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(54) **Ultrasonic cleaning assist to reduce friction between the cleaner and photoreceptor using normal force vibration**

(57) An apparatus for cleaning particles from a surface (11) in a printing machine that includes a blade (100) and a vibrational apparatus (150). The blade (100) has a fixed end and a free end opposed to one another. The free end contacts a side of the surface forming a cleaning edge to remove particles from the surface. The vibrational apparatus (150) is positioned opposite the blade (100) with the surface located between the blade and the vibrational apparatus. The vibrational apparatus reduces friction and lowers the level of blade force required between the blade and the surface to prevent tucking of the blade.

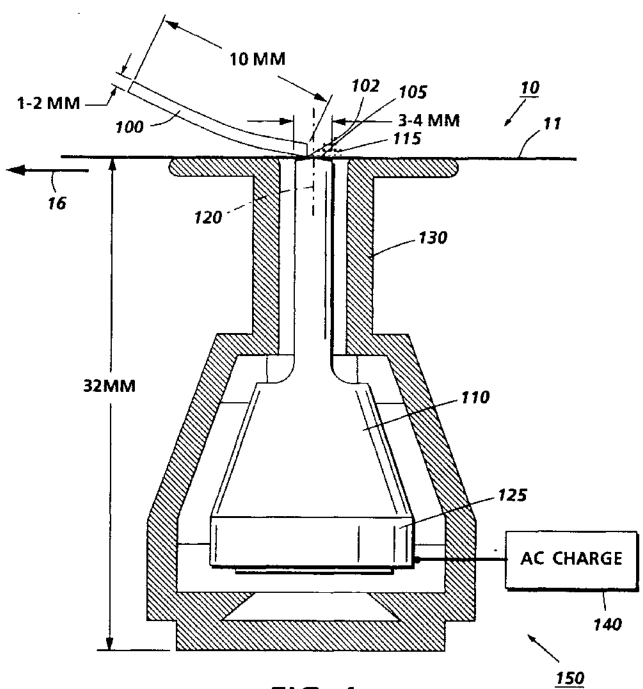


FIG. 1

EP 0 740 225 A2

Description

This invention relates generally to a cleaning apparatus, and more particularly concerns an ultrasonic cleaning assist (UCA) method causing vibration in a normal direction to the photoreceptor to clean the imaging surface.

Blade cleaning involves a blade, normally made of a rubberlike material (e.g. polyurethane) which is dragged or wiped across the surface to remove the residual particles from the surface. Blade cleaning is a highly desirable method, compared to other methods, for removing residual particles due to its simple, inexpensive structure. However, there are certain deficiencies in blade cleaning, which are primarily a result of the frictional sealing contact that must occur between the blade and the surface.

Dynamic friction is the force that resists relative motion between two bodies that come into contact with each other while having separate motion. This friction between the blade edge and the surface causes wearing away of the blade edge, and damages the blade's contact with the surface. Various blade lubricating materials or toner lubricant additives have been proposed to reduce friction which would thereby reduce wear. However, lubricants tend to change the operational characteristics of the printing machine undesirably. For example, a polyurethane blade with a good lubricant in the toner can ideally achieve a frictional coefficient of about 0.5, however, this rarely occurs because of the delicate balance involved in achieving the proper weight percent of lubricant in the toner. (Normal frictional coefficient values for cleaning blades that remove toner off the imaging surface range from a low of about 0.5 to a high of about 1.5). Without lubrication, the coefficient of friction for urethane cleaning blades is greater than 10, and causes a rapid devastating failure of the blade.

Many of the blade cleaners presently used have the disadvantage of high friction between the blade and the photoreceptor surface. This causes the blade to intermittently stick, particularly at start-up, to the photoreceptor surface creating a type of bouncing or skipping action of the blade as it rides on the photoreceptor. This bouncing or skipping action can cause copy quality defects and blade failures by over stressing the cleaning edge. Furthermore, blades that exhibit high friction can foldover when placed in pressure contact with the photoreceptor. When failure due to blade foldover, blade skipping, or blade bouncing occurs, the blade must be replaced.

US-A-4,111,546 to Maret discloses an electrostatographic reproducing apparatus and process including a system for ultrasonically cleaning residual material from the imaging surface. Ultrasonic vibratory energy is applied to the air space adjacent the imaging surface to excite the air molecules for dislodging the residual material from the imaging surface. Preferably pneumatic cleaning is employed simultaneously with the ultrasonic cleaning. Alternatively a conventional mechanical cleaning system is augmented by localized vibration of the imaging surface at the cleaning station which are provided from behind the imaging surface.

US-A-4,007,982 to Stange discloses a cleaning apparatus, electrostatographic machine and process are provided wherein particulate material is removed from the surface of an electrostatographic imaging member by at least one blade member having an edge engaging the surface. The blade edge is vibrated at a frequency sufficiently high to substantially reduce the frictional resistance between the blade edge and the imaging surface.

The present invention provides an apparatus for cleaning particles from a surface, comprising: a blade, having a fixed end and a free end opposed to one another, said free end, having a level of force thereon, contacting a side of the surface to form a cleaning edge to remove particles from the surface thereat; and vibrational means positioned opposed from said free end of said blade with the surface being interposed between said free end and said vibrational means, said vibrational means, in use, reducing friction and lowering the level of force on said free end to prevent tucking of said free end in contact with the surface.

The present invention provides several advantages. One important advantage is the extension of blade life due to reduced friction from the UCA when used in conjunction with a cleaner blade. The UCA eliminates severe blade tucks that are known to be a major cause of failure for cleaning blades. The elimination of blade tucking is especially important when the blade has to clean low percentage area coverage images from the imaging surface. Without the UCA, the blade is forced to ride on the photoreceptor surface where there is no toner lubrication. In these regions, the blade can severely tuck. Other advantages of the present invention include: ease of removal of spots that tenaciously adhere to the photoreceptor (i.e. these spots cannot normally be removed with a spots blade, however, they can be easily detached from the imaging surface with UCA); the UCA enables use of materials such as steel and thermoplastic blades for cleaning or removal of spots (i.e. caused by toner, additives or debris) without damaging the photoreceptor surface; and the use of a UCA is a cost efficient high volume cleaner. It is noted that the UCA improves blade reliability. Urethane cleaning blades in copiers have a Weibull slope of one. A Weibull slope of one corresponds to a random failure mode. Therefore, it is very desirable to increase the slope and make the blade failure more predictable. The expected Weibull slope value for a blade UCA device is three.

In recapitulation, the present invention describes positioning the ultrasonic transducer directly opposite the cleaning blade edge of a blade cleaner. The transducer creates a localized vibration area that reduces the intimate contact between the blade and the imaging surface to reduce frictional contact therebetween and thus reduce blade tuck. The localized vibration reduces the adhesion between the toner particles and the imaging surface for easier removal of the residual particles from the surface. The localized vibration area is defined as a region within 1 mm of the centerline of the transducer horn. The UCA reduces the coefficient of friction and the blade load required between the blade and photoreceptor. Therefore, the blade drag (F_f) is significantly reduced because both μ and N_L are also reduced. The reduction in friction and blade load extends blade life by eliminating blade tuck. This reduction improves blade reliability and the Weibull slope increases from one to three. The belt drag is also reduced which is important for copiers with limited belt drive capacity. It is also noted that the use of UCA applies to cleaning blades as well as spots blades.

Other features of the present invention will become apparent as the following description proceeds and upon reference to the drawings, in which:

Figure 1 is a schematic elevational view of the cleaner blade location relative to the ultrasonic cleaning assist device;

Figure 2 is an enlarged view of the blade location relative to the transducer tip shown in Figure 1; and

Figure 3 is a schematic illustration of a printing apparatus incorporating the inventive features of the present invention.

An electrostatographic machine, from which the present invention finds advantageous use, is illustrated in Fig.3; for conciseness, a detailed description thereof has been omitted from the present disclosure. For further information, reference is made to U.S. Application S.N. 08/352,839, a copy of which was filed with the present application.

Residual toner and debris remaining on photoreceptor belt 10 after each copy is made, may be removed at cleaning station F with a brush, blade or other type of cleaning system 70. A UCA (i.e. Ultrasonic Cleaning Assist) device 150 makes vibrational contact with the under side of the photoreceptive belt 10.

Reference is now made to Figure 1, which shows a schematic elevational view of the cleaner blade location relative to the UCA (e.g. ultrasonic transducer). The UCA 150 shown in Figure 1 comprises a horn (or waveguide) 110, a piezoelectric ceramic strip or section 125 attached to the transducer horn 110, and a vacuum plenum 130. (The overall height of the UCA device 150 shown in Figure 1 is about 32 mm (i.e. approximately 1.25 inches)). The tip 105 of the horn 110 contacts a narrow surface area on the under side of the photoreceptor belt 10, opposite the side containing the imaging surface 11. The vacuum plenum 130 houses the transducer horn 110 and piezoelectric ceramic 125. The vacuum plenum supports a negative pressure that provides sufficient suction to hold the photoreceptor 10 in contact with the vacuum plenum 130 and the transducer horn tip 105. (It should be noted that the vacuum plenum 130 is optional in the present invention.) The normal force of the blade 100 in contact with the imaging surface 11 side of the photoreceptor 10, in concert with an opposing force of the transducer horn tip 105 in contact with the opposite side of the photoreceptor 10, holds the photoreceptor belt 10 in place without the use of the suction force created by the vacuum plenum 130. The transducer is placed in adjacent contact with the underside of the photoreceptor 10 and acts as a back support.

An important element of the effectiveness of the present invention to reduce friction between the blade and the surface, is the location of the UCA device 150 in relation to the cleaning blade 100. (The length of the cleaning blade 100 is about 10 mm with a thickness of about 1 mm to about 3 mm for urethane materials or a thickness of about 0.05 mm to about 1 mm for thermoplastic or steel materials.) The cleaning blade 100 of the present invention is positioned, in contact with the photoreceptor 10, directly opposed to the narrow surface of the transducer horn tip 105 in an area where localized vibration occurs. The UCA significantly improves blade cleaning. The drag on the blade when it is cleaning is given by:

$$F_f = \mu N_L$$

Where F_f is the drag on the blade 100, μ is the coefficient of friction between the blade 100 and the photoreceptor belt 10, and N_L is the blade load. There are two distinct advantages in using the UCA to improve blade cleaning.

First, (see Table 1 below) the friction between a clean belt and blade is reduced with the UCA. This reduction in friction is a result of the creation of an "air" bearing effect. The blade becomes levitated reducing the coefficient of friction, which consequently eliminates the tucking of the blade. (i.e., The μ in the equation $F_f = \mu N_L$ is reduced.)

Secondly, the blade load is reduced because the UCA ultrasonically dislodges the toner, therefore reducing the blade force (N_L) required to clean (compare Tables 2 and 3 shown below). The UCA dislodges most of the toner reducing the amount of toner to be dislodged by the blade. Hence, reducing the normal force (N_L) required for effective cleaning. When the UCA is not used, the blade 100 is required to remove all of the residual toner from the photoreceptor 10 and thus a higher blade force is required.

Three tables follow which illustrate the experimental results regarding a UCA with blade cleaning.

Table 1

Belt Conditions	**Cleaner Configuration**	**Average PR Drag, gm** (average of four values)	**Blade Load & Coefficient of Friction**		Comment
			Load gm	■	
Clean (no Toner)	Blade	>10,465	1000	>10	Severe blade tuck and blade foldover
Clean (no Toner)	UCA and Blade	1176	1000	**1.18**	Dramatic drop in drag and coefficient of friction μ, and no blade foldever.
With Toner	Blade	1555	1000	1.56	Typical drag for typical blade force with toner
With Toner	UCA and Blade	424	1000	**0.42**	Dramatic drop in drag and μ

Table 1 shows the drag measurements which yield a value for the coefficient of friction between the blade and the belt under different test conditions. A drop occurs in the belt drag and the coefficient of friction with the use of UCA device. (The coefficient of friction is the drag value divided by the blade load. The blade used in these tests was 30 cm long, thus the total load divided by 30 cm yields the blade force in gm/cm.)

Table 2

Blade Cleaning **without** UCA			
Blade load gm		**Cleaning Efficiency**	Comment
Total	gm/cm		
1400	46.6	good	more than enough force
1200	40	good	enough force
1000	**33.3**	**good**	**enough force**
800	26.6	streaks	not enough
600	20	poor	not enough

Table 2 shows the cleaning results without the UCA. A 1000 grams of blade load is required for effective cleaning. This corresponds to 33.3 gm/cm.

Table 3

Blade Cleaning **with** UCA			
Blade load gm		**Cleaning Efficiency**	Comment
Total	gm/cm		
1000	33.3	good	more than enough force
800	26.7	good	enough force
600	20	good	enough force
500	**16.7**	**good**	**enough force**
400	13.3	few streaks	not enough

Table 3 (continued)

Blade Cleaning **with** UCA			
Blade load gm		**Cleaning Efficiency**	Comment
Total	gm/cm		
200	6.6	poor	not enough

Table 3 shows the cleaning results with the UCA. These results indicate that 500 grams or 16.6 gm/cm of blade force is required for effective cleaning. This is a 50% reduction in blade load to clean. Now coupled with a lower coefficient of friction this results in a significant reduction in belt drag.

With continued reference to Figure 1, the ultrasonic transducer 150 creates a vibratory action against the photoreceptor 10 in a localized area. This vibratory motion is created in Figure 1, by applying a pulsing charge 140 (e.g. AC) to the piezoelectric ceramic strip 125. This application of a pulsing charge 140 causes the piezoelectric ceramic strip 125 to alternate between expansion and contraction states. The expansion/ contraction motion of the piezoelectric ceramic strip 125 creates a vertical movement of the transducer horn 110 with an amplitude range of about 1 micron to about 2 microns. This vertical movement of the horn 110, contacting the inner (or under) side of the photoreceptor belt 10, occurs at a frequency of about 60 kilohertz to about 90 kilohertz. The vibratory motion of the transducer 150 in contact with the photoreceptor 10 causes localized vibration in the area where the transducer is located. This localized vibration reduces the intimate contact between the blade cleaning edge 102 (i.e. the line contact formed between the blade and the surface upon contact) and the photoreceptor surface 11 to sufficiently reduce the frictional contact and the level of required blade force needed between the blade 100 and the imaging surface 1 1 to eliminate blade tuck. Additionally, the localized vibration created by the ultrasonic transducer 150 temporarily reduces (or overcomes) the surface adhesion bond of the toner particles 115. (Thereby allowing vibration of the toner particles 115 to a controlled maximum amplitude for easier removal by the cleaning blade 100.) The localized vibration area of the present invention, is the region of the photoreceptor 10 where the blade cleaning edge 102 must be positioned for reduced frictional contact between the blade 100 and the imaging surface 11. However, it is noted that this reduced frictional contact, due to the localized vibration, still requires that the cleaning blade 100 maintain sufficient contact with the photoreceptor 10 surface to effectively clean toner particles 115 with reduced surface adhesion (i.e. the blade/imaging surface contact is sufficient to prevent particles from escaping past the blade during localized vibration by the ultrasonic transducer 150).

With continued reference to Figure 1, the narrow surface of the transducer horn tip 105 in contact with the photoreceptor 10 is about 3 mm to about 4 mm in width. A centerline 120, is located midway along the width of the narrow surface of the horn tip 105. The blade cleaning edge 102 can be positioned at any point within about a 1mm distance of the centerline 120 of the narrow surface of the horn tip 105 when the horn 110 has a width of about 3 mm to about 4 mm. (This ± mm tolerance relative to the center line 120 is important for manufacturing purposes.) Positioning the blade cleaning edge in this manner keeps it in the localized vibration region for reduced frictional contact between the blade 100 and the imaging surface 11.

Reference is now made to Figure 2, which shows an enlarged view of the blade 100 positioning relative to the horn 110. Lab testing of the positioning of the blade relative to the transducer horn, of the present invention, showed that the friction between the urethane cleaning blade and the photoreceptor was dramatically reduced with UCA. For example, with the UCA turned off and the absence of any lubrication on the surface, the blade was unable to move across an AMAT surface without causing the blade to squeal or chatter. However, when the UCA was turned on, the blade moved over the surface of the AMAT as if the surface was lubricated with fuser oil.

Claims

1. An apparatus for cleaning particles from a surface, comprising:

    a blade, having a fixed end and a free end opposed to one another, said free end, having a level of force thereon, contacting a side of the surface to form a cleaning edge to remove particles from the surface thereat; and
    vibrational means positioned opposed from said free end of said blade with the surface being interposed between said free end and said vibrational means, said vibrational means, in use, reducing friction and lowering the level of force on said free end to prevent tucking of said free end in contact with the surface.

2. An apparatus as recited in claim 1, wherein said vibrational means contacts a side of the surface opposed from

the first mentioned side opposed from the cleaning edge of said blade.

3. An apparatus as recited in claim 1 or 2, wherein said vibrational means comprises a narrow surface area contacting the surface for localized vibration to avoid uncontrolled separation of the particles from the surface.

4. An apparatus as recited in claim 3, wherein said narrow surface has a width of between about 3 mm and about 4 mm.

5. An apparatus as recited in claim 3 or 4, wherein the width of said narrow surface has a centerline positioned midway therealong, the cleaning edge of said blade being positioned in contact with the first mentioned side of the surface, opposite said narrow surface, within a distance of about 1 mm of the centerline in any direction along the surface.

6. An apparatus as recited in any of the preceding claims, wherein said vibratory energy enables the particles, being separated from the surface, to be momentarily airborne in an area by the localized vibration enabling ease of removal of the particles by the cleaning edge.

7. An apparatus as recited in any of the preceding claims, wherein said vibrational means comprises an ultrasonic transducer.

8. A printing machine having an apparatus for cleaning particles from a surface, according to any of the preceding claims.

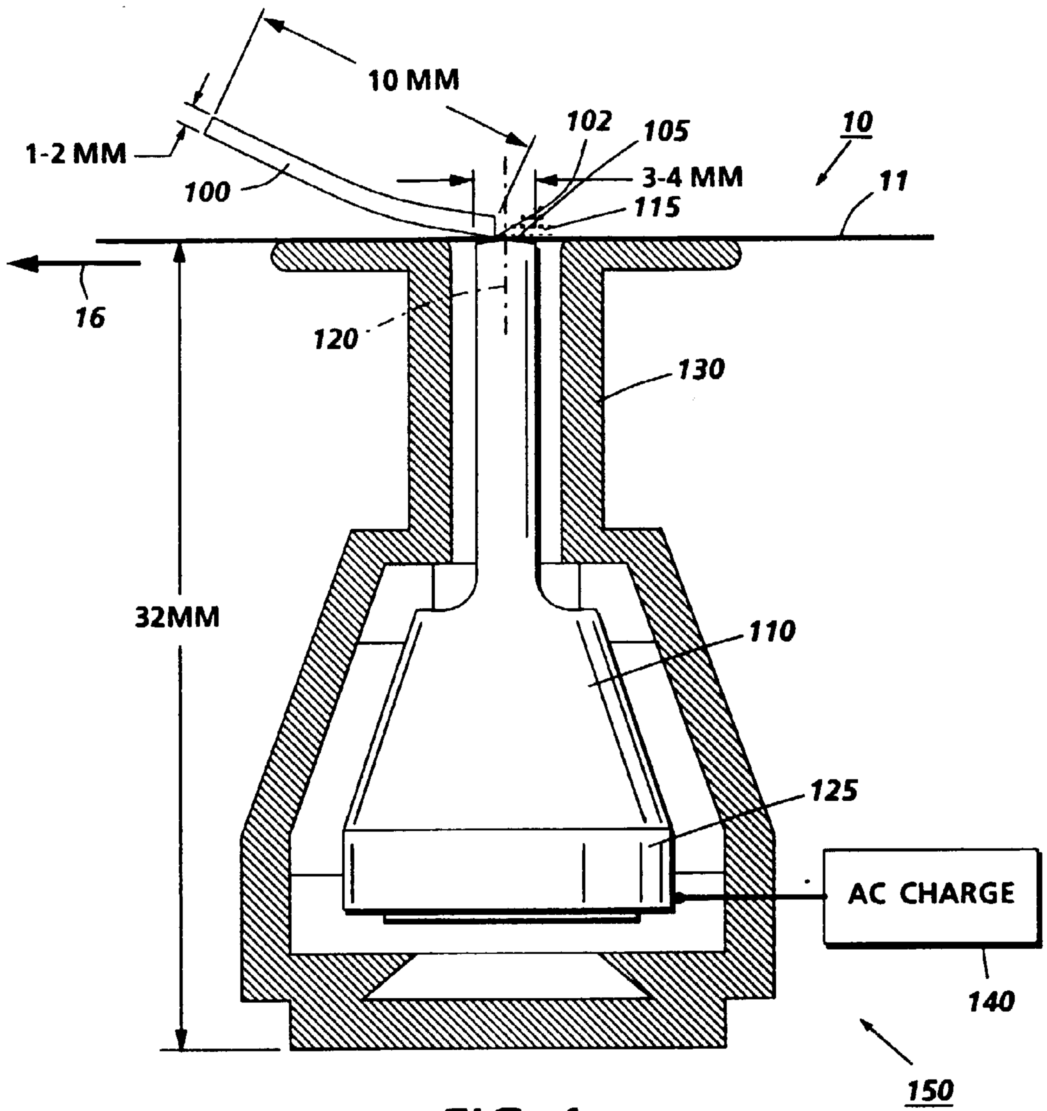
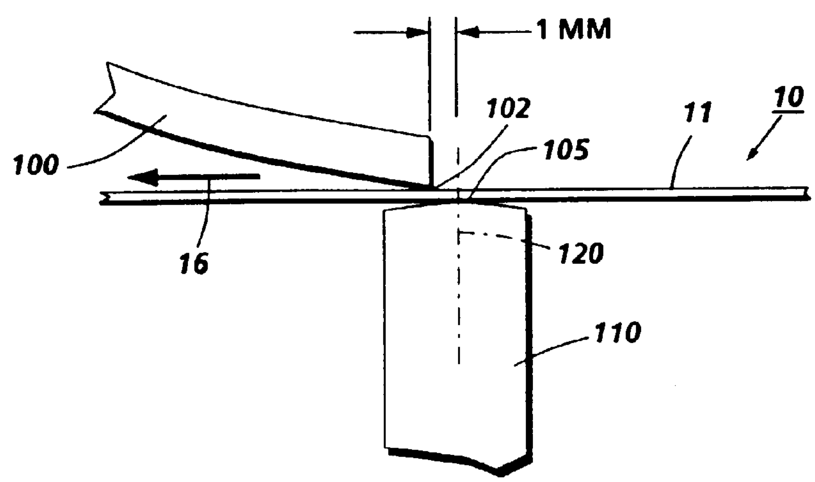

10 MM
1-2 MM
102
105
10
3-4 MM
11
100
115
16
120
130
32MM
110
125
AC CHARGE
140
150

FIG. 1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105
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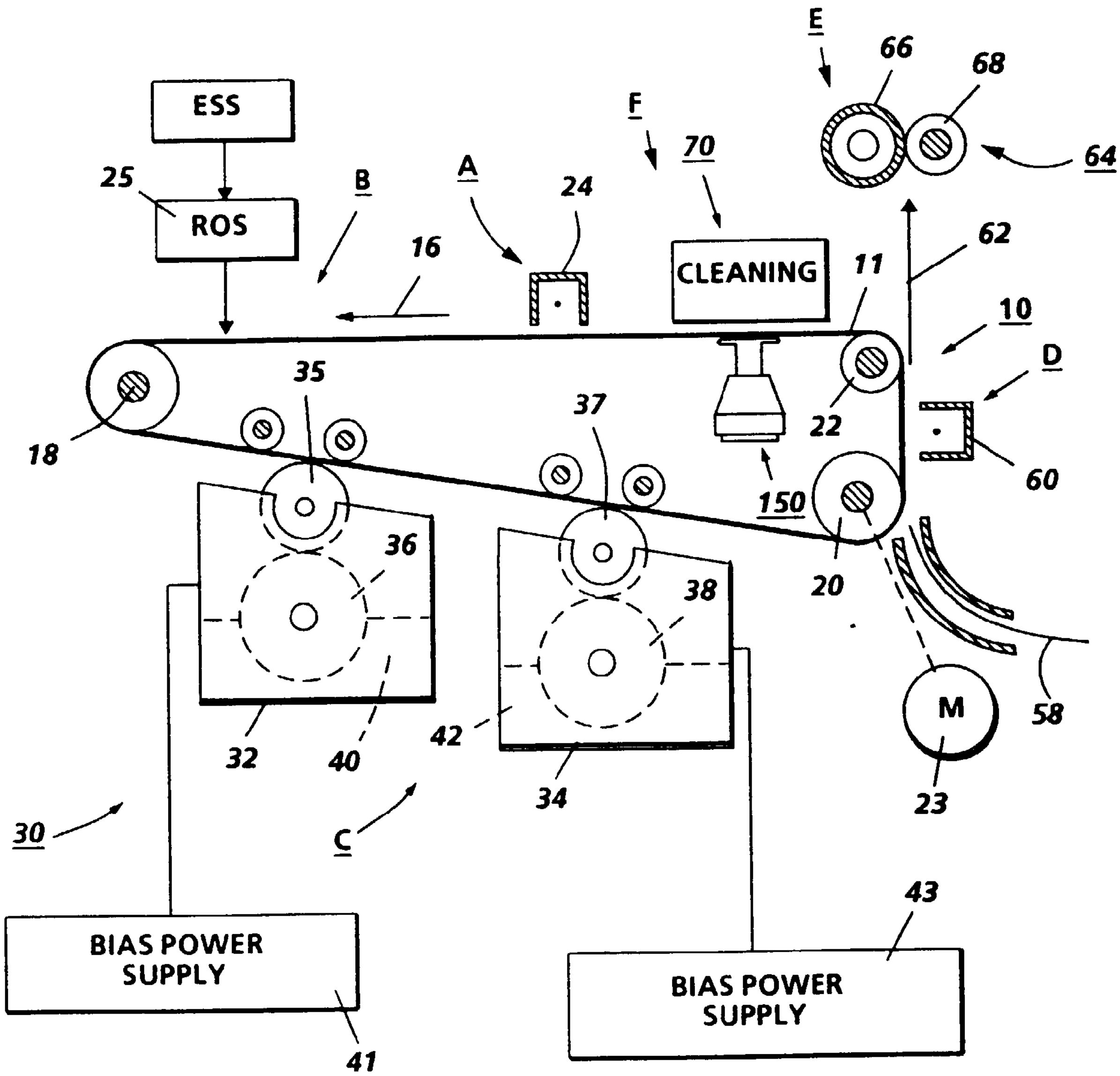
FIG. 2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150
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42
34
30
C
M
23
58
BIAS POWER SUPPLY
41
43
BIAS POWER SUPPLY

FIG. 3