(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 770 935 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**02.05.1997 Bulletin 1997/18**

(51) Int. Cl.[6]: **G03G 15/20**

(21) Application number: **96113570.4**

(22) Date of filing: **23.08.1996**

(84) Designated Contracting States:
**DE FR GB**

(30) Priority: **26.10.1995 JP 278944/95**

(71) Applicant: **SHARP KABUSHIKI KAISHA**
**Osaka-shi Osaka-fu (JP)**

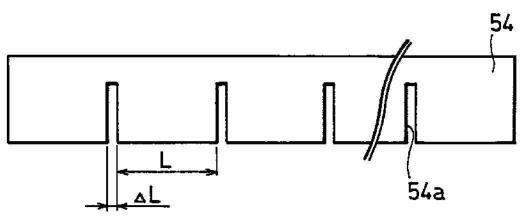
(72) Inventors:
- **Tsuji, Masaru**
**Nara-shi, Nara 630 (JP)**
- **Kagawa, Toshiaki**
**Sakurai-shi, Nara 633 (JP)**

(74) Representative: **Müller, Frithjof E., Dipl.-Ing. et al**
**Patentanwälte**
**MÜLLER & HOFFMANN,**
**Innere Wiener Strasse 17**
**81667 München (DE)**

# (54) Fixing device

(57) A heat-resistant sheet, which has slits formed therein, is provided between a fixing roller and a pressure member. The heat-resistant sheet, which has a thickness of 300 µm, is coated with a synthetic resin material having superior toner-releasing and heat-resisting properties, or incorporates such a synthetic resin material inside thereof. Here, a recording material is transported between the fixing roller and the heat-resistant sheet. As the surface temperature of the fixing roller increases, the heat-resistant sheet starts expanding gradually, causing its surface to be deflected. However, when the fixing roller reaches a set temperature, the expanded portion of the heat-resistant sheet and its surface deflection are all absorbed by the slits, and the slit width becomes zero. Therefore, it is possible to keep an optimal nip width while maintaining a proper applied pressure of the pressure member, without the necessity of having to use a heat-releasing device or increase the thickness of the heat-resistant sheet. As a result, a superior fixing operation is available by using the heat-resistant sheet having the slits.

FIG. 1




EP 0 770 935 A2

## Description

FIELD OF THE INVENTION

The present invention relates to a fixing device used for apparatuses, such as electrophotographic copying machines, printers and facsimiles, wherein the electrophotographic method is adopted.

BACKGROUND OF THE INVENTION

Conventionally, the apparatuses such as electrophotographic copying machines, printers and facsimiles, using the electrophotographic method is provided with a fixing device that consists of a fixing roller and a pressure roller that is depressed against the fixing roller. Here, at least either the fixing roller or the pressure roller is designed to be heated, and a recording material is transported between the fixing roller and the pressure roller and an image is fixed onto the recording material. This method is generally referred to as the roller method.

In the roller method, however, the paired roller have to be rotated in synchronism with each other. Further, the rollers have to be supported so that the rollers are free to rotate respectively. The resulting problems with the fixing device are a complicated structure of the device, high costs in the device itself and bulkiness of the device.

In order to solve the above-mentioned problems, for example, Japanese Examined Patent Publication 36996/1980 (Tokukoushou 55-36996) discloses a pressure pad method wherein a non-rotational depressing member is used in place of the pressure roller. In the pressure pad method, the depressing member is depressed against the fixing roller, and a recording material is transported between the fixing roller and the depressing member at which a fixing operation is carried out. Fig. 13 shows one example of the fixing device using the pressure pad method.

A fixing roller 112 is constituted of a hollow roller 112a made of aluminum, and a coating layer 112b with which the circumferential surface of the hollow roller 112a is coated. The coating layer 112b is made of a material having a high coefficient of friction, such as, for example, silicone rubber. A depressing member 111 is installed below the fixing roller 112.

A coating layer 114, made of a material having a low coefficient of friction, for example, such as tetrafluoroethylene resin is formed on a depressing surface of the depressing member 111, that is, the surface facing the fixing roller 112. The depressing member 111, which is fixed to the upper surface of a pressing plate 116 supported by a shaft 117, is depressed onto the fixing roller 112 through the coating layer 114 by a predetermined pressure applied by a pressure spring 118. A sheet of paper 101 bearing a prefixed toner image 102 is transported between the fixing roller 112 and the depressing member 111, and the prefixed toner image 102 is thus fixed onto the sheet of paper 101.

Moreover, Japanese Laid-Open Patent Publication 304481/1989 (Tokukaihei 1-304481) discloses a pressure sheet method wherein a pressure web member is used in place of the pressure roller. In the pressure sheet method, the pressure web member is pressed against the fixing roller with a predetermined wrapping angle, and a recording material is transported between the fixing roller and the pressure web member, and thus subjected to a fixing operation. Fig. 14 shows one example of the fixing device using the pressure sheet method.

A fixing roller 122 is constituted of a hollow roller 122a made of aluminum, and a coating layer 122b with which the circumferential surface of the hollow roller 122a is coated. The coating layer 122b is made of a material having a high coefficient of friction, such as, for example, silicone rubber. One end of a pressure web member 121 is engaged and stopped by a frame 123. The other end on the opposite side is, on the other hand, pulled by a coil spring 128 with a predetermined tension. Thus, the pressure web member 121 is pressed against the fixing roller 122 with a predetermined wrapping angle $\alpha$. A sheet of paper 101 bearing a prefixed toner image 102 is transported between the fixing roller 122 and the pressure web member 121, and the prefixed toner image 102 is thus fixed onto the sheet of paper 101.

Furthermore, for example, Japanese Patent Application No. 44647/1995 (Tokuganhei 7-44647), which has proposed by the same applicant as the present application, discloses a method wherein: a heat-resistant sheet is provided between the fixing roller and the pressure member, and the pressure pad method is adopted so that a recording material is transported between the fixing roller and the heat-resistant sheet so as to carry out the fixing operation, and a hear-releasing member, which is made of an aluminum foil or other materials, is installed outside the heat-resistant sheet. Fig. 15 shows one example of such an fixing device. Here, those members that have the same functions as the members used in the fixing device in Fig. 13 are indicated by the same reference numbers.

A fixing roller 112 is constituted of a thin hollow roller 112a made of aluminum, and a coating layer 112b with which the circumferential surface of the hollow roller 112a is coated. The coating layer 112b is made of a synthetic resin material having superior toner-releasing, paper-transporting and heat-resisting properties, that is, for example, heat-resistant rubber with a high coefficient of friction, such as, for example, silicone rubber. A pressure member 111 is installed on the under surface of the fixing roller 112.

Further, a heat-resistant sheet 114, which is secured to a lower frame 113 by a heat-resistant double-sided tape, is installed between the fixing roller 112 and the pressure member 111. The heat-resistant sheet 114 is formed by coating the surface of a glass-fiber base material (100 µm in thickness) with a synthetic resin material having superior toner-releasing and heat-resisting properties, or by incorporating such a synthetic resin material inside the base material. The synthetic resin material is, for example, a fluororesin such as, for example, PFA (polytetrafluoroethylene=perphloro-acryl-vinyl-ethel copolymer resin) or PTFE (polytetrafluoroethylene resin). Then, a sheet of paper 101 bearing a pre-fixed toner image 102 is transported between the fixing roller 112 and the heat-resistant sheet 114, and the fixing operation is carried out. Further, a metal foil, such as an aluminum foil, which is bonded to the lower frame 113, is installed on the rear-surface of the heat-resistant sheet 114.

However, in the above-mentioned fixing device using the pressure pad method, the following problems have been presented.

(1) Since the adhesive strength between the depressing member 111 and the coating layer 114 is weak, the coating layer 114 is easily worn and separated by the sliding motion against the fixing roller 112.
(2) Prior to feeding of a sheet of paper 101, or at the time before the next paper 101 is fed in the case when sheets of paper 101 are successively fed, the fixing roller 112 tends to cut and damage the depressing member 111 by its rotation, thereby causing the depressing member 111 to be deformed.
(3) In order to increase the adhesive strength between the depressing member 111 and the pressure plate 116, when the adhesive area between them is increased, the depressing member 111 becomes bulky, thereby increasing costs of the device.
(4) When the hardness of the depressing member 111 is too high, a sufficient nip width is not obtained, thereby occasionally causing fixing irregularities in the roller-axial direction of the fixing roller 112. In contrast, when the hardness of the depressing member 111 is too low, the depressing member 111 tends to be deformed permanently.
(5) Since the depressing member 111 is secured to the pressure plate 116, sheets of paper 101 are transported only by the transporting force of the fixing roller 112. Therefore, it is hard to transport sheets of paper 101 smoothly, and paper jams tend to occur.
(6) The coating layer 112b of the fixing roller 112 has to satisfy two properties, that is, a toner-releasing property and a paper-transporting property, which are contradictory to each other. For this reason, a greater transporting force is required, and it is necessary to optimize the transporting force.

Further, the following problems have been presented in the fixing device using the pressure sheet method:

(1) In order to obtain a sufficient fixing force (fixing strength), the wrapping angle $\alpha$ of the pressure web member 121 has to be increased with respect to the fixing roller 122. Then, the sheet of paper 101 after having been subjected to the fixing operation tends to be curled to a great degree.
(2) The pressure web member 121 tends to have an irregular pressure distribution in its roller-axis direction with respect to the fixing roller 122, thereby occasionally causing irregularities in fixing.

Moreover, the following problems have been presented in the fixing device using the pressure pad method with the heat-resistant sheet:

(1) The thickness of the heat-resistant sheet 114 is increased since the heat-resistant synthetic resin is formed on the glass fiber. As a result, it is difficult to maintain an appropriate nip width, and also difficult to obtain a good fixing operation.
(2) Since the glass fiber and the synthetic resin have different expansion coefficients under temperature, the heat-resistant sheet 114 is curled upon application of heat. For this reason, a heat-releasing device such as a metal foil is required.
(3) Prior to feeding of a sheet of paper 101, or at the time before the next paper 101 is fed in the case when sheets of paper 101 are successively fed, the fixing roller 112 tends to cut and damage the depressing member 111 by its rotation, thereby causing the depressing member 111 to be deformed.
(4) When the hardness of the depressing member 111 is too high, a sufficient nip width is not obtained, thereby occasionally causing fixing irregularities in the roller-axial direction of the fixing roller 112. In contrast, when the hardness of the depressing member 111 is too low, the depressing member 111 tends to be deformed permanently.
(5) The coating layer 112b of the fixing roller 112 has to satisfy two properties, that is, a toner-releasing property and a paper-transporting property, which are contradictory to each other. For this reason, a greater transporting force is required, and it is necessary to optimize the transporting force.

Further, the following problems are commonly presented in the fixing device using the pressure pad method and in the fixing device using the pressure sheet method. That is, during a double-sided printing process, when the prefixed toner image 102 is fixed on the sheet of paper 101 that bears the prefixed toner image 102 on its rear-surface (hereinafter, referred to as a reversed sheet), the prefixed toner image 102 of the rear-surface of the sheet of paper 101 tends to be blurred (hereinafter, referred to as blurredness of image) due to the sliding motion between the rear-surface of the sheet of paper 101 and the depressing member 111 or the pressure web member 121, or the toner on the rear-surface of the sheet of paper 101 fuses to the depressing member 111 or to the pressure web member 121, causing paper jams.

## SUMMARY OF THE INVENTION

The objective of the present invention is to provide a fixing device which carries out a superior fixing operation, and also has an excellent paper-carrying property with an appropriate transporting force.

In order to achieve the above-mentioned objective, the fixing device of the present invention, which has a fixing roller, a pressure member that is placed in contact with the circumferential surface of the fixing roller, and a heat-resistant sheet that is provided with slits and that is installed between the fixing roller and the pressure member, is characterized in that a recording material bearing a prefixed toner image is transported between the fixing roller and the heat-resistant sheet so as to fix the prefixed toner image onto the recording material.

With this arrangement, even if the heat-resistant sheet is heated up to high temperatures, the slits, provided in the heat-resistant sheet, make it possible to absorb deflection and distortion due to expansion of the heat-resistant sheet. Therefore, the use of a heat-releasing device, the increase in the thickness of the heat-resistant sheet, and the increase in the paper-transporting torque, which have been required in conventional devices, are no longer needed. Thus, it becomes possible to keep an optimum nip width while maintaining a proper pressuring force of the pressure member. As a result, a superior fixing operation is available by using the heat-resistant sheet having the slits.

Moreover, since the above-mentioned arrangement eliminates the necessity of having to increase the paper-transporting torque, the pressure member is free from damages caused by a shearing force that is exerted by the rotation of the fixing roller. Therefore, different from conventional arrangements, the above-mentioned arrangement makes it possible to prevent deformation of the pressure member, thereby improving the durability of the pressure member as compared with conventional arrangements.

Furthermore, since the pressure member is not subjected to such a shearing force, no consideration is required for the adhesive area for use in fixing the pressure member. Therefore, the pressure member is designed to have a minimum size required, and the compactness and cost reduction of the device can be achieved.

Here, it is preferable to design the slits of the heat-resistant sheet to tilt with respect to the transporting direction of the recording material; thus, even in the event of an imperfect fixing, for example, due to the fact that the heat-resistant sheet has been used beyond its service life, the imperfect fixing is not so conspicuous since the slits are not perpendicular to the transporting direction of sheets of paper. Therefore, this arrangement makes it possible to set factors, such as the slit width, the slit intervals and the fixing-roller temperature, with a comparatively wider range.

Moreover, since the slits are designed to tilt as described above, the friction force between the slits and the transported sheet of paper can be dispersed. This eliminates the necessity of having to increase the paper-transporting torque. Consequently, it becomes possible to reduce costs of the device by miniaturizing a motor, a power source and other components, and also to reduce the power consumption. Furthermore, since the slits are designed to tilt as described above, the pressuring effect is not impaired even when the heat-resistant sheet is depressed by the pressure member. In this case, it becomes possible to improve the fixing performance of toner as compared with conventional arrangements.

Furthermore, when the fixing roller is designed to contact the slits provided in the heat-resistant sheet at the center portion thereof in the lengthwise direction, it is possible to prevent warp and other defects that might occur at the edges of the heat-resistant sheet. This eliminates the necessity of having to increase the paper-transporting torque. Further, when the fixing roller is heated, heat is conducted uniformly to the heat-resistant sheet. This makes it possible to keep the surface temperature of the heat-resistant sheet uniform, thereby maintaining a stable fixing temperature.

Here, it is preferable to provide slashes between the slits of the heat-resistant sheet in parallel with the slits. With this arrangement, even if thick sheets of paper, such as envelopes and post cards, are transported, slight deflection and distortion occurring in the heat-resistant sheet are absorbed by the plural slashes. Consequently, it becomes possible to prevent imperfect fixing that might occur at portions of the sheet with which the edges of the paper come into contact. Therefore, even in the case when thick sheets of paper are transported, it is possible to prevent deflection and distortion of the sheets, and to positively carry out a superior fixing operation.

For a fuller understanding of the nature and advantages of the invention, reference should be made to the ensuing detailed description taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view showing one structural example of a heat-resistant sheet that is installed in a fixing device in accordance with the present invention.

Fig. 2 is a plan view showing a state where the heat-resistant sheet is heated up to a set temperature during a fixing operation.

Fig. 3 is a cross-sectional view showing a schematic construction of a laser printer that is provided with the fixing device.

Fig. 4 is an explanatory drawing that shows a schematic construction of the fixing device.

Fig. 5 is a plan view showing another structural example of a heat-resistant sheet.

Fig. 6 is a plan view of the heat-resistant sheet that indicates a contact portion between the heat-resistant sheet and the fixing roller.

Fig. 7 is a plan view of the heat-resistant sheet that indicates the contact portion and a nip between the heat-resistant sheet and the fixing roller.

Fig. 8 is a plan view showing a heat-resistant sheet wherein slits, each having a virtually triangular shape, are formed.

Fig. 9 is a plan view showing a heat-resistant sheet wherein slits, each having a virtually trapezoidal shape, are formed.

Fig. 10 is a plan view showing a heat-resistant sheet wherein slashes are provided between the slits.

Fig. 11 is a perspective view that shows a state where the paper-transporting force is measured.

Fig. 12(a) is an explanatory drawing that shows a state where a sheet of white paper is transported into the fixing device; and Fig. 12(b) is an explanatory drawing that shows a state where a sheet of solidly black-printed (100%) paper is transported into the fixing device.

Fig. 13 is a cross-sectional view showing one structural example of a conventional fixing device using the pressure pad method.

Fig. 14 is a cross-sectional view showing one structural example of a conventional fixing device using the pressure sheet method.

Fig. 15 is a cross-sectional view showing one structural example of a conventional fixing device using the pressure pad method in which a heat-resistant sheet is installed.

Fig. 16(a) is a plan view showing an image without blurredness; and Fig. 16(b) is a plan view showing a blurred image.

## DESCRIPTION OF THE EMBODIMENT

Referring to Figs. 1 through 12 as well as Fig. 16, the following description will discuss one embodiment of the present invention. Here, the present embodiment deals with an example wherein a fixing device in accordance with the present invention is applied to a laser printer.

As illustrated in Fig. 3, the laser printer has a paper-feed section 10, an image-forming device 20, a laser scanning section 30, and a fixing device 50 of the present invention. The paper-feed section 10 feeds a sheet of paper 1 to the image-forming device 20 that is installed in the printer. The image-forming device 20 transfers a toner image corresponding to an electrostatic latent image that has been formed by the laser scanning section 30 onto a sheet of paper 1 that has been transported. The fixing device 50 fixes the toner on the sheet of paper 1 that has been further transported thereto. Thereafter, the sheet of paper 1 is ejected out of the printer by paper-transport rollers 41 and 42. In other words, the sheet of paper 1 proceeds through a path indicated by a solid line, arrow A, in Fig. 3.

The paper-feed section 10 is constituted of a paper-feed tray 11, a paper-feed roller 12, a paper-separating-use friction plate 13, a pressure spring 14, a paper-detection actuator 15, a paper-detection optical sensor 16, and a control circuit 17.

Upon receipt of a printing instruction from an externally connected host computer (not shown), sheets of paper 1, which have been placed in the paper-feed tray 11, are fed one sheet by one sheet through functions of the paper-feed roller 12, the paper-separating-use friction plate 13 and the pressure spring 14, and successively transported through the inside of the printer. When the fed sheet of paper 1 pushes the paper-detection actuator 15 down, the paper-detection optical sensor 16 releases an electric signal indicating the corresponding information, thereby specifying the start of an image printing operation. The control circuit 17, which has been activated by the action of the paper-detection actuator 15, sends an image signal to a laser-diode light-emitting unit 31 of the laser scanning section 30, thereby controlling the turning on and off of the light-emitting diode.

The laser scanning section 30 is constituted of the laser-diode light-emitting unit 31, a scanning mirror 32, a scanning-mirror motor 33, and reflection mirrors 35, 36 and 37.

The scanning mirror 32 is constantly rotated at a high speed by the scanning-mirror motor 33. In other words, in Fig. 3, a laser light beam 34 carries out scanning in the axial direction of a photoconductor 21, which will be described later. The laser light beam 34, thus released from the laser-diode light-emitting unit 31, is directed onto the photoconductor 21 in the image-forming device 20 through the reflection mirrors 35, 36 and 37. In this case, the laser light beam 34 exposes the photoconductor 21 selectively, in accordance with the information of the turning on and off from the control circuit 17.

The image-forming device 20 is provided with the photoconductor 21, a transferring roller 22, a charging member 23, a developing roller 24, a developing unit 25, and a cleaning unit 26.

The surface of the photoconductor 21, which has been preliminarily charged to a predetermined electric potential by the charging member 23, is exposed by the laser light beam 34 so that the surface charge of the photoconductor 21 is selectively discharged. Thus, an electrostatic latent image is formed on the photoconductor 21. Toner, which is used for developing, is stored in the developing unit 25. The toner, which has electric charge applied thereto by being appropriately stirred inside the developing unit 25, is allowed to adhere to the surface of the developing roller 24. Then, a toner image corresponding to the electrostatic latent image is formed on the photoconductor 21 by the function of electric field that is exerted between a developing bias voltage applied to the developing roller 24 and the surface electric potential of the photoconductor 21.

Accordingly, the sheet of paper 1, which has been transported from the paper-feed section 10 to the image-forming device 20, is sent in a sandwiched state between the photoconductor 21 and the transferring roller 22. Then, the toner on the photoconductor 21 is electrically attracted and transferred onto the sheet of paper 1 by the function of electric field that is exerted by a transferring voltage applied to the transferring roller 22. In this case, some of the toner on the photoconductor 21 is transferred onto the sheet of paper 1 by the transferring roller 22, while untransferred toner is recovered by the cleaning unit 26.

Thereafter, the sheet of paper 1 is transported to the fixing device 50. Here, the fixing device 50 will be described in detail later. In the fixing device 50, appropriate temperature and pressure are applied by a pressure member 51 and a fixing roller 52 that is kept at a temperature of 170°C (both of which will be described later). Then, the toner is melted and fixed onto the sheet of paper 1 to form a stable image. The sheet of paper 1 is transported by the paper-transport rollers 41 and 42, and ejected out of the apparatus.

Next, referring to Fig. 4, the following description will discuss the fixing device 50. As illustrated in Fig. 4, the fixing device 50 is provided with the pressure member 51, the fixing roller 52, and a lower frame 53. The fixing roller 52 is constituted of a thin cylindrical body made of aluminum and a coating section with which the circumferential surface of the cylindrical body is coated. The coating section has superior toner-releasing, paper-transporting and heat-resisting properties, and is made of, for example, a synthetic resin material such as silicone rubber. A heater lamp 55 is inserted into the axial core section of the fixing roller 52.

The pressure member 51 is made of silicone sponge rubber with a thickness of 2 mm, and has a hardness of approximately 30 degrees on ASKER C scale. The pressure member 51, which is located between a L-letter-shaped metal plate 56 with a thickness of t1 and the circumferential surface of the fixing roller 52, is depressed by a pressure-applying spring 58 with an applied pressure of 1200 gf. Here, the pressure member 51 is secured onto the L-letter-shaped metal plate 56 by a heat-resistant double-sided tape. Further, the pressure member 51 is fitted to bosses that stick out from the lower frame 53 in the vicinity of the respective ends of the L-letter-shaped metal plate 56, and thus secured to the lower frame 53.

Shaft bushes 60 having a semi-circular arc shape are placed at the respective ends of the fixing roller 52 in the axial direction in a manner perpendicular to the axis of the fixing roller 52. Here, the shaft bushes 60 are fitted to a fixing cover 59 made of a heat-resistant resin. The fixing cover 59 is subjected to a pressure applied by an upper frame 51 through the pressure-applying spring 58.

A heat-resistant sheet 54 is inserted between the pressure member 51 and the fixing roller 52. The heat-resistant sheet 54 is secured to the lower frame 53 by a heat-resistant double-sided tape on the upstream side, that is, on the side to which a sheet of paper 1 is fed. The heat-resistant sheet 54 with a thickness of 300 μm is formed by coating the surface thereof with a synthetic resin material having superior toner-releasing and heat-resisting properties, or by incorporating such a synthetic resin material inside thereof. The synthetic resin material is, for example, a fluororesin such as, for example, PFA (polytetrafluoroethylene=perphloroacryl-vinyl-ethel copolymer resin) or PTFE (polytetrafluoroethylene resin). In the present embodiment, the heat-resistant sheet 54 is a sheet made of PTFE (which normally has a coefficient of friction of 0.04 to 0.1 with respect to aluminum) in which slit sections 54a (see Fig. 1) are formed.

In the lower frame 53, the upstream side (the side to which the paper 1 is fed) from the fixing roller 52 is set to be higher than the downstream side by a width corresponding to the thicknesses of the pressure member 51 and the heat-resistant sheet 54. The L-letter-shaped metal plate 56 is fitted to the border portion between the upstream side and the downstream side having such a height difference. Further, a prefixing guide 57, which guides the feeding of the sheet of paper 1, is formed on the paper-feeding side of the lower frame 53. A fixing guide 62, which guides the discharging of the sheet of paper 1 on which an image has been fixed, is formed on the paper-discharging side of the lower frame 53.

With this arrangement of the fixing device 50, the sheet of paper 1 bearing a prefixed toner image 2 is moved in the paper-transporting direction (in a direction indicated by arrow B in the drawing), and passes through a nip section between the fixing roller 52 and the heat-resistant sheet 54 by being guided by the prefixing guide 57. At this time, the prefixed toner image 2, which has electrostatically adhered to the sheet of paper 1, is fixed onto the sheet of paper 1 by heat and pressure of the fixing roller 52 so that desired characters or graphics are formed thereon. Thereafter, the sheet of paper 1 passes over the fixing guide 62, and ejected out of the machine. Thus, this arrangement carries out the final fixing stage of an electrophotographic process.

Referring to Figs. 1 and 2, the following description will discuss the heat-resistant sheet 54 in detail.

As illustrated in Fig. 1, the heat-resistant sheet 54 is made of the aforementioned synthetic resin material, such as, for example, PFT or PTFE. In the present embodiment, the heat-resistant sheet 54, which is made of PTFE, is set to have a thickness of 300 μm, a slit width ΔL of 1.2 mm, and a slit interval L of 80 mm. The thickness of the heat-resistant sheet 54 is determined by taking into consideration factors, such as the nip width between the heat-resistant sheet 54 and the fixing roller 52 (see Fig. 4), the strength of the pressure member 51 (see Fig. 4), the hardness of the heat-resistant sheet 54, and the abrasion loss due to friction between the heat-resistant sheet 54 and the fixing roller 52, so that long service life of the fixing device 50 can be maintained (in the present embodiment, up to 60000 sheets of paper can be handled). Moreover, the slit width ΔL and the slit interval L of the heat-resistant sheet 54 are determined by a set temperature of the fixing roller 52 and the inherent coefficient of thermal expansion of the resin under the temperature.

In a method using a conventional heat-resistant sheet, the heat-resistant sheet expands due to heat from the fixing roller, and causes deflection and distortion on the surface of the heat-resistant sheet, resulting in irregularities in the applied pressure between the fixing roller and the pressure member. Consequently, as illustrated in Fig. 16(b), an imperfect fixing, such as blurredness of image, tends to occur, failing to perform a superior fixing operation.

However, the heat-resistant sheet 54 of the present invention starts to expand gradually, as the temperature of the fixing roller 52 increases (wherein the temperature increase at this time (the surface temperature of the fixing roller 52 - ambient temperature) is represented by T). When the temperature of the fixing roller 52 further increases, the heat-resistant sheet 54 expands, resulting in deflection on its surface. When the fixing roller 52 reaches the set temperature, the heat-resistant sheet 54 has expanded as shown in Fig. 2 so that the slit width ΔL becomes zero. In other words, the expanded portion and the surface deflection of the heat-resistant sheet 54 are all absorbed by the slit sections 54a. Therefore, it is possible to keep an optimal nip width while maintaining a proper applied pressure of the pressure member 51, without the necessity of having to use a heat-releasing device or increase the thickness of the heat-resistant sheet 54. Thus, the application of the heat-resistant sheet 54 makes it possible to provide a superior fixing operation without blurredness of image, such as shown in Fig. 16(a).

Referring to Figs. 5 through 7, the following description will discuss another structural example of the heat-resistant sheet 54.

Fig. 5 is a plan view of a heat-resistant sheet 54 wherein slit sections 54a are designed to tilt with respect to the transporting direction of the paper. In this arrangement of the slit sections 54a, even in the event of an imperfect fixing, for example, due to the fact that the heat-resistant sheet 54 has been used beyond its service life, the imperfect fixing is not so conspicuous since the slit sections 54a are not perpendicular to the transporting direction of sheets of paper. Therefore, this arrangement makes it possible to set factors, such as the slit width ΔL and the slit interval L of the slit sections 54a, and the temperature of the fixing roller 52, with a comparatively wider range.

Moreover, Fig. 6 shows a contact portion indicated by an alternate long and short dashes line, which is made when the fixing roller 52 (see Fig. 4) is brought into contact with the heat-resistant sheet 54. Here, since the fixing roller 52 is designed to contact the slit sections 54a at the center portion thereof in the lengthwise direction, it is possible to prevent warp and other defects that might occur at the edges of the heat-resistant sheet 54. This eliminates the necessity of having to increase the paper-transporting torque.

Further, Fig. 7 shows a state of the heat-resistant sheet 54 upon application of heat to the fixing roller 52. In this case, the heat is conducted uniformly to the heat-resistant sheet 54 so that the entire surface of the heat-resistant sheet 54 has a uniform temperate. Consequently, it becomes possible for the slit sections 54a to positively absorb the expanded portion and deflection of the heat-resistant sheet 54. This arrangement makes it possible to maintain a stable fixing temperature.

Referring to Figs. 8 through 10, the following description will discuss still another structural example of the heat-resistant sheet 54.

Fig. 8 shows a plan view of a heat-resistant sheet 54 wherein each of the slit sections 54a has a virtually triangular shape. Further, Fig. 9 shows a plan view of a heat-resistant sheet 54 wherein each of the slit sections 54a has a virtually trapezoidal shape. With these arrangements of the shapes of the slit sections 54a, the slit sections 54a are allowed to positively absorb the expanded portion of the heat-resistant sheet 54 caused by heat. These arrangements also reduce fatigue of the heat-resistant sheet 54 due to expansion and contraction of the heat-resistant sheet 54, fatigue of the cut-out ends of the slit sections 54a, and other fatigues. As a result, it becomes possible to prevent the heat-resistant sheet 54 from being distorted permanently. Furthermore, the application of these heat-resistant sheets 54 provides a stable fixing operation up to the end of its service life.

Fig. 10 shows a plan view of a heat-resistant sheet 54 wherein a plurality of slashes are provided between the adjacent slit sections 54a. In the case of the heat-resistant sheet 54 without the slashes, when thick sheets of paper, such as envelopes and post cards, are transported, portions of the sheet with which the edges of the paper come into contact tend to be distorted, thereby causing imperfect fixing at the portions. Here, as illustrated in Fig. 10, with the arrangement having the plural slashes between the adjacent slit sections 54a, slight deflection and distortion occurring in the heat-resistant sheet 54 are absorbed by the plural slashes. Therefore, even in the case when thick sheets of paper are transported, it is possible to prevent deflection and distortion of the sheets, and to positively carry out a superior fixing operation.

Moreover, it is preferable to provide the above-mentioned slashes only along the center portion of the heat-resistant sheet 54 in the recording-material transporting direction. This arrangement sufficiently prevents warp and bent of the heat-resistant sheet 54, and makes the surface temperature of the heat-resistant sheet 54 more stable. Therefore, it becomes possible to make the surface temperature of the heat-resistant sheet 54 constant without having variations in the load of the fixing roller 52. Further, it is possible to positively compensate for distortion of the heat-resistant sheet 54 without the necessity of having to increase the paper-transporting torque, and thus to provide a superior fixing operation.

Here, experiments were carried out to examine the fixing property while the slit width $\Delta L$ and the slit interval L were varied. Supposing that the coefficient of expansion of PTFE is $1 \times 10^{-4}$ (1/°C), the outside air temperature is 20°C, the surface temperature of the fixing roller 52 is 170°C, and the slit interval L is 80 mm, the slit width $\Delta L$ under normal temperature is given as 1.2 mm in accordance with the following equation.

$$\Delta L = \alpha \bullet L \bullet T$$

where:

$\Delta L$ : slit width (mm) under normal temperature
$\alpha$ : coefficient of expansion of a material (1/°C)
L : slit interval (mm) under normal temperature
T : temperature rise (°C) of the heat-resistant sheet 54 (surface temperature of the fixing roller 52 - outside air temperature)

In other words, the heat-resistant sheet 54 whose slit width is 1.2 mm under normal temperature comes to have a slit width of zero when heated by the fixing roller 52 whose surface temperature is 170°C; thus, it becomes possible to provide a superior fixing operation. Table 1 shows the results of the experiments on the fixing property that were carried out while the slit width $\Delta L$ and the slit interval L were varied. In this case, the fixing property was evaluated by using residual-toner rate (fixing strength) after rubbing the sheet of paper to which toner adheres.

[Table 1]

| Slit interval L (mm) | 30 | 50 | 70 | 90 | 100 | 110 | 120 | 130 |
|---|---|---|---|---|---|---|---|---|
| Slit width ΔL (mm) | 0.45 | 0.75 | 1.05 | 1.35 | 1.5 | 1.65 | 1.8 | 1.95 |
| Fixing properties | ○ | ○ | ○ | ○ | ○ | ○ | △ | X |

○: Residual-toner rate of not less than 90%
△: Residual-toner rate of not more than 70% but less than 90%
X: Residual-toner rate of less than 70%

The results of Table 1 indicates that, when fixing properties are taken into consideration, the slit interval L becomes optimal when it is set to not more than 110 mm. Even if the slit interval is set to not less than 120 mm, it is theocratically possible for the slit sections 54a to absorb expansion and deflection of the sheet. However, in an actual operation, since the expansion concentrates on one portion, it is difficult to sufficiently absorb the deflection of the sheet in the case of wide slit intervals.

Therefore, it becomes possible to positively prevent deflection of the heat-resistant sheet 54 by setting the slit interval of the heat-resistant sheet 54 to not more than 110 mm. Further, this arrangement provides a stable fixing operation.

Referring to Figs. 11 as well as 12(a) and 12(b), the following description will discuss the paper-transporting force of the fixing roller 52. The fixing roller 52 is required to have a paper-transporting force in order to transport sheets of paper 1 in the paper-transporting direction. Here, in the present embodiment, in comparison with cases when a sheet of white paper 1 was transported and when a sheet of solidly black-printed (100 %) paper 1 was transported, the respective paper-transporting forces were measured. Fig. 11 shows a state wherein the paper-transporting force of the fixing roller 52 was measured. Further, Fig. 12(a) shows a state where a sheet of white paper 1 is transported into the fixing device, and Fig. 12(b) shows a state where a sheet of solidly black-printed (100%) paper 1 is transported into the fixing device. Additionally, the sheet of solidly black-printed paper 1 on the fixing roller 52 side shows a solidly black-printed state due to a prefixed toner image 2, and that on the heat-resistant sheet 54 side shows a solidly black-printed state due to a fixed image 3 after completion of the fixing operation.

As illustrated in Fig. 11, a sheet of paper 1 (128 g) is first inserted between the fixing roller 52 and the heat-resistant sheet 54. Next, the fixing roller 52 is rotated, and the sheet of paper 1 is transported with the temperature of the fixing roller 52 being set at 140 degrees. In this case, when a spring balance 63, which has been fixed to the sheet of paper 1, pulls the sheet of paper 1, the transport of the sheet of paper 1 is stopped during rotation of the fixing roller 52. Thereafter, when the pulling force of the spring balance 63 is gradually weakened, the transport of the sheet of paper 1 is started again. At the time when the sheet of paper 1 starts to be retransported, the corresponding value on the spring balance 63 is taken as the paper-transporting force.

Here, in order to transport the sheet of white paper 1, the following equation needs to be satisfied:

$$\mu 1\ (t1 \cdot m) \cdot p > \mu 2\ (t2 \cdot m) \cdot p + Mp \qquad (1)$$

$\mu 1$: friction coefficient of the coating member of the fixing roller 52 with respect to the sheet of paper 1
$\mu 2$: friction coefficient of the heat-resistant sheet 54 with respect to the sheet of paper 1
p : pressure applied to the sheet of paper 1
Mp: resisting force of the sheet of paper 1 + transporting force

In accordance with Equation (1), the relationship $\mu 1 > \mu 2$ needs to be satisfied. Here, the friction coefficient $\mu 1$ is a coefficient that is dependent on the temperature t1 and material of the coating member m of the fixing roller 52. Similarly, the friction coefficient $\mu 2$ is a coefficient that is dependent on the temperature and material of the heat-resistant sheet 54. In this manner, it becomes possible for the fixing roller 52 to stably transport the sheet of paper 1 by setting the friction coefficient $\mu 1$ to become greater than the friction coefficient $\mu 2$; thus, it is possible to reduce imperfect transport of sheets of paper.

In the present embodiment, the friction coefficient $\mu 2$ is 0.1, the applied pressure p is 1400 gf, and the transporting force Mp is 100 gf. Then, in accordance with Equation (1), the friction coefficient $\mu 1$ needs to be set not less than 0.17. Further, supposing that the friction coefficient $\mu 2$ is 0.1, the applied pressure p is 1000 gf, and the transporting force Mp is 100 gf, the friction coefficient $\mu 1$ needs to be set not less than 0.2 in accordance with Equation (1). Therefore, with respect to the heat-resistant sheet 54, it is preferable to use a material whose friction coefficient $\mu 2$ is small, and also to use a great applied pressure p. However, too great an applied pressure p makes the friction torque greater. As a result, the fixing roller 52 tends to easily wear, thereby increasing costs in exchanging fixing rollers 52.

In order to transport the sheet of solidly black-printed (100 %) paper 1, on the other hand, the following equations (2) and (3) need to be satisfied at the same time:

$$\mu C\ (t1 \cdot m) \cdot p > \mu S\ (t2 \cdot m) \cdot p + Mp \qquad (2)$$

$$F2 \cdot F2' > F3 > F1 \qquad (3)$$

$\mu C$: friction coefficient of the coating member of the fixing roller 52 with respect to the sheet of paper 1
$\mu S$: friction coefficient of the heat-resistant sheet 54 with respect to the sheet of paper 1
p : pressure applied to the sheet of paper 1
Mp: resisting force of the sheet of paper 1 + transporting force
F1: surface tension between the coating member and the toner (toner-releasing property of the coating member)
F2: surface tension between the sheet of paper 1 on the fixing roller 52 side and the toner (toner-releasing property of the sheet of paper 1)
F2': surface tension between the sheet of paper 1 on the heat-resistant sheet 54 side and the toner (toner-releasing property of the sheet of paper)
F3: surface tension between the heat-resistant sheet 54 and the toner (toner-releasing property of the heat-resistant sheet 54)

In the same manner as the transport of the sheet of white paper 1, the friction coefficients $\mu C$ and $\mu S$, the surface tensions F1, F2, F2' and F3 are respectively determined by the temperatures t1 and t2 as well as the material m.

Here, the fluidity of toner varies with temperatures, and at elevated temperatures, the surface tension and friction coefficient with respect to other material become greater. Therefore, in the case when the sheet of solidly black-printed (100 %) paper 1 is transported, $\mu S > \mu 2$ holds, thereby making the conditions more severe as compared with the transport of the sheet of white paper 1. Therefore, it is necessary to provide a coating member that has a greater friction coefficient $\mu C$ and a greater paper-transporting force Mp as, compared with the transport of the sheet of white paper 1.

Next, in the above-mentioned arrangement, paper-transporting tests of sheets of paper 1 were carried out, and the resulting paper-transporting states were evaluated. In this case, double-sided sheets of solid black paper, which have a black-toner density of 1.4, were used as the sheets of paper 1. Additionally, with respect to the sheets of solid black paper, the sheet of solid black paper on the fixing roller 52 side shows a solid black state due to a prefixed toner image 2, and that on the heat-resistant sheet 54 side shows a solid black state due to a fixed image 3 after completion of the fixing operation. The fixing roller 52 is combinedly provided with properties, such as a toner-releasing property, a heat-resistant property and a paper-transporting property. In the present embodiment, the evaluations were carried out by using paper-transporting forces of five types, that is, 170 gf, 250 gf, 300 gf, 500 gf, and 1500 gf. Moreover, the transport of sheets of paper 1 were carried out by using a multi-printing process with a paper-transport interval of 3 seconds and a single-multi-printing process with a paper-transport interval of 60 seconds. Here, in the multi-printing process, the fixing roller 52 was adjusted to have a temperature of 140 degrees during 3 seconds of a non-paper-transporting period of paper 1. In contrast, in the single-multi-printing process, the fixing roller 52 was not adjusted in its temperature during 60 seconds of a non-paper-transporting period of paper 1. Moreover, the paper-transporting speed was 25 mm/sec in the respective cases. Table 2 shows the results of the tests.

[Table 2]

| Paper-Transport Force (gf) | Paper-transporting property of samples whose rear-surface is 100% printed | | General Judgement |
|---|---|---|---|
| | Multi-Printing Process | Single-Multi-Printing Process | |
| 170 | X | X | C |
| 250 | △ | X | B |
| 300 | ○ | ○ | A |
| 500 | ○ | ○ | A |
| 1500 | ○ | ○ | A |
| Paper-Transporting property: ○ : Perfect △ : Occasionally Imperfect X : Imperfect<br>General Judgement: A : Perfect B : Occasionally Imperfect C : Imperfect | | | |

The results shows that when the paper-transporting force was set to 300 gf, 500 gf, and 1500 gf, the paper-transporting property was excellent both in the multi-printing process and the single-multi-printing process. Further, the fixing roller 52 was rotated without load with its roller surface temperature kept at 140 °C for the time corresponding to the passage of 60000 sheets of paper that is the usable period of the fixing device 50 (in a state where it was kept in contact with the heat-resistant sheet 54). More specifically, in the laser printer of the present embodiment that printouts four sheets per minute, the fixing roller 52 was rotated with its roller surface temperature kept at 140 °C, for 1500 minutes (250 hours). As a result, the paper-transporting force was lowered by 10%. The reasons are given as follows: One reason is friction between the fixing roller 52 and the heat-resistant sheet 54 (made of PTFE in the present embodiment). The other is that PTFE is shifted from the heat-resistant sheet 54 to the coating layer side of the fixing roller 52.

Therefore, with respect to the paper-transporting force required for the fixing roller 52, it is preferable to provide not less than 300 gf. It is possible to carry out a stable paper-transporting operation without causing any imperfect paper transport, irrespective of any type of paper 1, by determining the lower limit of the paper-transporting force in this manner. Moreover, it is possible to obtain a fixing roller 52 that has a superior toner-separating property by setting the paper-transporting force at a value in the vicinity of the lower limit. Consequently, the optimum value of the paper-transporting force is virtually set at 350 gf.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

## Claims

**1.** A fixing device comprising:

a fixing roller,
a pressure member that is placed in contact with the circumferential surface of the fixing roller, and
a heat-resistant sheet that is provided with slits and that is installed between the fixing roller and the pressure member,

wherein a recording material bearing a prefixed toner image is transported between the fixing roller and the heat-resistant sheet so as to fix the prefixed toner image onto the recording material.

2. The fixing device as defined in claim 1, wherein the slits of the heat-resistant sheet is designed to tilt with respect to the transporting direction of the recording material.

3. The fixing device as defined in claim 1, wherein the fixing roller is designed to contact the slits provided in the heat-resistant sheet at the center portion thereof in the lengthwise direction.

4. The fixing device as defined in claim 1, wherein each of the slits has a virtually triangular shape.

5. The fixing device as defined in claim 1, wherein each of the slits has a virtually trapezoidal shape.

6. The fixing device as defined in claim 1, wherein the heat-resistant sheet is made of a fluororesin.

7. The fixing device as defined in claim 1, wherein slashes are provided between the slits of the heat-resistant sheet in parallel with the slits.

8. The fixing device as defined in claim 1, wherein the interval between the adjacent slits is not less than 110 mm.

9. The fixing device as defined in claim 1, wherein the paper-transporting force of the fixing roller is set to not less than 300 gf.

10. The fixing device as defined in claim 1, wherein the paper-transporting force of the fixing roller is set to 350 gf.

11. The fixing device as defined in claim 6, wherein the fluororesin is polytetrafluoroethylene=perphloroacryl-vinyl-ethel copolymer resin.

12. The fixing device as defined in claim 6, wherein the fluororesin is polytetrafluoroethylene resin.

13. The fixing device as defined in claim 7, wherein the slashes are provided along the center portion of the heat-resistant sheet in the recording-material transporting direction.

FIG. 1

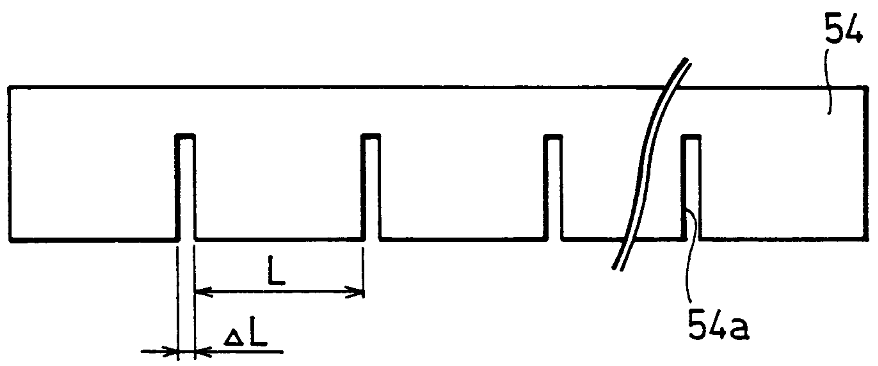



FIG. 2

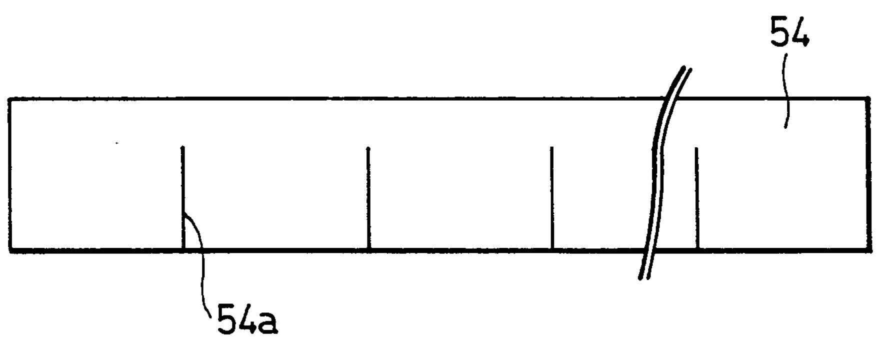
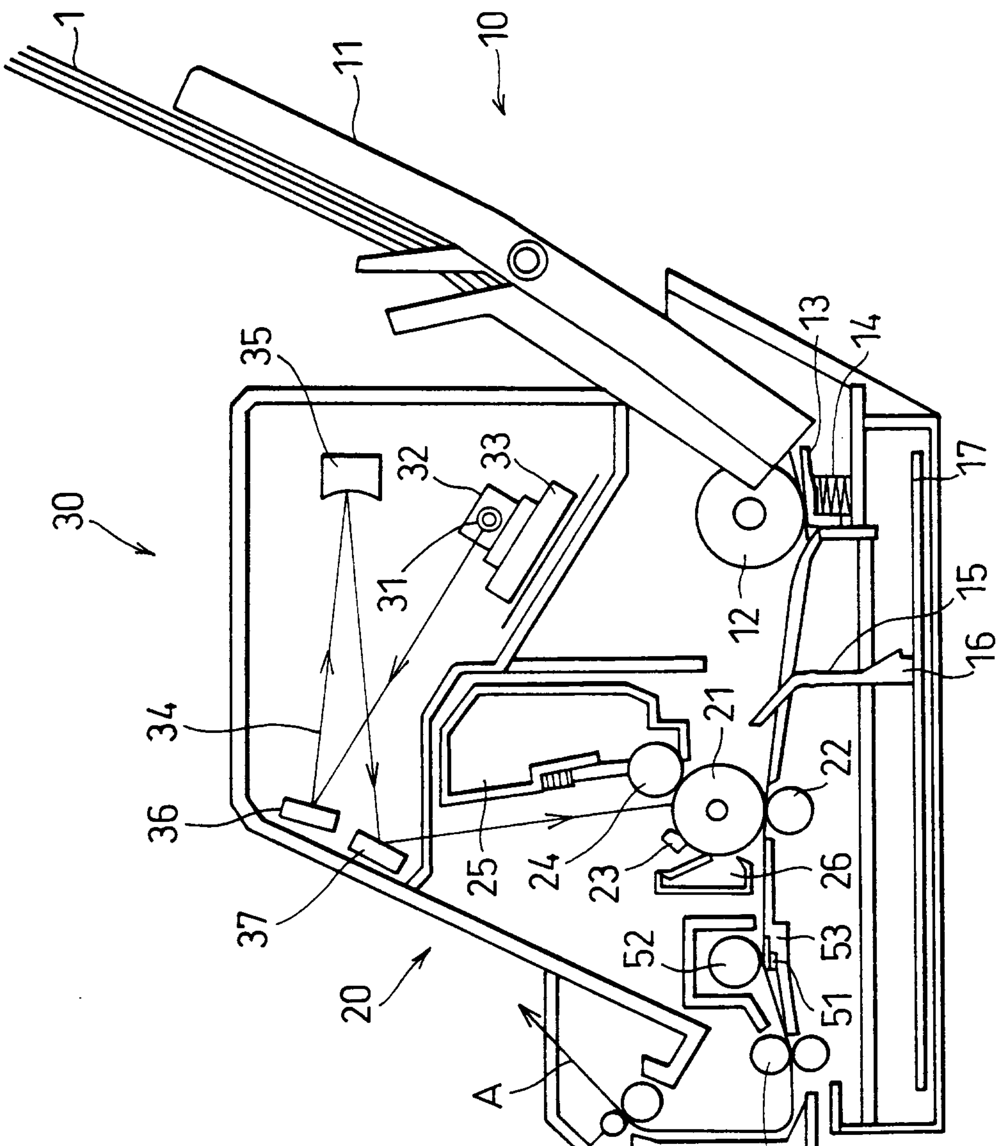


FIG. 3


1
10
11
12
13
14
15
16
17
20
21
22
23
24
25
26
30
31
32
33
34
35
36
37
41
42
50
51
52
53
A

F I G. 4

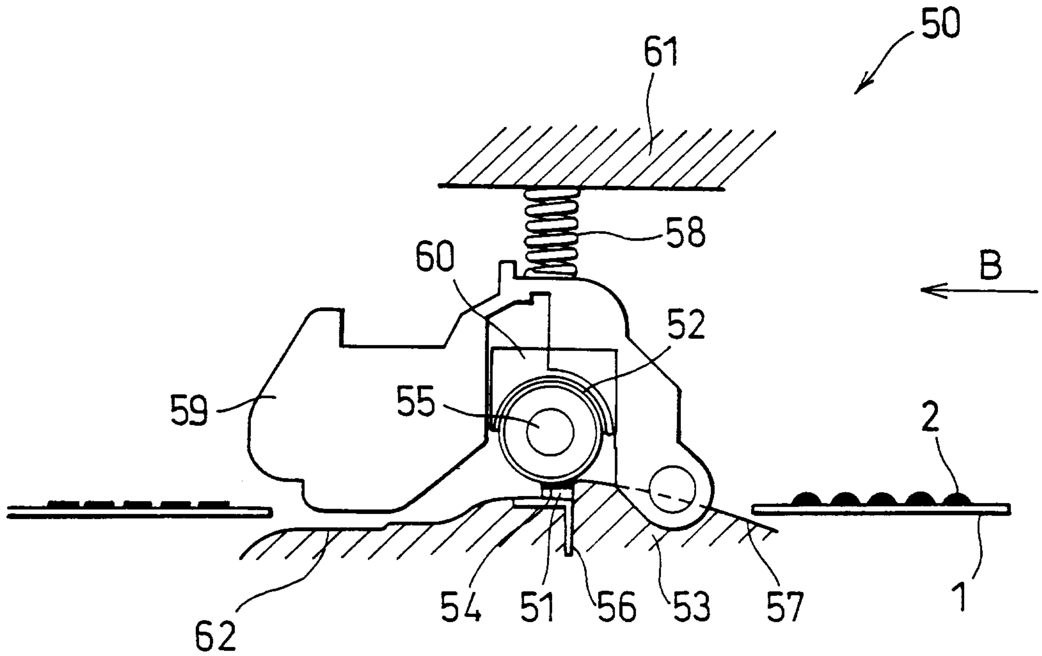


FIG. 5

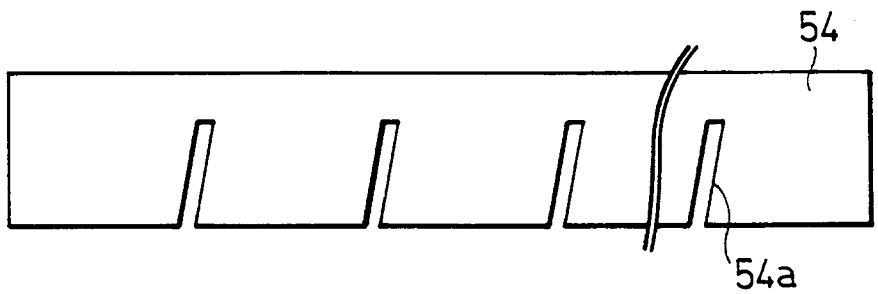



FIG. 6

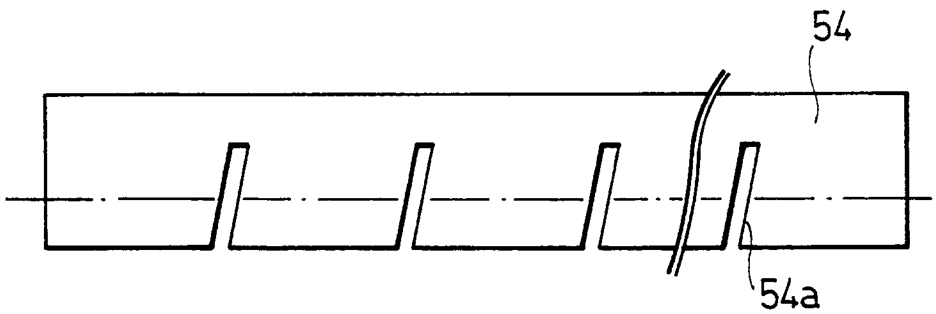



FIG. 7

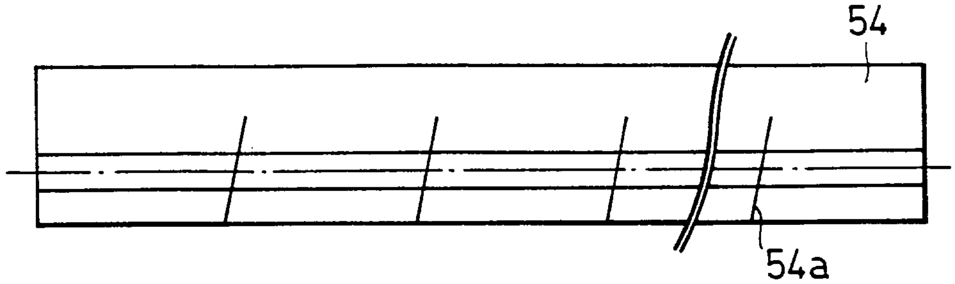


FIG. 8

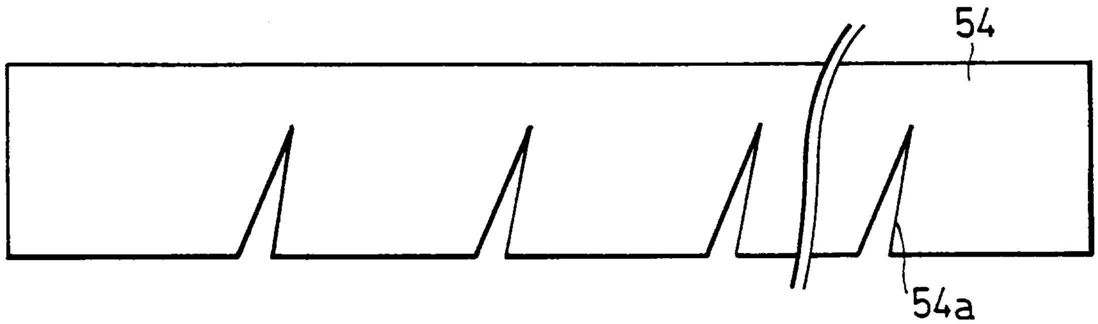



FIG. 9

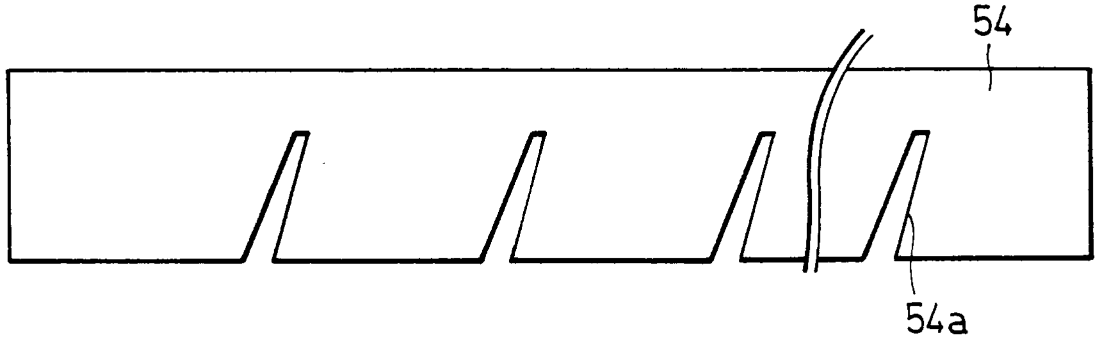
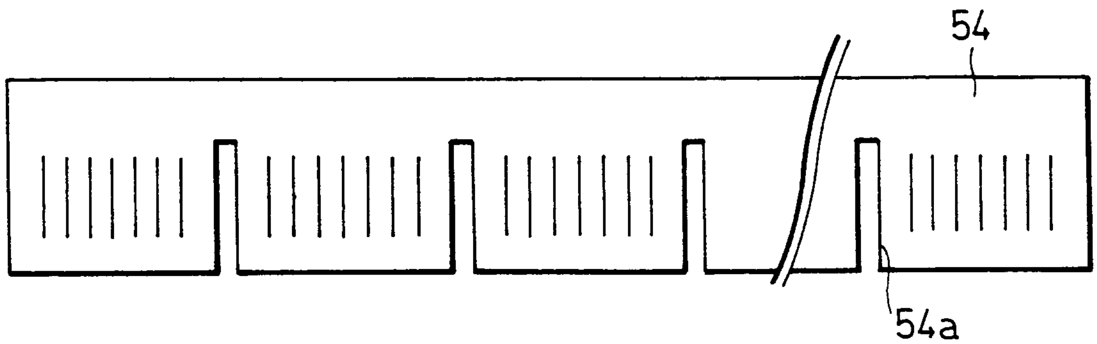



FIG. 10



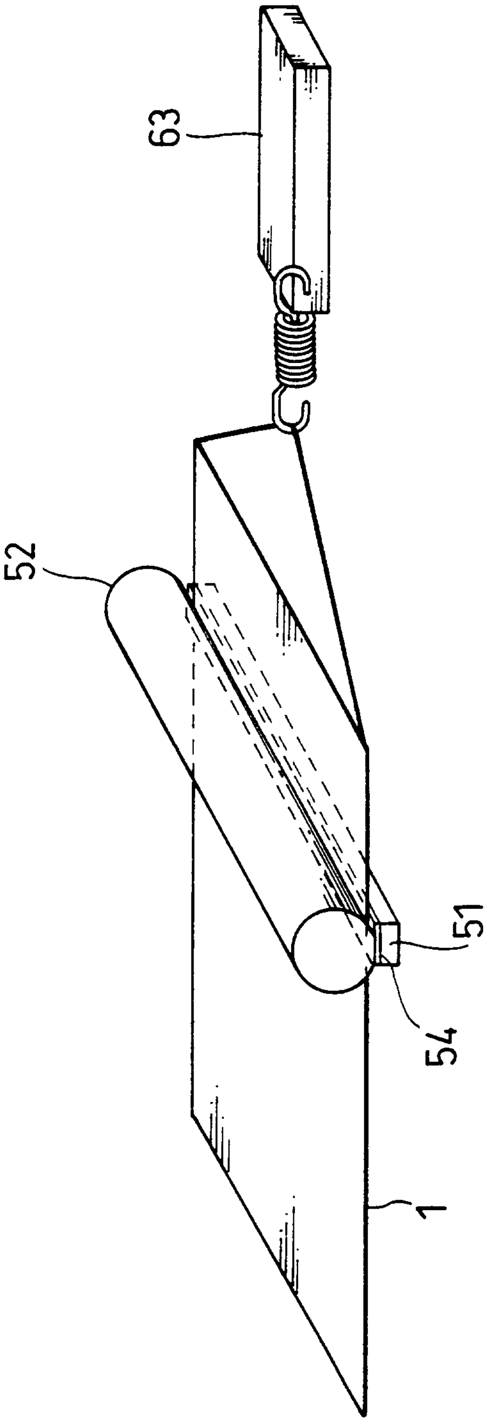
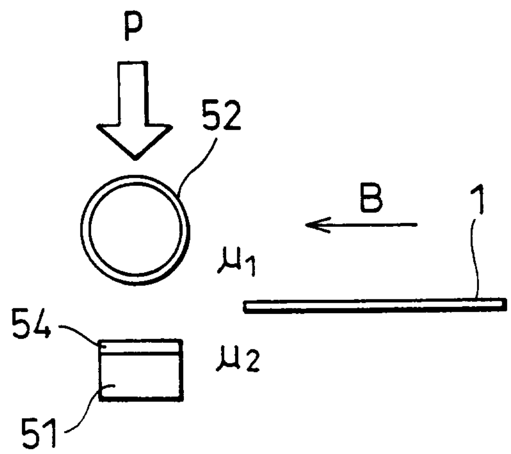



FIG. 11

F I G. 12 (a)




F I G. 12 (b)

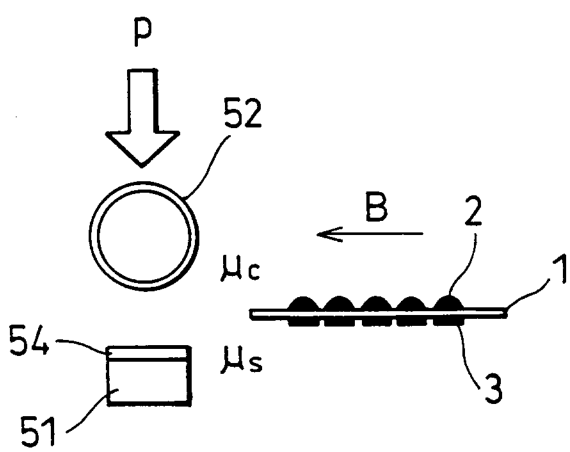


FIG. 13

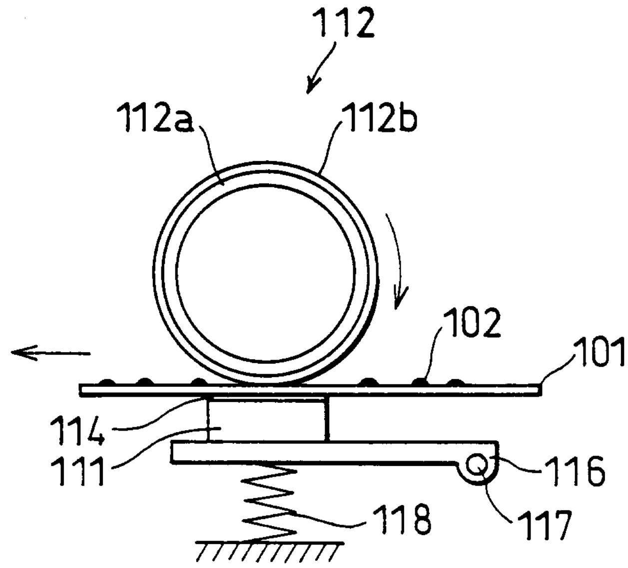
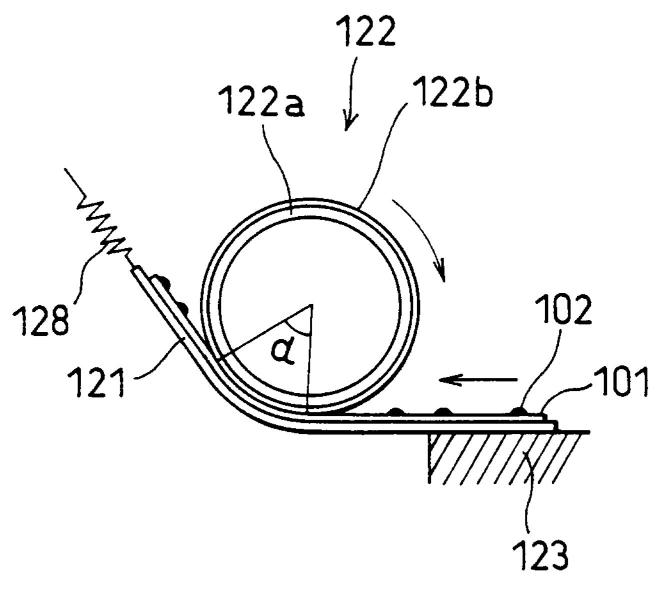
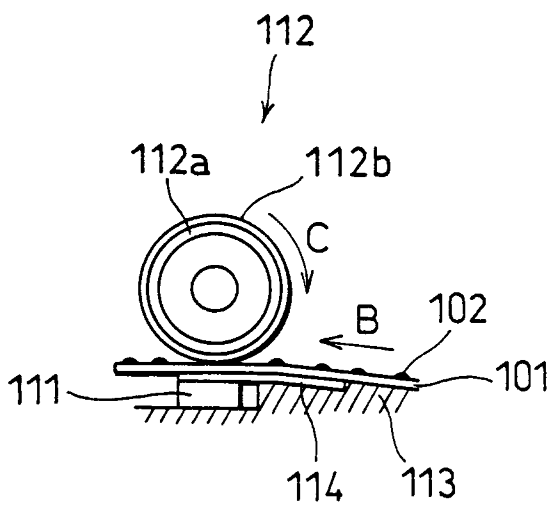

112
112a
112b
102
101
114
111
116
118
117

FIG. 14


122
122a
122b
128
α
121
102
101
123

F I G. 15



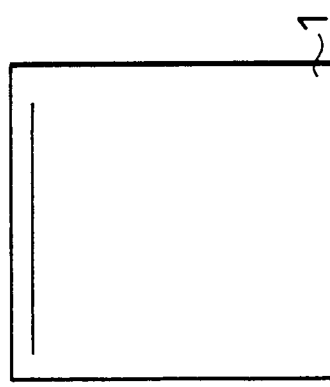



FIG.16(a)

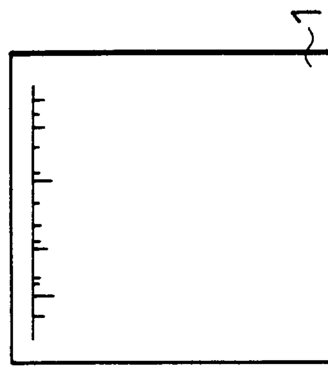



FIG.16(b)