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(54) Apparatus for printing, erasing, and rewriting visible images on thermochromic recording material

Vorrichtung zum Drucken, Löschen, und Wiederbeschreiben von sichtbaren Abbildungen auf thermochromischem Aufzeichnungsmaterial

Appareil pour imprimer, effacer, et réinscrire des images visibles sur un matériau d'enregistrement thermochromique

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to repeatable printing and erasing of a visible image on a thermochromic material by reversibly changing a dark color to white with application of heat.

2. The Related Art

[0002] In general, hard copies are made by externally applying a coloring agent (e.g. , ink or toner) onto a recording medium, such as plain paper, to form images. Alternatively, a semipermanent image is produced on thermosensitive recording paper by applying thermal energy to form a visible image.

[0003] In recent years, consumption of paper and other recording media has grown larger and larger along with the continued proliferation of photocopy machines and facsimile machines, and partially because of the increased amount of information downloaded from networks through computers. The huge paper consumption has become an object of public concern, causing destruction of woodlands and increase of waste. To overcome these problems, reusable thermochromic recording materials that allow recorded visible images to be erased have attracted a great deal of attention.

[0004] For example, JPA(Kokai)55-154198 (& EP0014826A) discloses a recording medium that makes use of a light scattering change of a polymer in which organic low molecular-weight crystal grains are dispersed. With this medium, two different states, that is, transparent state and opaque state, are produced in a reversible manner. This medium has already been put into practical use as a display on magnetic cards. However, this medium is unsuitable to ordinary hard copies because white images are formed on a black or blue background, or on a light-reflecting background (such as an aluminum evaporation film).

[0005] JPA5-124360 (EP492628A) discloses a thermochromic recording medium using a leuco-dye in a thermochromic recording layer. Leuco-dye takes two different states, that is, a colored state and a colorless state through heating or with different heat cycles, and it allows a monochrome or gray-scaled printing image to be formed on a white background. After the leuco-dye recording layer is heated exceeding a first temperature T1, coloring abruptly starts at a second temperature T2 (T2>T1). Then, by rapidly cooling the recording layer, the printed state (or the colored state) is fixed. In order to erase the printed image, the recording medium is heated again. The printed image abruptly loses the color near the first temperature T1, and the colorless state (or the erased state) is fixed at a temperature somewhere between T1 and T2.

[0006] FIG. 1A illustrates the rewritable printing apparatus 100 disclosed in JPA(Kokai)5-124360, which is designed for the above-described thermochromic recording medium, and FIG. 1B illustrates the thermal head 121 and the surroundings of the erasing unit 120. The printing apparatus 100 has an erasing unit 120 and a recording unit 130 in this order along the transportation path. The erasing unit 120 has an erasing thermal head 121, and a pressure adjusting mechanism 123 for pressing the erasing thermal head 121 against a pressure roller 122. The recording unit 130 has a recording thermal head 131, and a pressure adjusting mechanism 133 for pressing the recording thermal head 131 against a pressure roller 132.

[0007] Thermochromic recording medium 101 is set in the guide tray 111 and sensed by the sensor 112. The sensed recording medium 101 is fed by the pressure rollers 122 and 132 in the direction of the arrows. During the transportation, the visible images formed in the thermochromic layer of the recording medium 101 are erased by the erasing thermal head 121 of the erasing unit 120. The cleared recording medium 101 is transported horizontally along the guide 113 placed on the downstream side of the erasing thermal head 121. The recording medium 101 then passes between the pressure roller 132 and the recording thermal head 131 of the recording unit 130, and is subjected to a new recording process for printing letters or drawings on the cleared thermochromic layer. The recording medium 101 is finally ejected to the tray 114.

[0008] As illustrated in FIG. 1B, the erasing thermal head 121 has a base 125 and a belt-like heater 124 provided onto the base 125. The heater 124 faces the pressure roller 122, and applies heat onto the thermochromic layer (not shown) of the recording medium 101 to erase the image when the recording medium 101 passes through the heater 124 and the pressure roller 122.

[0009] JPA(Kokai)2000-132648 (& EP1004978A) discloses a similar type of rewritable printing apparatus designed to reprint cards. With this apparatus, a card having a thermochromic layer moves straight along the horizontal transportation path during erasing and recording.

[0010] JPA(Kokai)6-191116 discloses an erasing apparatus that can feed recording media continuously and successively regardless of the type of paper, and that can reduce time taken for reprinting images. If a recyclable sheet is used, the sheet is fed between a heat roller and a rubber roller to erase the printed information on the sheet by applying heat onto the sheet during transportation. If thermosensitive recording paper is used, a heat-insulating shutter is inserted below the heat roller so as to shut off heat from being applied to the thermochromic recording paper. JPA11-193164 discloses a heat-insulating structure that is provided to an ejected sheet stack unit for the purpose of reducing temperature rise inside the recording apparatus, although this apparatus is not of a thermochromic type.

[0011] The above-described erasing and recording apparatuses have only the limited use for rewriting on magnetic cards or IC cards, and they cannot be practically used for rewriting documents printed on standard sizes of paper. The surface of a thermochromic recording medium 101 of a regular card size (55mm×85mm) can be heated uniformly at an erasing temperature. However, if the thermochromic recording medium 101 is enlarged to a standard A4 size (210mm×297mm) for application to normal document use, uniform erasing and recording over the entire surface area cannot be achieved.

[0012] One reason of the inapplicability to normal-sized document is that the entire surface cannot be sufficiently heated at an appropriate range of temperature. If the thermochromic layer of the recording medium 101 is formed of a leuco-dye, the acceptable variance of erasing temperature is about 10°C to 20°C, which is a relatively narrow control range. With an A4 size thermochromic recording medium 101, the surface temperature distribution varies widely, and some portions of the medium can not reach the erasing temperature, leaving some images undeleted. In contrast, some portions may be heated exceeding the upper limit of the erasing temperature, which causes the thermochromic layer to slightly color.

[0013] Another problem in the known rewritable printing apparatus is associated with transportation of the thermochromic recording medium 101 in the apparatus. In order to render the thermochromic recording medium 101 practical, not only the size, but also the thickness has to be standard, which is the same as that of papers normally used for photocopiers or facsimile machines in offices or homes. In general, the thickness of plane paper is about 115μm. Accordingly, an experiment was conducted using a thermochromic recording paper 101 having a base with a thickness of 115μm to let this recording medium be subjected to the erasing and recording processes in the conventional rewritable printing apparatus 10 disclosed in JPA5-124360.

[0014] Erasing and coloring processes are carried out normally if the linear speed of transporting the recording medium 101 is set relatively slow. However, if the transportation speed increases up to the general transportation speed of a photocopier or a facsimile machine, printing errors occur. Such errors are due to insufficient heating time at an erasing temperature and insufficient cooling time prior to reprinting using the recording thermal head. The thermochromic recording medium 101 reaches the recording thermal head 131 before the surface is sufficiently cooled, and reprinting is conducted with the temperature of the thermochromic recording medium 101 still relatively high. Therefore, some cooling means, as well as the means for controlling the erasing temperature, is desired.

[0015] In addition, even if erasing and recording are carried out appropriately at a slow transportation speed, waves 115 appear on the surface of the thermochromic recording medium 101, as illustrated in FIG. 1C. Waves 115 appear regardless of the transportation speed of the medium, and they become conspicuous if an A4 size recording medium 101 is used. Such waves 115 prevent good contact between the recording medium 101 and the erasing thermal head 121 or the recording thermal head 131, and it results in poor reprinted images due to insufficient erasing and lack of uniformity in color density.

[0016] Thus, the conventional rewritable printing apparatuses can not guarantee stable erasing operations and uniform reprinted images.

[0017] Moreover US5517228A shows an erasing apparatus. The image data can be erased by the erasing member 26, thereafter the sheet can be ejected via sheet ejection passage 22 and reception rollers 13.

SUMMARY OF THE INVENTION

[0018] Therefore, the present invention aims to provide an erasing apparatus that can deal with a regular paper-size (e.g., A4 size) thermochromic recording medium, and that can erase printed images satisfactorily even at a higher transportation speed.

[0019] The present invention also aims to provide a rewriting apparatus that guarantees reliable operations of erasing and reprinting without causing undesirable waves on the thermochromic recording medium.

[0020] An erasing apparatus heats a thermochromic recording medium at a prescribed erasing temperature to erase a printed image printed on the thermochromic recording medium. The thermochromic recording medium has several layers of different materials, including a thermochromic layer, on a base. The erasing apparatus also lets the heated thermochromic recording medium cool, while applying tensile stress, to prevent the thermochromic recording medium from waving or deforming. Since the thermochromic recording medium consists of different materials of layers having different thermal expansion coefficients, these layers deform or contract independently from each other, which causes undesirable waving or curling. By applying tensile stress to the thermochromic recording medium that has been subjected to erasing (i.e., heating) during the cooling process, waving or curling can be prevented efficiently.

[0021] In one aspect of the invention, an erasing apparatus as defined in claim 1 is provided.

[0022] The stress applier is, for example, a curved surface of the transportation path that transports the thermochromic recording medium along the curved surface to the downstream side.

[0023] Preferably, the radius of curvature of the curved surface is equal to or smaller than 40mm. The transportation path can be defined by a curved guide, a plurality of rollers, a belt extending around multiple rollers, an air stream, or any other suitable means.

[0024] Alternatively, the stress applier is an inclined transportation path sloping at a prescribed angle with respect to the horizontal. In either case, the stress applier has a cooling area to cool the heated thermochromic recording medium.

[0025] In another aspect of the invention, a rewritable printing apparatus, which includes the above-described erasing apparatus and a recording unit positioned at the downstream side of the erasing apparatus, is provided. The recording unit prints a new image on the thermochromic recording medium erased by the erasing apparatus.

[0026] The recording unit has a recording heater that heats the thermochromic recording medium at a second temperature different from the erasing temperature.

[0027] With this rewritable printing apparatus, the image printed on the recycled thermochromic recording medium is erased satisfactorily without forming waves or damage to it, and therefore, a new image can be printed clearly on the erased thermochromic recording medium.

[0028] In another proposal not according to the invention as claimed, an erasing apparatus that has an erasing condition control feature is provided. The erasing apparatus includes a heating means for heating the thermochromic recording medium to an erasing tempearure to erase an image printed on the thermochromic recording medium, a pressure means for pressing the thermochromic recording medium against the heating means , a first temperature sensor for sensing the temperature of the pressure means, and an erasing condition control means for determining an erasing condition suitable to the thermochromic recording medium based on the temperature of the pressure means.

[0029] The erasing condition control means includes a temperature setting means for determining the erasing temperature of the heating means based on the sensed temperature of the pressure means, and a temperature control means for controlling and maintaining the temperature of the heat roller at the erasing temperature determined by the temperature setting means.

[0030] The erasing condition control means further includes a transportation speed selection means for selecting the transportation speed of the thermochromic recording medium based on the temperature of the pressure roller, and a transportation control means for controlling the operation of transporting the thermochromic recording medium at the selected speed.

[0031] With this erasing apparatus, the optimum erasing conditions are selected based on the temperature of the pressure roller. Accordingly, the thermochromic recording medium is transported to and from the heating means at the optimum transportation speed, and is heated to the optimum erasing temperature while it passes between the heating means and the pressure roller. Consequently, the images printed in the thermochromic recording medium can be erased uniformly over the entire area of the thermochromic recording medium without subjected to damages.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

[0032] Other objects, features, and advantages of the invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. 1A illustrates a conventional rewritable printing apparatus, FIG. 1B illustrates a conventional erasing apparatus used in the rewritable printing apparatus, and FIG. 1C illustrates waves appearing on the thermochromic recording medium;

FIG. 2 illustrates an example of thermochromic recording medium;

FIGs. 3A and 3B illustrate changing the transportation angle of the thermochromic recording medium after applying erasing heat;

FIG. 4 illustrates cooling the heated recording medium while guiding the recording medium at a certain angle with respect to the horizontal;

FIG. 5 illustrates temperature profiles of the recording medium transported along the transportation path shown in FIG. 4;

FIGs. 6A through 6D illustrate examples of the erasing apparatus according to the first embodiment of the invention;

FIGs. 7A and 7B illustrate examples of the erasing apparatus according to the second embodiment of the invention;

FIGs. 8A through 8D illustrate examples of the erasing apparatus according to the third embodiment of the innetion;

FIGs. 9A through 9G illustrate examples of the rewritable printing apparatus according to the fourth embodiment of the invention;

FIGs. 10A and 10B illustrate examples of the rewritable printing apparatus according to the fifth embodiment of the invention;

FIGs. 11A and 11B illustrate examples of the vertical-type erasing apparatus according to the sixth embodiment of the invention;

FIG. 12 illustrates a modifications of the vertical-type erasing apparatus according to the sixth embodiment of the invention;

FIG. 13 illustrates an example of the rewritable printing apparatus applicable to a vertical-type erasing apparatus according to the seventh embodiment of the invention; and

FIG. 14 illustrates a modification of the rewritable printing apparatus according to the seventh embodiment of the invention;

FIG. 15 illustrates another modification of the rewritable printing apparatus according to the seventh embodiment of the invention;

FIG. 16A illustrates still another modification of the rewritable printing apparatus, and FIG. 16B illustrates a curved guided used in the apparatus of FIG. 16A according to the seventh embodiment of the invention;

FIG. 17 illustrates an example of the rewritable printing apparatus having two sensors positioned at the beginning and the end of the transportation path between the erasing thermal head and the recording thermal head according to the eighth embodiment of the invention;

FIG. 18 illustrates a modification of the rewritable printing apparatus according to the eighth embodiment of the invention;

FIG. 19 illustrates an operation flow of controlling the transportation of the thermochromic recording medium according to the eighth embodiment of the invention;

FIG. 20 illustrates another modification of the rewritable printing apparatus according to the eighth embodiment of the invention;

FIGs. 21A and 21B illustrate decolorizing temperature characteristics of various types of thermochromic layers;

FIG. 22A ilustrates the chemical formula of the developers, and FIG. 22B illustrates the chemical formula of the leuco-dyes used in the thermochromic layers of FIGs. 21A and 21B;

FIGs. 23A and 23B illustrate experiments of obtaining the relationship between the transportation speed and the color density of the remaining image after erasing;

FIG. 24 is a graph showing appropriate erasing temperatures obtained from the experiments of FIGs. 23A and 23B;

FIG. 25 is a graph showing a change in surface temperature of the pressure roller;

FIGs. 26A and 26B illustrate examples of the erasing apparatus and FIGs. 26C and 26D illustrate examples of the rewritable printing apparatus using the erasing apparatuses shown in FIGs. 26A and 26B, respectively, according to a first proposal not according to the invention as claimed;

FIGs. 27A and 27B illustrate examples of the erasing apparatus and FIGs. 27C and 27D illustrate examples of the rewritable printing apparatus using the erasing apparatuses shown in FIGs. 27A and 27B, respectively, according to a second proposal not according to the invention as claimed;

FIG. 28A illustrates an example of the erasing apparatus and FIG. 28B illustrates an example of the rewritable printing apparatus using the erasing apparatus of FIG. 28A according to a third proposal not according to the invention as claimed ; and

FIG. 29A illustrates an example of the erasing apparatus according to a fourth proposal not according to the invention as claimed, and FIG. 29B illustrates an example of the rewritable printing apparatus using the erasing apparatus similar to that shown in FIG. 29B.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0033] The details of the invention will now be described with reference to the attached drawings.

[0034] FIG. 2 illustrates an example of thermochromic recording medium 1. The thermochromic recording medium 1 has a base 2, a thermochromic layer 3 formed over the top face of the base 2, a first transparent protection film 4, and a second transparent protection film 5. The bottom of the base 2 is covered with a back-coat film 6. The base 2 is made of, for example, paper, composite paper, or a resin such as polyethylenterephthalate (PET), and the thickness ranges from 0.05mm to 0.22mm. The thickness of the thermochromic layer 3 is 8-9μm, and the thickness of the first transparent protection film 4, the second transparent protection film 5, and the back-coat film 6 are set to about 2μm each.

[0035] Plane paper used for- photocopiers and facsimile machines in offices is about 0.05mm to 0.22mm thick. If the thickness is less than 0.05mm, the paper becomes flabby, and above 0.22mm, it is unsuitable for filing. By setting the thickness of the thermochromic recording medium 1 to that of plane paper, the thermochromic recording paper 1 can be handled easily in the same manner as plane paper. The mechanical characteristics (durability, bendability, etc.) of the thermochromic recording medium 1 are mainly defined by the base 2.

[0036] Thermochromic layer 3 is made of a resin binder in which a leuco-dye and a developer are dispersed. The leuco-dye used in the thermochromic layer 3 is a known dye precursor, such as phthalide compound, azaphthalide compound, fluoran compound, phenothiazine compound, or leukoauramine compound. The developer used in the thermochromic layer 3 is a compound that contains a chemical formula (e.g., phenol-type hydroxyl group, carboxylic acid group, phosphonic acid group, etc) exhibiting developing functions for causing the leuco-dye to show color in its molecules. The developer also has a chemical formula for controlling the aggregation between molecules, for example, a structure having a long-chain hydrocarbon group linked to it with or without a divalent group containing hetero atoms at the linking portion. The long-chain hydrocarbon group itself may include a divalent group containing hetero atoms, or an aromatic group. For example, the developers disclosed in JPA5-124360 can be used as the developer.

[0037] The first and second transparent protection films 4, 5 and the back-coat film 6 are made of a thermosetting polymer, and these films are provided to enhance the strength of the thermochromic recording medium 1 that is to be repeatedly subjected to the erasing process and the recording process. Especially, the top face of the thermochromic layer 3 needs to be protected because the thermochromic recording medium 1 is heated in direct contact with the erasing thermal head and the recording thermal head. For this reason, double protection films 4 and 5 are provided in the example shown in FIG. 2. However, a recording medium with a single transparent protection film may be used. In this case, the thickness of the transparent protection film may be increased. Back-coat film 6 may be omitted if the base 2 is not paper. The back-coat film 6 prevents curls when the paper base 2 expands or contract due to the moisture it absorbs.

[0038] Experiments for eliminating the undesirable waves 15 were made by the inventors using a thermochromic recording medium whose thickness is similar to that of plane paper and a. The erasing temperature suitable to the thermochromic recording medium 1 having a thickness of plane paper is about 100°C to 160°C.

(A) A thermochromic recording medium 101 was fed horizontally to the erasing thermal head 121, and heated at 100-160°C using the conventional erasing apparatus shown in FIG. 1A. Heated thermochromic recording medium 101 was guided straight in the horizontal direction from the erasing thermal head 121.

(B) A thermochromic recording medium 1 was fed horizontally to the erasing thermal head 21, and heated at 100-160°C using an erasing apparatus 10 shown in FIG. 3A. Heated thermochromic recording medium 1 was then guided obliquely upward at a certain angle with respect to the horizontal along the transportation path indicated by the arrows. In this case, the waves 115 were reduced a considerable extent, and depending on the thickness of the medium, no waves appeared. When the angle of the transportation path was set equal to or greater than 30° with respect to the horizontal, no waves appeared provided the thickness of the base (made of paper or PET) 2 of the thermochromic recording medium 1 was 0.05mm to 0.22mm.

(C) A thermochromic recording medium 1 is fed horizontally to the erasing thermal head 21, and heated at 100-160°C. The heated thermochromic recording medium 1 is then guided naturally by gravity downward at a certain angle with respect to the horizontal along the transportation path indicated by the arrows, as illustrated in FIG. 3B. In this case, the waves 115 were reduced a considerable extent, and depending on the type of the medium, no waves appeared. If the angle of the downward transportation path was equal to or greater than 30° with respect to the horizontal, no waves appeared.

(D) A thermochromic recording medium 1 was fed horizontally to the erasing thermal head 21, and heated at 100-160°C. The heated thermochromic recording medium 1 was guided obliquely either upward or downward along the transportation path under the regulation of a guide 13, as illustrated in FIG. 3A or 3B. In this case, the angle of the transportation path was regulated by the guide 13, and no waves appeared when the angle was regulated at 30° or greater.

(E) A thermochromic recording medium 1 was fed horizontally to the erasing thermal head 21, and heated at 100-160°C. The heated thermochromic recording medium 1 was guided from the erasing thermal head 21 by a guide having a curved surface. This experiment was done by changing the radius of curvature of the curved surface. The waves appearing on the erased thermochromic recording medium 1 were greatly reduced, and especially, if the radius of curvature was set equal to or less than 40mm, no waves appeared.

(F) A thermochromic recording medium 1 was fed horizontally to the erasing thermal head 21, and heated at 100-160°C. The heated thermochromic recording medium was guided straight for a certain distance after the erasing thermal head 21, as illustrated in FIG. 4. Then, the transportation direction of the thermochromic recording medium 1 was regulated upward or downward using a guide 13 as in experiment (C). When the guide 13 regulated the transportation angle of the thermochromic recording medium 1 after the surface temperature of the thermochromic recording medium 1 is reduced below 60°C, waves appeared in the thermochromic recording medium 1 provided the base (paper or PET) has a thickness of 0.05mm to 0.22mm. In contrast, when the transportation angle was changed before the surface temperature of the thermochromic recording medium 1 as a whole is reduced below 60°C, then no waves appeared.

(G) A card-size thermochroic recording medium having a base 1 made of PET and with a thickness of 0.25mm was prepared. With this thermochromic recording medium, no waves appeared under any of the conditions (A) through (F) above.

[0039] From the experimental results, the following are concluded.

[0040] First, from experiments (A) through (E), waves form in the thermochromic recording medium 1 unless some kind of physical influence is given to the heated thermo chromic recording medium 1 during the process in which the thermochromic recording medium becomes rigid after heating. Since the thermochromic recording medium 1 includes multiple layers (the base 2, the thermochromic layer 3, the transparent protection films 4 and 5, and back-coat film 6) made of different materials having different heat contraction rates, these layers exhibit different thermal deformations with the cycle of heating under pressure and abrupt release for cooling. In order to prevent the thermochromic recording medium 1 from forming waves, it is necessary to avoid rapid cooling to the thermochromic recording medium 1, or to keep the thermochromic recording medium 1 under tension during its rigidification in the cooling process. The former method (i.e., cooling slowly) is impractical because it is known from another experiment that cooling the thermochromic recording medium 1 without causing waves to form takes a relatively long time. This results in a big slowdown of the erasing speed and the transportation speed. The latter method is much better because the mutual reaction of the overlaid layers caused by heat contraction can be prevented by making use of the rigidification of the thermochromic recording medium 1 by applying tension to the thermochromic recording medium 1 during the cooling process. This method does not adversely affect the erasing speed or the size of the apparatus at all.

[0041] Second, from experiment (F), it is concluded that tension should be applied to the thermochromic recording medium 1 when the surface temperature of the thermochromic recording medium 1 is on or above 60°C. FIG. 5 illustrates the temperature profiles of thermochromic recording media 1 corresponding to the structure shown in FIG. 4. These profiles were obtained based on the measurements of the temperature sensors 16 and 17. The thermochromic recording medium 1 is heated instantaneously at an erasing temperature T0 (120°C) by a belt-like heater 24 of the erasing thermal head 21, and cooled along the transportation path. The sensors 16 and 17 are movable along the transportation path at a speed corresponding to the linear speed of the transportaion path. The sensors 16 and 17 used in the experiment were infrared emission thermometers (IT2-50 manufactured and sold by Keyence Inc.).

[0042] No waves appeared in thermochromic recording media A and B, whose surface temperatures were between 60°C to 100°C, when they reached point P at which tension was applied to the recording media A and B by inclination of the transportation path. At temperatures from 60°C to 100°C, the thermochromic recording medium 1 started rigidifying. On the other hand, waves appeared in thermochromic recording medium C whose surface temperature was below 60°C at point P. Waves also appeared in thermochromic recording medium D even when its surface temperature was above 60°C at point P. This is because the surface temperature of the recording medium D was above 100°C and rigidification had not started yet even at the end point Q. The recording medium D is further cooled, while it started rigidifying, along a horizontal path (not shown) without the-further application of tensile stress.

[0043] In order for a conventional rewritable printing apparatus to erase and reprint A4-size thermochromic recording media 1 at a high rate, such as several tens of pages per minutes (PPM), a long transportation path is required to sufficiently cool down the thermochromic recording media 1. In contrast, the erasing apparatus of the present invention is designed so as to efficiently cool the thermochromic recording medium 1 by furnishing a radiator or a heat sink with good heat conductivity along the slope or curved path extending between points P and Q. This arrangement allows high-speed transportation. If the transportation speed is slower (e.g., several PPM), the thermochromic recording medium 1 is sufficiently cooled along the slope or curved path without using a radiator. Another feature is that the erasing apparatus of the present invention makes use of rigidification of the thermochromic recording medium 1 under tension during the cooling process. This arrangement efficiently prevents the thermochromic recording medium 1 from forming waves.

[0044] Concerning the surface temperature, it is necessary for the thermochromic recording medium 1 to have a surface temperature of 60°C or higher at point P because, below 60°C at point P, the recording medium 1 forms waves even when transported along the slope, because it is almost impossible to control the surface temperature once it drops below 60°C before point P. Here, importance of the temperature profile along the linear path is emphasized because forming waves by the thermochromic recording medium 1 is a phenomenon particular to an apparatus having a linear thermal distribution using a heat roller or a ceramic heater. With an apparatus that is capable of temperature control in the entirety of the apparatus (for example, heating and cooling in an isothermal chamber), waves 15 do not occur. In conclusion, it is efficient for the heat-roller type or ceramic heater type erasing apparatus to transport the thermochromic recording medium 1 from the heater 24, while applying tension, before the surface temperature is reduced below 60°C.

[0045] Third, from experiment (G), the thermochromic recording medium 1 waves if it has a thickness of plane paper (i.e., 0.05mm to 0.22mm). A card-size thermochromic recording medium in which the thickness of the base 2 is 0.25mm does not form waves because the rigidity and the mechanical strength are sufficient to prevent thermal deformation.

[0046] An additional experiment was conducted searching for the possibility of reducing the apparatus size. In the experiment, the temperature of the erasing thermal head 21 was set to 140°C. Ten successive recording media were fed horizontally to the erasing thermal head 21, and were subjected to the erasing operation continuously. When the entire rewritable printing apparatus was made vertical with the erasing unit 20 positioned higher than the recording unit 30, the erasing quality was maintained satisfactory even at the latter pages of the thermochromic recording media 1. This is as a result of the superior effect over the conventional horizontal transportation path extending from the erasing unit 120. By placing the erasing unit 20 above and placing the recording unit 30 at the bottom of the apparatus, thermal influence from the erasing unit can be avoided when the thermochromic recording medium 1 is subjected to the reprint process. By reducing the thermal influence from the erasing unit 20, the thermochromic recording medium 1 can becomes colored clearly at the reprinting temperature.

[0047] Based on the above-described experimentation and observation, the inventors developed various types of erasing apparatuses and rewritable printing apparatuses that can prevent the thermochromic recording medium 1 from forming waves in the cooling process and that allow clear coloring in the reprinting process, while maintaining the apparatus in a compact form.

<First Embodiment>

[0048] FIGs. 6A through 6D illustrate examples of the erasing apparatus 40 according to the first embodiment of the invention. The erasing apparatus 40 has an erasing thermal head 21 for heating a thermochromic recording medium 1 (not shown), and a stress applier 41 positioned after the thermal head and applying tensile stress to the thermochromic recording medium 1 that has been heated by the erasing thermal head 21 and the pressure roller 22. The erasing apparatus 40 also has a pressure roller 22 as a pressure means that presses the thermochromic recording medium 1 against the thermal head 21. The pressure roller 22 transports the thermochromic recording medium 1 toward the stress applier 41 during the heating.

[0049] The stress applier 41 is, for example, a guide 411 having a curved surface 411a on the top face, as illustrated in FIGs. 6A through 6C, or alternatively, it is a guide 412 having a curved surface 412a facing down, as illustrated in FIG. 6D. The guides 411 and 412 are made of, for example, aluminum having good heat conductivity. The curved surfaces 411a and 412a define a transportation path 42. Guide 411 (or 412) applies tension to the heated thermochromic recording medium 1 (not shown) with its curved surface 411a (or 412a) during transportation, and at the same time, it removes heat from the thermochromic recording medium 1.

[0050] The radius of curvature of the curved surfaces 411a and 412a is 40mm or less, and the curving position, from which the feed angle of the transportation path changes with respect to the horizontal, is determined so that the surface temperature of the thermochromic recording medium 1 is still at or above 60°C when the thermochromic recording medium 1 reaches the curving position. In the example shown in FIG. 6C, the curving position starts at a distance L from the erasing thermal head 21, and a temperature sensor 16 (e.g., a thermistor or a thermocouple of either non-contact type or contact-type) is placed at the beginning of the curving position in order to sense the surface temperature of the thermochromic recording medium 1 (not shown). A straight transportation path extends from the erasing thermal head 21 for the distance L, and the curved transportation path 42 starts at the curving position at which the sensor 16 is provided. The distance L may change depending on the transportation speed of the thermochromic recording medium 1.

[0051] The erasing apparatus may further have an auxiliary guide 413 having the same radius of curvature as the curved surface 411a (or 412a), as illustrated in FIGs. 6B and 6D. The auxiliary guide 413 is also made of a material having a heat radiating ability. In this, case, the thermochromic recording medium 1 (not shown) is guided between the guide 411 (or 412) and the auxiliary guide 413, and the cooling effect of the transportation path 42 is further improved. If applying this structure to the example shown in FIG. 6C, the distance L can be reduced due to the improved heat radiating function.

[0052] In this manner, the thermochromic recording medium 1 with the surface temperature at or above 60°C is guided along the curved surface 411a (or 412a) of the guide 411 (or 412), and during transportation, tensile stress is applied to the thermochromic recording medium 1. The thermochromic recording medium 1 becomes rigid without forming waves under tensile stress during the cooling process.

<Second Embodiment>

[0053] FIGs. 7A and 7B illustrate examples of the erasing apparatus 40 according to the second embodiment of the invention. In the second embodiment, the guide has an inclined surface or a slope, in place of the curved surface, to change the transportation angle.

[0054] In FIG. 7A, the erasing apparatus 40 has a guide 414 having an inclined surface 414a, which defines a transportation path 43. In FIG. 7B, the erasing apparatus 40 has a guide 414 having an inclined surface 414a facing down, and an auxiliary guide 415 shaped so as to correspond to the guide 414. Guide 414 and the auxiliary guide 415 are made of a heat-conductive material, such as aluminum. The thermochromic recording medium 1 having passed the erasing thermal head 20 strikes the inclined surface 414a, which gives rigidity to the heated thermochromic recording medium 1. Then, the thermochromic recording medium 1 is guided along the inclined surface 414a, and it is cooled and rigidifies under tension due to gravitational force. If the inclination angle of the surface 414a is set to 30° or more, the stretching effect becomes greater, and waving is efficiently prevented in the thermochromic recording medium 1 of a'thickness of plane paper (with the base 2 having a thickness from 0.05mm to 0.22mm).

<Third Embodiment>

[0055] FIGs. 8A through 8D illustrate examples of the erasing apparatus 40 according to the third embodiment of the invention. In the examples shown in FIGs. 8A and 8B, the erasing apparatus 40 has a set of rollers 416 including multiple auxiliary rollers. These rollers 416 function as a stress applier. The set of rollers 416 is configured so as to define a curved transportation path 42, as illustrated in FIG. 8A, or alternatively, it is configured to define a sloped path 43, as illustrated in FIG. 8B.

[0056] In FIG. 8C, fan 417 is used as a stress applier. The fan 417 applies the force of wind obliquely from downward to form an upward transportation path 42 after the erasing thermal head 20. With this structure, the thermochromic recording paper 1 is transported along a gentle curve under tension, while being cooled efficiently. The power of the fan 417 is determined depending on the thickness of the thermochromic recording medium 1 (not shown) and the transportation speed.

[0057] In FIG. 8D, a belt and a set of rollers 416 are used as the stress applier. The rollers 416 are arranged so as to define a curved transportation path 42, and the belt 418 extends around the rollers 416. This arrangement achieves stable transportation of the thermochromic recording medium 1. By adjusting the arrangement of the rollers 416, the radius of curvature of the transportation path 42 is set arbitrarily.

<Fourth Embodiment>

[0058] FIGs. 9A through 9G illustrate examples of a rewritable printing apparatus 10, in which an erasing apparatus described in the first through third embodiments is assembled. The rewritable printing apparatus 10 includes an erasing unit 20 that heats a thermochromic recording medium 1 (not shown) at a first temperature T1 to erase images printed on the thermochromic recording medium 1; a stress applier 41 positioned after the erasing thermal head 21 to apply tension to the heated thermochromic recording medium 1; and a recording unit 30 positioned after the stress applier 41 and heating the thermochromic recording medium 1 at a second temperature T2 to reprint images on the erased thermochromic recording medium 1.

[0059] The stress applier 41 defines a curved transportation path 42 (FIGs. 9A-9D and 9G) or a sloped transportation path 43 (FIGs. 9E and 9F) between the erasing unit 20 and the recording unit 30. The thermochromic recording medium 1 is transported along this transportation path, while it is subjected to tensile stress applied by the stress applier 41. The stress applier 41 supplies the erased thermochromic recording medium 1 to the recording unit 30 without causing waves. The recording unit 30 has a recording thermal head 31 and the pressure roller 32 against which the recording thermal head 31 is pressed via the thermochromic recording medium 1. Since no waves appear in the thermochromic recording medium 1 transported to the recording unit 30, good contact between the recording thermal head 31 and the thermochromic recording medium 1 is maintained during the reprinting operation at the recording unit 30. Consequently, clear images can be formed in a stable manner.

<Fifth Embodiment>

[0060] FIGs. 10A and 10B illustrate examples of the rewritable printing apparatus 10 according to the fifth embodiment of the invention. In the firth embodiment, the rewritable recording apparatus 10 has a temperature sensor 16 on the transportation path 43 extending from the erasing unit 20.

[0061] In the example shown in FIG. 10A, the stress applier 41 comprises a pair of guides 414 that have inclined surfaces 414a to define a bending transportation path 43. One of the guides 414 has a window 419 at the bending position. The temperature sensor 16 measures the surface temperature of the thermochromic recording medium 1 transported along the bending transportation path 43 through the window 419. The measurement of the temperature sensor 16 is fed back to the erasing thermal head 21 of the erasing unit 20, and controls the erasing temperature of the erasing thermal head 21 so that the surface temperature of the thermochromic recording medium 1 is at or above 60°C at the bending position. The thermochromic recording medium 1 heated by the erasing thermal head 21 strikes the inclined surface 414a of the guide 414, and changes its path along the inclined surface 414a. Consequently, tensile stress is applied to the thermochromic recording medium 1, while cooling the thermochromic recording medium 1 along the transportation path 43.

[0062] In FIG. 10B, a path switcher 19 is placed between the recording unit 30 and paper eject rollers 18. The path switcher 19 is connected with the temperature sensor 16. If the detected surface temperature of the thermochromic recording medium 1 is below 60°C, then the path switcher 19 switches the transportation path to the return path 45 to return the reprinted thermochromic recording medium 1 to the feed tray 11. At the same time, the detection result of the temperature sensor 16 is supplied to the erasing thermal head 21 to raise the erasing temperature. The returned thermochromic recording medium 1 is again subjected to the erasing and reprinting processes. In this manner, recording error is effectively prevented in advance.

<Sixth Embodiment>

[0063] FIGs. 11A and 11B illustrate examples of the erasing apparatus 40 according to the sixth embodiment of the invention. In the sixth embodiment, the erasing apparatus 40 is of a vertical type. The erasing unit 20 is positioned below the feed rollers 50, and a transportation path 44, which functions as a tension applier 41, extends downward in the gravitational direction from the erasing unit 20. In this example, tensile stress is applied more effectively to the heated thermochromic recording medium 1. Heat rollers 23 are used in place of thermal head 21 to heat the thermochromic recording medium 1.

[0064] In FIG. 11B, the tension applier 41 consists of a vertical path 44 and a curved path 42 that continuously extends from the vertical path 44. Consequently, tensile stress is applied to the thermochromic recording medium 1 doubly due to gravitational force and tensile stress given by the curved path 42. This arrangement allows the erasing apparatus 40 to be compact, and to be set on a desk easily.

[0065] In either example shown in FIG. 11A or 11B, the erasing unit 20 is positioned in the upper part of the apparatus 40, so that heat is easily released away from the transportation path 44 or 42. This arrangement prevents accumulation of heat at the bottom of the apparatus 40. The heated thermochromic recording medium 1 can be cooled efficiently under tensile stress due to gravitational force.

[0066] The heat released toward the top of the apparatus can be recycled to preheat the thermochromic recording medium 1 supplied to the feed rollers 50. This preheating can moderate the temperature change on the path from the feed roller 50 to the erasing unit 20, thereby preventing the thermochromic recording medium 1 from crinkling.

[0067] FIG. 12 illustrates an example of the rewritable printing apparatus 10 in which a vertical-type erasing apparatus is assembled. A recording unit 30 is positioned at the downstream side of the transportation path 42. The thermochromic recording medium 1 is supplied to the recording unit 30 without forming waves after it is cooled sufficiently. Consequently, the reprinted image exhibits good coloring characteristics. The reprinted thermochromic recording medium 1 is ejected to the tray 14. This rewriting printing apparatus 10 can repeat erasing and printing in a stable manner without deterioration of image quality.

<Seventh Embodiment>

[0068] FIG. 13 illustrates an example of the rewritable printing apparatus 10 according to the seventh embodiment of the invention. The rewritable printing apparatus 10 has a U-shaped transportation path 42 that extends from the erasing unit 20. A recording unit 30 is positioned on the opposite end of the U-shaped path 42, and the reprinted thermochromic recording medium is ejected back to the feed tray 11, as indicated by the dashed arrow. The U-shaped path 42 can apply rigidity to the heated thermochromic recording medium 1, while guaranteeing a sufficiently long cooling region. As a result, waves can be prevented from appearing and clear images can be reprinted on the erased thermochromic recording medium 1.

[0069] The U-shaped transportation path 42 is defined by, for example, a guide 45 made of aluminum and having a U-shaped surface. Alternatively, it may be defined by rollers, a belt, or a combination thereof. In order to reduce the apparatus size, it is preferable to use a curved guide for guiding the thermochromic recording medium having been subjected to erasing and reprinting toward the feeding tray 11 from which the recycled thermochromic recording medium 1 is supplied to the apparatus 10. By setting the radius of curvature of the u-shaped transportation path 42 to 40mm or greater, arbitrary kinds of thermochromic recording media having a thickness of plane paper can be used, regardless of the material of the base 2 (e.g., paper, PET, etc.).

[0070] FIG. 14 illustrates a modification of the rewritable printing apparatus 10, in which the U-shaped transportation path 42 is defined by a set of rollers 416, and FIG. 15 illustrates another modification of the rewritable printing apparatus 10, in which the U-shaped transportation path 42 is defined by a belt 418 and auxiliary rollers. In either example, a temperature sensor 16 is placed at the exit of the erasing unit 20, and after the temperature sensor 16, the transportation path 42 changes the orientation of the transported thermochromic recording medium 1.

[0071] FIG. 16(A) illustrates still another modification of the rewritable printing apparatus 10. This rewritable printing apparatus 10 has a cooling fan 47 and a guide 45 shown in FIG. 16(B). The guide 45 has one or more grooves 46 extending along the longitudinal axis of the guide 45 to release heat from the thermochromic recording medium 1 in cooperation with the fan 47. This arrangement can further improve the cooling efficiency, while applying tensile stress to the heated thermochromic recording medium 1 without increasing the apparatus size.

<Eighth Embodiment>

[0072] FIG. 17 illustrates an example of the rewritable printing apparatus 10 according to the eighth embodiment of the invention. The apparatus 10 includes a first temperature sensor 16, which is positioned at the beginning of the U-shaped transportation path 42, and a second temperature sensor 17, which is positioned at the end of the U-shaped transportation path 42. The erasing temperature of the erasing unit 20 is controlled based on the output of the first sensor 16, so that the surface temperature of the thermochromic recording medium 1 sensed by the sensor 16 is at or above 60°C. Furthermore, the temperature of the U-shaped transportation path 42 is controlled by, for example, adjusting the power of the. fan 47 (FIG. 16(A)) based on the output of the second temperature sensor 17, so that the surface temperature of the thermochromic recording medium 1 is at or below 100°C.

[0073] The erasing temperature of the erasing unit 20 varies ±10°C depending on the material of the thermochromic layer 3 (FIG. 2). If the thermal energy of the erasing unit 20 changes so as to be suitable to the thermochromic recording medium 1 actually used, the surface temperature of the thermochromic recording medium 1 may still be above 100°C at the end of the transportation path 42. In this case, the thermochromic recording medium 1 become wavy, and the reprinted image recorded by the recording unit 30 deteriorates. To avoid this situation, the second temperature sensor 17 is used to monitor the surface temperature of the recording medium 1 at the end of the transportation path 42.

[0074] FIG. 18 illustrates a modification of the rewritable printing apparatus 10 of this embodiment. This modification has a path switcher 51 and a test sheet ejecting path 52 between the recording unit 30 and the end of the transportation path 42. The path switcher 51 switches the path between the normal ejecting path 46 and the test sheet ejecting path 52. With this apparatus, before actual erasing and reprinting, the erasing temperature of the erasing unit 20 and the temperature of the U-shaped transportation path 42 are adjusted by the first and second sensor 16 and 17 using a test sheet. In the test operation, the ejecting path is set to the test sheet ejecting path 52 by the path switcher 51, and a test sheet is supplied from the feed tray 11. The test sheet is subjected to erasing, and follows the transportation path 42. The path switcher 51 switches the path back to the normal path 46 if the surface temperature of the test sheet becomes at 60°C or above at the beginning of the transportation path 42 and becomes 100°C or below at the end of the transportation path 42.

[0075] FIG. 19 is a flowchart showing the above-described switching operation. In step S901, a test sheet is supplied to the apparatus 10. In step S902, the first surface temperature T_A is sensed by the first sensor 16 at the beginning of the transportation path 42. In step S903, it is determined whether the detected first temperature T_A is at or above 60°C. If the sensed temperature is below 60°C (NO in S903), the test sheet ejecting path 52 is selected by the path switcher 51 (S904) and the erasing temperature of the erasing unit 20 is adjusted in step S905. Then the process returns step S901 and repeats S901 trough S903. If the sensed temperature is at or above 60°C (YES in S903), then the second surface temperature T_B is sensed by the second sensor 17 at the end of the transportation path 42. In step S907, it is determined whether the detected second temperature T_B is at or below 100°C. If the sensed temperature is above 100°C (NO in S907), the process returns to step S904, in which the test sheet ejecting path 52 is selected. If the sensed second temperature T_B is at or below 100°C (YES in S907), then regular feeding operation starts in S908 to actually feed the thermochromic recording medium 1. In this manner, erasing and reprinting are carried out stably and reliably under temperature control.

[0076] FIG. 20 illustrates another modification of the rewritable printing apparatus of this embodiment. In this modification, the transportation path extending between the erasing unit 20 and the recording unit 30 consist of a combination of an inclined path 44 and a U-shaped path 42. The inclined path 44 extends from the erasing unit 20 at an angle equal to or greater than 30° (e.g. 35°) with respect to the vertical. The combination of the guide with grooves and the cooling fan shown in FIG. 16A may be applicable to this structure.

<Ninth Embodiment>

[0077] In the fifth, seventh, and eighth embodiments, the erasing temperature is controlled based on the surface temperature of the thermochromic recording medium 1 at the beginning (and the end) of the transportation path extending from the erasing unit. In the ninth embodiment, the erasing temperature of the erasing unit 20 is controlled based on the temperatures of the thermal head (or the heat roller) and the pressure roller. This provides a more direct control of maintaining the erasing temperature constant in order to heat the entire surface of A4-size thermochromic recording medium 1 uniformly.

[0078] Before describing the ninth embodiment, the erasing characteristic of the thermochromic recording medium 1 in relation to temperature will be explained. FIGs. 21A and 21B are graphs showing the erasing characteristics of various types of thermochromic recording media. FIGs. 22A and 22B illustrate chemical formulas of the developer and the leuco-dye used in the thermochromic recording media shown in the graphs of FIGs. 21A and 21B.

[0079] The range of erasing temperature varies among different types of thermochromic recording media, and some recording media have a narrow acceptable range of 10°C or less. If a thermochromic recording medium is used for document use, images on the recycled recording medium must be erased completely because even a little amount of remaining image adversely affects the image quality of the reprinted recording medium. The acceptable color density of the remaining image (after erasing) on a conventional card-type thermochromic recording medium is about 0.02 for practical use. On the contrary, the color density of the remaining image has to be 0.01 or less for document use. This means that control of the erasing temperature is much stricter for a document-use thermochromic recording medium.

[0080] Another experiment was conducted for obtaining the relation between the heat roller temperature and the color density of the remaining image after erasing at various transportation speeds, using the test erasing apparatus 400 shown in FIG. 23B. The test apparatus 400 has an erasing unit 401 including a heat roller 402 and a pressure roller 404. The heat roller 402 is a stainless steel pipe having a diameter of 40mm and a thickness of 3mm. A halogen lamp 403 is furnished inside the stainless steel pipe. The pressure roller 404 is made of silicon rubber having a hardness (Hs) of 50 (JIS-A) and a thickness of 4mm.

[0081] The base 2 of the test sheet 410 used in the experiment was coat paper with a thickness of 110μm. The thermochromic layer 3 of the test sheet contained developer PAU0-5-18 shown in FIG. 22A and leuco-dye L1 shown in FIG. 22B. The thickness of the thermochromic layer 3 was about 10 μm. The test sheet bore a square image (8mm×8mm) having a color density of 1.00 to 1.05.

[0082] FIG. 24 is a graph showing the appropriate temperature range for erasing at each transportation speed. At the transportation speed of 20mm/sec, the printed image was completely erased at the erasing temperature ranging from 120°C to 170°C. At 30mm/sec, the erasing temperature ranged from 130°C to 170°C, and at a 50mm/sec, the erasing temperature ranged from 150°C to 170°C. When the transportation speed was raised to 80mm/sec, the erasing temperature ranged became 160°C to 170°C. Since the nip width between the heat roller 402 and the pressure roller 404 was about 3mm in this experiment, heating time is 0.15 seconds at the transportation speed of 20mm/sec. The heating time decreased as the transportation speed increased, and it becomes 0.10 seconds at 30mm/sec, 0.06 seconds at 50mm/sec, and 0.04 seconds at 80mm/sec. The higher the transportation speed (or the shorter the heating time), the narrower the erasing temperature range of the heat roller 402.

[0083] The surface area of the document-use thermochromic recording medium 410 is relatively large, and therefore, it becomes important to keep the temperature of the heat roller 402 within the range of the erasing temperature corresponding to the transportation speed until the trailing edge of the recording medium 1 completely passes through the nip position. When applying the erasing apparatus to document use, total elapsed time required for each sheet has to be reduced. For example, it is required for an A4-size thermochromic recording medium 410 with a length (from the leading edge to the trailing edge) of about 300mm to pass through the nip portion within 10 seconds. Furthermore, deformation and wave formation are likely to appear in the document-use thermochromic recording medium 410 because it is large and thin, as compared with a card-type recording medium.

[0084] If the transportation speed is set to 50mm/sec, the acceptable temperature change for the heat roller 402 is 20°C. Taking thermal deformation into account, it is desirable for the thermochromic recording medium 410 to be heated at near the lower limit (i.e., about 150°C) of the temperature range under precise temperature control. From the above, the acceptable range for an erasing apparatus or a rewritable printing apparatus having a practical transportation speed of 30mm/sec or faster is narrower than 10°C, and preferably, narrower than 5°C. To this end; it is necessary to control the temperature of the heat roller 402 at high precession.

[0085] To realize this, the pressure roller 404 is rotated and preheated before the actual erasing operation so that both the heat roller 402 and the pressure roller 404 reach thermal equilibrium before the thermochromic recording medium 410 enters into the nip portion. At thermal equilibrium, the temperature of the pressure roller 404 is about 15-30°C lower than the heat roller 402. By using a heat roller 402 having a large heat capacity, and by setting the temperature of the pressure roller 404 relatively high, the temperature drop in the nip portion during the passing through the thermochromic recording medium 410 can be maintained small.

[0086] On the other hand, from the viewpoint of economizing energy, it is desirable for the halogen lamp 403 of the heat roller 402 to be turned on only during the actual operation of the apparatus. However, rise time (i.e., time required for the heat roller 402 and the pressure roller 404 to reach thermal equilibrium) has to be as short as possible when the apparatus is actually used. In order to reduce the rise time, the thickness of the stainless steel pipe of the heat roller 402 is made thin to reduce the heat capacity. The smaller the heat capacity of the heat roller 402, the greater the temperature change of the heat roller 402 due to heat transfer to the thermochromic recording medium 410 and the pressure roller 404, resulting in insufficient erasing ability.

[0087] To confirm this, a second experiment (Exp. 2) was conducted using a 500W halogen lamp 403 and a stainless steel pipe of 0.5mm thickness with an outer diameter of 15mm having a black heat-resistant coating on the inner face. The pressure roller 404 is made of silicon rubber of hardness 30 (JIS-A) with a thickness of 3mm.

[0088] The heat roller 402 and the pressure roller 404 were heated from room temperature (about 30°C) by turning on the halogen lamp 403, and at the same time, by rotating the heat roller 402 and the pressure roller 404 at a rate corresponding to the prescribed transportation speed. The temperatures of the heat roller 402 and the pressure roller 404 were monitored by thermocouples (not shown, manufactured and sold by Anritsu) that were ON/OFF controlled by a controller (E5CK-QR1 manufactured and sold by Omron). After reaching the setting temperature (150-160°C), the temperature of the heat roller 402 was controlled within the range of ±3°C.

[0089] After 10 seconds from the beginning of the heating, the temperature of the heat roller 402 was 140°C, and a test sheet bearing a square image of 8mm ×8mm was supplied to the nip portion at 30mm/sec to erase the squire image. The image was not erased completely. The color density of the remaining image was 0.02-0.08

[0090] In a third experiment (Exp. 3), a test sheet bearing the same image was supplied to the nip portion at 30mm/sec after 22 seconds from the beginning of the heating. The other conditions were the same as in Experiment 2. In this case, the image was erased satisfactorily, and the color density of the erased surface of the test sheet (thermochromic recording medium 410) was 0.01 or less.

[0091] When the temperature of the heat roller 402 was set to 160°C, the printed image was also erased satisfactorily with a color density less than 0.01 even when the test sheet was supplied to the nip portion after 10 seconds from the beginning of the heating (Exp. 4).

[0092] In experiments 2 and 3, the surface temperature of the pressure roller 404 was also measured by the thermocouple. FIG. 25 is graph showing the temperature change of the pressure roller 404 when the heat roller 402 was set to 140°C. In Experiment 2, the surface temperature of the pressure roller 404 changed from 55°C to 48°C during the erasing operation, and in Experiment 3, the temperature of the pressure roller 404 changed from 65°C to 57°C. Although not shown in the graph, the temperature drop of the pressure roller 404 was much smaller in Experiment 4, in which the temperature of the pressure roller 404 changed from 56°C to 50°C with the heat roller 402 whose temperature was set to 160°C.

[0093] This means that the printed image is erased satisfactorily if the temperature of the pressure roller 404 is higher. This is because if the temperature of the pressure roller 404 is low, heat diffuses easily from the heat roller 402 through the thermochromic recording medium 410 to the pressure roller 404. In this case, the temperature of the thermochromic layer 3 of the thermochromic recording medium 410 does not reach the surface temperature of the heat roller 402 measured by the thermocouple.

[0094] In still another experiment (Exp. 5), the halogen lamp 403 was turned off after the test sheet was subjected to the erasing operation under the conditions of Experiment 3, and the rotation of the heat roller. 402 and the pressure roller 404 was stopped. The erasing apparatus was turned on again twenty (20) seconds after the turning off. The temperature of the heat roller 402 reached 140°C after 5 seconds from the restart (turning on), and a new test sheet was supplied to the nip portion. The temperature of the pressure roller 404 changed from 67°C from 59°C when the test sheet (thermochromic recording medium) 410 was passing through the nip portion. The image on the new test sheet was erased satisfactorily even with the rise time of only 5 seconds.

[0095] From the observation result of Experiments 2 through 5, it is confirmed that reliable erasing and reduced rise time are achieved simultaneously by setting the erasing conditions appropriately based on the temperature of the pressure roller 404. For example, the temperature of the heat roller 402 is set to 160°C if the surface temperature of the pressure roller 404 is at or below 40°C. The heat roller 402 is set to 150°C if the surface temperature of the pressure roller 404 is above 40°C and at or below 60°C, and the heat roller 402 is set to 140°C if the temperature of the pressure roller 404 is higher than 60°C. Selecting the appropriate erasing condition can prevent the thermochromic recording medium 410 from forming waves or deforming.

[0096] In the sixth experiment (Ept. 6), the temperature of the heat roller 402 is set to a constant temperature (e.g., 150°C), and the transportation speed is slowed to 15mm/sec. A test sheet (i.e., a thermochromic recording medium) 410 having the same image was supplied to the nip portion after 10 seconds. The color density of the erased test sheet was less than 0.01. In this case, the transportation speed was adjusted, in stead of changing the temperature of the heat roller 402, based on the temperature of the pressure roller 404. By slowing the transportation speed, the heating time of the thermochromic recording medium 410 becomes long. Accordingly, even if the temperature of the pressure roller 404 is slightly low, and even if the temperature drop of the heat roller 402 at the nip portion becomes large, the thermochromic recording medium 410 can be appropriately heated in the correct range of erasing temperature. If a series of thermochromic recording media are supplied to the apparatus, the first one may take slightly longer time, but erasing operation for the second and subsequent becomes shorter because the temperature of the pressure roller 404 rises as the operation proceeds. To avoid thermal stress onto the thermochromic recording medium 410, which may be caused when the heating time is too long, the transportation speed is selected so as to minimize the thermal stress while allowing the thermochromic recording medium 410 to be sufficiently heated by the heat roller 402.

[0097] In the seventh experiment (Exp. 7), the heat roller 402 was constantly set to 150°C, and the pressure of the pressure roller 404 was set double when the surface temperature of the pressure roller was not sufficiently high. A test sheet 410 was supplied to the nip portion at 30mm/sec after 10 seconds. The color density of the erased test sheet was less than 0.01. By increasing the pressure of the pressure roller 404, the area of the nip portion between the heat roller 402 and the pressure roller 404 increases, and the heated period for a unit area of the thermochromic recording medium 410 increases. In addition, since the thermochromic recording medium 410 comes into tight contact with the heat roller 402, heat promptly transfers to the thermochromic layer 3 of the recording medium 410, thereby efficiently erasing the printed image.

[0098] Adjusting at least one of the temperature of the heat roller 402, the transportation speed, and the pressure of the pressure roller 404 is also applicable to the erasing apparatus 300 shown in FIG. 23A. In this case, the heater substrate 302 having a belt-like heater 303 is used in place of the heat roller 402 with the halogen lamp 403. Therefore, at least one of the temperature of the heater substrate 303, the transportation speed of the thermochromic recording medium 310, and the pressure of the pressure roller 304 are appropriately selected based on the temperature of the pressure roller 304. Consequently, the images on the recycled thermochromic recording medium 310 can be erased uniformly over the entire area, without causing the thermochromic recording medium 310 to wave or deform.

[0099] As a control operation, the temperature of the pressure roller 404 is controlled based on the direct measurement of the surface temperature of the pressure roller itself. For example, under the condition that the temperature of the heat roller 402 is set to 140°C, the thermochromic recording medium 410 is supplied to the nip portion when the surface temperature of the pressure roller 404 reaches 65°C. In this case, transportation timing is also controlled. By appropriately selecting the material and the thickness of the heat roller 402, the temperature of the pressure roller 404 can be raised from room temperature to 65°C quickly (for example, in 17 seconds in this experiment).

[0100] As a second example of control operation, transportation of the thermochromic recording medium starts if the temperature of the pressure roller 404 has reached the prescribed temperature, and if the temperature of the heat roller 402 has also reached the preset erasing temperature. This arrangement guarantees reliable erasing. For example, in above-described 'Experiments 2 through 7, transportation of the thermochromic recording medium was started when the heat roller 402 has reached 140°C and the pressure roller 404 has reached 65°C. In this case, the image printed on the thermochromic recording medium was completely erased. In a third example of control operation, with the erasing apparatus 400 having fixed conditions, time required to reach a predetermined temperature is experimentally known in advance. Accordingly, the preheating time for the pressure roller 404 may be selected based on the initial temperature of the pressure roller 404 at the beginning of the erasing operation. In this context, the preheating time is a time period from turning on the halogen lamp 403 (and at the same time, start of the rotation of the heat roller 402 and the pressure roller 404) to starting the transportation of the thermochromic recording medium 410. This method is simpler than changing the transportation timing while constantly monitoring the surface temperature of the pressure roller 404. Of course, as a premise, the heat roller 402 must have reached the erasing temperature. To this end, it is preferable to start transportation of the thermochromic recording medium 1 when the preheating time has passed and when the heat roller 402 reaches the predetermined temperature.

[0101] In a fourth example of control operation, the rise time from room temperature to the erasiang temperature is reduced. To reduce the rise time, the first and second target temperatures may be set in the heat roller 402. Immediately after starting heating, the target temperature is set higher than the actual erasing temperature because the heat diffusion to the pressure roller 404 is large. This temperature is the first target temperature. If a predetermined time has passed, or if the measured temperature exceeds a predetermined value, the target temperature is set to the actual erasing temperature (that is, the second target temperature). For example, in the above-described experiments, the temperature of the heat roller 402 was set to 170°C (the first temperature) immediately after starting the erasing operation, and the target temperature was changed to 150°C (the second target temperature) when the measured temperature of the heat roller 402 exceeded 130°C. This arrangement allows the temperature of the heat roller 402 to rise rapidly, and the rise time can be shortened. Three or more target temperatures may be set to control the temperature more precisely.

[0102] FIG. 26A and 26B illustrate the erasing apparatus 60 according to a first proposal not according to the invention as claimed. The erasing apparatus shown in FIG. 26A uses a heat roller 65 having a halogen lamp 66, as heating means, while the erasing apparatus 60 shown in FIG. 26B uses a heater substrate 65a having a heater (e.g., a belt-like heater with a width of 3mm) 66a, as the heating means.

[0103] The erasing apparatus 60 in either FIG. 26A or FIG. 26B includes heating means 65 for heating a thermochromic recording medium 1 to erase an image in the thermochromic recording medium, and a pressure roller 67 for pressing the thermochromic recording medium 1 against the heating means 65. The erasing apparatus 60 also includes a first sensor 68 for sensing the temperature of the pressure roller 67, a second sensor 69 for sensing the temperature of the heat roller 65, and a temperature controller 63 for determining a target temperature and controlling the temperature of the heat roller 65 so as to reach the target temperature based on the measurement of the first sensor 68 (i.e., the temperature of the pressure roller 67).

[0104] The erasing apparatus 60 further includes a transportation controller 64 for determining the transportation timing and the transportation speed based on the measurement of the first sensor 68, a power source 61, a driving unit 62, and feed rollers 71 if necessary. The pressure roller 67 may function as the feed roller in place of the feed rollers 67.

[0105] The temperature controller 63 and/or the transportation controller 64 function as an erasing condition control means that controls the erasing conditions including the temperature of the heat roller 65, the transportation speed, and the transportation timing of the thermochromic recording medium 1.

[0106] Erasing operation starts upon manipulation of a start button (not shown) by a user or upon detection of insertion of the thermochromic recording medium 1. The pressure roller 67 starts rotating, and the first sensor 68 monitors the temperature Tr of the pressure roller 67. The temperature controller 63 selects an appropriate target temperature, which is determined in advance corresponding to the value of Tr. The temperature controller 63 controls the ON/OFF operation of the halogen lamp 66 of the heat roller 65 so as to raise the temperature of the heat roller 65 to the selected target temperature and maintain the heat roller 65 at the target temperature.

[0107] When the second sensor 69 detects that the temperature of the heat roller 65 has reached the target temperature, a signal is supplied from the temperature controller 63 to the transportation controller 64. The transportation controller 64 drives the feed rollers 71 to start feeding the thermochromic recording medium 1 to the nip portion between the heat roller 65 and the pressure roller 67. While the thermochromic recording medium 1 is passing between the heat roller 65 and the pressure roller 67, the thermochromic recording medium 1 is heated to a predetermined erasing temperature (i.e., the selected target temperature), and the image contained in it is erased. During the passage, the temperature of the heat roller 65 is controlled so as to be substantially constant.

[0108] In this manner, the optimum temperature of the heat roller 65 is selected based on the temperature of the pressure roller, and the once the heat roller 65 reaches the selected temperature, that temperature is maintained constant during the erasing. With this arrangement, the images can be erased in a reliable manner, and in addition, formation of waves or curling of the heated thermochromic recording medium 1 is greatly reduced. Even after the thermochromic recording medium 1 is repeatedly subjected to erasing and reprinting, the condition of the thermochromic recording medium 1 is maintained good with little wave formation, and the reliability of the erasing operation is kept high.

[0109] FIG. 26C and FIG. 26D illustrate examples of the rewritable printing apparatus 70, in which the erasing apparatuses shown in FIGs. 26A and 26B are assembled, respectively. In either example, the rewritable printing apparatus 70 has a recording unit that comprises a recording thermal head 73 and a platen roller 74 on the downstream of the erasing section. However, the recording unit is not limited to this example, and any type of recording unit may be used in combination with the erasing apparatus. The rewritable printing apparatus 70 also has an imaging control circuit 75 that causes the recording thermal head 73 to form images on the erased thermochromic recording medium 1, based on image signals supplied from a computer or other apparatus. In this example, heating elements of the thermal head 73, which correspond to the pixels of the image to be printed, convert electric energy to heat, and heat the thermochromic layer 3 of the recording medium 1 at a coloring temperature.

[0110] With this rewritable printing apparatus 70, a new image is printed clearly on the thermochromic recording medium 1 because the previously formed image is satisfactorily erased with little color left on it, and because the thermochormic recording medium 1 is supplied to the recording unit without having waves or curling. Even after the reprinting operation is repeated a hundred (100) times, the conditions of the thermochromic recording medium 1 are still good.

[0111] As a modification of the erasing apparatus 60 shown in FIG. 26A and 26B, the transportation controller 64 may determine transportation speed based on the temperature of the pressure roller 67 sensed by the first sensor 68. In operation, the halogen lamp 66 (or the belt-like heater 66a) is turned on, and maintained at a predetermined temperature (e.g., 150°C) by the temperature controller 63. The pressure roller 67 is rotated, and the surface temperature Tr of the pressure roller 67 is sensed by the first sensor 68. The transportation controller 64 receives the monitoring result of the first sensor 68, and selects an appropriate feeding speed that is determined in advance corresponding to the value of Tr. If the second sensor 69 detects that the temperatures of the heat roller 65 (or thermal head 65a) has reached the predetermined temperature, the transportation controller 64 activates the drive motor (not shown) to start transporting the thermochromic recording medium 1 at the selected speed.

[0112] In this modification, the optimum transportation speed is selected based on the temperature of the pressure roller 67, and the thermochromic recording medium 1 can be heated uniformly over the entire surface. Consequently, the image contained in the thermochrmoic recording medium 1 is erased with little remaining image. In addition, the condition of the thermochromic recording medium 1 is maintained good without having waves or curls even after a hundred (100) times of erasing and reprinting are repeated.

[0113] In another modification of the erasing apparatus 60, the transportation controller 64 drives the feed rollers 71 to start transporting the thermochromic recording medium 1 if the temperature Tr of the pressure roller 67 reaches a predetermined temperature that is determined in advance as an erasing condition. The thermo chromic recording medium 1 is pressed against the heat roller 65 by the pressure roller 67 that has reached the optimum temperature. Consequently, the erasing ability of the erasing apparatus 60 is improved

<Tenth Embodiment>

[0114] FIG. 27A and FIG. 27B illustrate examples of the erasing apparatus 60 according to a second proposal not according to the invention as claimed. In this proposal the temperature controller 63 is connected directly to the transportation controller 64 so that signals are transferred between them. Since the difference between the structures in FIG. 27A and FIG. 27B is only the heating means using a heat roller 65 or a thermal head 65a, explanation will be made based on FIG. 27A.

[0115] In operation, the temperature controller 63 receives the monitoring result of the second temperature sensor 69, and supplies a drive signal to the transportation controller 64 when the temperature of the heat roller 65 reaches a predetermined erasing temperature. On the other hand, the transportation controller 64 constantly receives the monitoring result of the first sensor 68 representing the temperature Tr of the pressure roller 67. The transportation controller 64 activates the feed roller 71 to start transporting the thermochromic recording medium 1 if the temperature Tr of the pressure roller 67 reaches a prescribed temperature and if it receives the drive signal from the temperature controller 63 indicating that the heat roller 65 has reached the erasing temperature.

[0116] The thermochromic recording medium 1 is supplied to the nip portion between the heat roller 65 and the pressure roller 67, both of which are sufficiently heated to the optimum temperature. Accordingly, the entire surface of the thermochromic recording medium 1 is heated uniformly, and the images contained in the recording medium 1 can be erased satisfactorily without damaging the recording medium 1. In addition, undesirable wave formation or curling in the erased thermochromic recording medium 1 can be prevented efficiently. This effect can be equally achieved by the apparatus shown in either FIG. 27A or FIG. 27B.

[0117] FIG. 27C and FIG. 27D illustrate the rewritable printing apparatus 70 that incorporates the erasing apparatus shown in FIG. 27A and FIG. 27B, respectively. The rewritable printing apparatus 70 has a recording unit, as in the previous proposal. Erasing and reprinting is repeated a hundred times using the rewritable printing apparatus 70 shown in either FIG. 27C or 27D. The erasing effect and the wave preventing effect are maintained even after the repetition.

[0118] In a modification, the transportation controller 64 checks the temperature Tr of the pressure roller 67 supplied from the first sensor 68 when it receives an erasing start command. The transportation controller 64 selects an appropriate preheating time that is determined in advance corresponding to the value of Tr. After the selected preheating time has passed, the transportation controller 64 activates the driving motor (not shown) to start transporting the thermochromic recording medium 1 at a predetermined feeding speed. This modification also allows the pressure roller 67 to be sufficiently preheated.

[0119] The control operation of the second proposal is simpler, as compared with that in the first proposal, because the transportation controller 64 checks the temperature Tr of the pressure roller 67 only when it receives an erasing start command, and it waits for a predetermined time period before activating the feed rollers 71. This modification can achieve the same effect, and is applicable to the rewriting printing apparatuses shown in FIGs. 27C and 27D

[0120] In another modification, the transportation controller selects a preheating time, as an erasing condition, based on the temperature Tr of the pressure roller 67. Then, after the selected preheating time has passed, the transportation controller 64 receives the temperature of the heat roller 65 from the second sensor 69 via the temperature controller 63. The transportation controller 64 activates the drive motor (not shown) to start transporting the thermochromic recording medium 1 when the temperature of the heat roller 65 has reached a predetermined level. This arrangement guarantees that both the pressure roller 67 and the heat roller 65 are heated sufficiently at the optimum temperatures, and the same effect can be achieved.

[0121] In still another modification, the temperature controller 63 uses two different target temperatures. When the temperature controller 63 receives an erasing start command, it selects a first target temperature higher than the final target temperature (or the second target temperature) of the heat roller 65. For example, assuming the final (or the second) target temperature is 150°C, the temperature controller 63 sets the first target temperature to 170°C, and starts heating. Then, if the temperature of the heat roller 65 reaches 130°C, the temperature controller 63 changes the target temperature to 150°C, which is the final (or the second target temperature).

[0122] This arrangement can reduce the rise time for the heat roller 65 to reach the final target temperature. In the above-described example, the heat roller 65 takes 12 seconds to reach 150°C. This is 3 seconds shorter than the conventional temperature control.

[0123] The above described modifications can be combined arbitrarily, which may further improve the erasing efficiency and quality.

[0124] FIG. 28A illustrates an example of the erasing apparatus 60 according to a third proposal not according to the invention as claimed, and FIG. 28B illustrates an example of the rewritable printing apparatus in which the erasing apparatus of FIG. 28A is incorporated

[0125] In the third proposal, a third temperature sensor 81 is placed at the feeding port, from which the thermochromic recording medium 1 is inserted in the erasing apparatus 60. The third temperature sensor 81 measure the atmospheric temperature near the feeding port, which is assumed to be close to the surface temperature of the thermochromic recording medium 1.

[0126] In operation, upon an erasing start command, the heat roller 65 and the pressure roller 67 start rotating. The first temperature sensor 68 detects the temperature Tr of the pressure roller, and at the same time, the third temperature sensor 81 detects the temperature To outside the erasing apparatus 60. The temperature controller 63 selects an erasing temperature for the heat roller 65 based on the detected temperatures Tr and To. The value of the erasing temperature is determined in advance corresponding to the values of Tr and To. Then, the temperature controller 63 controls the heat roller 65 so as to be at the selected temperature through ON/OFF control of the halogen lamp 66 while the thermochromic recording medium 1 passes through the nip portion.

[0127] In this proposal, the erasing temperature of the heat roller 65 is determined taking into account not only the temperature of the pressure roller 67, but also the atmospheric temperature outside the apparatus 60 approximating the temperature of the thermochromic recording medium 1. The optimum temperature is maintained during the erasing operation. Accordingly, the entire surface area of the thermochromic recording medium 1 is heated uniformly without damage to it, and consequently, the erasing reliability is improved.

[0128] Erasing and reprinting are repeated a hundred times using the rewritable printing apparatus 70 shown in FIG. 28B. The image contained in the recycled thermochromic recording medium 1 is erased almost completely without causing wave formation or curling, and a new image can be printed clearly on the erased thermochromic recording medium 1.

[0129] In a modification, a target temperature of the pressure roller 67 may be determined based on the outside temperature To detected by the third temperature sensor 81. The transportation controller 64 activates the feed rollers 71 to start transporting the thermochromic recording medium 1 when the temperature of the pressure roller 67 sensed by the first sensor 68 has reached the selected target temperature, and when the temperature of the heat roller 65 sensed by the second sensor 69 has reached the set temperature. This arrangement can also achieve the same effect, that is, uniform heating of the thermochromic recording medium 1 without causing waves or curls. These effects can be maintained even after erasing and recording are repeated a hundred time by the rewritable printing apparatus 70.

[0130] FIG. 29A illustrates an example of the erasing apparatus 60 according to a fourth proposal not according to the invention as claimed, and FIG. 29 illustrates an example of the rewritable printing apparatus 70 in which the erasing apparatus similar to that shown in FIG. 29A is incorporated. The only difference from the erasing apparatus shown in FIG. 29A is that the erasing section of the rewritable printing apparatus 70 in FIG. 29B uses a heater substrate 65a and a belt-like heater 66a as the heating means, in place of the heat roller 65 and the halogen lamp 66 as the heating means. The functions and the effects of the heating means of both structures are the same.

[0131] In the fourth proposal, a fourth temperature sensor 82 is placed near the feeding port inside the apparatus, instead of placing the third sensor 81 outside the apparatuses in the previous embodiment. The fourth sensor 82 senses the surface temperature Tm of the thermochromic recording medium 1.

[0132] In operation, upon receiving an erasing start command, the heat roller 65 and the pressure roller 67 are rotated. The first sensor 68 senses the temperature Tr of the pressure roller 67, and the fourth sensor 82 senses the surface temperature Tm of the thermochromic recording medium 1 that stands just ready at the feed port. The temperature controller 63 selects an appropriate erasing temperature for the heat roler 65 based on Tr and Tm. The optimum erasing temperature corresponding to the values of Tr and Tm is determined in advance, and therefore, the temperature of the heat roller 65 is controlled to the most suitable condition under the ON/OFF control of the halogen lamp 66. When the temperature of the heat roller 65 sensed by the second sensor 69 has reached the selected temperature, the transportation controller 64 activates the feed rollers 71 to start transporting the thermochromic recording medium 1 toward the nip portion between the heat roller 65 and the pressure roller 67. While the thermochromic recording medium 1 passes through the nip portion, the temperatures of the heat roller 65 and the pressure roller 67 are maintained at the selected temperatures by the temperature controller 63.

[0133] Since not only the temperature of the pressure roller 67, but also the surface temperature of the thermochromic recording medium 1 are taken into account to select the erasing temperature, the thermochromic layer 3 of the recording medium 1 can be heated uniformly over the entire area without damage on it.

[0134] After the erasing operation was actually conducted using the erasing apparatus shown in FIG. 29A, the image printed on the thermochromic recording medium 1 was erased in the reliable manner without forming waves in the thermochromic recording medium 1. Even after repeating the erasing operations a hundred times, the image was erased still in the reliable manner, while maintaining the thermochromic recording medium 1 in good condition.

[0135] In addition, erasing and reprinting were repeated a hundred times using the rewritable printing apparatus 70 shown in FIG. 29B, in which a recording unit is placed on the downstream side of the erasing unit. The images in the recycled recording medium 1 were erased satisfactorily without remaining images and without forming waves, and a new image is printed clearly on the erased thermochromic recording medium 1.

[0136] In a modification, the temperature Tr of the pressure roller 67 is selected based on the surface temperature Tm of the thermochromic recording medium 1 detected by the fourth sensor 82. The temperature controller 63 select an appropriate set temperature for the pressure roller 67, which is determined in advance corresponding to the value of Tm. The transportation controller 64 activates the feed rollers 71 to start transporting the thermochromic recording medium 1 if the temperature of the pressure roller 67 sensed by the first sensor 69 has reached the selected temperature, and if the temperature of the heat roller 65 has reached a predetermined erasing temperature.

[0137] In this modification, the thermochromic recording medium 1 is supplied to the nip portion when the temperature of the pressure roller 67 has reached the optimum temperature defined by the temperature Tm of the thermochromic recording medium 1, and when the temperature of the heat roller 65 has reached a predetermined temperature. Accordingly, uniform heating over the entire surface of the thermochromic recording medium 1 is realized without causing undesirable damage or wave formation.

[0138] Erasing operation was actually conducted using this modified erasing apparatus, and the image printed on the thermochromic recording medium 1 was erased in the reliable manner without forming waves in the recording medium 1. Even after repeating the erasing operations a hundred times, the image was erased still in the reliable manner, while maintaining the thermochromic recording medium 1 in good condition.

[0139] Using the rewritable printing apparatus incorporating the modified erasing apparatus that operates in the above-described manner, image quality of the reprinted thermochromic recording medium 1 is maintained high even after erasing and reprinting were repeated a hundred times.

[0140] Thus, the erasing apparatus erases the image printed in the thermochromic recording medium 1 by heating the thermochromic layer 3 to a temperature within a predetermined range. According to the ninth through twelfth embodiments, the erasing apparatus comprises a heat roller 65 or a heater substrates 65a (functioning as a heating means) that heats the thermochromic layer 3 of the recording medium 1, a pressure roller 67 (functioning as a pressure means) that comes into contact with the thermochromic recording medium 1 to press it against the heating means, a first sensor 68 sensing the temperature of the pressure roller 67, and an erasing condition control means for controlling the erasing conditions affecting the erasing operation, based on the temperature Tr of the pressure roller 67 sensed by the first sensor 68. The erasing condition control means includes temperature controller 63 and/or a transportation controller 64. The erasing condition control means controls the erasing temperature of the heat roller 65, the transportation speed and the transportation timing of the recording medium 1, and other factors. With this arrangement, the temperature of the heat roller 65 is set to and maintained at the optimum temperature. Accordingly, uniform and reliable heating operation can be conducted within the appropriate range of erasing temperature for the thermochromic layer 3 without excessive stress to the recording medium 1 under an arbitrary condition.

[0141] Especially in the first proposal, the heat controller 63 functions as the erasing temperature determination means and the heating temperature control means. The erasing temperature of the heat roller 65 is determined by the temperature controller 63, based on temperature Tr of the pressure roller 67 sensed by the first sensor 68. The temperature of the heat roller 65 is maintained at the selected temperature during the erasing operation. By setting the erasing temperature of the heat roller 65 as one of the erasing conditions based on temperature Tr of the pressure roller 67, the reliability of erasing operation can be improved, while reducing excessive stress to the thermochromic recording medium 1.

[0142] In the modifications, transportation controller 64 functions as the transportation speed determination means and the transportation control means. The transportation speed of the transportation rollers 71 is determined as one of the erasing conditions based on temperature Tr of the pressure roller 67 sensed by the first sensor 68. The revolution rate of the transportation roller 71 is regulated by the transportation controller 64 so that the thermochromic recording medium 1 is transported at the selected speed. By appropriately regulating the transportation speed based on temperature Tr of the pressure roller 67, the heating time is adjusted correctly. Consequently, the reliability of the erasing operation is improved, while reducing the entire process time and excessive stress to the thermochromic recording medium 1.

[0143] In another modification, the transportation controller 64 controls the transportation roller 71 so that the thermochromic recording medium 1 enters the nip portion, at which the thermochromic recording medium 1 is heated in contact with the heat roller 65, on or after the temperature Tr of the pressure roller sensed by the first sensor 68 having reached a predetermined temperature. This arrangement also improves the reliability of the erasing operation, and at the same time, the process time and adverse influence of excessive stress are minimized.

[0144] In the second proposal, the transportation controller 64 functions as a timing control means, and it controls the operation of the transportation roller 11 based on temperature Tr of the pressure roller so that the thermochromic recording medium 1 enters the nip portion at appropriate timing. In an example, the thermochromic recording medium 1 is supplied to the nip portion when temperature Tr of the pressure roller 67 has reached a predetermined temperature. This arrangement improves the reliability of prompt erasing operation, while preventing excessive stress to the recording medium to minimize adverse influence. In another example, the transportation timing is determined based on a predetermined pre-heating time, which is easier than the former example to achieve the same effect.

[0145] In still another example of the second proposal, a second sensor 69 for sensing the temperature of the heat roller 65 is provided. The transportation controller 64 controls the revolution of the transportation roller 71 so that the thermochromic recording medium 1 enters the nip portion when the temperature of the heat roller 65 sensed by the second sensor 69 has reached at a predetermined temperature. The arrangement takes into account not only the temperature of the pressure roller 67, but also the temperature of the heat roller 65, and guarantee's the reliability of the erasing operation, while minimizing the processing time and influence of excessive stress on the thermochrmoic recording medium 1.

[0146] In still another example of the second proposal, the temperature controller 63 functions as a pre-heating means and a temperature control means. The temperature of the heat roller 65 is controlled by the temperature controller 63 so that the heat roller 65 is heated up to the first temperature (e.g., 170°C) upon an erasing command, and then the temperature is maintained at the second temperature (e.g., 150°C) during actual heating of the thermochromic layer 3 of the recording medium 1. By quickly heating the heat roller 65 to the first temperature that is higher than the target temperature (i.e., the second temperature) upon receiving the erasing command, the rising time of the erasing apparatus is shortened

[0147] In the third proposal, a third temperature sensor 81 for sensing the atmospheric temperature outside the erasing apparatus is provided. The temperature controller 63 and the transportation controller 64, which constitute an erasing condition control means, control the erasing conditions of the thermochromic recording medium 1 based on temperature Tr of the pressure roller sensed by the first sensor 68, as well as on temperature

To sensed by the third sensor 81. The temperature To is considered to represent the temperature of the thermochromic recording medium 1. Since, in addition to the temperature of the pressure roller, the temperature of the thermochromic recording medium 1 is taken into account to select and control the setting temperature of the heat roller 65, more precise temperature control is achieved. As a result, the reliability of the erasing operation is improved.

[0148] In a modification, the transportation controller 63 controls the transportation roller 71 so that the thermochromic recording medium 1 enters the nip portion when the temperature Tr of the pressure roller 67 has reached a predetermined temperature selected in accordance with the temperature of the thermochromic recording medium 1 that is represented by the atmospheric temperature sensed by the third sensor 81. The reliability of the erasing operation is further improved.

[0149] In the fourth proposal, a fourth temperature sensor 82 is provided, which senses the temperature Tm of the thermochromic recording medium 1 inside the erasing apparatus before the surface of the thermochrmoic recording medium 1 comes into contact with the heat roller 65. In this case, the temperature controller 63 and the transportation controller 64, which constitute an erasing condition control means, control the erasing operation based on temperature Tr of the pressure roller sensed by the first sensor 68 and temperature Tm of the recording medium 1 sensed by the fourth sensor 82. In this example, the direct measurement of the temperature of the thermochromic recording medium 1 is taken into account, as well as temperature Tr of the pressure roller 7, to select the setting temperature of the heat roller 5. Consequently, the reliability of the erasing operation is improved.

[0150] In a modification, the transportation controller 63 controls the transportation roller 71 so that the thermochromic recording medium 1 enters the nip portion when the temperature Tr of the pressure roller 67 has reached a predetermined temperature selected in accordance with direct measurement Tm of the thermochromic recording medium 1. The reliability of the erasing operation is further improved.

[0151] Thus, uniform and reliable heating operation is conducted within the appropriate erasing temperature of the thermochromic layer 3 of the recording medium 1 under an arbitrary condition, while preventing excessive stress to the thermochromic recording medium 1. The image printed on the thermochromic recording medium 1 is erased in the stable manner without forming waves or curls and without leaving colors on the recording medium 1. An A4 size (plane paper size) thermochromic recording medium 1 is recycled many times, while keeping the conditions of the thermochromic recording medium 1 satisfactory. Consequently, public concerns including destruction of environment and natural resources due to huge paper consumption and disposal of wastes can be reduced.

[0152] It should be noted that the heating means is not limited to the heat roller or the thermal head, but includes arbitrary means suitable to heating a thermochromic recording medium. For example, heating means using laser beams may be used. Similarly, the pressure means is not limited to the pressure roller, but includes any means suitable to pressing the thermochromic recording means against the heating means.

[0153] Although the invention has bee described using only those components required to explain the structure and the operations of the erasing apparatus and the rewritable printing apparatus, feed guide, feed rollers , paper feed sensors, paper feed trays, ejection trays, exhaust fans, and so on may be provided in the apparatus as necessary.

Claims

1. An erasing apparatus for use with a thermochromic recording medium, comprising:

    a heating means for heating the thermochromic recording medium at an erasing temperature to erase an image printed on the thermochromic recording medium;
    a stress applier positioned downstream of the heating means and for applying tensile stress to the thermochromic recording medium heated by the heating means;

    wherein the stress applier has a cooling area to cool the heated thermochromic recording medium; and
    wherein the stress applier applies the tensile stress to the thermochromic recording medium, when the surface temperature of the thermochromic recording medium resides in a prescribed range after. the erasing.

2. The erasing apparatus according to claim 1, wherein the stress applier is a curved transportation path extending downstream of the heating means.

3. The erasing apparatus according to claim 2, wherein the curved transportation path has a curved surface having a radius of curvature equal to or smaller than 40mm.

4. The erasing apparatus according to claim 2 or 3, wherein the curved transportation path is defined by a guide having a curved surface.

5. The erasing apparatus according to claim 4, wherein the guide has one or more grooves extending along the longitudinal axis thereof.

6. The erasing apparatus according to claim 2 or 3,

wherein the curved transportation path is defined by a plurality of rollers.

7. The erasing apparatus according to claim 2 or 3, wherein the curved transportation path is defined by a belt around one or more rollers.

8. The erasing apparatus according to claim 2 or 3, wherein the curved transportation path is defined by an air current.

9. The erasing apparatus according to claim 1, wherein the stress applier is positioned below the heating means in the gravitational direction.

10. The erasing apparatus according to claim 1, wherein the stress applier is a bending transportation path extending from the heating means and having a slope at a predetermined angle with respect to the horizontal.

11. The erasing apparatus according to claim 10, wherein the predetermined angle is at least 30 degrees with respect to the horizontal.

12. The erasing apparatus according to claim 10 or 11, wherein the bending transportation path is defined by a guide having an inclined surface.

13. The erasing apparatus according to claim 12, wherein the guide has one or more grooves extending along a longitudinal axis thereof.

14. The erasing apparatus according to claim 10 or 11, wherein the bending transportation path is defined by a plurality of rollers.

15. The erasing apparatus according to claim 10 or 11, wherein the bending transportation path is defined by a belt around one or more rollers.

16. The erasing apparatus according to any one of the preceding claims, wherein the stress applier applies the tensile stress to the thermochromic recording medium before the surface temperature of the thermochromic recording medium is reduced to 60°C or below.

17. The erasing apparatus according to any one of the preceding claims, wherein the stress applier applies the tensile stress to the thermochromic recording medium, when the surface temperature of the thermochromic recording medium is below 100°C.

18. The erasing apparatus according to any one of the preceding claims, wherein the stress applier has a cooling feature for removing heat from the thermochromic recording medium.

19. A rewritable printing apparatus **characterized by**:

the erasing apparatus described in any one of claims 1 through 18 for erasing the image printed on the thermochromic recording medium; and

a recording unit positioned downstream of the erasing apparatus and for printing a new image on the erased thermochromic recording medium.

Patentansprüche

1. Löschvorrichtung für die Verwendung mit einem thermochromischen Aufzeichnungsmedium, die umfasst:

Heizmittel zum Heizen des thermochromischen Aufzeichnungsmediums auf eine Löschtemperatur bzw. bei einer Löschtemperatur, um ein auf das thermochromische Aufzeichnungsmedium gedrucktes Bild zu löschen;

eine Beanspruchungsausübungseinrichtung, die auf der Auslassseite der Heizmittel angeordnet ist und um auf das durch die Heizmittel geheizte thermochromische Aufzeichnungsmedium eine Zugbeanspruchung auszuüben;

wobei die Beanspruchungsausübungseinrichtung einen Kühlungsbereich besitzt, um das geheizte thermochromische Aufzeichnungsmedium zu kühlen; und

wobei die Beanspruchungsausübungseinrichtung die Zugbeanspruchung auf das thermochromische Aufzeichnungsmedium ausübt, wenn die Oberflächentemperatur des thermochromischen Aufzeichnungsmediums nach dem Löschen in einem vorgeschriebenen Bereich bleibt.

2. Löschvorrichtung nach Anspruch 1, bei der die Beanspruchungsausübungseinrichtung ein gekrümmter Transportweg ist, der sich auf der Auslassseite der Heizmittel erstreckt.

3. Löschvorrichtung nach Anspruch 2, bei der der gekrümmte Transportweg eine gekrümmte Oberfläche mit einem Krümmungsradius, der gleich oder kleiner als 40 mm ist, besitzt.

4. Löschvorrichtung nach Anspruch 2 oder 3, bei der der gekrümmte Transportweg durch eine Führung definiert ist, die eine gekrümmte Oberfläche besitzt.

5. Löschvorrichtung nach Anspruch 4, bei der die Führung eine oder mehrere Nuten besitzt, die sich in Richtung ihrer Längsachse erstrecken.

6. Löschvorrichtung nach Anspruch 2 oder 3, bei der der gekrümmte Transportweg durch mehrere Rollen definiert ist.

7. Löschvorrichtung nach Anspruch 2 oder 3, bei der der gekrümmte Transportweg durch einen Riemen um eine oder mehrere Rollen definiert ist.

8. Löschvorrichtung nach Anspruch 2 oder 3, bei der der gekrümmte Transportweg durch einen Luftstrom definiert ist.

9. Löschvorrichtung nach Anspruch 1, bei der die Beanspruchungsausübungseinrichtung in Schwerkraftrichtung unter den Heizmitteln positioniert ist.

10. Löschvorrichtung nach Anspruch 1, bei der die Beanspruchungsausübungseinrichtung ein Biegetransportweg ist, der sich von den Heizmitteln erstreckt und eine Neigung mit einem vorgegebenen Winkel zu der Horizontalen hat.

11. Löschvorrichtung nach Anspruch 10, bei der der vorgegebenen Winkel in Bezug auf die Horizontale wenigstens 30 Grad ist.

12. Löschvorrichtung nach Anspruch 10 oder 11, bei der der Biegetransportweg durch eine Führung mit einer geneigten Oberfläche definiert ist.

13. Löschvorrichtung nach Anspruch 12, bei der die Führung eine oder mehrere Nuten besitzt, die sich in Richtung ihrer Längsachse erstrecken.

14. Löschvorrichtung nach Anspruch 10 oder 11, bei der der Biegetransportweg durch mehrere Rollen definiert ist.

15. Löschvorrichtung nach Anspruch 10 oder 11, bei der der Biegetransportweg durch einen Riemen um eine oder mehrere Rollen definiert ist.

16. Löschvorrichtung nach einem der vorhergehenden Ansprüche, bei der die Beanspruchungsausübungseinrichtung die Zugbeanspruchung auf das thermochromische Aufzeichnungsmedium ausübt, bevor die Oberflächentemperatur des thermochromischen Aufzeichnungsmediums auf 60 °C oder weniger abgefallen ist.

17. Löschvorrichtung nach einem der vorhergehenden Ansprüche, bei der die Beanspruchungsausübungseinrichtung die Zugbeanspruchung auf das thermochromische Aufzeichnungsmedium ausübt, wenn die Oberflächentemperatur des thermochromischen Aufzeichnungsmediums unter 100 °C liegt.

18. Löschvorrichtung nach einem der vorhergehenden Ansprüche, bei der die Beanspruchungsausübungseinrichtung eine Kühlungseigenschaft besitzt, um Wärme von dem thermochromischen Aufzeichnungsmedium abzuführen.

19. Wiederbeschreibbare Druckvorrichtung, **gekennzeichnet durch**:

die Löschvorrichtung nach einem der Ansprüche 1 bis 18 zum Löschen des auf das thermochromische Aufzeichnungsmedium gedruckten Bildes; und
eine Aufzeichnungseinheit, die hinter der Löschvorrichtung positioniert ist, um auf das gelöschte thermochromische Aufzeichnungsmedium ein neues Bild zu drucken.

Revendications

1. Appareil d'effacement pour une utilisation avec un support d'enregistrement thermochrome, comprenant :

un moyen de chauffage pour chauffer le support d'enregistrement thermochrome à une température d'effacement pour effacer une image qui est imprimée sur le support d'enregistrement thermochrome ;
un moyen d'application de contrainte qui est positionné en aval du moyen de chauffage et qui et prévu pour appliquer une contrainte de tension au support d'enregistrement thermochrome qui est chauffé par le moyen de chauffage ;

dans lequel le moyen d'application de contrainte comporte une zone de refroidissement pour refroidir le support d'enregistrement thermochrome chauffé ; et
dans lequel le moyen d'application de contrainte applique la contrainte de tension sur le support d'enregistrement thermochrome lorsque la température en surface du support d'enregistrement thermochrome se situe dans une plage prescrite après l'effacement.

2. Appareil d'effacement selon la revendication 1, dans lequel le moyen d'application de contrainte est une voie de transport courbe qui s'étend en aval du moyen de chauffage.

3. Appareil d'effacement selon la revendication 2, dans lequel la voie de transport courbe comporte une surface courbe qui présente un rayon de courbure égal ou inférieur à 40 mm.

4. Appareil d'effacement selon la revendication 2 ou 3, dans lequel la voie de transport courbe est définie par un guide qui comporte une surface courbe.

5. Appareil d'effacement selon la revendication 4, dans lequel le guide comporte une ou plusieurs gorges qui s'étendent suivant son axe longitudinal.

6. Appareil d'effacement selon la revendication 2 ou 3, dans lequel la voie de transport courbe est définie par une pluralité de rouleaux.

7. Appareil d'effacement selon la revendication 2 ou 3, dans lequel la voie de transport courbe est définie par une courroie autour d'un ou de plusieurs rouleaux.

8. Appareil d'effacement selon la revendication 2 ou 3, dans lequel la voie de transport courbe est définie par un courant d'air.

9. Appareil d'effacement selon la revendication 1, dans lequel le moyen d'application de contrainte est positionné au-dessous du moyen de chauffage suivant la direction de gravitation.

10. Appareil d'effacement selon la revendication 1, dans lequel le moyen d'application de contrainte est une voie de transport de flexion qui s'étend depuis le moyen de chauffage et qui présente une pente selon un angle prédéterminé par rapport à l'horizontale.

11. Appareil d'effacement selon la revendication 10, dans lequel l'angle prédéterminé est à au moins 30 degrés par rapport à l'horizontale.

12. Appareil d'effacement selon la revendication 10 ou 11, dans lequel la voie de transport de flexion est définie par un guide qui comporte une surface inclinée.

13. Appareil d'effacement selon la revendication 12, dans lequel le guide compend une ou plusieurs gorges qui s'étendent suivant son axe longitudinal.

14. Appareil d'effacement selon la revendication 10 ou 11, dans lequel la voie de transport de flexion est définie par une pluralité de rouleaux.

15. Appareil d'effacement selon la revendication 10 ou 11, dans lequel la voie de transport de flexion est définie par une courroie autour d'un ou de plusieurs rouleaux.

16. Appareil d'effacement selon l'une quelconque des revendications précédentes, dans lequel le moyen d'application de contrainte applique la contrainte de tension sur le support d'enregistrement thermochrome avant que la température en surface du support d'enregistrement thermochrome ne soit réduite jusqu'à 60°C ou moins.

17. Appareil d'effacement selon l'une quelconque des revendications précédentes, dans lequel le moyen d'application de contrainte applique la contrainte de tension sur le support d'enregistrement thermochrome lorsque la température en surface du support d'enregistrement thermochrome est inférieure à 100°C.

18. Appareil d'effacement selon l'une quelconque des revendications précédentes, dans lequel le moyen d'application de contrainte présente une caractéristique de refroidissement pour enlever de la chaleur du support d'enregistrement thermochrome.

19. Appareil d'impression réinscriptible **caractérisé par** :

l'appareil d'effacement décrit selon l'une quelconque des revendications 1 à 18 pour effacer l'image sur le support d'enregistrement thermochrome ; et
une unité d'enregistrement qui est positionnée en aval de l'appareil d'effacement et pour imprimer une nouvelle image sur le support d'enregistrement thermochrome effacé.

FIG.1A PRIOR ART

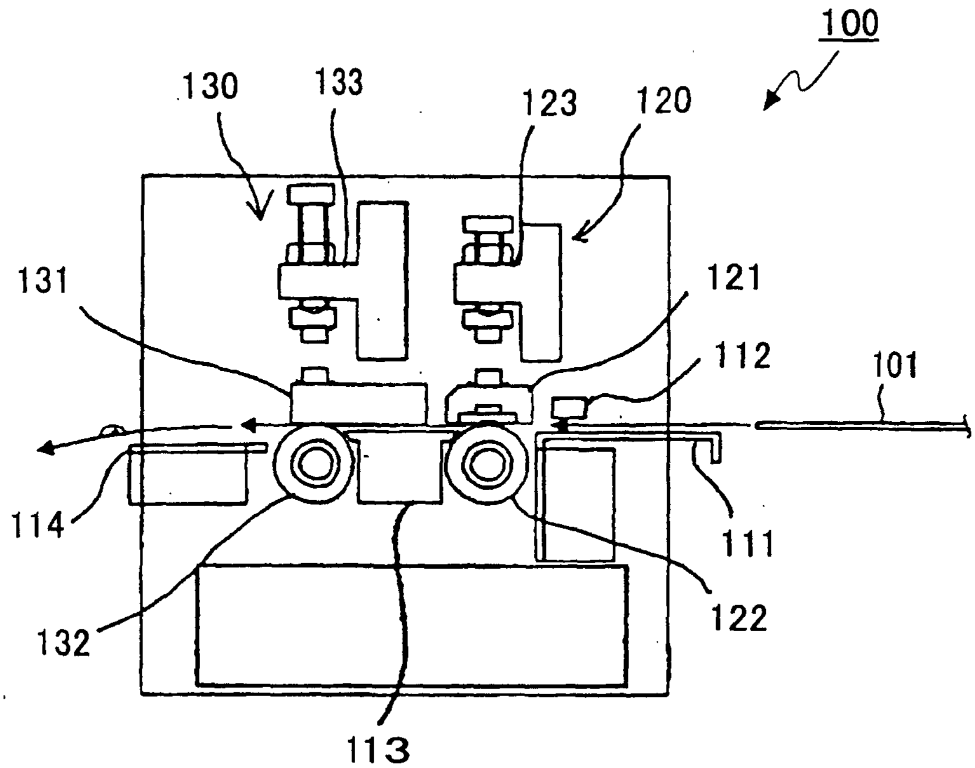


FIG.1B PRIOR ART

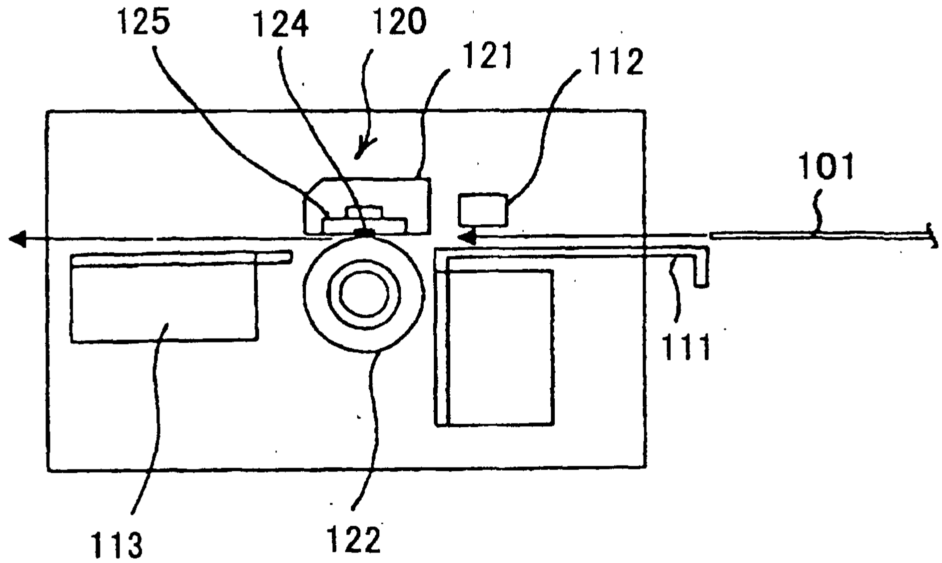


FIG.1C PRIOR ART

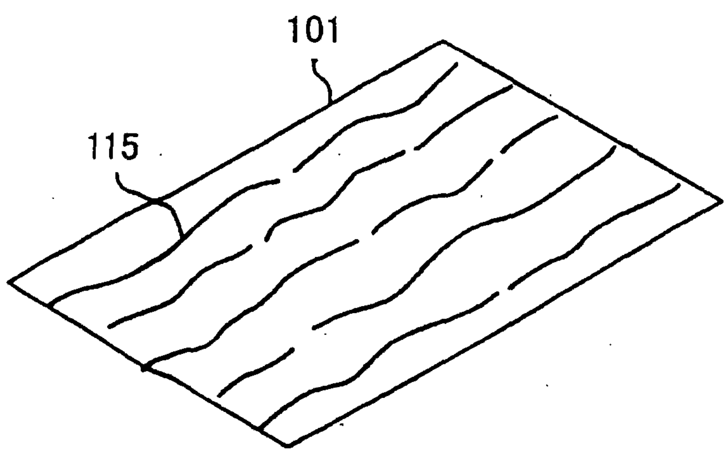


FIG.2

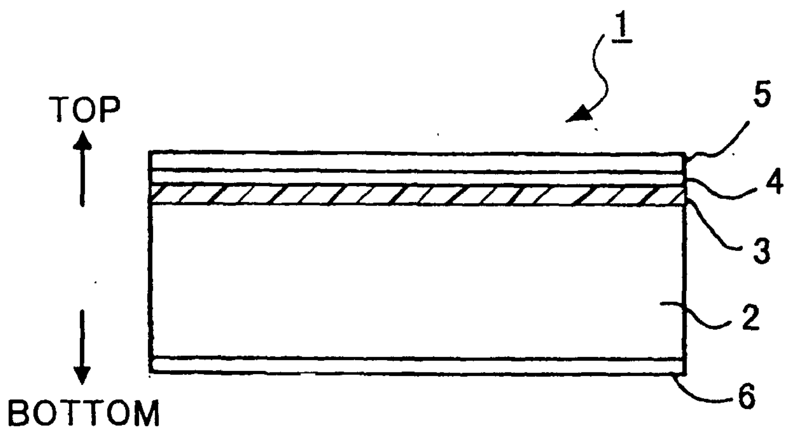


FIG.3A

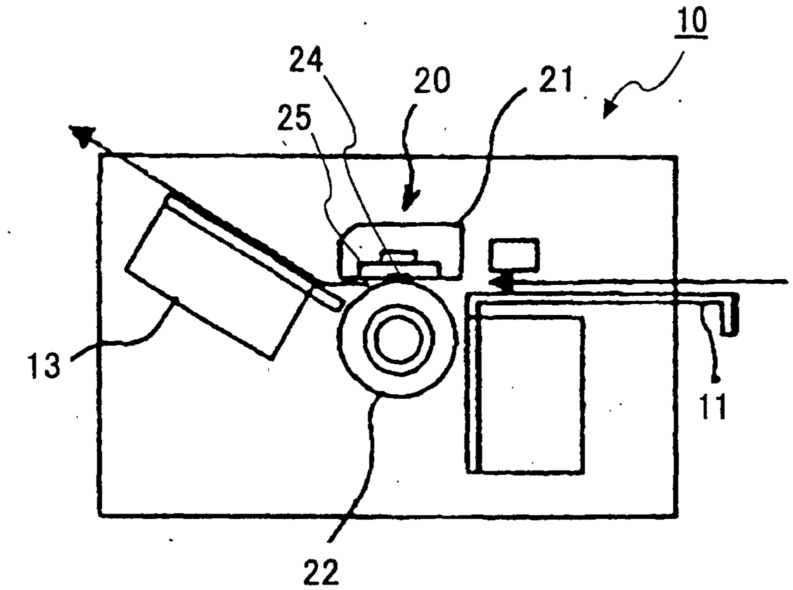


FIG.3B

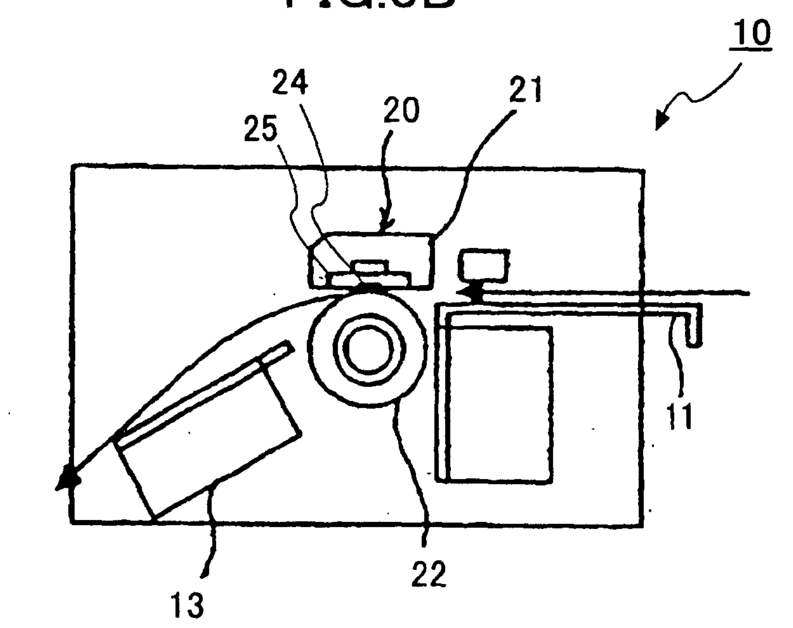
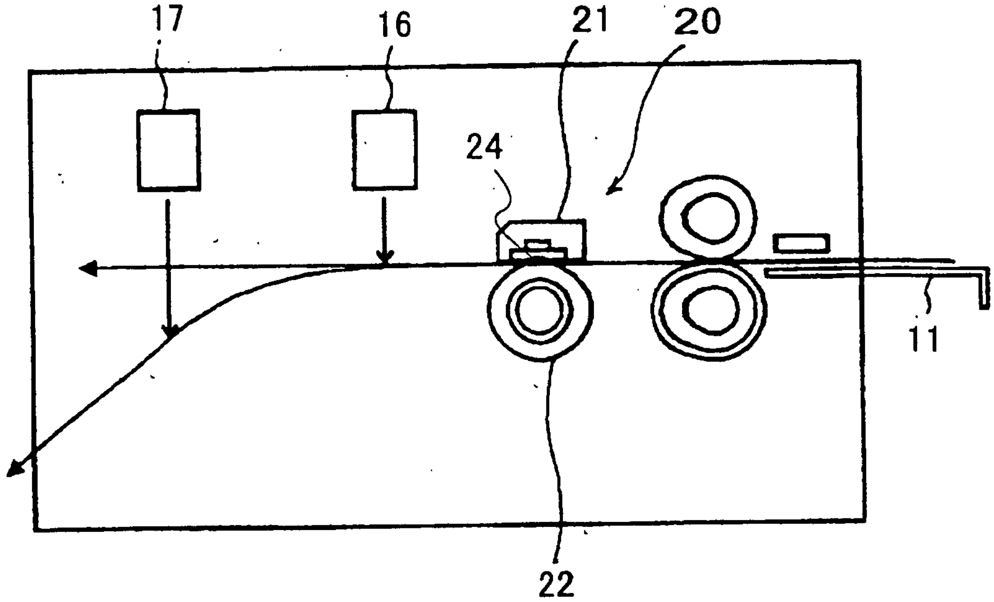


FIG.4


17
16
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24
11
22

FIG.5

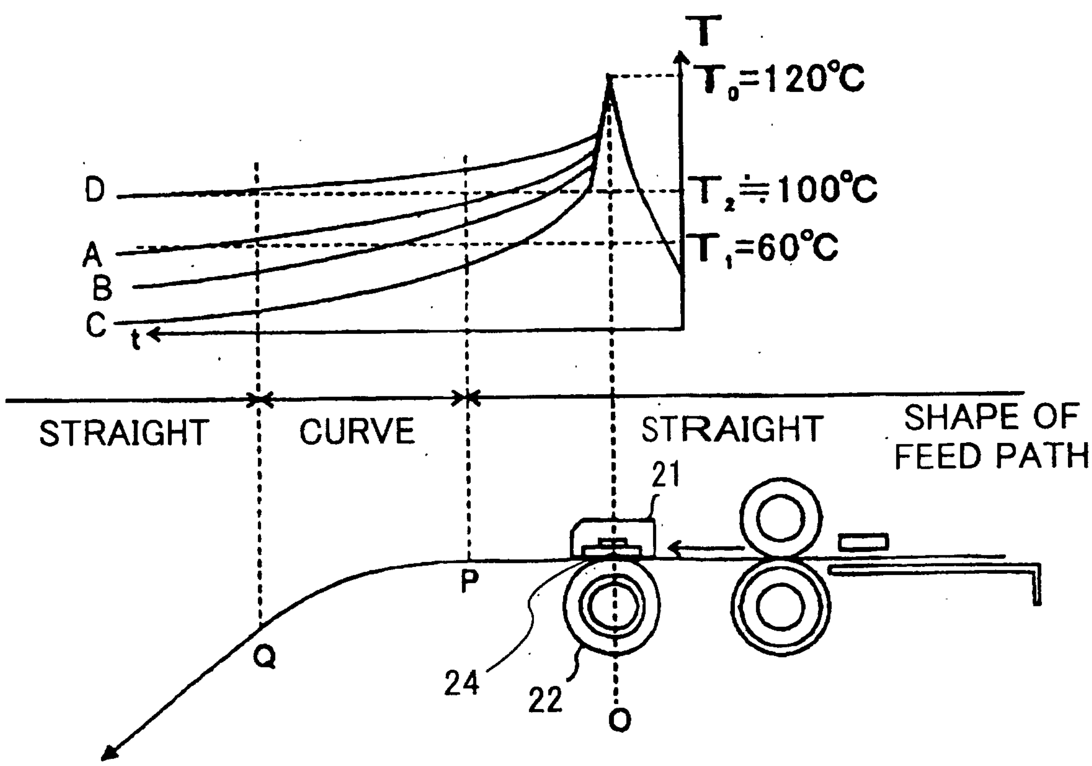

T
T₀=120°C
D
T₂≒100°C
A
T₁=60°C
B
C
t
STRAIGHT
CURVE
STRAIGHT
SHAPE OF
FEED PATH
21
P
Q
24
22
O

FIG.6A

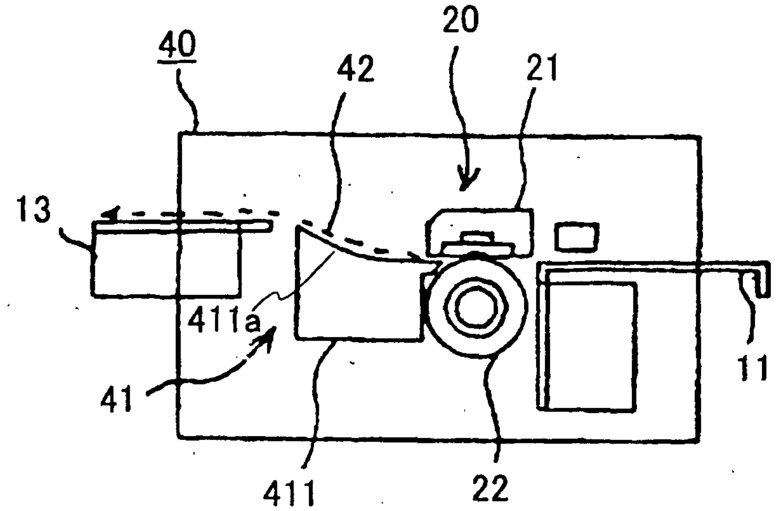


FIG.6B

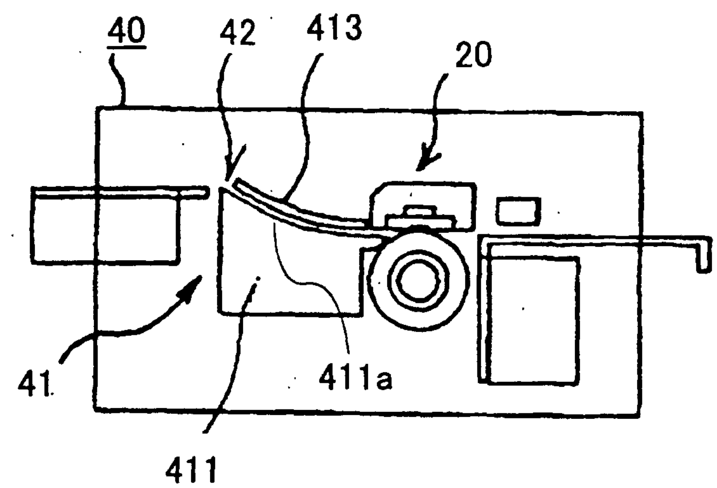


FIG.6C

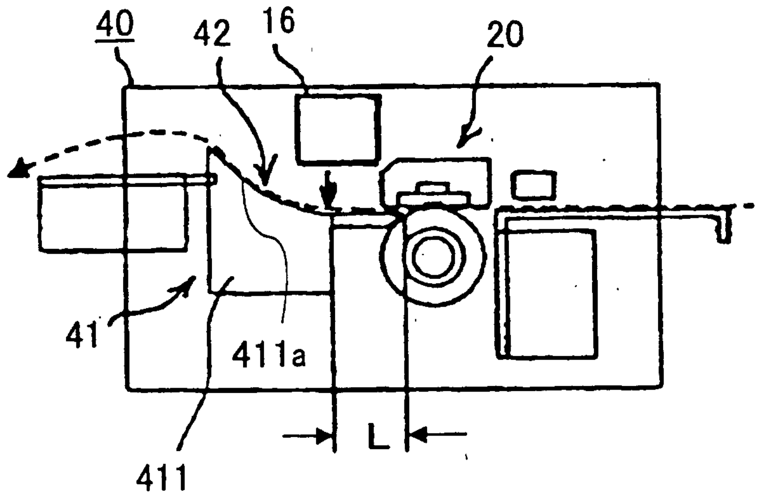


FIG.6D

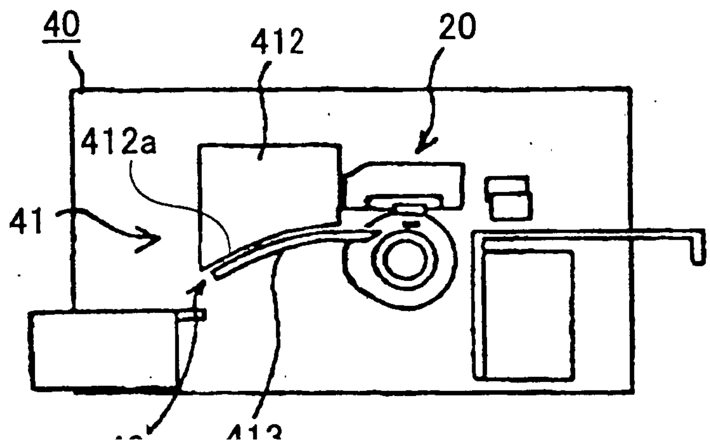


FIG.7A

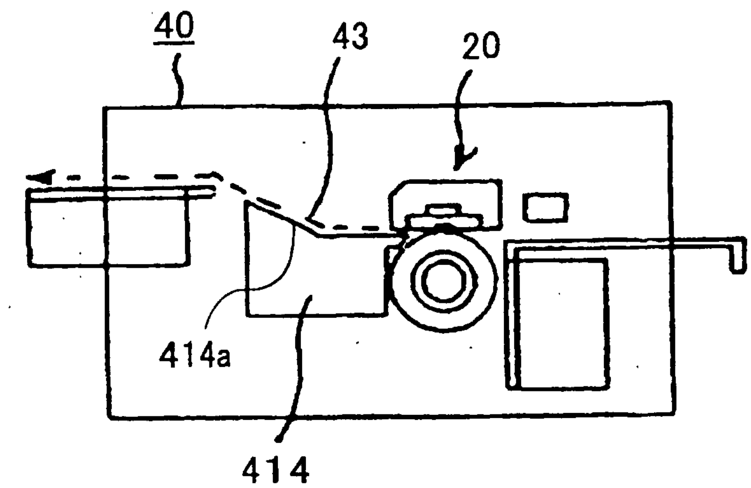


FIG.7B

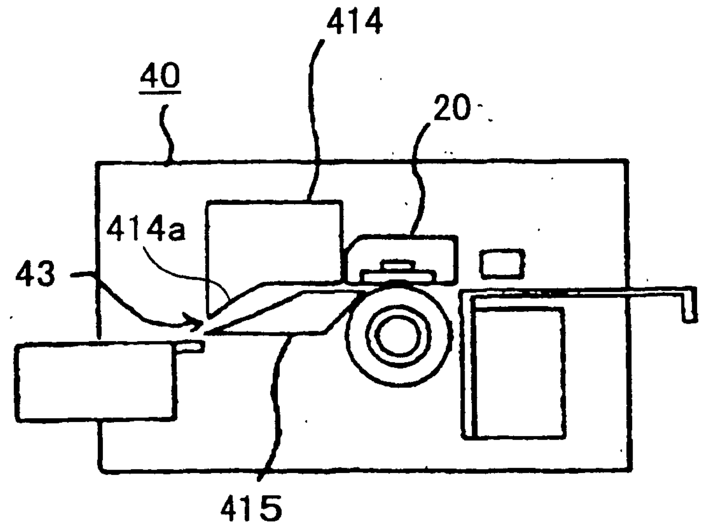


FIG.8A

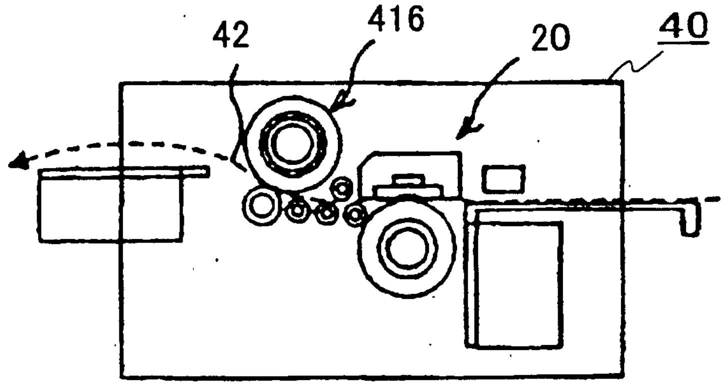


FIG.8B

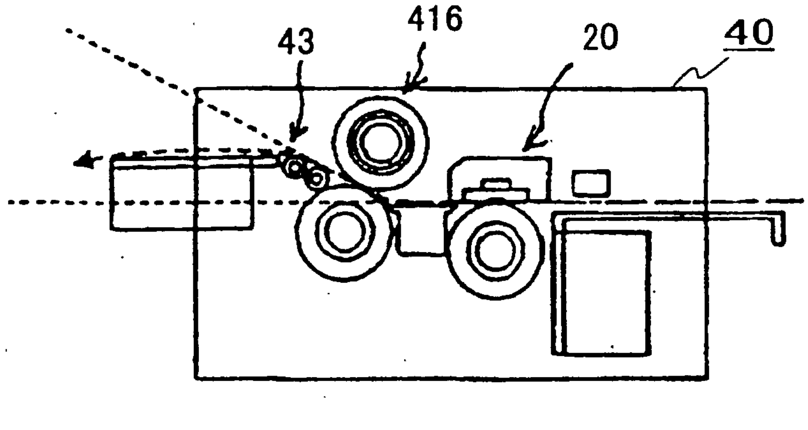


FIG.8C

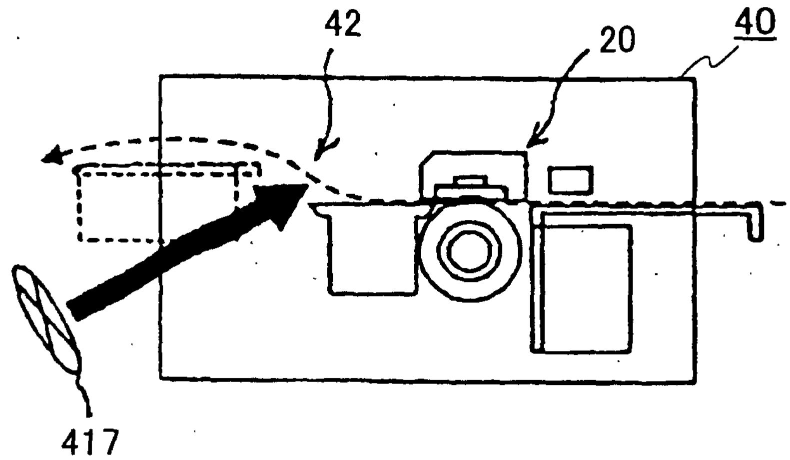


FIG.8D

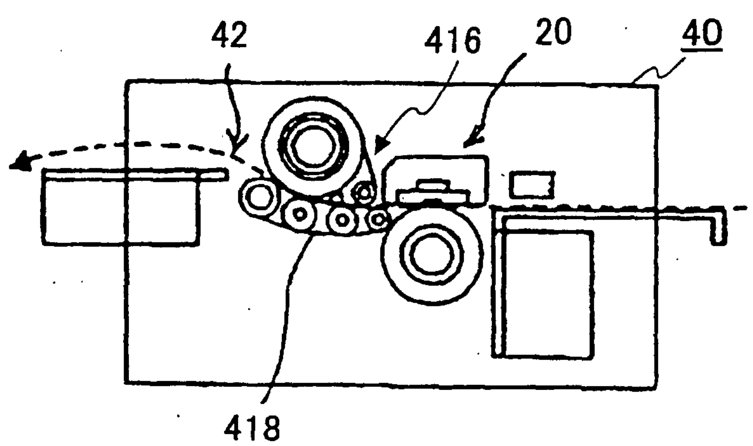
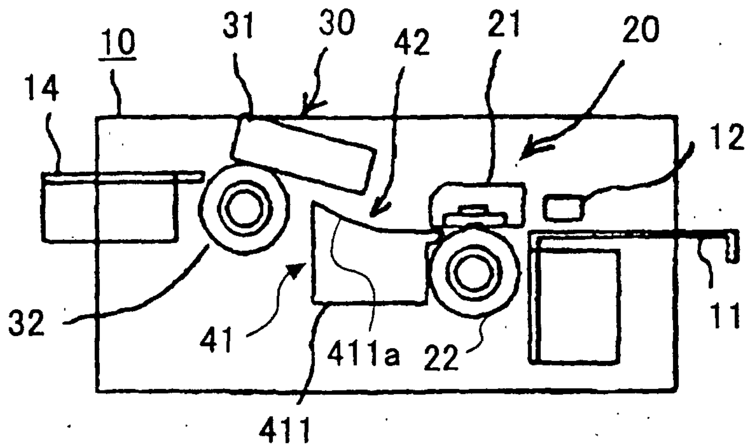


FIG.9A


10
14
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42
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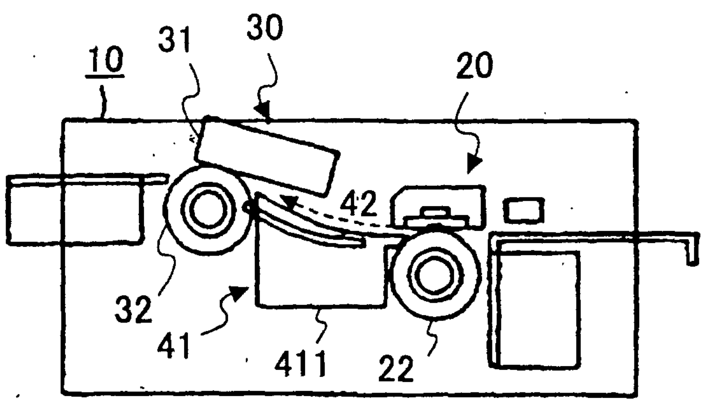
12
11
32
41
411a
22
411

FIG.9B


10
31
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411
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FIG.9C

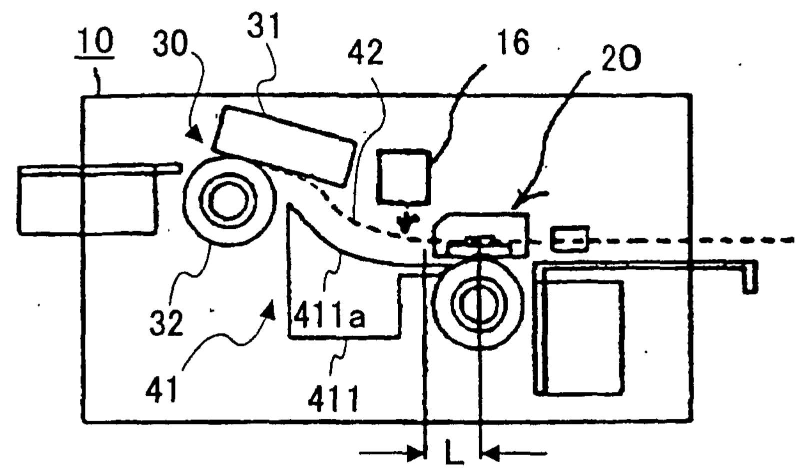


FIG.9D

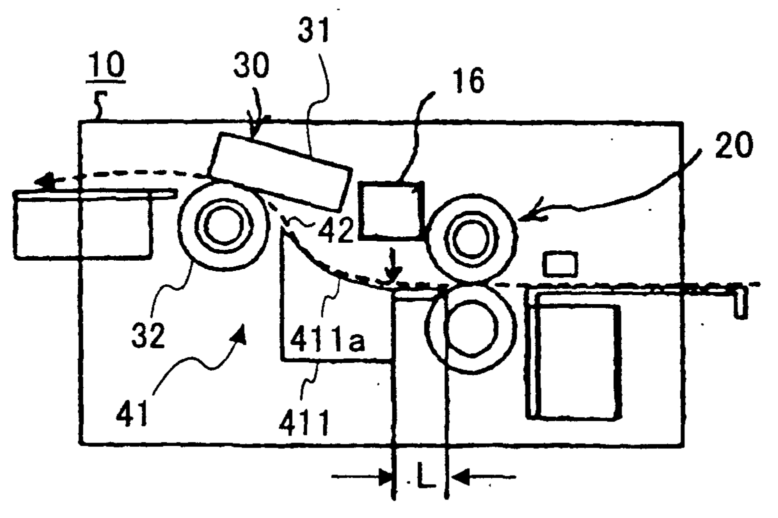


FIG.9E

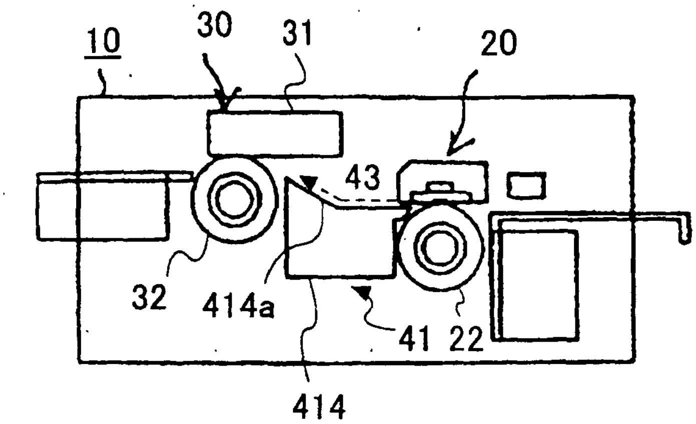


FIG.9F

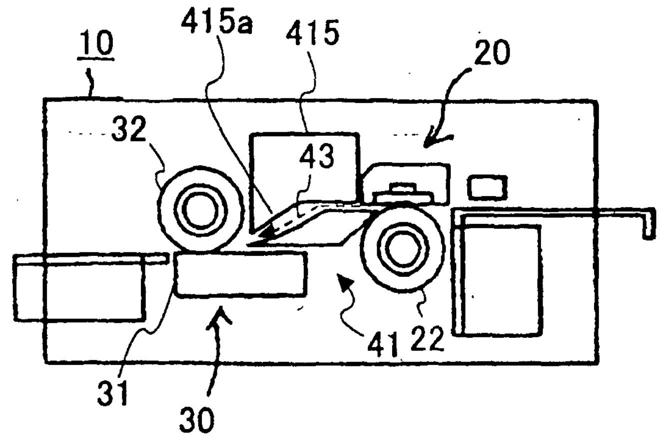


FIG.9G

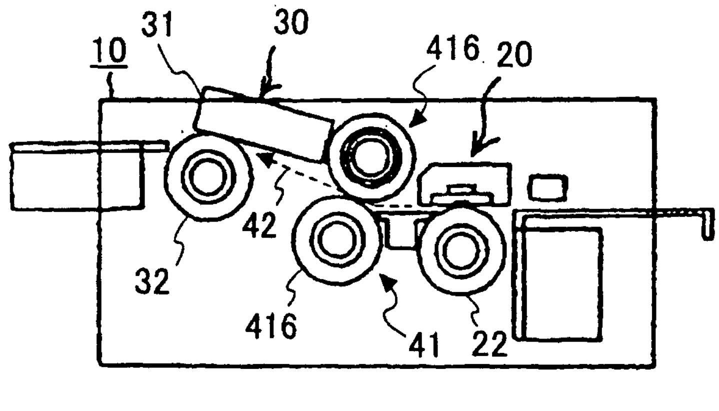


FIG.10A

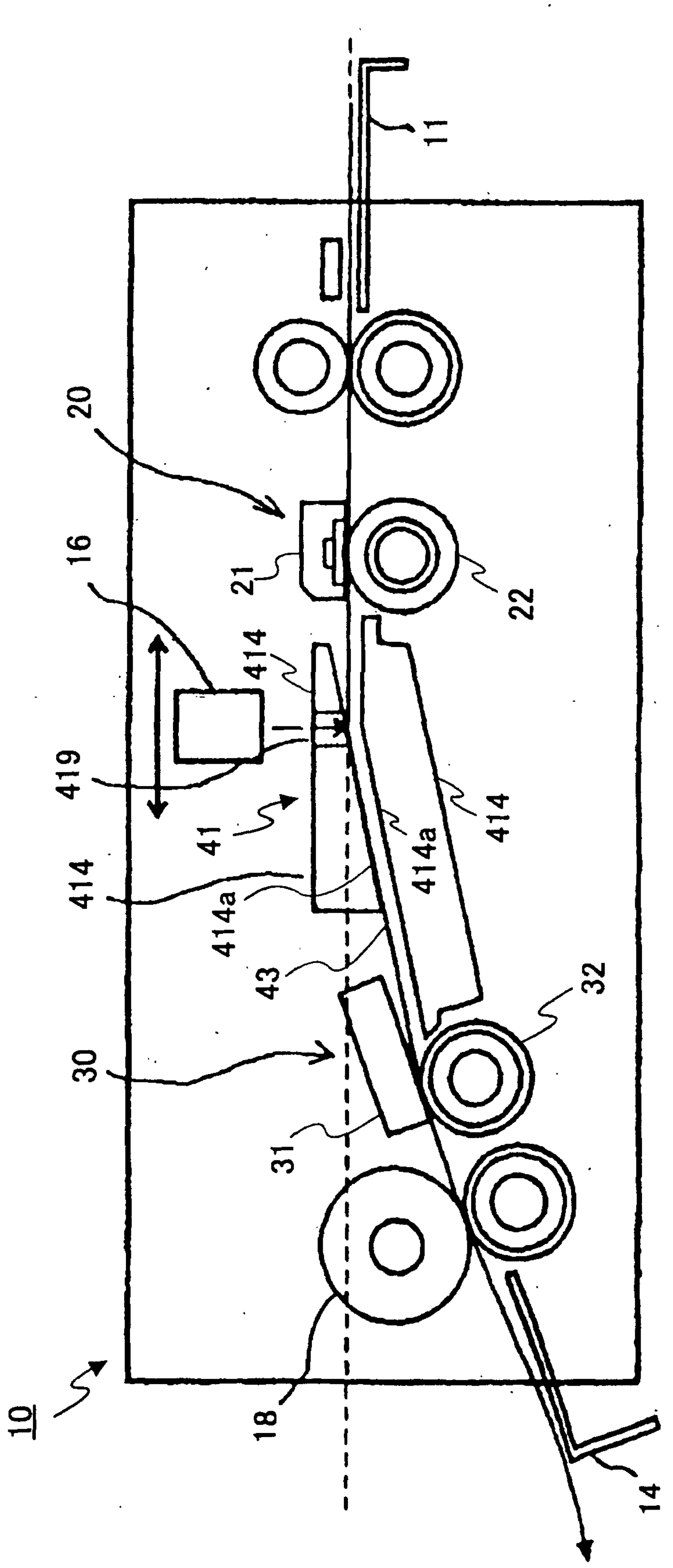


FIG.10B

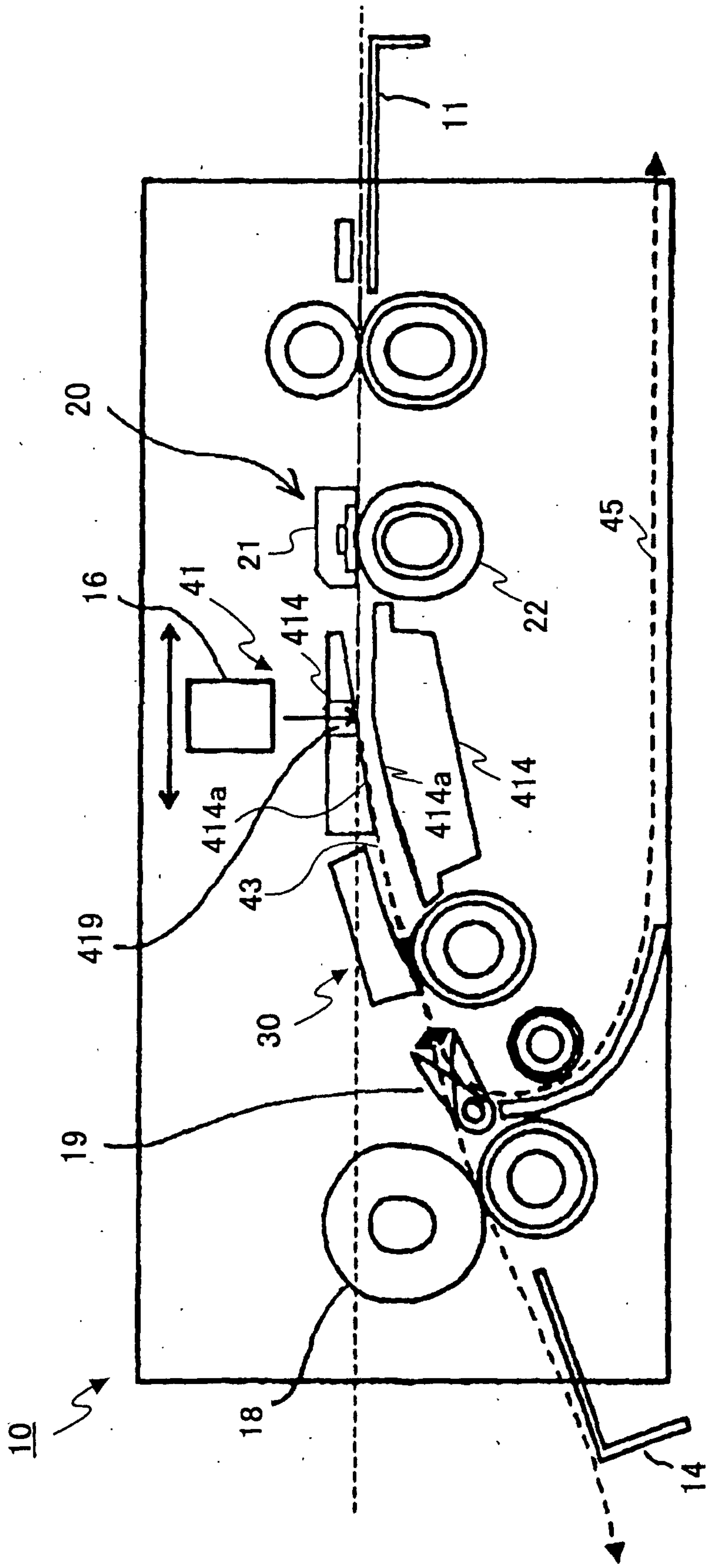


FIG.11B

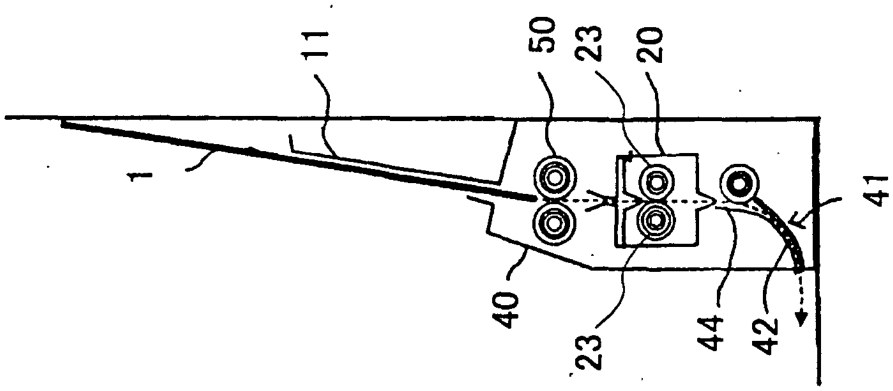


FIG.11A

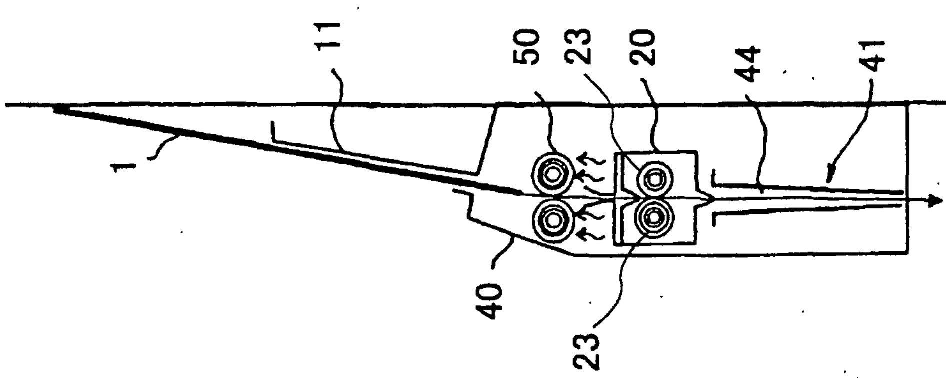


FIG.13

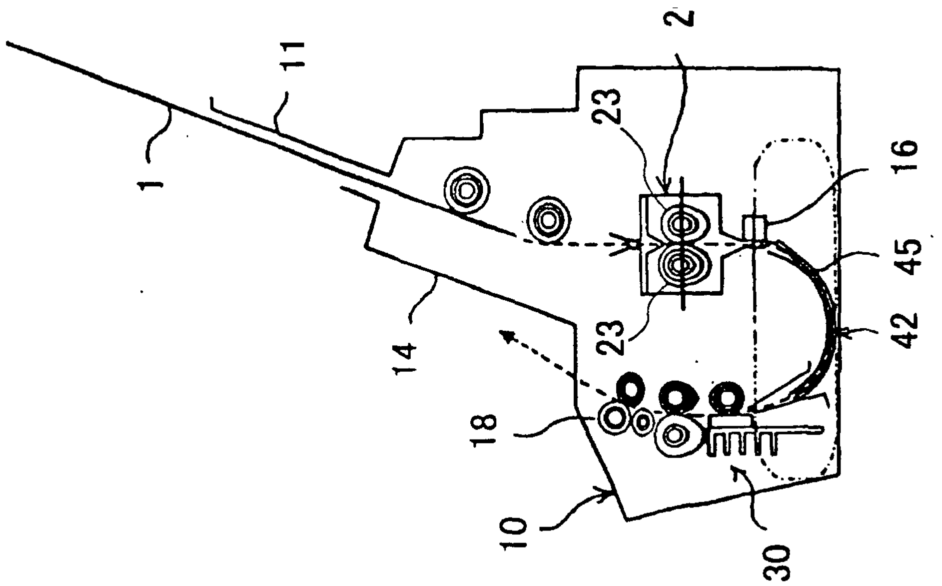


FIG.12

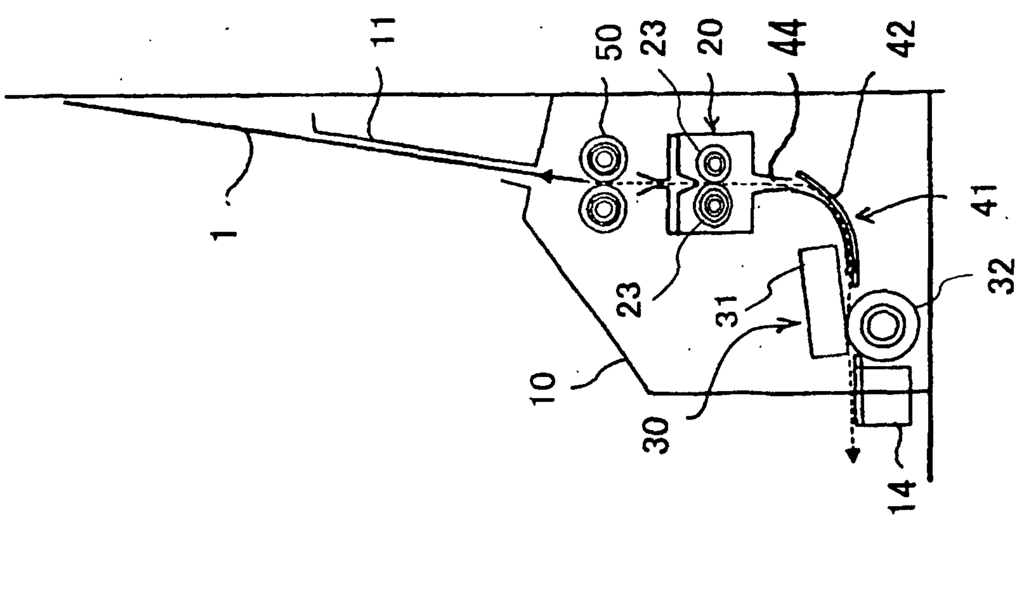


FIG.14

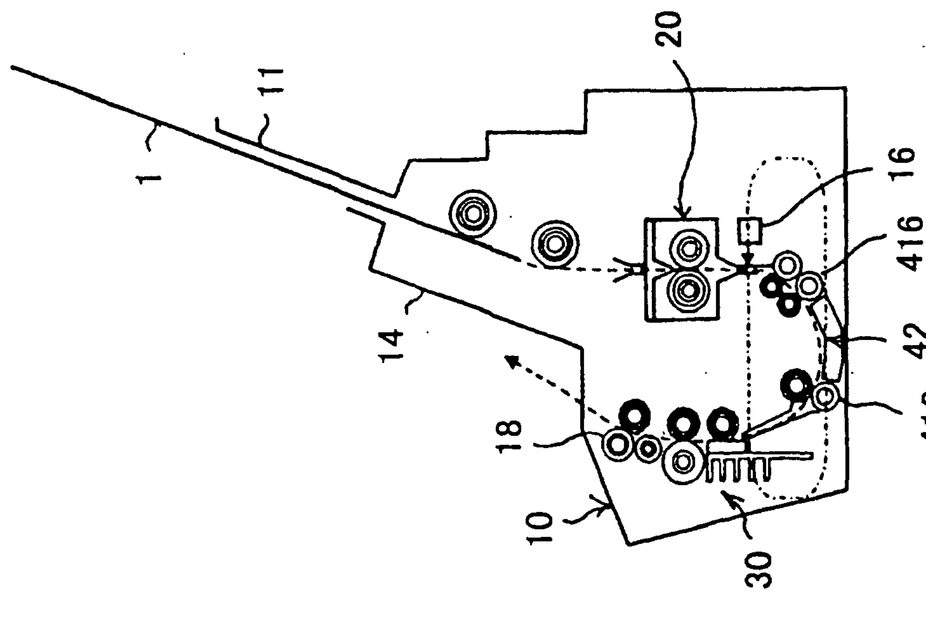


FIG.15

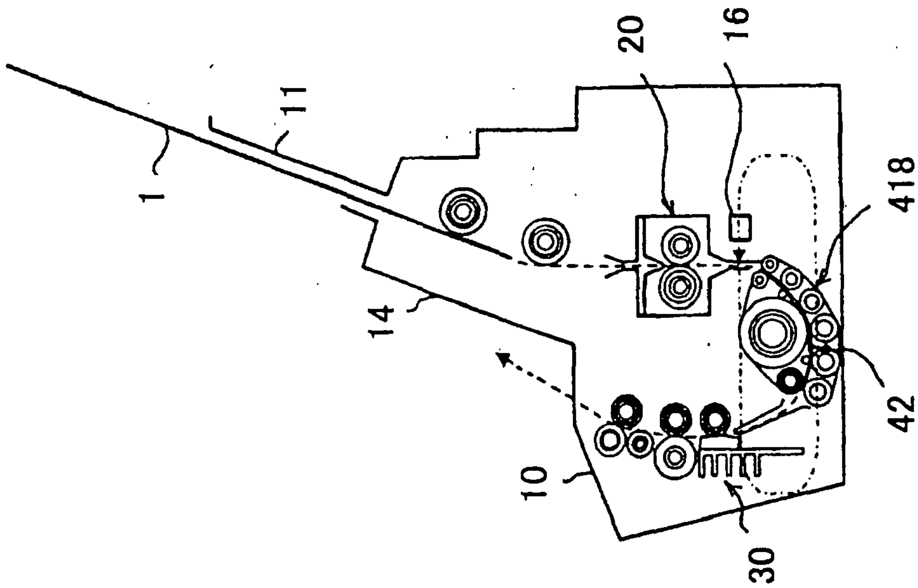


FIG.16B

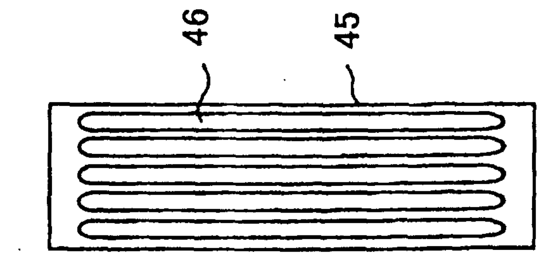
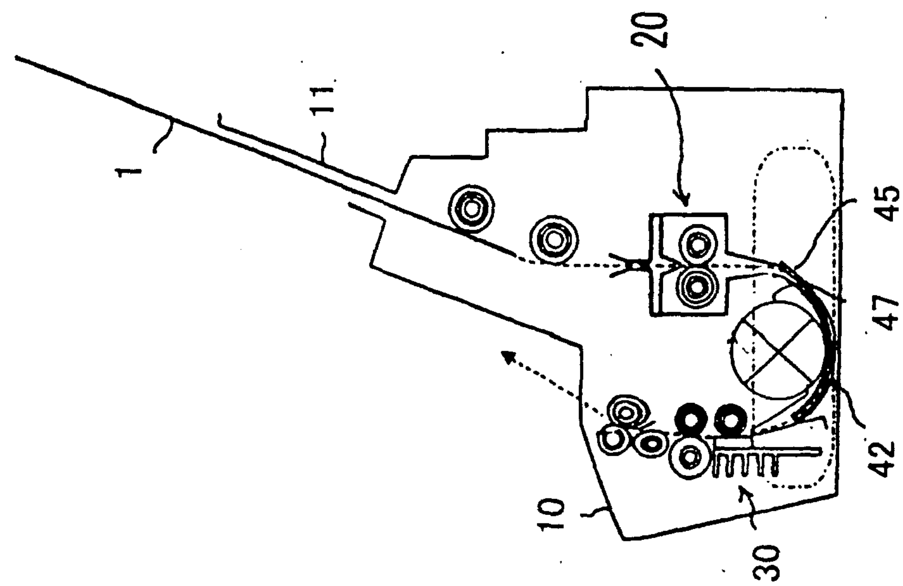


FIG.16A



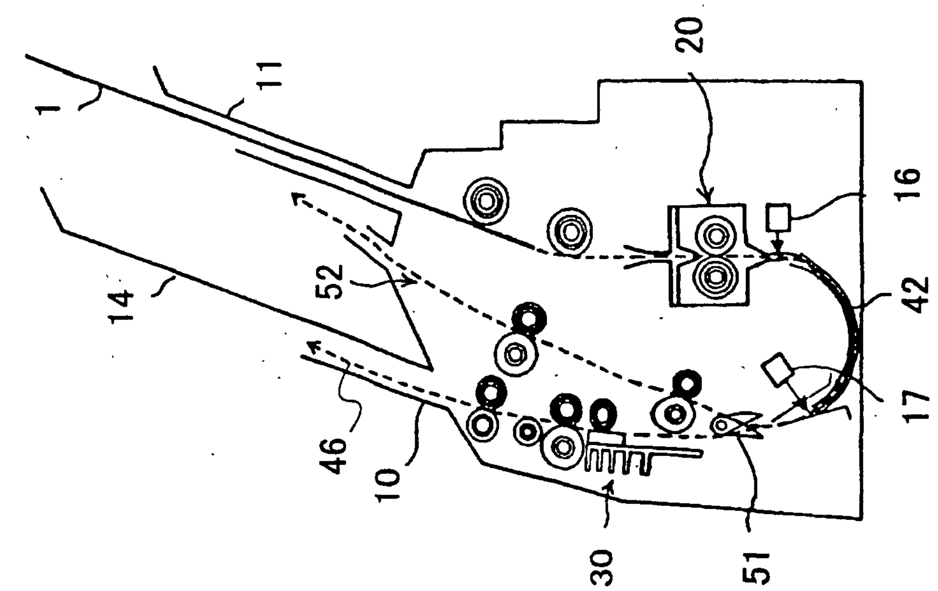


FIG.18

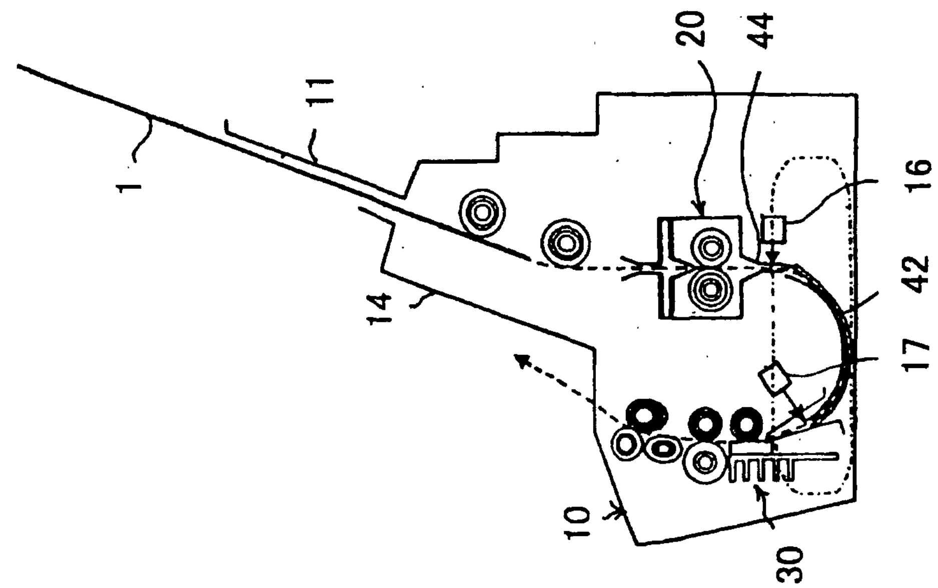


FIG.17

FIG.19

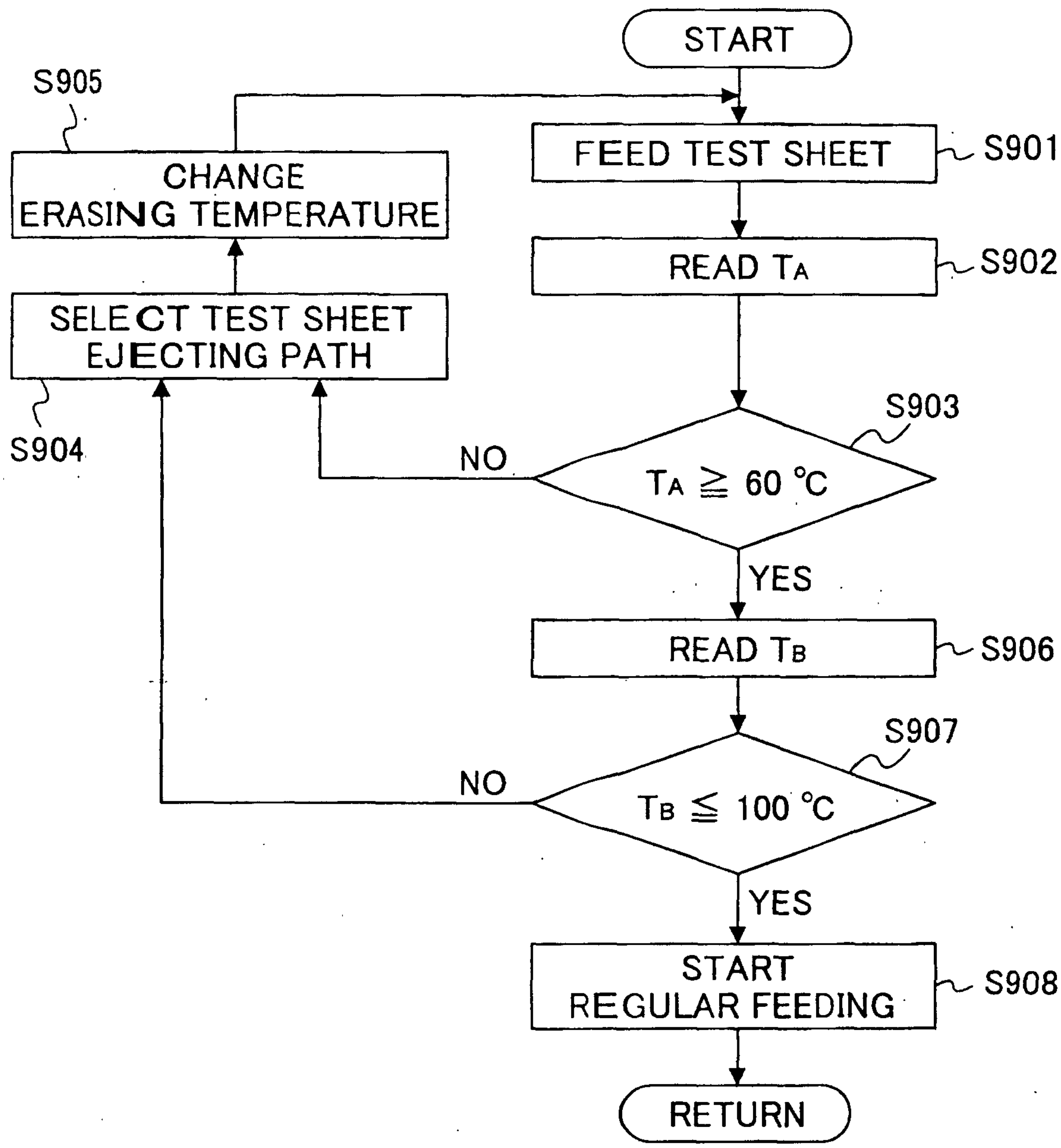

START
FEED TEST SHEET
S901
READ TA
S902
TA ≧ 60 °C
S903
NO
YES
SELECT TEST SHEET EJECTING PATH
S904
CHANGE ERASING TEMPERATURE
S905
READ TB
S906
TB ≦ 100 °C
S907
NO
YES
START REGULAR FEEDING
S908
RETURN

FIG.20

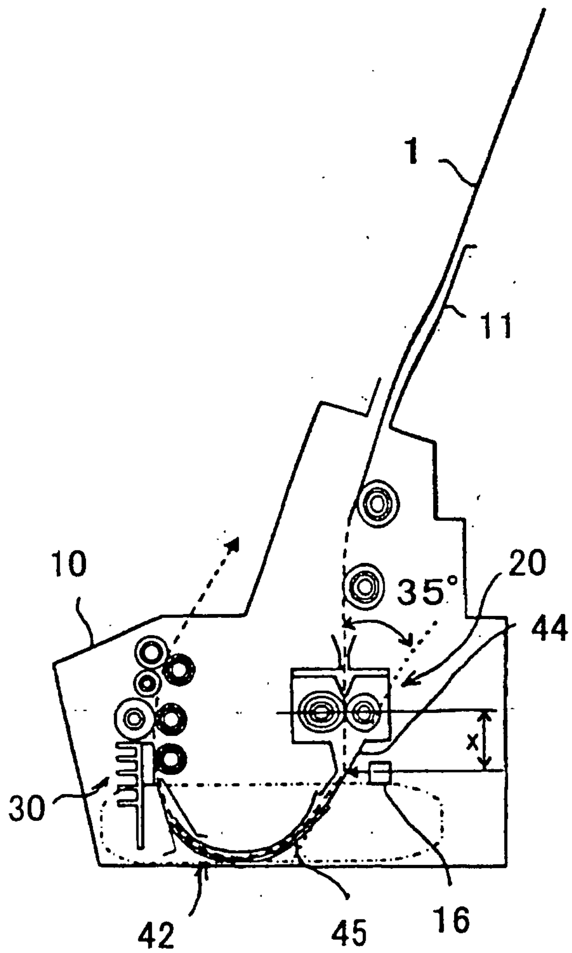


FIG.21A

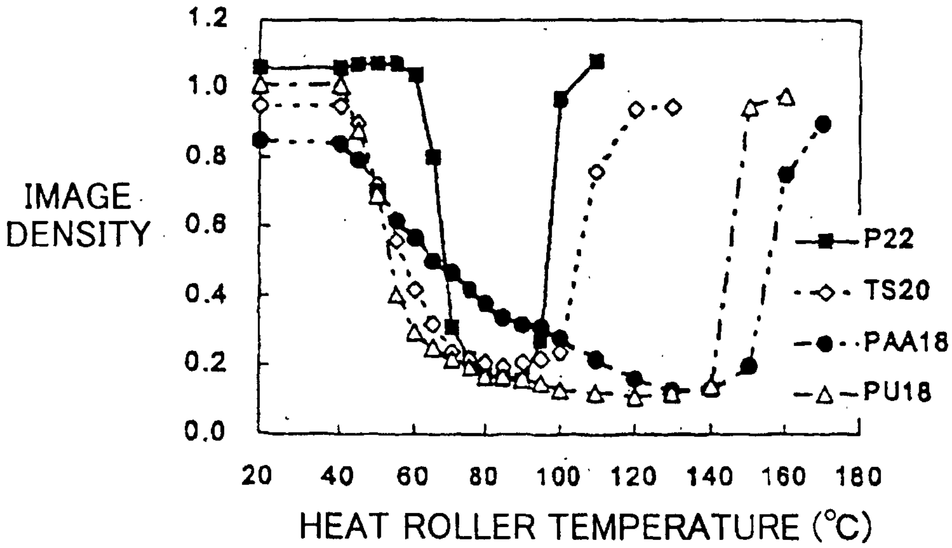


FIG.21B

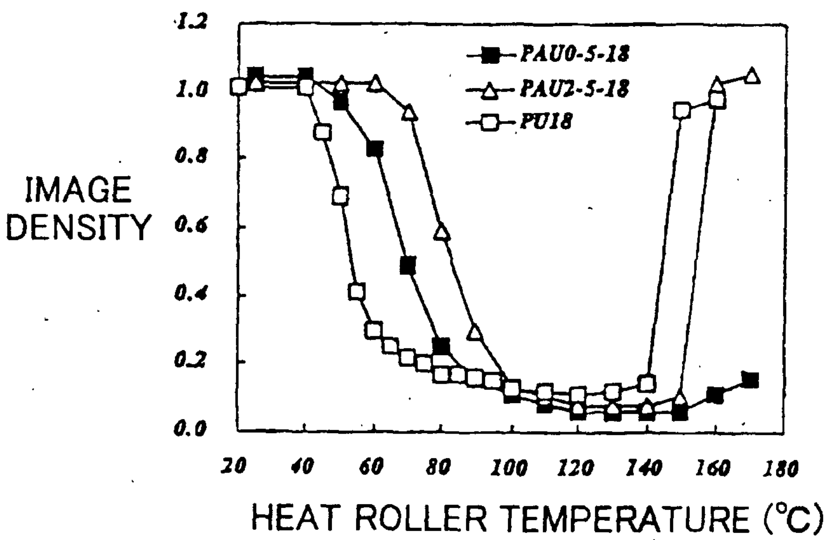
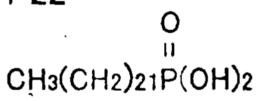


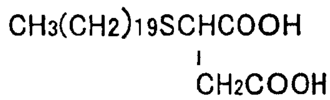
FIG.22A

DEVELOPER

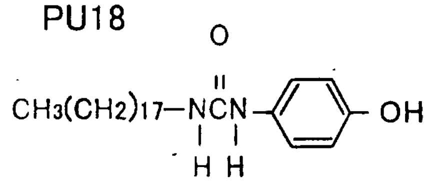
P22



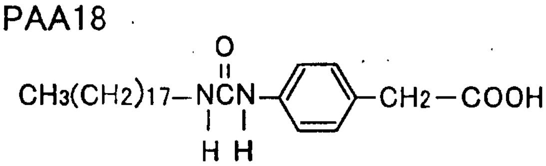
TS20



PU18



PAA18



PAUp-q-r

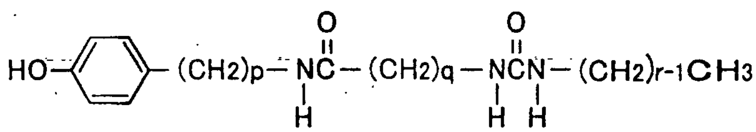
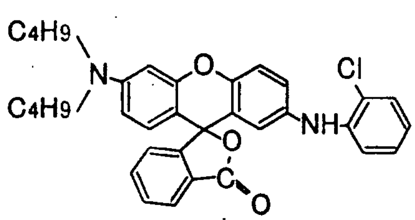
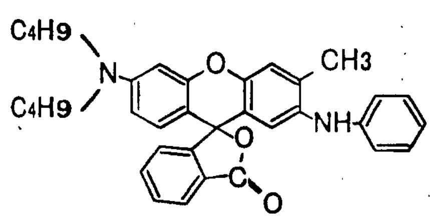


FIG.22B

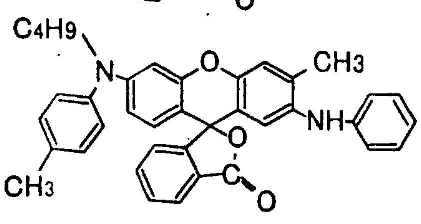
LEUCO-DYE



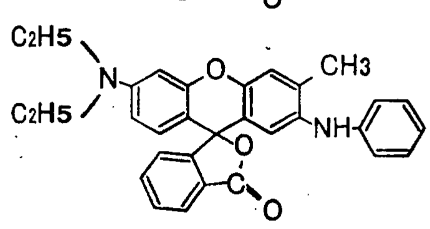
L1



L3



L2



L4

FIG.23A

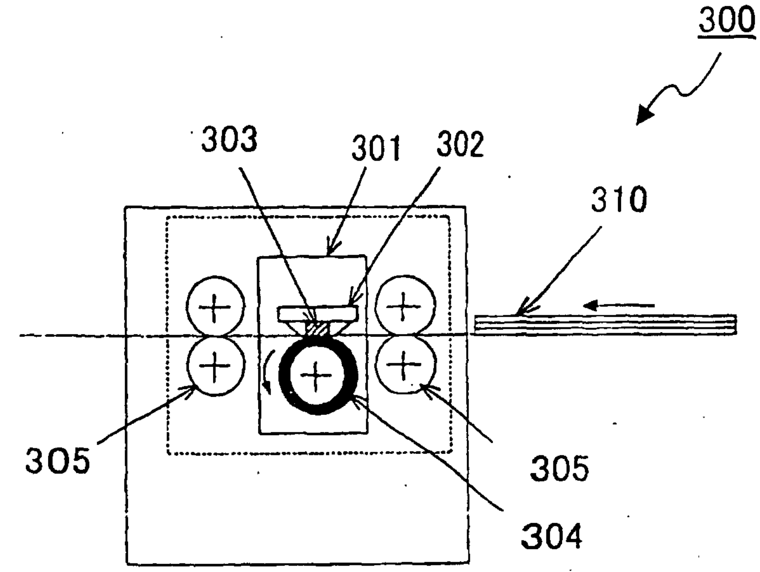


FIG.23B

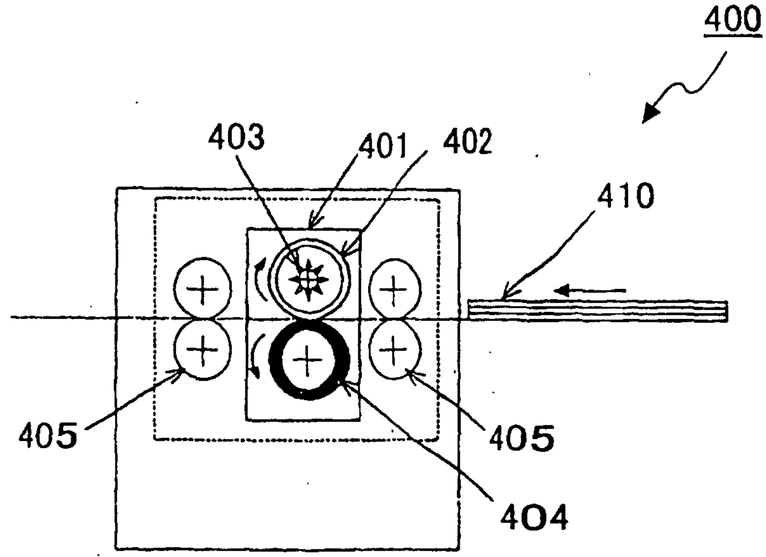


FIG.24

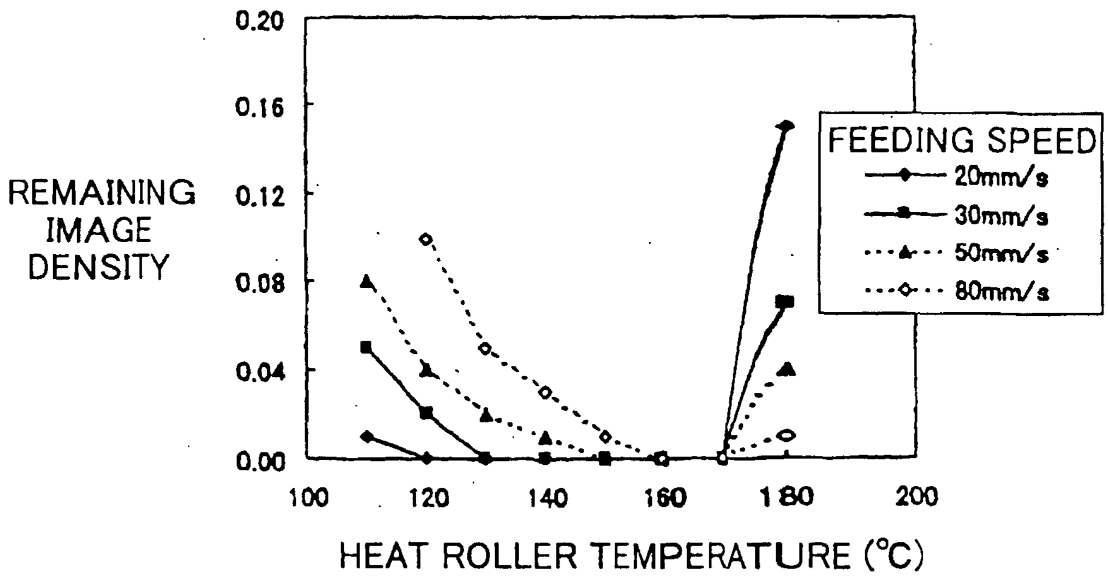

REMAINING IMAGE DENSITY
0.20
0.16
0.12
0.08
0.04
0.00
100
120
140
160
180
200
HEAT ROLLER TEMPERATURE (°C)
FEEDING SPEED
20mm/s
30mm/s
50mm/s
80mm/s

FIG.25

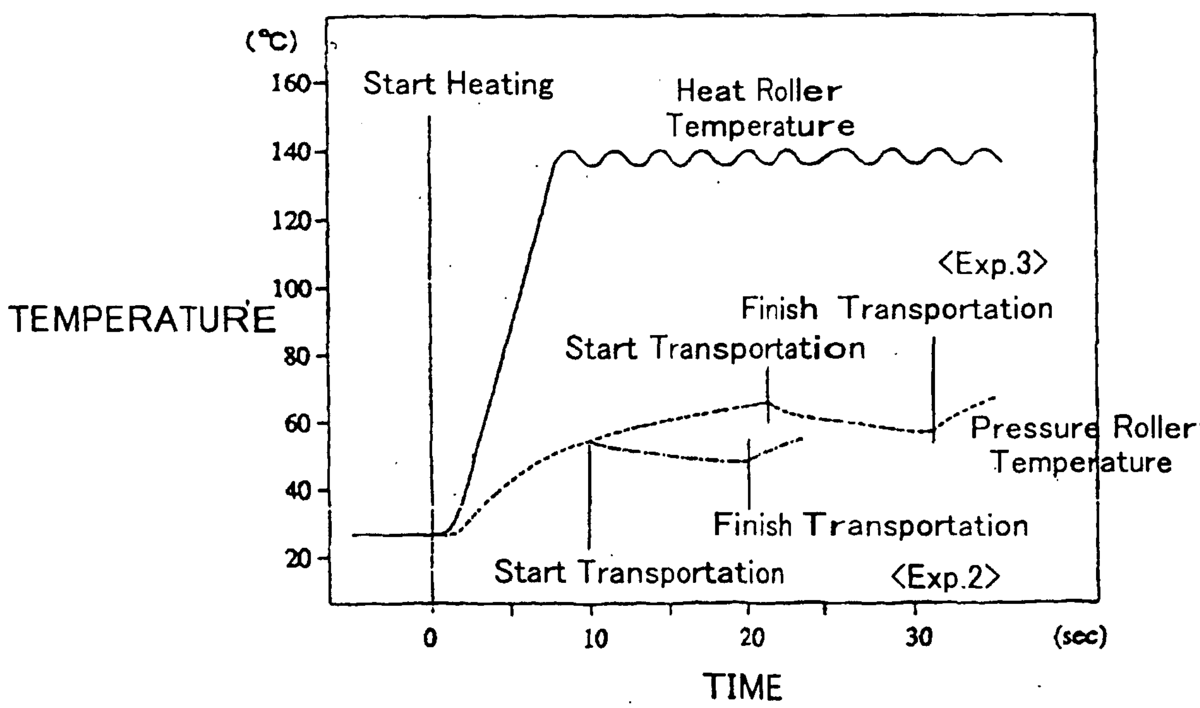

(°C)
160
140
120
100
80
60
40
20
TEMPERATURE
Start Heating
Heat Roller Temperature
<Exp.3>
Finish Transportation
Start Transportation
Pressure Roller Temperature
Finish Transportation
Start Transportation
<Exp.2>
0
10
20
30
(sec)
TIME

FIG.26A

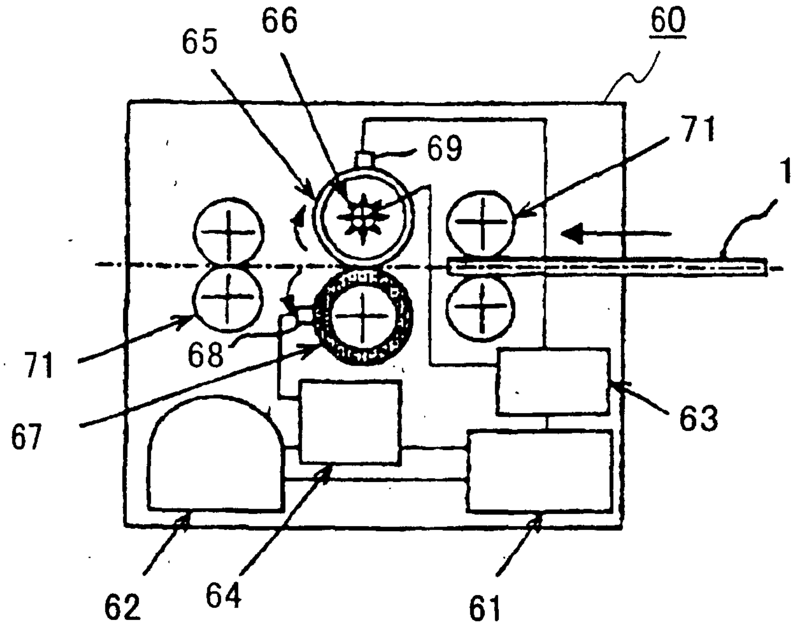


FIG.26B

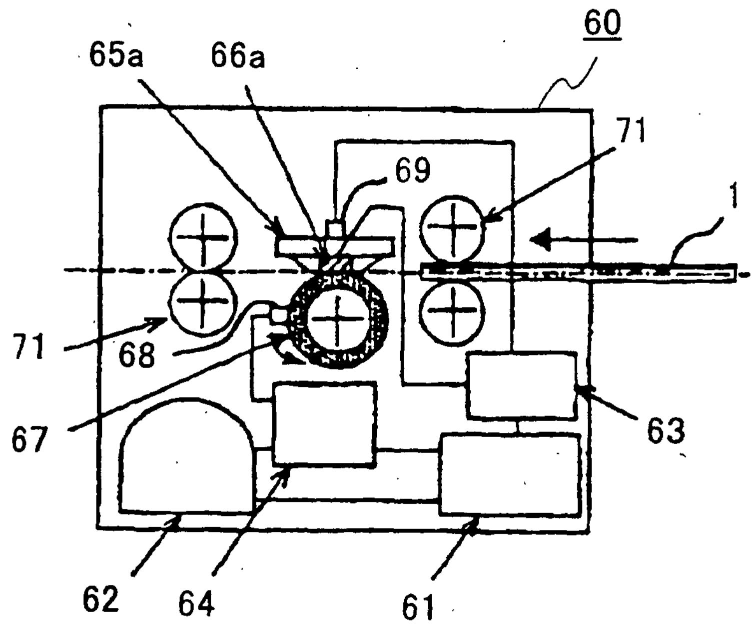


FIG.26C

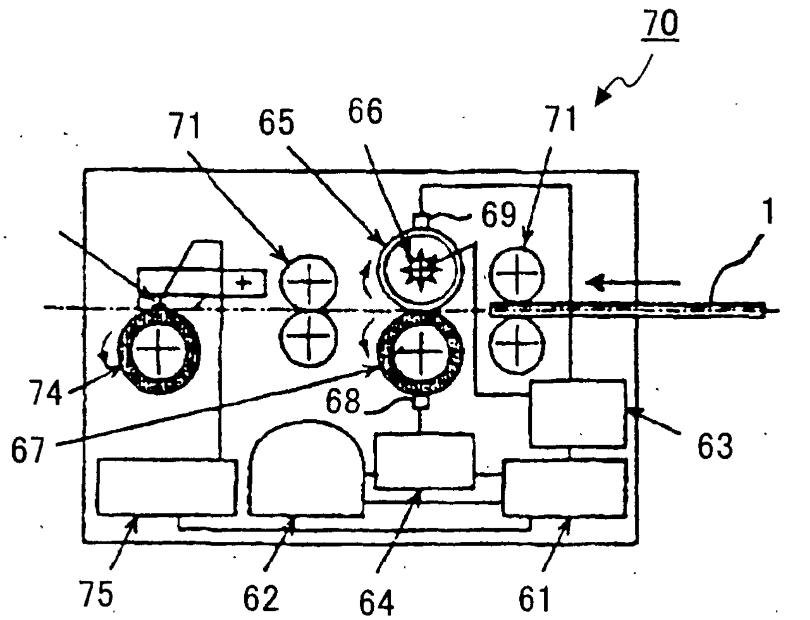


FIG.26D

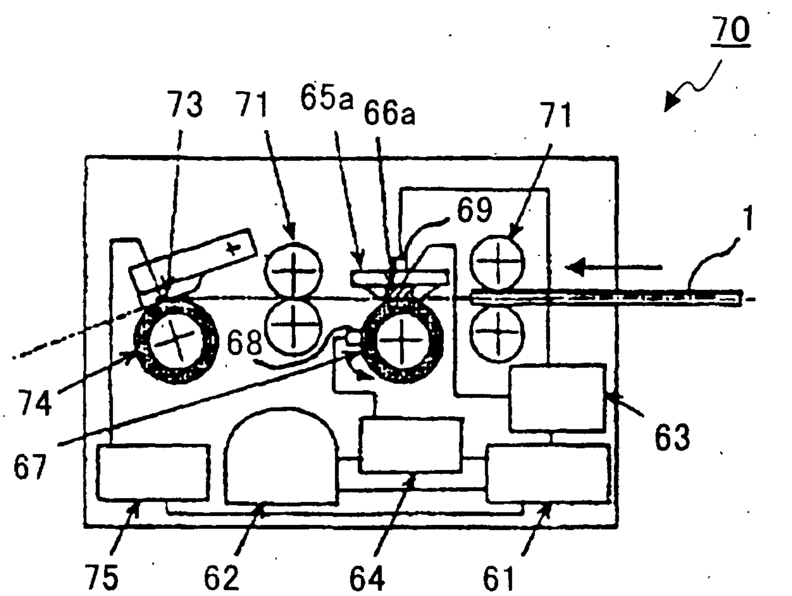


FIG.27A

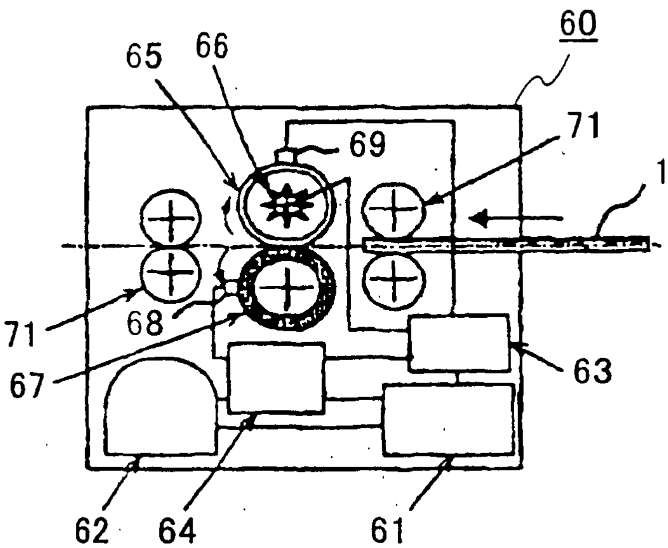


FIG.27B

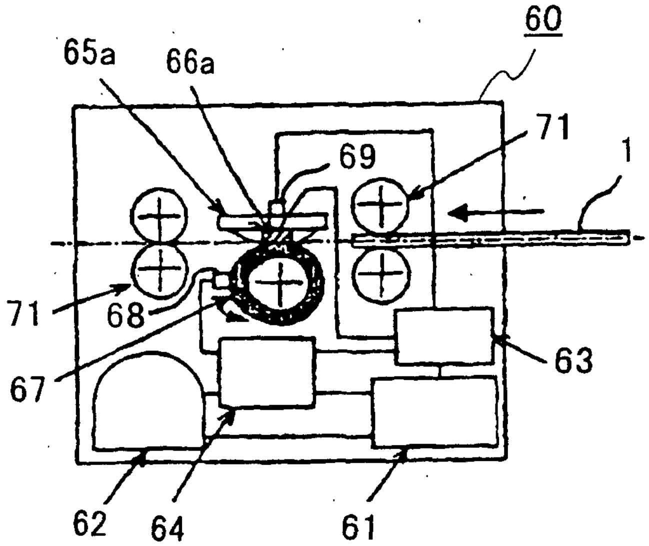


FIG.27C

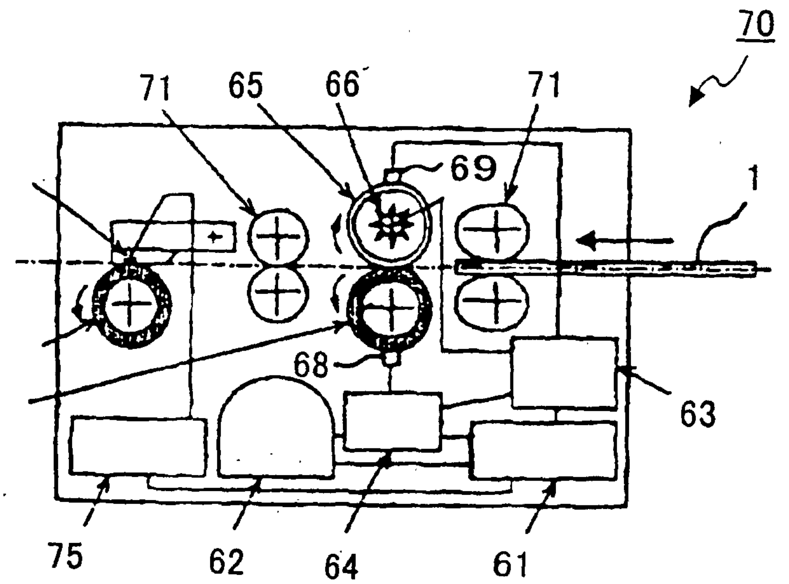


FIG.27D

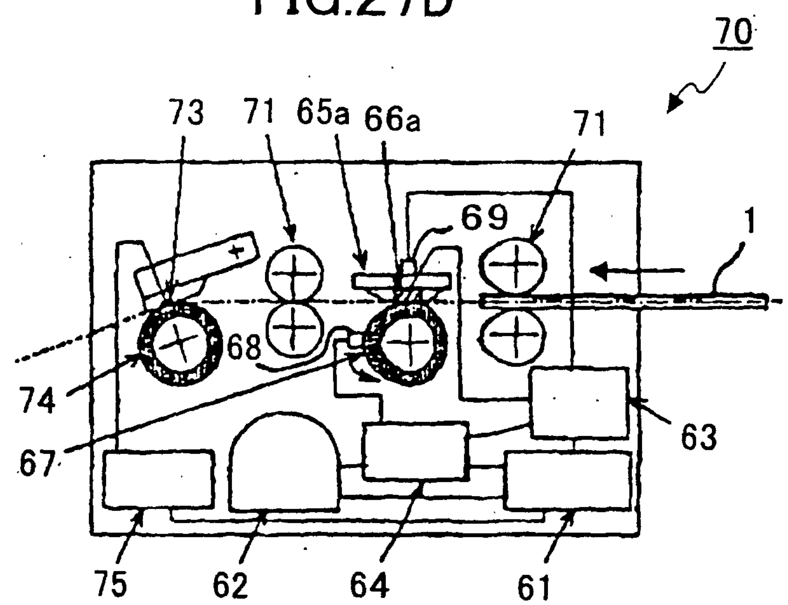


FIG.28A

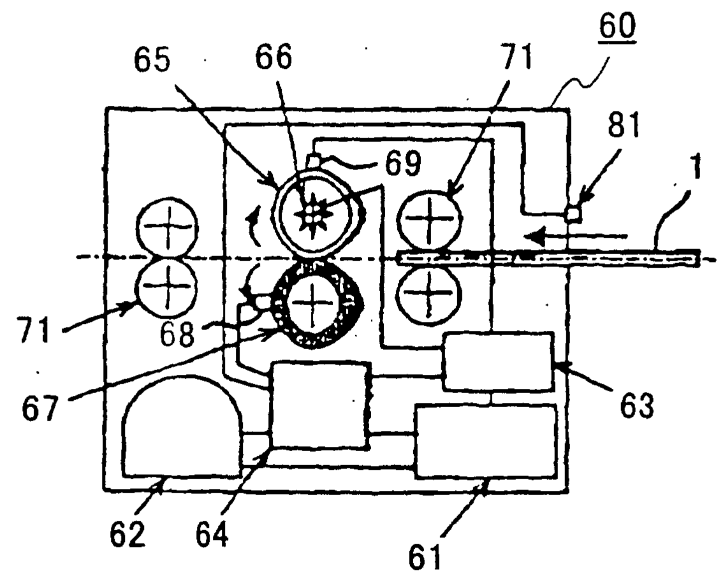


FIG.28B

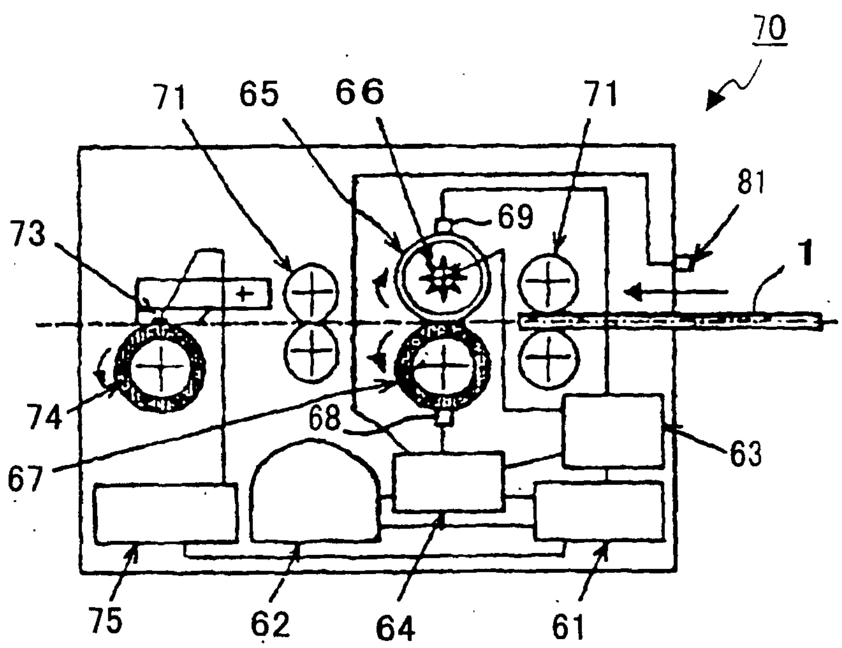


FIG.29A

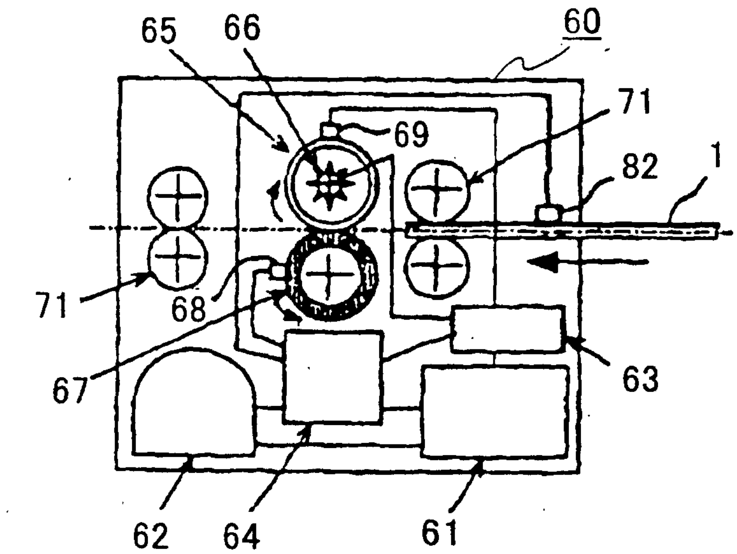


FIG.29B