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(54) IMPROVEMENTS IN AND RELATING TO THERMAL PLAIN-PAPER RECORDING SYSTEMS

(71) We, NIPPON TELEGRAPH AND TELEPHONE PUBLIC CORPORATION a Japanese Body Corporate of 1—6 Uchisaiwaicho 1-chome, Chiyoda, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a thermal plain-paper recording system for thermally recording a visible image on a recording sheet.

According to a first aspect of the invention, there is provided a thermal plain-paper recording system comprising heater means including a heating element adapted to be energised and de-energised in response to a series of time-spaced signals, a transport system for transporting a recording sheet through the system in one direction with one of the surfaces thereof in contact with said heater means, and heat-sensitive coloring substance supply means for supplying a heat-sensitive coloring substance over the other surface of said recording sheet, whereby in use, said heat-sensitive coloring substance is adhered to said other surface of said recording sheet in accordance with a distribution of heat over the sheet produced by said heater means in response to said series of time-spaced signals.

According to a second aspect of the invention, there is provided a thermal plain-paper recording system comprising first and second heater means spaced apart from each other in the direction of transport of a recording sheet through the system, arranged for contact with one of the faces of said recording sheet during transport of the recording sheet and adapted to be energized and de-energized in response to a series of time-spaced signals, and first and second heat-sensitive coloring substance supply means so disposed in relation to said first and second heater means that, in use, said supply means supply first and second heat-sensitive coloring substances respectively over the other surface of a recording sheet transported through the system, whereby, in use, said first and second heat-sensitive coloring substances are thermally adhered to said the other surface of said recording sheet in accordance with a distribution of heat on the sheet produced by said first and second heater means in response to said series of time-spaced signals.

The following is a more detailed description of some embodiments of the invention, by way of example, reference being made to the accompanying drawings, in which:—

Figs. 1 to 8 are schematic views of first to eighth preferred embodiments, respectively, of a thermal plain-paper recording system in accordance with the present invention;

The first, second and third embodiments, shown in Figs. 1 to 3, respectively, are of a type incorporating a magnetic brush;

The fourth embodiment, shown in Fig. 4, is of a type wherein unused toner is recovered from a recording sheet by means of a suction blower for recirculation or reuse;

The fifth embodiment, shown in Fig. 5, is of a type wherein a heat-sensitive coloring substance is circulated and blown over a recording sheet;

The sixth embodiment, shown in Fig. 6, is of a type wherein a heat-sensitive coloring substance is scattered and dispersed upwardly toward a recording sheet by vibration caused by a vibrator;

The seventh embodiment, shown in Fig. 7, is of a type wherein two-color or multi-color images may be recorded;

The eighth embodiment, shown in Fig. 8, is of the type wherein a flowable heat-sensitive coloring substance or ink is used; and

Figs. 9a and 9b are views used for the explanation of an image formation process in conjunction with the seventh embodiment shown in Fig. 7.

The same reference numerals are used to designate similar parts throughout the figures.

In Fig. 1, the first embodiment of a thermal plain-paper recording system has a recording sheet 10 advanced in a direction indicated by the arrow by a transport system comprising a drive or capstan roller 13 co-operating with a pressure or pinch roller 14, the drive roller 13 being drivingly coupled by an endless belt 12 to a motor 11 connected to power source 26. A heating element 16 of a heater or thermal print head or hot stylus 15 contacts the undersurface of the recording sheet 10 and is supplied with a series of time spaced heating and cooling signals from a driver circuit 19 through a lead wire 17 and in response to signals from a signal source 18; the driver circuit 19 being connected to a power source 28. A coloring substance supply device, generally indicated by the reference numeral 20, is disposed on the opposite side of the recording sheet 10 to the heating element 16 and comprises a magnetic brush 23 which is driven through an endless belt 22 by a motor 21 which in turn is powered from a power source 27. The supply device also includes a hopper 25 storing a heat-sensitive coloring substance 24 which is magnetizable to allow the substance to be disposed around the periphery of the magnetic brush 24.

In operation, the driver circuit 19 generates the hot or heating and cooling or cold signals in response to the signals from the signal source 18, and these hot and cold signals are applied through the lead wire 17 to the heating element 16 of the hot stylus 15 so that desired portions or elemental areas of the recording sheet 10 are heated or left unheated. The heat-sensitive coloring substance 24 then adheres to the heated elemental areas, thus forming images 29 or dots which define images.

In Fig. 2 the embodiment is substantially similar in construction to the first embodiment described above in conjunction with Fig. 1 except that the magnetic brush 23 is provided with a sleeve 30 and the hot stylus 15 is provided with auxiliary heating elements 32 energizable by a power source 31. Unlike the first embodiment in operation of the second embodiment, the magnet 23 is maintained stationary while the sleeve 30 is driven by the motor 12. Since the auxiliary heating elements 32 are provided, the heating element 16 may be maintained at a temperature lower than a softening or melting point of the heat-sensitive coloring substance 24, and this arrangement is advantageous in that the power consumption of the heating element 16 may be reduced by half, as compared with the first embodiment.

In Fig. 3, the third preferred embodiment of the present invention is substantially similar in construction to the second embodiment except that an auxiliary heating element 34 energized by a power source 33 is disposed adjacent the undersurface of the recording sheet 10 for preheating the recording sheet. The third embodiment also has the advantage that the power consumption of the heating element of the hot stylus 15 may be reduced by half as compared with the first embodiment.

In Fig. 4, the fourth preferred embodiment of the present invention is substantially similar in construction to the first embodiment except that the heat-sensitive coloring substance supply device comprises a heat-sensitive coloring substance hopper 35 including a feed roller 38 drivingly coupled through an endless belt 37 to a motor 36 connected to a power source 43, a heat-sensitive coloring substance suction duct 41 with a suction port located downstream of the hopper 35, a suction blower 40 which has a suction port communicated with the duct 41 and is driven by a motor 39 which in turn is energized by a power source 44, and a cyclone dust collector 42 whose inlet opening is communicated through a duct with a discharge port of the suction blower 40 and whose discharge opening is directed toward the hopper 35.

In operation, the feed roller 38 rotates in the direction indicated by the arrow to spread, the heat-sensitive coloring substance 24 over the recording sheet 10. It is not important whether or not the heat-sensitive coloring substance 24 is uniformly distributed over the recording sheet 10, but it is essential that the coloring substance 24 is continuously spread over the recording sheet 10 without any discontunity. To this end it is preferable to spread the heat-sensitive coloring substance in a relatively large amount. The heat-sensitive coloring substance 24 adheres only to the elemental areas of the recording sheet 10 which are heated by the hot stylus 15 to form an image or dot 29, and the heat-sensitive coloring substance 24 on the elementary areas which have not been heated is sucked through the duct 41 by the suction blower 40 to be returned to the cyclone dust collector 42, from which the heat-sensitive coloring substance 24 is charged into the hopper 35 for reuse. In the first to fourth embodiments described above with reference to the drawings, only one hot stylus 15 is shown, but it will be understood that a plurality of such hot styli 15 may be arranged in a desired pattern.

In Fig. 5, the fifth preferred embodiment of the present invention is substantially similar to the fourth embodiment shown in Fig. 4 except that the heat-sensitive coloring substance supply device is provided with a heat-sensitive coloring substance recirculation duct 46 in the form of a loop having a feed opening 45 extending transversely of the recording sheet 10, which is moved in a direction normal to the plane of Fig. 5. A suction blower 47 driven by a motor 48 is arranged in the duct 46 so that unused coloring substance 24 may be sucked and recirculated as indicated by the arrows. Therefore the feed roller 38 feeds the heat-sensitive coloring substance in an amount sufficient to supplement the used coloring substance 24. The thermal print head 15 has a plurality of heating elements 16 in contact with the undersurface of the recording sheet 10 and energizable in response to the hot and cold signals from the driver circuit 19.

In Fig 6, the sixth preferred embodiment of the present invention has the hot stylus 15 and its associated components disposed on the upper surface side of the recording sheet 10 transported in the direction indicated by the arrow, while a heat-sensitive coloring substance supply device is disposed below the recording sheet 10. The supply device comprises a vibrating, coloring substance storage container 49 disposed opposite the hot stylus 15 and a vibrator 51 attached to a bottom 50 of the container 49 and operatively connected to a power source 52. The bottom 50 of the container 49 is vibrated by the vibrator 51 so that the heat-sensitive coloring substance 24 in the container 49 is caused to scatter and disperse upwardly toward the undersurface of the recording sheet 10 and adheres to the heated elemental areas to form the images or dots 29.

The first to sixth embodiments described above have common advantages in that a thermal print head or a plurality of hot styli may be used for electron switching or scanning purpose and that the recording system may be made compact in size and simple in construction because only the thermal print head or hot styli and the heat-sensitive coloring substance supply device are used to form images or dots.

The recording sheet, the heat-sensitive coloring substance and other components will now be described in more detail. Two types of heater 15 may be used, one type being a hot stylus which is normally energized and the other type being such that it is selectively energized in response to an electrical signal. The latter type may be assembled in the form of a thermal print head for thermally recording various patterns.

The recording sheet 10 may be of paper, a plastics material, or metal foil, and a laminated sheet may be also used. With the recording sheet of paper, it has been found that the higher the bulk density and the thinner the thickness of the paper, the better the resulting images or dots; the bulk density being defined as:

weight per unit of area (gram/m^2) / thickness microns). It is preferably more than 0.8 or between 0.8 and 1.55.

The heat-sensitive coloring substance is preferably made of compounds having a relatively low melting or softening point. When it is made of a colorless compound, it is preferable to color or add a pigment so that a visible image may be formed. To this end, it is preferable to use a toner which is widely used in electrography and electrostatic recording systems. In electrophotography, the toner transferred onto a recording sheet is thermally fixed after development, and moreover the toner is colored so that it can be used in the embodiments described with reference to the drawings. However, it is desirable that the toner used in the embodiments described with reference to the drawings efficiently adheres to the recording sheet at a temperature lower than the fixing temperature used in electrophotography. That is, the toner will not exhibit adhesiveness at room temperature, but will adhere strongly to the recording sheet at a temperature slightly higher than room temperature. For instance, the toner may be made of polystylene resin, an epoxy resin, polyvinylchloride and polyvinylbutyral and other organin compounds having a melting point between 50 and 200°C. Moreover, it is preferable that the toner has a low thermal conductivity so that a rapid temperature drop of the toner may be avoided. To this end, two methods may be used. One method is to use a compound having a low thermal conductivity while the other method is to make the toner porous. Compounds with a low thermal conductivity are, for instance, polyvinylchloride, polystyrene, polymethacrylate, natural rubber, and natural compounds such as silica, dried clay, mica, and oxides such as titanium oxide, glass, silicon oxides, aluminium oxides.

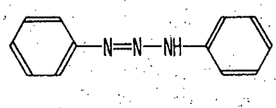
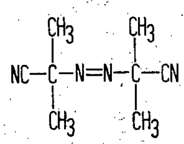
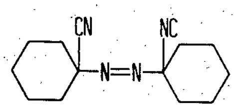
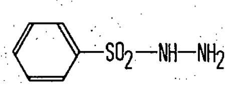
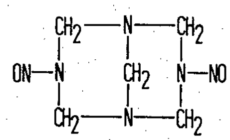
In general, porosity is very closely corelated with thermal conductivity. Therefore a low thermal conductivity, heat-sensitive coloring substance may be made of, for instance, a mixture consisting of a porous compound such as cyclor dextrin, cellulose powder, porous silica or a like thermoplastic resin, and a pigment. Alternatively, it may be made of a foam plastics material as will be described in detail below. The fact that natural silica with the porosity of 3% has a thermal conductivity three times as high as natural silica with the porosity of 15% proves that the higher the porosity of a compound, the lower the thermal conductivity of that compound becomes.

Porous or foam plastics materials can be manufactured in general by (a) a physical method utilizing gas under pressure, (b) a method utilizing a solvent, (c) a method including foaming plastics with foaming agents and (d) a chemical method.

Therefore the porous, heat-sensitive coloring substance can be manufactured by the physical method (a) by heating, under high pressure (100 to 300 times atmospheric pressure), a mixture of powders including thermoplastic resins. Alternatively, it can be manufactured by dissolving into the powder mixture an inert gas such as the nitrogen, carbon dioxide or the like at room temperature and charging the powder mixture into an air stream of 300 to 400°C.

The foaming method (b) generally uses thermoplastic resins. For instance, salt or the like is added as a solvent into polyvinylchloride, and is mixed with a pigment and a stabilizer by cooled rolls. Thereafter the mixture is crushed, and the salt is removed with water. Thus, the porous, heat-sensitive coloring substance is obtained.

The foaming method (c) utilizes inorganic and organic foaming or blowing agents which are thermally decomposed to generate or liberate gases such as nitrogen, carbon dioxide, formalin. Alternatively, a solvent having a low boiling point such as alcohol, benzene, acetone or ether, is heated in excess of its boiling point to foam plastics. The inorganic foaming or blowing agents are for instance bicarbonate, peroxide, aside compounds, and the typical organic foaming or blowing agents are listed below:

Name	Formula	Decomposition Point, °C	Gas Liberated
Diazoamino-benzene		97	N_2
Azoisobutyro-nitrile		103 – 104	N_2
Azocyclohexyl-nitrile		114 – 115	N_2
Benzenesulfo-hydrozine		103 – 104	N_2
Dinitrosopenta-methylene-tetramine		202 – 203	N_2, CH_2O
Calciumazide	CaN_6	110	N_2

The porous, heat-sensitive coloring substance may be manufactured by the foaming method (d). In this method, the phenomenon that urea resin, phenol resin, polyester, isocyanate resin, upon being heated will decompose and liberate gases such as formalin, CO_2, and water, which form small bubbles (foam cells).

With the low thermal conductivity and/or porous, heat-sensitive coloring substances of the types described, the thermal energy required for adhering them to the recording sheets can be considerably reduced. With a conventional toner or heat-sensitive coloring substance having a greater thermal conductivity, there has been observed a tendency of the toner to adhere too much to the recording sheet. This problem may be substantially solved with the toner or heat-sensitive coloring substances described above. Furthermore, such substances give improved image quality and economic advantages.

In addition to the heat-sensitive coloring substances of the types described above, compounds which exhibit plasticity at room temperature or when heated may be also used in the embodiments of the invention described above with reference to the drawings. For instance, polyvinylacetate or emulsion type resins with a pigment or dye may be used. This type of heat-sensitive, coloring substance exhibits plasticity or elasticity at room temperature and increases its adhesiveness at a temperature higher than room temperature.

Regarding a magnetized toner, reference is made to Japanese Patent Publication Nos. 37—14799 and 43—3434 and US Patent No. 3,639,245. However, in the embodiments of the invention described with reference to the drawings it is not required to make the heat-sensitive coloring substances of electrically conductive compounds or to impart the electroconductivity to the heat-sensitive coloring substances so that the limitations imposed upon the materials for heat-sensitive coloring substances may be much relaxed and consequently the freedom of the selection of materials may be considerably increased.

When the magnetized, heat-sensitive coloring substance is used in the first, second and third embodiments, the maintenance of the recording system may be simplified and facilitated. That is due to the fact that the magnetized, heat-sensitive coloring substance itself serves as a carrier, and thus other carriers are not required. Therefore, the problem of adhesion of carriers may be solved. In the second and third embodiment shown in Figs. 2 and 3, the rotary sleeve 30 be divided into a portion affected by the magnetic fields of the stationary magnet 23 and a portion unaffected thereby. Therefore when the heat-sensitive coloring substance adheres to the sleeve 30, it may be removed from the unaffected portion thereof. The heat-sensitive coloring substance adhered to the sleeve 30 may be physically or chemically removed. For example, there are a physical method for scraping away the substance from the sleeve 30 and a chemical method for wiping the sleeve 30 by solvent.

In general, when a heat-sensitive coloring substance is heated, its particle size is increased. Since the heat-sensitive coloring substance can be completely removed off the sleeve 30 as described above, the over-sized particles of the heat-sensitive coloring substance may be easily removed by a suitable conventional screening method.

In Fig. 7, the seventh preferred embodiment of the present invention is capable of reproducing multi-color copies. The seventh embodiment is substantially similar in construction to the sixth embodiment except that additional hot stylus and heat-sensitive coloring substance supply device are installed. That is, the heating elements 16a and 16b of the first and second hot styli 15a and 15b are spaced apart from each other by a suitable distance in the direction of transport of the recording sheet 10, and first and second heat-sensitive coloring substance containers 49a and 49b are disposed in opposed relationship with the first and second heating elements 16a and 16b, respectively. First and second vibrators 51a and 51b are attached to the bottoms 50a and 50b, respectively, of the first and second containers 49a and 49b and are operatively connected to a power source 52. The heating elements 16a and 16b are electrically connected to driver circuits 19a and 19b, respectively, so that they may be energized in response to the hot signals from the first and second driver circuits 19a and 19b in a manner substantially similar to that described above with reference to Figures 1 to 6. The driver circuits 19a and 19b are connected to a common power source 28 and independent signal sources 18a and 18b, respectively.

In operation, the first and second heat-sensitive coloring substances 24a and 24b are scattered and dispersed upwardly toward the undersurface of the recording sheet 10 as the first and second containers 49a and 49b are vibrated by the vibrators 51a and 51b. Then the first or second hot stylus 15a or 15b is energized in response to the hot signal from the driver circuit 19a or 19b, the heating element 16a or 16b is heated so that the heat is transmitted through the recording sheet 10 from the upper surface to the undersurface thereof. As a result, the first or second heat-sensitive coloring substance 24a or 24b adheres to heated elementary areas, thereby forming the images or dots 29a and 29b.

In this embodiment, it is assumed that the first heat-sensitive coloring substance 24a is black while the second coloring substance 24b, red and that the first and second heating elements 16a and 16b are energized in response to the black and red pattern signals. Then the image or dot 29a is black while the image or dot 29b, red, and two-color (black and red) copies or records may be reproduced.

When the thermal printer heads or hot styli and their corresponding heat-sensitive coloring substances of different colors are increased in number, multi-color copies or records can be obtained. Furthermore, the dots or image of each color may be wholly or partly overlapped to form combinations of many colors. To this end, the dots in each color must be exactly registered with each other in order to avoid color misalignments. One countermeasure may be to form a pair of hot styli 15a and 15b as an integral unit in order to exactly maintain the distance therebetween, but this method cannot overcome the color fringing due to the different thermal expansions of the hot styli 15a and 15b. This problem, however, can be substantially solved as described below.

This solution is based on the additive or subtractive process in a light absorbing area. That is, when the first dot 29a of the first heat-sensitive coloring substance 24a is overlapped by the second dot 29b of the second heat-sensitive coloring substance 24b, an additively or subtractively mixed color is produced. The first additive type heat-sensitive coloring substance 24a consists of a thermally fusable resin, a pigment of a desired color and a transparent substance capable of producing some color only when thermally fused and mixed with the second heat-sensitive coloring substance 24b. Therefore the first dot 29a as formed on the recording sheet 10 exhibits its inherent color, but when it is overlapped partly or wholly by the second dot 29b an additively mixed color is seen. For instance, assume that the first additive type heat-sensitive coloring substance is red and that the second additive type heat-sensitive coloring substance 24b is colorless but capable of producing its inherent color blue only when thermally fused and reacted with the transparent substances contained in the first additive type heat-sensitive coloring substance 24a. Then the first dot 29a as formed is red, but when it is overlapped by the second dot 29b, the overlapped portion becomes dark green or black. The second dot 29b which is not overlapped with the first red dot 29a is transparent.

The examples of the combinations of heat-sensitive additive type coloring substances are listed below:

1. Ferric stearate and tannic acid,
2. Nickel palmitate and sodium thisulfate,
3. Silver oxalate and polyhydroxy alcohol,
4. Silver behenate and protocutechuic acid,
5. Lead behenite and ethylene thiourea,
6. Leuco dye and phenol compounds, organic acids or acidic terra abla, and
7. pH-indicators and acidic or alkaline compounds.

Next a subtractive method or process will be described. The first heat-sensitive coloring substance 24a is color subtractable while the second heat-sensitive coloring substance 24b is a color subtracting agent. Here the color subtraction means that the visible color of the first heat-sensitive coloring substance 24a are decreased by the superimposition of the second heat-sensitive coloring substance 24b. Color subtractable substances contain a mixture of a color forming substance which is colorless or lightly colored and a developer which is colorless. For instance, the color forming substance may be lactone compounds, lactam compounds, sultone compounds, spiropyran compounds, leucotriphenyl methan compounds, leucodiphenyl methan compounds, amyl phenothianzine compounds and the developers are for instance phenol compounds, phenol resin, organic acids, Kaolin-type mineral, silicic acid anhydride, aluminum oxide.

The first heat-sensitive coloring substance 24a therefore consists of a colored substance which is not chemically or thermally affected by the second heat-sensitive coloring substance 24b and a color subtractable substance which is color subtracted by the second coloring substance 24b. The color subtracting substance 24b consists of for instance poly ether and its derivatives, polyethylene glycol derivatives and the like. For instance, assume that the first heat-sensitive coloring substance includes a black pigment. Then the portion of the first dot 29a overlapped with the second dot 29b turns red.

In Fig. 8 the eighth embodiment of the present invention utilizes a plastic flowable, heat-sensitive coloring substance. The eighth embodiment is substantially similar in construction to the first embodiment except that the heat-sensitive coloring substance supply device comprises an ink applicator roller 53 driven through an endless belt by a motor 54 powered by a power source 55 and a doctor 57 for inking the applicator roller 53 with a plastic flowable, heat-sensitive coloring substance 56, hereinafter referred to as "ink." When the ink 56 is in contact with an elemental area of the recording sheet 10 which is heated by the hot stylus 15, it is fused and adhered to the recording sheet 10, forming images or dots 58. As a result, recesses or cavities 59 are formed in the layer of ink 56 around the applicator roller 53, but they may be filled with the ink 56 by the doctor 57 as the applicator roller 53 rotates in the direction indicated by the arrow, so that a continuous layer of ink 56 is always in contact with the recording sheet 10. A large number of copies or recordings may be obtained without causing any serious degradation or ageing of the ink 56 and applicator roller 53.

The ink 56 must be plastic and flowable and exhibit increased adhesivity when heated. The compounds which satisfy these conditions are for instance carnauba wax, paraffin, vinylchloride with a low degree of polymerization, plastics added with plasticizers and, colloidal solutions, but most of these materials are colorless so that dyes and pigments must be added to them. In operation, it is preferable normally to heat the ink 56 in order to adjust suitably the plasticity or flowability of the ink 56.

Next some EXAMPLES of the present invention will be described in conjunction with the preferred embodiments thereof.

EXAMPLE 1.

The recording system shown in Fig. 1 was used with a magnetized black toner used in electrophotography. The recording sheet 10 was transported at a speed of about 30 cm/min. while the hot stylus 15 was intermittently energized. A straight line consisting of 20 black dots per centimeter was obtained. Since the straight line was lightly adhered to the recording sheet 10, this sheet was heated at 200°C for a few seconds with a heating plate to fix the dots so as to obtain a permanent image.

EXAMPLE 2.

Following the procedures of EXAMPLE 1, a straight line consisting of black dots was recorded on a recording sheet of polyester film, and then the polyester film (25 μm thickness) was placed in contact with a plain paper sheet and was heated to 200°C. Thereafter the sheet and film were separated from each other and the black straight line was transferred onto the plain paper sheet. Since the thermal conductivity of the plain paper sheet does not affect the recording process, thick plain paper sheets may be used.

EXAMPLE 3.

The recording system of a type shown in Fig. 2 was used with the auxiliary heating elements 32 being normally energized so as normally to maintain the temperature of the hot stylus 15 at about 70°C. A heat-sensitive coloring substance having a softening point between 121°C and 128°C was used. The power consumption of the heating element 16 could be reduced by one half as compared with a recording system not provided with the auxiliary heating elements 32.

EXAMPLE 4.

The recording system of the type shown in Fig. 3 was used so that the recording sheet 10 was preheated to 90°C by the auxiliary heating element 34. The recording was made following the procedures of EXAMPLE 1, and it was found that the power consumption of the hot stylus 15 is reduced to one half as compared with a recording system not provided with the preheating element 34.

EXAMPLE 5.

The recording system of the type shown in Fig. 4 was used, and wax powder having a melting point of about 80°C was used as the heat-sensitive coloring substance 24. The image obtained was colorless so that the recording sheet 10 was heated again to melt the wax image and a red pigment was sprayed over the recording sheet 10 so as to obtain a red image

EXAMPLE 6.

The recording system of the type shown in Fig. 5 was used, and a powder consisting of carbon black and finely divided particles of thermoplastic resin was sprayed as a heat-sensitive coloring substance 24 over the recording sheet 10 while the heating elements 16 were selectively energized so that a black image was obtained.

EXAMPLE 7.

The two-color recording system of the type shown in Fig. 7 was used. The first heat-sensitive coloring substance 24a consisted of 50% by weight of red iron oxide and 50% by weight of finely divided particles of bisphenol-A, and the second coloring substance 24b consisted of crystal violet lactone. In order to form a red image 24a, the first hot stylus 15a was energized while the second hot stylus 15b was kept de-energized. To form a black image, a red image or dot was first formed and then was reheated by the second hot stylus 15b so that the bisphenol-A contained in the first heat-sensitive coloring substance 24a and crystal violet lactone contained in the second coloring substance 24b reacted to produce a blue pigment. The red and blue pigments are additively mixed to produce greenish black so that a dot or image 29b′ in which the first heat-sensitive coloring substance 24a was overlapped with the second coloring substance 24b turned to greenish black. Since the second coloring substance 24b was colorless, the image or dot formed thereby and out of contact with the image or dot of the first coloring substance 24a remains colorless. Therefore the image formed on the recording sheet 10 essentially consists of dots of the first heat-sensitive coloring substance 24a formed by the energized hot stylus 15a so that a color misalignment problem will not occur which will degrade the image quality.

EXAMPLE 8.

The recording system of the type shown in Fig. 7 was also used in this example. The first heat-sensitive coloring substance 24a was prepared by mixing two parts by weight of 3, 7-bisdiethylamino fluoran, two parts by weight of p-hydroxybenzoate and one part by weight of cadminum red with 10 parts by weight of toluene, drying this solution to obtain black substance and thereafter finely dividing this black substance. The second coloring substance 24b consisted of finely divided particles of polyethylene glycol which reacts with 3, 7-bisdiethylamino fluoran contained in the first heat-sensitive coloring substance 24a so as to render 3, 7-bisdiethylamino fluoran colorless.

Following the procedures of EXAMPLE 7, first a black image or dot was formed by energizing the first hot stylus 15a, and thereafter the second hot stylus 15b was energized to heat the black dot so that the second coloring substance 24b was overlapped or superimposed on the black dot, which in turn was subtractively turned to red.

In both EXAMPLES 7 and 8, the elemental area heated by the first hot stylus 15a is smaller than the elemental area heated by the second hot stylus 15b in order to avoid the color misalignments due to the misregistration of the elemental areas heated by the first and second hot styli 15a and 15b. This will be described in more detail with particular reference to Figs. 9A and 9B. When, as shown in Fig. 9A, the first and second dots 60 and 61 of the first and second coloring substance 24a and 24b, respectively, have the same size, even a very small misregistration between the first and second dots 60 and 61 leaves some portion (white area) of the first dot 60 uncovered with the second dot 61, the overlapping portion being indicated by black. However, when the second dot 61 is larger in size than the first dot 60 as shown in Fig. 9B, the first dot 60 is completely overlapped with the second dot 61 even when there occurs some misregistration or misalignment therebetween so that the colors of the first and second dots 60 and 61 may be completely additively or subtractively mixed as indicated by 62. Moreover the second coloring substance 24b and hence the second dot 61 are colorless so that the portion of the second dot which does not overlap with the first dot 61 remains colorless or is not "recorded". One method for varying the areas of the first and second dots 60 and 61 is to vary the elemental areas to be heated by the first and second hot styli 15a and 15b, and another method is to vary the heating time and/or the heat applied to the elemental areas. By either method good image quality may be ensured.

EXAMPLE 9.

The recording system as shown in Fig. 8 was used with the ink 56 consisting of paraffin having a melting point between 42 and 44°C and carbon black. The recording sheet 10 was transported at a speed of 30 cm/min., and a black straight line consisting of 20 dots per centimeter was formed. The recording sheet 10 was not colored by mere contact with the black ink 56, but is colored only when heated.

EXAMPLE 10.

Following the procedures of EXAMPLE 9, recording was made with emulsion wax on a plain paper sheet. The image thus obtained was discernible because of the difference in transparency.

EXAMPLE 11.

Following the procedures of EXAMPLE 9, the recording was made with a plastic flowable ink 56 consisting of vinylchloride with the degree of polymerization of about 300 added with oilblue-G extra, the temperature of the ink being maintained about 50°C. An image of a straight line was obtained.

WHAT WE CLAIM IS:—

1. A thermal plain-paper recording system comprising heater means including a heating element adapted to be energized and de-energized in response to a series of time-spaced signals, a transport system for transporting a recording sheet through the system in one direction with one of the surfaces thereof in contact with said heater means and heat-sensitive coloring substance supply means for supplying a heat-sensitive coloring substance over the other surface of said recording sheet, whereby in use, said heat-sensitive coloring substance is adhered to said other surface of said recording sheet in accordance with the distribution of heat over the sheet produced by said heater means in response to said series of time-spaced signals.

2. A thermal plain-paper recording system as defined in claim 1 wherein said heater means are arranged in a row extending in a direction which is, in use, across the width of the recording sheet.

3. A thermal plain-paper recording system as defined in claim 1 or claim 2 wherein said heater means comprises a plurality of heating elements arranged in a row extending in a direction which is, in use, across the width of the recording sheet.

4. A thermal plain-paper recording system as defined in any one of claims 1 to 3 wherein said heater means include auxiliary heating elements which, in use, are normally energized by power source means.

5. A thermal plain-paper recording system as defined in any one of claims 1 to 3 wherein there is provided a preheating element which, in use, is normally energized by a power source means and, contacts said recording sheet for preheating the recording sheet before the recording sheet reaches the heating means.

6. A thermal plain-paper recording system as defined in any one of claims 1 to 5 wherein said heat-sensitive coloring substance supply means includes a magnetic brush which, in use, rotates to supply said heat-sensitive coloring substance to the recording sheet.

7. A thermal plain-paper recording system as defined in any one of claims 1 to 5 wherein said heat-sensitive coloring substance supply means includes a stationary magnet and a sleeve fitted thereover, the sleeve, in use, rotating to supply said heat-sensitive coloring substance to the recording sheet.

8. A thermal plain-paper recording system as defined in any one of claims 1 to 5 wherein said heat-sensitive coloring substance supply means is for spraying said heat-sensitive coloring substance over said other surface of said recording sheet and includes a suction blower for recovering unused heat-sensitive coloring substance therefrom for recirculation after heating by said heating means.

9. A thermal plain-paper recording system as defined in any one of claims 1 to 5 wherein said heat-sensitive coloring substance supply means is for blowing said heat-sensitive coloring substance over said other surface of said recording sheet.

10. A thermal plain-paper recording system as defined in any one of claims 1 to 5 wherein the transport system is for transporting the recording sheet in a horizontal disposition and

wherein said heat-sensitive coloring supply means is disposed beneath the path of the recording sheet and includes a vibrator for vibrating a supply of said heat-sensitive coloring substance so that, in use, said heat-sensitive coloring substance is scattered and dispersed upwardly toward said other surface of said recording sheet.

11. A thermal plain-paper recording system as defined in any one of claims 1 to 10 wherein the heat-sensitive coloring substance supply means contains a heat-sensitive coloring substance including magnetic particles.

12. A thermal plain-paper recording system as defined in any one of claims 1 to 11 wherein the heat-sensitive coloring substance supply means contains a heat-sensitive coloring substance including porous materials.

13. A thermal plain-paper recording system as defined in any one of claims 1 to 11 wherein the heat-sensitive coloring substance supply means contains a heat-sensitive coloring substance having a porous structure.

14. A thermal plain-paper recording system as defined in any one of claims 11 to 13 wherein said magnetic particles are selected from a thermally adherent organic compound group consisting of polystylene resin, epoxy resin, polyvinylchloride and polyvinylbutyral.

15. A thermal plain-paper recording system as defined in any one of claims 1 to 10 wherein the heat-sensitive coloring substance consisting of a plastic flowable ink.

16. A thermal plain-paper recording system as defined in claim 15 wherein said ink includes paraffin or polyvinylacetate.

17. A thermal plain-paper recording system comprising first and second seater means spaced apart from each other in the direction of transport of a recording sheet through the system, arranged for contact with one of the surfaces of said recording sheet during transport of the recording sheet and adapted to be energized and de-energized in response to a series of time-spaced signals, and first and second heat-sensitive coloring substance supply means so disposed in relation to said first and second heater means that, in use, said supply means supply first and second heat-sensitive coloring substances respectively over the other surface of a recording sheet transported through the system, whereby in use, said first and second heat-sensitive coloring substances are thermally adhered to said the other surface of said recording sheet in accordance with a distribution of heat on the sheet produced by said first and second heater means in response to said series of time-spaced signals.

18. A thermal plain-paper recording system as defined in claim 17 wherein said second heater means is, in use, so energized that said second heat-sensitive coloring substance is caused to adhere thermally to and overlap with an image or dot formed by said first heat-sensitive coloring substance on energization of said first heater means.

19. A thermal plain-paper recording system as defined in claim 17 or claim 18 wherein a plurality of first and second heater means are provided, each of said plurality having corresponding first and second heat-sensitive coloring substance supply means.

20. A thermal plain-paper recording system as defined in claim 18 wherein the first and second heat-sensitive coloring substance supply means contain respective first and second heat-sensitive coloring substances and wherein, when in use, said second heat-sensitive coloring substance is overlapped with an image or dot formed by the first heat-sensitive coloring substance on energization of said first heater means, an additively mixed color is produced.

21. A thermal plain-paper recording system as defined in claim 18 wherein the first and second heat-sensitive coloring substance supply means contain respective first and second heat-sensitive coloring substances and wherein, when in use, said second heat-sensitive coloring substance is overlapped with an image or dot formed by the first heat-sensitive coloring substance on energization of said first heater means, a subtractively mixed color may be produced.

22. A thermal plain-paper recording system as defined in any one of claims 18 to 21 wherein said second heater means is such that, in use, said second heater means heats an elementary area of said recording sheet greater than an elementary area heated by said first heater means.

23. A thermal plain-paper recording system as defined in claim 20 wherein said first heat-sensitive coloring substance includes a colorless or lightly colored compound selected from a group consisting of lactones, lactames, sultones, spiropyrans, leucotriphenylmethanes, leucodiphenylmethanes, and almiphenothiazins; and said second heat-sensitive coloring substance includes a compound selected from a group consisting of phenols, phenol resins, organic acids, kaoline type minerals, silicic acid anhydride, and aluminum oxides.

24. A thermal plain-paper recording system as defined in claim 21 wherein said first heat-sensitive coloring substance includes one compound or a combination of compounds selected from a group consisting of lactones, lactames, sultones, and a group consisting of phenols, phenol resins and organic acids; and said second heat-sensitive coloring substance includes one compound selected from a group consisting of poylethers, derivatives thereof, polyglycols and derivatives thereof.

25. A thermal plain-paper recording system substantially as hereinbefore described with reference to Figure 1 or to Figure 2 or to Figure 3 or to Figure 4 or to Figure 5 or to Figure 6 or to Figure 7 and 9 or to Figures 8 and 9 of the accompanying drawings.

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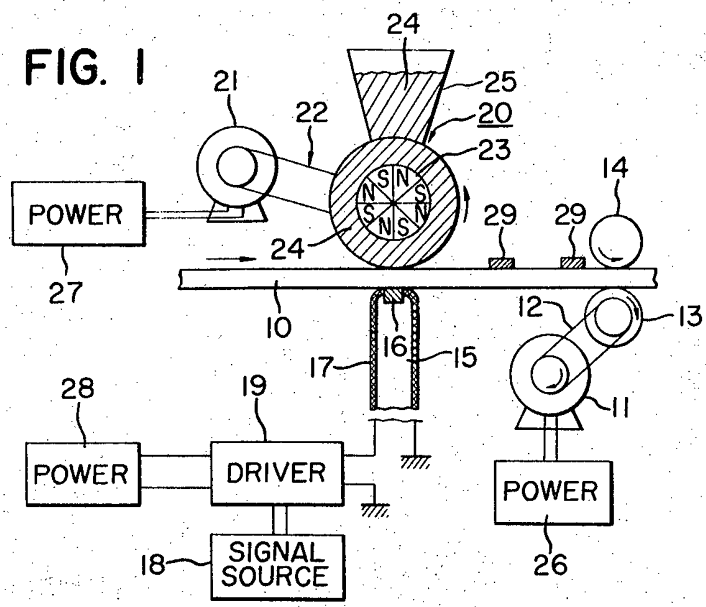
FIG. 1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18
SIGNAL SOURCE
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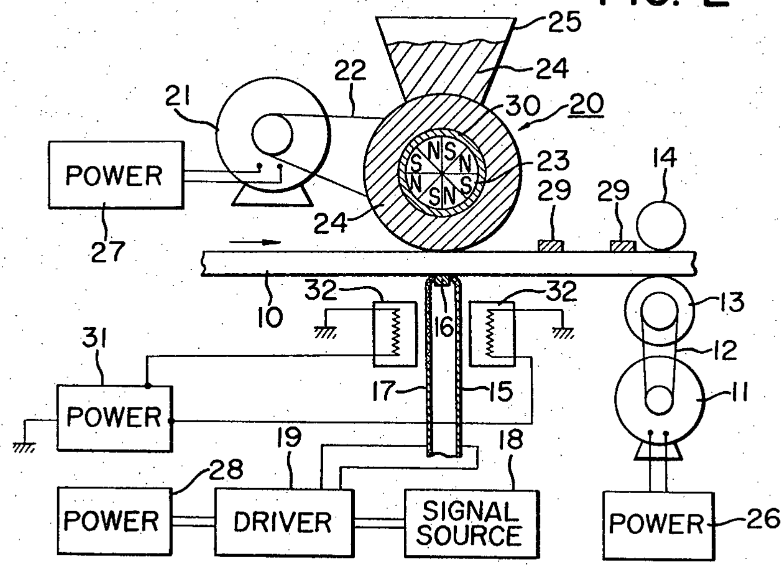
FIG. 2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POWER
DRIVER
SIGNAL SOURCE
POWER
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1583979 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

FIG. 3

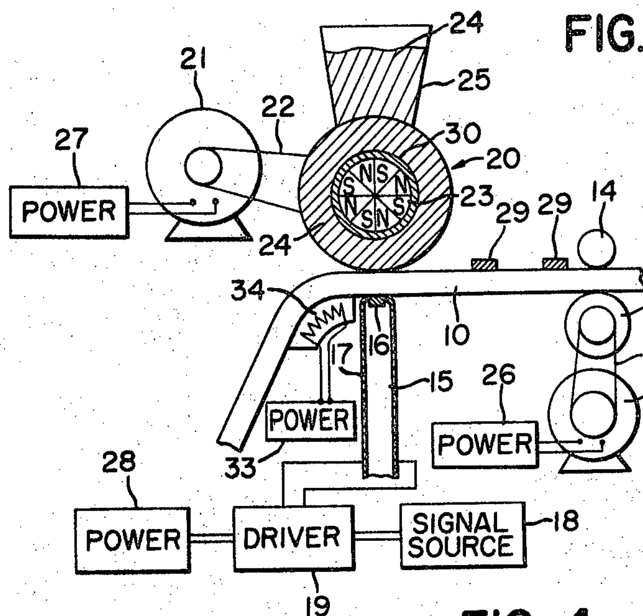


FIG. 4

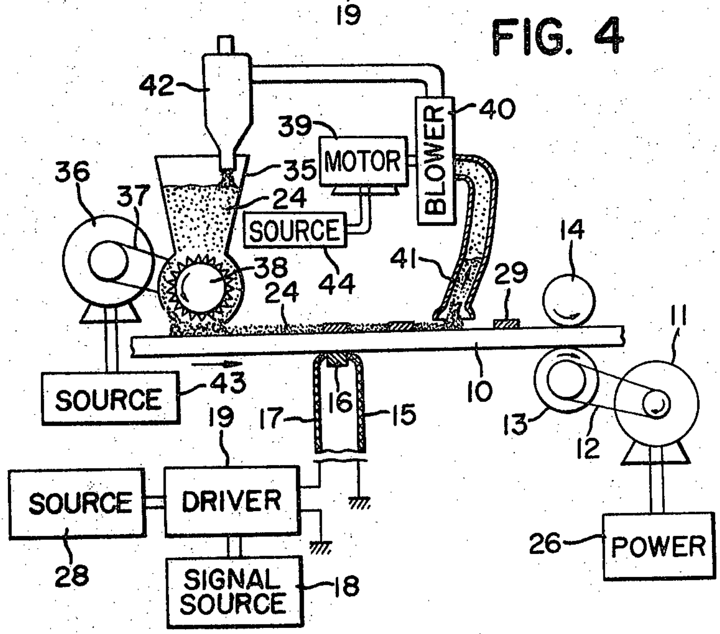
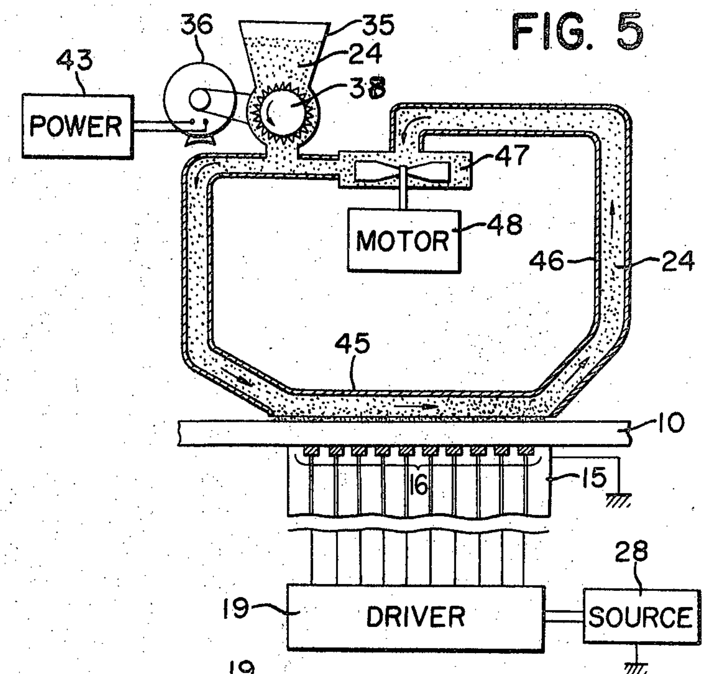


FIG. 5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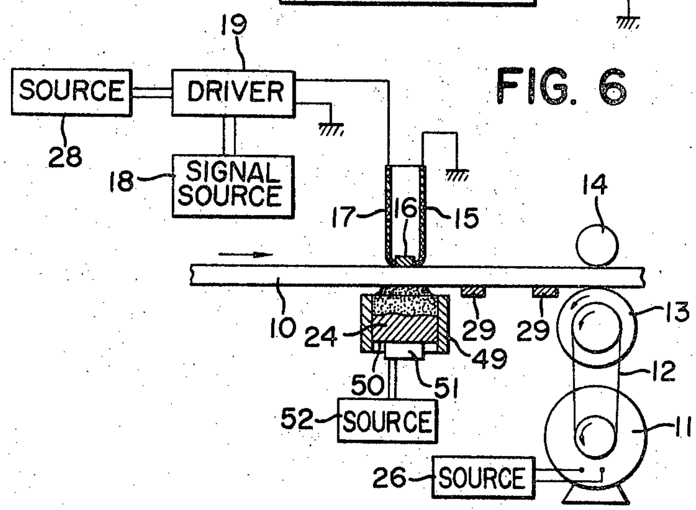
DRIVER
SOURCE

FIG. 6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DRIVER
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SIGNAL SOURCE
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SOURCE
11
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SOURCE

FIG. 7

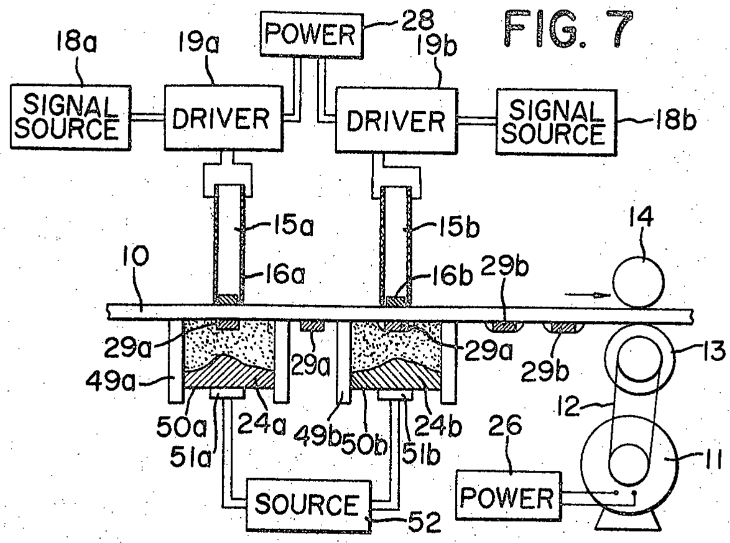

FIG. 8

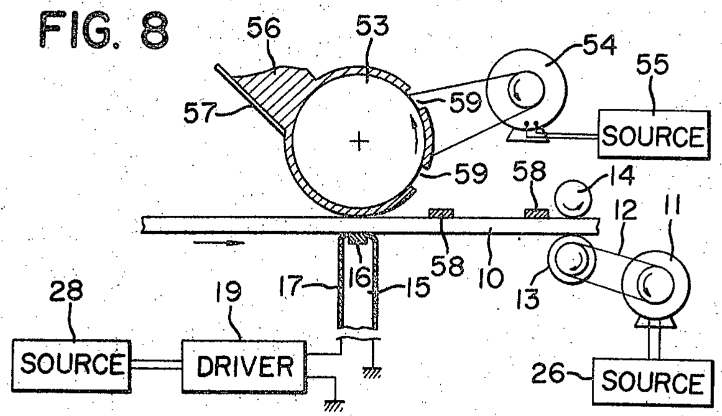

FIG. 9A

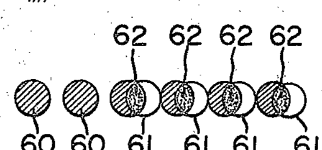

FIG. 9B