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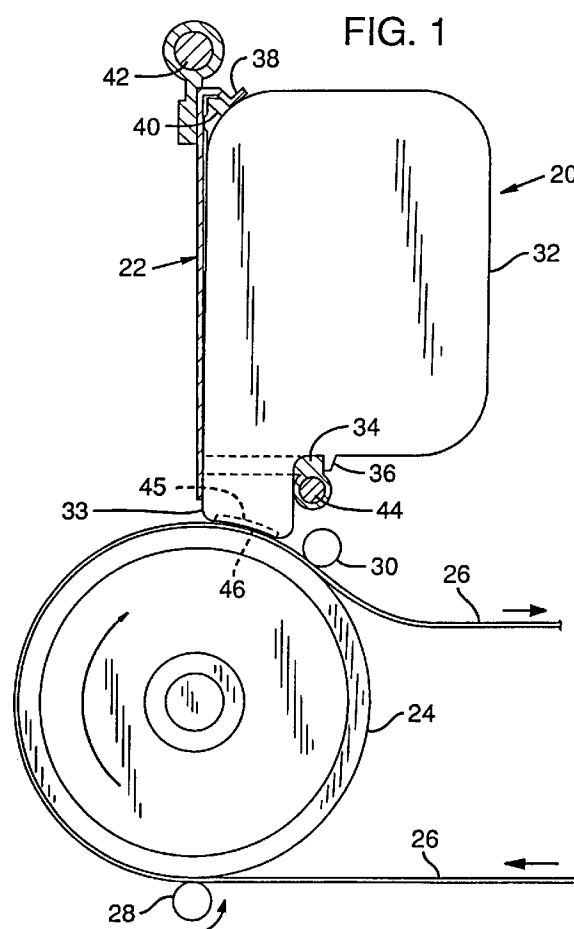
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(54) **Curved print zones in ink-jet printing.**

(57) An ink-jet printer has components that are constructed to define a curved print zone between the print head (45) of the pen (20) and the paper (26). The curved print zone effectively lengthens the zone otherwise provided by straight or flat print zones and provides for greater control of the paper (26) during the printing process.



Background and Summary of the Invention

This invention is directed to ink-jet printing, and particularly to methods and mechanisms for defining a curved print zone, through which zone ink is directed from an ink-jet pen to paper.

Pens used for ink-jet printing are described in numerous publications, including U.S. Patent No. 4,500,895 to Buck et al. The Buck patent describes a printing apparatus having a thermal-type print head in communication with an ink reservoir. The print head is controlled for selectively ejecting ink drops to paper to form an image or characters.

An ink-jet print head may include an outer layer that is designated an orifice plate. The orifice plate includes nozzles or orifices formed at least part-way through it. Ink is delivered from a storage location in the body of the pen through channels formed in the print head to connect with each orifice. Drops of ink are ejected through the orifices toward the adjacent paper or other printing medium.

Mechanisms for controlled ejection of ink drops through an orifice may include a thin-film resistor, which is carried on a print head substrate adjacent to the orifice. Whenever a drop of ink is to be ejected from the orifice, a current pulse is directed to the resistor to ohmically heat the resistor and to vaporize a portion of the ink next to the resistor. The resultant expansion of the ink portion forces a correspondingly sized ink drop through the orifice toward the paper.

One may characterize the region of space that is bounded by the paper and the orifice plate as the print zone of the ink-jet pen. In the past, the mechanisms for moving the paper through the printer and for moving the pen relative to the paper were constructed such that the paper was held in a plane parallel to the plane of the flat orifice plate. Such a print zone, therefore, could be characterized as straight.

This invention is generally directed to an ink-jet printer having components (print head and paper path) that are curved to define a curved print zone. The curved paper path provides for very precise control of the paper motion throughout the print zone. The enhanced control of the paper movement is primarily attributable to the stiffening of the paper that occurs when normally flat paper is bent into a curved configuration, thereby increasing the tension on the convex side of the curved paper. The increased tension in the paper through the curved print zone also tends to minimize cockle, which can be described as any unwanted paper deformation due to wetting associated with the printing operation.

The use of a curved paper path juxtaposed with a correspondingly curved print head also allows for a lengthening (as measured along the arced direction of paper travel) of the print zone over what was heretofore available with prior, straight, print zone arrangements.

A longer print zone can increase the printer performance in a number of ways. For example, the curved orifice plate can be lengthened to match the increased length of the print zone, thereby providing space on the orifice plate for an increased number of orifices for ejecting ink; hence, increased printer throughput (that is, the printer speed, commonly designated in paper sheets per minute).

With or without additional orifices, the rated throughput of the printer having a curved, lengthened print zone may remain undiminished even when a shingled printing technique is employed to improve graphics quality. In the past, shingled printing was achieved by turning off some orifices during printing. With the implementation of a longer print zone available as a result of the present invention, the print head nozzles can be arranged for shingled printing that uses all nozzles, hence enabling the use of this printing technique to improve graphics quality at the full rated throughput of the printer.

Color printing may be accomplished by arranging four pens, each having a particular ink color (cyan, magenta, yellow and black), and depositing the colored ink in the correct combination to produce on the paper the desired color by subtractive color mixing. Such mixing properly occurs when ink from one color substantially dries before ink of another color is added. If a subsequent ink color is added before the preceding color dries, undesirable bleeding between colors can take place.

The lengthened print zone available as a result of the present invention permits the colored-ink pens to be arranged so that the sets of orifices associated with each color can be spaced-apart over the entire length of the print zone, thereby extending the drying time between deposition of different ink colors for the purpose of eliminating the bleed problem just described.

It is contemplated that many, if not all, of the advantages mentioned above will also arise as a result of providing the curved paper path in the vicinity of a conventionally flat print head.

Brief Description of the Drawings

Fig. 1 is a diagram showing from the side an ink-jet pen having a curved print head that is carried adjacent to a curved paper path, thereby defining a curved print zone.

Fig. 2 is a perspective view of the pen and paper in the relationship depicted in Fig. 1.

Fig. 3 is an exploded perspective view of a pen showing the primary components that assemble into an ink-jet pen having a curved surface in the region of the print head.

Fig. 4 is an enlarged sectional view of part of a print head formed in accordance with the present invention.

Fig. 5 is an enlarged sectional view of the substrate component of the print head of Fig. 4.

Fig. 6 is a diagram showing from the side a curved print zone defined by a curved paper path and adjacent pens that have curved print head surfaces.

Fig. 7 is a perspective view of the four-pen arrangement of Fig. 6.

Fig. 8 is a diagram showing from the side a pen and paper path arrangement wherein the print zone is concave curved.

Fig. 9 shows in perspective the four-pen and paper path arrangement of Fig. 8.

Detailed Description of Preferred Embodiments

The diagrams of Figs. 1 and 2 depict components of an ink-jet printer that are constructed and arranged in accordance with the present invention to define a curved print zone. Specifically, the ink-jet pen 20 is supported by a carriage 22 for reciprocal movement in a direction perpendicular to the plane of Fig. 1. The pen 20 moves adjacent to a cylindrical guide roller 24. Normally flat sheets of paper 26 are successively fed such that the paper edges pass through the nip defined by lower pinch rollers 28 and the guide roller 24. The paper 26 is carried along the surface of the guide roller and exits between the upper pinch rollers 30 and the guide roller 24. The rollers are arranged so that in the vicinity of the pen 20 the exposed surface 21 of the paper is convexly curved, thereby stiffening the paper 26.

The upper pinch rollers 30 are, preferably, slightly frustum shaped and arranged so that the diameter of each roller decreases in the direction of the lateral edge of the paper, thereby to provide a lateral tension force component to the paper (that is, in the direction perpendicular to paper travel) as the paper moves between the rollers 24, 30. This force component further stiffens the paper in the vicinity of the pen. Other roller configurations, such as rollers having helical patterned contact surfaces, may be employed for increasing lateral tension in the paper.

It will be appreciated by one of ordinary skill in the art that any of a number of mechanisms other than those shown may be employed for defining and controlling the curved path of the paper through the printer in the vicinity of the pen.

The pen 20 includes a body 32, the upper portion of which defines a reservoir for storing ink. A nose portion 33 protrudes from the body 32. The body 32 fits into the carriage 22 that is controlled to provide the reciprocal motion mentioned above. The carriage 22 includes a feature 34 that fits between the pen nose 33 and a protruding rib 36 formed in the underside of the pen body 20. A spring latch 38 that is attached to the carriage 22 snaps against a protrusion 40 in the upper part of the pen body 32 to secure the pen 20 to the carriage 22. The reciprocal motion of the

carriage 22 is guided by elongated rigid rods 42, 44 that are slidably engaged by the carriage.

It will be appreciated by one of ordinary skill in the art that any of a plurality of carriage constructions and conventional drive mechanisms may be employed for supporting and moving the pen 20 relative to the paper path.

With particular reference to Figs. 3-5, the pen 20 comprises of generally box-shaped body 32 for holding a supply of ink. The internal reservoir of the pen body may be hollow, or filled in part or completely with open-cell foam as described in U.S. Patents Nos. 4,771,295 to Baker et al., and 4,794,409 to Cowger et al. Ink from the reservoir is supplied to a print head 45 that is attached to the underside of the nose 33. The outer surface 46 of the print head 45 is concave curved and faces the paper surface 21 that is moved past the pen 20.

Referring to Figs. 4 and 5, the print head 45 includes a gold-plated nickel orifice plate 48 that has formed in it a plurality of orifices, one of which 50 is shown greatly enlarged in Fig. 4. The orifice plate 48 may be formed by a conventional electrodeposition technique on a mandrel that is curved to define on the outer surface 46 of the plate 48 a concave curve, of about 3 mm to 30 mm radius.

The orifice plate is bonded to a barrier layer 51 formed of polymer, such as that manufactured by DuPont under the trademark Vaclel. An ink channel 52 is etched into the barrier layer 51 contiguous with the orifice 50 for delivering by capillarity ink from the reservoir to the orifice. Each orifice 50 of the plurality of orifices in the orifice plate 48 is formed to be contiguous with an ink channel 52 for supplying the ink to the orifice.

A heater 54 including a tantaluminum planar resistor element 56 and connected gold or aluminum leads 58, is centered adjacent to the orifice 50. Electric current supplied through the resistor 56 via leads 58 heats the portion of the ink adjacent the heater 54, thereby rapidly vaporizing that portion, the resultant expansion propelling a drop of ink out of the orifice 50 as mentioned above. A passivation layer 60 overlies the resistor 54 to protect it from corrosion by the ink.

The heater 54 is supported on a multi-layer substrate 62, which is shown in enlarged detail in Fig. 5. The substrate 62 includes a plastic base 64, preferably formed of a polyimide sheet, such as the Kapton product manufactured by DuPont. The base may be made of any required thickness, preferably from about 25 micrometers to about 3000 micrometers thick. A metalization layer 66 overlies the base 64. The metalization layer is preferably from about 50 angstroms to about 1000 angstroms thick. The metalization aids in bonding the overlying structure to the base 64 and, to some extent, to serve as a heat sink.

A dielectric structure 68 overlies the metalization layer 66. The dielectric structure 68 includes a dielec-

tric layer 70 of material that has low electrical conductivity, such as aluminum oxide. The dielectric layer is preferably from about 0.1 to about 10 micrometers in thickness. Between the dielectric layer 70 and the metalization layer 66 is a buffer layer 72. The buffer layer 72 is preferably a layer of titanium between about 700 to about 3000 angstroms thick. The buffer layer buffers the high tensile strain of the metalization layer 66, thereby preventing cracking of the dielectric layer.

The substrate base 64 is held on a surface or mandrel that is curved to match the desired curvature of the print head, and the metalization layer 66, buffer layer 72 and dielectric layer 70 are successively deposited in a continuous fashion as by sputtering or vapor deposition, or by electroplating or electroless deposition for the metallic layers. The resistor element 56 layer is then applied to the prepared substrate material, followed by masking and deposition to produce the electrical leads 58. The resulting assembly is then bonded to the barrier layer 51 that underlies the orifice plate 48.

The print head 45 is installed, such as with thermal-cure epoxy adhesive, into a correspondingly shaped recess in the underside of the nose 33 of the pen. The recess is shaped so that the curved surface 46 of the print head is flush with the undersurface of the nose 33 of the pen body.

A flexible circuit 80 is bonded to the exterior surface of the end body 32 (Fig. 3). The flexible circuit generally comprises a thin, flexible plastic strip, preferably a polyimide, that is mounted to the exterior of the pen. The side of the strip that faces the pen body as permanently bonded to it a number of conductive copper traces (not shown). Each trace connects at one end with a lead 58 on the print head, the other end of each trace terminates in a contact pad 82 on the opposing side of the strip. The contact pads 82 on the circuit connect with contacts carried on a ribbon-type multiconductor that terminates at the carriage 22. Accordingly, when the pen 20 is mounted to the carriage, signals for driving the individual heaters 54 for each orifice 50 are generated by a microprocessor and associated drivers that apply the signals to the resistors via multiconductor and the traces in the flexible circuit 80.

Figures 6 and 7 show an arrangement wherein pens having concave orifice plates as described above are provided, for example, to permit color printing with four pens, each pen carrying a color suitable for subtractive color mixing. The four ink-jet pens 20 may be mounted to a carriage 122. The carriage 122 includes a pair of spring latches 138 and features 134 for securing the pens as shown for reciprocal movement along guide rods 142, 144.

Figure 8 depicts a pen 220 that is constructed generally along the lines described with respect to the pen 20, except that the underside of the pen nose 233

and its connected print head 245 are shaped to define a convex outer surface. Such a pen may be carried either alone, as shown in Fig. 9, or in a combination of four pens, by a carriage adjacent to paper 226. The path of the paper is defined to be concave in the vicinity of the print head 245.

Figures 8 and 9 shows one embodiment for controlling the paper path to define the concave shape, including paper-edge guides 223 that cooperate with an endless belt or tractor-type feed mechanism 225 at each edge of the paper for moving the paper through the printer. It will be appreciated that the resultant curved print zone, in this latter embodiment being concave shaped, provides the same advantages as earlier described with respect to the convex shaped print zone.

While having described and illustrated the principals of the invention with reference to the preferred embodiments and alternatives, it should be apparent that the invention can be further modified in the arrangement and detail without departing from such principals. Accordingly, it is understood that the present invention includes all such modifications that come within the terms of the following claims and equivalents thereof.

Claims

1. A printing assembly for a printer, comprising:
 - a pen body (32) defining a region to which may be attached a print head (45);
 - a print head (45) attached to the region of the body (32) and including an outer surface (46) in which there is formed orifices (50), the surface being curved; and
 - delivery means for delivering the stored ink to and out of the orifices (50).
2. The assembly of claim 1 further comprising paper (26) path means for moving paper (26) past the print head (45) in a manner to curve the path taken by the paper (26) as the paper (26) moves adjacent to the print head.
3. The system of claim 2 wherein the outer surface (46) of the print head (45) is curved by an amount that substantially matches the amount of curvature of the paper (26) adjacent to the print head.
4. The system of claim 3 wherein the outer surface (46) is concave.
5. The system of claim 3 wherein the outer surface (46) is convex.
6. The system of claim 2 further comprising:
 - a second pen (20) having a body (32), the

second pen being mounted adjacent to the first-mentioned pen in the direction of the paper (26) path;

a second print head (45) attached to the second pen body (32) and having an outer surface (46), the outer surface of the second print head (45) having orifices (50) formed therein through which ink may be projected; and wherein the printer means further selectively projects drops of ink through the orifices (50) in the second print head.

7. The system of claim 2 wherein the paper (26) path means includes tensioning means for applying lateral tension to the paper (26) in the vicinity of the print head (45).
8. A method of manufacturing a print head (45) for an ink-jet pen (20) comprising the steps of:
 - providing a pen body (32);
 - constructing a print head (45) to have a curved outer surface (46) through which curved surface there is formed orifices (50); and
 - attaching the print head (45) to the pen body (32) so that ink may flow through the print head and out of the orifices (50) in the outer surface (46) of the print head.
9. The method of claim 8 wherein the constructing step includes shaping the print head (45) to have a concavely shaped outer surface (46).
10. The method of claim 8 wherein the constructing step includes shaping the print head (45) to have a convexly shaped outer surface (46).

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FIG. 1

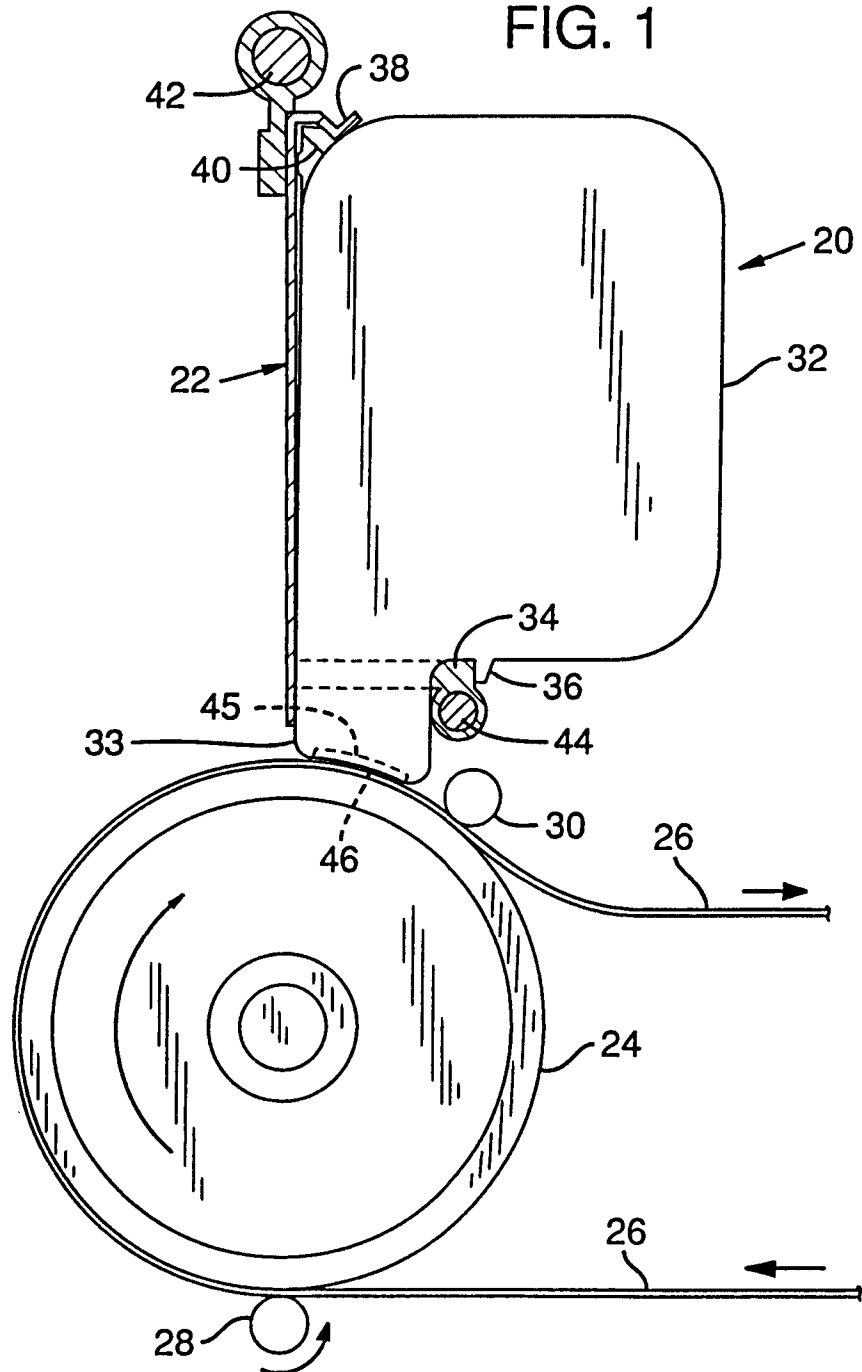


FIG. 2

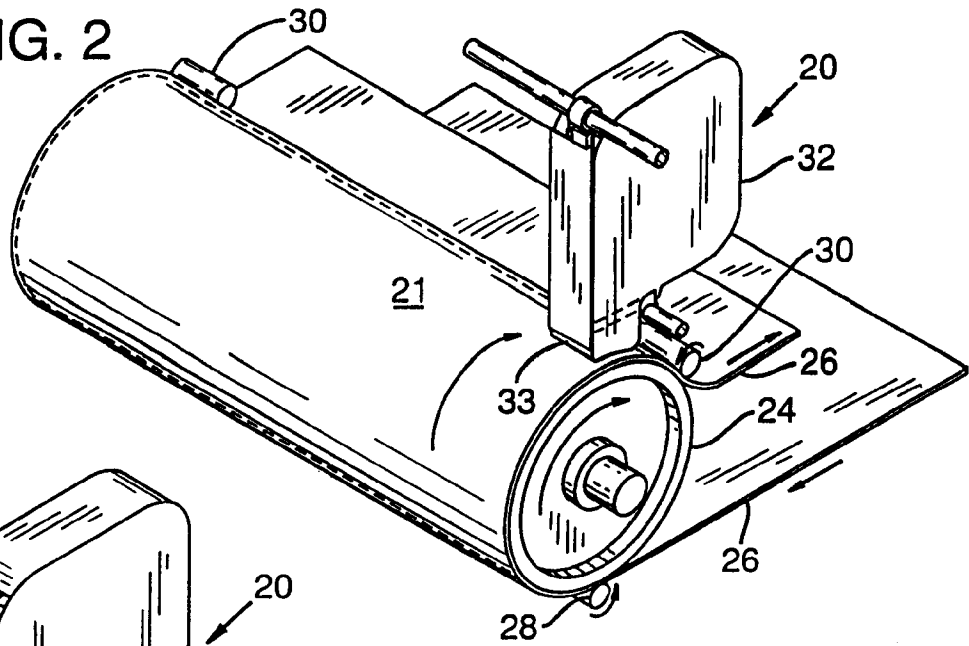


FIG. 3

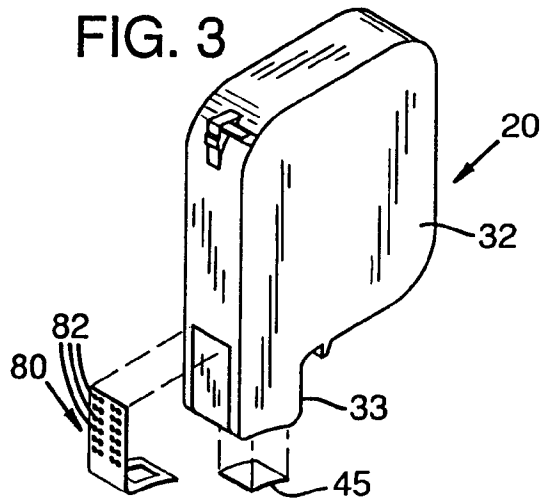
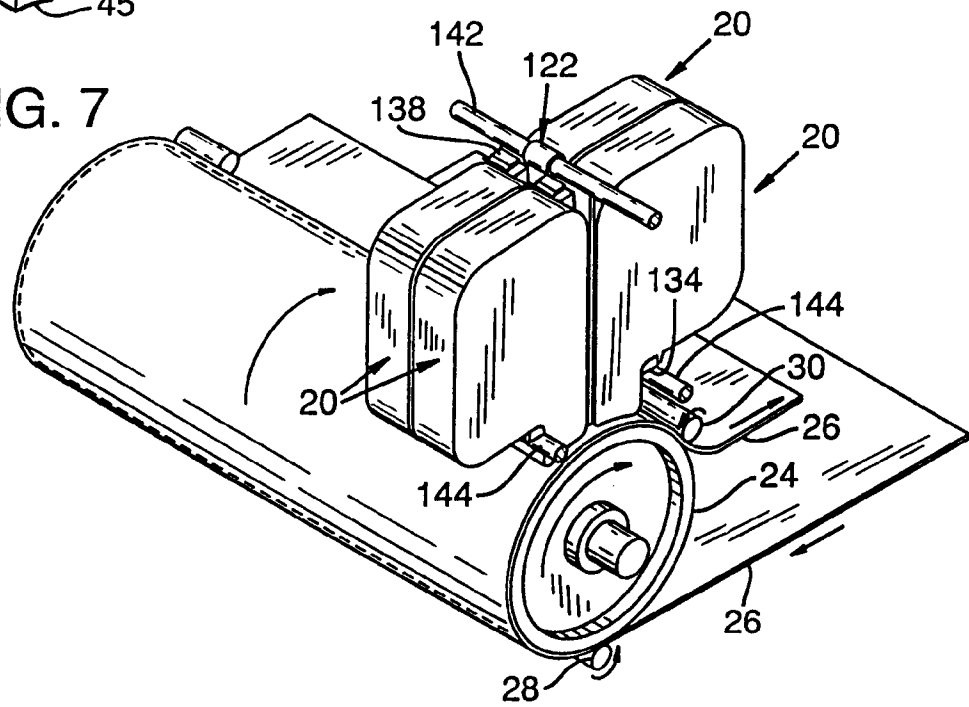
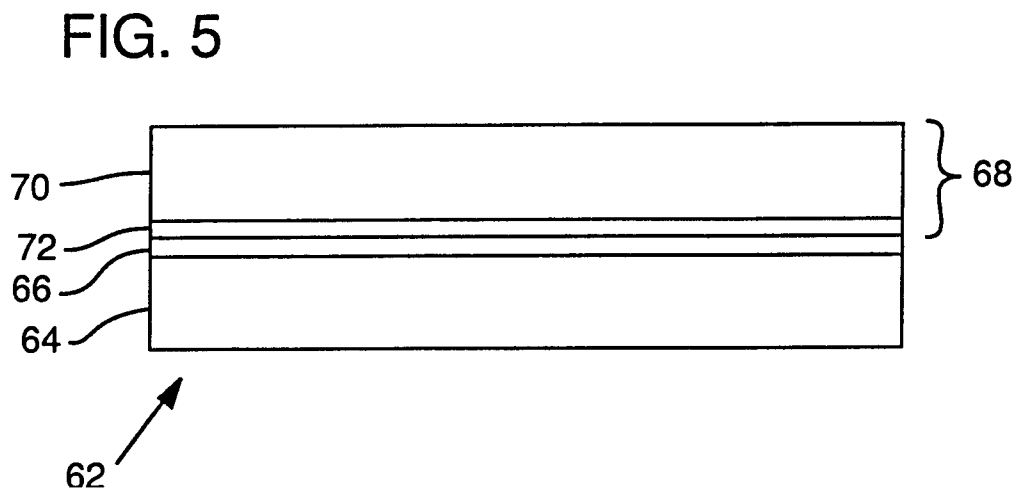
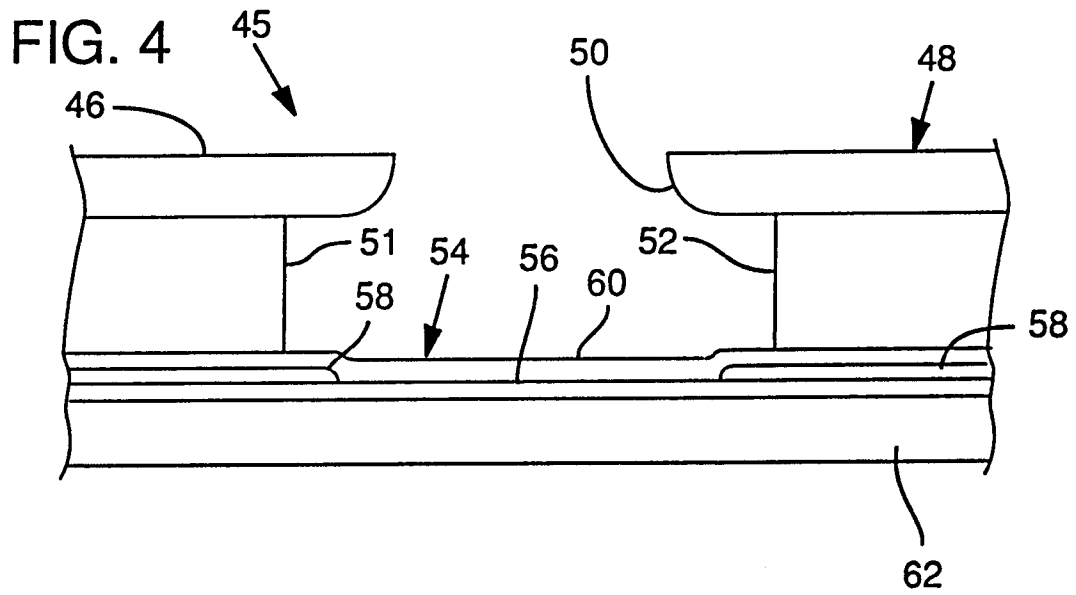


FIG. 7





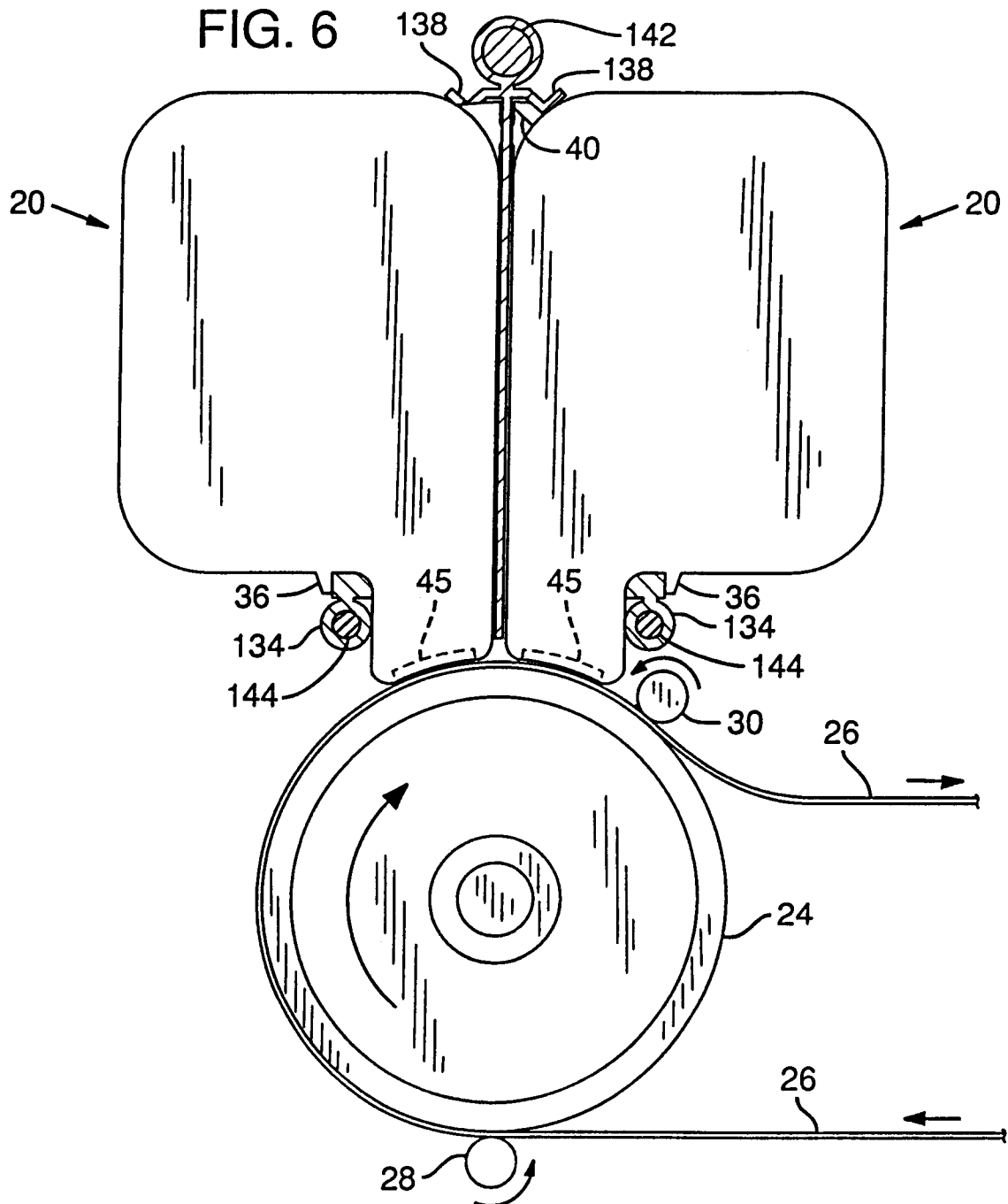


FIG. 8

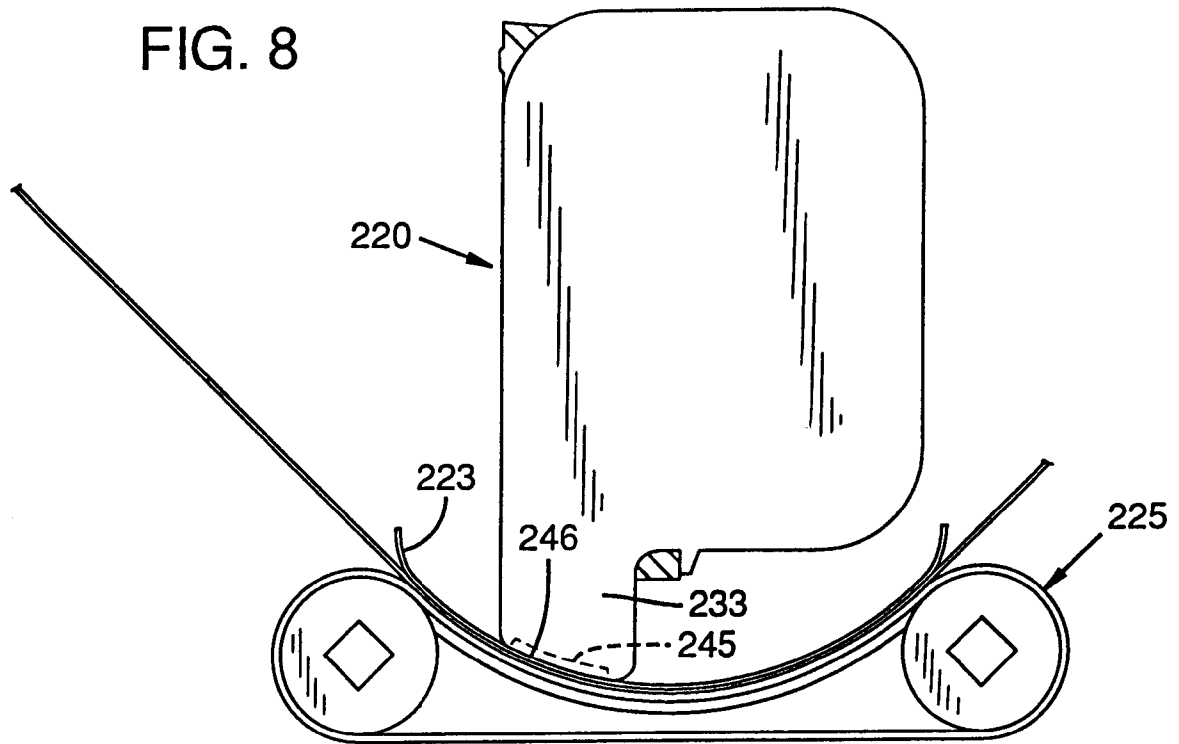


FIG. 9

