

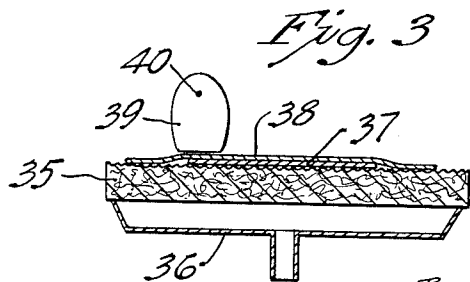
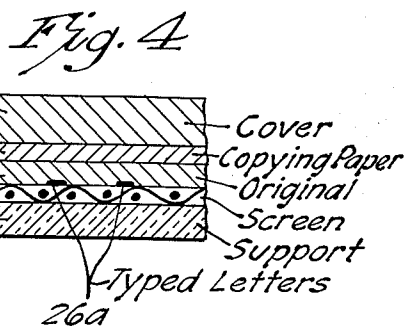
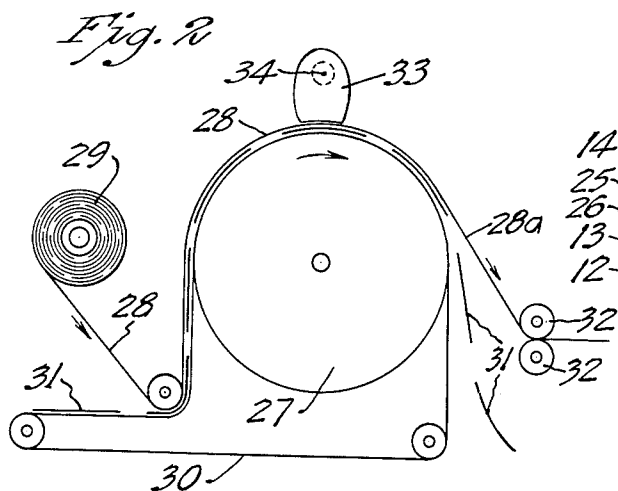
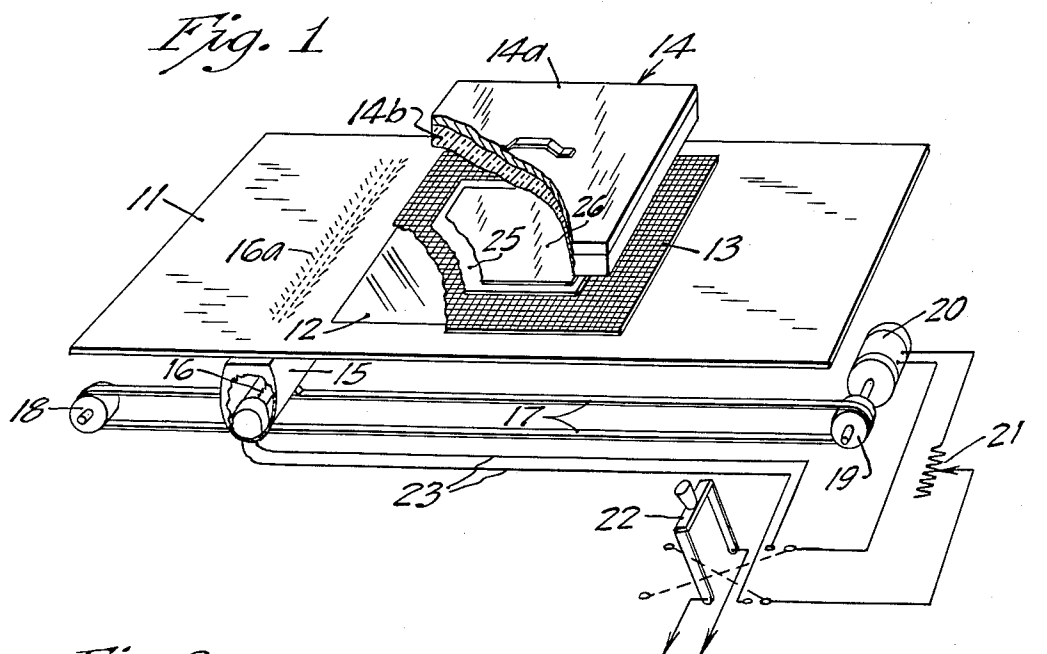
April 3, 1956

C. S. MILLER

2,740,895

THERMOPRINTING APPARATUS

Filed Aug. 21, 1950



Inventor
Carl S. Miller
 By *Carpenter, Abbott, Coalter & Kinney*
 Attorneys

2,740,895

THERMOPRINTING APPARATUS

Carl S. Miller, St. Paul, Minn., assignor to Minnesota Mining and Manufacturing Company, St. Paul, Minn., a corporation of Delaware

Application August 21, 1950, Serial No. 180,617

10 Claims. (Cl. 250—65)

This invention relates to the reproduction of printed matter or the like, and involves the brief application of intense radiant energy to the graphic subject-matter of which a copy is desired, the conversion of radiant energy to heat energy in a pattern determined by such subject-matter, and the formation of visible copy in a heat-sensitive sheet material as the result of the localized heating thus obtained.

The present application is a continuation-in-part of my copending application Serial No. 747,338, filed May 10, 1947, and is particularly directed to the method of copying and to apparatus for carrying out the method.

It is therefore a primary object of the invention to provide a method, and apparatus, for the copying or duplicating, on heat-sensitive copying-paper, of typewritten letters, printed pages of books, and other graphic subject-matter by a simple, direct process involving merely intense irradiation of the subject to produce a corresponding heat-pattern, and utilization of the heat-pattern to produce the desired copy.

Exemplary embodiments will now be described in connection with the accompanying drawings, in which

Figure 1 is a partially broken schematic perspective view of a preferred example of my novel thermoprinting machine, suitable for intermittent operation,

Figure 2 is a schematic representation of a continuous thermoprinting machine,

Figure 3 is a schematic representation of a further modification of portions of my thermoprinting machine, and

Figure 4 is a cross-sectional representation of an alternative arrangement of copying-paper and typewritten page in the apparatus of Figure 1.

In Figure 1, a frame 11 supports a transparent panel 12, suitably a heavy plate of glass, on which is placed a transparent heat screen 13 such as a section of open-mesh silk bolting-cloth. A cover 14, consisting essentially of a supporting frame 14a and a conformable rounded heat-insulating compression pad 14b is preferably pivotally mounted on one side of frame 11 so that it may be pressed against the screen 13. A line source of light, preferably comprising a focusing reflective housing 15 and a tubular lamp having a linear filament 16, as hereinafter more fully described, is movably mounted beneath the frame 11, in a plane parallel to the frame and at a distance such that the line of focus of the reflective housing 15 falls just beyond the plane of the screen 13, as indicated by the dotted lines 16a.

The light source is moved along suitable guideways, not shown, by a belt 17 passing around driven pulley 18 and drive pulley 19, the latter being connected to motor 20. The lamp is connected to the source of power through flexible connectors 23. A switch 22 connects the power line to the motor through a rheostat 21, and to the flexible connectors 23, when thrown to the right as shown. Throwing the switch 22 to the left disconnects the lamp and reverses the motor 20.

Alternatively, the reversing switch may be operated by

the movement of the lamp carriage. The lamp may be brought to full brilliance while at rest, and then traversed across the page, by means of a time-delay switch. The lamp may be operated in both directions of travel. A chain and sprocket drive, or sprocket and rack, or screw thread drive may replace the belt and pulley system illustrated; or the lamp may be traversed by means of a hand crank or the like, provided sufficiently uniform travel is ensured.

In making a copy of a typewritten or printed page, for example, a sheet of transparent heat-sensitive copying-paper 25, such, for example, as described in my copending application Serial No. 747,338, is first placed upon the screen 13. The printed page 26 is placed against the copying-paper and with the printed surface, of which a copy is desired, in contact with the upper surface of the copying-paper. The cover 14 is then closed against the composite, first providing a smoothing action and then holding the page 26 and sheet 25 smoothly and tightly together. With the light source in the position shown, the switch 22 is then closed by throwing it to the right. The motor 20, acting through the pulley 19 and belt 17, moves the light below the panel 12. The lamp reaches full brilliance by the time it approaches the edge of the support, and this brilliance is maintained as the lamp moves past the heat-sensitive copying-paper. The switch 22 is then thrown to the left, disconnecting the filament and reversing the motor 20 whereby the lamp is returned to its initial position.

The intense illumination of the printed page afforded by the passage of the line of focus 16a along the plane of the page produces a pronounced heating effect at the printed characters or other graphic subject-matter, and a much smaller temperature increase at adjacent unprinted areas. The temperature pattern thus produced causes a corresponding visible pattern to appear in the heat-sensitive copying-paper. When the cover 14 is tipped back and the page 26 and sheet 25 removed, the latter is found to contain a visible facsimile of the original graphic subject-matter. Since the sheet 25 is transparent, this copy can be read directly from the side of the sheet which was not in contact with the printed page.

The rheostat 21 serves to control the speed of the motor 20 and hence the extent of illumination of the page 26, since the lamp has a constant output. This in turn influences the printing characteristics of the copying-sheet 25. With any particular light source and copying-sheet, the legibility and clarity of each successive reproduction will be at a maximum when the degree of temperature differential and the time of exposure are properly correlated. The ambient temperature of the copying-paper is substantially that of the transparent support 12, and that temperature, due apparently to absorption of some of the light by the glass, gradually increases as successive copies are made. The rate of travel of the lamp must therefore be speeded up, in the type of machine illustrated in Figure 1, to compensate for this temperature increase and to avoid over-exposure. The rheostat 21 provides a means of effecting such control. It may be manually operated as required, or may be automatically operated by a thermostatic control connected to the plate 12.

Other means of controlling the extent of illumination may be substituted for the rheostat 21. A shutter may be placed over a portion of the open face of the reflector 15, the position of the shutter being controlled either manually or automatically in accordance with the radiation requirements and with variations in the ambient temperature. The voltage impressed across the filament 16 may be raised or lowered, thus slightly altering the filament temperature as required. These or other analogous controls are advantageous where the ambient tem-

perature varies during operation, or where different types of heat-sensitive copying-papers are to be used. Where only a single type of paper is used, it is sometimes more convenient to operate the machine at a constant controlled temperature. For this purpose, air-circulating fans, or other means of maintaining the temperature of the plate 12 and cover 14 at a constant temperature have been found useful. In any event, the temperature of the plate must be kept below the temperature at which a visible change occurs in the heat-sensitive sheet.

The machine of Figure 1 is designed to reproduce individual sheets or pages of printed matter or the like, and is particularly useful where only a few copies are desired. The same principles may be employed, however, in a machine designed for continuous operation, one example being illustrated schematically in Figure 2. In this figure, a rotating drum 27 carries with it a carrier belt 30 as it rotates in front of a light source similar to that of Figure 1 and comprising an incandescent filament 34 in a focusing reflector 33. Heat-sensitive transparent copying-paper 28 in continuous web form is fed from supply roll 29 around the belt-covered portion of the drum, being pulled taut by pull drums 32. The printed pages 31 are fed in between the carrier web and the copying-paper, with the printed side in contact with the latter. The light from the filament 34 is focused by reflector 33 in a narrow line along the surface of the drum at the printed surface of the pages 31. Completed copies are delivered as a continuous sheet 28a by the pull drums 32.

In the continuous machine of Figure 2, as in the intermittently-operated machine of Figure 1, it will be seen that automatic or manual controls may be added for controlling the drum speed, light intensity, temperature, etc. The drum 27 may be held at a constant desired temperature by circulation of fluid throughout its interior. A constantly refluxing constant-boiling liquid, either within the drum or in an external boiler, affords a convenient means of maintaining an exact temperature. The contact pressure between copying-paper 28 and printed page 31 may be improved by drastically reducing the diameter of the drum, or by substituting a stationary rounded straight-edge for the rotating drum. In all cases, the sheet material is permitted to come to temperature equilibrium with the drum 27 or equivalent support means prior to irradiation.

In Figure 1, the copying-sheet and original are held in heat-conductive smooth and uniform pressure-contact with each other by means of the cover 14 and the supporting plate 12. The compressible layer 14b of the cover 14 may be, for example, a sponge rubber pad, or an inflated air bag, or a thick layer of blotting paper. The air bag is preferred, since it automatically assumes a rounded shape which is effective in progressively increasing the area of contact during positioning and in thus smoothing out the sheet material and avoiding wrinkles. It serves also to provide equalized pressure over the entire sheet area and to retard the passage of heat from the adjacent printed page. The heat screen 13 of Figure 1 similarly retards the passage of heat from the copying-paper into the heat-conductive transparent supporting plate 12. Thus the maximum amount of heat, generated at the printed letters or areas by absorption of the radiation from the light source, is retained within the outwardly insulated and heat-conductive composite of copying-sheet and printed page, resulting in a maximum temperature intensity heat-pattern and the production of maximum contrast in the copy. Where no means is provided for minimizing heat transfer from the page and sheet, the copy is found to be blurred and indistinct. For example, removing the screen 13 of Figure 1 results in badly blurred copies; the same effect is obtained when a metal backing-up plate is substituted for the cover 14.

The same functions are provided in the structure of Figure 2 by the carrier belt 30 and the heat-sensitive web 28 as are provided by the screen 13 and cover 14

of Figure 1. The belt insulates the printed pages 31 from direct contact with the rotating drum 27. The heat-sensitive web 28, being held under tension over the rounded surface beneath, maintains adequately close and uniform smooth pressure-contact with the printed pages. Since the other surface of this web is exposed to the air and is not in direct contact with any heat-conductive portion of the structure, no additional heat-insulating member is required.

Figure 3 discloses another embodiment of the invention. A roughened but plane-surfaced porous plate 35, e. g. an unglazed ceramic or fritted glass plate, provides a supporting insulating surface on which the printed page 37 and the transparent heat-sensitive copy-paper 38 are placed in order. A vacuum box 36, mounted on the reverse side of the plate and connected to a vacuum pump, creates a partial vacuum at the roughened surface; atmospheric pressure then forces the sheets into close contact with each other and with the plate. Hand smoothing of the sheets before application of the vacuum may be resorted to in order to obtain smooth uniform contact. Heat insulation is provided at the inner surface by the point contacts between plate and page, and at the outer surface by exposure to the atmosphere. A source of light comprising a filament 40 and reflector 39 is passed across the composite to produce the desired copy, after which the vacuum is released and the sheets are removed.

In the preceding description, only one method of obtaining copies of graphic subject-matter has been described. In that method, and particularly in connection with the apparatus of Figure 1, the light passes through the transparent support 12, then through the transparent heat-sensitive copying-sheet, and impinges on the printed page, where a portion is reflected or diffused by the unprinted areas, and a portion is absorbed by the printed characters and its energy converted to heat energy. The method requires that both the support and the copying-paper be infra-red-transparent, by which is meant that these elements are capable of transmitting most or all of the incident infra-red rays of the radiation spectrum. These rays range from about 7500 A. to at least about 25,000 A. in wave length. The copying-paper may also be transparent to visible light, in which case the copy may be read directly rather than as a reverse copy or mirror image, regardless of the position of the heat-sensitive materials within or on a surface of the sheet.

Another method of obtaining copies will now be described, which is equally applicable to visibly transparent copying-paper and in addition may be used to provide direct copies on both visibly and infra-red opaque copying-paper. The method is, however, restricted to copying from thin and relatively readily heat-conductive originals. Letters 26a typed on the usual letterhead bond paper or the like, and indicated in cross-section in Figure 4, may be copied successfully. In this method, and in connection with Figure 4, the printed page 26 is first placed on the heat screen 13, with the printed surface, of which a copy is desired, in contact with the screen and in position for irradiation. The heat screen rests on the transparent support 12. The presence of printed characters on the upper or reverse side of this page does not interfere, provided the page is not so thin or the printing so dark that it is visible through the sheet. The heat-sensitive copying-paper 25 is next placed over the upper surface of the printed page. Where the copying-paper comprises a surface coating of a heat-sensitive composition on a base sheet, the coated surface is placed in contact with the exposed surface of the printed page. The cover 14 is then pressed into place. Illumination of the printed area through the plate 12 and screen 13 then provides a temperature-differential pattern within the printed page, which passes through the page and affects the heat-sensitive composition of the copying-paper, producing a direct copy.

The same procedure may be employed with apparatus similar to that of Figure 2, but with certain changes which

will be apparent in view of the above discussion. For example, a continuous strip of printed matter may be substituted for the continuous heat-sensitive copying-paper web 28 of Figure 2, the printed surface being disposed outwardly from the drum and toward the light source; and individual sheets, or a continuous strip, of heat-sensitive copying-paper then substituted for the printed pages 31. In another variation, the drum may be covered with a heat-insulating layer, and the carrier belt made of a flexible transparent film or of silk bolting-cloth or other transparent heat-insulating material. The printed page and the copying-paper would then be inserted between the carrier web and the drum. In a still further modification, a transparent cylindrical shell may be substituted for the drum 27, and the light source suitably disposed within the cylinder.

As will now be apparent, only that portion of the total radiant energy which provides a large amount of heat on absorption by printed letters and the like, and which is largely in the infra-red range, is of value in my novel copying-process. The most suitable sources of such radiation produce additionally a considerable amount of visible light, as well as some ultra-violet radiation. One such source which has been found highly suitable, and which is indicated in Figures 1-3 of the drawing, consists of a 2000-watt coiled tungsten line-filament incandescent lamp, 10 inches long and with "Pyrex" glass envelope, mounted with the filament along the enclosed focal line of a reflector having an elliptical cross-section, the opposite side of the reflector being open so that most of the radiation is concentrated along the opposite focal line and coincident with the surface to be irradiated. Such a light source may be passed across a sheet of letter-paper to provide extremely uniform and intense irradiation. The amount of radiation convertible to heat is very high, being sufficient to cause charring or burning of the paper under continuous exposure.

The order of radiation intensity thus provided may be better understood by reference to the following data obtained with my copying apparatus. A lamp having a 2000-watt coiled tungsten filament 10 inches in length was mounted in a cut-away elliptical-cross-section reflector as previously described. The efficiency of the unit as a source of infra-red was first tested by focusing the beam on a black lacquered glass tube for a definite time interval with the lamp in operation, measuring the resulting rise in temperature of water contained within the tube, and comparing the electrical energy input with the amount of electrical energy required to impart the same temperature rise from a resistance wire placed within the tube. Assuming that the non-glossy carbon-black lacquer coating absorbs the radiant energy at about 95% efficiency, the efficiency of the lamp unit in converting electrical energy to infra-red radiant energy and focusing it to a line was found to be about 40%.

The width of the focal line of radiation focused on the page to be copied was $\frac{1}{4}$ inch, and the lamp carriage advanced at a rate of three inches per second; hence, any given point on the printed page was irradiated for $\frac{1}{12}$ second. At an input wattage of 200 watts per inch of filament length, calculation shows that the total energy received at the copy surface as infra-red radiation suitable for absorption and conversion to heat was 26.7 watt seconds per square inch in the system described. This brief and intense radiation is found to be effective in providing clear and distinct copies of typewritten messages on heat-sensitive copying-paper designed to provide a visible change at about 65° C. For papers requiring a higher temperature, increased intensity would be required. With much longer exposure time and much reduced intensity of irradiation, the copy produced is correspondingly poorer in contrast and definition.

Where other light sources of sufficient intensity in the proper range of wavelength are available, they may be substituted for the specific source just described. Small

areas may be uniformly irradiated in stationary position and in a single brief exposure. For example, a standard 500-watt infra-red bulb with internal reflector, operated under overload conditions of 800 watts input, and at a distance of about 3 inches from the printed surface, has produced good results.

Larger areas are more conveniently uniformly irradiated either by moving the light source over the original or by moving the original past the light source, as already described in connection with the drawings.

Having now described my invention in terms of specific embodiments, but without intending to be limited thereto, what I claim is as follows:

1. In a thermoprinting machine suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: means for smoothly supporting said page and said sheet as a two-ply combination in mutually heat-conductive pressure-contact and in position for irradiation; means for minimizing heat transfer from said two-ply combination of said page and sheet; and means for strongly and briefly uniformly irradiating said printing with radiation high in infra-red.

2. In a thermoprinting machine suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: a support for said page and said sheet; means for maintaining said page and sheet as a two-ply combination in mutually heat-conductive pressure-contact on said support; means for minimizing heat transfer from said two-ply combination of said page and sheet; and means for strongly and briefly uniformly irradiating said printing through said support with radiation high in infra-red.

3. In a thermoprinting machine suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: an infra-red-transparent support; an infra-red-transparent heat-insulating fibrous sheet on said support; a heat-insulating compression cover for holding said page and said sheet in mutually heat-conductive pressure-contact against said fibrous sheet on said support; and means for strongly and briefly uniformly irradiating said printing through said transparent support and fibrous sheet with radiation high in infra-red.

4. In a thermoprinting machine suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: means for supporting said page and said sheet as a two-ply combination in mutually heat-conductive pressure-contact and in position for irradiation; means for minimizing heat transfer from said two-ply combination of said page and sheet; means for strongly and briefly uniformly irradiating said printing with radiation high in infra-red; and means for controlling the extent of irradiation of said printing in accordance with the ambient temperature in producing consecutive thermocopies of equal legibility.

5. In a thermoprinting machine suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: means for supporting said page and said sheet as a two-ply combination in mutually heat-conductive pressure contact and in position for irradiation; means for minimizing heat transfer from said two-ply combination of said page and sheet; means for strongly and briefly uniformly irradiating said printing with radiation high in infra-red; and means for maintaining a substantially constant ambient temperature.

6. In a thermoprinting machine suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: means for supporting said page and said sheet as a two-ply combination in mutually heat-conductive pressure-contact and in position for irradiation; means for pre-heating said two-ply combination of said page and said sheet; means for minimizing heat transfer from said two-ply combination of said page and sheet; means for strongly and briefly

7

uniformly irradiating said printing with radiation high in infra-red; and means for maintaining a substantially constant ambient temperature.

7. In a thermoprinting machine suitable for the production on a heat-sensitive copying-paper sheet of permanent facsimile copies of a graphic original having a pattern consisting of portions highly absorptive of radiant energy, said radiant energy on absorption thereby being converted to heat energy, and other portions sufficiently less absorptive of said radiant energy so that, on irradiation of said original, the highly absorptive portions will preferentially attain a temperature sufficient to cause a visible change in an associated heat-sensitive copying-paper, the combination of: means for smoothly supporting said copying-paper and said graphic original as a two-ply combination in mutually heat-conductive pressure-contact and in position for irradiation; means for minimizing heat transfer from said two-ply combination; and means for strongly and briefly irradiating said graphic original with said radiant energy.

8. In a thermoprinting machine suitable for the production on a heat-sensitive copying-paper sheet of permanent facsimile copies of a graphic original having a pattern consisting of portions highly absorptive of radiant energy, said radiant energy on absorption thereby being converted to heat energy, and other portions sufficiently less absorptive of said radiant energy so that, on irradiation of said original, the highly absorptive portions will preferentially attain a temperature sufficient to cause a visible change in an associated heat-sensitive copying-paper, the combination of: means for smoothly supporting said copying-paper and said graphic original as a two-ply combination with the original in position for irradiation and with the two plies in mutually heat-conductive pressure-contact and protected from external heat-loss during said irradiation; and means for strongly and briefly irradiating said graphic original with said radiant energy.

9. In an exposure unit suitable for the reproduction of a printed or typewritten page on a heat-sensitive copying-paper sheet, the combination of: an infra-red-transparent

8

supporting plate; a thin open-mesh fabric over one surface of said plate; a heat-insulating compression cover above said fabric and adapted to hold said printed page and said sheet as a two-ply combination in smooth mutually heat-conductive pressure-contact against said fabric on said plate; and a light source adapted to strongly and briefly uniformly irradiate said printing through said supporting plate with radiation high in infra-red, and comprising an incandescent-filament lamp focused to provide a high-intensity line of irradiation at the printed surface of said page and uniformly traversable across said surface.

10. In an exposure unit capable of producing, on a heat-sensitive copying-paper sheet, permanent facsimile copies of a graphic original having a pattern consisting of portions highly absorptive of infra-red radiation, said radiation on absorption thereby being converted to heat energy, and other portions sufficiently less absorptive of said radiation so that, on irradiation of said original, the highly absorptive portions will preferentially attain a temperature sufficient to cause a visible change in an associated heat-sensitive copying-paper, the combination of: means for smoothly supporting said copying-paper and said graphic original as a two-ply combination with the original in position for irradiation and with the two plies in mutually heat-conductive pressure-contact and protected from external heat-loss during said irradiation; and means for strongly and briefly uniformly irradiating said graphic original with radiation high in infra-red.

References Cited in the file of this patent

UNITED STATES PATENTS

1,968,037	Hartman	July 31, 1934
2,503,758	Murray	Apr. 11, 1950
2,503,759	Murray	Apr. 11, 1950
2,523,306	Kaiser et al.	Sept. 26, 1950
2,543,013	Glassey	Feb. 27, 1951
2,556,550	Murray	June 12, 1951
2,647,464	Ebert	Aug. 4, 1953