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- [57]
- ABSTRACT**

- An ink cartridge for an ink jet printing apparatus wherein ink jets ("Spritzers") are mounted at the periphery of a rotationally driven disc member and a recording medium is guided past an arcuate portion of the periphery of the disc member at a proximate distance therefrom. The cartridge has the form of a disc and includes magnetostrictive ink jets mounted at the periphery of the disc and an ink reservoir within the disc communicating with the ink jets to supply ink to the ink jets. The ink jets are operable in response to a magnetic field coupled to the ink jets. The ink cartridge is adapted to be removably mounted on a turntable. The turntable includes magnetic field elements coupled to electrical control signals manifesting printing information for inducing a magnetic field in the magnetostrictive ink jets to operate the ink jets in response to the electrical control signals.

- [21] Appl. No.: 456,127

- May 21, 1973 Great Britain 24139/73

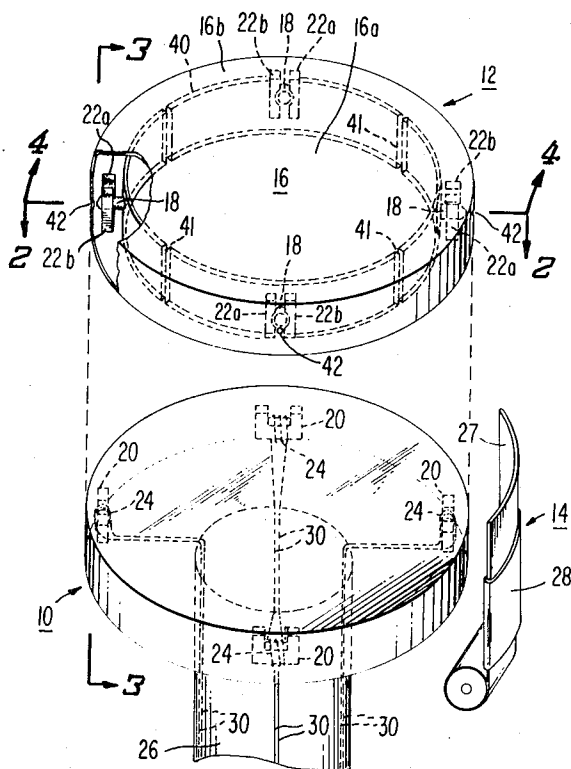
- [51] Int. Cl. G01d 15/18

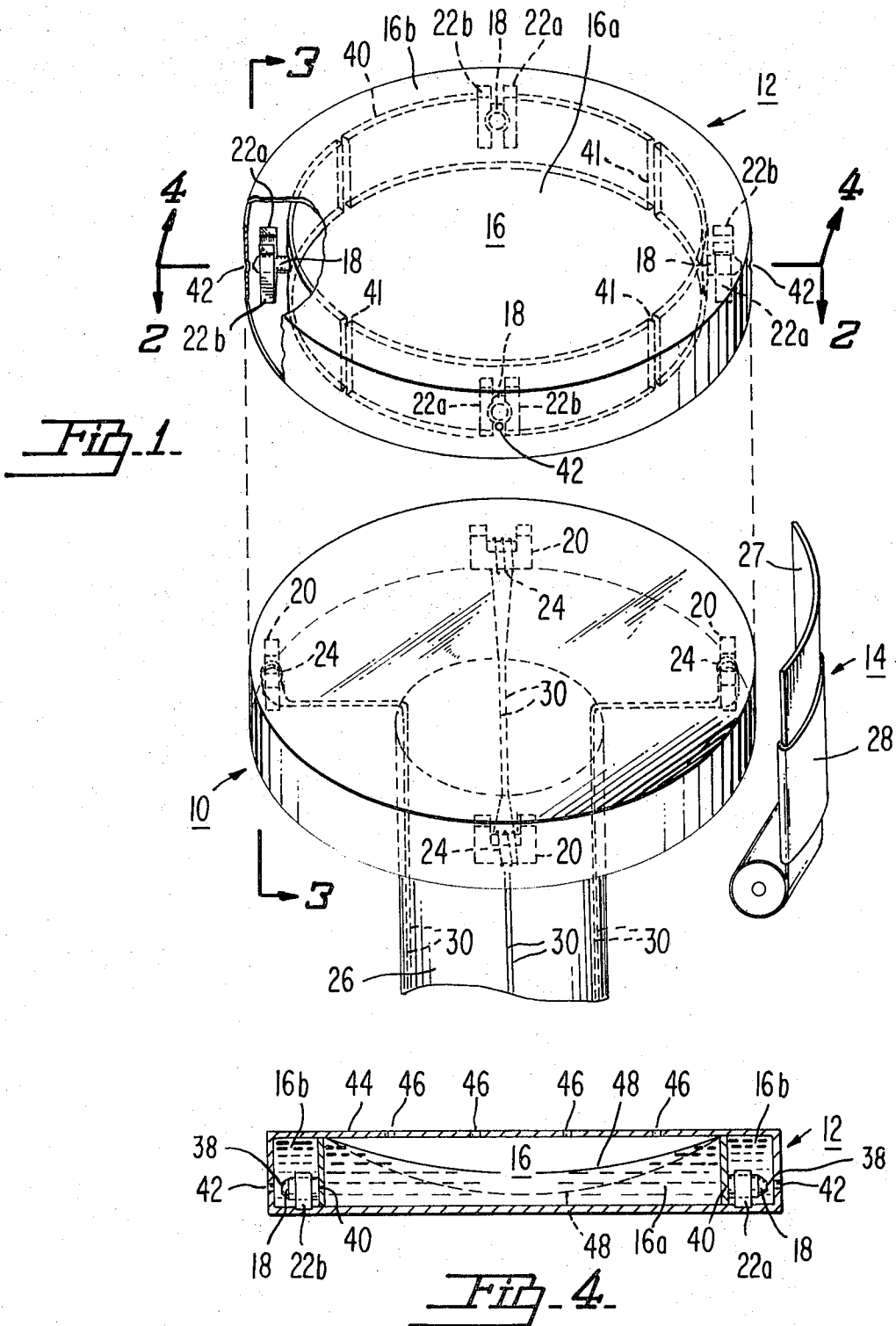
- [58] **Field of Search**..... 346/140, 75; 197/1 R

- [56]
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UNITED STATES PATENTS

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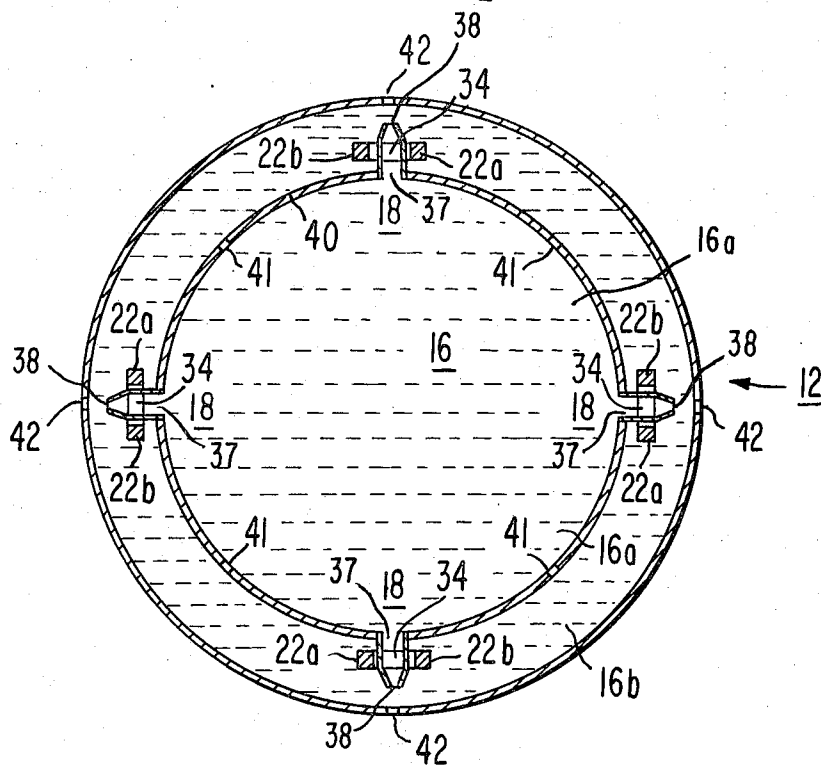


FIG. 2.

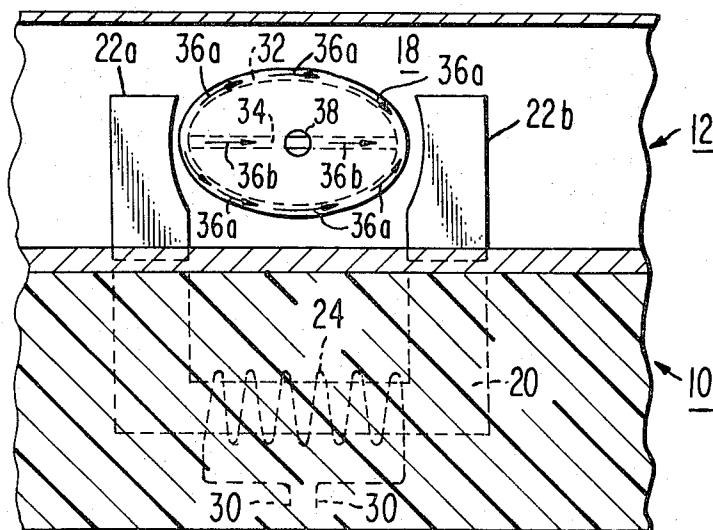


FIG. 3.

REPLACEABLE FLUID CARTRIDGE INCLUDING MAGNETICALLY OPERABLE FLUID JET DEVICES

CROSS REFERENCE TO RELATED APPLICATIONS

Of interest are the following copending patent applications: Ser. No. 414,756, filed Nov. 12, 1973, entitled "Printing Apparatus," by the same inventor as the present inventor, and assigned to the same assignee as the present assignee; Ser. No. 456,162, filed on Mar. 29, 1974, entitled "Fluid Ejection or Control Device," by the same inventor as the present inventor and Eric McPhail Leyton, and assigned to the same assignee as the present assignee; and Ser. No. 463,996, filed on Apr. 25, 1974, entitled "Image Generator Having A Plurality Of Marker Units Operated In A Predetermined Sequence To Inhibit The Formation Of Patterns," by the same inventor as the present inventor, and assigned to the same assignee as the present assignee.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of ink jet printing apparatus and particularly relates to ink jet printing apparatus of the type in which ink jets mounted at the periphery of a rotating disc are operated to impinge drops of ink on a recording medium guided past the periphery of the disc.

2. Prior Art

Ink jet printing apparatus are well known, wherein ink is supplied to ink jets, at times termed "ink spritzers," which are either electrically or magnetically operated to impinge ink on a recording medium. In one type of such ink jet printing apparatus a recording medium is moved past a stationary array of ink jets as the ink jets are operated in response to control signals. As an example of this type of printing apparatus see FIG. 1 of U.S. Pat. No. 3,596,275, entitled "Fluid Drop Recorder," issued to Richard G. Sweet on July 27, 1971. In another type of ink jet printing apparatus the ink jets are operated in response to control signals as the ink jets are moved past a stationary recording medium. For an example of this type of ink jet printing apparatus see FIG. 7 of the Sweet patent. In one form of the latter type of ink jet printing apparatus ink jets are mounted at the periphery of a rotating disc. As the ink jets are swept past a recording medium which is guided past the periphery of the disc, electrical signals, commutated to the ink jets through slip rings or the like, operate the ink jets to impinge ink on the recording medium.

In these prior art apparatus the ink supply is remote from the ink jets. As an example of an ink jet printing apparatus having a remotely located ink supply see U.S. Pat. No. 3,564,120, entitled "Image Construction System With Arcuately Scanning Drop Generators," issued to Richard P. Taylor on Feb. 16, 1971. Ink jet printing apparatus having remotely located ink supplies require relatively complex interconnecting structure between the ink supply and the ink jets and therefore do not lend themselves to be easily maintained.

In one printing apparatus of the type employing a rotationally driven disc having ink jets mounted at its periphery, the disc itself contains an ink reservoir which communicates with the ink jets mounted at its periphery to supply ink to the ink jets. Such printing apparatus

is described in copending U.S. Pat. application having Ser. No. 414,756, entitled "Printing Apparatus," filed by the same inventor as the present inventor on Nov. 12, 1973 and assigned to the same assignee as the present assignee. In the printing apparatus described in said application, the disc is a removable ink cartridge which may be refilled or replaced when the ink is depleted.

Facsimile systems intended for home use and the like will be more in demand as telephonic, cable television and like forms of data transmission systems become more available in the consumer market. For such applications, printing apparatus of the type described above should preferably have relatively simple maintenance procedures. Therefore, there is a need in the art for ink cartridges for use in ink jet printing apparatus which may be readily replaced.

SUMMARY OF THE INVENTION

According to the invention, an ink cartridge is provided for an ink jet printing apparatus of the type wherein ink jets in relative motion to a recording medium are operated in response to electrical control signals to impinge jets of ink drops on the recording medium. The ink cartridge is self contained and requires no electrical or ink supply connections to the printing apparatus and is therefore readily attached and detached from the printing apparatus. Therefore, the ink jet printer may be readily maintainable.

The ink cartridge includes a housing member adapted to be readily and replaceably mounted on a support member. The housing member is substantially hollow defining a cavity serving as an ink reservoir for storing ink. The ink cartridge also includes a magnetically operable ink jet communicating with the reservoir to be supplied with ink from the reservoir. The magnetically operable ink jet is operable in response to a magnetic field coupled to the magnetically operable ink jet from the support member to direct jets of ink from the housing member to the recording medium. The support member is provided with magnetic means coupled to the electrical control signals for coupling a magnetic field to the magnetically operable ink jet in accordance with the electrical control signals. The housing member and the support member are adapted to mate to form an efficient magnetic field path between the magnetic means and the magnetically operable ink jet.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an isometric exploded view of a printing apparatus embodying the preferred embodiment of the present invention.

FIG. 2 is a sectional view taken in the direction of section line 2—2 of FIG. 1, showing a plan view of the ink cartridge (12) of FIG. 1.

FIG. 3 is a sectional view taken in the direction of section 3—3 of FIG. 1 showing the ink jet of FIG. 1 in detail.

FIG. 4 is a cross sectional view taken in the direction of section 4—4 of FIG. 1 showing a modification to the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following description of the preferred embodiment the same reference numerals in different figures correspond to the same element. Concurrent reference to FIGS. 1, 2 and 3 will be helpful.

The printing apparatus of FIG. 1 comprises three components: turntable 10, ink cartridge 12, and recording medium guide structure 14. In operation cartridge 12 is positioned on turntable 10 from its separated position as shown in FIG. 1, to an abutting position as shown in FIG. 3.

Cartridge 12 is a removable ink cartridge generally in the form of a disc having a cavity serving as an ink reservoir 16 and ink jets 18 mounted at its periphery. The cavity for reservoir 16 extends substantially throughout disc 12 and in a preferred embodiment is divided by segmented cylindrical wall 40 into inner chamber 16a and outer chamber 16b. Inner chamber 16a of reservoir 16 is exposed to input ports 37 of ink jets 18 through apertures in wall 40 to supply ink to ink jets 18. Ink from inner chamber 16a reaches outer chamber 16b through openings 41 in wall 40. Ink jets 18 extend radially outward into annular outer chamber 16b of reservoir 16 such that orifice 38 of ink jet 18 is surrounded with ink to prevent the formation of air bubbles during the printing operation, as will be explained later. Each ink jet 18 is positioned in the periphery of cartridge 12 to eject ink radially outward through a corresponding output orifice 42 in the outer wall of cartridge 12 when operated. Ink jets 18 may be any suitable type of magnetically operable ink jet, such as a magnetostrictive type of ink jet, and are preferably of the magnetostrictive type of ink jet described in copending United States patent application having Ser. No. 67,164, entitled "Fluid Ejection or Control Device," filed by K. H. Fischbeck and E. M. Leyton on Mar. 29, 1974, and assigned to the same assignee as the present invention.

Cartridge 12 is arranged to be coaxially mounted on turntable 10 in such a manner that each of the U-shaped magnetic field pole pieces 20 mounted on turntable 10 are in longitudinal alignment with a respective set of magnetic field pole pieces or elements 22a and 22b of ink jets 18, as shown in FIG. 3. Cartridge 12 is provided with keying structure so that cartridge 12 mates with turntable 10 in a registered manner and prevents slipping. Cartridge 12 is locked in position and thus to be held in non-slip contact with turntable in any suitable manner including, for example, a press fit connection, magnetic connectors or the like, not shown, which permits cartridge 12 to be readily removed from and replaced on turntable 10.

When a current is provided to flow through a coil 24, wound about each pole piece 20, a magnetic field is induced in a respective pole piece 20, which is coupled to a respective set of magnetic field pieces 22a and 22b. In response to this magnetic field, ink jets 18 operate to eject ink radially outwardly in a manner known in the art.

Although pole pieces 20 are shown as having a U-shape, it should be appreciated that they may have any other suitable shape.

Turntable 10 is fixedly mounted on shaft 26 which, in turn, is rotationally driven by means, not shown. As shaft 26 is rotated, ink jets 18 are rotatably driven past a recording medium 26 which is suitably guided past

the periphery of an arcuate portion of disc 14 at a proximate distance therefrom by guide member 28.

Cartridge 12 may be of the expendably replaceable type that is meant to be discarded after the ink therein is depleted or cartridge 12 may be of the refillable type having provisions for being refilled with ink after the ink therein is depleted. Cartridge 12 may be formed by any suitable material having sufficient strength and rigidity to withstand the centrifugal forces to which it is subjected when rotated on turntable 10. An inexpensive, nonporous and rigid plastic material such as a polyethylene plastic is particularly appropriate if cartridge 12 is to serve as the disposable type, if not as a refillable type.

Control leads 30 carry electrical control signals manifesting synchronization information, used to synchronize the operation of ink jets 18 with the movement of recording medium 27, as well as printing information used to control the intensity and/or spacing of the ink drops produced by ink jets 18. The electrical control signals carried by control leads 30 are commutated to shaft 26 by any suitable means such as slip rings or electro optical transducers from a control unit, not shown, which generates these signals to operate ink jets 18 as they are swept past recording medium 26 as is known in the art. Another portion (not shown) of the control unit of the printing apparatus is arranged to maintain the speed of shaft 26 in synchronism with the motion of recording medium 27 in a manner as is well known in the art.

As stated before, ink jets 18 are preferably of the type described in copending U.S. application having Ser. No. 456,162, filed on Mar. 29, 1974, entitled "Fluid Ejection or Control Device." Briefly, the preferred ink jets 18 are formed by a magnetostrictive tube 32 (FIG. 3) having a generally elliptical cross section and magnetostrictive planar lateral member 34, which is disposed within and longitudinally along the axis of tube 32 and spans the major axis of the generally elliptical cross section of tube 32. Magnetostrictive tube 32 is adapted to contract circumferentially in response to azimuthal or circumferential magnetic field 36a. Lateral member 34 is adapted to expand laterally in the direction of span in response to a lateral magnetic field 36b. Azimuthal magnetic fields 36a and lateral magnetic field 36b are generated by the magnetic field induced in the magnetic core formed by the field pieces 22a and 22b of cartridge 12 and field piece 20 of turntable 10 when a current flows through coil 24. The current may, for example, be a pulse train being frequency modulated or amplitude modulated or both; the modulation manifesting print control information respectively controlling the spacing, size or both of the ink drops impinged on recording medium 27. The end of tube 32 directed radially outwardly is tapered to a nozzle terminating in an outlet orifice 38. When current flows through coil 24, the cross section area of tube 32 of ink jet 18 undergoes a geometric distortion in response to the magnetic action thereby causing a jet of ink to be ejected from orifice 38 and through orifice 42.

The efficiency of a type of ink jet such as ink jet 18 is generally dependent on the magnitude of the magnetic field to which it is subjected. Therefore, cartridge 12 and turntable 10 should be adapted to mate to place magnetic field piece 20 in close proximity to field pieces 22a and 22b to form an efficient magnetic field

path with a minimum gap in the magnetic circuit as well known in the art.

In a preferred embodiment, reservoir 16 is divided into an inner chamber 16a and an outer chamber 16b by cylindrical wall 40 to form what may be termed a "fluidic rectifier" which functions to prevent air bubbles from developing during operation causing ink jets 18 to malfunction or otherwise perform erratically. To achieve this action, ink jets 18 are mounted on wall 40 in axial alignment with output orifices 42 of cartridge 12. The nozzle end of ink jets 18 extends radially outwardly into outer chamber 16b while the input open end of ink jets 18 are open or exposed to inner chamber 16a to receive and thereby be supplied with the ink from inner chamber 16a. Wall 40 is provided with a plurality of access openings 41 so that ink within inner chamber 16a may readily flow out to outer chamber 16 and surround orifice 38 of ink jet 18 with ink. In operations, when a jet of ink is ejected from ink jet 18 through orifice 42 of cartridge 12, the ink in outer chamber 16b surrounding orifice 38 fills the vacuated space created by the jet of ink thereby inhibiting the formation of air bubbles in ink jet 18.

As is known in the art, fluidic rectifiers are imperfect and, although they mitigate the problem, they generally do not entirely prevent air bubbles to a degree necessary in some printing applications. It should be appreciated by those skilled in the art that the adverse effect of air bubbles on the reliable and continuous operation of ink jets 18 will be considerably diminished because of the advantageous utilization of an inherent pressure gradient established in the ink within reservoir 16 by the centrifugal forces acting on the ink as cartridge 12 is rotationally driven by turntable 10. That is, since the pressure is greater at the periphery of reservoir 16 than it is near the center of reservoir 16 due to the centrifugal force acting on the ink within reservoir 16, any bubbles that may be formed by the operation of ink jets 18 are urged to the center of reservoir 16 and away from ink jets 18. Thus, the inherent pressure gradient due to centrifugal force set up within reservoir 16 tends to prevent bubbles from being developed in the jet 18.

Notwithstanding the advantages of inhibiting the formation of air bubbles by the centrifugal action causing the inherent pressure gradient described above, a cartridge 12 having rigid walls that is sealed from the ambient except for the apertures established through the ink jets 18, will tend to develop a partial vacuum that will thereby inhibit the discharge flow of ink since, the centrifugal force is not great enough to cause the ink to be ejected. This action is well known in the art and may be termed for the present description as the tendency to create a "void." The pressure in such a void is low, and in some cases, approaches that of vacuum pressure. As ink is depleted more and more, the increasingly lowered pressure tends to retard the flow of ink to ink jets 18. FIG. 4 is a cross sectional view taken in the direction of section 4-4 of FIG. 1 showing a modification of ink cartridge 12 according to the invention wherein means are provided so that the ambient pressure outside of ink cartridge 12 can act on ink within reservoir 16 to counteract the retarding effect of the low pressure void. Top surface portion 44 of cartridge 12 is provided with a plurality of orifices 46 serving as vents communicating with the interior of the cartridge to allow the pressure outside cartridge 12 to act on the ink within reservoir 16. To prevent the ink from

leaking or spilling from cartridge 12, membrane 48, formed of any suitable material such as a flexible plastic material, is provided to cover the ink within reservoir 16. As the ink is depleted through orifices 38 of jets 18, the ambient pressure external to cartridge 12 acts on membrane 48 forcing it downward (as indicated in phantom) to thereby urge the ink radially outward toward jets 18. Top surface portion 44 of cartridge 12 may be eliminated as desired.

It will further be appreciated that to the extent air bubbles are removed from ink jets 18 by the inherent pressure gradient within cartridge 12 when rotationally driven by turntable 10, a separate fluidic rectifier structure to prevent malfunction due to the presence of air bubbles may not be required, and therefore, outer chamber 16b may not be required.

In overall operation of the apparatus, ink cartridge 12 is placed on turntable 10 locating the sets of field pieces 22a and 22b of ink cartridge 12 in alignment with and at a proximate vertical distance from respective field pieces 20 of turntable 10. Turntable 10 is rotationally driven. As ink jets 18 are periodically swept past recording medium 27, current control signals manifesting print control information such as the spacing of or the size of the ink drops to be deposited on recording medium are conducted to respective coils 24. In response to these current control signals, magnetic fields are induced in the magnetic field paths formed by respective field pieces 22a, 22b and 20 thereby operating respective ink jets 18 to impinge jets of ink or ink drops on recording medium 27 in accordance with the current control signals. When the ink in cartridge 12 is depleted, cartridge 12 is removed for refilling or entirely replaced.

It will be appreciated by those skilled in the art that although the invention is described in terms of an embodiment useful in an ink jet printing apparatus, the scope of the invention is not limited to the embodiment described. Therefore, it should now be understood that in accordance with the invention a replaceable fluid cartridge is provided which includes a reservoir for fluid and a magnetically operable fluid metering device for controlling the flow of fluid into and out of the reservoir. The cartridge is adapted to mate with a support structure, such as a turn table or the like, which includes means for generating a magnetic field to control the operation of the magnetically operable fluid metering device.

What is claimed is:

1. An ink cartridge for an ink jet printing apparatus of the type wherein ink jets in relative motion to a recording medium are operated in response to electrical control signals to deposit drops of ink on the recording medium, comprising:

a housing member including a cavity extending substantially throughout said housing member, said cavity forming an ink reservoir for storing ink within said housing member, said housing member being adapted to be replaceably mounted on a support member; and

a magnetically operable ink jet mounted on said housing member and communicating with said reservoir to be supplied with ink from said reservoir for directing jets of ink outwardly from said housing member and on to said recording medium, said magnetically operable ink jets being operable in re-

sponse to a magnetic field coupled to said magnetically operable ink jets from the support member; said support member including magnetic means coupled to said electrical control signals for coupling said magnetic field to said magnetically operable ink jet in response to said electrical control signals; said housing member and said support member being adapted to mate to form a magnetic field path between said magnetic means and said magnetically operable ink jet.

2. The apparatus recited in claim 1 wherein said support member is driven to move the ink jets past said recording medium.

3. An ink cartridge for an ink jet printing apparatus of the type wherein ink jets mounted on a rotationally driven member are operated as they are driven past a recording member which is guided past the rotationally driven member, comprising:

a disc member adapted to be removably and coaxially mounted on a turntable adapted to rotationally drive said disc member about its axis, said disc member including a cavity extending substantially throughout said disc member, said cavity forming an ink reservoir for storing ink within said disc member;

a magnetically operable ink jet mounted at the periphery of said disc member and communicating with said reservoir to be supplied with ink from said reservoir for directing jets of ink drops radially outward from said disc on to said recording medium, said magnetically operable ink jets being operable in response to a magnetic field coupled to said magnetically operable ink jet from said turntable; and

said turntable including magnetic means coupled to said electrical control signals for coupling said magnetic field to said magnetically operable ink jet in response to said electrical control signals;

said disc member and said support member being adapted to mate to form a magnetic field path between said magnetic means and said magnetically operable ink jet.

4. A printing apparatus wherein ink is deposited on to a recording medium in response to electrical control signals, comprising:

a shaft;
means for rotationally driving said shaft about its axis;

a turntable coaxially mounted on said shaft to be rotationally driven by said shaft;

a disc member removably and coaxially mounted on said turntable to be rotationally driven by said turntable said disc member being arranged to serve as a replaceable ink cartridge wherein said disc member includes a magnetically operable ink jet mounted at the periphery of said disc member for directing jets of ink radially outward from said disc, a cavity extending substantially throughout said disc and located generally radially inward from said magnetically operable ink jet, said cavity forming an ink reservoir for storing said ink within said disc member and adapted to supply ink to said magnetically operable ink jet, said magnetically operable ink jet being operable in response to a magnetic field coupled to said magnetically operable ink jet from said turntable

said turntable including magnetic means coupled to said electrical control signals for coupling said magnetic field to said magnetically operable ink jet in response to said electrical control signals;

said disc member and said turntable being adapted to mate to form a magnetic field path between said magnetic means and said magnetically operable ink jets; and

means for guiding said recording medium past the periphery of said disc member.

5. The printing apparatus recited in claim 4 wherein said magnetically operable ink jet is of the magnetostrictive type.

6. The printing apparatus recited in claim 5 wherein said magnetically operable ink jet comprises:

a tube adapted to channel the flow of said ink having an input at one end for receiving said fluid from said reservoir and a nozzle at the other end for expelling fluid from said tube;

a lateral member located within said tube, disposed along the axis of said tube and spanning between opposite wall portions of said tube;

said tube and said lateral member forming a passageway for fluid, said passageway having a cross-section comprising an arcuate section, formed from said tube, and a straight line section, formed from said lateral member, spanning said arcuate section;

said tube being formed of a magnetostrictive material adapted so that said arcuate section contracts circumferentially in response to a magnetic field passing circumferentially through said arcuate section; said lateral member being adapted so that said straight line section expands laterally in the direction of span in response to a magnetic field passing laterally through said straight line section in the direction of span;

said arcuate section and said straight line section being arranged to form a closed loop magnetic path;

magnetic pole pieces having opposite polarities located at opposite sides of said tube and adapted to simultaneously induce a magnetic field circumferentially through said arcuate section and laterally through said straight line section in response to said control signal;

said cross-section of said tube becoming geometrically distorted in response to said control signal, said volume of said tube decreasing as a result of said geometric distortion of said cross-section, whereby said jets of ink drops are ejected from said jet.

7. The printing apparatus recited in claim 6 wherein said means for coupling said magnetic field to said ink jet includes a magnetic core adapted to mate proximately with said magnetic field pieces and a coil coupled to said electrical control signals wound around said core.

8. The printing apparatus recited in claim 4 wherein said cavity is arranged to serve as a fluidic rectifier and includes inner and outer chambers separated by a cylindrical wall, said magnetically operable ink jets being mounted on said wall, said periphery of said disc including an orifice opposite said magnetically operable ink jet through which said jets of ink are ejected, said outer chamber communicating with said inner chamber so that ink within said inner chamber is supplied to said

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outer chamber, said outer chamber being adapted to surround the output orifice of said magnetically operable ink jet with ink to inhibit the formation of air bubbles as ink is ejected from said magnetically operable ink jet.

9. The printing apparatus recited in claim 4 including

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venting means for equalizing the pressure in said cavity to that of the ambient pressure outside of said disc.

10. The apparatus according to claim 9 further including a flexible membrane in said cavity.

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