

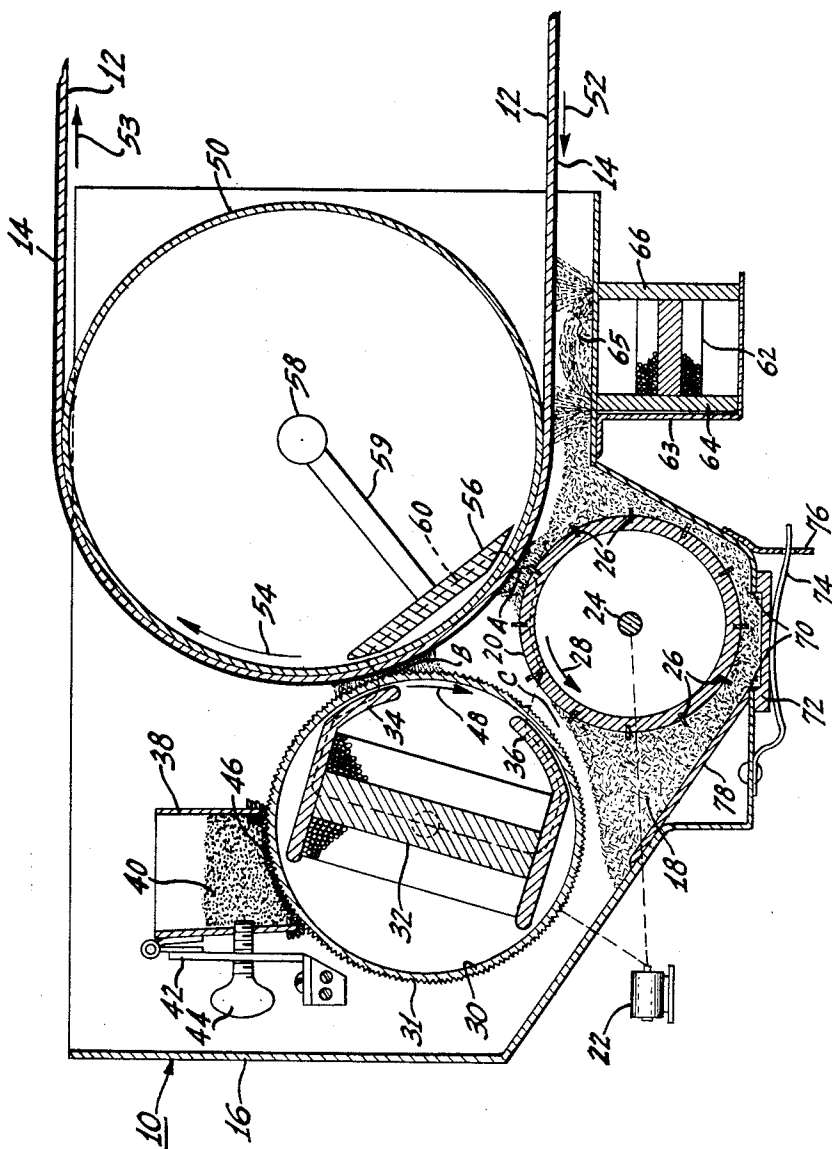
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M. M. SOWIAK

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ELECTROSTATIC DEVELOPING APPARATUS

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INVENTOR.
Milton M. Sowiak
BY *J. L. Whitaker*
ATTORNEY

1

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ELECTROSTATIC DEVELOPING APPARATUS
Milton M. Sowiak, Mercerville, N.J., assignor to Radio Corporation of America, a corporation of Delaware
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This invention relates generally to electrostatic printing, and more particularly to improved apparatus for developing an electrostatic latent image on an electrophotographic recording element by means of an electroscopic developer mixture of magnetic particles and toner particles. The improved apparatus of the present invention is particularly useful for developing images on a recording element in the form of a web moving at a relatively high speed.

It has been proposed to develop latent electrostatic images on a recording element in the form of a web by drawing the web through an electroscopic developer mixture of magnetic particles and toner particles. At relatively slow speeds of travel, this method of development is quite satisfactory. At relatively higher speed, however, the actual developing time is decreased and there is a relatively greater tendency for the magnetic particles of the developer mixture to adhere to the recording element. This is especially true when the ambient humidity is low. To provide satisfactory development of latent electrostatic images on a recording element moving at a relatively high speed, therefore, means must be provided to remove unwanted magnetic particles from the recording element.

Accordingly, it is an object of the present invention to provide improved apparatus for developing latent electrostatic images on a recording element moving at a relatively high speed.

Another object of the present invention is to provide improved apparatus for removing magnetic particles of an electroscopic developer mixture from a recording element in an electrostatic printing system wherein the recording element is moved at a relatively high speed.

A further object of the present invention is to provide improved apparatus of the type described that is relatively simple in structure, easy to operate, and highly efficient in use.

In accordance with the present invention, the improved developing apparatus comprises three drums, each one being slightly spaced from the other two and each one having its axis disposed parallel to the axes of the other two. The three drums are disposed within a trough-like container for an electroscopic developer mixture of magnetic particles and toner particles. One of the drums, a mixing drum, is made of magnetic material and is connected to means to cause it to rotate in the developer mixture to stir the latter. Another of the drums, a toner-feed drum, is made of non-magnetic material. A magnet is fixedly disposed within the toner-feed drum, and means are provided to cause the drum to rotate about its axis, the magnet remaining stationary. The third drum, an element-guiding drum, may comprise only a portion of a drum, and serves to guide the recording element along the path for proper development. A pole piece is fixedly disposed within the element-guiding drum in a manner to form a magnetic circuit with the aforementioned magnet and the mixing drum. The gaps between the drums are paths in the magnetic circuit. Magnetic particles and toner particles adhering to the magnetic particles tend to be concentrated in the gaps between the drums. The recording element, in contact with the element-guiding drum, is moved through the gaps so that the toner particles develop the latent electrostatic image previously established thereon. With this arrangement, the latent electrostatic image is developed in two gaps wherein

2

strong magnetic fields cause the magnetic particles to act as stiff brushes, thereby reducing the possibility of magnetic particles adhering to the recording element.

Other novel features of the present invention, as well as additional objects and advantages thereof, will be described in greater detail with reference to the accompanying drawing, the single figure of which is partly schematic, cross-sectional side elevational view of the developing apparatus of the present invention.

Referring now to the drawing, there is shown developing apparatus 10 for developing a latent electrostatic image on a recording element 12. The recording element 12 may comprise a web of relatively conductive material, such as paper having a predetermined moisture content, and coated with an insulating layer 14, on which the latent electrostatic image may be formed by any suitable means known in the art. An example of a suitable recording element 12 is described in RCA Review, December 1954, Volume XV, No. 4.

The developing apparatus 10 comprises a trough-like non-magnetic container 16 for holding a quantity of an electroscopic developer mixture 18 of magnetic particles and toner particles. The developer mixture 18 exhibits a tribo-electric effect in that the magnetic particles and the toner particles acquire electric charges of opposite polarity when they are separated from each other after having been stirred together. It is the charged toner powder of the developer mixture that develops the latent electrostatic image as will hereinafter be explained.

Means are provided to stir the developer mixture 18 to provide a relatively uniform mixture of magnetic particles and toner particles and also to enhance the tribo-electric effect. To this end, a mixing drum 20 is mounted for rotation about its axis, counterclockwise as viewed in the drawing as within the container 16. The mixing drum 20 is disposed within the developer mixture 18, and a motor 22 is coupled to the shaft 24 of the drum 20 to rotate the latter. The mixing drum 20 is made of magnetic material and a plurality of non-magnetic blades 26 are fixed to the drum 20 to increase the efficiency of the drum's stirring action.

A toner-feed drum 30 is also disposed within the container 16. The toner-feed drum 30 is made of non-magnetic material and has an outer knurled surface 31. The toner-feed drum 30 is slightly spaced from the mixing drum 20 and has its axis substantially parallel to the axis of the mixing drum 20. The toner-feed drum 30 is coupled to the motor 22 for rotation about its axis, by any suitable means (not shown).

A magnet 32, such as an electromagnet, is fixedly disposed within the toner-feed drum 30 so that it remains stationary when the toner-feed drum 30 revolves. The magnet 32 has two pole pieces, an upper pole piece 34 and a lower pole piece 36, and the axis between them is transverse to the axis of rotation of the toner-feed drum 30.

A toner-feed trough 38 is disposed over the toner-feed drum 30 for supplying toner particles 40 to the developer mixture 18 to replace the toner particles that are removed from the developer mixture 18 during the developing process. The trough 38 is hinged to a bracket 42. A wing screw 44, threaded in the bracket 42 and captivated in a wall of the trough 38, provides means to adjust the trough 38 with respect to the toner-feed drum 30. A cloth material, such as plush 46, is disposed between the lower edges of the trough 38 and the knurled surface of the toner-feed drum 30. Thus, toner particles 40 caught in the grooves of the knurled surface of the toner-feed drum 30 are conveyed to the developer mixture 18 as the toner-feed drum 30 is rotated.

The toner-feed drum 30 is caused to rotate clockwise in the direction indicated by the arrow 48, that is, in a direction opposite to the direction of rotation of the mix-

ing drum 20. The speeds of rotation of the drums 20 and 30 may be adjusted by any suitable means (not shown) and may be different from each other, as will be hereinafter explained.

The recording element 12 is guided adjacent to the surfaces of the mixing drum 20 and the toner-feed drum 30 by means of an element-guiding drum 50 of non-magnetic material. The element-guiding drum 50 is mounted for free rotation around its axis, the latter being substantially parallel to the axes of the drums 20 and 30. Thus, a continuous web of the recording element 12 can be moved in the directions indicated by the arrows 52 and 53 by pulling the recording element 12 to the left as viewed in the drawing, so that the friction between the drum 50 and the recording element 12 causes the drum to rotate clockwise as indicated by the arrow 54. A magnetic pole piece 56 is fixedly disposed within the element-guiding drum 50. One end of the pole piece 56 is adjacent to the pole piece 34 of the magnet 32, and the other end is adjacent to the mixing drum 20. The pole piece 56 is fixed to a fixed shaft 58 by means of a bar 59.

The drums 20, 30, and 50 are slightly spaced from each other. A gap A between the drums 20 and 50 is larger than a gap B between the drum 30 and the drum 50, but is smaller than a gap C between the drum 30 and the drum 20. A magnetic circuit, indicated by the dashed closed path 60, is formed by the upper pole piece 34 of the magnet 32, the pole piece 56, a portion of the mixing drum 20, and the lower pole piece 36 of the magnet 32. The gaps A, B, and C also form portions of the magnetic circuit path 60. During the developing process, as will be hereinafter explained, magnetic particles and toner particles adhering to the magnetic particles form a brush-like structure in the gaps A and B for brushing the toner particles onto the latent electrostatic image on the recording element 12 to develop the latter. The lengths of the gaps A, B, and C may be for example, $\frac{3}{16}$ in., $\frac{1}{16}$ in., and $\frac{1}{8}$ in., respectively.

A magnet 62, such as an electromagnet, is disposed underneath the container 16, by means of bracket 63, just below the point where the recording element 12 comes in contact with the element-guiding drum 50. The magnet 62 comprises pole pieces 64 and 66 to provide a magnetic path 65 between the lower wall of the container 16 and the photosensitive layer 14 of the incoming recording element 12. Developer mixture 18 is held in a brush-like manner by the magnetic field 65 so that the latent electrostatic image on the recording element 12 is wiped with the developer mixture 18 as the recording element 12 enters the container 16. The developer in the magnetic field 65 not only provides a preliminary developing action, but also serves as a seal to prevent loss of the developer mixture from the container 16.

The developer mixture 8 may be removed from the container 16 through an opening 70 in the lowermost wall of the container 16. The opening 70 is covered with a cover 72 that is retained in place by means of a spring latch 74. One end of the spring latch 74 is riveted to the lower wall of the container 16, and the other end of the spring latch 74 is releasably retained in a spring lock 76. A baffle plate 78 is disposed within the container 16 to cause the developer mixture to gravitate toward the mixing drum 20 and to prevent the developer mixture 18 from being retained in "dead" space.

The operation of the improved developing apparatus 10 will now be described: The recording element 12 is moved to the left in the direction of the arrows 52 and 53 so as to cause the element-guiding drum 50 to rotate clockwise in the direction of the arrow 54. The insulating layer 14 of the recording element 12 is the remote surface of the recording element 12 with respect to the element guiding drum 50. As the latent image on the insulating layer 14 passes the magnetic field 65, toner particles are brushed onto the layer 14 and partial development of the latent electrostatic image results. The mix-

ing drum 20 is rotated counterclockwise so that its peripheral speed is different from that of the drum 50. Thus, as the recording element 12 passes the gap A, stiff, bush-like, magnetic particles produce a wiping action on the insulating layer 14, thereby continuing the developing action. Any magnetic particles that are retained on the recording element 12 are picked up in the gap B between the drums 30 and 50 as the recording element 12 is moved. The direction of rotation of the drum 30 is such as to brush the magnetic particles back into the bottom of the container 16. Toner particles 40 from the trough 38 are also brought into the gap B so that they can mix with any magnetic particles there and thus provide further developing action of the latent electrostatic image. The developer mixture 18 is prevented from clogging the gaps A, B, and C because each of the three drums 20, 30 and 50 is rotated. Thus it will be seen that the recording element 12 encounters two stiff magnetic brushes in the air gaps A and B. Since these magnetic brushes are formed in the concentrated magnetic flux of the magnetic path 60, magnetic particles tend to remain in the magnetic path rather than move with the recording element 12.

The blades 26 on the mixing drum 20 are of non-magnetic material so that they do not distort the magnetic field and the magnetic brush formed in the gap A as the drum is rotated. A distorted magnetic field may result in non-uniform development of the recording element 12. The toner-feed drum 30 should be rotated at a speed at which a good magnetic brush is maintained in the gap B and at which an equilibrium condition is obtained wherein the quantity of magnetic particles removed from the gap B is equal to the quantity of magnetic particles brought into the gap B by the recording element 12. The gap C is slightly larger than the gap A so that it is not possible for more developing mixture 18 to enter the space between the three drums than is leaving. The developer mixture 18 emerging from the gap C eventually falls into the bottom of the container 16.

The pressure of the toner-feed trough 38 against a knurled surface of the toner-feed drum 30 is adjusted so as to provide a state of equilibrium between the amount of toner particles 40 admitted into the container 16 and the amount of toner particles removed by the development of the latent electrostatic images on the recording element 12. Since the magnetic particles of the developer mixture 18 are constantly being returned to the developer mixture, no special provision need be made to replace magnetic particles in the developer mixture 18.

It is within the contemplation of the present invention that the element-guiding drum 50 be fixed so that the recording element 12 may be pulled past the gaps A and B without the drum 50 rotating. Under the latter conditions, the element-guiding drum 50 need not even comprise a complete drum, but may comprise only that portion of the drum necessary to guide the recording element 12 past the gaps A and B. As used herein, therefore, and in the appended claims, the term "element-guiding drum" may comprise a complete drum or only that portion of a drum (which may be stationary) necessary to guide the recording element past the gaps where development takes place.

From the foregoing description, it will be apparent that there has been provided improved apparatus for developing an electrostatic latent image on a recording element. By means of the apparatus described, the recording element receives most of its development in a gap between a mixing drum and an element-guiding drum, the gap being a portion of a path in a strong magnetic circuit. Substantially any magnetic particles that adhere to the recording element after it is developed in the first gap are removed by a brush of magnetic particles in another gap of the magnetic circuit between a toner-feed drum and the element-guiding drum. The direction of rotation of the toner-feed drum is such as to brush the magnetic particles back into the developer mixture. The

mixing drum and the toner-feed drum are rotated at different speeds from the speed of rotation of the element-guiding drum to provide a wiping action on the recording element. For example, the mixing drum may be rotated at a speed of 60 revolutions per minute, the toner-feed drum may be rotated at 50 revolutions per minute, and the element-guiding drum may be rotated at 90 revolutions per minute in a typical case. Also, the developing apparatus of the present invention may be used for direct developing or reversal developing with toners of the type described in U.S. Patent 2,874,063, for Electrostatic Printing, issued February 17, 1959, and in U.S. Patent 2,986,521, for Reversal Type Electrostatic Developer Powder, issued May 30, 1961, respectively. While the apparatus has been illustrated partly in schematic form, variations in the apparatus coming within the spirit of this invention will, no doubt, readily suggest themselves to those skilled in the art. Hence, it is desired that the foregoing description shall be considered merely as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus comprising a container for a developer mixture of magnetic particles and toner particles, a first drum of magnetic material, a second drum and a third drum both of non-magnetic material, at least portions of said drums being disposed within said container, each of said drums being spaced slightly from the other of said drums and forming gaps therebetween, each of said drums having an axis substantially parallel to the axes of said other of said drums, means coupled to said first drum and to said second drum to rotate them in opposite directions, said first drum being adapted to stir said developer mixture when it is rotated, and said third drum being adapted to support a web recording element for movement through the gap between said third drum and said first drum and the gap between said second drum and said third drum and magnetic means fixedly disposed within said second drum and within said third drum and forming a magnetic circuit with a portion of said first drum, said gaps comprising portions of the path of said magnetic circuit, the elements forming said magnetic circuit cooperating to produce a magnetic brush of magnetic and toner particles in the gap between said first and second drums and in the gap between said second and third drums.

2. Apparatus comprising a container for a developer mixture of magnetic particles and toner particles, a mixing drum, a toner-feed drum, and an element-guiding drum, at least portions of said drums being disposed within said container, each of said drums being spaced slightly from the other of said drums the forming gaps therebetween and having an axis substantially parallel to the axes of said other of said drums, said element guiding drum being adapted to support a web recording element for movement through the gap between said element guiding drum and said mixing drum and the gap between said element guiding drum and said toner-feed drum, means coupled to said mixing drum and to said toner-feed drum to rotate said mixing drum and said toner-feed drum in opposite directions, said mixing drum comprising magnetic material, said toner-feed drum and said element-guiding drum comprising non-magnetic material, and magnetic means fixedly disposed within said toner-feed drum and within said element-guiding drum, said magnetic means forming a magnetic circuit with a portion of said mixing drum, the elements forming said magnetic circuit cooperating to produce a magnetic brush of magnetic and toner particles in the gap between said element guiding drum and said toner feed drum.

3. Apparatus comprising a container for a developer mixture of magnetic particles and toner particles, a mixing drum of magnetic material, a toner-feed drum and an element-guiding drum both of non-magnetic material, at least portions of said drums being disposed within said container, each of said drums being spaced slightly

from the other of said drums and forming gaps therebetween, each of said drums having an axis substantially parallel to the axes of said other of said drums, means coupled to said mixing drum and to said toner-feed drum to rotate said mixing drum and said toner-feed drum in directions opposite to each other, said element guiding drum being adapted to support a web recording element for movement through the gap between said element guiding drum and said mixing drum and the gap between said element guiding drum and said toner-feed drum, and magnetic means fixedly disposed within said toner-feed drum and within said element-guiding drum and forming a magnetic circuit with a portion of said mixing drum, the elements forming said magnetic circuit cooperating to produce a magnetic brush of magnetic and toner particles in the gap between said element guiding drum and said mixing drum and in the gap between said element guiding drum and said toner-feed drum.

4. Developing apparatus comprising a container for a developer mixture of magnetic particles and toner particles, a mixing drum, a toner-feed drum, and an element-guiding drum, at least portions of said drums being disposed within said container, each of said drums being slightly spaced from the other of said drums and forming gaps therebetween, each of said drums having an axis substantially parallel to the axis of said other of said drums, means coupled to said mixing drum and said toner-feed drum to rotate them in directions opposite to each other, said mixing drum comprising magnetic material and being adapted to stir said developer mixture when rotated, said toner-feed drum and said element-guiding drum comprising non-magnetic material, and magnetic means fixedly disposed within said toner-feed drum and within said element-guiding drum and forming a magnetic circuit with a portion of said mixing drum and with said gaps, said element-guiding drum comprising means to support a web recording element for movement through the gap between said element guiding drum and said mixing drum and the gap between said element guiding drum and said toner-feed drum, the gap between said mixing drum and said element-guiding drum being larger than the gap between said toner-feed drum and said element-guiding drum, the elements forming said magnetic circuit cooperating to produce a magnetic brush of magnetic and toner particles in the gap between said element guiding drum and said mixing drum and in the gap between said element guiding drum and said toner-feed drum.

5. Apparatus for developing a latent electrostatic image on a web recording element by means of an electroscopic developer mixture of magnetic particles and toner particles, said apparatus comprising a container for said mixture, a mixing drum of magnetic material disposed within said container, means connected to said mixing drum to rotate it about its axis whereby to stir said mixture, a second drum of non-magnetic material spaced from said mixing drum and disposed substantially parallel thereto, a magnet fixedly disposed within said second drum and having one of its poles adjacent to said mixing drum, means to rotate said second drum in an opposite direction to the direction of rotation of said mixing drum, a third drum mounted for rotation adjacent to said mixing drum and to said second drum and disposed substantially parallel thereto, and a pole piece fixed within said third drum and having one end disposed adjacent to said mixing drum and another end adjacent to the other of said poles of said magnet, said third drum being spaced from said mixing drum and from said second drum and forming gaps therebetween, said third drum comprising means to support said web recording element for movement through the gap between said third drum and said mixing drum and the gap between said third drum and said second drum, said gaps comprising a portion of the path of a magnetic circuit formed with said magnet, said pole piece, and said mixing drum, the elements forming

7

said magnetic circuit cooperating to produce a magnetic brush and magnetic and toner particles in the gap between said third drum and said mixing drum and in the gap between said third drum and said second drum.

6. In an electrostatic printing system of the type where-
in a latent electrostatic image on a web recording ele-
ment is developed with toner particles from an electro-
scopic mixture including magnetic particles, improved
developing apparatus comprising three drums each of
said drums being spaced slightly from each other and
forming gaps therebetween, each of said drums having an
axis substantially parallel to the axes of the others of
said drums, the first of said drums comprising magnetic
materials, and magnetic means fixedly disposed within
each of the second and third of said drums and forming
a magnetic circuit with a portion of said first drum, said
gaps comprising portions of said magnetic circuit, and
means to rotate said first and second drums in opposite
directions, said third drum being adapted to support said
web recording element for movement through the gap
between said first and third drums and the gap between
said second and third drums, the elements forming said
magnetic circuit cooperating to produce a magnetic brush
of said electroscopic mixture in the gap between said first
and third drums and the gap between said second and
third drums.

7. In an electrostatic printing system of the type where-
in a latent electrostatic image on a web recording ele-
ment is developed with toner particles from an electro-
scopic mixture including magnetic particles, improved
developing apparatus comprising three drums each of
said drums being spaced slightly from each other and
forming gaps therebetween, each of said drums having an
axis substantially parallel to the axes of the other of
said drums, the first of said drums comprising magnetic
material, magnetic means fixedly disposed within each of
the second and third of said drums and forming a mag-
netic circuit with a portion of said first drum, said gaps
comprising portions of said magnetic circuit, and said first
drum being adapted to be disposed in said mixture and
having non-magnetic mixing means fixed thereto, and

8

means to rotate said first and second drums in opposite
directions, the third of said drums being adapted to sup-
port said web recording element for movement through
the gap between said first and third drums and the gap
between said second and third drums, the elements form-
ing said magnetic circuit cooperating to produce a mag-
netic brush of said electroscopic mixture in the gap be-
tween said first and third drums and in the gap between
said second and third drums.

8. In combination, a container for a developer mixture
of magnetic particles and toner particles, a mixing drum
of magnetic material disposed within said container and
adapted to stir said developer mixture when rotated, a
toner-feed drum disposed substantially parallel to said
mixing drum and spaced therefrom, an element-guiding
drum disposed substantially parallel to both said mixing
drum and said toner-feed drum and spaced therefrom,
said element-guiding drum being adapted to support a
web recording element for movement through the space
between said element-guiding drum and said mixing drum
and the space between said element-guiding drum and
said toner-feed drum, magnetic means fixedly mounted
within said toner-feed drum and within said element-
guiding drum and forming a magnetic circuit with a
portion of said mixing drum, the elements forming said
magnetic circuits cooperating to produce a magnetic
brush of said developer mixture in the space between
said element-guiding drum and said mixing drum and in
the space between said element-guiding drum and said
toner-feed drum, and means for rotating said toner-feed
drum and said mixing drum in opposite directions, said
element-guiding drum being adapted to rotate freely.

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