higher ambient temperature.

A further important object of my invention is to provide a heating unit of novel construction using a plurality of heating elements to give a uniform distribution of heat over a selected area.

These and other objects and advantages are secured by my invention, as will be more fully understood by those skilled in the art. It may be pointed out that the particular heater here disclosed was developed initially for the heating of sheet glass to form it into hollow vessel-like objects, as disclosed in my application Serial No. 718,866, filed March 3, 1958, now abandoned, and my more recent application Serial No. 816,498, filed May 28, 1959. However these applications are merely illustrative of one use for the heater and it may be used elsewhere, particularly where a high energy output or high temperature and close



conditions of control and a rapid rate of response are important.

In the accompanying drawings:

FIG. 1 is a longitudinal vertical section through a heater embodying my invention;

FIG. 2 is a horizontal section in the plane of line II—II of FIG. 1;

FIG. 3 is a view partly in plan and partly in horizontal section in the plane of line III—III of FIG. 1;

FIG. 4 is a longitudinal section, on a larger scale, of a single complete heating element assembly and showing at one end only the support for the heater and tube, the support at the other end being omitted for clarity of illustration;

FIG. 5 is a transverse vertical section in the plane of line V—V of FIG. 4; and

FIG. 6 is a vertical section through a furnace embodying my invention showing it positioned over a table in which is set a mold with a sheet of glass thereover.

Referring first to FIGS. 4 and 5, there is shown a single infra-red electric heating element designated generally as **2**. It is a commercially available unit forming no part in itself of the present invention, but utilized because it has the highest infra-red energy output per unit of area that I have found to be available. The heating element here shown typically and only by way of example, has an overall length of about 25 inches, and it comprises a thin wall hollow fused quartz tube **3** about ⅜ of an inch in diameter. A coiled wire filament **4** extends through this tube from one end to the other. The filament is supported at intervals by spacing disks **5**. There is a press at each end of the tube through which the lead wires to the filament pass, and there is an external metal terminal **2***a* on each end. The fused quartz envelope absorbs only a small percentage of the total radiant energy from the filament. As explained above, the fused quartz tends to devitrify rapidly as the temperature of the quartz increases over 1800° F.; that is, it changes from its amorphous condition to a polycrystalline structure, whereupon it becomes brittle and will crack and break upon thermal shock or mechanical shock.

According to the present invention, each such element is concentrically positioned inside a second tube **6** of fused quartz or high temperature melting point glass, such for example as a high quartz glass. One such glass is that presently available under the trademark "Vycor." The outer tube is spaced from the inner one, being about ¾ of an inch in diameter. The tube **6** is substantially coextensive with the heating element, except that the terminals of the heating element extend beyond the outer tube. Each outside tube preferably has a branch pipe **7** leading from the middle thereof. As hereinafter more fully pointed out, the branch pipe leads to a suction pump so that air may be drawn in from each end of the tube **6** and discharged through tube **7**. This air will first contact the terminals of the heater element to cool them. More important, however, the air does not absorb infra-red radiation, but by contact with the exterior of the tube **3** and the inside of the tube **6**, keeps these elements below a critical temperature. As a result the heating element can be operated at a substantially higher temperature, and the ambient temperature outside the tube **6** may be much higher than the critical temperature. Actually, in an enclosed environment the ambient temperature outside tube **6** becomes the limiting factor establishing the maximum temperature of operation.

Through the expedient of cooling the heating element, I am therefore able to operate the elements at a much higher temperature for sustained periods of time than has heretofore been possible. Ambient temperatures of the order of 1900° F. can be maintained outside the tube **6**. With the air flow inside the tube **6** of less than two cubic

feet per minute, the heat loss from this process is relatively low. The heating elements under these conditions can release 15,000 and more watts of heat energy per square foot of area for sustained periods of time without damage, and operated at ratings and temperatures higher than the maximum for which they are designed.

According to the present invention a number of these tubes are generally used at one time, and for the purpose of giving the most uniform heat distribution, I prefer to arrange theme in two tiers with the elements of each tier in spaced parallel relation with each other, and preferably with those of one tier at right angles to those of the other, although those of both tiers may extend in the same direction with the elements of one tier staggered with respect to those of the other so that the ones of the upper tier will be over the spaces between those of the lower tier. I arrange these elements in front of or below a reflector, preferably in a hood-like structure, so that the heat can be directed against the work piece and the hood brought close to, or even enclose, the work piece in situations where a high ambient temperature enveloping the work piece is desired.

I therefore have shown a hood-like enclosure having a top plate **10** and depending sides **11**. The depending sides are of a heat-insulating construction, comprising refractory molded inner and outer sheets **12** of heat-resistant material, such as a mica composition board, and between these sheets is a felt-like mat **13** of mineral wool of a high temperature melting point. The two opposite side walls have spaced holes therethrough into which are set the ends of the tubes **6** at one level. At a different level the opposite end walls have similar openings to receive the ends of a second series of tubes **6** at right angles to the first ones, and out of physical contact with the first ones. There is an angle bar **14** around all four sides of the hood. To this are secured clips **14***a* to support the ends of the heater tubes **3** and hold them centered in the tubes **6**, the portion of the clips which engage the ends of the heating elements being electrically insulated from the terminals of the heaters, as shown in FIG. 4. Insulation is indicated at **14***b*. The tubes **6** thus open at each end to the atmosphere and the heater elements have their ends in the atmosphere outside the hood.

Hung from the outer edge of the angle **14** by means of hinges **15***a* are double-walled panels **15**, the main wall areas of which are formed of screen, and mineral wool **16** fills the space between these screens to filter air entering the tubes **6**. The wires which carry current to the heating elements are not shown, but they rest on a ledge **17** on the side walls at the lower edge of the enclosures **15**. The air filtering panels are hinged so as to give ready access to the heater terminals. All of the heaters may be connected in parallel with a single control circuit, or groups of them with separate control circuits may be provided. For example, in my copending application Serial No. 718,866, now abandoned, I have shown heaters of this type with each two elements having a separate control circuit in addition to an overall control, and the circuits for the elements form no part of the present invention.

The branch tubes **7** of the upper series of tubes are all aligned in one direction and extend up through a row of holes in the reflector plate **10**. The tubes **7** of the lower series of heaters are aligned in the opposite direction and extend up through holes in the plate **10**. The plate **10** has side walls **18** therearound on which sets a cover **21**. There is a water-tight system of walls **20**, as best shown in FIG. 3 of generally cross-shaped contour surrounding the tubes **7**. The tubes **7** also extend through the cover plate **21**. Water can enter the space between the plates **10** and **21** through nipple **22***a* and be carried off through nipple **22***b*. In this way plate **10** can be cooled by forced circulation of water, but the water need not contact the tubes **7**. On the top of plate **17** are four ducts **23** into which the tops of the tubes **7** open, and these four ducts or manifolds lead to a central discharge pipe **24** that is connected to a vacuum pump (not shown). The ducts **20** decrease outwardly from the center to more or less equalize suction through all of the tubes **7**. With this arrangement cooling air is drawn into each end of each tube **6**, initially passing over and cooling the terminal of each heater element. It then moves along and around the heating element **3** inside the tube **6** and flows out through the branch tube **7**.

The hood thus described can be lowered or moved against the object to be heated, or placed over an object to be heated. The sides of the hood may press against the object or against a table supporting said object or work piece to exclude outside air. In my copending application Serial No. 816,498, filed May 23, 1959, I have shown a method of using the hood for heating a glass mold and sheet of glass rested on the rim of the mold, and which is to be shaped by the mold. This is also illustrated in FIG. 6, wherein the furnace hood above described has the bottom edges of the side walls **11** engaged on a table **25** in which is set a mold **26** above which is shown a sheet of glass or other material **27** to be heated. The furnace hood, making contact with the table, excludes free circulation of air from under the hood, and this is especially desirable where uniformly high temperatures are required or the free entrance of outside air would be otherwise detrimental.

As explained above, the air flowing through tube **6** will cool the exterior of the heater tube **3** and the interior of the tube **6**. Thus the ambient temperature under the hood can be substantially higher than the temperature of the air outside tube **3** and inside tube **6**. The ambient temperature under the hood is limited by the extent to which the tube **6** may be cooled. An ambient temperature under the hood of 1900° F. to 2000° F. can be safely maintained. In the shaping of glass sheets as disclosed in my application, ambient temperatures of the order of 1430° F. are used, but at higher temperatures the heater or furnace may be used to melt glass and many metals. Without tube **6** and the forced circulation of air through it, the safe ambient temperature has been a maximum of 1000° F. This is because air is a poor conductor of heat, and absent the forced circulation of air provided by this invention, the air immediately contacting the surface of the quartz tube is at a much higher temperature than the ambient air generally.

While I have explained that the ambient temperature is the limiting factor, it may be explained that the ambient temperature is determined by the temperature of the furnace walls and by objects enclosed in the hood. Actually, therefore, the radiation of heat back to the shielding tube **6** from the surrounding enclosure constitutes the real limiting factor. Ideally the outer tube **6** should be no more absorptive to infra-ray radiation than the tube **3** per unit of area, and its diameter should not be unnecessarily larger than the tube **3** because of the area exposed to re-radiation of heat.

As hereinbefore indicated, the heater elements respond almost instantaneously to an increase or decrease in applied voltage, and they can be quickly brought up to operating temperature. Infra-red radiation travels at the speed of light, so that any change in the temperature of the heating element is immediately effective against the object being heated, whereby very accurate control and quick response may be secured. A further advantage is that the furnace is relatively small and compact in proportion to the amount of heat energy which the radiant heaters emit, so there need be no time lag in the rate of response of the furnace temperature by reason of the mass of material to be heated or cooled. Moreover, large areas can be uniformly heated.

While the present invention finds especial use for applications requiring close temperature control and high temperatures, the same furnace may also be operated at

lower temperatures, so that it is versatile for various uses. For a heating element of the specific dimensions herein described, calculations indicate that the tube **6** should be of an internal diameter of ¾ of an inch. The air flow through each tube should be between one and two cubic feet per minute, and the air flowing inside tube **6** and around tube **3** will keep them at about the same temperature. The volume of air should be such that its maximum temperature, upon being exhausted, is not substantially above 750° F., and in order to protect the vacuum pump, atmospheric air in controlled amounts can be introduced into pipe **24** as indicated at **28**.

The glass or material of which the tube **6** is composed desirably has a melting point as high as the temperature at which the fused quartz devitrifies and desirably does not have any greater absorption of infra-red than fused quartz, and the two may in fact be identical. However in less severe service conditions, any high melting point glass of low infra-red absorption may be use, and by high melting point I mean one that will not soften below 1000° F.

As indicated above, the heater is applicable to many industrial applications other than the softening of glass sheets, such as heat treating metals, evaporating moisture from traveling webs of paper or fabric without scorching the same, heating traveling strips or sheets of metal, "burning on" ceramic glazes, to mention some of them. Also while I have here illustrated the furnace in an inverted horizontal plane, it may be used in various positions, including a vertical position.

While I have shown and described one specific embodiment of my invention, it will be understood that this is by way of illustration and that various changes and modifications may be made therein.

I claim:

1. The method of operating an infra-red electric heating element inside a protective envelope which comprises enclosing the heating element with its envelope in a surrounding enclosure transparent to infra-red radiation and radiating infra-red radiation through the protective envelope and enclosure into an environment to be heated while circulating air through the space between the protective envelope and surrounding enclosure, and raising the ambient temperature in the environment outside the envelope to a temperature above the devitrification temperature of said protective envelope, the circulation of the air being at a rate to cool the protective envelope and the interior of the transparent surrounding enclosure below said devitrification temperature.

2. A radiant heater comprising an electric heating element in which there is an infra-red emitter within a fused quartz tube, the element having a terminal at each end, a second transparent tube surrounding the first one and in spaced relation thereto, the ends of the second tube being open with the terminals of the heating element extending beyond but being close to the ends of the second tube, the second tube having a branch pipe leading therefrom intermediate its ends, means for moving air into the ends of the second tube and exhausting it through the branch pipe, and an enclosure having side walls with the heating element and second tube extending across the enclosure from one wall to the other, the second tube having its ends projecting through the side walls, the terminals of the heating element also being outside the space within the enclosure.

3. An infra-red furnace comprising a hood-like enclose comprising a reflector plate, side walls perpendicular thereto about the reflector plate, a plurality of radiant heating elements in the enclosure extending from one wall to the other in side-by-side spaced relation, the heating elements each comprising a quartz tube with an infra-red emitter extending axially through it, the element having a terminal at each end of the tube, the end portions of the elements extending through the side walls so that the terminals are outside the enclosure, a second transparent tube concentrically positioned about each element and spaced therefrom and of a high softening point glass-like material having a low infra-red absorption, the ends of these tubes also passing through the side walls, and means for circulating air through these second tubes.



4. An infra-red furnace comprising a hood-like enclosure having a reflector plate with side walls perpendicular thereto at the periphery of the reflector plate, a plurality of radiant heating elements in the enclosure extending from one wall to the other in side-by-side spaced relation, the heating elements each comprising a quartz tube with an infra-red emitter extending axially through it, the element having a terminal at each end of the tube, the end portions of the elements extending through the side walls so that the terminals are outside the enclosure, a second tube concentrically positioned about each element and spaced therefrom and of a high softening point transparent glass-like material having a low infra-red absorption, the ends of these tubes also passing through the side walls and opening to the atmosphere, branch tubes leading off the second tubes and passing out through the reflector, manifolds into which the branch tubes lead, and a suction tube leading to the manifolds whereby air may be drawn through the manifolds and branch tubes and in through the open ends of the second tubes.

5. An infra-red furnace as defined in claim 3 in which the reflector plate is water-cooled.

6. An infra-red furnace as defined in claim 4 in which there is a water-circulating chamber on the reflector plate on the surface opposite the surface which is exposed to the heating elements, the branch tubes projecting through the water-circulating chamber and the manifolds being above the water-circulating chamber.

7. The method of operating infra-red heaters of a type having a heat-emitting filament inside a transparent protective envelope according to which the heater is contained in an enclosed environment to which it radiates heat and where the ambient temperature in the environment exceeds the devitrification temperature of the transparent envelope, said method comprising interposing a transparent protecting member between the envelope of the heater and the environment to which heat is radiated, operating the heater and raising the ambient temperature in said environment above the devitrification temperature of the envelope and forcing a flow of cooling gas between the said transparent member and the said envelope and cooling the interior of the transparent protecting member and the exterior of the envelope of the heater below the ambient temperature in said environment and below the devitrification temperature of said envelope.

8. The method of using the heat-radiating capacity of infra-red heat-radiating lamp having a filament within the fused quartz envelope which comprises operating the filament at a temperature above the temperature at which the envelope will devitrify and generating in an environment to which the lamp radiates an ambient temperature above 1,000° F. which comprises interposing a transparent protecting member spaced from the lamp between the envelope and the heated environment, and circulating gas between the lamp and said transparent protecting member and cooling the outside of the envelope of the lamp and the inside of the transparent protecting member below a temperature where devitrification of the quartz envelope occurs.

9. The method of heating a work piece by infra-red radiation from an incandescent electric resistor enclosed within a fused quartz envelope to a temperature higher than the temperature reached by said fused quartz envelope which comprises circulating gas over the envelope to cool the same and confining the flow of gas over the envelope by a transparent medium along which the gas also flows, and raising the temperature of the work piece to a temperature higher than that to which the exterior surface of the envelope is operated.

10. An infra-red radiant heater comprising a bank of

infra-red radiating lamps of rod-like form and of the type comprising an elongated filament sealed within a fused quartz envelope, there being a terminal at each end of each lamp for connecting the lamp with a source of current, means forming an enclosed chamber supporting the ends of the lamps with the terminals exterior of the supporting means and the lamps spanning the distance across the chamber between the supporting means, a transparent enclosure spaced from the lamps through which infra-red radiation from the lamps is transmitted, and means for circulating cooling gas over both terminals of each lamp and within the enclosure along each lamp and exhausting it from the enclosure intermediate the ends of the lamps and discharging it outside said chamber.

11. An infra-red radiation heating furnace comprising a reflecting plate, a chamber with the reflecting plate forming the bottom thereof through which cooling water may be circulated to cool the reflecting plate, the reflecting plate having side and end walls depending therefrom to provide with the reflecting plate a hood-like enclosure, the side and end walls being of heat-insulating construction, a bank of radiant heating elements arranged in side-by-side relation under the reflector plate and extending from one side wall to the other with the ends of the elements passing through the side walls and projecting therefrom, a second bank of radiant heating elements under the reflector plate at a different level from the first bank and extending from one end wall to the other with the ends thereof passing through the end walls and projecting therefrom, each radiant heating element being of rod-like form and comprising a tubular envelope of high melting-point glass-like material of low infra-red absorptivity surrounding a filament and within which the filament is sealed, each element having a terminal at each end thereof, a tube of glass-like material of low infra-red absorptivity positioned concentrically about each element and spaced therefrom with the ends of said tubes passing through the respective



side and end walls and opening into the atmosphere around said side and end walls, each such tube having a branch midway between its ends extending through the reflector plate and the water chamber, and a manifold above the water chamber connecting all of the branch tubes with a suction line whereby the atmosphere around the ends of the elements may be drawn through said tubes from each end thereof to cool the several tubes and the heating elements which they surround.

12. A high energy output infra-red heater comprising a furnace structure having two banks of spaced parallel rod-shaped infra-red generating lamps therein with the lamps of one bank being above and at right angles to the lamps of the other bank, whereby the lamps of one bank cross the lamps of the other to provide a high density of radiation each lamp in each bank being separately enclosed in a transparent tube of larger internal diameter than the lamp, and gas circulating connections to each tube through which a forced circulation of cooling gas may be sustained with the gas flowing from the exterior of the furnace into the tubes and being discharged from the tubes exteriorly of the furnace.

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