Feb. 24, 1953 A. MURRAY 2,629,671

PHOTOTHERMOGRAPHY, PRINTING SHEET AND PRINTING INK THEREFOR

Filed Aug. 16, 1947 2 SHEETS—SHEET 1

FIG. 1.

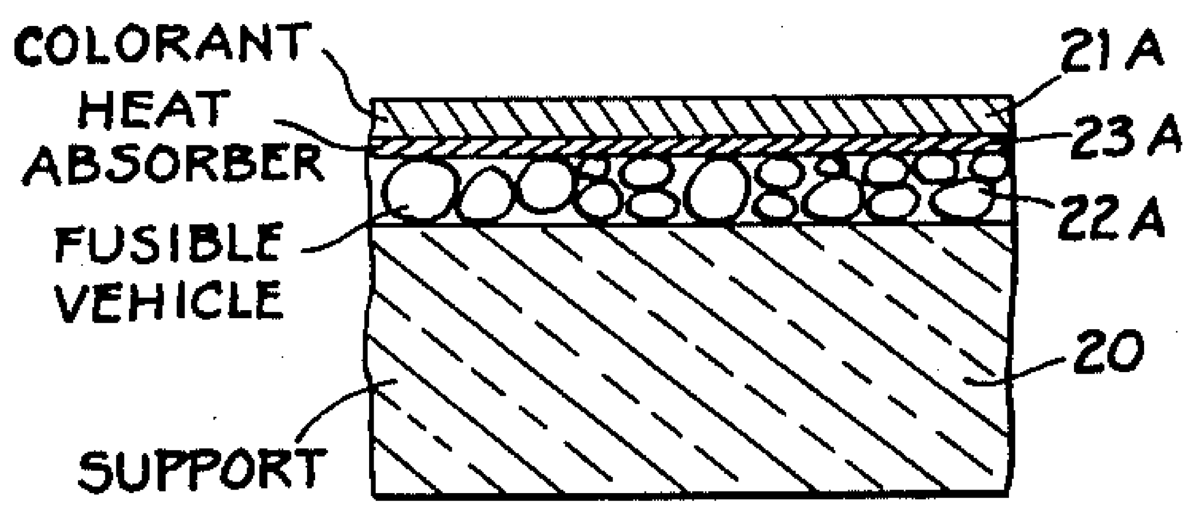


FIG. 2.

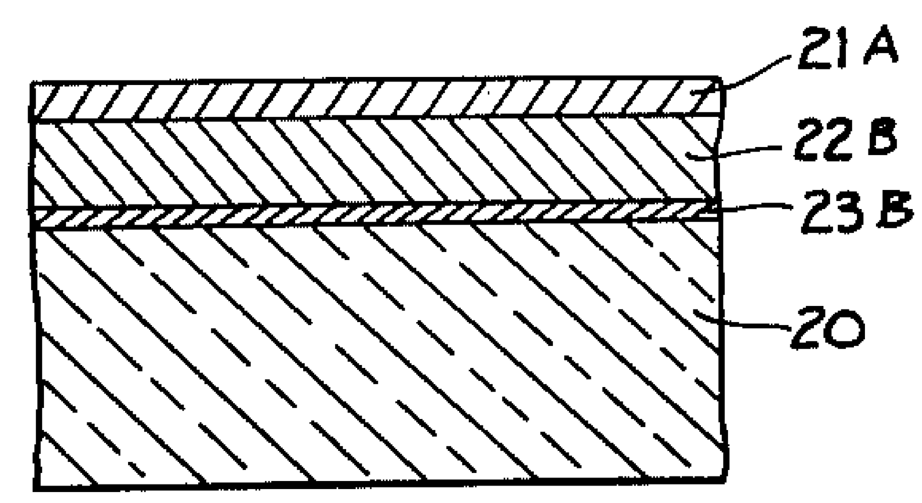


FIG. 3.

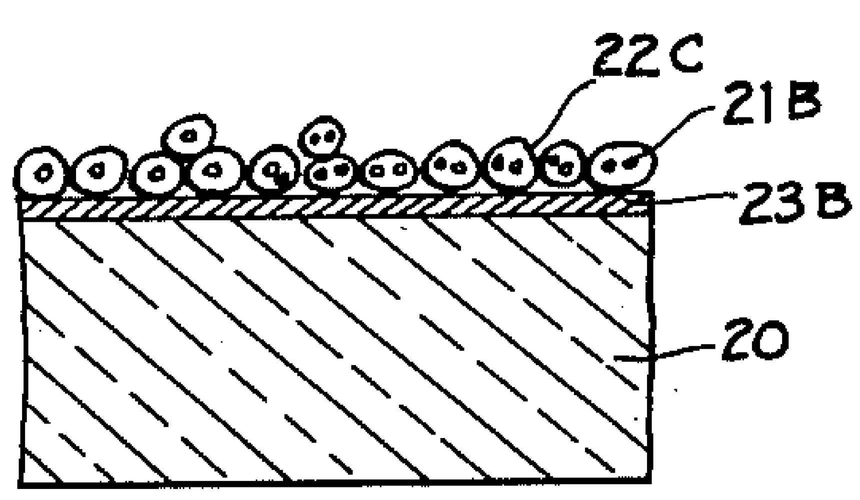


FIG. 4.

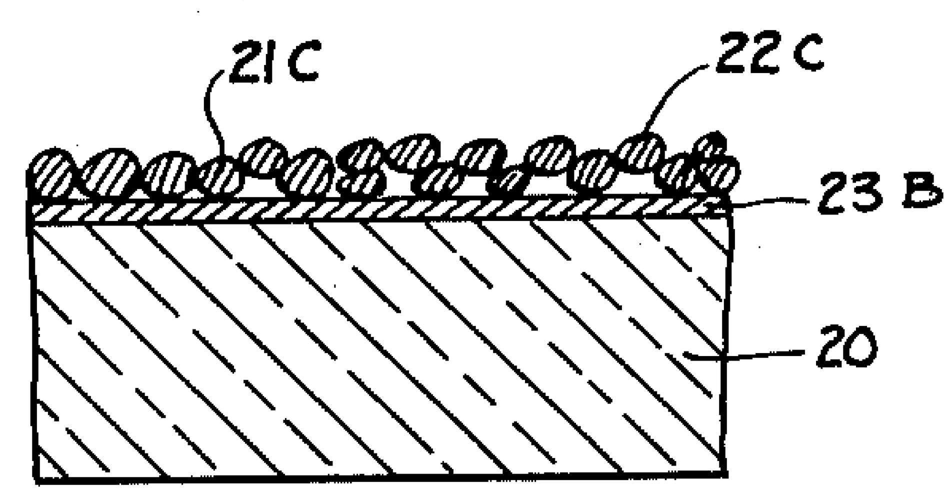


FIG. 5.

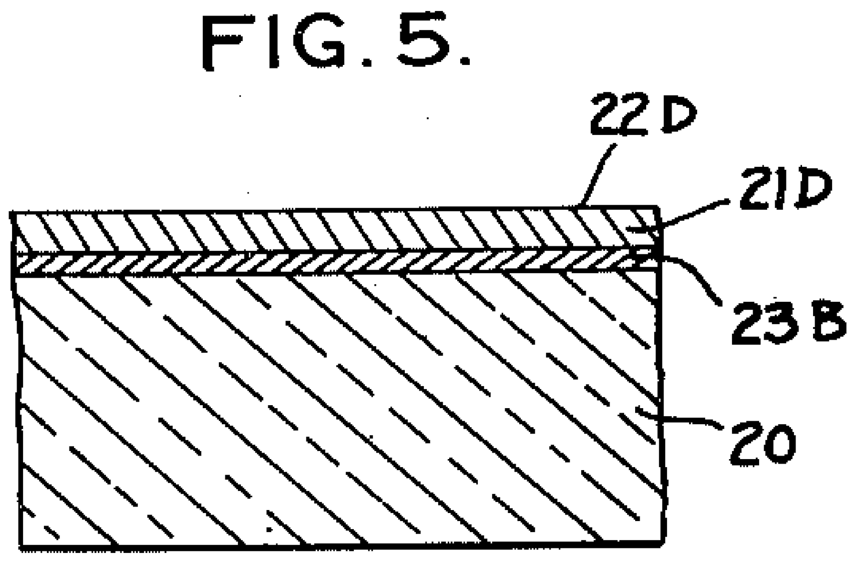


FIG. 6.

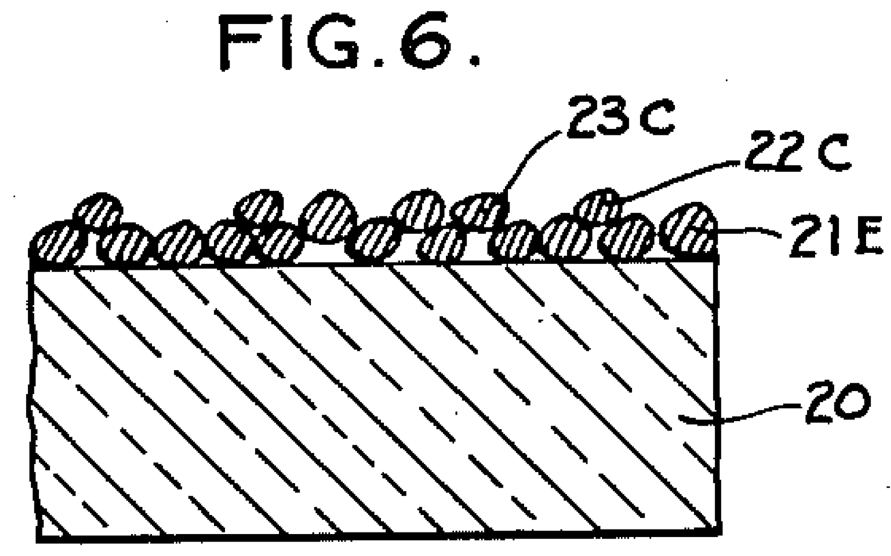


FIG. 7.

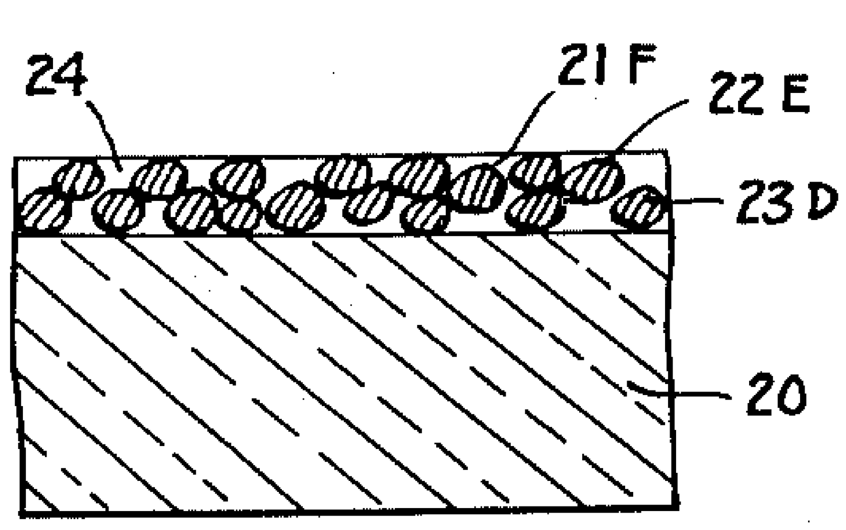


FIG. 8.

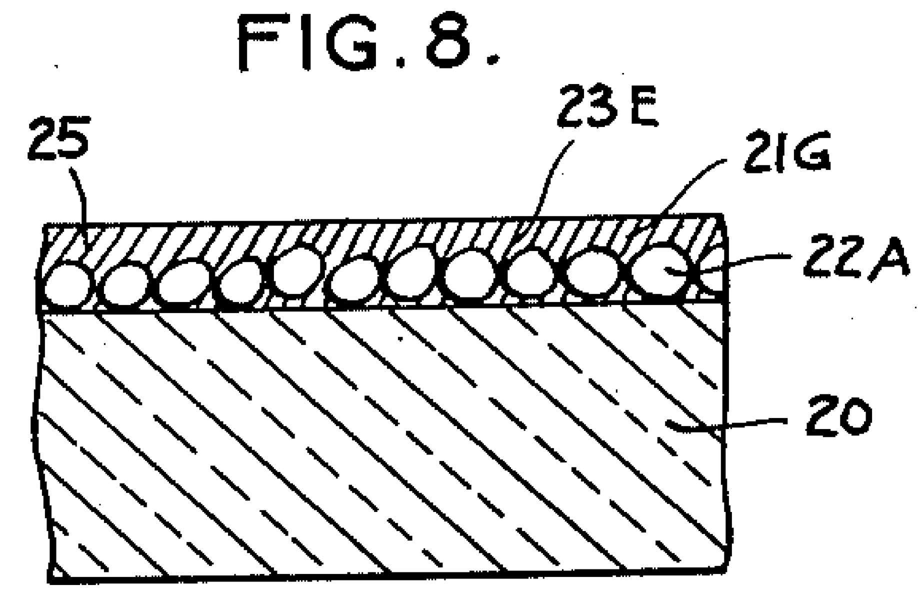
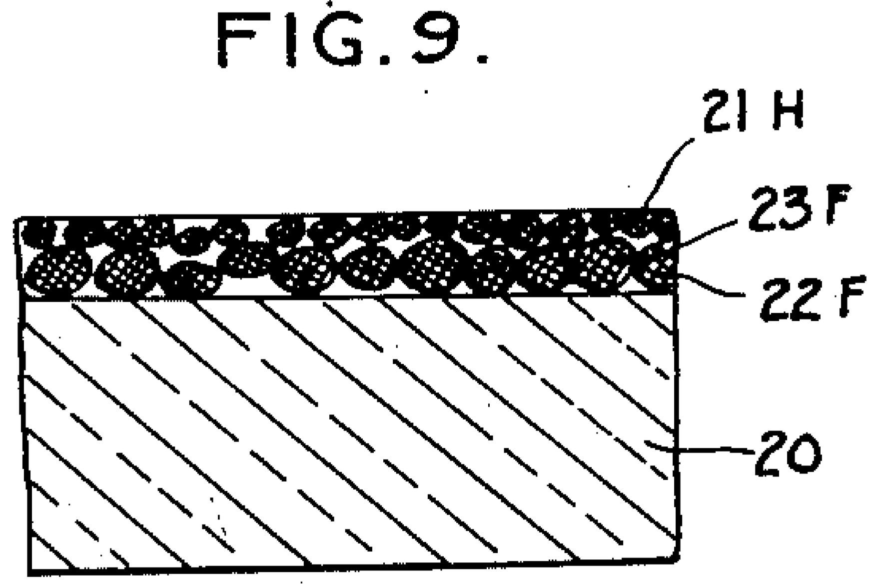


FIG. 9.



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2,629,671

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2 SHEETS—SHEET 2

FIG. 10.

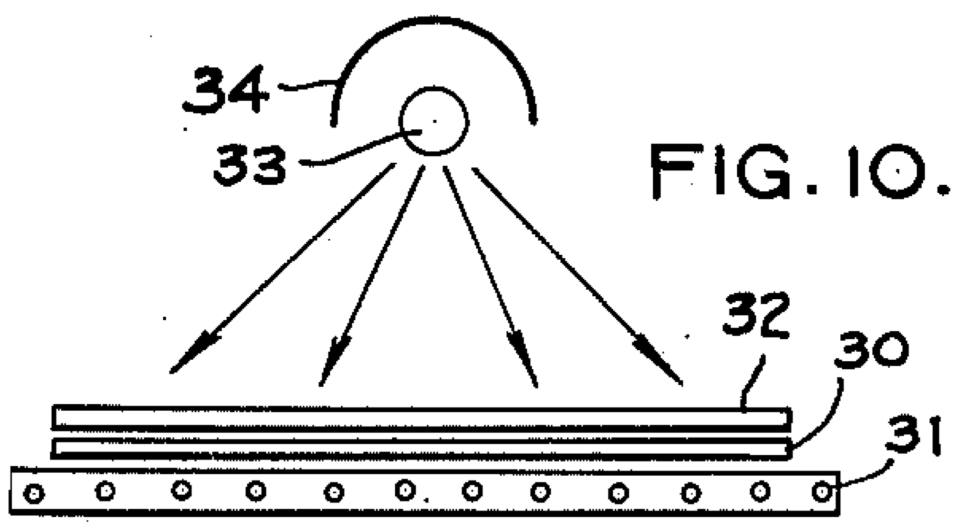


FIG. 11.

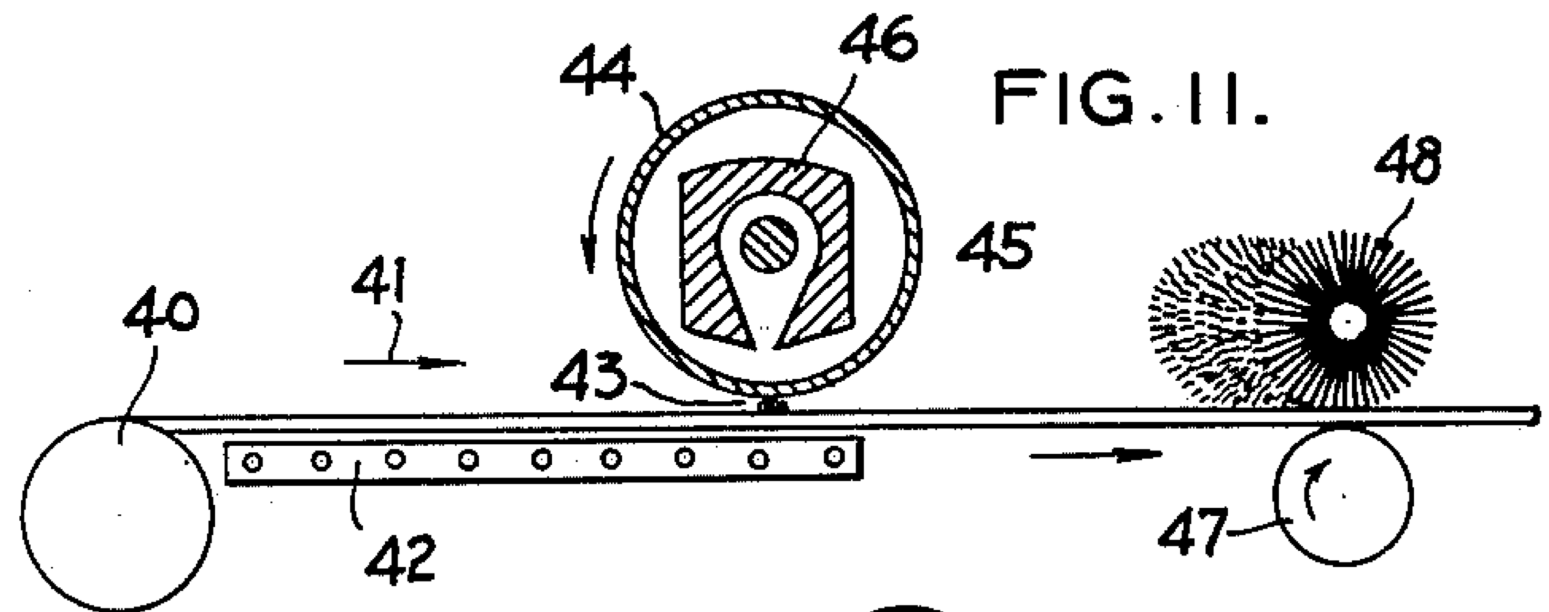


FIG. 12.

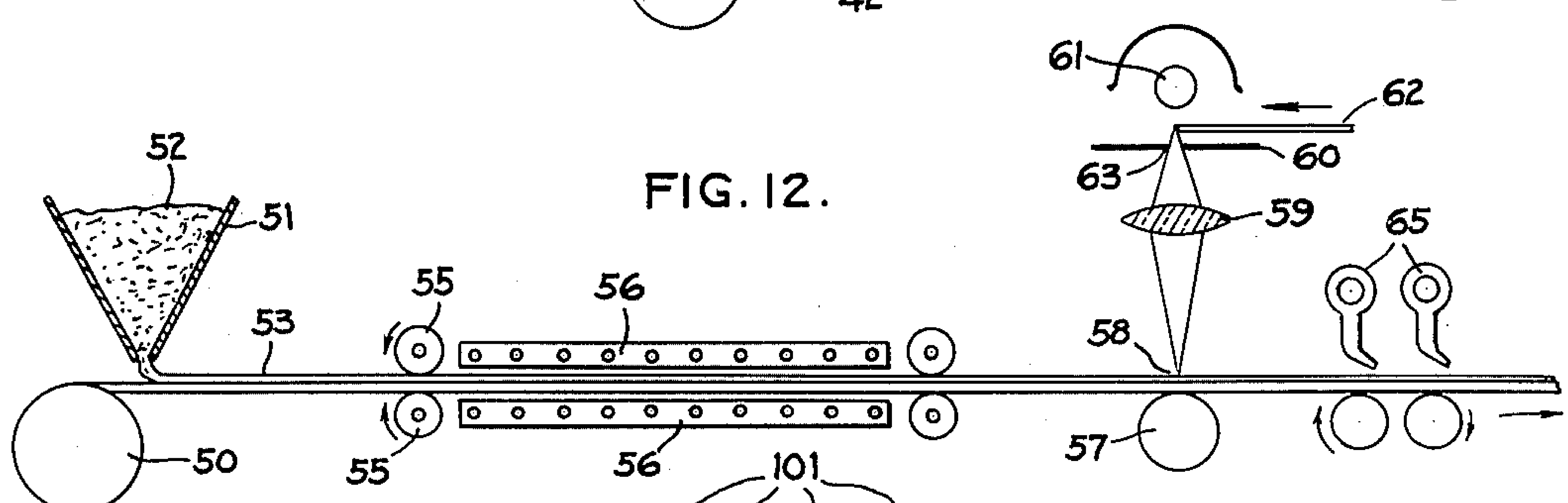


FIG. 15.

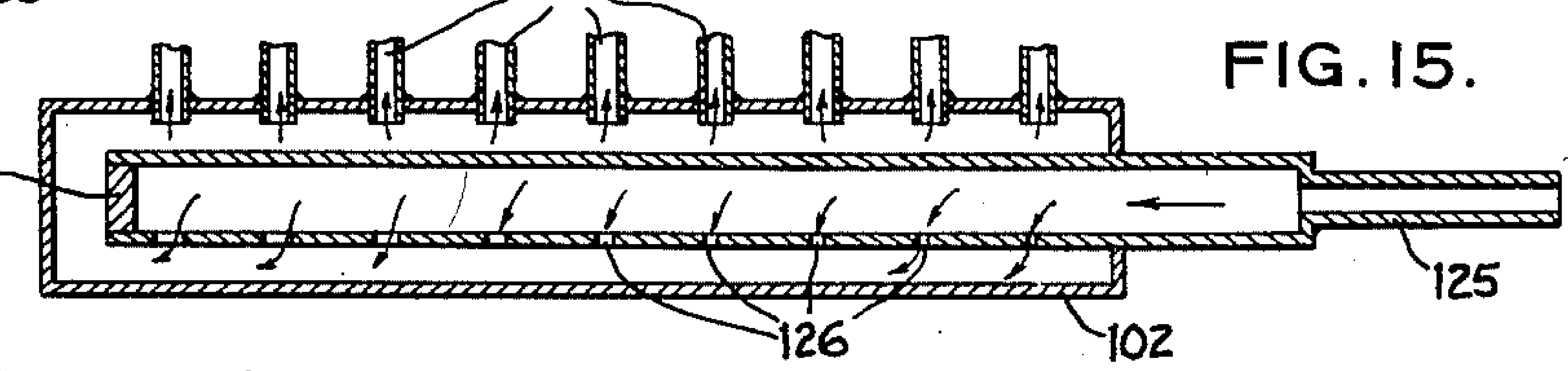


FIG. 14.

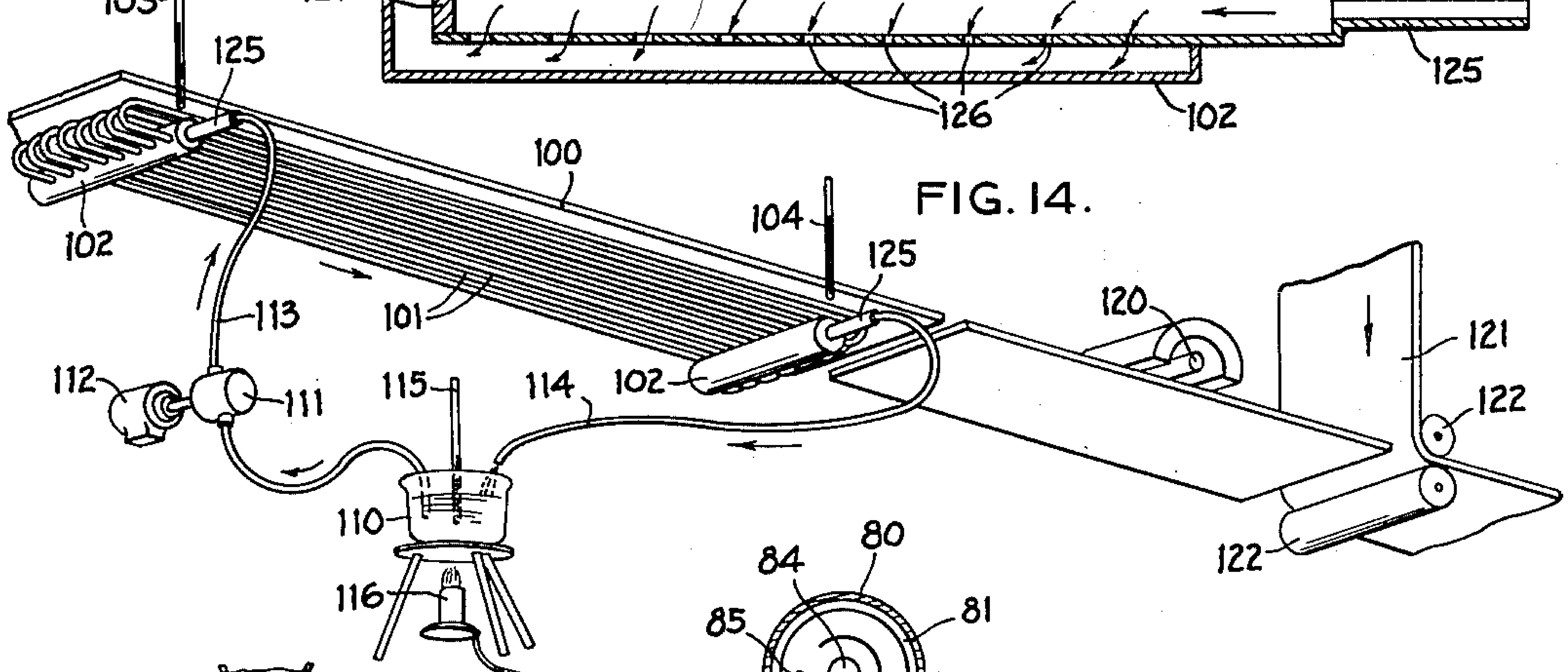
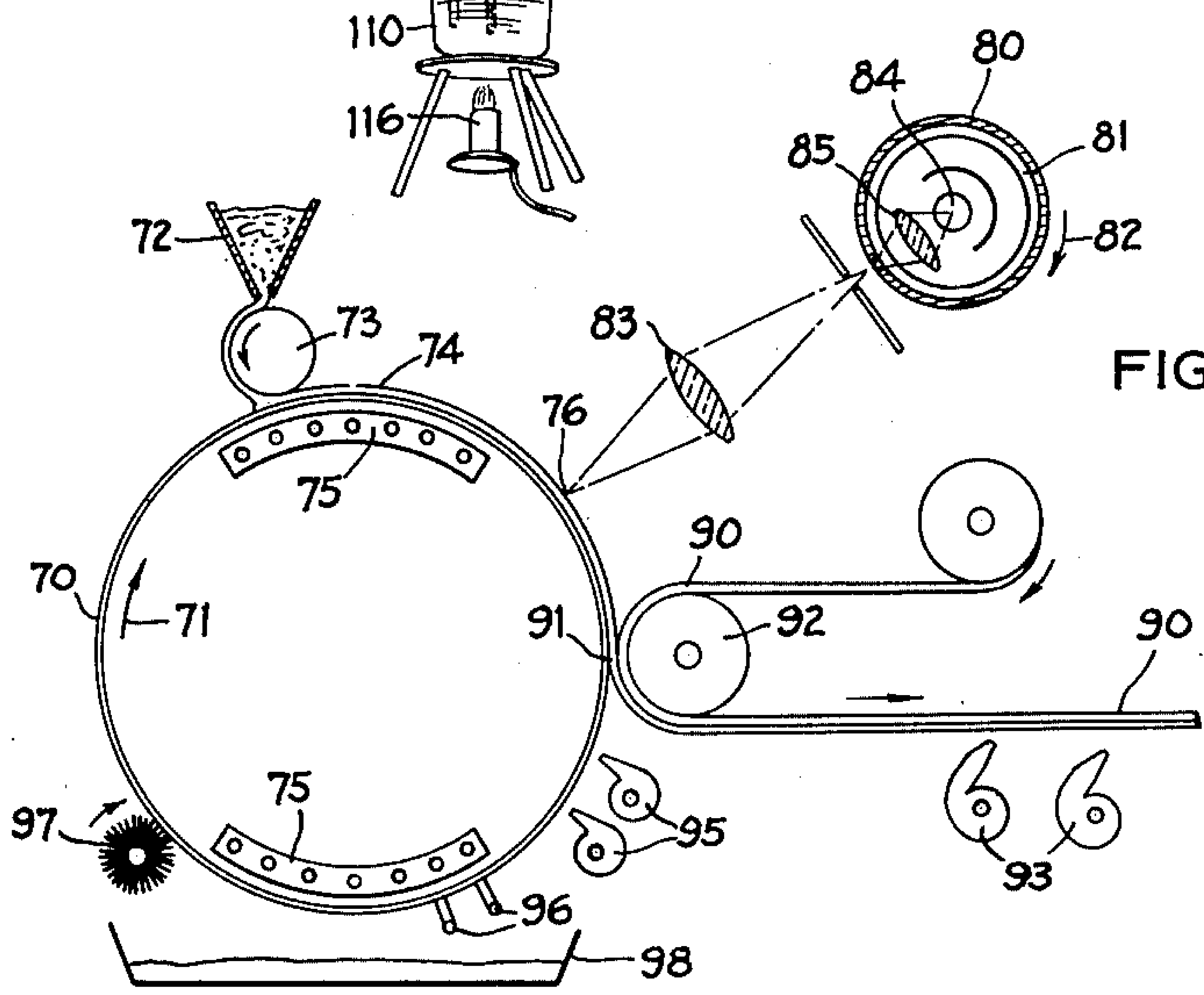


FIG. 13.



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Patented Feb. 24, 1953

2,629,671

UNITED STATES PATENT OFFICE

2,629,671

PHOTOTHERMOGRAPHY, PRINTING SHEET AND PRINTING INK THEREFOR

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Application August 16, 1947, Serial No. 768,979

7 Claims. (Cl. 117—8)

1

This invention relates to printing, either monochrome or multicolor printing, of a halftone or a line image, i. e. of a two-tone image.

The object of the invention is to eliminate the need for specialized printing plates such as those used in photoengraving or photolithography and particularly to provide a simple, direct and rapid process which requires relatively inexpensive equipment.

In common with the line scanning processes described in Serial Numbers 731,372 Glassey, now U. S. Patent 2,487,865 and 731,173 Murray, filed February 27, 1947, now U. S. Patent 2,556,550 and the expansion photothermography processes described in Serial Number 745,019 Glassey, filed April 30, 1947, now U. S. Patent 2,543,013 and Serial Numbers 749,445, 749,446, and 749,447 Murray, filed May 21, 1947, now U. S. Patents 2,543,045, 2,543,046, and 2,543,047 one object of the present invention is to provide a method of printing which permits the print to be made directly from the image. As distinguished from the line scanning and expansion photothermography processes, the present invention is referred to as fusion photothermography. It has the direct and very important advantage of requiring only very simple equipment. It does require, however, that the image to be printed, be a two-tone image either line or halftone. The quality of any continuous tone image printed by fusion photothermography is not of commercially acceptable quality, and therefore in the present specification, the description is limited to the printing of two-tone images. In fact, it is limited to the printing of such images from two-tone records although fusion photothermography is not inherently so limited.

One embodiment of the present invention, particularly described in the present application, employs a radiant image as the controlling factor in making the print. A second embodiment, particularly described in copending application, Serial Number 768,977 Murray, filed concurrently herewith now U. S. Patent 2,503,758 has the control image formed in a heat receptor which is uniformly irradiated to form the required heat image.

A heat image is one in which the light and dark tones are represented by different amounts of heat instead of different degrees of brightness as in an image formed by light. Since the following description is confined to a discussion of two-tone images, the heat image will be made up solely of hot areas and cool areas just as a line or halftone print is made up of white and black areas only. A positive heat image is one in which the highlights are hotter than the shadows and a negative heat image is one in which the shadows are hotter than the highlights.

Cross reference is also made to my copending applications on other forms of photothermography, Serial Number 768,978, filed concurrently herewith, now U. S. Patent 2,503,759 involving ink evaporation before fusion, Serial Number 774,478, filed September 17, 1947, now U. S. Patent 2,552,209 involving fusion from cell plates of different size cells and fusion of ink droplets of different sizes, and Serial Number 790,115, filed December 6, 1947, on heat sensitive recording paper.

2

According to the present invention a method of printing is provided which involves forming a sheet which absorbs radiant heat and which includes a uniformly distributed layer of ink in a vehicle which melts at a temperature between 20° C. and 200° C., preferably between 30° C. and 70° C. so as to be well above room temperature but still cool enough to permit rapid and convenient operation. A vehicle melting at 102° C. allows boiling water to be used as the temperature control but such temperatures interfere with the comfort of the operators unless air conditioned rooms and heavy insulation of the press are used. The various forms which the ink sheet itself may take and preferred embodiments thereof which have proven particularly satisfactory will be described in detail later in this specification. In every case the sheet is brought to a uniform temperature just below the melting point of the vehicle. For the sake of definiteness, I specify that the temperature should be within 20° of the melting point of the vehicle, but in practice I select a temperature about 2° below the melting point. In order to get the sharpest prints and clearest reproductions, it is desirable to have nothing in the sheet, other than the ink vehicle itself, which melts within 20° of the melting point of the vehicle or which spoils the sharpness of this melting point. Thus as a general rule it is desirable to avoid mixtures of two or more vehicles, but impurities up to 5% are not too objectionable.

When the sheet has been uniformly heated to a temperature just below its melting point, a two-tone heat image is applied to the sheet by radiation thereon of sufficient intensity and time to raise the hot tone areas above the melting point and thus to melt the ink vehicle in those areas, but not hot enough or long enough to melt the sheet in the cool tone areas. The two-tone heat image may be provided simply by projection or contact print through a negative, the radiation on to the sheet thus containing the negative image. In this case the heat absorbing portion of the sheet should be uniformly distributed as is the ink, either in the ink vehicle or in a separate sheet as described below. On the other hand, the heat absorbing material may be distributed as a two-tone positive image with the greater density in the shadows and this image of absorbing material is then uniformly illuminated by radiation with sufficient intensity and for a sufficient time to raise the temperature in the hot tone areas above the melting point as required. It should be noted that the heat image is a negative one, as required because the image in heat absorbing material appears positive when illuminated with light. In both cases the heat image is formed by radiation. The melted areas of ink are then allowed to fuse into the support on which the sheet is mounted or into a separate support brought into contact with the sheet. After fusion has taken place the unmelted areas of ink are removed, thus leaving a positive print.

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 for absorbing radiation and converting it to heat" is used since the actual operation is the conversion of radiant energy into heat energy.

The preferred embodiments described in the present application have the ink sheets and absorber mounted semi-permanently, either by pressure or by a soft binding agent, on the support into which the ink is ultimately fused. The unmelted areas of ink are removed by brushing either with an air squeegee or by a simple mechanical brush. The use of a blast of air as the brush has proven to be the most satisfactory as to uniformity of results obtained thereby.

In order to permit rapidity of operation, the ink vehicle should have a relatively low latent heat of fusion, preferably less than 30 calories per cc. Reference to any standard table will prove that this is not too exacting a requirement since many materials have latent heats of fusion below 30 calories per cc. The process may be made to operate with a large number of different materials but for obvious reasons, the use of materials which have a disagreeable odor or which are toxic or otherwise objectionable have been avoided in practical operation of the invention. After certain materials have been melted and fused, it is noted that they do not harden on cooling quite as rapidly as some other materials. Slow hardening is not fatal to the present invention, but it is preferable to select the faster hardening materials since this permits greater freedom in handling the final print immediately after it is printed and also permits a plurality of superimposed impressions in rapid succession, as for multicolor printing.

The essential constituents of the printing sheet or thermal element are the heat absorber, the vehicle with specified melting properties and the pigment or other coloring material. These may be combined in a number of ways and different advantages are obtained by the different ways, or all three may be quite separate. In general the vehicle is in a powdered form but may be in a continuous phase. The colorant is usually, but not necessarily, incorporated in the particles of the vehicle. The colorant may be discrete particles in the larger particles of the vehicle or may color the vehicle particles uniformly. The colorant may be the heat absorber itself, but it has been found preferable to include minute, almost invisible amounts of finely divided copper, silver, iron, nickel or carbon black. The heat absorber may be coated as a separate layer on the sheet support or may be incorporated into the particles of vehicle along with the colorant. One may even have the absorber in the vehicle and the pigment separate therefrom, but this arrangement appears to have no particular advantage over the ones in which the pigment and the absorbing material are both in the vehicle. The vehicle must be a warm melting material of low heat of fusion as mentioned above and is preferably a material selected from the group consisting of benzophenone, methyl o-benzylbenzoate, benzoic anhydride and p-nitro-anisole. The sheet may be carried by the support which is to form a base of the final print and may be semi-permanently attached thereto by pressure or by a soft binder or alternatively the ink sheet may be on a temporary support from which the melted areas are transferred to the final print support. Separation of the temporary support and the final print support then removes the unmelted areas from the final print as required, with or without additional brushing of the final print.

The invention will be fully understood from the following description thereof when read in connection with the accompanying drawings, in which:

Fig. 1 to Fig. 9 inclusive, show greatly enlarged cross sections of various forms of the printing ink sheet which may be used with the present invention.

Fig. 10 to Fig. 13 inclusive, illustrate four different preferred embodiments of the present invention.

Fig. 14 is a perspective view from below of another embodiment of the invention particularly showing the temperature control mechanism.

Fig. 15 is a cross section of one element of the temperature control mechanism of Fig. 14.

In each form of the invention the printing sheet includes a support, a coloring material, a vehicle for the coloring material and heat absorbing material. Various arrangements thereof are shown in Fig. 1 to Fig. 9 inclusive in which the support in each case is labeled **20**. The coloring material is labeled **21**A to **21**H inclusive, the letters being used to indicate different forms described separately below. The vehicle is labeled **22A** to **22F** inclusive. The heat absorbing layer is labeled **23A** to **23F** inclusive.

In Fig. 1 the vehicle, coloring material and heat absorber are all separate. The vehicle **22A** is in the form of discrete particles which are pressed onto but not into the support **20** and are overcoated lightly with an almost invisible amount of carbon black **23A** upon which a uniform layer of coloring material **21A** is then coated. Fusion of one or more of the particles of vehicle **22A** into the paper support **20** or onto a separate support brought into contact with the front surface of the layer **21A** carries with it a small amount of the coloring material **21A**, and perhaps also a small amount of the heat absorber **23A**. The advantage of this arrangement is the relative simplicity of operation and the easy control which is provided concerning the amount of the coloring material, etc. However, results are not as uniform as with other embodiments. Fig. 2 differs from Fig. 1 by having the heat absorbing layer **23B** coated directly on the support and by having the vehicle **22B** also coated as a continuous layer. This is perhaps the least preferable form of the invention because sharpness of definition is lost due to the unevenness of the melting of the layer **22B** as compared to the melting of a vehicle arranged as discrete particles.

Fig. 3 and Fig. 4 both show very satisfactory arrangements of the ink sheet. The heat absorbing layer **23B** is coated directly on the support and the coloring material, as pigment particles **21B** in Fig. 3 and as a dye **21C** in Fig. 4, is incorporated into discrete particles of vehicle **22C**. This arrangement has been found to work quite well and to require such a small amount of heat absorber **23B** as to be almost invisible. There is definitely not enough of the absorber **23B** present to spoil the effective color of the coloring material **21B** or **21C** even when used in four color printing.

Fig. 5 is similar to Fig. 4 in that the coloring material **21B** is included as a dye in the vehicle **22D**, but the vehicle there is a continuous one rather than formed as discrete particles.

Fig. 6 is a modification of Fig. 4 in which the heat absorber **23C** is included along with the coloring material **21E** in the vehicle **22C**. With certain coloring materials, the heat absorption is sufficient without the addition of any further heat absorber so that only a single material constitutes both **21E** and **23C**. With various coloring materials which I have used, however, I find that higher speed of operation and hence greater uniformity can be obtained when an additional amount of a separate heat absorber is added even though the amount may be very small indeed. The important property of the sheet is of course its ability to absorb heat and to leave coloring material on the final print sheet in proportion to the amount of heat absorbed.

In Fig. 7 the heat absorbing material **23D** is incorporated in the vehicle **22E** which is in the form of discrete particles in a soft binder **24**. In Fig. 7 the coloring material **21F** is included in the soft binder, but as in Fig. 6, both the coloring material and the heat absorber may preferably be incorporated in the vehicle **22E**.

In Fig. 8 both the coloring material **21G** and the heat absorber **23E** are incorporated in a soft binder and the fusible vehicle **22A** is in the form of discrete particles attached to the support **20** by the soft binder **25**. Still another embodiment is shown in Fig. 9 wherein the vehicle **22F** includes the heat absorbing material **23F**, but the coloring material **23H** is coated thereon as a separate layer of discrete particles.

In those embodiments of the invention wherein the sheet is carried by the paper or other support on which the final print is to be made, this support **20** may take practically any form. The quality of the final print depends of course on the quality of the paper, but satisfactory results may be obtained with any form of support from newsprint stock to highly varnished paper or with transparent films of various types which do not repel the ink.

The simple arithmetic of printing with any normal powdered colorant for example will show that a satisfactory print requires about 2×10^{-8} grams of solid coloring material per element of a 300 line scan image to produce a satisfactory maximum density. The highlights, of course, require less material, but any calculations as to the amount of heat required will necessarily be computed on the basis of maximum shadow density and hence this figure, representing an area 1/300 of an inch on a side, is taken as the controlling one.

The infrared absorbing layers or materials which are added to the vehicle and colorant may take various forms, especially since thermal absorption alone appears to be the controlling factor and thermal conductivity does not appear to be so important, probably because of the close proximity between the absorber and the vehicle. That is, high thermal conductivity does not appear to be necessary to conduct the heat to the vehicle, and on the other hand the presence of high thermal conductivity does not appear to be detrimental to image quality as might be expected due to the conductivity of heat from the hot areas to the adjacent cool areas of the image. Practice has shown that the hot areas are melted and a satisfactory print made long before sufficient heat is conducted to the cool areas to spoil the quality of the print. This is true even if glass or metal is used for the support for the absorbing layer as, for example, in those embodiments of the invention in which the ink image is transferred to a separate support later. The process is strictly governed by known laws of physics, but in those cases where all the parameters are not known, the results specifically contradict common beliefs. The relative minor importance of thermal conductivity of the heat absorber and of the supporting material was not expected, and it came as a pleasant surprise to find that one does not have to worry too much about this factor. It should be realized that one might even expect the conductivity of the support to prevent entirely the formation of a heat image due to radiation, but fortunately this has proven not to be the case. When the absorbing layer is a developed photographic emulsion, there is a much greater weight of the thermal insulator, gelatine, present than of the silver conducting absorber. I assume, however, that the absorbing layer and the support should not both be thermal conductors in the same example. All of this means that there is considerable latitude in the intensity and time of exposure, but the advantages of high intensity, short exposures will be analyzed later in this specification.

In the following table, a list of satisfactory vehicles is given together with the melting point in degree centigrade and the latent heat of fusion in calories per cubic centimeter:

Name	M. P., °C	Heat of Fusion, Cals. per cm.³
Phenyl Salicylate	42–43	20.1
Benzoic Anhydride	42–43	16.5
Benzyl Phthalate	42–44	16.7
α-Naphthyl Acetate	44–45	----
Benzyl Succinate	44–46	16.0
Benzophenone	47–48	25.8
Hydrocinnamic acid	47–49	30.1
Succinonitrile	47–49	11.5
Triphenyl Phosphate	49–50	20.3
Ethyl-n-Phenylcarbamate	49–51	16.6
Methyl-o-benzoylbenzoate	50–52	----
p-Nitro-anisole	51–52	----
1,3, dimethyl 1,3, diphenyl cyclobutane	51–53	14.7
Methyl β-naphthyl ketone	53–55	----
Trichloracetic acid	54–57	11.5
Acetophenone Oxime	56–58	13.2
Diphenyl	65–67	28.8

To the above table may be added rosin and synthetic resins, but since it is desirable to have a sharply melting material these are less satisfactory than those listed. On the other hand 10% of carbon ground in fused rosin will give a fairly satisfactory black and white print because the carbon acts both as the colorant and the heat absorber, particularly as suggested in connection with Fig. 6. One other factor which has been noted and which probably explains why the operation of the present invention is less critical than originally expected is the fact that deterioration of sharpness of the dot in the final image appears mainly as a transition between a halftone image and the equivalent continuous tone effect. In fact the rosin-carbon couple just mentioned gives definite indications of a continuous tone effect whereas sharply melting compounds give line print or halftones of very high contrast and dot quality.

Of the above list of suitable vehicles, benzophenone is the best for many purposes since the pigment dispersion in this vehicle is excellent and after the print has been made the vehicle solidifies very fast on cooling. Also the odor of the print is very light and pleasant. This is to be compared with p-nitro-anisole, for example, which makes quite satisfactory prints, but the heavy odor and possible toxicity render it unpleasant to work with. The first three materials have perhaps too low a melting point although everything above 30° C. can be used with fair ease. On the other hand benzoic anhydride gives quite satisfactory prints by the present photothermography process provided the material is free from contamination. This particular material is sensitive to contamination and therefore I prefer to use the benzophenone. Cyclohexanol can give a satisfactory print but since it has a melting point near room temperature it is not easy to provide for the necessary cooling of the print immediately after printing. The best region is thus about 50° C. which requires some preheating of the ink sheet accompanied by accurate control and at the same time does not require such high temperature as to be inconvenient for high speed printing. The methyl o-benzoylbenzoate is also quite satisfactory, having a negligible odor, a fair degree of pigment dispersion and the ability of giving a good quality print. It does not solidify as rapidly as benzophenone on cooling and is therefore less preferable particularly in multicolor printing where several transfers onto a single support in accurate register are required in rapid succession. It is to be understood that the invention is not limited to these particular vehicles, but they are listed here because of the various advantages which they contain The fact that the most preferable one, benzophenone, has the highest heat of fusion is interesting since this is an important factor, but its importance is out-weighed by other considerations such as thermal conductivity of the crystalline mass, pigment dispersion, rapid solidification, etc. The latent heat of fusion figures are either taken from standard reference tables or were determined specifically for the present purpose and are omitted from this table when not available. Thus the methyl o-benzoylbenzoate heat of fusion is not readily available for comparison, this material being the second best one of those listed. The third best is the benzoic anhydride which has a particularly low heat of fusion and theoretically the lower the heat of fusion the more satisfactory the material should be.

In Fig. 10 an ink sheet **30** of one of the above types is brought to a uniform temperature, about two degrees below its melting point, by means of a hot plate **31** through which water is circulated at the desired temperature. For example, the sheet **30** consists of a layer of bond paper on which there is a layer of powdered benzophenone containing a color pigment and 5% by weight of copper powder. The benzophenone powder is pressed on to the paper by suitable pressure rollers but is not bonded to the paper permanently. The hot plate **31** is accurately heated to a temperature of 45° C. which is just two degrees

below the melting point of the benzophenone. The inked paper layer **30** is left on the heater plate **31** long enough to reach this uniform temperature of 45° C. Because of the low heat capacity of the paper, the vehicle, the colorant and the heat absorber, only a few moments are required to bring the layer **30** up to the required temperature. A halftone negative **32** is placed in contact with the upper inked surface of the sheet **30** and is illuminated by a lamp **33** rich in infrared. Preferably the reflector **34** is a stainless steel shell with a matte gold plate on the reflecting area. This reflector **34** may include a water cooling system since only radiant heat is desired. The halftone negative **32** transmits a halftone negative radiant heat image on to the layer **30**. The invention works equally well with line images or other two-tone images. The hot tone areas of this image falling on the ink layer **30** causes the ink in those areas to melt and to fuse into the paper support of the sheet **30**. The time and intensity of exposure are selected so as just to melt the hot tone areas and not to melt the cold tone areas. Considerable latitude in exposure time and intensity is available because of the contrast of the heat image. The sheet **30** is then removed from the hot plate into a cooler region, such as elsewhere in the printing room and the excess unmelted areas of ink are removed, for example, by shaking the paper or by brushing mechanically or by an air blast. The term "brushing" is intended to apply both to mechanical and pneumatic brushing.

In Fig. 11 a continuous process is illustrated in which precoated paper from a stock roll **40** is fed as indicated by arrow **41** over a hot plate **42** so that it is at the correct temperature just below the melting point of the ink vehicle, as it reaches the point **43**. At this point **43** it comes into contact with a halftone negative arranged on a cylinder **44** which is rotating synchronously with the movement of the traveling sheet **40**. Light from a lamp **45** in a suitable shield **46** illuminates a line or strip of the negative **44** adjacent to the point **43** so that the ink is fused into the paper **40** forming the image thereon as the line of light from the lamp **45** scans the negative **44** and paper **40**. The paper **40** then passes over a roller **47** and excess ink is removed by a rotating mechanical brush **48**, leaving the finished print on the paper **40**. The brush **48** is arranged on a diagonal to send the ink dust to one side. This simple arrangement is one of the most satisfactory of those embodiments in which the ink is fused into the support on which it is coated as distinguished from other embodiments in which ink is transferred to a separate sheet, after the differential melting thereof.

In Fig. 12 a roll of raw paper stock **50** passes under a hopper **51** from which a powdered ink vehicle **52** containing both colorant and heat absorber is spread or dusted on to the paper forming a thin layer **53**. The sheet is then passed between pressure rollers **55** and heaters **56** so that the sheet is brought to a temperature just below the melting point of the vehicle in the powder **52**. The sheet then passes over a roller **57** whereat it is scanned by an image **58** produced by a suitable optical system shown as a lens **59**, a mask **60** and a light source **61**. The negative **62** to be printed is moved synchronously with the movement of the paper sheet, past a slit **63** in the mask **60** so that the image **58** is synchronized with the motion of the sheet being scanned. This is not "scanning" in the electro-optical sense which uses a point of light with no image differential within the point itself. In fact, the image 58 is not only more than a point which has no dimensions, but is more than a mere line with one dimension. The image 58 has both width and length corresponding to the width and length of the slit 63 as magnified by the lens 59. The image 58 thus covers a finite area and the image is defined throughout this area. The ink is fused into the paper forming a positive image therein and then by suitable air squeegee 65 all excess ink is removed from the sheet, leaving a positive halftone print as required. Instead of the squeegee 65, a simple vacuum system such as a vacuum cleaner has been found to be saisfactory for removing the excess ink. The pressure provided by the rollers 55 acts to compress the ink powder on the supporting surface 50 and this has been found to have the additional effect of reducing the exposure required at the image 58—a phenomenon not fully explained but probably due in some way to the improvement in heat transfer in the compacted powder.

By way of illustrating the exposure required, it is pointed out that, in the example given using benzophenone as a vehicle, the following factors are important. The melting point is about 47° C.; the heat of fusion is about 25 calories per cc., the heat absorption factor is about 0.8. The temperature increase of two degrees must be allowed for as well as the heat required for fusing. The thermal conductivity of the paper has a coefficient of about .0003. Thus the total heat that must be applied to an area 7″ x 7″ is about 8 calories which is equivalent in power to about 32 watt-seconds. However, when low intensity, long exposure are used there is considerable but not fatal thermal conduction loss. For example, using a 300 watt heat lamp and two seconds' exposure about 80% thermal conduction loss occurs under the most unfavorable conditions. This obviously is not too efficient although the quality of the resulting print is not too badly spoiled even by this wandering of the heat. On the other hand if one can use 5000 watts input with an exposure of only .03 second, the thermal conduction loss is only 7%.

The possibility of printing from a crystalline layer rather than a powdered layer has been investigated and this may have some advantages, but in general the image is grainy and somewhat broken compared to the ones obtained with powdered images. The fusible compounds used as vehicles together with their pigments, can be dispersed in water readily, e. g. by grinding and when dried this water color gives a fine textured coating. A print made therefrom is quite satisfactory but the energy efficiency is low compared to that when the thermal couple inks are dusted onto the paper. For color printing, any of the usual yellow, magenta and cyan pigments may be used and the additional care required for four-color printing as compared with monochrome printing by the present invention is just that due to registration and other well known problems of color photography and color printing.

In Fig. 13 there is shown a satisfactory continuous embodiment of the invention in which the fused image is transferred to a separate support after printing. In this figure a cylinder 70 is rotated as indicated by arrow 71 under an inking mechanism consisting of a hopper 72 and a roller 73 from which a uniform fusible ink 74 is coated on the cylinder 70. The cylinder is maintained at a temperature just below the melting point of the fusible ink layer 74 by heaters 75. By the time the ink arrives at an image 76 it is uniformly (along the length of the cylinder) at a temperature just below its melting point. The optical image 76 scans the layer 74 somewhat in the manner of Fig. 12. A halftone negative 80 is wrapped on a transparent cylinder 81 which rotates as indicated by the arrow 82 synchronously with the rotation of the cylinder 70 so that there is no relative movement between the ink layer 74 and the image 76 of the negative 80 as formed by the lens 83. Illumination is provided by an infrared lamp 84 and a condenser 85 which concentrates a line of light along the width of the negative 80. The hot tone areas of the image 76 melt the ink but the cool tone areas do not contain sufficient heat to do this. While the ink in the hot tone areas of the heat image is still in the melted condition, the layer 74 is brought in contact with a paper support 90 at the point 91 at which the ink layer 74 and the paper 90 pass under a pressure roller 92. If any of the unfused areas transfer with the fused areas to the paper 90, these unfused areas are removed by an air brush 93, leaving a positive print on the paper 90. Although theoretically the ink particles remaining on the cylinder 70 could be used over again, uniform results require that the cylinder be cleaned and air brushes 95, doctor blades 96 and a rotating brush 97 serve this purpose, brushing the excess unfused ink into a tray 98. This excess ink is usually reground before being replaced in the hopper 72. Obviously this is a very satisfactory embodiment of the present invention since only raw paper stock is used for making the final prints. Furthermore, the cylinder 70 may be of a black or other heat absorbing material so that the ink particles in the hopper 72 may be made up solely of the fusible vehicle and the colorant. That is, the ink sheet essential to the present invention consists in this case of the cylinder 70 and the powder coated thereon.

One relatively simple proving press according to the present invention which has been found to work quite satisfactorily is illustrated in Figs. 14 and 15. For high quality it is necessary to bring the ink sheet to a uniform temperature within a fraction of a degree of absolute uniformity. To do this, the ink sheet together with the halftone image from which it is to be printed is placed on a metal plate 100 on the bottom of which are soldered a large number of copper tubes 101. Water is fed into one end of each of these tubes 101 from a feeder chamber 102 illustrated in detail in Fig. 15. The water flows simultaneously and uniformly through all of the tubes 101 rather than back and forth through a very elongated tube, in order to obtain the maximum uniformity. With this arrangement a metal plate 6″ x 26″ was held at a temperature of 45° C. uniformly within a quarter of a degree centigrade. Two thermometers 103 and 104 at opposite ends of the plate are used to gauge the uniformity. Furthermore the temperature of the plate can be quickly brought to the desired temperature in a matter of just a few moments. To do this, water from a beaker 110 is driven by a pump 111 and motor 112 through a supply tube 113. The water after passing through the circulating system is returned to the beaker 110 by a rubber tube 114. The temperature of the water in the beaker is read off directly by a thermometer 115. Any standard thermal control system may be used for controlling the temperature of the water, but for simplicity, I simply show a Bunsen burner 116 under the beaker 110 with the flame adjusted to give the desired temperature. Very satisfactory temperature control has been obtained even with this simple arrangement although for production printing, the usual automatic temperature control mechanisms are employed such as those involving electrical heating of the water with thermostat controlled switches.

After the sheet has been brought to the temperature required it is moved from the plate 100 under an infrared lamp 120 whose radiation through a halftone negative (or into a halftone positive thermal absorber which transfers the heat to the ink layer) produced the required negative heat image. The fused ink image formed thereby is then pressed into contact with the paper 121 by suitable rollers 122 and it transfers to the paper 121.

One of the important features of the thermal control plate 100 is the method whereby the flow through the many tubes 101 is maintained uniform from tube to tube. As shown in Fig. 15 the heated water is introduced into the distributing chamber 102 by a central tube 125 having a large number of orifices 126 facing in the direction opposite to that from which the water is to flow into the tubes 101. It should be noted that the orifices 126 gradually increase in diameter as one goes from the source of supply to the end 127 of the tube 125 which is a closed end. The tubes 101 are of ¼″ brass or copper and sufficient solder is used in fastening these to the plate 100 to insure low resistance to heat transfer. The tube 125 is ½″ diameter and the orifices 126 reading from left to right are drilled respectively with drills Nos. 13, 14, 15 and so on up to 24 for 12 tubes which is the number I have used on a plate 6 inches wide although fewer are shown in the Figs. 14 and 15 for clarity. The top surface of the plate 100 which does not appear in the drawing may be provided with a groove around the edge which is connected to a vacuum system so that the ink plate and halftone negative or positive placed thereon can be held by vacuum firmly on the plate 100 while heating. This refinement, which corresponds to a vacuum back process camera, merely insured maximum uniformity in the minimum heating time.

Having thus described various embodiments of my invention I wish to point out that it is not limited to these materials and structures but is of the scope of the appended claims.

I claim:

1. The method of printing onto paper which comprises (1) coating onto a flat support a uniform layer of ink which absorbs heat producing radiation and converts it to heat and which contains a coloring material and a vehicle which is an organic compound selected from the group consisting of benzophenone and methyl o-benzoylbenzoate, said ink containing no material other than said vehicle melting within 20° C. of the melting point of the vehicle 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 paper, (2) bringing the support and ink layer to a uniform temperature below and within 20 degrees centrigrade of the melting point of the vehicle, (3) illuminating all at one time an area of said layer with heat producing radiation by projecting said radiation onto said area through a negative sheet which has radiation transparent and radiation opaque areas, said radiation being of sufficient intensity and projected for a sufficient time to raise the temperature of the ink at the radiated areas above the melting point without melting the ink at the non-radiated areas, (4) allowing the melted areas of ink to fuse to a sheet of paper forming a positive print and (5) physically removing the unmelted areas only of the ink.

2. The method according to claim 1 in which said coating of ink is directly onto said paper which thus constitutes said flat support and in which said allowing to fuse is directly to said flat support paper.

3. The method according to claim 1 including the steps of (6) immediately after said illuminating and melting of the hot areas of ink, pressing the ink layer into contact with a sheet of paper which is different from said flat support and which is at a temperature below said melting point, the hot areas of ink fusing to said sheet of paper and (7) separating the paper sheet with the positive image from the ink layer and flat support.

4. The method according to claim 1 in which the physical removing consists of brushing.

5. The method according to claim 1 in which the physical removing consists of air blasting.

6. A printing sheet comprising a support and a layer of particulate ink uniformly distributed on the support, the particles of ink consisting of a coloring material incorporated in an organic vehicle selected from the group consisting of benzophenone and methyl o-benzoylbenzoate, which vehicle melts sharply in not more than 2 centigrade degrees at a temperature between 42° C. and 52° C. with a latent heat of fusion less than 30 calories per c. c., said ink containing no material other than said vehicle melting within 20° C. of the melting point of said vehicle.

7. A powdered printing ink to be spread uniformly on paper for printing by fusion consisting of a coloring material and a minute amount, less than an amount substantially visible in the presence of said coloring material, of a finely divided heat absorbing material selected from the group consisting of copper, silver, and nickel incorporated in benzophenone.

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