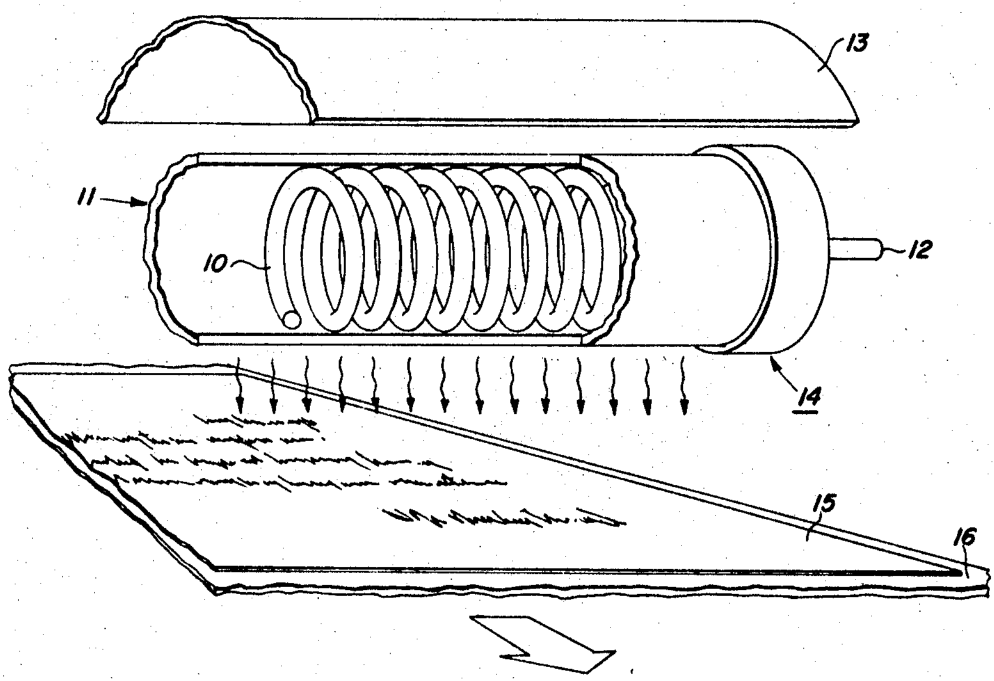

FIG. 1

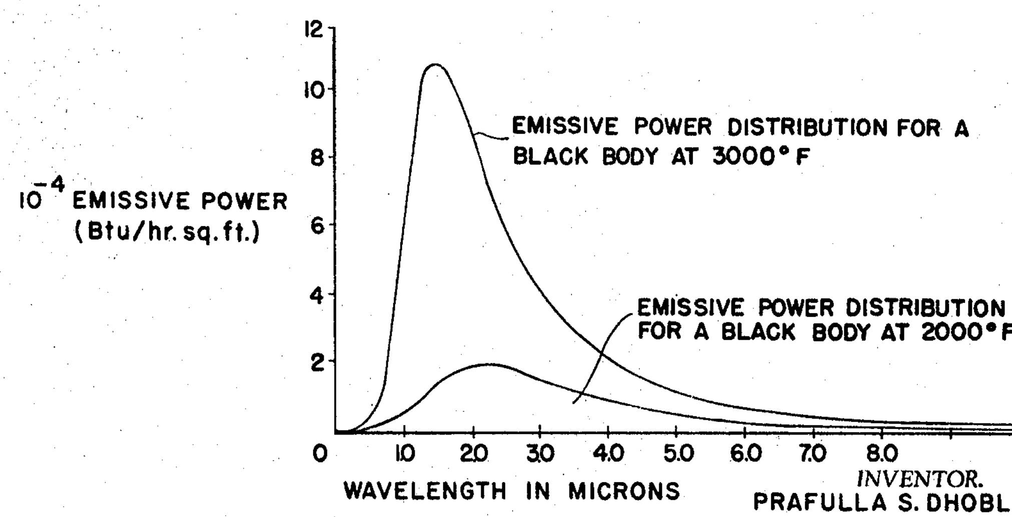

FIG. 2

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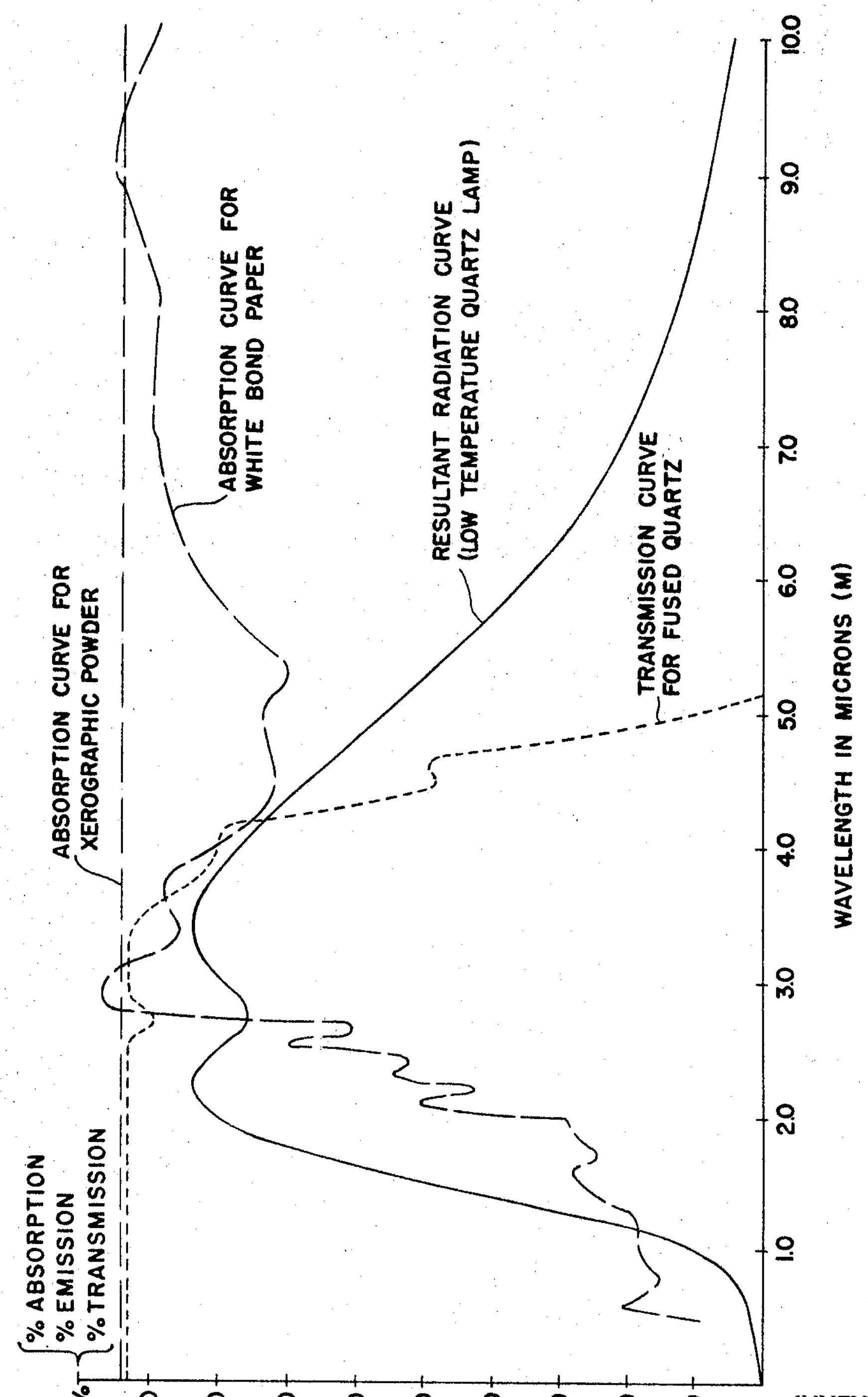

FIG. 3

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United States Patent Office

3,449,546
Patented June 10, 1969

3,449,546
INFRA-RED HEATER

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Filed June 23, 1966, Ser. No. 559,922
Int. Cl. G01n *21/34*
U.S. Cl. 219—216 **3 Claims**

ABSTRACT OF THE DISCLOSURE

A xerographic fusing apparatus for simultaneously heating a xerographic powder image and a paper support material to different temperatures with infrared radiation, the fusing apparatus having the capability of efficiently heating the powder image to its fusing temperature while at the same time heating, without deleterious effects, the paper support material to a different temperature wherein the paper acts as a heat source to aid in the fusing process.

This invention relates to apparatus for producing high intensity radiant energy over a wide infrared portion of the electromagnetic wave spectrum and, in particular, to apparatus for heat fusing a xerographic powder image to a support with radiant energy.

Radiation is a term used to describe energy which is transmitted by electromagnetic waves. For the purpose of heat transfer the radiant energy of primary interest is the infrared energy falling within a band of wavelengths between 0.8 micron and 7.0 micons for it is within this range that most materials will absorb some or all of the radiant energy incident thereon. Although the true nature of radiation and its associated transport mechanism has not been fully explained, it is known that radiation travels in free space at the speed of light and that no medium, such as conductive metal or the like, is required for its propagation. To produce this emissive radiant energy heat transfer, a body must first give up some of its internal energy in the form of electromagnetic waves which then move through space until they strike another body where they will be absorbed therein and converted once again into internal energy, mostly heat.

A good source of infrared radiation, that is, a source that converts a high percentage of the available internal energy to radiant heat energy, will produce high intensity radiation concentrated about a wavelength at which peak power occurs. The higher the temperature of the source, the more concentrated will be the energy within a narrow band of wavelengths and the higher will be the intensity of this energy. A relationship also exists between the peak power wavelength and the source temperature. Raising the source temperature causes the peak power wavelength to be displaced towards the shorter end of the spectrum. It can be said, therefore, that an efficient infrared source produces high intensity energy which is concentrated in a narrow band of wavelengths usually found at the shorter end of the infrared spectrum.

Bodies which receive radiant heat energy, herein referred to as "receivers," show varying absorptive qualities to radiations at different wavelengths, absorptivity being the ability of the receiver to accept the radiant energy incident thereon and convert this energy to internal energy or heat. Carbon black, for instance, will absorb

about 96% of all the energy incident thereon regardless of wavelength of the radiation. A polished aluminum plate, on the other hand, will reflect most of the radiation it receives, absorbing only a small percentage found at the longer wavelengths. Generally, most materials will fit somewhere between these two extremes in that they will shown good absorptive qualities to radiation at some particular wavelengths, while showing a reluctance to accept radiation at other wavelengths.

This latter principle was utilized by Roshon, in U.S. Patent No. 2,807,707, in which he teaches of selectively heat fusing xerographic toner images to paper support material by means of intermittently energized radiant lamps (flash fusing). The lamps are flashed on for a short period of time to emit high intensity energy concentrated in a narrow band of wavelengths at which the toner will readily absorb radiant energy. The paper support, however, will reflect most of this high intensity energy concentrated at short wavelengths and, therefore, remains relatively cool during the fusing operation.

In the process of xerography, a plate comprising a photoconductive insulating coating on a conductive backing is provided with an electrostatic charge and then exposed to a light image, whereupon the coating becomes conductive under the influence of light and the electrostatic charge is selectively dissipated to produce a latent image. The latent image is then developed by means of a variety of pigmented resins that have been specifically developed for this purpose, these resins referred to as xerographic toner. The toner is electrostatically attracted to the latent image in proportion to the amount of charge found thereon so that areas of small charge concentration become areas of low toner density while areas of greater charge concentration become proportionally more dense. The developed image is then transferred to a support material and permanently fixed; the application most generally employed being to transfer the image to a paper support and heat fixing the toner to form a bond with the paper fibers.

Selective flash fusing, although applicable in many xerographic fusing processes, has not proven a successful method of heat fixing areas of low toner concentration. These areas are unable to absorb sufficient energy during the short flash period to be properly fused. Attempts to deliver more energy to the areas of low toner concentration by increasing the intensity of the infrared energy during the flash period cause the support material to be damaged before proper fusing can be accomplished. Further, the image areas of high density concentration will absorb an excess of this high intensity energy during this short flash period causing them to literally explode or burn through the paper support before the areas of low toner concentration are fused.

Ideally what is desired in the xerographic heat fusing process is to bring the temperature of the support material as near as possible to the fusing temperature of the xerographic developing powder so that a sufficient amount of heat will be delivered at the bond between toner and support, a point where it is most needed, to produce fusing. However, a high efficiency infrared source producing an almost monochromatic emissive energy response generally favors the absorptive qualities of one material over the other so that it is impossible to produce the same temperature in both within a short period of time. Attempts to broaden the wavelength at which usable infrared energy is produced by use of multi-source devices has not proven successful. When two or more high temperature infrared sources are placed in close proximity to each other, they interact in such a manner so as to approach a resultant single equilibrium temperature in each source. A single resultant mostly monochromatic emissive power wave form is emitted rather than a resultant energy distribution covering a broad band of wavelengths.

In many known commercial processes, as well as in the xerographic fusing process, two or more materials of varying physical properties may be desired to be heated in the presence of each other. Some commercial processes which readily come to mind are: drying paint on articles fabricated of different materials such as plastic, wood, metal and fiber board; heating the interior of a home containing many articles fabricated of various materials; heating at one time two different foods such as meat and vegetables; or the sterilization of hospital instruments. Attempts to rapidly and efficiently transfer heat to these materials from a single infrared source have proven difficult, and in some cases impossible, because of the wide variance in absorptive properties between materials in the receiver.

It is therefore an object of this invention to improve apparatus for heating with infrared radiation.

A further object of this invention is to improve apparatus for heating with infrared radiation so that usable infrared heat energy is produced over a broad band of wavelengths on the infrared wave spectrum.

A still further object of this invention is to improve infrared heating apparatus to produce at a single source infrared energy of high intensity covering a broad portion of the infrared wave spectrum.

A still further object of this invention is to improve infrared heating apparatus for fusing xerographic images.

Another object of this invention is to improve infrared heating apparatus for fusing xerographic images so that toner and a support material having different absorptive qualities may be heated rapidly and efficiently at the same time to fuse the xerographic image.

A still further object of this invention is to improve apparatus for radiant heating of material having varying absorptive qualities by a single source of radiant heat energy.

These and other objects of this invention are attained by producing at a primary emitting source infrared radiation having peak power occurring at a first power characteristic wave form. The infrared energy from the primary source is then directed incident to a body having properties such that the primary radiation is partially absorbed and partially transmitted by the body. The absorbing body is heated to a condition of thermal equilibrium at which time it will act as a secondary or "dummy" source of infrared radiation reradiating the absorbed infrared energy from the primary source at a second characteristic peak power wavelength. This reradiated energy combines with the partially transmitted energy of the primary source to produce a resultant wave form which covers a broad band of wavelengths on the infrared wave spectrum.

For a better understanding of this invention as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings, wherein:

FIG. 1 is an isometric view in partial section of an infrared heating device embodying the present invention,

FIG. 2 shows two spectroradiometric curves for an ideal radiator plotted on coordinates of the emissive power output and wavelengths showing the resultant wavelength distribution of radiant energy produced by a source at two temperatures,

FIG. 3 is a plot of the parameters important in the xerographic fusing operation against wavelengths on which are superimposed the characteristics of the apparatus shown in FIG. 1.

Referring now to FIG. 2, two curves are plotted for the wavelength distribution of an ideal radiator which is emitting radiant heat energy at two different temperatures. One curve represents the wavelength distribution for an ideal source producing energy at a source temperature of approximately 3,000° F. while the other is a distribution curve for a source which is operating at approximately 2,000° F. A comparison of these two curves, known as spectroradiometric curves, shows:

(a) The total amounts of radiation, represented by the area under these curves is greater for a body which is operating at a higher temperature;

(b) A source operating at a higher temperature produces peak power at a shorter wavelength than one operating at a lower temperature, the black body operating at approximately 3,000° F. has a peak power wavelength occurring at approximately 1.5 microns while the source operating at 2,000° F. will have a peak power point occurring at about 2.2 microns;

(c) Regardless at what temperature the source is operating, radiant heat energy is being produced at all wavelengths, however, the peak distribution of this energy is determined by the temperature at which the source is operating. A comparison of the two curves shown in FIG. 2 reveals that a high percentage of the energy produced by the source operating at 3,000° F. is concentrated about the peak power wavelength while the total energy produced at the lower source temperature is distributed more evenly throughout the spectrum.

An understanding of the variations in the spectroradiometric curves shown in FIG. 2 is important, for if these curves are understood it will be clear that the peak or effective wavelength and the intensity of the energy associated therewith are characteristics of a particular source and these characteristics are dependent on the temperature at which this source is operating. Further, it should also be clear from the graph shown in FIG. 2 that the two curves for an ideal radiator emitting energy at different temperatures will never cross, and therefore the intensity of the energy and the total energy emitted by a source can never equal or be greater when that same source is operating at a lower temperature. Thus, there can only be one peak power wavelength for each particular heat source.

In practice it has been found that an efficient radiator, that is, a radiator that converts a high percentage of the internal energy available to radiant energy, will closely approximate the wavelength distribution of a black body. For example, a tungsten filament, which is considered a good source of infrared radiation, will convert 86% of the internal energy available when operating at a temperature of approximately 4,000° F. This energy is found to be concentrated within a narrow band of wavelengths centered about 1.1 microns.

However, because the radiation produced by an efficient infrared source is concentrated within a narrow band of wavelengths, usually found at the shorter end of the infrared spectrum, this energy may exist primarily at wavelengths at which a receiver reflects rather than absorbs energy. In a xerographic fusing process, for instance, experiments have shown that a paper support will absorb very little infrared energy at wavelengths shorter than 3.0 microns. Therefore, high efficiency radiation sources, such as a tungsten filament operating at high temperatures, would not readily produce heating in a paper support material.

The "intensity" of the energy produced at the surface of a source is the amount of radiation emitted per unit area by that source. As can be seen by comparing the two curves in FIG. 2, the intensity (height of the curves) at which an ideal radiator is producing energy, is dependent on the temperature of the source. The higher the source temperature, the higher the intensity at all wavelengths.

Xerographic developing powder is known to act as a black body in that it will absorb a high percentage of radiation at all wavelengths. However, the toner in most xerographic applications covers a relatively small percentage of the total exposed support area. Therefore, an infrared source of radiation which produces peak power at a wavelength at which paper has good absorptitve quality (3.0 microns or longer) will not produce infra-red radiation of an intensity capable of rapidly heating the lightly toned image areas. As previously noted, however, high intensity energy capable of efficiently heating the xerographic toner would be at the shorter wavelength at which paper has relatively poor absorptive qualities. Therefore, what is desired in the xerographic heating process is an infrared source which can produce both high intensity infrared radiation at shorter wavelengths to efficiently heat the toner and high intensity infrared radiation at the longer wavelengths to rapidly and efficiently heat the support material.

FIG. 1 shows the present invention utilized as a heat source in the xerographic fusing process. A support **15** upon which developing powder or toner has been loosely adhered is passed under the infrared lamp **14**. The image bearing support is transported by belt **16** or similar transporting means so that both the toner and support material remain in thermal contact with the lamp for a period of time sufficient to fuse the toner to the support.

Lamp **14** comprises a relatively heavy filament **10** wound in a helical coil configuration which is placed within envelope **11** so that the outer surface of the coiled filament is maintained in physical contact with the inner surface of cylindrical envelope **11**. The heating filament **10** can be electrically energized by connecting contacts **12** to the terminal ends of any suitable power source (not shown). A reflector **13** suspended above the lamp concentrates the propagated energy from lamp **14** upon receiver material **15** moved thereunder by transport **16**.

Filament **10** can be constructed of any conductive metal capable of efficiently emitting infrared radiation when electrically energized, however, it has been found that tungsten is preferred because this material has properties giving the filament high efficiency and long operating life at elevated temperatures.

The lamp **14** shown in FIG. 1 is designed to operate at half voltage, that is, at half the capacity to which such a lamp could be energized without failing, rated capacity being dependent upon the size and physical qualities of the filament. The operating temperature of filament **10** is controlled by spacing the coils in coterminous relation so that a filament temperature at about 2,100° F. is maintained when the filament is energized to half voltage point. It has been estimated that an infrared lamp operating at half voltage and a relatively low temperature (2,100° F.) will have an unlimited operating life. On the other hand, a high temperature quartz lamp operating at full capacity and a filament temperature of about 4,000° F. has a relatively short operating life in the nature of 5,000 hours.

Envelope **11** is constructed of a material having good thermal properties at high temperatures and also being capable of partially transmitting and partially absorbing infrared energy incident thereon. Some vitreous (noncrystalline) glasses such as Vicor, rock salt and quartz are examples of materials having these desired properties. It has been found experimentally, however, that fused quartz lends itself most readily to use in this type of device.

In operation the tungsten filament is placed directly in physical contact with the quartz envelope. In contrast, known infrared lamps have the filament supported on tantalum discs at some distance from the quartz envelope to prevent crystallization of the quartz at this high operating temperature (4,100° F.). A quartz envelope which has been crystallized no longer has the ability to transmit infrared energy and, therefore, becomes a barrier between the source of radiation and a receiver. Fused quartz has a softening temperature of approximately 3,035° F. and, therefore, a tungsten filament operating at a temperature of 2,100° F., as herein disclosed, may be safely placed in physical contact with the envelope without danger of destroying the transmission properties of the quartz.

The present invention will be explained as a heating device in the xerographic fusing process with reference to the curve plotted on the graph in FIG. 3. Shown plotted on the graph in FIG. 3 is (1) the curve for the resultant emissive power distribution of the infrared lamp shown as a solid dark line, (2) the transmission curve of the fused quartz envelope shown as a dotted line, and (3) the absorptive curves for xerographic toner and white bond paper shown as dashed lines.

The curves shown in FIG. 3 are a plot of energy against the wavelength at which this energy exists. The curves are based upon theoretical energy levels and expressed as percentages of the total energy so the various parameters can be compared.

In operation the lamp is first energized to its operating potential which is half power voltage. As previously noted, filament **10** (FIG. 1) is wound so that the coils, when energized, interact in such a manner as to produce a filament temperature of between 1,900° F. and 2,100° F. It has been found that a tungsten filament which is operating in this temperature range produces infrared radiation having a characteristic peak wavelength occurring at approximately 2.2 microns.

Referring now to the transmission curve for fused quartz shown in FIG. 3, it can be seen that the quartz will transmit about 92% of the radiant energy incident thereon which is traveling at wavelengths shorter than 4.0 microns. It can be seen, however, that the transmission properties of the quartz drops rapidly from a level plateau of about 92% to 0 between the wavelengths of 4.0 and 5.0 microns meaning quartz becomes opaque to infrared radiation traveling at wavelengths longer than 5.0 microns. A tungsten filament which is operating at temperatures of approximately 2,200° F. has a high efficiency, that is, a tungsten filament operating at elevated temperatures converts a high percentage of its input energy into infrared radiation. The infrared radiation propagated by the tungsten filament, which is concentrated about 2.2 microns, will be readily transmitted by the quartz envelope. This peak power energy which is propagated from the tungsten filament and transmitted by the quartz envelope is discernible as the first peak occurring on the resultant radiation curve at about 2.2 microns.

Fused quartz which is heated to a temperature of between 1,100° F. and 1,200° F. approaches a condition of thermal equilibrium in that it will reradiate as infrared energy between 80 and 90% of all internal energy that it receives (.8 to .9 emissivity at about 1,200° F.). A quartz body which is at 1,200° F. is not capable of receiving and storing internally more heat energy, therefore, any heat energy it receives must be thrown off in some manner. It is found that quartz at elevated temperatures reradiates this excess energy as infrared radiation.

As can be seen from the transmission curve for high purity fused quartz (FIG. 3), infrared radiation traveling at wavelengths longer than 5.0 microns will not be transmitted through the quartz envelope. This energy at the longer wavelengths will, however, be absorbed within the quartz and converted to heat energy. Heat flow is analogous to electrical flow in that they must obey similar laws and equations. In both cases, the less resistance placed between the source of energy and a receiver of this energy, the greater will be the amount of energy reaching the receiver. In the present invention, the heating filament is placed in direct physical contact with the quartz envelope so that the most efficient heat flow may be maintained between the two bodies. At elevated temperatures the predominant heat flow mechanism is radiation rather than convection or conduction because radiant heat flow is dependent on the absolute temperature of the source raised to the fourth power rather than a temperature difference between bodies as in convection, or a temperature gradient occurring through some medium as in conduction. However, at elevated temperatures convective and conductive heat flow cannot be neglected. It has been found experimentally that by placing a relatively massive filament, that is, a filament having close-wound turns and a diameter of 0.020 inch or greater, in contact with a quartz envelope, sufficient heat can be transferred by the three previously named heat transfer mechanisms to place the quartz envelope at the desired operating temperature (800° F. to 1,200° F.). Further, it has been found that a tungsten filament operating under the previously mentioned conditions will supply sufficient energy to the quartz envelope to raise the intensity of the reradiated energy to a high enough level so that the quartz envelope can be utilized as a secondary or dummy source of radiation. Thus, the two sources are simultaneous in their response.

As was previously noted, the distribution of radiant heat energy is dependent on the source temperature. A reradiating quartz envelope, as herein described, which is operating at a temperature of about 1,200° F., will distribute most of the reradiated energy so that it is concentrated about a peak power point occurring at a wavelength of 3.4 microns.

As shown in FIG. 3, the resultant emissive power curve for the lamp has a secondary peak power point which is discernible at about 3.4 microns, the peak power wavelength about which the quartz envelope concentrates its reradiated energy. As previously noted, 92% of the energy propagated from the filament which is traveling at wavelengths shorter than 4.0 microns will be transmitted by the envelope. However, energy emitted by the tungsten filament at longer wavelengths is first absorbed within the quartz where it is later redistributed and reradiated at wavelengths concentrated in a narrow band centered about 3.4 microns. This redistributed energy propagated from the envelope reinforces the energy transmitted from the primary source which is at like wavelengths to produce a resultant wave distribution which is similar to that depicted by the resultant radiation curve shown in FIG. 3.

For explanatory purposes the second peak power point found on the resultant radiation curve at about 3.4 microns is shown at the same intensity level as the peak power propagated from the tungsten filament, that is, at the same level as the energy transmitted through the quartz envelope. However, it should be obvious to one skilled in the art that in actual practice the intensity of the second peak power point may not reach that produced by the primary source, the intensity of the resultant energy concentrated about the second peak power point (3.4 microns) being a product of energy being transmitted through the quartz and the energy being reradiated by the envelope.

The resultant energy propagated from lamp **14** (FIG. 1), rather than being mostly monochromatic in wave form, has a high intensity energy distribution covering a relatively broad portion of the infrared spectrum capable of heating any material having an absorptivity between 0.5 and 1.0 falling within the lamp's effective wavelength range.

Superimposed over the resultant emissive power curve are the absorptive curves for both xerographic toner and white bond paper, the curves being represented by dashed lines. It should be noted that xerographic toner closely approaches a black body in that it will absorb 94% of all energy incident thereon regardless of the wavelengths at which the energy is traveling. However, it can be further seen from these curves that the absorptive quality of white bond paper is entirely different from that of the toner. White bond paper will reflect most of the radiant energy incident thereon which exists at wavelengths shorter than 3.0 microns while absorbing between 80 and 90% of the infrared energy striking it at longer wavelengths.

As previously noted, the operating temperature of a source and the efficiency of the source are directly proportional, that is, any increase in source temperature will also produce an increase in source efficiency. It has been found that a single source of infrared energy which operates within a band of wavelengths at which white bond paper has good absorptive qualities (3.0 microns or longer) must operate at relatively low temperatures and hence, by definition, must be an inefficient source. In the present invention an efficient source of infrared energy is utilized to produce high intensity infrared energy at the longer wavelengths capable of heating white bond paper while at the same time producing efficient high intensity energy found at the shorter wavelengths for rapidly and effectively heating xerographic toner. This principle is graphically illustrated by comparing the superimposed resultant radiation curve for the infrared lamp with the absorptive curve for white bond paper as shown in FIG. 3.

It has been found experimentally that a heat lamp as herein described is capable of fusing xerographic toner to a white bond paper within an operating range of 40 volts. That is, there is a 40 volt range between the no-fuse temperature and the temperature at which a white paper support material will be damaged. Heretofore, most known xerographic heat fusers operated within a relatively narrow 4 volt range because such fusers were designed to produce a highly selective, semi-monochromatic, band of infrared energy for reasons of efficiency.

While the invention has been described with reference to the structure disclosed herein, it is not confined to the details set forth, and this application is intended to cover such modifications or changes as may come within the purpose of the improvements or the scope of the following claims.

What is claimed is:

1. A xerographic fusing apparatus for heat fixing a xerographic powder image to a paper support material including

a primary source of infrared energy comprising a spiral wound filament for radiating energy concentrated about a first peak power point occurring at a wavelength of approximately 2.0 microns and being of an intensity capable of heat fixing the xerographic powder image,

a second source of infrared energy encompassing said primary source comprising an envelope having an inside diameter substantially equal to the outside diameter of said primary source such that the filament is supported in contiguous relation with the inside surface of the envelope, the envelope transmitting radiation emitted by said primary source concentrated about the first peak power point, the envelope re-radiating other heat energy transferred thereto from said primary source at a second peak power point concentrated at a wavelength of approximately 3.4 microns and being of an intensity to heat the paper support material,

transport means for moving the image bearing support material into thermal communication with the radiation for a period of time sufficient to transfer heat energy to the paper support material and the toner images to heat fix the images thereto, the period of thermal communication being insufficient to damage the support material.

2. The apparatus of claim **1** wherein said primary source of radiation comprising a tungsten wire filament having a cross-sectional diameter of approximately 0.020 inch which radiates infrared energy at between 1900° F. and 2100° F. when operating at a half voltage capacity.

3. The apparatus of claim **2** wherein the secondary source of radiation comprises a quartz envelope reradiating heat energy received from said primary source at a temperature of between 1100° F. and 1200° F.

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U.S. Cl. X.R.

219—353, 355, 388; 250—65