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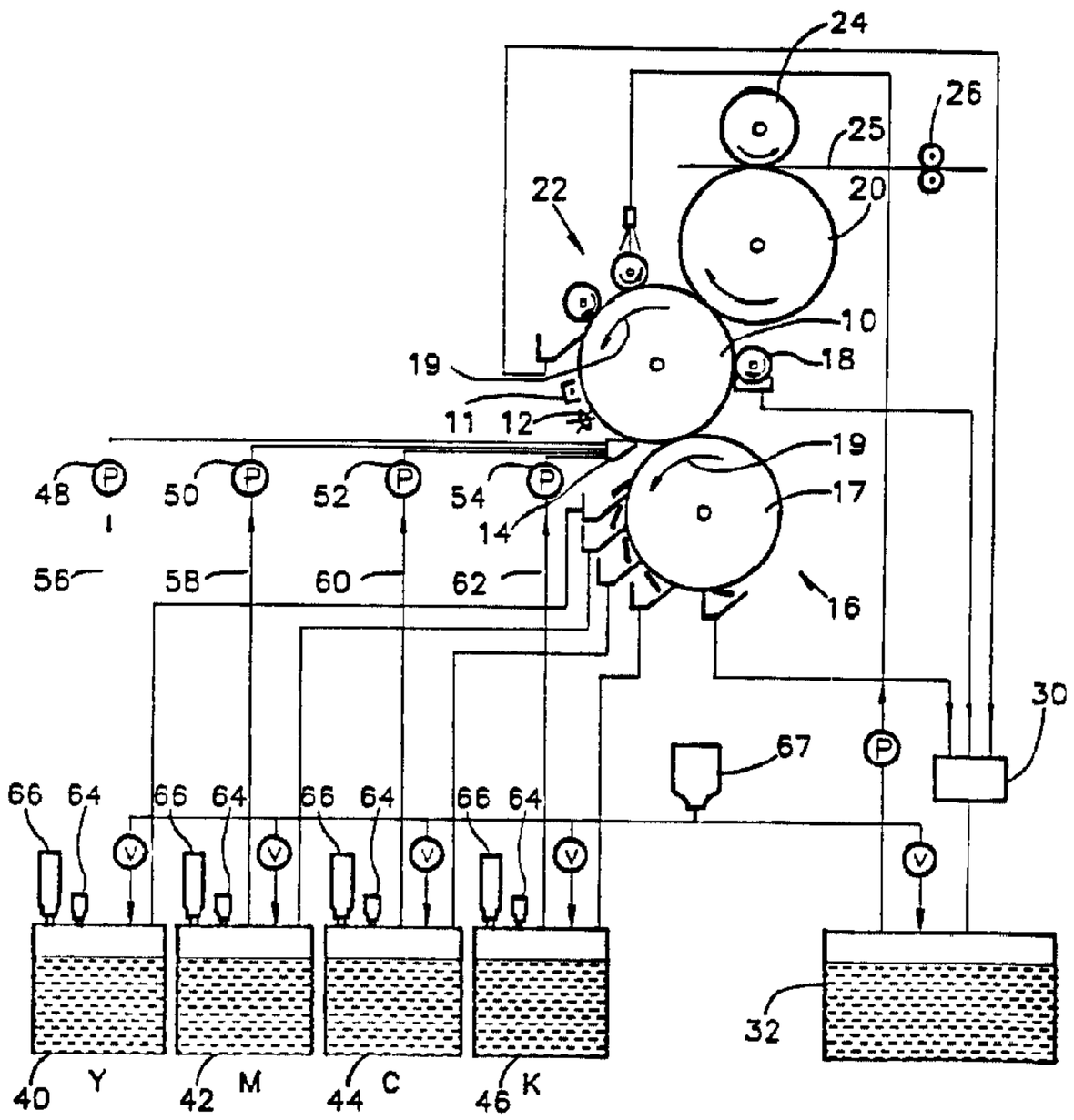

(57) Abrégé/Abstract:
A multicolor electrostatic imaging system has multicolor spray apparatus (14) for supplying a liquid toner of a selectable color to an electrostatic image. The spray means (14) has a multiplicity of spray outlets including a plurality of spray outlets distributed among the multiplicity of outlets, for supplying liquid toner of each of a plurality of colors. The apparatus utilizes a reverse development roller (17) and the spray apparatus (14) supplies the liquid developer to the region at which the reverse roller (17) leaves the development region.

(57) Abstract

A multicolor electrostatic imaging system has multicolor spray apparatus (14) for supplying a liquid toner of a selectable color to an electrostatic image. The spray means (14) has a multiplicity of spray outlets including a plurality of spray outlets distributed among the multiplicity of outlets, for supplying liquid toner of each of a plurality of colors. The apparatus utilizes a reverse development roller (17) and the spray apparatus (14) supplies the liquid developer to the region at which the reverse roller (17) leaves the development region.

COLOR IMAGING SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to multicolor imaging.

BACKGROUND OF THE INVENTION

Proposals for various types of multicolor imaging apparatus and techniques appear in the patent literature. There is described in Japanese Patent document 58002863 to Kawamura an image recording device for use in a color printer which include nozzle heads which spray liquid coloring toner onto electrostatic latent images on the side of a photosensitive drum and thus develop images thereon. A single nozzle is provided for each color and the nozzles reciprocate along a nozzle guide. Alternating current apparatus is disposed between the nozzle and the drum in order to spread out the impingement area of the toner on the drum.

U.S. Patent 4,690,539 describes transfer apparatus in which a plurality of liquid images are transferred from a photoconductive member to a copy sheet. The liquid images, which include a liquid carrier having toner particles dispersed therein, are attracted from the photoconductive member to an intermediate web. A substantial amount of the liquid carrier is removed from the intermediate web and the toner particles are secured thereon. Thereafter, anotner liquid image having toner particles of a different color from the toner particles of the first liquid image is attracted to the intermediate member. Once again the liquid carrier material is removed from the web and the toner particles of the second liquid image are secured thereon. Thereafter, all of the toner particles are transferred from the intermediate member to the copy sheet, in image configuration.

U.S. Patent 3,900,003 describes a liquid developing device for use in multicolor electrophotographic copying machines, having a plurality of feed pipes for supplying different liquid color developers to a developing station, which feed pipes are connected to a common developer supply

pipe. Valves are provided in the feed pipes wherein each of the valves are actuated by an electrical signal to supply only one selected liquid color developer to the developing station at a time. The liquid developing device is also provided with a belt for removing residual liquid developer remaining on an image bearing member after development and with a plurality of blades for scraping and collecting the thus removed liquid developer, which are selected and actuated in correspondence with a selected color.

U.S. Patent 4,504,138 describes a method and apparatus for developing electrostatic latent images formed on a photoconductor surface comprising the steps of applying a thin viscous layer of electrically charged toner particles to an applicator roller preferably by electrically assisted separation thereof from a liquid toner suspension. A restricted passage is defined between the applicator roller and the photoconductor surface approximately the thickness of the viscous layer and the toner particles are transferred from the applicator roller to the photoconductor surface due to their preferential adherence to the photoconductor surface under the dominant influence of the electric field of the electrostatic latent image carried by the photoconductive surface.

U.S. Patent 4,400,079 describes a developing system for an electrophotographic copier in which a roller having a conductive outer surface is disposed adjacent to the imaging surface to form a gap. The roller is driven at a peripheral linear velocity substantially greater than the velocity of movement of the imaging surface and is supplied with liquid developer at a location spaced from the gap to cause the roller to inject the developer into the gap. The roller is coupled to a source of electrical potential.

U.S. Patent 4,342,823 describes a perforate development electrode and a method for developing electrostatic images directly on a final image bearing sheet, formed of electrophotographic material coated onto a substrate, by means of a perforate development electrode and liquid toner, without immersing the material in a bath of toner. The method

comprises spraying liquid toner against pressure reducing means adjacent to the electrode to reduce and make uniform the pressure of the flowing liquid toner and flowing the liquid toner uniformly over and through the perforate development electrode and over the image side of the sheet without contacting the side opposite the image side with the toner.

U.S. Patent 4,233,385 describes a method of liquid development of charge images formed on a surface of a tape-like record carrier, for example by an electrostatic printer. The record carrier is simultaneously sprayed with developer liquid in two flows which are directed towards each other. As a result two separate, uniform and oppositely directed flow zones meeting at one common turbulent flow zone are obtained. Both during pre-development and final development the charge images are brought into contact with a large quantity of fresh developer liquid.

U.S. Patent 4,073,266 describes apparatus for developing a latent electrostatic image on an electrophotographic copying material by means of a toner dispersion. An infeed roller applies the toner dispersion to the copying material and downstream thereof, a distribution roller acts on the surface of the copying material. Squeegee rollers downstream of the distribution roller effect removal of unused toner. Toner which adheres to the distribution roller during application of voltage thereto is sprayed off and recovered for recycling, the spraying agent being toner dispersion.

U.S. Patent 3,405,683 describes apparatus for the development of latent electrostatic images on an electrophotographic material with a liquid developer which includes means to feed the electrophotographic material through a pair of rotatable nip rolls and nozzle means adapted to simultaneously spray the electrostatic image and the nip roll which contacts the latent image.

U. S. Patent 3,910,231 describes a developer system including a forward belt developer and a photoconductive drum and includes means for supplying liquid toner to the

belt developer at the point where the belt and drum both enter the development region.

SUMMARY OF THE INVENTION

It is a particular feature of the present invention that a highly efficient, simple and relatively low cost

"instant" color change multicolor electrostatic imaging system is provided.

There is thus provided in accordance with a preferred embodiment of the present invention a multicolor electrostatic imaging system including an electrostatic imaging surface, apparatus for applying an electrostatic image to the electrostatic image surface, multicolor spray apparatus for supplying a liquid toner of a selectable color to the electrostatic imaging surface, the spray apparatus including a multiplicity of spray outlets including a plurality of spray outlets, distributed among the multiplicity of spray outlets, for supplying liquid toner of each of a plurality of colors, developing apparatus for developing the electrostatic image using the liquid toner, and apparatus for transferring the developed image to a substrate.

Further in accordance with a preferred embodiment of the present invention, the multicolor electrostatic imaging system includes an electrostatic imaging surface, apparatus for applying an electrostatic image to the electrostatic image surface, multicolor spray apparatus for supplying a liquid toner of a selectable color to the electrostatic imaging surface, developing apparatus for developing the electrostatic image using the liquid toner, the developing apparatus including a plurality of single color cleaning assemblies engaging a developing electrode, each cleaning assembly corresponding to a given one of a plurality of colors, and apparatus for transferring the developed image to a substrate.

Further in accordance with a preferred embodiment of the present invention, the multicolor electrostatic imaging system includes an electrostatic imaging surface, apparatus for applying an electrostatic image to the electrostatic image surface, multicolor spray apparatus for supplying a liquid toner of a selectable color to the electrostatic imaging surface, developing apparatus for developing the electrostatic image using the liquid toner, apparatus for transferring the developed image to a substrate, and

apparatus for recycling excess liquid toner to the multicolor spray apparatus.

Further in accordance with a preferred embodiment of the present invention, the electrostatic imaging system includes an electrostatic imaging surface, apparatus for applying an electrostatic image to the electrostatic image surface, spray apparatus for spraying a liquid toner into engagement with a generally downward facing portion of the electrostatic imaging surface, developing apparatus for developing the electrostatic image using the liquid toner, and apparatus for transferring the developed image to a substrate.

Additionally in accordance with a preferred embodiment of the present invention, the spray apparatus includes apparatus for directing a spray of liquid toner in a direction having an upward component.

Further in accordance with a preferred embodiment of the present invention, the spray apparatus includes apparatus for directing a spray of liquid toner onto a downward facing surface of the electrostatic imaging surface.

Additionally in accordance with a preferred embodiment of the present invention, the electrostatic imaging surface includes a cylindrical surface.

Still further in accordance with a preferred embodiment of the present invention, the spray apparatus includes apparatus for directing a spray of liquid toner onto at least part of the lower hemisphere of the cylindrical surface.

Further in accordance with a preferred embodiment of the present invention, the spray apparatus includes a linear array of spray outlets.

Additionally in accordance with a preferred embodiment of the present invention, the multiplicity of spray outlets include interdigitated spray outlets for liquid toner of differing colors.

Still further in accordance with a preferred embodiment of the present invention, the developing

apparatus includes a rotating cylindrical developing electrode.

Further in accordance with a preferred embodiment of the present invention, the electrostatic imaging surface moves in a first direction and the surface of the rotating cylindrical developing electrode moves in adjacent spaced relationship thereto in a second direction opposite to the first direction.

Additionally in accordance with a preferred embodiment of the present invention, the developing apparatus includes a plurality of single color cleaning assemblies, each corresponding to a given one of a plurality of colors.

Still further in accordance with a preferred embodiment of the present invention, the developing apparatus includes a final cleaning assembly, downstream of the plurality of cleaning assemblies.

Further in accordance with a preferred embodiment of the present invention, the system also includes single color toner receiving apparatus associated with at least one of the single color cleaning assemblies.

Still further in accordance with a preferred embodiment of the present invention, the system also includes apparatus communicating with the single color toner receiving apparatus for recycling single color toner to the spray apparatus.

Further in accordance with a preferred embodiment of the present invention, the developing apparatus includes a rotating cylindrical developing electrode and the single color cleaning assemblies include apparatus for selectably engaging the developing electrode.

Still further in accordance with a preferred embodiment of the present invention, the cleaning assemblies include scraper blade apparatus.

Additionally in accordance with a preferred embodiment of the present invention, the system also includes a squeegee cooperating with the image bearing surface downstream of the developing apparatus for removal of excess liquid.

Further in accordance with a preferred embodiment of the present invention, the electrostatic image includes image regions maintained at a first electrical potential and wherein the squeegee is maintained at a voltage having a sign opposite to the sign of the first electrical potential.

Still further in accordance with a preferred embodiment of the present invention, the electrostatic imaging surface moves in a first direction with a first velocity and the surface of the squeegee moves in touching relationship thereto in the first direction at the first velocity.

Additionally in accordance with a preferred embodiment of the present invention, the system also includes separator apparatus for separating toner particles from dispersant.

Still further in accordance with a preferred embodiment of the present invention, the separator apparatus receives toner from at least one of the following sources: the developer apparatus, apparatus for removing excess liquid from the image bearing surface prior to transfer of the developed image from the image bearing surface, and apparatus for cleaning the image bearing surface after transfer of the developed image from the image bearing surface.

Additionally in accordance with a preferred embodiment of the present invention, the system also includes apparatus for supplying clean dispersant produced by the separator apparatus to the apparatus for cleaning to aid in removal of residual toner from the image bearing surface.

Further in accordance with a preferred embodiment of the present invention, the apparatus for transferring includes an intermediate transfer member which is operative sequentially to receive a plurality of developed images from the image bearing surface before transferring them to the substrate.

Still further in accordance with a preferred embodiment of the present invention, the multicolor spray apparatus comprise a manifold formed of a stack of

individual outlet defining members, which stack defines separate toner supply conduits corresponding to each of the plurality of colors.

Additionally in accordance with a preferred embodiment of the present invention, the stack also includes a multiplicity of separator members, each pair of adjacent outlet defining members being separated by a separator member, which seals the outlets defined by adjacent outlet defining members from each other.

Still further in accordance with a preferred embodiment of the present invention, the stack includes a repeating series of outlet defining members corresponding to different colors.

Additionally in accordance with a preferred embodiment of the present invention, the spray apparatus includes apparatus operative to provide a plurality of jets of toner whose cross sectional extent upon impingement with the electrostatic imaging surface does not significantly exceed the cross sectional extent thereof upon leaving the spray apparatus.

Further in accordance with a preferred embodiment of the present invention there is provided an electrostatic imaging system with a generally cylindrical electrostatic imaging surface rotating in a first sense, apparatus for applying an electrostatic image to said electrostatic image surface, supply apparatus for supplying a liquid toner to the electrostatic imaging surface, and developing apparatus for developing said electrostatic image using said liquid toner, including a roller in spaced relationship with the image surface and rotating in the first sense.

There is further provided in a preferred embodiment of the invention a multicolor electrostatic imaging system including a movable electrostatic imaging surface, apparatus for providing an electrostatic image on the electrostatic image surface, a development electrode having a developer surface including contiguous portions and being in spaced relationship with the electrostatic imaging surface to form a development region and apparatus for moving the developer

surface such that the contiguous portions of the developer surface sequentially enter the region at an entrance and exit the region at an exit, apparatus for providing a liquid developer of a selectable color to the development region at the exit, and apparatus for transferring the developed image to a substrate.

In a preferred embodiment of the invention the apparatus for providing a liquid developer includes multicolor spray apparatus having a multiplicity of spray outlets including a plurality of spray outlets, sequentially distributed among the multiplicity of spray outlets, for supplying liquid developer of each of a plurality of colors.

In a preferred embodiment of the invention the apparatus for providing a liquid developer supplies the liquid developer to the developer surface after it exits from the development region. Alternatively in a preferred embodiment of the invention the apparatus for providing a liquid developer supplies the liquid developer directly to the electrostatic imaging surface.

The imaging system includes, in a preferred embodiment of the invention, apparatus for moving the electrostatic imaging surface so that it enters the development region at the exit and leaves the region at the entrance. Additionally in a preferred embodiment of the invention the apparatus for providing a liquid developer supplies the liquid developer to the imaging surface before it enters the development region.

In a preferred embodiment of the invention the electrostatic imaging surface is cylindrical and the system also includes apparatus for moving the imaging surface with a velocity having a direction opposite of that of the developer surface at the development region.

There is further provided an imaging system including an imaging surface, apparatus for forming multiple electrostatic latent images sequentially on the imaging surface, development apparatus for sequentially developing the multiple electrostatic images with separate liquid developers, the development apparatus including: a

development electrode having a developer surface including contiguous portions and which is closely spaced from the electrostatic imaging surface to form a development region, apparatus for moving the developer surface such that the contiguous portions of the developer surface sequentially enter the region at an entrance and leave the region at an exit, apparatus for sequentially supplying the separate liquid developers to the developing region to separately develop each of the multiple images and separate apparatus for removing residual amounts of each of the separate residual developers remaining on the surface of the development electrode after it exits the development region.

In a preferred embodiment of the invention the imaging apparatus also includes apparatus for reusing the residual developer after its removal from the development electrode.

In a preferred embodiment of the invention the separate apparatus for removing includes a plurality of single color cleaning assemblies, each corresponding to a given one of a plurality of colors. The separate apparatus for removing includes in a preferred embodiment of the invention, a final cleaning assembly, downstream of the plurality of cleaning assemblies.

In a preferred embodiment of the invention the imaging system also includes single color toner receiving apparatus associated with at least one of the single color cleaning assemblies. In a preferred embodiment of the imaging system also includes apparatus communicating with the single color toner receiving apparatus for recycling single color toner to the apparatus for sequentially supplying. In a preferred embodiment of the invention, the single color cleaning assemblies include apparatus for selectably engaging the developing electrode. The cleaning assemblies include scraper blade apparatus in a preferred embodiment of the invention.

In a preferred embodiment of the invention the apparatus for removing residual developer includes at least one resilient blade in contact with the development electrode.

There is further provided, in a preferred embodiment of the invention, imaging apparatus including an imaging surface, apparatus for forming an electrostatic latent image on the imaging surface and development apparatus for sequentially developing the electrostatic images with a liquid developer, the development apparatus including: a development electrode having a developer surface including contiguous portions and which is closely spaced from the electrostatic imaging surface to form a development region, apparatus for moving the developer surface such that the contiguous portions of the developer surface sequentially enter the region at an entrance and leave the region at an exit and apparatus for providing the liquid developer to the development region to separately develop the images, wherein the liquid developer is in a turbulent state at the development region.

In a preferred embodiment of the invention the apparatus for providing the liquid developer supplies the liquid developer to the development region at the exit. In a preferred embodiment of the invention the liquid developer is sprayed on the developer surface after it exits the development region.

In a preferred embodiment of the invention the imaging surface includes contiguous portions which subsequently enter the development region at the exit and leave the development region at the entrance and wherein the apparatus for providing the liquid developer includes spraying the liquid developer on the imaging surface before it enters the development region.

There is further provided, in a preferred embodiment of the invention, an imaging system for imaging with liquid developer, the developer comprising carrier liquid, toner particles and charge director, the system including an electrostatic imaging surface, apparatus for supplying an electrostatic image to the electrostatic imaging surface, a reservoir for the liquid developer, a developer electrode for developing the electrostatic image with the liquid developer to form a developed image, apparatus for supplying

the liquid developer to the electrostatic surface and for removing residual liquid developer from the developer electrode and returning the removed developer to the reservoir, apparatus responsive to the charge level of the liquid developer, for supplying charge director at the developer electrode for maintaining the charge level of the liquid developer, and apparatus for transferring the developed image to a substrate.

There is further provided in a preferred embodiment of the invention apparatus for imaging with developers, each developer comprising carrier liquid, toner particles and charge director, the system including an electrostatic imaging surface, apparatus for sequentially supplying electrostatic images to the electrostatic imaging surface, separate reservoirs for each of the plurality of liquid developers, a developer electrode for selectively developing the electrostatic images with one of the plurality of liquid developers, apparatus for supplying liquid developer of a selectable color to the electrostatic imaging surface, apparatus for removing residual developer from the developer electrode for return to the reservoir of the liquid developer, apparatus responsive to the charge level of at least one of the liquid developers, for supplying charge director at the developer electrode for separately maintaining the charge of the at least one liquid developer, and apparatus for transferring the developed image to a substrate.

In a preferred embodiment of the invention the apparatus for supplying, directly delivers the liquid developer to the electrostatic imaging surface.

In a preferred embodiment of the invention the apparatus for removing is also operative to remove the charge director from the developer electrode for supplying the charge director to the reservoir.

The developer electrode includes, in a preferred embodiment of the invention, a rotating cylindrical developing electrode whose surface moves in adjacent spaced relationship to the imaging surface, and the apparatus for

supplying supplies the charge director onto the developing electrode surface after it leaves the proximity of the imaging surface. Preferably the apparatus for removing includes a plurality of single color cleaning assemblies for removing material including charge director supplied thereto from the developing electrode, each assembly corresponding to a given one of the liquid developers. Preferably the material removed by the cleaning assemblies from the developing electrode is supplied to its respective reservoir.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1 is a generalized schematic illustration of an imaging system constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 2 is a pictorial illustration of a portion of the apparatus of Fig. 1;

Fig. 3 is a pictorial illustration of one embodiment of spray apparatus employed in the present invention;

Figs. 4A and 4B are respective pictorial and partially sectional illustrations of a preferred embodiment of spray apparatus employed in the present invention;

Figs. 5A, 5B, 5C, 5D and 5E are sectional illustrations of modular sections of the spray apparatus of Fig. 4;

Fig. 6 is a sectional illustration of part of the apparatus of Fig. 1 which particularly illustrates a multicolor, non-contaminating developer assembly particularly useful in the present invention;

Fig. 7 is a pictorial illustration of an alternative embodiment of the spray apparatus employed in the present invention;

Figs. 8A, 8B, 8C and 8D are sectional illustrations of modular sections of the spray apparatus of Fig. 7;

Fig. 9 is a sectional illustration of part of the apparatus of Fig. 1 utilizing the spray apparatus of Fig. 7 and which particularly illustrates a multicolor, non-

contaminating developer assembly particularly useful in the present invention;

Fig. 10 is a sectional illustration of the build-up of liquid developer on the developer roller in the absence of the photoconductor drum;

Fig. 11 is a generalized schematic illustration of an imaging system constructed and operative in accordance with another preferred embodiment of the present invention;

Fig. 12 is a enlarged view of a portion of Fig. 11;

Fig. 13 is a side, sectional view of the spray apparatus for the embodiment of Fig. 11;

Fig. 14 is a perspective view of the spray apparatus for the embodiment of Fig. 11; and

Fig. 15 is a generalized schematic illustration of an imaging system constructed and operative in accordance with yet another preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Reference is now made to Fig. 1 which illustrate a multicolor electrostatic imaging system constructed and operative in accordance with a preferred embodiment of the present invention. As seen in Fig. 1 there is provided an image bearing surface typically embodied in a rotating photoconductive drum 10. Operatively associated with photoconductive drum 10 is photoconductor charging apparatus 11 and imaging apparatus 12, for providing a desired latent image on drum 10. The latent image normally includes image areas at a first electrical potential and background areas at another electrical potential.

Also associated with photoconductive drum 10 are a multicolor liquid developer spray assembly 14, a developing assembly 16, an excess liquid removal assembly 18, and intermediate transfer member 20 and a cleaning station 22.

The developing assembly 16 preferably includes a developer roller elecrode 17 spaced from the photoconductive drum 10 and typically rotating in the same sense as drum 10, as indicated by arrows 19. This rotation provides for the surface of drum 10 and roller 17 to have opposite velocities in their region of propinquity.

Photoconductive drum 10, photoconductor charging apparatus 11 and imaging apparatus 12 may be any suitable drum, charging apparatus and imaging apparatus such as are well known in the art. Developing assembly 16 is of particular construction several embodiments of which are described in detail hereinbelow.

Excess liquid removal assembly 18 typically includes a biased squeegee roller preferably formed of resilient conductive polymeric material, and is charged to a potential of several hundred to a few thousand volts with the same sign as the sign of the charge on the toner particles.

Intermediate transfer member 20 may be any suitable intermediate transfer member and is arranged for electrostatic transfer of the image from the image bearing surface. Intermediate transfer member 20 is preferably associated with a pressure roller 24 for transfer of the image onto a further substrate 25, such as paper, preferably by heat and pressure. A fuser 26 may be associated with the substrate 25, for fixing the image thereon, if required. Cleaning station 22 may be any suitable cleaning station, such as that described in U.S. Patent 4,439,035.

In accordance with a preferred embodiment of the invention, after developing each image in a given color, the single color image is transferred to intermediate transfer member 20. Subsequent images in different colors are sequentially transferred onto intermediate transfer member 20. When all of the desired images have been transferred thereto, the complete multi-color image is transferred from transfer member 20 to substrate 25. Pressure roller 24 therefore only produces operative engagement between intermediate transfer member 20 and substrate 25 when transfer of the composite image to substrate 25 takes place.

Alternatively, each single color image is transferred to the paper after its formation. In this case the paper is fed through the machine once for each color or is held on a platen and contacted with intermediate transfer member 20 during image transfer. Alternatively, the intermediate transfer member is omitted and the developed single color images are transferred sequentially directly from drum 10 to substrate 25.

According to a preferred embodiment of the invention, excess liquid, containing toner particles of various colors, is collected from cleaning station 22, excess liquid removal assembly 18 and developer assembly 16 and supplied to a separator 30 which is operative to separate relatively clean carrier liquid from the various colored toner particles. Clean carrier liquid is supplied from separator

30 to a carrier liquid reservoir 32, which also may receive additional supplies of carrier liquid, as necessary. Carrier liquid from reservoir 32 is supplied to cleaning station 22.

Reference is now made additionally to Fig. 2, which is a pictorial illustration of part of the apparatus of Fig. 1, not including photoconductive drum 10, intermediate transfer member 20, roller 24, substrate 25 and fuser 26. It is seen in Figs. 1 and 2 that multicolor toner spray assembly 14 receives separate supplies of colored toner from four different reservoirs 40, 42, 44 and 46, typically containing the colors Yellow, Magenta, Cyan and Black respectively. Pumps 48, 50, 52 and 54 may be provided along respective supply conduits 56, 58, 60 and 62 for providing a desired amount of pressure to feed the colored toner to multicolor spray assembly 14.

Associated with each of reservoirs 40, 42, 44 and 46 are typically provided containers of charge director and concentrated toner material, indicated respectively by reference numerals 64 and 66 as well as a supply of carrier liquid, indicated generally by reference numeral 67.

Each of the reservoirs 40, 42, 44 and 46 also typically receives an input of recycled toner of a corresponding color from developer assembly 16, which will be described hereinbelow in greater detail.

Reference is now made to Fig. 3 which illustrates one embodiment of a multicolor toner spray assembly 14 indicated by reference number 69. In the embodiment of Fig. 3 it is seen that there is provided a linear array of spray outlets 70, each of which communicates with one of the four conduits 56, 58, 60 and 62. The spray outlets are preferably interdigitated such that every fourth outlet is of the same color and that every group of four adjacent outlets includes outlets of four different colors. The spacing of the spray outlets and their periodicity is selected to enable substantially complete coverage of the photoconductor to be realized for each given color separately.

Preferably the center to center spacing of the outlets is as small as possible. In the embodiment of Fig. 3, the

center to center spacing of outlets 70 is typically 2 mm. The nozzle openings of the outlets are restricted to provide a desired flow configuration and preferably have a generally rectangular cross section. In any event, the amount of toner that is applied to the drum in accordance with the present invention is sufficient to provide a layer of toner of thickness at least sufficient to substantially fill the gap between drum 10 and developer roller 17.

It is a characteristic of preferred embodiments of the invention that developer roller 17 is a reverse roller, that is, the surfaces of developer roller 17 and drum 10 move in opposite directions at the development region. In the present invention the flow of liquid toner is believed to be high enough so that there is a substantial amount of liquid developer at the point of propinquity of drum 10 and roller 17 such that the toner is in a turbulent rather than laminar state. For reasons which are not clearly understood, this turbulent flow has resulted in excellent images. It is also believed that this turbulence allows for relatively high spacings between the spray outlets without substantial deterioration of image quality.

Reference is now made to Figs. 4A and 4B and Figs. 5A - 5E, which together illustrate an additional preferred embodiment of spray assembly 14 indicated by reference number 81, which is composed of a predetermined sequence of modular elements 72, 74, 76, and 78 arranged in a stack.

Disposed in sealing engagement between each of the adjacent modular elements illustrated in Figs. 5A - 5D is a spacer element 84 (Fig. 5E), typically much thinner than the remaining modular elements, which seals the various spray outlets from each other and prevents color contamination.

It may be appreciated from a consideration of Figs. 5A-5E, that each of the modular elements illustrated therein defines a part of four conduits corresponding to conduits 56, 58, 60 and 62 as well as two apertures 80 and 82 for accommodating connection and tightening bolts (not shown) which hold spray assembly 81 together.

Additionally each modular element has formed at one end

a slit 86 which together with adjacent spacer elements 84 forms a rectangular spray outlet 90 each communicating via a respective channel 88 to respective conduits 56, 58, 60 and 62.

It may be appreciated that the modular element 72 illustrated in Fig. 5A corresponds to a spray outlet communicating with conduit 62, while the modular element 74 illustrated in Fig. 5B corresponds to a spray outlet communicating with conduit 60. The modular element 76 illustrated in Fig. 5C corresponds to a spray outlet communicating with conduit 58, while the modular element 78 illustrated in Fig. 5D corresponds to a spray outlet communicating with conduit 56.

Modular elements 72, 74, 76 and 78 are each typically of thickness 1 mm. This thickness defines one generally rectangular dimension of each spray outlet, whose other dimension, the width of slit 86, is normally selected to provide a desired application of toner to the drum 10 as described hereinabove. Spacer elements 84 typically have a thickness of 0.1 mm. Slit width is typically 0.6 mm.

It is a feature of the embodiment of Figs. 4A-5E that relatively small spatial separations between adjacent spray outlets may be realized. For the typical dimensions mentioned above, the center to center spacing between adjacent outlets for the same color is 4.4 mm, while in the embodiment of Fig. 3, the corresponding spacing is 8 mm.

Reference is now made to Fig. 7 and Figs. 8A - 8D, which together illustrate a preferred alternative embodiment of a multicolor spray assembly which is indicated by reference number 15, similar to the embodiment illustrated in Figs. 4A-4B and Figs. 5A-5E and indicated by reference number 14. The major differences between the two embodiments are in the shape of the spray outlets and in the resultant change in the distance between the modular elements.

In the embodiment of Figs. 4A and 4B, the spray outlet is rectangular and formed by the upper and lower walls of slit 86 and spacer elements 84 adjoining the modular element. The spray outlets for the embodiment of Figs. 7 and

8A-8D is formed of a tubular extension 108 at the end of each modular element 110, 112, 114 and 116.

Modular elements 110, 112, 114 and 116 are each typically of thickness 2 mm. Tubular extensions 108 have a typical inner diameter of 1 mm and a typical outer diameter of 1.5 mm. Thus the spray outlet center to center spacing for this embodiment is typically 2.1 mm, compared to 1.1 mm for the embodiment of Fig. 4A and 4B, and the spacing between sprays of the same color is about 8.4 mm instead of 4.4 mm for the embodiment of Figs. 4A and 4B.

The outer surfaces of tubular extensions 108 are tapered at their exit ends in order to reduce the wall thickness at the output face of the extensions to a minimum. It is believed that this reduction reduces dripping of the liquid developer.

Reference is now made to Fig. 6 which illustrates a developer assembly 90 constructed and operative in accordance with a preferred embodiment of the invention. The developer assembly includes developer roller electrode 17 which operatively engages photoconductor drum 10 in spaced relationship therewith and, due to its rotation in the same sense as photoconductor drum 10, acts as a metering device. Developer roller 17 is typically maintained at +200 Volts when the voltage of the image areas of the photoconductor 10 is approximately +1000 Volts and the voltage on the background areas of the photoconductor 10 is approximately +100 Volts. The above voltages are suitable for the use of negatively charged toner and a selenium coated photoconductor drum. If it is desired to use a positively charged toner or another type of photoconductor material, correspondingly different voltages will be appropriate. This embodiment utilizes multicolor spray assembly 14, illustrated in Figs 4A-4B and 5A-5E and the spray is directed toward the under surface of photoconductor drum 10.

Fig. 9 illustrates a different preferred embodiment of the invention with a developer assembly 91, similar to that of Fig. 6, but utilizing spray assembly 15 of Fig. 7. Here the spray is directed to the upper surface of developer

roller 17. It should be noted that the rotation of developer roller 17 is such as to carry the developer liquid away from a development region 93. Nevertheless the multicolor spray assembly produces a sufficient amount of force to assure that there is a supply of liquid developer at the development region as will be illustrated with the aid of Fig. 10.

In Fig. 10 photoconductive drum 10 is shown in phantom and liquid developer sprayed from the tubular extension is seen to form in its absence a thick accumulation of developer. It is now understood that the net effect of the spray, and the movement of developer roller 17 and photoconducting drum 10 is to form development region 93 filled with developer at the point of propinquity of drum 10 and roller 17 and to the left of that point. The amount of developer in that region and its extent is easily changed by varying the rotation speeds of drum 10 and roller 17 and the amount of liquid developer supplied.

Very little liquid carries through to the right of the development region due to the metering effect of developer roller 17. It is also clearly understood that for this embodiment as well as for the others disclosed herein, there may be substantial turbulence of the liquid developer in the development region.

A preferred type of toner for use with the present invention is that described in Example 1 of U.S. Patent 4,794,651

Other toners may alternatively be employed. For colored liquid developers, carbon black is replaced by color pigments as is well known in the art.

Returning to Figs. 6 and 9, operatively associated with developer roller 17 are a plurality of color specific toner cleaning assemblies 92, each of which is selectably brought into operative association with developer roller 17 only when toner of a color corresponding thereto is supplied to development region 93 by spray assembly 14.

Each of cleaning assemblies 92 includes a blade member 94 including a preferably resilient main portion 96

and side wiping portions 98 arranged to engage the two edges of the roller developer surface. Blade member 94 is mounted on a linkage 100 which is selectably positioned by a conventional actuator 102. Associated with each of the cleaning assemblies 92 is a toner collection member 104 which serves to collect the toner removed by the cleaning assembly 92 from the developing electrode and thus to prevent contamination by mixing of the various colors.

As noted above, the toner collected by collection members 104 is recycled to the corresponding toner reservoirs. A final toner collection member 106 always engages the developer roller 17. The toner collected thereby is supplied to separator 30 (Fig. 1). Alternatively the toner collected by collection member 106 may be supplied directly to the black (K) toner reservoir 46.

For both the embodiments of Fig. 6 and Fig. 9 it is seen that the toner at the developer interface is removed from the development region quickly after the flow is interrupted. This allows for almost instant change of developer color at development region 93. Additionally developer roller 17 is well cleaned between colors, so that cross-contamination between colors is practically non-existent.

An alternative preferred embodiment of the invention is shown in Figs. 11-14. Fig. 11 shows a general cross-sectional schematic view of the system. The liquid handling is similar to that of the previous embodiments with the changes therefrom mainly in the development and image transfer regions. These changes are shown more clearly in Fig. 12 which is an enlarged view of the relevant portion of Fig. 11. In Figs. 11 and 12 functionally unchanged elements are referenced with the same reference numbers as used in earlier drawings illustrating the other embodiments of the invention.

In the embodiment of Figs. 11 and 12 developer roller 17 is approximately at 7:30 o'clock in relation to drum 10 and a multicolor spray assembly 120 is at approximately 10 o'clock. Cleaning station 22 utilizes a wetted sponge roller

118 followed by a resilient blade 119.

Multicolor spray assembly 120 includes a linear spray assembly for each of the colors. Unlike the embodiments of spray assembly 14, spray outlets 121 do not form a linear array for all of the colors, but rather each linear color array is displaced from its neighbors both axially and in the process direction to form an interdigitated spray assembly having a plurality of linear arrays of outlets for liquid toner of different colors. This arrangement is shown most clearly in Figs. 13 and 14.

Spray outlets 121 spray downward onto a downward moving portion of photoconductive drum 10 and are formed with a bend which changes the direction of flow from generally upward at the connection to supply conduit manifolds 124, 126, 128 and 130 respectively to an downward angle at the exits from spray outlets 121. This change in direction has been found to reduce dripping from the exits of the spray outlets when the color is changed, which is important to reduce the time required between color changes. Supply conduit manifolds 124, 126, 128 and 130 are continuations of supply conduits 56, 58, 60 and 62 and are fed with liquid toner preferably from both ends.

In a preferred embodiment of the invention the supply conduits are fed by elastic tubing in order to allow for faster cut-off of the flow.

In the embodiment of the invention shown in Figs 11 and 12, substrate 25 is held on a backing roller 125. The apparatus can operate in two ways. In both cases the individual color images are formed and sequentially developed on drum 10 and sequentially transferred to intermediate transfer member 20. In the first preferred embodiment of the invention the images are all transferred to intermediate transfer member 20 in registration and then the complete multicolor image is transferred as a whole to substrate 25. In the second preferred embodiment the single color images are transferred individually to substrate 25 without being assembled as a group on intermediate transfer member 20.

It is understood that in some preferred embodiments of the present invention the multicolor spray assemblies spray onto a downward facing portion of photoconductor drum 10. The spray may be upward or with an upward directional component, as shown in Fig 1. For other embodiments of the invention the spray direction may be horizontal or alternatively the spray direction may have a downward component or it may be directed at developer roller 17. It is a further feature of a preferred embodiment of the invention that the multicolor spray assembly is operative to provide a plurality of jets of toner whose cross sectional extent upon impingement with the drum does not significantly exceed the cross sectional of the opening of each spray nozzle.

It is a further characteristic of the illustrated preferred embodiments of the invention that developer roller is a reverse roller and that the liquid developer is supplied to a development region including the side of the region of propinquity between roller 17 and drum 10 at which roller 17 leaves that region. This has a number of effects.

Development takes place in this development region and the developer roller 17 carries excess carrier liquid away from the development region for reuse. Additionally, roller developer 17 also acts as a metering roller, so that the amount of liquid remaining on the background areas of the image on drum 10 when it leaves the development area is reduced and loosely adhering toner on the image which tends to reduce image quality is removed and carried away by development roller 17. If sufficient liquid developer is supplied, the liquid developer is in a turbulent state which is believed to reduce the close spacing requirement for the spray nozzles.

As is known in the art, liquid developer may become electrically discharged for a number of reasons and may then require recharging by the addition of small amounts of charge director. In the embodiment shown in Fig. 15, the separate mechanisms for replenishment of charge director,

shown schematically in Figs. 1, 2 and 11 by reference numeral 64 are eliminated. A charge director solution container 200 contains a solution of charge director in carrier liquid. Rather than being directly added to the individual reservoirs 40, 42, 44 and 46, the charge director solution is supplied via a pump 202 and a nozzle 204 directly to the surface of developer roller 17.

In operation, measurement of the conductivity of the liquid developer in one of the reservoirs is carried out by conductivity measurement apparatus 206. In a preferred embodiment of the invention the apparatus described in U.S Patent 4.860,924

is used to measure conductivity. The results of ~~this~~ measurement are compared with a reference value in a charge director control circuit 208. Circuit 208 also receives signals via input 210, indicative of the state of engagement of respective cleaning assemblies 92. When the conductivity for a particular color of liquid developer drops below the reference value for that color, and the cleaning assembly for that color is engaged on roller 17, pump 202 is activated to inject a measured amount of charge director solution onto the surface of roller 17.

This charge director solution is then removed from the roller by the respective cleaning assembly 92, and added to the reservoir in which the measurement was made. This apparatus thus utilizes only a single charge director replenishment mechanism, while allowing for each of the liquid developers to be separately replenished to its own optimum conductivity.

While the invention has been described utilizing a roller developer and a drum photoconductor, it is understood that the invention can be practiced utilizing a belt developer and/or a belt photoconductor.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow:

C L A I M S

1. A multicolor electrostatic imaging system comprising:

an electrostatic imaging surface (10);

means for applying an electrostatic image to said electrostatic image surface;

means for selectively supplying (14, 69, 81, 15 or 120) a liquid developer including toner particles of a selected color to said electrostatic imaging surface;

developing means (16) for developing said electrostatic image using said liquid developer to form a developed image; and

means (20) for transferring said developed image to a substrate,

characterized in that said means for supplying includes multicolor spray means comprising a multiplicity of stationary spray outlets (70, 108, 121) wherein each of the outlets supplies liquid developer of one of at least two selected colors, which color being different from the color supplied by at least one neighboring outlet.

2. A system according to claim 1 wherein said spray means comprises a linear array of spray outlets.

3. A system according to any of the preceding claims wherein said multiplicity of spray outlets include interdigitated spray outlets for liquid developer of differing colors.

4. A system according to any of the preceding claims wherein said multicolor spray means comprise a manifold formed of a stack of individual outlet defining members (72, 74, 76, 78, 110, 112, 114, 116), which stack defines separate developer supply conduits (56, 58, 60, 62) corresponding to each of said plurality of colors.

5. A system according to claim 4 wherein said stack also comprises a multiplicity of separator members (84), each pair of adjacent outlet defining members being separated by

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a separator member, which seals the outlets defined by adjacent outlet defining members from each other.

6. A system according to claim 4 or claim 5 wherein said stack comprises a repeating series of outlet defining members corresponding to different colors.

7. A system according to any of the preceding claims wherein said spray means includes means (90, 108, 121) operative to provide a plurality of jets of developer whose cross sectional extent upon impingement with the electrostatic imaging surface does not significantly exceed the cross sectional extent thereof upon leaving the spray means.

8. A system according to any of the preceding claims wherein said spray means comprises means for directing a spray of liquid developer in a direction having an upward component.

9. A system according to any of the preceding claims wherein said spray means comprises means for directing a spray of liquid developer onto a downward facing surface of said electrostatic imaging surface.

10. A system according to any of the preceding claims wherein said electrostatic imaging surface comprises a cylindrical surface.

11. A system according to claim 10 wherein said spray means comprises means for directing a spray of liquid developer onto at least part of the lower hemisphere of said cylindrical surface.

12. A system according to any of claims 1-11 wherein said developer means comprises a developing electrode (17).

13. A system according to any of claims 1-8 wherein:

said electrostatic imaging surface is movable; and

said development means comprises a development electrode (17) having a developer surface comprising contiguous portions and being in spaced relationship with said electrostatic imaging surface to form a development region (93), the system also comprising:

means for moving said developer surface such that said contiguous portions of said developer surface sequentially enter said region at an entrance and leaves said development region at an exit, and wherein said multicolor spray means includes means for providing said liquid developer of a selectable color to said development region at said exit.

14. An imaging system comprising:

a movable electrostatic imaging surface (10);

means (11,12) for providing an electrostatic image on said electrostatic imaging surface;

development means including a development electrode (17) having a developer surface comprising contiguous portions and being in spaced relationship with said electrostatic imaging surface to form a development region (93);

means for moving said developer surface such that said contiguous portions of said developer surface sequentially enter said development region at an entrance and leaves said development region at an exit; and

means (20) for transferring said developed image to a substrate,

characterized in that it includes means (14, 69, 81, 15 or 120) for providing a liquid developer of a selectable color to said development region at said exit.

15. A system according to claim 14 wherein said means for providing a liquid developer further comprises:

multicolor spray means (14, 69, 81, 15 or 120) for supplying liquid developer of a selectable color to said electrostatic imaging surface, said spray means comprising a multiplicity of spray outlets (70, 108, 121) wherein each of

the outlets supplies liquid developer of one of at least two selected colors, which color being different from the color supplied by at least one neighboring outlet.

16. An imaging system according to any of claims 13-15 and including means for moving said electrostatic imaging surface so that it enters said development region at said exit and leaves said region at said entrance.

17. An imaging system according to any of claims 13-16 wherein said means for providing a liquid developer supplies said liquid developer directly to said electrostatic imaging surface.

18. An imaging system according to any of claims 13-17 wherein said means for providing a liquid developer supplies said liquid developer to said imaging surface before it enters said development region.

19. An imaging system according to any of claims 13-17 wherein said means for providing a liquid developer supplies said liquid developer directly to said developer surface after it exits from said development region.

20. A system according to any of claims 12-19 wherein said liquid developer of a selectable color comprises carrier liquid, toner particles and charge director, the system further comprising:

means (200, 202, 206, 208, 210), responsive to the charging level of said liquid developer of a selectable color for supplying charge director at said development electrode for separately maintaining the charge of said liquid developer.

21. A system according to any of claims 12-20 wherein said developing electrode comprises a rotating cylindrical developing electrode.

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22. A system according to claim 21 and wherein said electrostatic imaging surface moves in a first direction and the surface of said rotating cylindrical developing electrode moves in adjacent spaced relationship thereto in a second direction opposite to said first direction.

23. A electrostatic imaging system comprising:
an electrostatic imaging surface (10);
means (11, 12) for applying an electrostatic image to said electrostatic image surface;
developing means (16) for developing said electrostatic image using said liquid developer; and
means (20) for transferring said developed image to a substrate,
characterized in that it also includes stationary spray means (14, 69, 81, 15 or 120) for spraying a liquid developer upwardly into engagement with a generally downward facing portion of said electrostatic imaging surface.

24. A system according to any of the preceding claims wherein said developing means comprises a plurality of single color cleaning assemblies (92), each corresponding to a given one of a plurality of colors.

25. A system according to claim 24 wherein said developing means comprises a rotating cylindrical developing electrode and said single color cleaning assemblies include means (102) for selectably engaging said developing electrode.

26. A system according to claim 24 or claim 25 and comprising single color developer receiving means associated with at least one of said single color cleaning assemblies.

27. A system according to claim 26 and also comprising means communicating with said single color developer receiving means for recycling single color developer to said spray means.

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28. A system according to claim 24 or claim 25 and including:

a reservoir for each said developer of a selectable color; and

means (104) for supplying material removed by said single color cleaning assembly to its respective reservoir.

29. A system according to any of claims 24-28 wherein said cleaning assemblies include scraper blade means (96).

30. A system according to any of claims 24-29 wherein said developing means comprises a final cleaning assembly (106), downstream of said plurality of cleaning assemblies.

31. A system according to any of the preceding claims and comprising a squeegee (18) cooperating with said image bearing surface downstream of said developing means for removal of excess liquid.

32. A system according to claim 31 wherein said liquid developer comprises charged particles having a given polarity and wherein said squeegee is maintained at a voltage having the given polarity.

33. A system according to claim 31 or claim 32 wherein said electrostatic imaging surface moves in a first direction with a first velocity and the surface of said squeegee moves in touching relationship thereto in said first direction at said first velocity.

34. A system according to any of the preceding claims and comprising separator means (30) for separating toner particles from dispersant.

35. A system according to claim 34 wherein said separator means receives toner from at least one of the following sources:

said developer means;

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means (18) for removing excess liquid from said image bearing surface prior to transfer of said developed image from said image bearing surface; and

means (22) for cleaning said image bearing surface after transfer of said developed image from said image bearing surface.

36. A system according to claim 34 or claim 35 and also comprising means for supplying clean dispersant produced by said separator means to said means for cleaning to aid in removal of residual toner from said image bearing surface.

37. A system according to any of the preceding claims wherein said means for transferring comprises an intermediate transfer member (20) which is operative sequentially to receive a plurality of developed images from said image bearing surface before transferring them to said substrate.

38. A multicolor system for imaging with a plurality of liquid developers, each developer comprising carrier liquid, toner particles and charge director, the system comprising:

an imaging surface (10) adapted to sequentially support a series of electrostatic images;

separate reservoirs (40, 42, 44, 46) for each of said plurality of liquid developers; and

a common developer system for selectively developing said electrostatic images with one of said plurality of liquid developers,

characterized in that it includes means (204), responsive to the charging of at least one of said liquid developers, for supplying charge director at said common developer system for separately maintaining the charge level of said at least one liquid developer.

39. A multicolor imaging system according to claim 38, wherein said common developer system comprises:

a rotating cylindrical developing electrode whose

surface moves in adjacent spaced relationship to said imaging surface, and

said means for supplying supplies said charge director onto said developing electrode surface after it leaves the proximity of said imaging surface.

40. A system according to claim 39 wherein said common developer system comprises a plurality of single color cleaning assemblies (92) for removing material from said developing electrode, each corresponding to a given one of said liquid developers.

41. A system according to claim 40 and also including means for supplying material removed by said cleaning assemblies from said developing electrode to its respective reservoir.

42. A system according to any of claims 38-41 wherein said developer system further comprises:

multicolor spray means (14, 69, 81, 15 or 120) for supplying liquid developer of a selectable color to said electrostatic imaging surface, said spray means comprising a multiplicity of spray outlets (70, 108, 121) wherein each of the outlets supplies liquid developer of one of at least two selected colors, which color being different from the color supplied by at least one neighboring outlet.

43. A system for imaging with liquid developer, the developer comprising carrier liquid, toner particles and charge director, the system comprising:

an electrostatic imaging surface (10);

means (11, 12) for forming an electrostatic image to said electrostatic imaging surface;

a reservoir for said liquid developer (40, 42, 44, 46);

a developer electrode (17) for developing said electrostatic image with said liquid developer to form a developed image;

means for supplying (14, 69, 81, 15 or 120) said liquid developer to said electrostatic surface and for removing

(92) residual liquid developer from said developer electrode and returning said removed developer to said reservoir; and

means (20) for transferring said developed image to a substrate,

characterized in that it also includes charge director supply means (204) responsive to the charge level of said liquid developer, for supplying charge director at said developer electrode for maintaining the charge level of said liquid developer.

44. A system according to claim 43 wherein said means for supplying directly delivers said liquid developer to said electrostatic imaging surface.

45. A system according to claims 43 or claim 44 wherein said means for removing is also operative to remove said charge director from said developer electrode for supplying said charge director to said reservoir.

46. A system according to any of claims 43-45 wherein said developer electrode comprises:

a rotating cylindrical developing electrode whose surface moves in adjacent spaced relationship to said imaging surface, and

said means for supplying supplies said charge director onto said developing electrode surface after it leaves the proximity of said imaging surface.

47. A system according to claim 46 and wherein said means for removing comprises a plurality of single color cleaning assemblies (92) for removing material including charge director supplied thereto from said developing electrode, each assembly corresponding to a given one of said liquid developers.

48. A system according to claim 47 and including means for supplying material removed by said cleaning assemblies from said developing electrode to its respective reservoir.

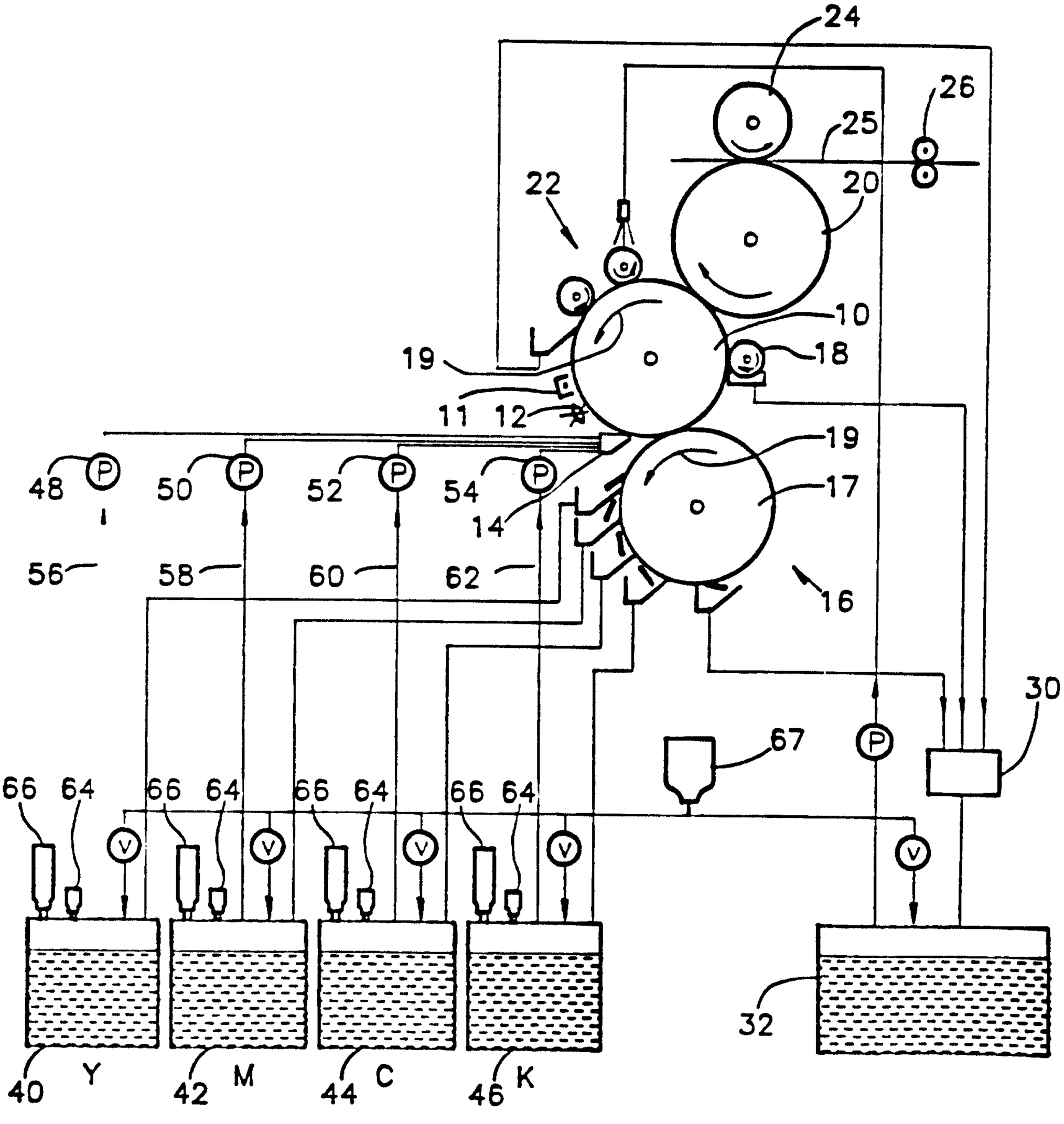
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FIG.1

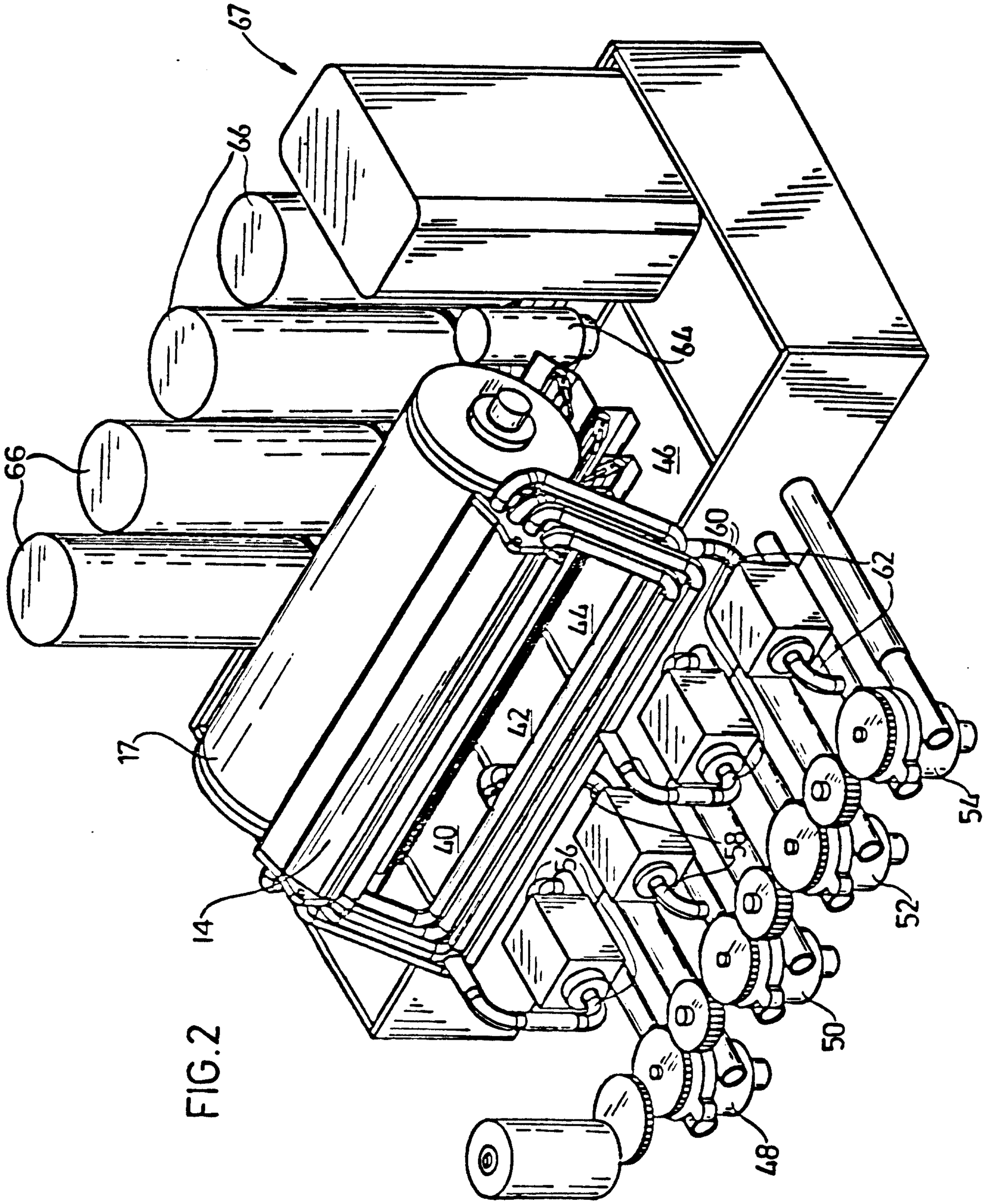
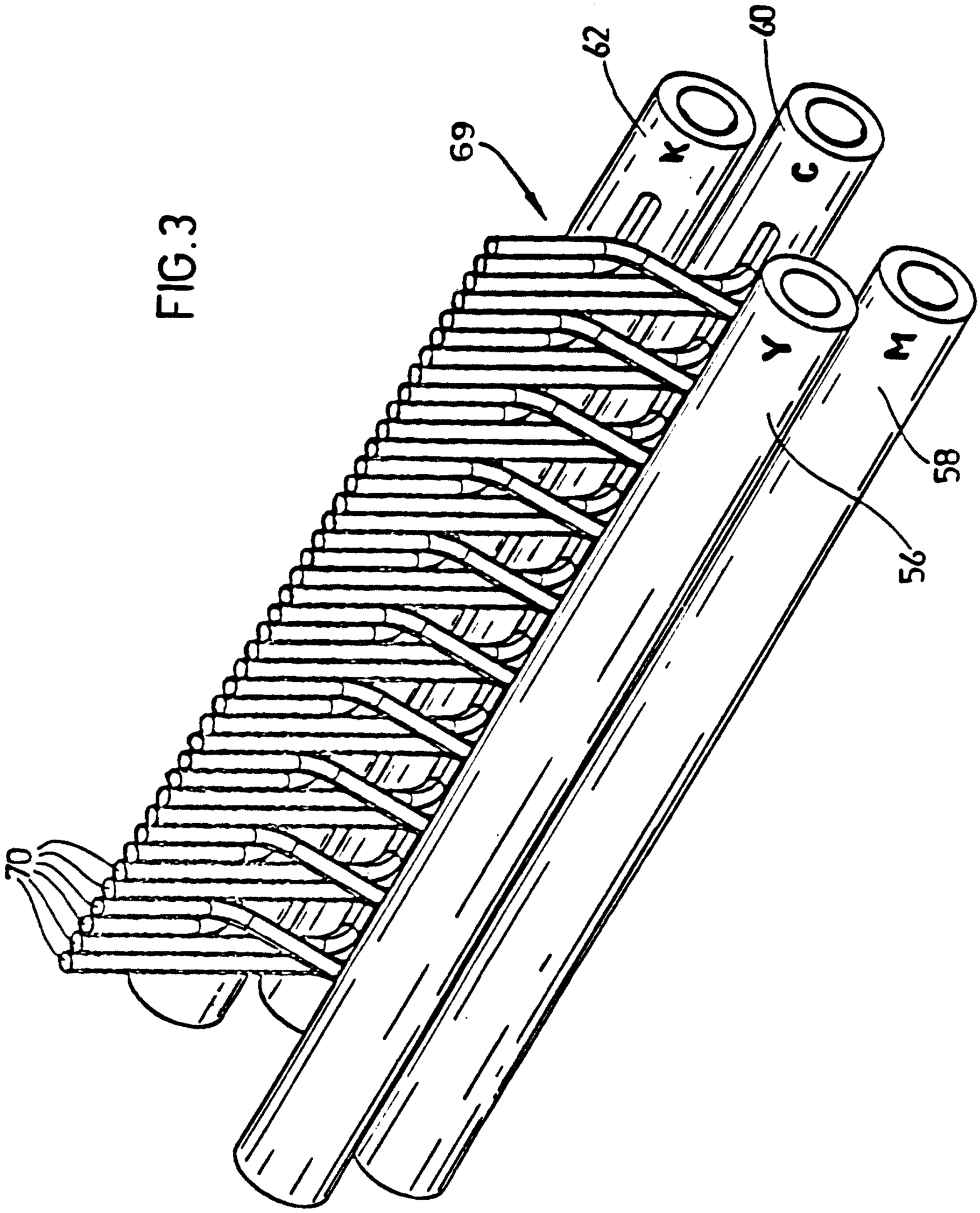


FIG.2

FIG.3



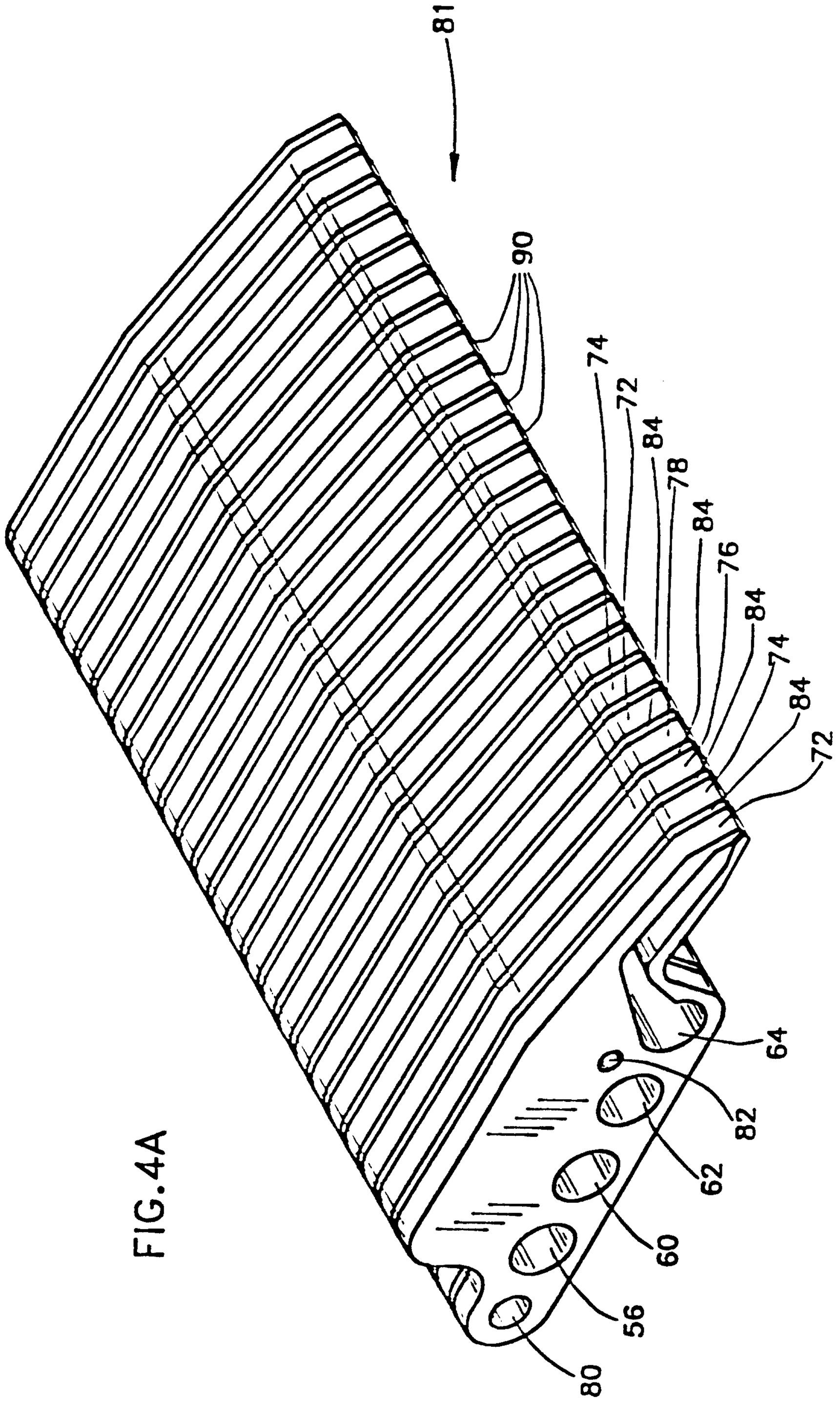


FIG.4A

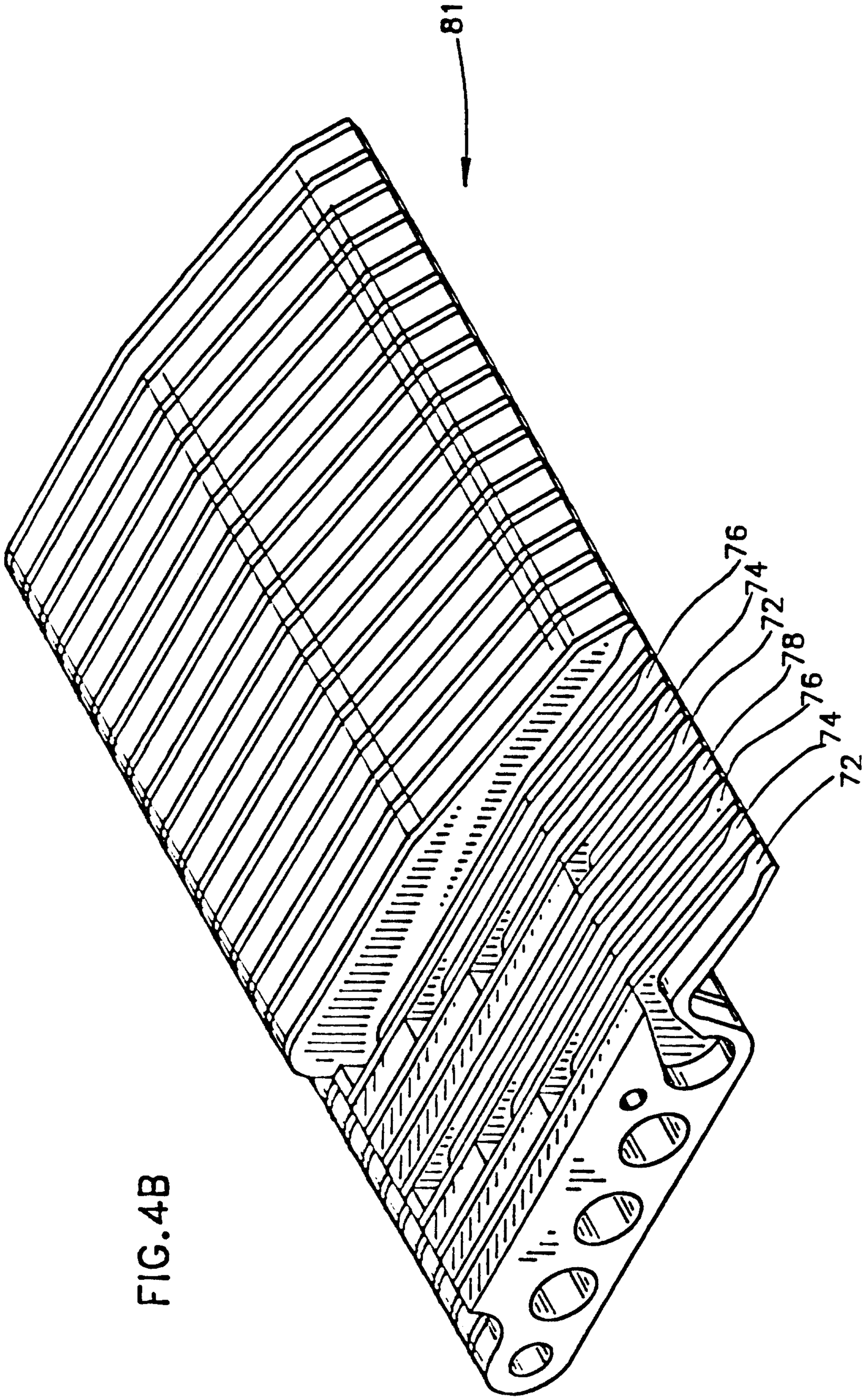


FIG.4B

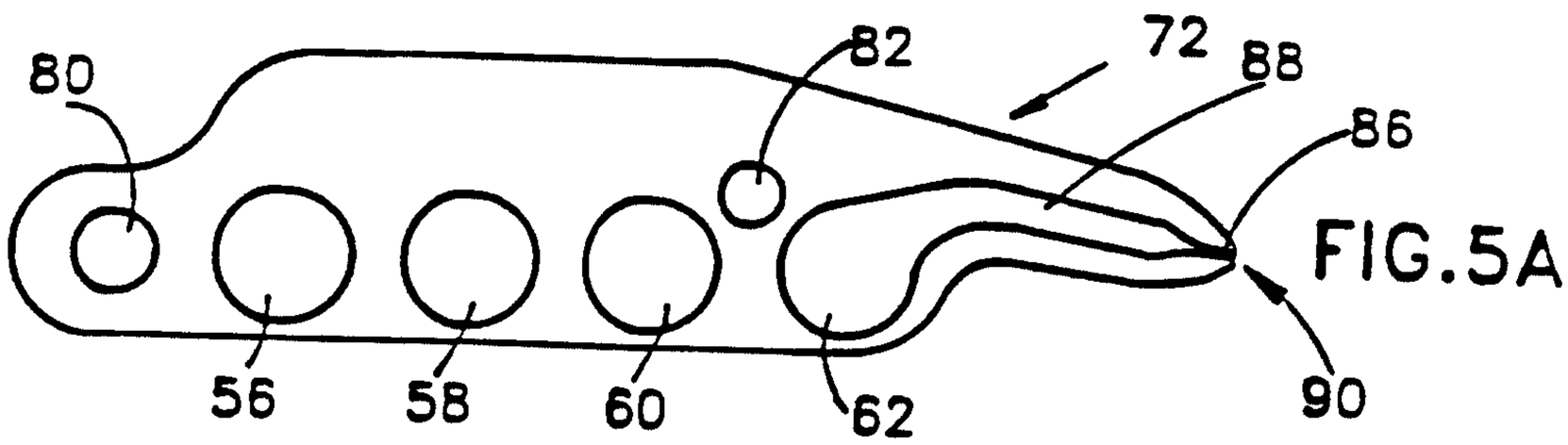


FIG.5A

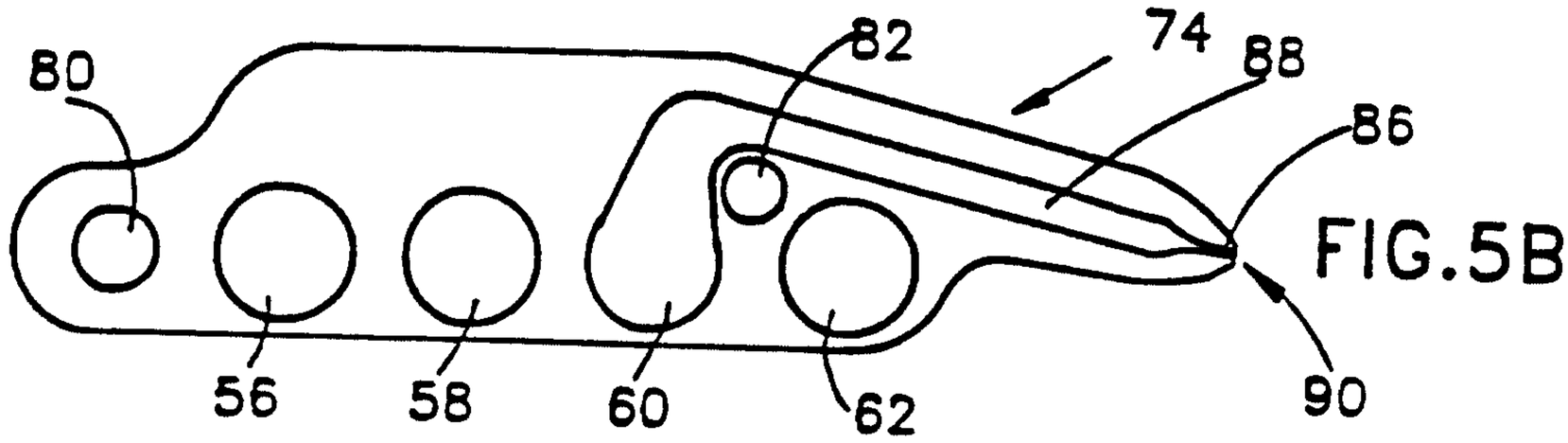


FIG.5B

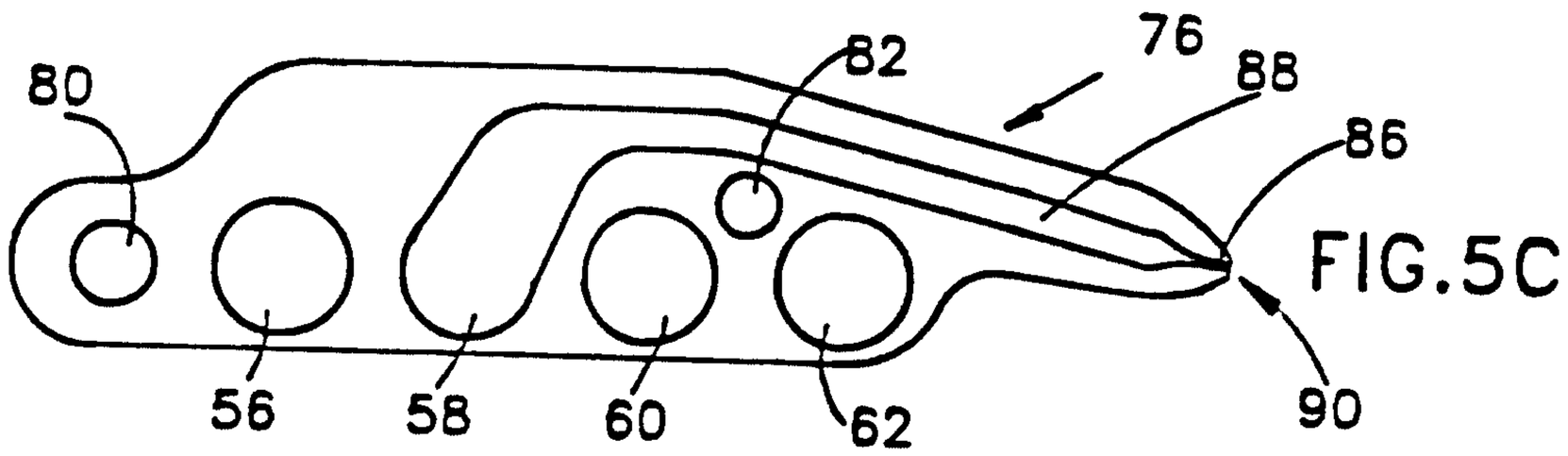


FIG.5C

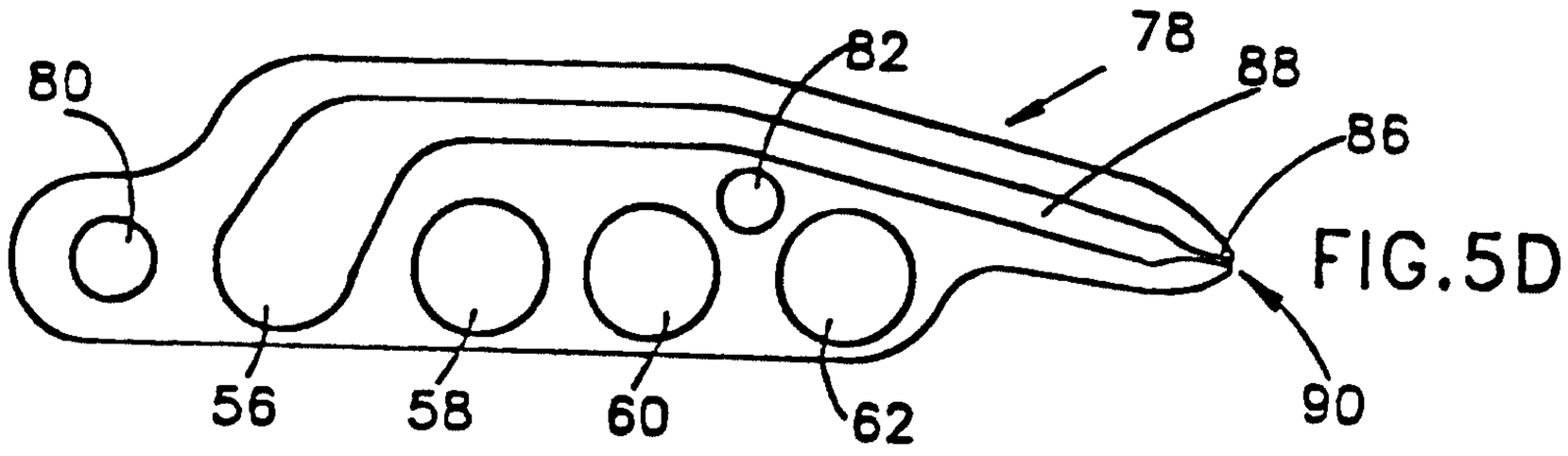


FIG.5D

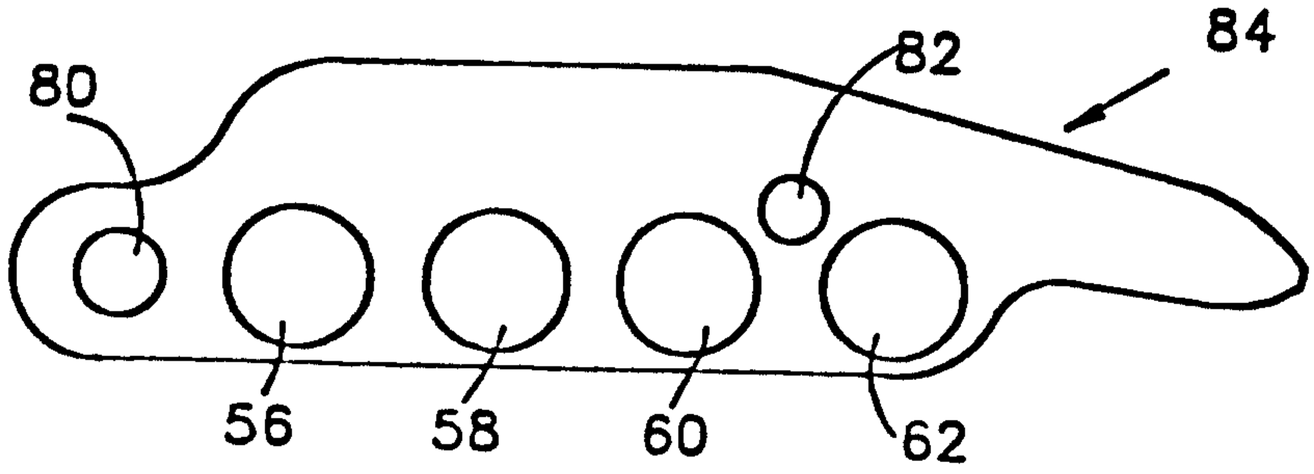


FIG.5E

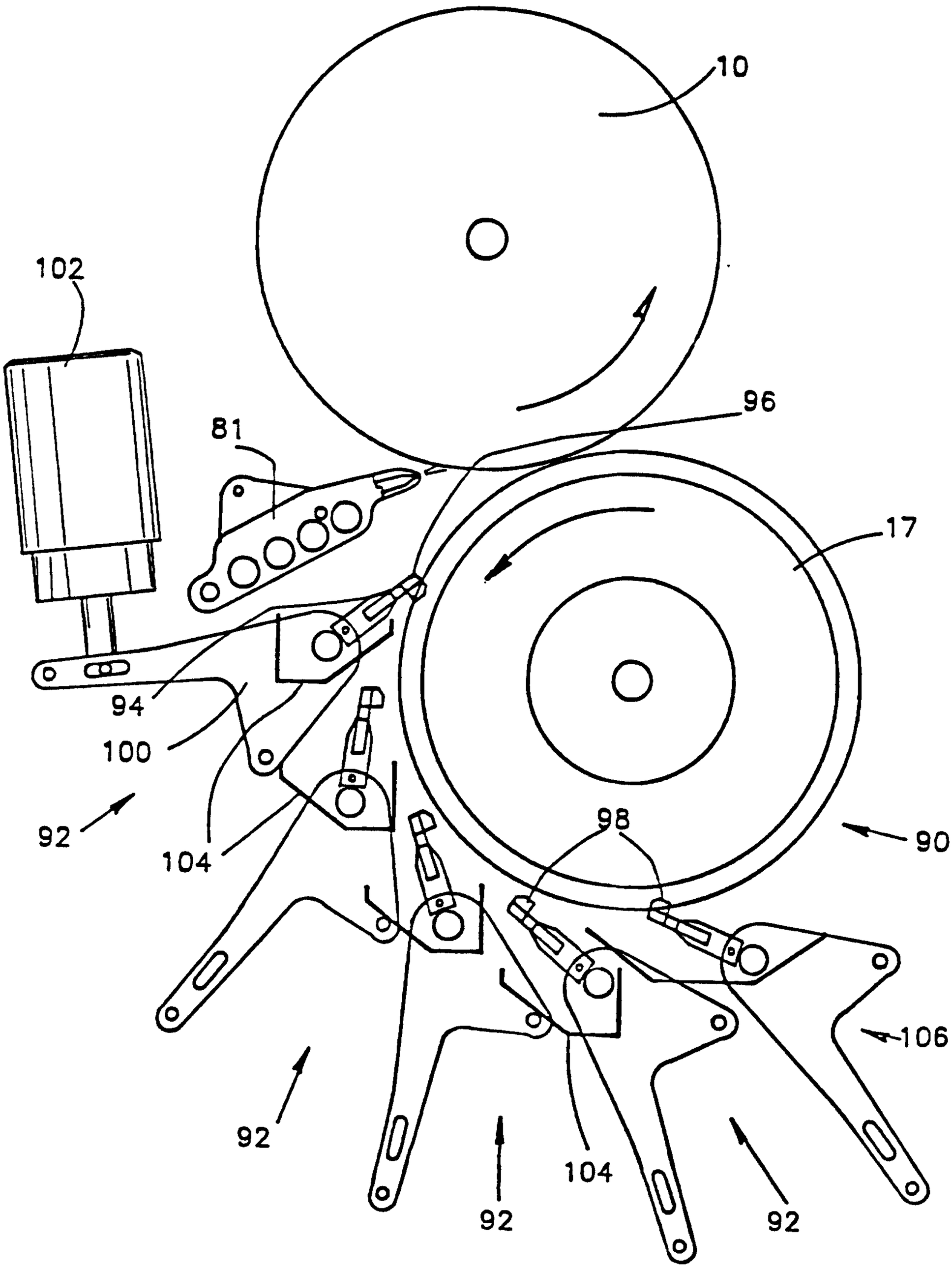


FIG.6

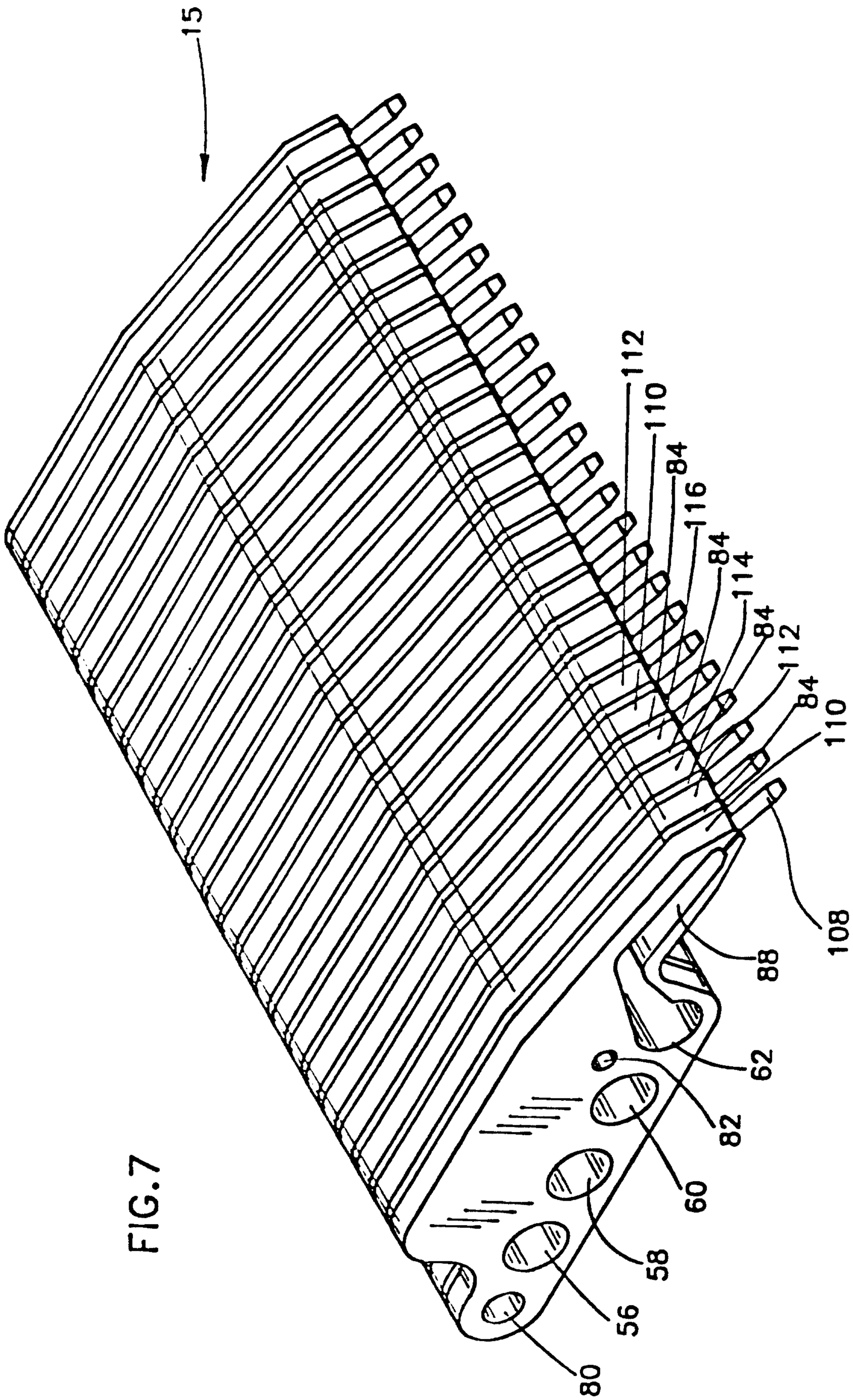


FIG.7

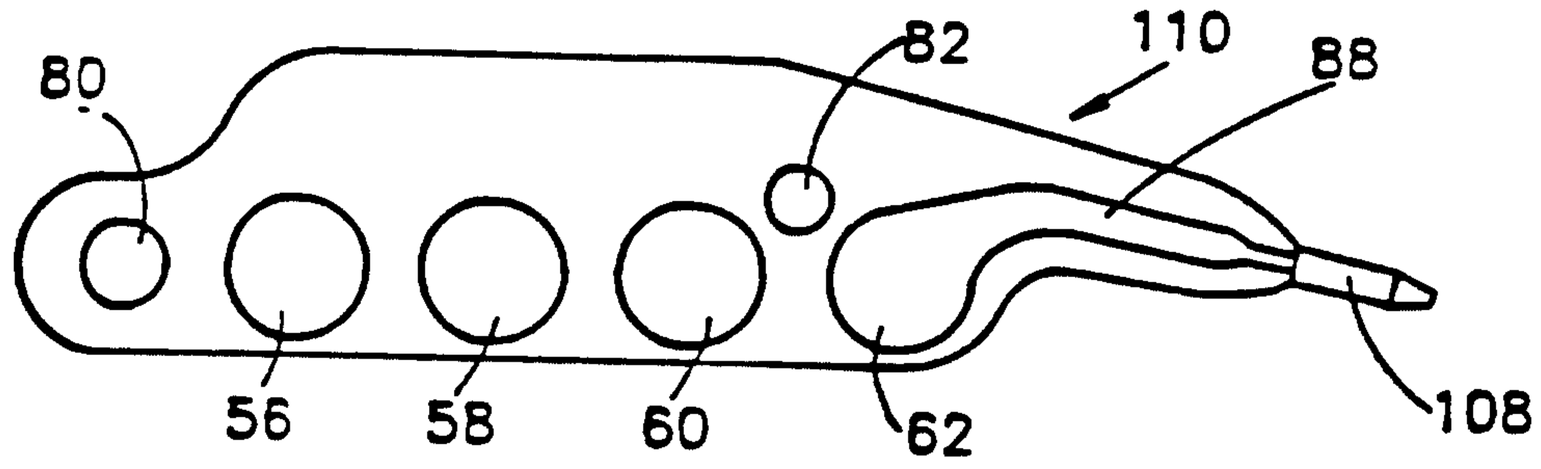


FIG.8A

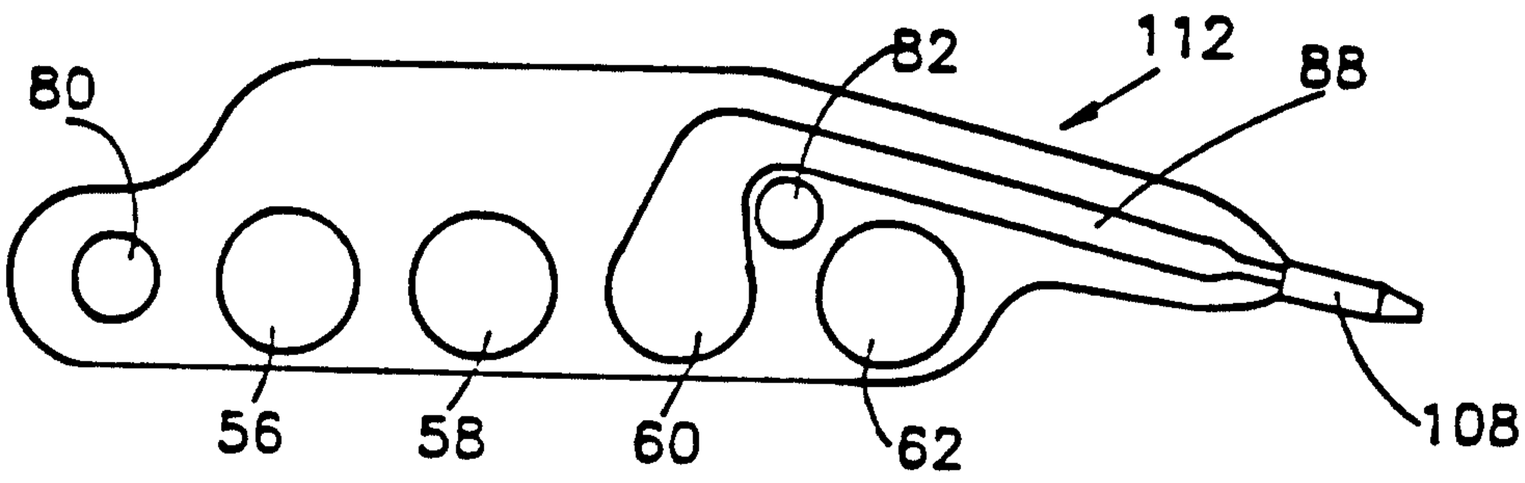


FIG.8B

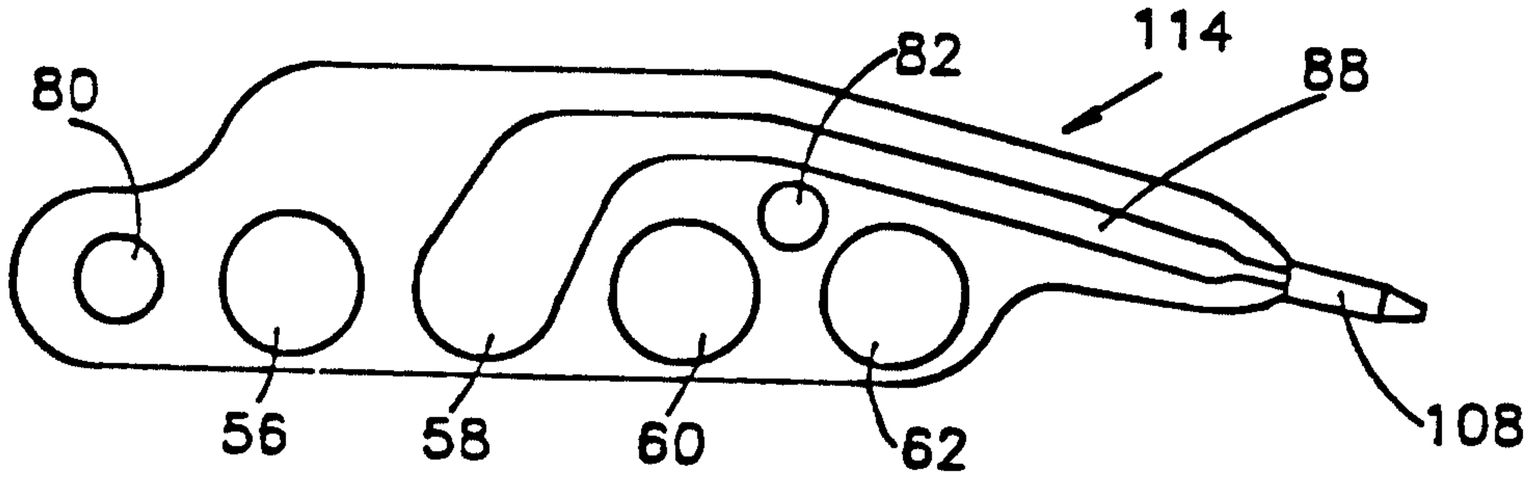


FIG.8C

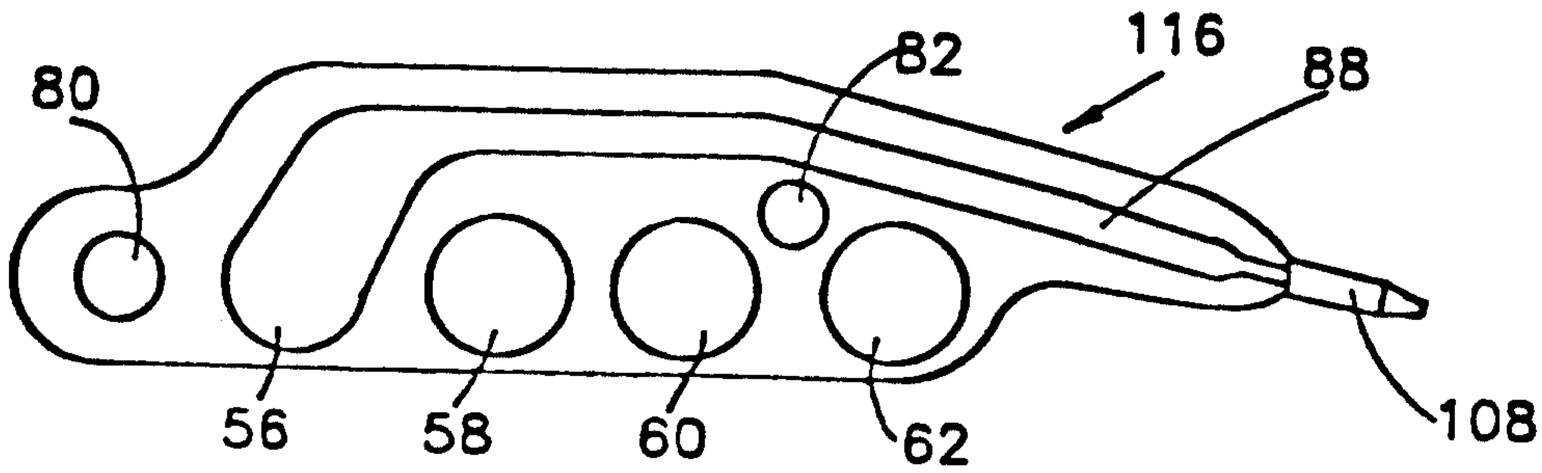


FIG.8D

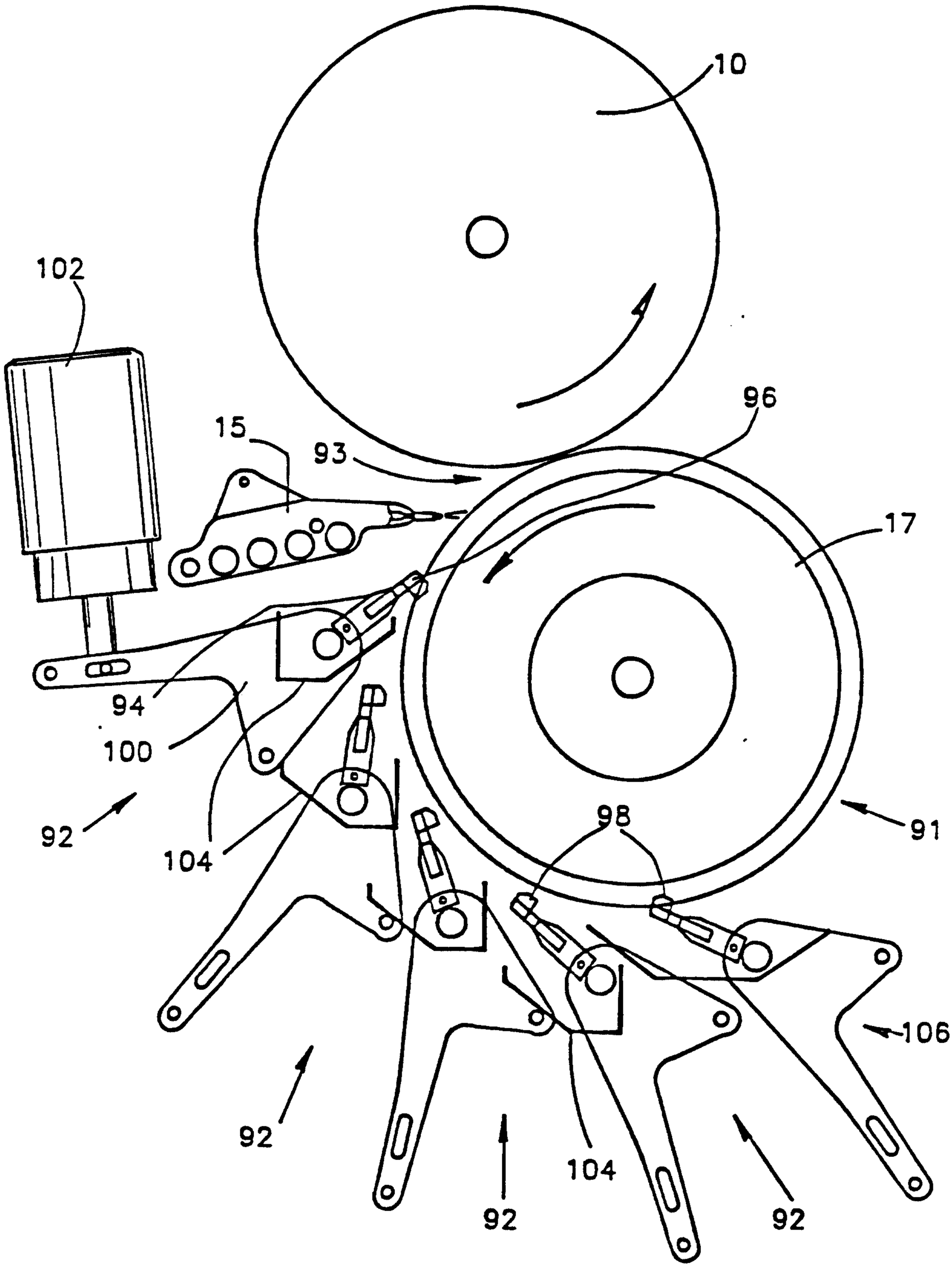


FIG.9

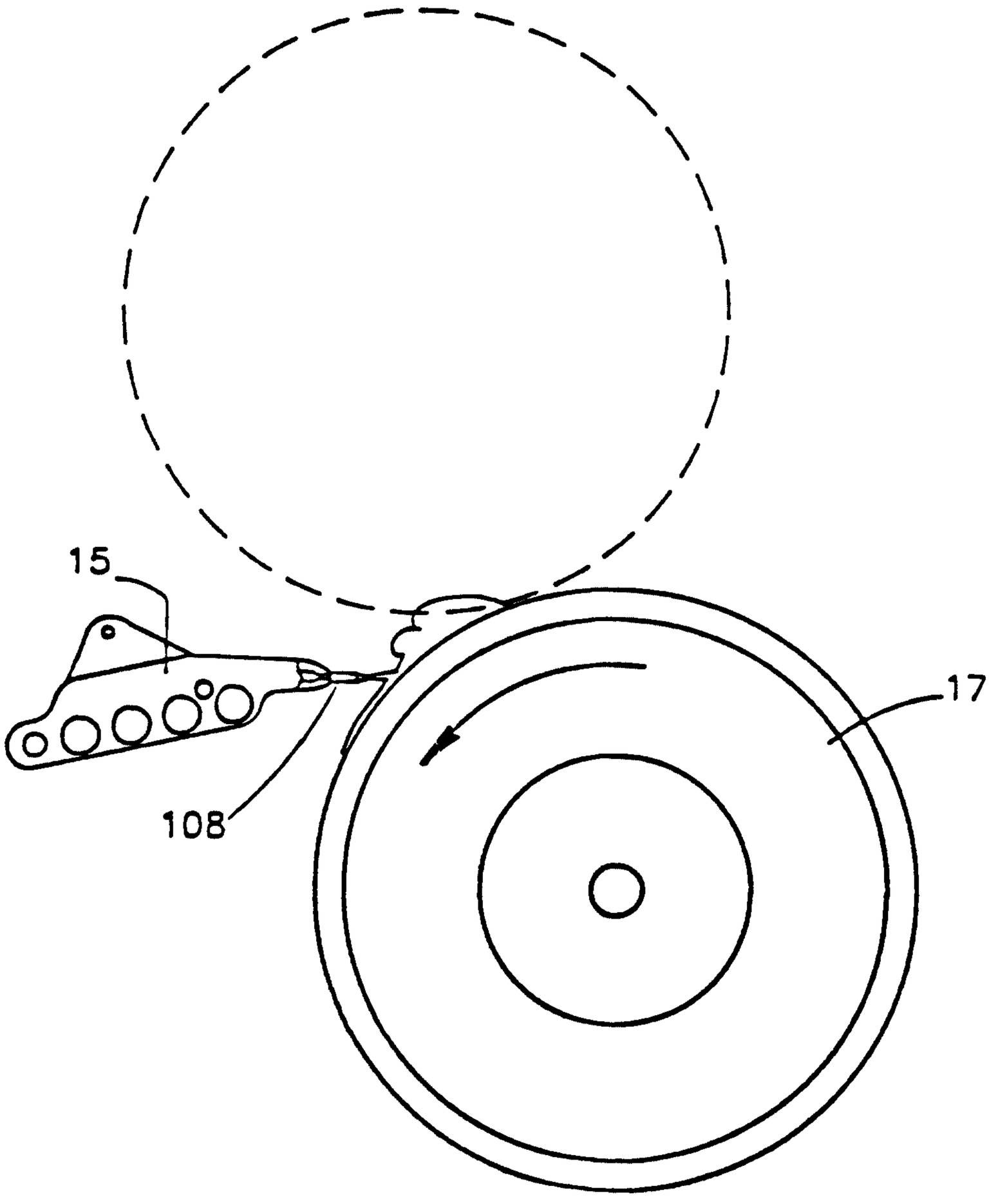


FIG.10

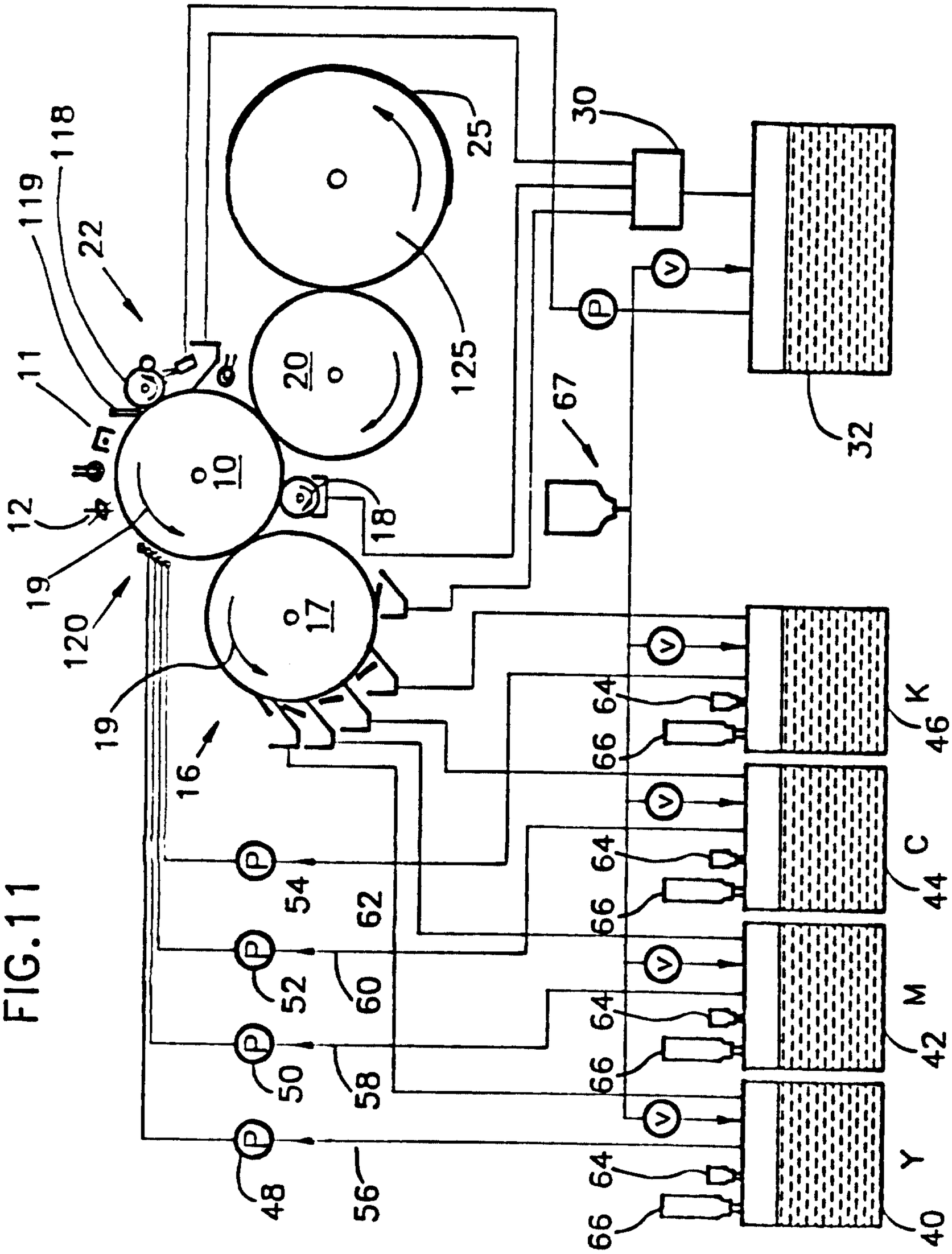

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FIG.11

FIG.12

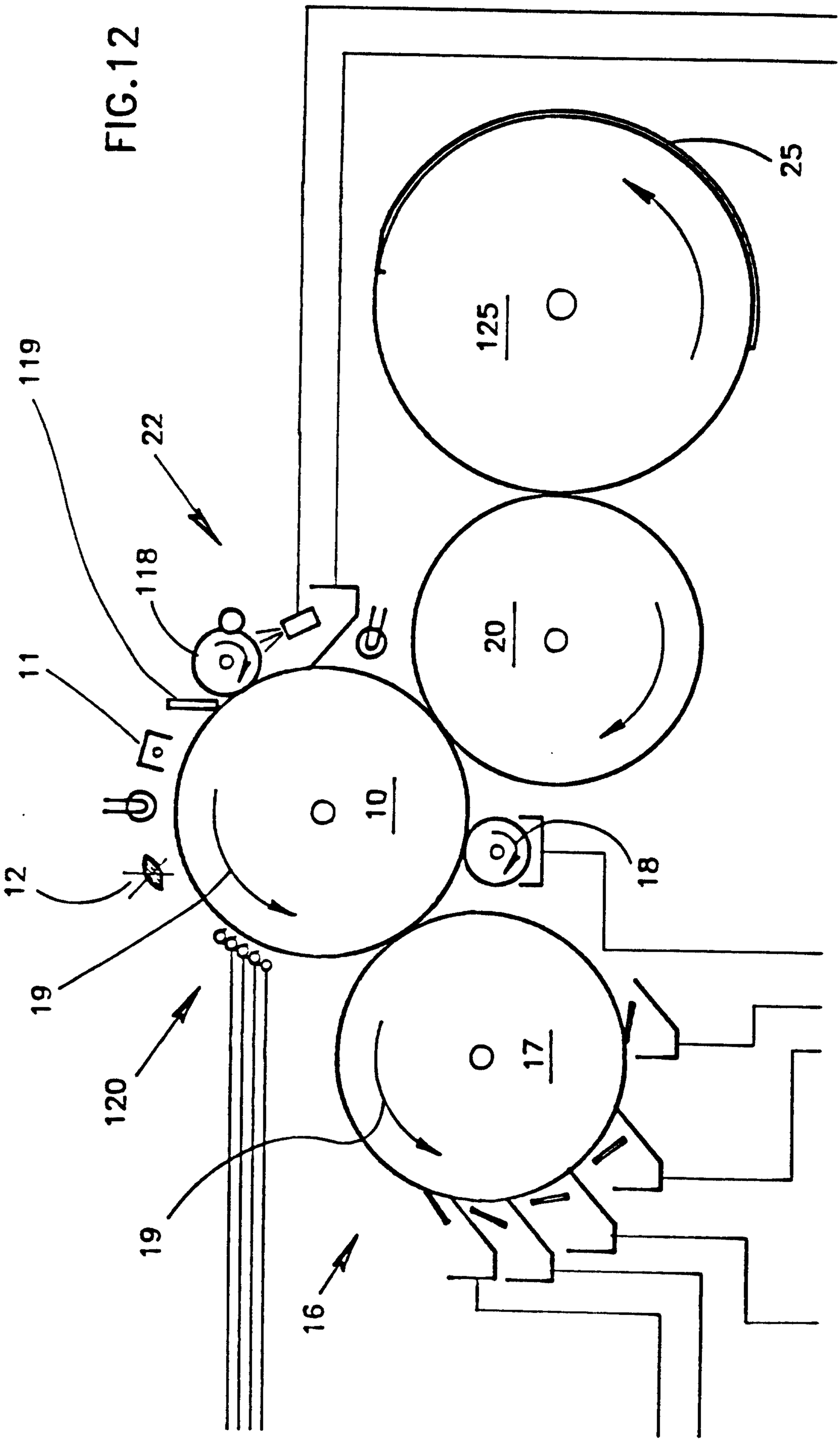


FIG.14

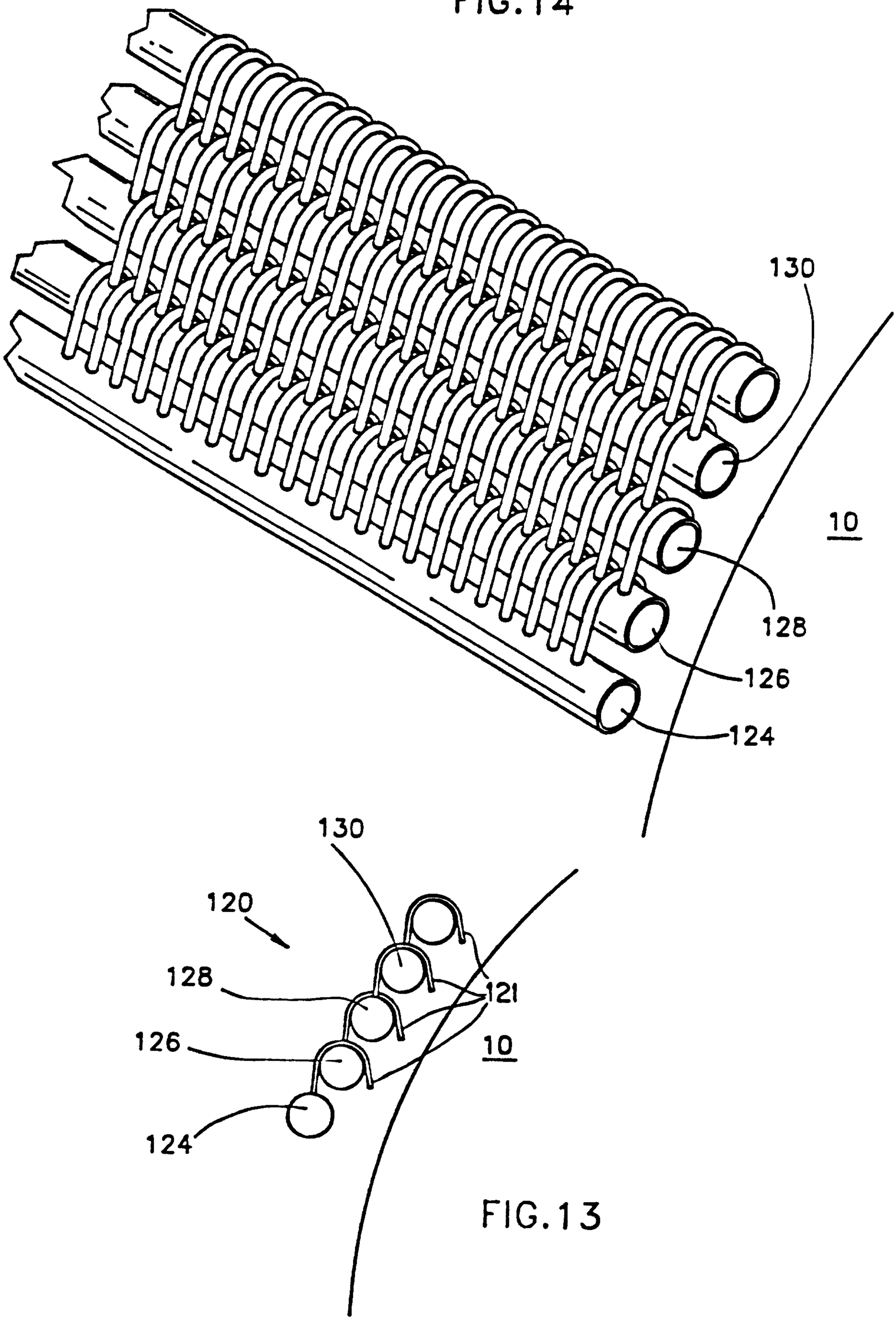
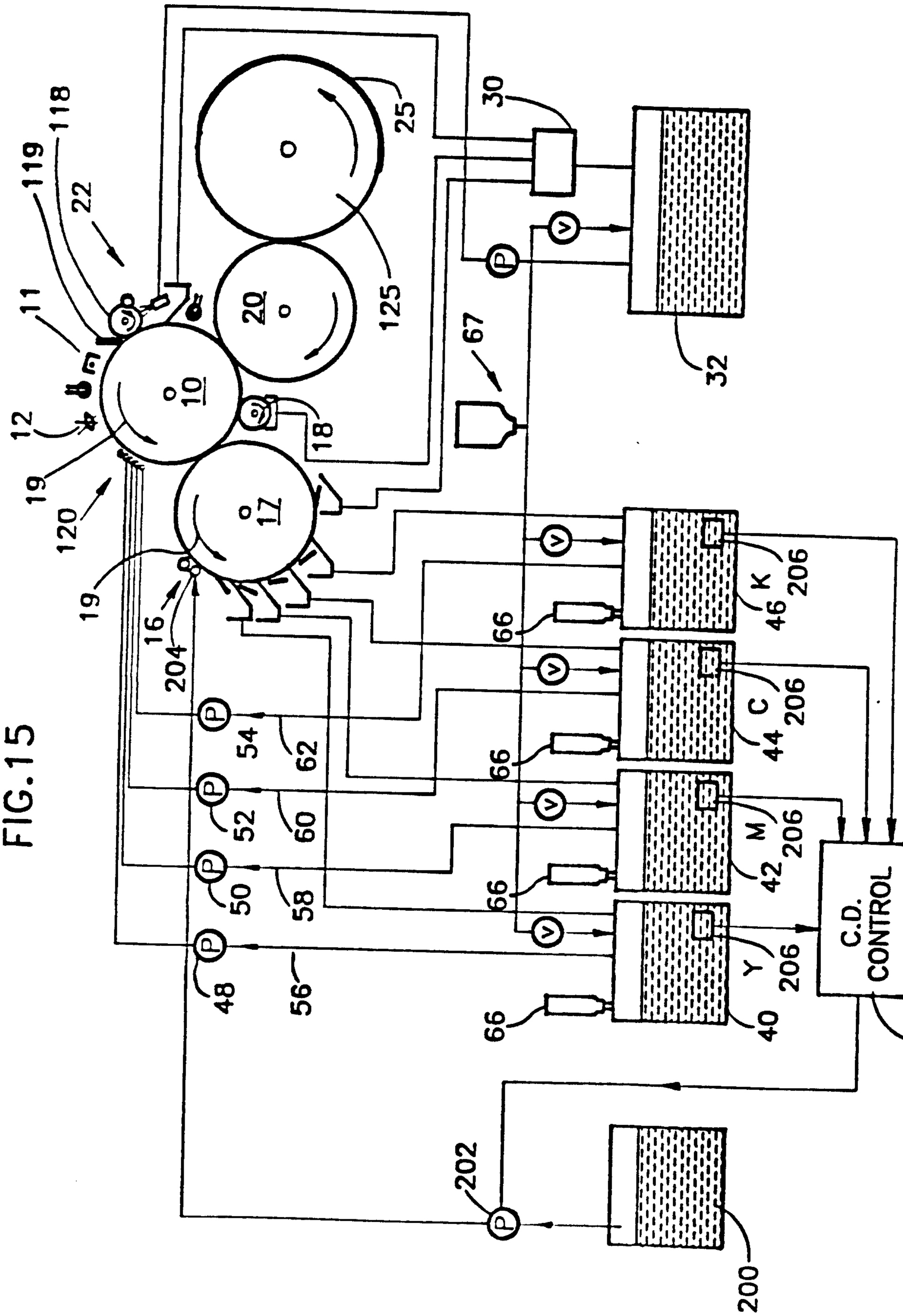


FIG.13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119
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204
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46
K
206
44
C
206
42
M
206
40
Y
206
54
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50
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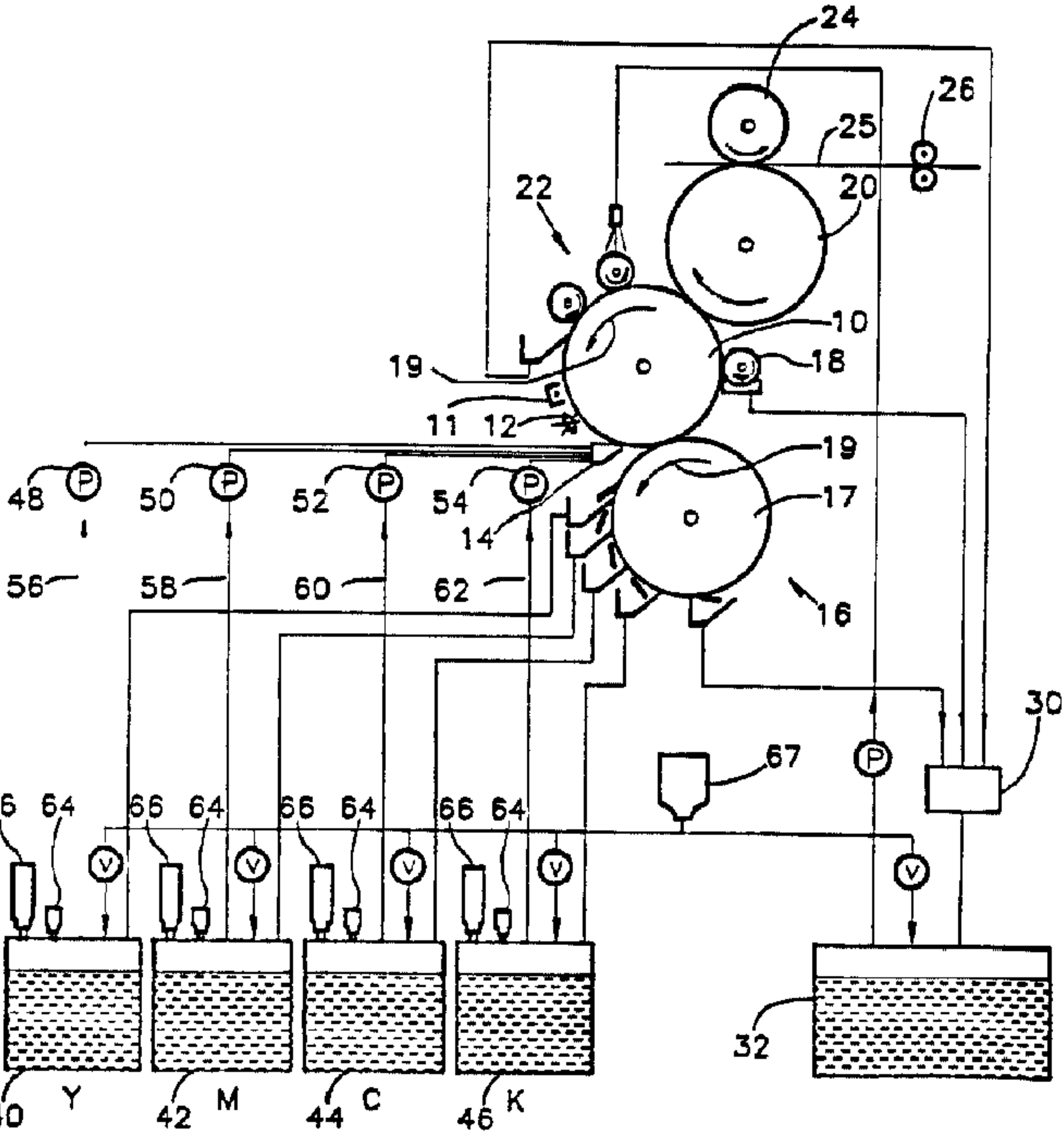
C.D.
CONTROL
208
210 (FROM CLEANING ASSEMBLIES)
202
200

FIG.15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