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[11] **3,905,332**

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[54] **ELECTROPHOTOGRAPHIC DEVELOPING APPARATUS USING DEVELOPING ROLLER**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **118/637**; 118/DIG. 23; 117/37 LE

[51] **Int. Cl.**[2] **G03G 15/10**

[58] **Field of Search** ..... 118/637, DIG. 23, 258, 118/419, 423; 117/37 LE

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[57] **ABSTRACT**

An electrophotographic developing apparatus which supplies a developing solution to only one surface of the copy sheet which is to be developed, by using a developing roller, around the periphery of which are provided multiple threads having an optimum lead angle for the supply of the solution.

4 Claims, 9 Drawing Figures

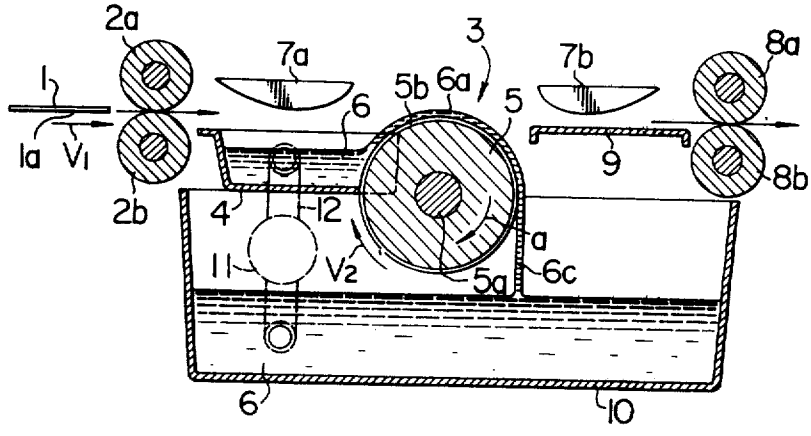


FIG. 1

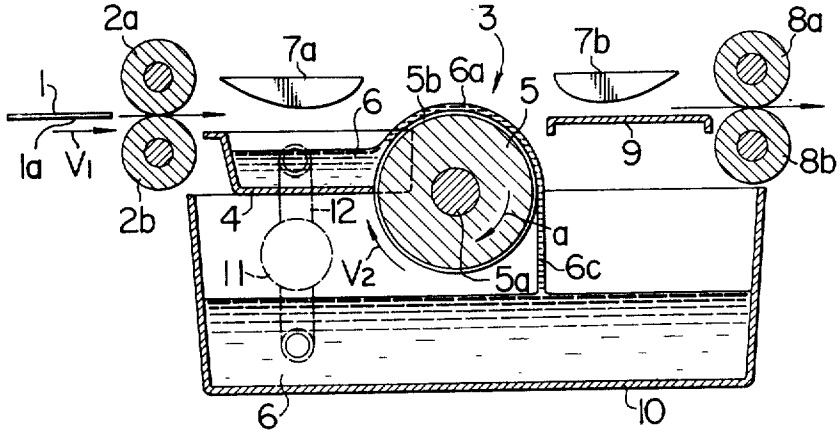


FIG. 2

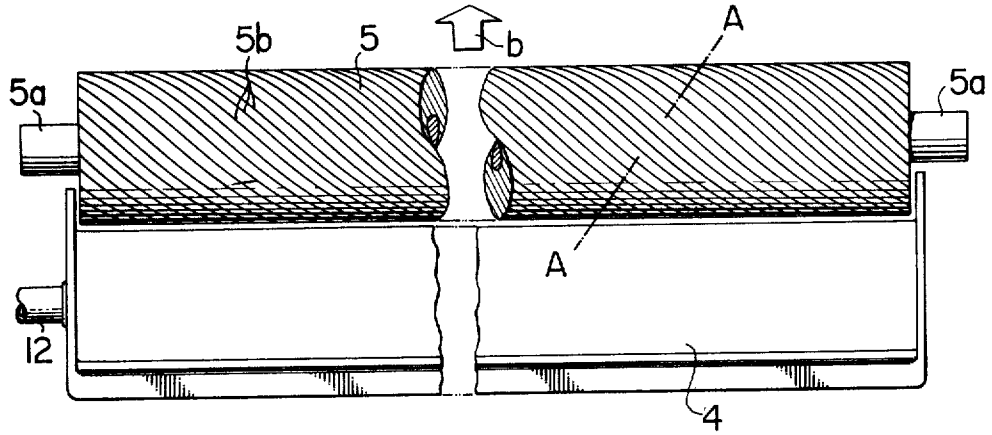


FIG. 3

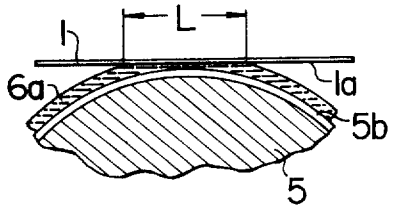


FIG. 4

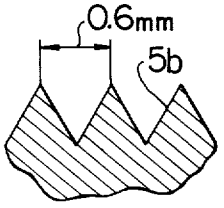


FIG. 5

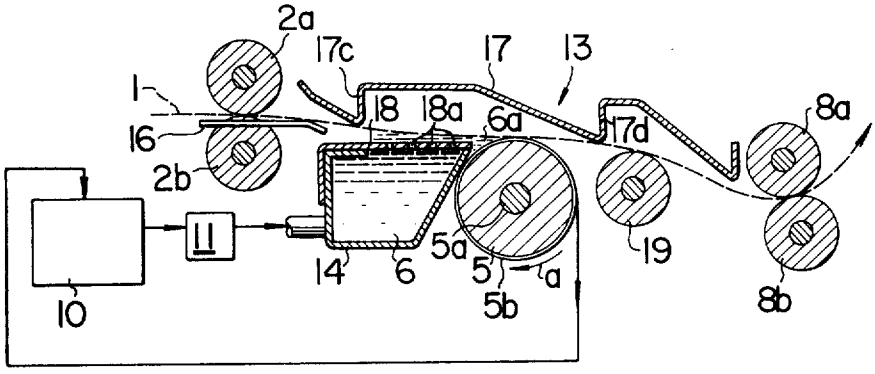


FIG. 9

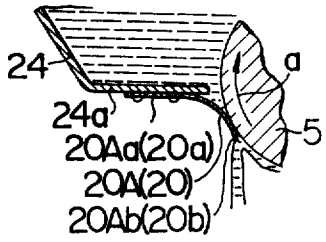


FIG. 6

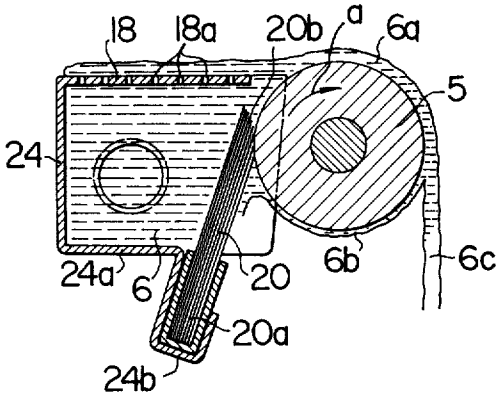


FIG. 7

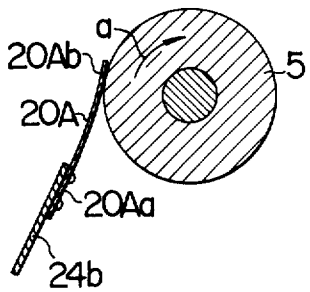
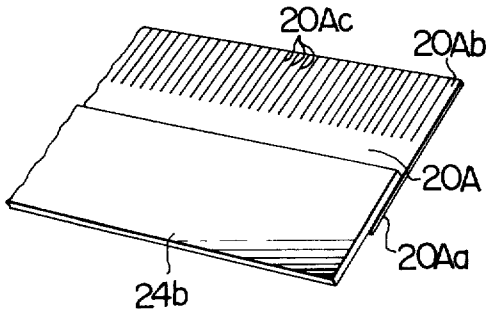


FIG. 8



ELECTROPHOTOGRAPHIC DEVELOPING APPARATUS USING DEVELOPING ROLLER

BACKGROUND OF THE INVENTION

The invention relates to electrophotographic developing apparatus, and more particularly, to a wet developing apparatus using a roller in which developing solution is supplied to only one surface of the sheet to be developed through the action of the roller.

Both wet and dry developing means are known in electrophotography, that is, electrostatic photography and electrostatic recording. In the wet developing technique, the developing solution supplied to the surface of a sheet to be developed must be well stirred, since the developing solution serves as a carrier for a toner powder mixed therein, and unless the developing solution is well stirred, there cannot be achieved a uniform supply of toner powder to the surface to be developed, which results in a disadvantageous non-uniformity of developing. For this reason, the present applicant has previously proposed an apparatus for developing only one surface in which a developing solution is pumped by means of a roller around the periphery of which is formed a layer of developing solution, the surface to be developed of the sheet fed into the apparatus being caused to bear against such layer. In this manner, a stirring action is achieved through the pumping action of the developing solution. On the other hand, it is known that the greater the speed of relative movement between the developing solution and the surface to be developed, the better the developing effect which is achieved will be improved. This can be satisfactorily accomplished by the use of a developing process incorporating a roller.

The developing roller used in the developing solution of the kind described comprises either (1) a roller without a groove, (2) a roller with a simple groove or single thread groove, or (3) a roller having a plurality of grooves running parallel or substantially parallel to the axis of rotation. As a matter of practice, however, a developing apparatus incorporating such a developing roller failed to provide a smooth supply of the developing solution which is essential to the effectiveness of the roller developing technique. Specifically, the roller without groove under (1) could not practically assure a smooth supply, while the roller under (2) resulted in a non-uniformity of developing in the direction of travel of the surface to be developed. Finally, the roller mentioned under (3), while improved over the first mentioned roller, cannot still achieve a completely smooth supply of the developing solution and is liable to induce developing non-uniformity on the surface to be developed in the direction of the axis of rotation.

SUMMARY OF THE INVENTION

The present invention provides an electrophotographic developing apparatus using a roller in which the above-mentioned disadvantages are eliminated by forming on the periphery of the developing roller multiple threads having a suitable lead angle. In accordance with the invention, there is provided a developing apparatus using a roller which eliminates the various disadvantages of the prior apparatus of this kind and capable of a smooth supply of developing solution to remove developing non-uniformity by forming on the developing roller multiple threads having a lead angle equal to or greater than

$$\alpha = \tan^{-1} \frac{b}{L(V_2/V_1 - 1)}$$

As a further development of the invention, developing solution once used can be scraped off from the periphery of the developing roller by means of a cleaning member, thereby enabling fresh developing solution to be continuously supplied to the surface to be developed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross section of a developing apparatus using a roller in accordance with one embodiment of the present invention;

FIG. **2** is a top view illustrating the relative arrangement of the developing roller and the developing solution supply tank shown in FIG. **1**;

FIG. **3** is a fragmentary enlarged view of the developing station;

FIG. **4** is a cross section, to an enlarged scale, taken along the line A—A of FIG. **2**;

FIG. **5** is a cross section of developing apparatus using a roller in accordance with another embodiment of the invention;

FIG. **6** is a schematic cross section showing a modification of the apparatus according to the invention in which a cleaning member is added to the developing roller; and

FIGS. **7**, **8** and **9** are views illustrating other examples of the cleaning member.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring to FIG. **1**, a sheet **1** to be developed having an electrostatic latent image formed thereon, as a result of exposure to radiation or by stylus recording, is fed, with its image surface located downside, by a pair of upper and lower feed rollers **2***a*, **2***b* into a developing apparatus **3**. The developing apparatus **3** comprises a developing solution supply tank **4**; a developing roller **5** located adjacent to the tank **4**, a pair of guide plates **7***a*, **7***b* constraining the sheet **1** fed into the developing apparatus **3** so as to bring its lower surface, which is the surface to be developed, into contact with a layer of developing solution **6***a* to be formed on the upper periphery of the developing roller **5**; another guide plate **9** for conveying the developed sheet toward a pair of upper and lower delivery rollers **8***a*, **8***b*; and a reservoir **10** of developing solution disposed below the supply tank **4** and the developing roller **5**.

The developing solution supply tank **4** is formed of a trough-shaped vessel and extends transversely to the direction of travel of the sheet **1**, with its top and its side wall adjacent to the developing roller being open. A developing solution **6** contained in the reservoir **10** is pumped up into the supply tank **4** by means of a pump **11** and piping **12**, both shown in phantom lines. The pumped developing solution is drawn out of the tank **4** by the rotating developing roller **5** to form a layer of developing solution **6***a* on the upper periphery thereof; the roller **5** being rotated clockwise, that is, in the direction of travel of the sheet **1** to be developed, with a peripheral speed V_2 which is from two to four times the feed rate V_1 of the sheet **1**. As shown in FIG. **3**, the surface **1***a* to be developed of the sheet **1** fed into the apparatus is brought into contact with the layer of

developing solution 6*a* thus formed for the purpose of developing by the developing solution 6.

In the arrangement shown, it will be appreciated that by denoting the effective length of the developing station by L; the distance through which a point on the sheet 1 traverses the region of effective length of the developing station by l_1; and the length of travel measured along the periphery of the developing roller 5 of a point thereon which passes through the long on the sheet 1, while the latter traverses the effective length of the developing station, by l_2, the following relationship applies:

$$l_2 = l_1 \times \frac{V_2}{V_1} = L \times \frac{V_2}{V_1} \quad (1)$$

Thus l_2 is proportional to the peripheral speed V_2 of the roller 5.

The developing roller 5 which draws the developing solution 6 from the supply tank 4 is formed of a material such as aluminium, stainless steel of the like, and is positioned partly received within the open side wall of the supply tank 4 as shown in FIGS. 1 and 2, with its shaft 5*a* being connected with a drive source, not shown, to be driven for clockwise rotation as indicated by an arrow *a* in FIG. 1.

Multiple threads 5*b* are formed in the periphery of the developing roller 5. The multiple threads 5*b* have a lead angle α which is defined as:

$$\alpha = \tan^{-1} \frac{b}{l_2 - l_1} \quad (2)$$

Substitution from equation (1) yields:

$$\alpha \geq \tan^{-1} \frac{b}{L(V_2/V_1 - 1)} \quad (3)$$

For practical purposes, a lead angle α_0 defined as:

$$\tan^{-1} \frac{b}{L(V_2/V_1 - 1)} < \tan^{-1} \alpha_0 < 2 \tan^{-1} \frac{b}{L(V_2/V_1 - 1)}$$

is found to be extremely useful.

The passage of thread grooves having a suitable lead angle α across the surface 1*a* to be developed in a chronologically concurrent manner while the sheet 1 traverses the region of the effective length of the developing station L assures a developing action which is free from developing non-uniformity on the developed surface 1*a*.

Thus, with the developing apparatus of the invention, thread grooves, having a suitable lead angle α_0, carry the developing solution to the surface to be developed in a region from its supply side across the effective area for development is maintained covered with a fresh supply of developing solution. This can be best understood when compared against the prior art in which a roller without a groove or a developing roller having grooves running parallel to the axis of rotation is used to cause the formation in the area of contact between the sheet to be developed and the film of developing solution on the roller, from a sump of used developing solution or non-uniform distribution of fresh and used developing solutions, which prevents a supply of fresh developing solution from being maintained. By contrast, in accordance with the invention, a supply of fresh developing solution 6 is maintained across the surface 1*a* to be developed of the sheet 1 for the purpose of developing.

The developed sheet is conveyed on the guide plate 9 and discharged externally of the apparatus by means of the delivery rollers 8*a*, 8*b*. At the same time, the developing solution 6 which has been drawn out of the supply tank 4 by the developing roller 5 falls downwardly with the rotation of the roller, subsequent to the formation of the layer of developing solution 6*a* on the upper periphery thereof, and is received into the reservoir 10.

In one embodiment of the developing roller 5, the roller has an outer diameter of about 25 mm and is formed with multiple thread grooves 5*b* which comprise 110 threads with a lead length of 132 mm and a pitch (width of groove) of 1.2 mm and with the angle of thread of 60°. In this embodiment, the lead angle amounts to about 60°, and when the ratio of V_2 to V_1 is chosen to be a value in a range from 2 to 4, the effective length L of the developing station becomes nearly 3 to 5 mm. In this instance, the normal circular pitch or the pitch determined in the A—A plane shown in FIG. 2, of the multiple thread grooves 5*b* has a value of 0.6 mm (FIG. 4). Experiments have shown that the optimum results are obtained with a lead angle α of from 45° to 60° with $V_2/V_1 = 2$ to 4.

Preferably, the direction in which the developing roller 5 is rotated is chosen coincident with the direction of travel of the sheet to be developed, as indicated by an arrow *b* in FIG. 2.

FIG. 5 shows another embodiment of the invention. Referring to this FIGURE, the sheet 1 to be developed is fed, with its image surface located down side, by a pair of upper and lower feed rollers 2*a*, 2*b*, and guided by a guide plate 16 into a developing apparatus 13. The developing apparatus 13 comprises a developing solution supply tank 14, a developing roller 5 located adjacent to the tank 14, and an upper guide plate 17 which constrains the sheet 1 fed into the apparatus so as to bring its lower surface or the surface to be developed into contact with the developing solution.

The developing solution supply tank 14 is in the form of a trough-shaped vessel and extends in a direction perpendicular to the direction of travel of the sheet 1, with its top being open and covered by an apertured plate 18. The apertured plate 18 is formed with a multiplicity of small apertures 18*a* having a diameter on the order of 1 mm, with a density of 10 to 30 per square centimeter. In the present example, the density is chosen as 25 per square centimeter. The supply tank 14 is supplied with a developing solution from a reservoir 10 of developing solution by means of a pump 11, and the developing solution supplied by the pump 11 fills the supply tank 14 and is caused to flood through the apertures 18*a* in the apertured plate 18 to the top thereof. Located adjacent to the supply tank 14 is a developing roller 5, similar to the one described above, which is formed with multiple threads 5*b* having a suitable lead angle α_0. The roller 5 is rotated in the direction of an arrow *a* at a higher speed, for example, 2.5 times higher than the feed rate of the sheet 1 fed into the developing apparatus 13. A delivery roller 19 is disposed beyond the roller 5 as viewed in the direction of travel of the sheet 1. The guide plate 17 is positioned

to cover the supply tank **14**, developing roller **5** and delivery roller **19**, and is formed with a depending portion **17***c* which extends downwardly toward the supply tank **14** and another depending portion **17***d* which extends downwardly toward the space between the developing roller **5** and the delivery roller **19**. These depending portions **17***c* and **17***d* serve to press down the rear surface of the sheet **1** so as to bring its surface to be developed into contact with the developing solution.

In operation, as the developing solution is supplied from the reservoir **10** to the supply tank **14** by means of the pump **11**, the developing solution **6** fills the tank **14** and is caused to flood through the apertures **18***a* to the upper side of the apertured plate **18**. This flooding developing solution is drawn by the periphery of the developing roller **5** which is rotating at a high speed to form a layer of developing solution **6***a* on the periphery thereof. The developing solution after contacting sheet **1** falls down the periphery of the roller **5** and is collected in the reservoir **10**. Thus the developing solution **6** is subjected to circulation along a path comprising the reservoir **10**, pump **11**, supply tank **14**, small apertures **18***a*, the periphery of the developing roller **5** and back to the reservoir **10**. The developing solution is sufficiently stirred when it is supplied into the supply tank **14** by the pump **11**. When the sheet **1** is fed, with its image surface disposed downwardly, into the developing apparatus **13**, the upper surface of the leading edge of the sheet is initially constrained by the depending portion **17***c* to thereby bring the surface to be developed of the sheet **1** into contact with the developing solution which has flooded through the small apertures **18***a*, the leading edge is then fed toward the developing roller **5**. Subsequently, the surface to be developed moves into contact with the layer of developing solution **6***a* formed on the periphery of the developing roller **5**, and after passing thereover is fed toward the delivery roller **19**. During this process, the developing solution is supplied to only one surface of the sheet, that is, the surface to be developed. As the sheet **1** approaches the delivery roller **19**, the depending portion **17***d* of guide plate **17** prevents it from lifting up, so that the sheet **1** assumes a suitable configuration in which it is pressed down by the depending portions **17***c* and **17***d* during the time of travel through the apparatus with its surface to be developed maintained in contact with the layer of developing solution **6***a* formed on top of the developing roller as well as with the body of the developing solution which has flooded through the apertured plate **18**. After passing over the delivery roller **19**, the developed sheet is discharged externally of the apparatus by a pair of upper and lower discharge rollers **8***a*, **8***b*.

With the above arrangement of the developing apparatus, the developing roller **5** is forced to rotate with a peripheral speed which is several times the feed rate of the sheet **1**, while the developing solution moves at substantially the same speed as the feed rate of the sheet **1**. The arrangement is such that the developing solution once supplied to the surface **1***a* to be developed of the sheet **1** falls off the developing roller **5** as it rotates and is collected by the reservoir **10**. However, because of the high speed with which the developing roller **5** rotates, a portion **6***b* (see FIGS. **1** and **6**) of the used developing solution **6***c* which should normally drop into the reservoir **10** tends to continue rotating with the developing roller without being released from the periphery thereof, thus undergoing a circulation around the periphery of the roller **5**. Such circulation results in a reduced toner concentration in the developing solution supplied to the surface **1***a* to be developed, since it has once been used in the developing process before being brought into contact with the surface to be developed. While such circulation is undesirable, it is similarly undesirable when the developing solution mixed with a toner powder is in a still condition since a sufficient developing effect cannot be achieved for the later half of the sheet because the amount of toner in the developing solution placed in contact with the latent image becomes insufficient for the later half.

Such disadvantageous reductions in the toner concentration are avoided by the use of a cleaning member in the apparatus of the invention as shown in FIG. **6**. Referring to this Figure, the developing apparatus shown comprises a developing solution supply tank **24** which is covered at its top by an apertured plate **18** and has an open side adjacent to the developing roller **5**, the roller **5** being partly received in the tank **24**. That portion **6***b* of the used developing solution which remains attached to the periphery of the roller **5** is scraped off by a cleaning member **20** which is located within the supply tank **24**. The cleaning member **20** comprises a brush and its base **20***a* is retained within a support **24***b* which is formed such as by folding the bottom plate **24***a* of the tank **24** into a U-shaped cross section. The free end of the cleaning member **20** extends into the developing solution **6** within the supply tank **24**, and its forward end abuts against the periphery of the developing roller **5** in the interior of the supply tank **24**. The portion **6***b* of the used developing solution which goes around the periphery of the developing roller **5** can be scraped off by the forward end **20***b* of the brush or cleaning member **20** before it reaches the layer of developing solution **6***a* formed on top of the developing roller **5**, whereby the roller periphery is cleaned. As a consequence, the layer **6***a* on the roller periphery is formed by a supply of fresh developing solution which passes over the forward end **20***b* of the brush and through the apertured plate **18**.

FIG. **7** shows another embodiment of the cleaning member **20** which comprises a film **20A** of polyester such as Mylar (registered trademark) or the like. The base **20A***a* is mounted on a suitable support member **24***b*, and the forward end **20A***b* is held in abutment against the periphery of the developing roller **5**. It is desirable that the forward end **20A***b* of the cleaning member **20***a* be formed with a number of cuts **20A***c* just in the manner of a brush, as shown in FIG. **8**, in order to ensure its abutment against the periphery of the developing roller which is provided with thread grooves **5***b* for the purpose of drawing the developing solution.

While in the above examples, the cleaning member **20**, **20A** is disposed within the supply tank **24**, it may be located immediately beyond the point at which the developing solution falls off the roller periphery, as viewed in the direction of rotation of the roller.

Alternatively, the forward end **20A***b* (**20***b*) of the cleaning member **20A** (**20**) may be held abutting against the developing roller **5** in a direction opposite to the direction of rotation thereof, as shown in FIG. **9**. Specifically, the base **20A***a* (**20***a*) of the cleaning member **20A** (**20**) is mounted on the outside of the bottom plate **24***a* of the supply tank **24**, and its forward end **20A***b* (**20***b*) may be held in abutment against the pe-

riphery of the developing roller 5 in a direction opposite to the direction of rotation of the roller. In this manner, the used developing solution can be scraped off by the cleaning member, thereby enabling a supply of fresh developing solution to be maintained against the surface to be developed.

What is claimed is:

1. A developing apparatus for use at the developing station in wet-type electrophotographic copying machines comprising:

a. a tank for holding and supplying a developing solution; and

b. a developing roller means, disposed at the developing station and adjacent said tank with the peripheral surface thereof forming at least a part of a wall of said tank, for receiving developing solution from said tank on its peripheral surface and transferring it to the surface of a sheet fed thereby, said roller means rotating at a peripheral speed greater than the speed at which a sheet to be developed is fed thereby, and said peripheral surface of said roller means being formed with a series of threads having a lead angle α in accordance with the relationship:

$$\alpha \geq \tan^{-1} \frac{b}{L(V_2/V_1-1)}$$

where L is the effective length of the developing station, b is the thread pitch, V_1 is the speed at which a sheet to be developed is fed by said roller means, and V_2 is the peripheral speed of said roller means.

2. Apparatus as in claim 1 wherein said lead angle α is less than $2 \tan^{-1} \frac{b}{L(V_2/V_1-1)}$

3. Apparatus as in claim 1 wherein said lead angle α is in the range from 45° to 60° and V_2/V_1 is in the range from 2 to 4.

4. Apparatus as in claim 1 further comprising a cleaning member abutting against the peripheral surface of said developing roller means at a point in the rotation of said developing roller means subsequent to its passing through said developing station.

* * * * *