

April 11, 1950

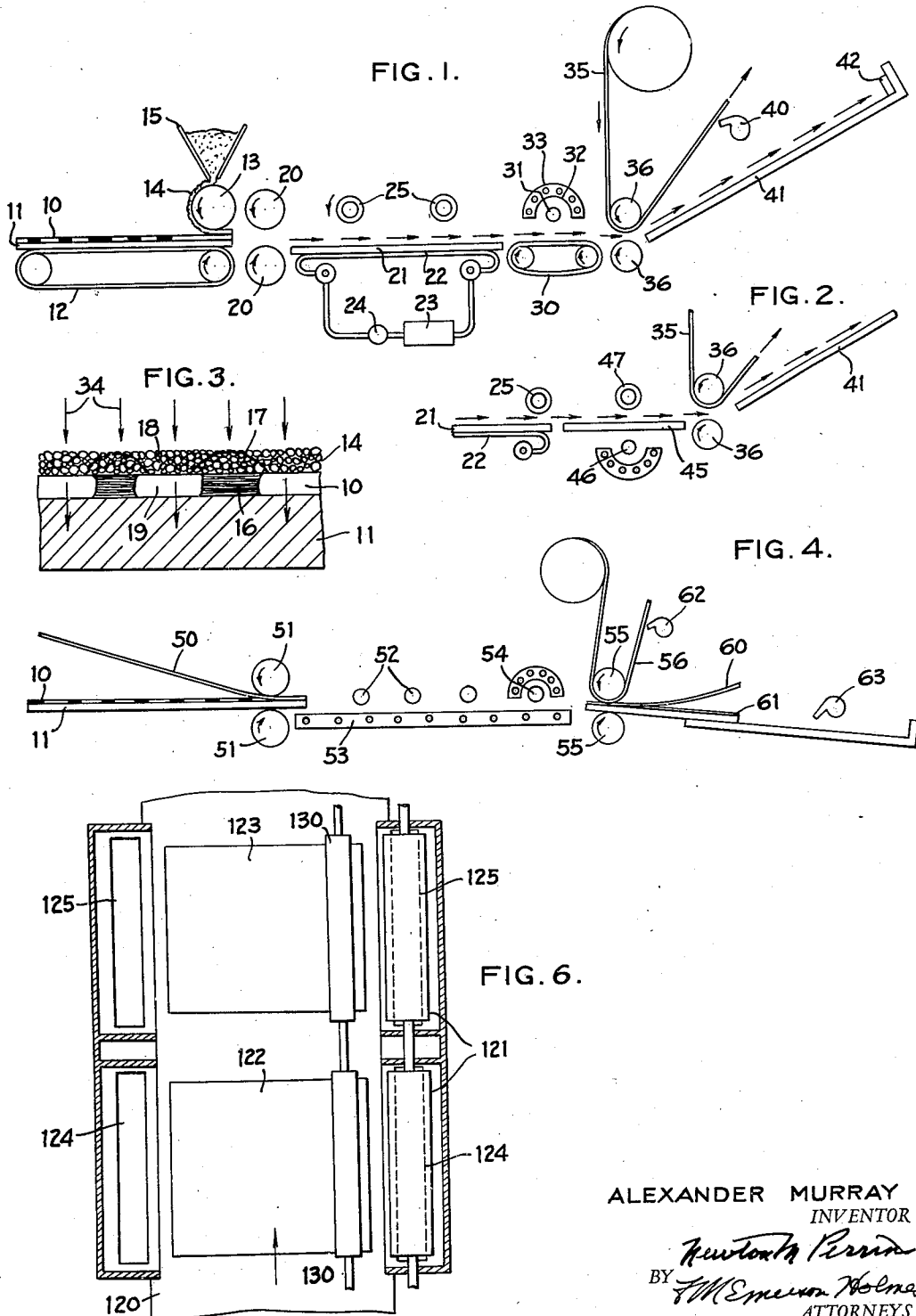
A. MURRAY

2,503,758

FUSION PHOTOTHERMOGRAPHY

Filed Aug. 16, 1947

3 Sheets-Sheet 1



April 11, 1950

A. MURRAY

2,503,758

FUSION PHOTOTHERMOGRAPHY

Filed Aug. 16, 1947

3 Sheets-Sheet 2

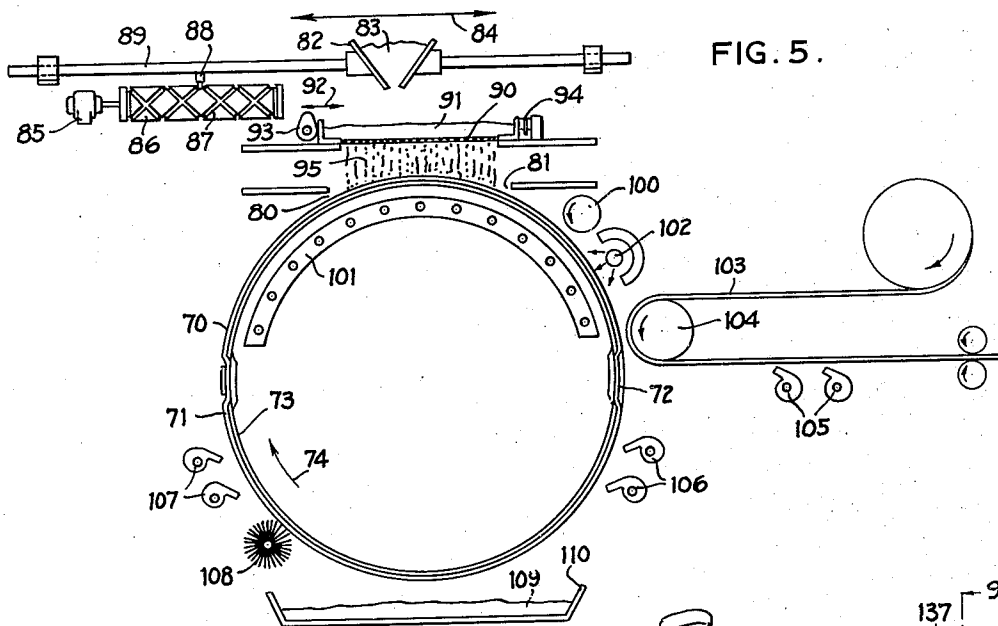


FIG. 5.

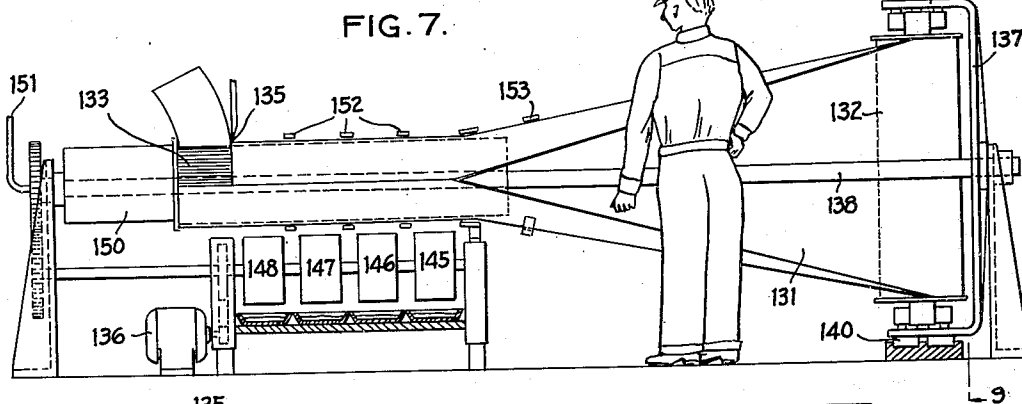


FIG. 7.

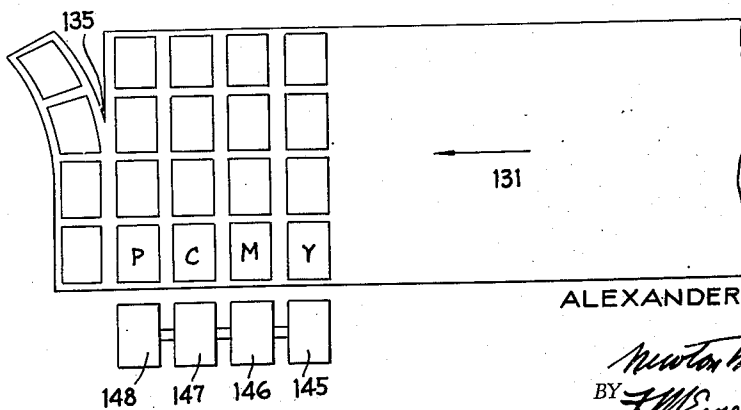


FIG. 8.

ALEXANDER MURRAY
INVENTOR

BY *Newton M. Currier*
F. M. Emerson Holmes
ATTORNEYS

April 11, 1950

A. MURRAY
FUSION PHOTOTHERMOGRAPHY

2,503,758

Filed Aug. 16, 1947

3 Sheets-Sheet 3

FIG. 9.

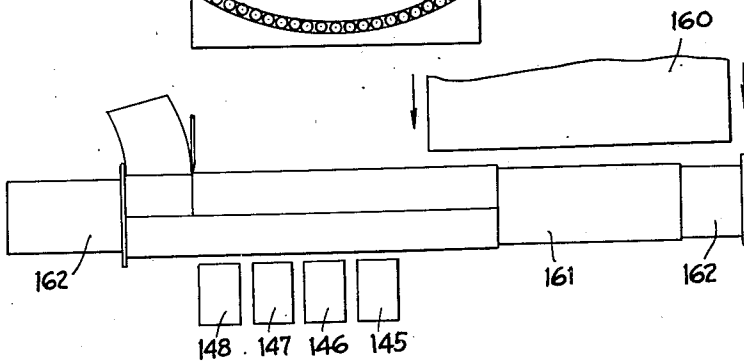
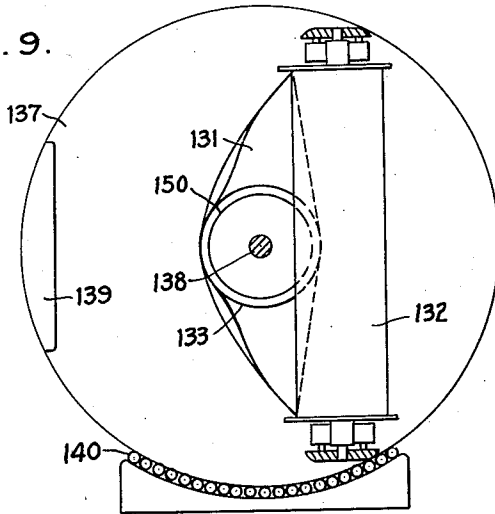


FIG. 10.

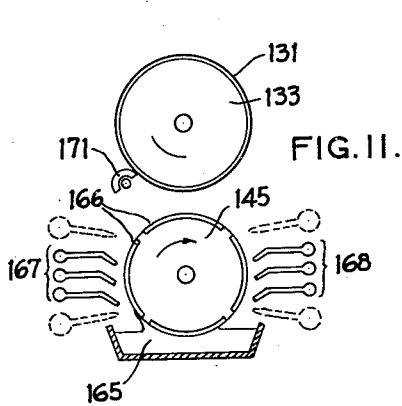


FIG. 11.

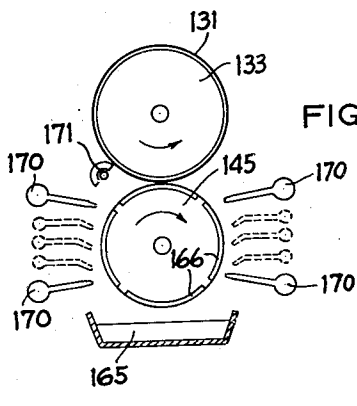


FIG. 12.

ALEXANDER MURRAY
INVENTOR
Newton M. Benson
BY *F. M. Emerson Holmes*
ATTORNEYS

UNITED STATES PATENT OFFICE

2,503,758

FUSION PHOTOTHERMOGRAPHY

Alexander Murray, Rochester, N. Y., assignor to
Eastman Kodak Company, Rochester, N. Y., a
corporation of New Jersey

Application August 16, 1947, Serial No. 768,977

3. Claims. (Cl. 117—37)

1

This invention relates to fusion photothermography and is particularly directed to a preferred species thereof. Fusion photothermography is described generically in my application, Serial Number 768,979, filed concurrently herewith.

The object of the present invention is to provide a simple, high quality printing process which requires only inexpensive equipment. One particular advantage of the present embodiment is the fact that it is directly adaptable to multi-color printing. Four-color prints, for example, produced by the present invention have been found to have quite satisfactory quality.

As pointed out in the above mentioned concurrently filed application, fusion photothermography requires a uniform layer of coloring material in a fusible vehicle maintained at a uniform temperature just below the melting point of the vehicle. A negative two-tone heat image applied to this layer differentially fuses the ink vehicle to a support such as paper. The distinguishing feature of the present invention is the manner in which this negative heat image is obtained. A two-tone image is formed as a positive in heat absorbing material. For example, a positive transparency made on extremely high contrast film having only a very thin emulsion, is coated with a powdered fusible ink and then uniformly irradiated with infrared light. The radiation is absorbed by the silver grains in the dark areas of the positive which heats these areas and melts the ink adjacent thereto while the ink adjacent to clear areas of the film remains unmelted. Note that the dark areas of the positive are the hot ones so that the heat image is a negative one. The melted areas of ink are immediately transferred to a paper support by pressing it into contact with the positive record. The unmelted parts of the ink are then removed by brushing, mechanically or with air, from both the paper and the positive film record which is immediately re-inked and used over again.

It is common parlance to refer to materials which absorb radiation and get hot as heat absorbers, but in the accompanying claims the critically precise phrase "material which absorbs radiation and converts it to heat" is used since the actual operation is the conversion of radiant energy into heat energy.

A moment's reasoning shows that the positive record in heat absorbing material must be on a support of low heat absorption, but even a thin layer of film or glass has proven adequate for this purpose and the whole record may be lying on a metal plate while being irradiated from the front.

2

The exposure to infrared light may be either from the front through the ink layer or from the rear through the transparent film base. Experience has shown that more satisfactory results are obtained when the exposure is from the front through the ink layer rather than through the film. Various possible explanations of this difference have been proposed but none of them has specifically led to any further discoveries and therefore there is no point in considering them.

The ink may be rolled onto the record, or dusted onto the record, or pre-formed into a thin sheet which is applied to the record by passing both between pressure rollers. The vehicle of the ink layer should have a melting point above room temperature for convenience in operation of the invention and the temperature should not be too high since it would become difficult to control temperatures greater than 200°C. Preferably the melting point should be between 30°C. and 70°C. for most convenient operation. For most rapid printing, the ink should be preheated to within one or two degrees of its melting point, at least within 20° thereof.

The paper or other support which is to receive the final print image by fusion with the melted areas of the ink should preferably be at a temperature below the melting point of the ink so that the ink solidifies immediately after fusion to the paper. The invention and preferred embodiments thereof will be fully understood from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 illustrates schematically in cross-section a preferred embodiment of the invention.

Fig. 2 similarly illustrates an alternative arrangement of one of the features of Fig. 1.

Fig. 3 is a greatly magnified cross-section of a printing plate during the exposing operation of the invention.

Fig. 4 schematically illustrates an embodiment of the invention alternative to that shown in Fig. 1.

Fig. 5 similarly illustrates a highly automatic and continuous embodiment of the invention.

Fig. 6 is a top view of a simple four-color press employing the invention.

Fig. 7 is a front view of a four-color press employing an embodiment of the invention.

Fig. 8 diagrammatically illustrates the operation of the press shown in Fig. 7.

Fig. 9 is an end view of the press shown in Fig. 7.

Fig. 10 is an alternative arrangement of the paper feeding mechanism of Fig. 7.

Figs. 11 and 12 illustrate the "hot" or inking revolution and the "cold" or printing revolution respectively of the printing procedure using the press shown in Fig. 7.

In the first five figures the use of the invention in one-color printing, such as black and white printing, is illustrated for clarity although the invention is primarily intended for multicolor printing. Any of the embodiments shown are directly applicable to four-color printing, merely by using four similar sets of apparatus respectively with the four color inks, the usual provision for registration of the four colors being made. For example, merely using the arrangement schematically shown in Fig. 1, I have produced four-color prints merely by changing the color of the ink and registering the successive ink transfers, by hand although the automatic registering embodiments are preferable for obvious reasons.

In Fig. 1 a halftone positive made up of a halftone record 10 on a support 11 is carried on a moving belt 12 and is thereby moved under an ink roller 13 which applies fusible powdered ink 14 to the surface of the record 10. The ink powder is supplied from a hopper 15. After a uniform layer of ink 14 has been applied to the record 10, they are passed together between pressure rollers 20 and on to a hot plate 21. The hot plate is maintained very accurately at a constant temperature just below the melting point of the ink 14 by means of a water circulating system including brass tubes 22 soldered to the bottom of the hot plate 21 and through which water from a constant temperature bath 23 is fed by a pump 24.

The record is driven along the hot plate at a constant speed by means of edge rollers 25 which engage the edge of the record. The uniformly heated record then passes on to a moving belt 30 and under a highly intense infrared lamp 31 which is provided with a gold plated reflector 32 which in turn is cooled by water circulating through pipes 33 in the reflector. At this point, the ink adjacent to the black areas 16 of the record 10 is melted as shown by broken lines 17 in Fig. 3. The ink particles 18 adjacent to the clear areas 19 of the halftone record are not melted and remain as a powder which can be brushed or blown away after the melted ink has been transferred to a paper support. The arrows 34 in Fig. 3 merely represent the radiation from the lamp 31 and it will be noted that a portion of this radiation passes through the clear areas 19, whereas the rest of the radiation is absorbed into and heats the areas 16.

Referring again to Fig. 1, the record with the melted ink areas is passed, together with paper 35, between pressure rollers 36 at which point the melted ink areas transfer to the paper 35 forming the final image thereon. Any unmelted ink which happens to transfer to the paper is removed by an air squeegee 40. The record together with the rest of the unfused ink particles is moved onto a catch board 41 which is sloped upward and is provided with a rubber cushion 42, in order to catch the rapidly moving record and stop it without damage thereto. The ink is removed from the record and the whole operation repeated.

Fig. 2 differs from Fig. 1 merely by having transparent support 45 for the record at the point in the printing cycle whereat the record is irradiated with infrared light from a lamp 46. Additional driving rollers 47 are provided for moving the record across the plate 45. Exposure through the record 10 as thus provided does not

give quite as satisfactory results as exposures from the front as illustrated in Fig. 1.

In Fig. 4 the record 10 on support 11 is laminated to a thin sheet 50 of fusible ink by means of pressure rollers 51. The sandwich is then driven by rollers 52 along a hot plate 53 and brought to a uniform temperature just below the melting point of the ink. The sandwich is then illuminated by a highly intense infrared lamp 54 and the melted areas of the ink are transferred by pressure rollers 55 to a paper sheet 56. The unmelted areas of the ink in some cases still tend to remain as a sheet and may be removed as illustrated at 60 from a record 61, but in general it is also desirable to apply an air brush or squeegee both to the paper 56 as shown at 62 and to the record 61 as shown at 63.

One of the most satisfactory methods of applying a fusible powder ink to a layer uniformly is by dusting the powder on to the layer. A highly automatic arrangement for doing this is illustrated in Fig. 5. In this figure two positive records 70 and 71 which are to be printed are fastened by clamps 72 onto a large drum 73 which is rotated as indicated by arrow 74 by means not shown. The record 70 is in the stage of being dusted between the points 80 and 81 with a fusible ink which gradually builds up from the point 80 to the point 81 forming a uniform layer of ink on the record 70. The uniform dusting is provided first by moving a hopper 82 of particles 83 of ink back and forth as indicated by the arrow 84 over an oscillating screen 90. The reciprocating motion of the hopper 82 is provided by a reciprocating drive consisting of a motor 85 driving a drum 86 with oppositely disposed helical grooves 87 engaging a pin 88 on a sliding shaft 89.

The powdered ink 83 from the hopper 82 is thus spread evenly in a layer 91 on the screen 90. This screen 90 is agitated, i. e. oscillated rapidly, as indicated by arrow 92 by means of a cam 93 engaging one edge of the screen and operating against the force of a spring 94. The cloud 95 of ink particles settles uniformly onto the record 70 and as the drum 73 rotates the ink is pressed into firm contact with the record 70 by a pressure roller 100 which is very smooth and cold so that the ink particles have no tendency to adhere thereto. The record and the ink are brought to a uniform temperature just below the melting point of the ink by means of a hot plate 101 disposed inside the rotating drum 73. The inked record is then exposed by infrared radiation from an infrared lamp 102 which is of sufficient intensity to melt the ink adjacent to the dark areas of the positive record 70 but not to melt the ink adjacent to the light areas as the record moves by. The melted ink is then transferred to a paper sheet 103 by means of a pressure roller 104. Any unmelted ink which adheres to the paper 103 is removed by air squeegee 105. The unmelted ink which adheres to the records 70 and 71 is removed by air squeegees 106 and 107 and by a mechanical brush 108. This excess ink 109 is caught in a pan 110 and usually I prefer to return the ink to the grinding mill before using it again in the hopper 82.

My copending application referred to repeatedly above describes many ink vehicles suitable for fusion photothermography. They are equally applicable to the present process.

With the present process and using only simple apparatus such as that illustrated in Fig. 1, or at least using four sets of such devices so as

5

to provide four-color printing, I have been able to make all four-color impressions allowing sufficient cooling time between each, in a total of one eighth of a second. In general the record 10 is formed in a stripping emulsion such as now available on the market for lithographic work. The stripping emulsion is mounted on a support consisting of a film about .015 inch thick laminated to a flexible steel or iron sheet in order to withstand rapid printing. The hot plate is about 6" x 25" and after the heated record leaves the hot plate it travels a distance of about 23 inches, during exposure, before it reaches the pressure rollers at which the ink is transferred to the paper.

Ink applied in sheet form as illustrated in Fig. 4 is not as efficient as that applied by dusting as shown in Fig. 5. The fusible compounds together with the color pigments can be dispersed in water readily, for example, by grinding, and when dried on the positive record, this water color gives a fine textured coating. However, the energy efficiency is somewhat lower than that of the dusted-on or rolled-on powders which probably accounts for the fact that there is not much difference in quality obtained with these fine textured coatings as compared with the dusted or rolled-on ones. It should be noted that the ink is in general applied before the exposure of the record which has been found necessary because the heat capacity of the silver image is too small to insure good quality when the ink is applied after radiation, with the expectation that the ink will melt in the proper areas and not in the others.

In Fig. 6 the paper 120 to be printed is moved in a direction transverse to that in which the inking rollers 121 move across the records to be printed which in this embodiment remain fixed. Assuming that the paper stock 120 is in the plane of the drawing, then the records 122 and 123, which are color separation records are first raised from the paper stock 120 by means not shown. The inking rollers 121 carrying ink from the ink wells 124 and 125 move across the underside of the records inking them with appropriate ink colors. The records are then pressed by means of setting rollers 130 into tight contact with the printing stock 120, the records, the ink and the printing stock 120 all being brought to a temperature just below the melting point of the ink. Illumination by infrared light is then provided through the records 122 and 123 which melts the ink adjacent to the dark areas of the record and transfers it to the printing stock 120. As the stock moves forward between impressions, one frame at a time, it receives the successive color impressions. Obviously this may be expanded to three and four color printing merely by adding additional impression steps.

A more elaborate system is shown in Figs. 7, 9, 11 and 12 wherein the paper web 131 from a roll 132 is wrapped transversely around an impression cylinder 133. This cylinder is arranged to move, between successive impressions, by an amount exactly equal to one printing frame so that perfect registration is insured. The final print after the four impressions are made is cut off at the point 135 while the paper web is still wrapped in cylindrical form. The motor for driving the printing cylinder is shown at 136. It should be noted that the impression cylinder rotates transversely to the direction of travel of the paper web and thus the supply roll 132 along with all of the housing 137 therefore is mounted to rotate around the central shaft 138 of the

6

impression cylinder. The housing is provided with a counterweight 139 partly to balance the paper roll and it moves on bearings 140.

Printing takes place by rotation of the shaft 138 and printing roll 133 with the paper 131 wrapped thereon in contact with four plate rolls 145 (yellow), 146 (magenta), 147 (cyan) and 148 (purple or black). The paper receives its yellow printing first then moves forward one frame and receives its magenta impression and so on for cyan and purple after which the completed print—or more exactly four prints—is cut off at the point 135. The effect is shown "unwrapped" in Fig. 8.

The printing roll 133 moves back and forth as a sleeve on drum 150, between carefully adjusted stops which insure proper registration. Starting at the point in the printing cycle in which the finished prints have just been cut off (the cutting off operation is performed during the printing revolution of the plate rolls) the next step is the movement of the plate rolls down away from the paper. At this same time the vacuum, provided through pipe 151, is temporarily cut off so that the paper which is held by this vacuum to the sleeve 133 is released but is kept from unwrapping or moving longitudinally by rings 152 and clamps 153. The sleeve 133 is then moved back, inside the paper cylinder, one frame and the paper reclamped by turning on the vacuum. The sleeve 133 and the paper clamped thereto moves forward one frame and is thus ready for the cutting off and printing revolution, the plate rolls having in the meantime been through a hot or inking revolution, discussed in detail below.

Fig. 10 is merely an alternative paper feed. In it the paper is supplied in sheets 160 which may be any multiple of one frame wide, preferably four or more, and should have a length approximately equal to the circumference of the sleeve 161 on to which a new sheet is wrapped immediately next to the previous sheet as the last frame of the latter receives its yellow impression. As in Fig. 7, the sleeve 161 moves accurately back and forth on the drum 162 an amount equal to the width of one frame.

The details of the printing cycle are shown in Fig. 11 and Fig. 12. In the first part of the cycle, the printing cylinder 145 rotates in an ink bath 165 to pick up a fusible ink maintained at a temperature just above its melting point. The liquid ink is then uniformly distributed on the halftone record 166 being printed by means of hot air jets 167. After the cylinder has received the uniform layer of colorant and any residual ink removed by further hot air blasts from jets 168, the inked cylinder is raised from the colorant pan 165. This completes the hot or inking revolution, during which the paper has been moved forward one frame width as discussed above. In the next step of the cycle the ink is cooled by relatively cool air from jets 170 until it just solidifies and remains at a temperature just below its melting point. The impression cylinder 133 is brought into contact with the paper cylinder 145 by the raising of the latter as shown in Fig. 12 and one revolution of both cylinders is performed while exposing the ink to infrared radiation from a lamp 171 immediately adjacent to the contact point between the cylinders 133 and 145. Thus, as before, the ink is melted according to the halftone pattern in the transparency 136 and transferred to the paper which is wrapped around the cylinder 133. This embodiment of

the invention involves the application of the colorant in melted form to the record and solidification thereof in situ.

By way of specific example, in one procedure I make up a magenta ink powder consisting of 70 parts of a fusible vehicle, phenyl salicylate or triphenyl phosphate or preferably, benzophenone. To this I add 5 parts of a colorant (rhodamine 3B extra in the case of magenta), 5 parts of dry soap for anti-static purposes and 20 parts of fine white silica as a separator. This is all reduced to a fine dust in a suitable mill. For each impression the discrete ink is distributed upon the selective absorber, namely the halftone positive image, and exposed from either or both sides to a light source rich in infrared. Only sufficient exposure is used to melt the fusible material adjacent to the black areas of the positive. Phenyl salicylate remains fluid for some time even upon a cool surface whereas benzophenone solidifies much more rapidly. In either case, before the vehicle solidifies, the fused image is transferred to the print stock which may be either paper or a film pellicle. It has been found that the spatial selectivity which corresponds to the resolving power, is inversely proportional to the exposure time and to some extent to the thermal conductivity of the material of construction. According to a second procedure, the soap is omitted and the fusible compound is melted with the colorant, which, in the case of an insoluble pigment, is dispersed minutely by a supersonic oscillator inserted in the liquid. This is fed quantitatively to the surface of the selectively absorbing layer, which is fastened to the surface of a rotating cylinder. The warm ink is applied dropwise from a line of controllable valves in an ink reservoir. The ink drops are quickly spread out by an air or vapor squeegee or by an electrostatic field. The temperature of the cylinder is maintained below the solidification point of the ink, which is crystallized quickly and in uniform, fine, crystals by supersonic vibrations applied to the ink or the support. The inked surface then passes under a line radiator then into contact with the paper stock, then under a hot suction squeegee to remove the unused ink, and then under the ink applicator again.

Another method of removing unused ink and applying fresh ink that uses a single device is to have an inking cylinder kept above the melting point of the ink, with a porous metal surface, tightly connected with an ink well in the cylinder that has hydraulic or pneumatic connections leading to a pump or plunger. With suction on the reservoir, the warm, porous metal melts all the unused ink, which is drawn into the porous metal, pressure is then applied to force ink out through the porous member and onto the surface of the absorbing layer, whereupon the other operations described above take place.

By way of example of the effect of exposure time on resolving power, it is noted that with pure triphenyl phosphate a resolution of 50 lines per inch is obtained with a one second exposure whereas a resolution of 300 lines per inch requires an exposure of about $\frac{1}{100}$ of a second. However, these limits will probably change with varying conditions and are to be interpreted only relative to one another, not as absolute.

As mentioned above, the thermal conductivity of the record support has some effect but not as great as originally expected. The support may be of glass which has considerably higher conductivity than film or it may be of metal if there

is a good heat insulator between the metal and the fusible ink. For example, when a gelatin silver positive on glass .055" thick is maintained at a temperature just below the melting point of the fusible vehicle, the required fusion takes place with exposure not appreciably higher than with such positives on thin films over an air space. On the other hand, I prefer to include an insulating layer of a synthetic plastic such as polystyrene between the record and any highly thermal conducting support. It is also an advantage to use as thin a layer of gelatin as possible for the image layer because of the thermal conductivity of gelatin.

The thermal diffusivity coefficients are 0.0057 for glass, 0.001 for gelatin or cellulose acetate and as low as 0.0006 for certain polystyrene resins. Silver absorbs heat 300 times as fast as glass and proportionately faster relative to the other materials just mentioned. For the source of radiation, standard drying lamps in 250, 500 or 1000 watt sizes are highly efficient when used with gold plated reflectors and have a life greater than 5000 hours. They are quite satisfactory with just a simple reflector as illustrated up to 120 line per inch quality and are therefore useful for poster and medium quality commercial work. The 1000 watt lamp requires about .05 second minimum exposure to supply the calories required for fusion unless some condenser system in addition to the gold plated reflector is used giving a narrow line of concentrated radiation for scanning the printing surface with only .01 second or even less local exposure. These shorter exposures permit higher quality work as pointed out above.

The two tone positives may have various forms as described above. Films giving 4.0 maximum density have proven to be quite satisfactory but even with the maximum density as low as 1.5, only 10% more photothermal exposure is required and the differential between clear areas and dot areas is still sufficient. When using the fused ink layer as in Fig. 7 instead of the powdered layers of Figs. 1 and 5 and to some extent even with the powdered layers, the pin point dots of the highlights tend to require greater exposure time than shadow dots. This is solved by the usual expedient of photoengraving, namely the use of large dots in the highlights. The photothermal process according to the examples just described, tends to give clean whites with high contrast in the highlights.

The following table gives a number of suitable ink vehicles mainly by way of illustrating the large choice of materials which is available:

Name	M. P., °C.	Heat of Fusion, Cals per cm. ³
Phenyl Salicylate.....	42-43	20.1
Benzole Anhydride.....	42-43	16.5
Benzyl Phthalate.....	42-44	16.7
α -Naphthyl acetate.....	44-45	16.0
Benzyl Succinate.....	44-46	25.8
Benzophenone.....	47-48	11.5
Hydrocinnamic acid.....	47-49	20.3
Succinonitrile.....	47-49	16.6
Triphenyl Phosphate.....	49-50	14.7
Ethyl-n-phenyl Carbonate.....	49-51	53-55
Methyl-o-benzoyl benzoate.....	50-52	54-57
p-nitro-anisole.....	51-52	56-58
1,3, dimethyl 1,3, diphenyl cyclobutane.....	51-53	65-67
Methyl- β -naphthyl ketone.....	53-55	
Trichloroacetic Acid.....	54-57	
Acetophenone Oxime.....	56-58	
Diphenyl.....	65-67	

Of the above, benzophenone appears to give the best quality, highest speed, fusion photo-

thermographic prints. It is applicable either to black and white printing or multicolor printing, particularly because of its fast solidification. Various properties of the vehicle must be taken into consideration and some of the above would be objectionable because of their heavy and unpleasant odor or their inability to disperse certain pigments. However, benzophenone appears to be quite satisfactory in all respects and therefore appears to be the No. 1 choice of the materials listed.

As pointed out in the co-filed parent application, the coloring materials used may be either pigment or dyes and are selected according to the color desired.

It is to be understood that the above embodiments are merely illustrative of the preferred forms of the invention and that the invention is not limited to these embodiments.

I claim:

1. The method of printing which comprises (1) forming a positive two tone image record of a material which absorbs infrared radiation and converts it to heat, on a support of low infrared absorption, (2) putting onto the record a uniform layer of ink which contains a coloring material and a vehicle which melts at a temperature between 20° C. and 200° C. and which ink both in its solid state below the melting point and its liquid state immediately above the melting point is stable and does not adversely affect the record and which ink is transferable in its liquid state, (3) bringing the record and the ink layer to a uniform temperature below and within 20 centigrade degrees of the melting point of the

vehicle, (4) uniformly illuminating the record with infrared radiation of sufficient intensity and time to raise the temperature of the ink overlying the infrared absorbing areas of the record above the melting point without melting the ink overlying the other areas of the record (5) pressing a print support layer, which does not react adversely with the ink and which will receive the ink in its liquid state, onto the front of the ink layer with the print support layer at a temperature below the melting point of the ink to fuse the melted areas of the ink layer to the print support layer and (6) separating the print support layer with the ink image fused thereto from the ink layer.

2. The method according to claim 1 in which the putting on of the ink layer uses one whose vehicle has a latent heat of fusion less than 30 calories per cc. and a melting point between 30° C. and 70° C.

3. The method according to claim 1 in which the ink layer is put on as a compacted powder of particles of said vehicle containing a uniform percentage of coloring material.

ALEXANDER MURRAY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,590,648	Sadtler	June 29, 1926
2,254,483	Hess et al.	Sept. 2, 1941
2,317,789	Marriott	Apr. 27, 1943