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(54) Developing device and image forming apparatus including the developing device

(57) An arrangement which makes good development possible, in a developing device (14) of a contact development type using non-magnetic monocomponent toner and using a developing roller (25), by keeping low the driving torque produced by the developing roller (25). To achieve this the coefficient of surface dynamic friction μ of the developing roller 25 against the surface of a photosensitive drum 11 is arranged to satisfy the relationship $0.2 \leqq \mu \leqq 2.5$. Also, the apparent density (AD) of toner to be used satisfies the relationship 0.25 (g/cc) $\leqq$ AD $\leqq 0.55$ (g/cc). As a result, there are portions on which no toner adheres at both ends of the developing roller (25). Even when the portions are brought into contact with the photosensitive drum 11, friction in the contact portion is not too large, and driving torque produced by the developing roller (25) may be low. Further, a toner thin layer formed on the developing roller (25) reaches uniformity, whereby good development is achieved.

FIG. 1

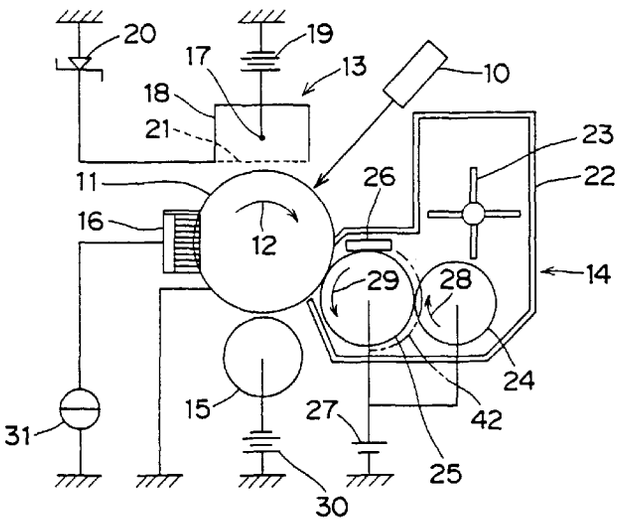

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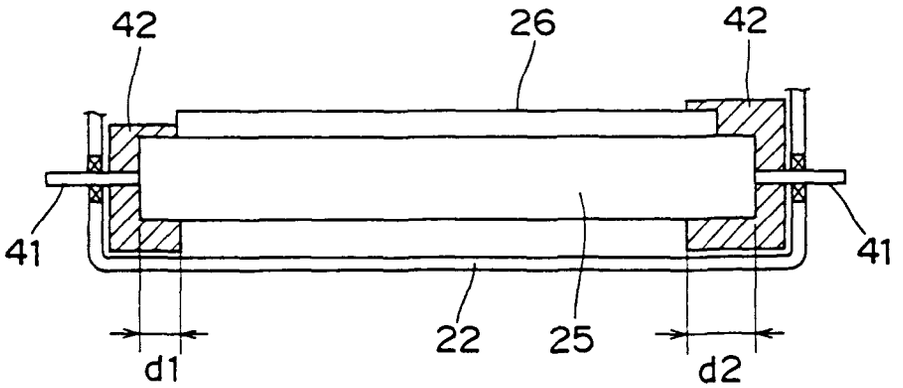
FIG. 2



Description

The present invention relates generally to a developing device applicable to an image forming apparatus such as an electrostatic process copying machine, a printer or a facsimile, and an image forming apparatus to which the developing device is applied. More particularly, it relates to a developing device of a contact development type using as a developer non-magnetic monocomponent toner.

An electrostatic process image forming apparatus using as a developer non-magnetic monocomponent toner has been conventionally known. In such an apparatus, a contact development type has generally been employed, in that a developing roller is used for developing an electrostatic latent image formed on a photosensitive drum and is brought into contact with the surface of the photosensitive drum.

In the contact development type using as a developer non-magnetic monocomponent toner, the toner adhering on the peripheral surface of the developing roller is not attracted to the developing roller by a magnetic force. The toner in contact with the peripheral surface of the developing roller only adheres on the peripheral surface of the developing roller upon being triboelectrically charged by the rotation of the developing roller. Therefore, toner particles, which cannot adhere on both ends of the developing roller, of the toner, triboelectrically charged from both the ends of the developing roller, are blown out of a developing housing.

In the conventional apparatus, therefore, a part of the peripheral surface of the developing roller is covered with a sealing member so that no toner adheres on both the ends of the developing roller.

Provided no toner adheres on both the ends of the developing roller, the ends of the developing roller are directly brought into contact with the surface of the photosensitive drum with no toner interposed therebetween.

Furthermore, a thin-layer blade for regulating the amount of toner adhering on the peripheral surface of the developing roller is generally brought into contact with the developing roller. Accordingly, portions, on which no toner adheres, of both the ends of the developing roller are also directly brought into contact with the thin-layer blade.

Since the developing roller is generally made of rubber, the coefficient of friction on the peripheral surface thereof is high. If the developing roller is so constructed that both the ends thereof are directly brought into contact with the photosensitive drum, therefore, large torque is required to rotate the developing roller. In other words, a large motor is required to rotate the developing roller. Further, when torque produced by the motor is insufficient, the rotation of the developing roller is swayed, thereby adversely affecting development. Therefore, there arise some problems. For example, a formed image is distorted.

Therefore, an object of the present invention is to provide, in a developing device using as a developer non-magnetic monocomponent toner for performing contact development using a developing roller, a developing device capable of miniaturizing the motor for rotating the developing roller and performing good development.

Furthermore, the present invention provides an image forming apparatus using the developing device.

In accordance with one aspect, the present invention is characterized in that in a developing device of a contact development type, using as a developer non-magnetic monocomponent toner, for bringing a developing roller having the toner adhering on its peripheral surface into contact with the surface of a photosensitive drum, the coefficient of surface dynamic friction μ of the developing roller against the surface of the photosensitive member satisfies the following relationship:

$$0.2 \leqq \mu \leqq 2.5$$

In the above-mentioned construction, when the coefficient of surface dynamic friction μ of the developing roller is less than 0.2, friction between the peripheral surface of the developing roller and the surface of the photosensitive member is too small. When the toner adhering on the peripheral surface of the developing roller is brought into contact with the surface of the photosensitive member, therefore, the toner may, in some cases, slide from the surface of the photosensitive member. Therefore, a developed image attracts dust of the toner, and is insufficient in density.

On the other hand, when the coefficient of surface dynamic friction μ of the developing roller exceeds 2.5, contact friction between both the ends of the developing roller and the photosensitive member is too large, whereby the rotation of the developing roller may, in some cases, be caused to sway. The non-uniformity in rotation can be overcome by considerably increasing torque produced by a driving motor. However, this makes the initial object unfeasible.

In the developing device, therefore, the coefficient of surface dynamic friction μ of the developing roller is set in the above-mentioned range, whereby good development can be performed, and driving torque produced by the developing roller is not increased.

In accordance with another aspect, the present invention is characterized in that in the above-mentioned developing device, the apparent density (AD) of toner to be used satisfies the following relationship:

$$0.25\ (g/cc) \leqq AD \leqq 0.55\ (g/cc)$$

By further adding the above-mentioned construction, the developing performance can be kept good, and the rotation of the developing roller can be prevented from being swayed.

Specifically, when the apparent density (AD) of the toner to be used is less than 0.25 g/cc, the rotation of the developing roller may, in some cases, be swayed even when the coefficient of surface dynamic friction μ of the developing roller is maintained in the above-mentioned range.

On the other hand, when the apparent density (AD) of the toner exceeds 0.55 g/cc, the fluidity of the toner is too high, whereby a uniform thin layer may not be formed on the peripheral surface of the developing roller.

Therefore, a developing device capable of reliably attaining the initial object can be achieved by setting the apparent density (AD) of the toner to be used in the above-mentioned range in addition to setting the coefficient of surface dynamic friction μ of the developing roller in the above-mentioned range.

"Apparent density" is determined based on the volume including voids in the toner as well as the toner itself, as compared to a measurement of "density" determined based on the volume of toner itself excluding voids therein.

As described in the foregoing, according to the present invention, in the developing device of a contact development type using as a developer non-magnetic monocomponent toner and using the developing roller, driving torque for rotating the developing roller can be decreased, whereby the driving motor can be miniaturized, and made low in cost. Further, in such a developing device, development can be prevented from being non-uniform.

Furthermore, in an image forming apparatus employing the developing device, a clean image can be formed.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic diagram showing the construction of an image forming apparatus comprising a developing device according to one embodiment of the present invention; and

Fig. 2 is an illustration for explaining a structure relating to a developing roller.

Fig. 1 is a schematic diagram showing the construction of an image forming apparatus to which one embodiment of the present invention is applied. The image forming apparatus comprises a photosensitive drum 11. The photosensitive drum 11 is rotated at predetermined speed in a direction indicated by an arrow 12. A main charger 13, an exposing unit 10, a developing device 14 according to one embodiment of the present invention, a transfer roller 15, and a brush 16 are successively arranged in the direction of rotation as indicated by the arrow 12 around the photosensitive drum 11.

The main charger 13 is a discharger for charging the surface of the photosensitive drum 11 to a predetermined high potential (for example, + 800 V). The main charger 13 comprises a discharge wire 17 and a shielding case 18. A voltage from a high-voltage DC unit 19 is applied to the discharge wire 17. Further, a grid 21 connected to a voltage regulating diode 20 is provided in an opening opposite to the surface of the photosensitive drum 11 of the shielding case 18 in order to control the potential discharged from the discharge wire 17.

The surface of the photosensitive drum 11 is charged to a predetermined high potential by being opposite to the main charger 13. A charged region is moved in a clockwise direction as the photosensitive drum 11 is rotated. The charged surface of the photosensitive drum 11 is exposed to light produced on the basis of image data outputted from the exposing unit 10. A portion exposed to light is made low in potential upon emission of charge in the portion. Consequently, an electrostatic latent image comprising a high potential area and a low potential area is formed on the surface of the photosensitive drum 11.

When the electrostatic latent image reaches the developing device 14 upon further rotation of the photosensitive drum 11, the electrostatic latent image is developed into a toner image by the developing device 14.

The developing device 14 comprises a housing 22, an agitating blade 23 provided in the housing 22, a sub-roller 24, a developing roller 25 so arranged as to be in contact with the sub-roller 24 and the photosensitive drum 11, a thin-layer blade 26 so arranged as to be in contact with the peripheral surface of the developing roller, and a sealing member 42 as described later (indicated by a one-dot and dash line). Non-magnetic monocomponent toner is used as the toner. The toner does not include a so-called carrier.

The agitating blade 23 is for agitating the toner in the housing 22 to uniformly supply the toner to the sub-roller 24 and the developing roller 25.

The sub-roller 24 and the developing roller 25 are respectively rotated in directions indicated by arrows 28 and 29, and the toner is electrostatically adsorbed to their peripheral surfaces upon being triboelectrically charged by the rotation. The sub-roller 24 is provided in order to triboelectrically charge the toner more effectively.

The toner adhering on the peripheral surface of the developing roller 25 is brought into a thin layer by the thin-layer blade 26. Consequently, the toner adhering on the peripheral surface of the developing roller 25 reaches uniformity, whereby the toner is prevented from being non-uniformly transferred to the photosensitive drum 11. Further,

the developing roller 25 is so rotated that its peripheral speed is higher than the peripheral speed of the photosensitive drum 11 so that the transferred toner is not insufficient.

Furthermore, predetermined bias voltages are respectively applied to the sub-roller 24 and the developing roller 25. Specifically, a bias voltage of + 300 V, for example, is applied by a DC power supply 27. Consequently, suitable development is performed. More specifically, the surface potential of the photosensitive drum 11 is a low potential VL in an exposed region, while being a high potential VH in an unexposed region. On the other hand, the developing roller 25 is charged to a positive potential VM by the developing bias voltage. The potential VM at the developing roller 25 (for example, + 300 V) is made lower than the high potential VH (for example, + 800 V) in the unexposed region on the surface of the photosensitive drum 11 and higher than the low potential VL (for example, + 100 V) in the exposed region. Accordingly, the toner adhering on the surface of the developing roller 25 is electrostatically adsorbed on only the exposed region on the surface of the photosensitive drum 11, whereby development is performed.

Paper is fed from a conveying path (not shown) as the leading end of a toner image on the surface of the photosensitive drum 11 is opposite to the transfer roller 15, and the paper is passed between the photosensitive drum 11 and the transfer drum 15. The transfer roller 15 is connected to a high-voltage DC unit 30, and a negative potential is applied thereto. Therefore, paper whose reverse surface is brought into contact with the transfer roller 15 is charged to the negative potential. The toner on the surface of the photosensitive drum 11 positively charged is transferred to the paper negatively charged.

Although the surface of the photosensitive drum 11 after the transfer should ideally enter a state where no toner exists, it is actually in a state where some residual toner which has not been transferred adheres thereto. Further, paper is brought into contact with the surface of the photosensitive drum 11, whereby paper powder or the like resulting from the paper, together with the residual toner, also adheres on the surface of the photosensitive drum 11.

When a region, on which the residual toner adheres, of the photosensitive drum 11 passes through the brush 16, the residual toner is scratched by the tip of the brush 16, whereby electrostatic coupling between the residual toner and the surface of the photosensitive drum 11 is weakened. Further, in order that electrostatic coupling be weakened electrically too, the brush 16 is biased with predetermined current by a constant-current power supply 31. The bias helps the brush 16 to adsorb the paper powder adhering on the surface of the photosensitive drum 11, and prevents the toner erroneously adhering on the brush 16 from being adsorbed by the photosensitive drum 11 again. The surface of the photosensitive drum 11 passing through the brush 16 is in a state where electrostatic coupling between the charge on the surface of the photosensitive drum 11 and the toner is weakened as described above, whereby toner particles electrostatically adhere on the surface of the photosensitive drum 11 loosely.

The surface of the photosensitive drum 11 in the above-mentioned state is charged to a predetermined high potential again by the main charger 13 for the purpose of the subsequent image formation upon being opposite to the main charger 13. The surface of the photosensitive drum 11 is exposed to light corresponding to an image by the exposing unit 10, and is moved to the developing device 14. In this case, the amount of residual toner remaining on the surface of the photosensitive drum 11 is small. Moreover, the residual toner is scratched by the brush 16. When the surface of the photosensitive drum 11 is charged again by the main charger 13 or is exposed to light by the exposing unit 10, therefore, the residual toner does not distort the formed electrostatic latent image.

When the residual toner on the photosensitive drum 11 reaches the developing device 14, the residual toner is recovered upon being drawn to the developing roller 25 by the bias applied to the developing roller 25. At the same time, the developing roller 25 develops the electrostatic latent image on the photosensitive drum 11 into a toner image.

Fig. 2 is an illustration showing the mounting structure of the developing roller in the developing device 14, which illustrates a structure relating to the developing roller 25 in a case where the developing device 14 shown in Fig. 1 is viewed from the left of the drawing.

Description is made with reference to Fig. 2. Shafts 41 extend toward both sides from both the ends of the developing roller 25. The shafts 41 extend outward upon penetrating through the housing 22. A driving motor is connected through a gear or the like, which is not illustrated, to one of the shafts 41 extending outward from the housing 22.

Sealing members 42 so adapted as to cover the innermost side in Fig. 2, that is, almost all the right half of the developing roller 25 in Fig. 1 are provided at both the ends of the developing roller 25. The sealing members 42 are for preventing toner from adhering on both the ends of the developing roller 25. The sealing member 42 is a member having bristles composed of a synthetic fiber, for example, studded on its surface opposite to the developing roller 25. The studded bristles prevent the toner in the housing 22 from adhering on both the ends of the developing roller 25, and prevent toner particles from being blown out from both the ends of the developing roller 25 toward the photosensitive drum 11.

A region on which no toner adheres, the width of which is d1 in the axial direction, is formed at the left end in Fig. 2 of the developing roller 25 by the sealing member 42. On the other hand, a region on which no toner adheres, the width of which is d2 in the axial direction, is formed at the right end of the developing roller 25 by the sealing member 42.

The length of the thin-layer blade 26 is made slightly smaller than the axial length of the developing roller 25 in the present embodiment. However, the thin-layer blade 26 is so adapted that both its ends are slightly brought into

contact with the regions on which no toner adheres at both the ends of the developing roller 25. This is for making a toner layer adhering on the peripheral surface of the developing roller 25 uniform. If the thin-layer blade 26 is not brought into contact with the developing roller 25 in a wider region than the region on which toner adheres in the developing roller 25, the toner layer may not be uniform in a portion where the thin-layer blade 26 is not in contact with the developing roller 25.

Furthermore, the whole in the axial direction of the developing roller 25 is brought into contact with the photosensitive drum 11 in the present embodiment. In other words, surface regions on which no toner adheres which exist at both the ends of the developing roller 25 are also brought into contact with the photosensitive drum 11.

When the region on which no toner adheres is formed on the peripheral surface of the developing roller 25, the frictional force between the region and the photosensitive drum 11 is increased. Further the frictional force between the region and the thin-layer blade 26 is also increased. The reason for this is that the toner functions as a lubricant to weaken the frictional force between the developing roller 25 and the photosensitive drum 11 or the thin-layer blade 26 when the toner adheres on the peripheral surface of the developing roller 25. Without toner thus functioning as a lubricant on the photosensitive drum 11, the frictional force is necessarily increased accordingly.

Therefore, when the region on which no toner adheres is formed on the developing roller 25, the coefficient of surface friction of the developing roller must be decreased. However, since the toner must be contacted with the surface of the developing roller to be triboelectrically charged and must adhere on the surface of the developing roller, the coefficient of surface friction must be high to some extent. Therefore, the developing roller 25 has been conventionally made of rubber.

Furthermore, if torque produced by the motor for rotating the developing roller 25 is increased, the rotation of the developing roller 25 can be prevented from being swayed. However, this requires a motor producing large torque, that is, a large-sized motor or high-cost motor.

In the present embodiment, therefore, the coefficient of surface dynamic friction μ of the developing roller 25 against the surface of the photosensitive member is set in the following range:

$$0.2 \leqq \mu \leqq 2.5$$

When the coefficient of dynamic friction μ is less than 0.2, friction between the peripheral surface of the developing roller 25 and the surface of the photosensitive drum 11 is too small. When the toner adhering on the peripheral surface of the developing roller 25 is brought into contact with the surface of the photosensitive drum 11, therefore, the toner may, in some cases, slide from the surface of the photosensitive drum 11. As a result, a developed image attracts dust of the toner, and is insufficient in density.

On the other hand, when the coefficient of dynamic friction μ exceeds 2.5, friction between the developing roller 25 and the photosensitive drum 11 is too large, whereby the rotation of the developing roller 25 is swayed. Accordingly, the coefficient of dynamic friction μ is set in the above-mentioned range.

Furthermore, the apparent density (AD) of toner to be used is set in the following range:

$$0.25 \text{ (g/cc)} \leqq \text{AD} \leqq 0.55 \text{ (g/cc)}$$

Consequently, the rotation of the developing roller 25 is prevented from being swayed, whereby a uniform toner thin layer can be formed on the developing roller 25.

Description is now made of the foundation on which the coefficient of dynamic friction μ and the apparent density (AD) of the toner are set in the above-mentioned ranges.

The coefficient of dynamic friction of the developing roller 25 against the surface of the photosensitive drum 11 is measured with respect to the photosensitive drum 11 and the developing device 14 having the structures shown in Figs. 1 and 2 (specifically, a photosensitive drum and a developing device used for an electrostatic process facsimile manufactured by Mita Industrial Company, Ltd. and a TC-650 type modified machine).

"Peeling/Slipping/Scratching TESTER HEIDON-14" is employed as a measuring device, and measurements are taken on condition that the moving speed of the surface of the photosensitive drum is 70 mm/sec in a state where a load of 50 g is applied to the developing roller 25 as measurement conditions.

The following are the contents of the measurements and the results of the measurements.

Table 1

toner to be used	manufacturing method	particle diameter	apparent density
	polymerization	10 μm	0.50 g/cc
	polymerization	9 μm	0.44 g/cc
	grinding	9 μm	0.38 g/cc
	grinding	8 μm	0.20 g/cc
	grinding	7 μm	0.18 g/cc

developing rubber roller: coefficient of friction is varied depending on type of surface treatment using urethane rubber roller as a base

coefficient of friction of developing roller	apparent density of toner (g/cc)	non-uniformity in solid-black portion	non-uniformity in rotation
0.18	0.50	x	o
	0.44	x	o
	0.38	x	o
0.20	0.52	x	o
	0.50	o	o
	0.44	o	o
	0.20	o	o
0.64	0.50	o	o
	0.38	o	o
	0.20	o	o
1.69	0.50	o	o
	0.38	o	o
	0.20	o	o
2.50	0.38	o	o
	0.20	o	o
	0.18	o	x
2.82	0.38	-	x
	0.20	-	xx
	0.18	-	xx

non-uniformity in solid-black portion (visual observation)	o : no problem x : low density portion occurs - : non-uniformity in rotation is large, solid image cannot be evaluated
non-uniformity in rotation (visual observation)	o : no problem x : transverse stripe-shaped non-uniformity occurs in several places xx : transverse stripe-shaped non-uniformity occurs on whole surface

From the results of the measurements, the values of the coefficient of dynamic friction μ and the apparent density (AD) of the toner are obtained.

Claims

1. A developing device of a contact development type, using as a developer non-magnetic monocomponent toner, for bringing a developing roller (25) having the toner adhering on its peripheral surface into contact with the surface of a photosensitive member (11), characterised in that
the coefficient of surface dynamic friction μ of said developing roller (25) against the surface of the photosensitive member (11) satisfies the following relationship:

$$0.2 \leqq \mu \leqq 2.5$$

2. A developing device according to claim 1, wherein the apparent density (AD) of toner to be used satisfies the following relationship:

$$0.25\ (g/cc) \leqq AD \leqq 0.55\ (g/cc)$$

3. A developing device according to claim 1 or 2, further comprising

a housing (22) for containing said toner,
an agitating blade (23) provided in the housing (22) for agitating the toner contained in the housing, and a sub-roller (24) arranged in the housing,
wherein the developing roller (25) being so arranged as to be brought into contact with the sub-roller (24) and the photosensitive member (11).

4. A developing device according to claim 3, wherein sealing members (42) for covering predetermined portions on the peripheral surface at both ends of the developing roller (25) to prevent the toner from adhering on the peripheral surface at the ends of the developing roller and prevent the toner from leaking out of the ends of the developing roller toward the photosensitive member are respectively provided at the ends of the developing roller.

5. A developing device according to claim 4, wherein each sealing member (42) comprises a member having a plurality of bristles studded on its surface opposite to the peripheral surface of the developing roller.

6. A developing device according to any of claims 3 to 5, wherein
a thin-layer blade (26) so arranged as to be in contact with the peripheral surface of the developing roller (25) for making the toner adhering on the peripheral surface of the developing roller thin and uniform, is further provided in the housing (22).

7. A developing device according to claim 6, wherein the developing roller (25) and the sub-roller (24) are rotated in

directions opposite to each other, and the toner is electrostatically adsorbed on the peripheral surface of the developing roller upon being triboelectrically changed by the rotations.

8. A developing device according to claim 7, wherein said photosensitive member is a cylindrical-shaped photosensitive drum, and

the developing roller is so rotated that its peripheral speed is higher than the peripheral speed of the photosensitive drum.

9. An image forming apparatus having a developing device according to any of claims 1 to 8, wherein

said photosensitive member is a cylindrical-shaped photosensitive drum, and
a main charger, an exposing unit, the developing device as set forth in any of claims 1 to 6, a transfer roller, and a brush are successively arranged in the direction of rotation of the photosensitive drum around the photosensitive drum.

FIG. 1

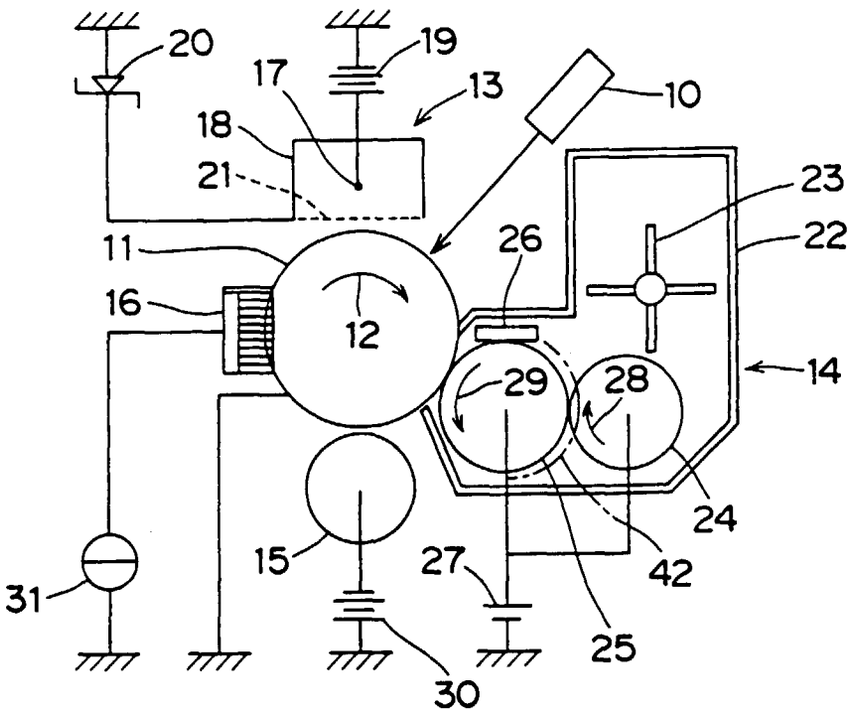

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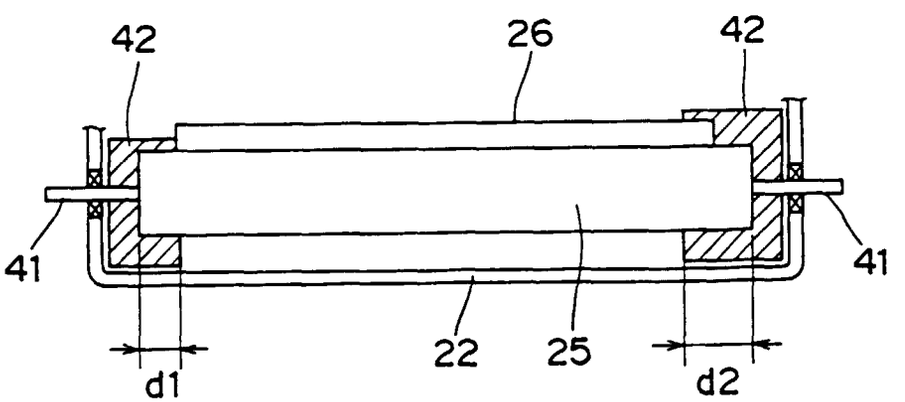
FIG. 2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