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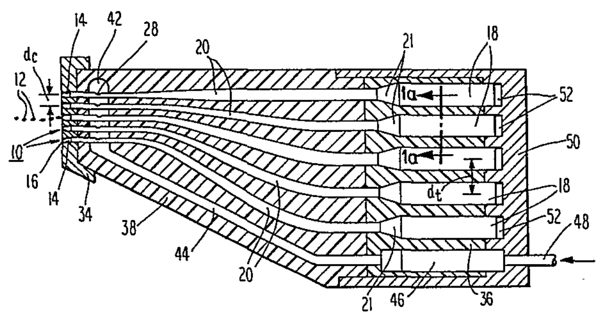
(54) Ink jet apparatus.

(57) An elongated acoustic waveguide (20) couples a transducer (18) to an ink jet chamber (14) including an outlet orifice (16) through which droplets of ink are ejected. In one embodiment, the waveguide (20) is directly coupled to ink within the chamber (14). Arrays are formed utilizing such ink jet chambers (14) and waveguides (20). Because the transducers (18) are located separately from the ink jet chambers (14), the latter can be arranged in a very compact array.



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INK JET APPARATUS

This invention relates to ink jets, more particularly, to ink jets adapted to eject a droplet of ink from an orifice for purposes of marking on a copy medium.

It is desirable in certain circumstances to provide an array of ink jets for writing alpha-numeric characters. For this purpose, it is frequently desirable to provide a high density ink jet array. However, in many instances, the stimulating element or transducers of such an array are sufficiently bulky so as to impose serious limitations on the density in which ink jets may be arrayed. In this connection, it will be appreciated that the transducers must typically comprise a certain finite size so as to provide the energy and displacements required to produce a change in ink jet chamber volume which results in the ejection of a droplet of ink from the orifice associated with the ink chamber.

It will also be appreciated that efforts to create a high density ink jet array may produce undesirable cross talk between the ink jets in the array. This is a result, at least at large part, of the relatively close spacing of ink jets in the array.

When efforts are made to achieve a high density array, the ink jet transducers become intimately associated with the fluidic section of the ink jet, i.e., the ink chambers and orifices. As a consequence, any failure in the fluidic section of the device, which is far more common than a failure of the transducer, necesitates the disposal of the entire apparatus, i.e., both the fluidic section and the transducer.

It is an object of this invention to provide a high density ink jet array.

It is a further object of this invention to provide an ink jet array to minimize cross talk between ink jets.

It is a still further object of this invention to provide an ink jet array which facilitates disposability of the fluidic channel section of the ink jets independently of the transducers of the ink jets.

It is a further object of this invention to provide a fluidic feeding system to the jets that minimize air entrapment and cavitation sites.

It is a further object of this invention to provide a waveguide array that is encapsulated in a suitable material to prevent generation of flexural vibration that can cause cross talk to neighboring fluidic feeding channels.

In accordance with these and other objects of the invention, an ink jet apparatus comprises an ink jet chamber including an inlet port for receiving ink in the chamber and an outlet orifice for ejecting ink droplets from the chamber. A transducer is remotely located from the chamber and an elongated either solid or tubular acoustic waveguide is coupled between the ink jet chamber and the transducer. The acoustic waveguide transmits acoustic pulses generated at the transducer to the chamber for changing the volume of the chamber in response to the state of energization of the transducer.

In accordance with this invention, acoustic pulses are transmitted along the waveguide in the following manner. When the transducer is energized, the ends thereof move in an axial direction in an amount determined by the voltage applied to the transducer. If one end of said transducer is affixed to a solid back piece, the other end will move against the abutted end of the waveguide. The abutted end of the waveguide will then be driven along in the same direction by an amount corresponding to that of the end of the transducer. If the driving pulse (voltage) is sharp, e.g., the voltage takes a short time to reach its final value, the end of the transducer will move fast; the end of the waveguide will move accordingly fast, and only part of said waveguide will be able to follow the fast motion.

The rest of the waveguide will stay at rest. The end of the waveguide that was initially deformed will relax by pushing and elastically deforming consecutive portions along the waveguide. This successive displacement of the elastic deformation ultimately reaches the distal end of the waveguide. The last portion thereof causes the fluid within the chamber to be compressed and thus causes the ejection of fluid droplets from the nozzle orifice. The physical properties used in this invention are those of a true wave traveling along the waveguide length and not those of a push rod whereby when one end of the rod is moved, the other end will move in unison.

In accordance with one important aspect of the invention, a plurality of such ink jets are utilized in an array such that the spacing from center to center of transducers is substantially greater than the spacing from axis to axis of the orifices. This relative spacing of transducers as compared with orifices is accomplished by converging the acoustic waveguide toward the orifices.

In accordance with another important aspect of this invention, all of the transducers are located at one side of the axis of the orifice at one extremity of the array.

In accordance with another important aspect of the invention, the waveguides are of differing lengths along the axes of elongation.

In accordance with another important aspect of the invention, the waveguides are tapered so that their diameter at the distal ends are substantially smaller than those at the transducer ends. This tapering of the waveguides provides yet closer spacing between the waveguides, thus further increasing the channel density.

In accordance with yet another important aspect of the invention, the tapered ends of the waveguides are made of tubular material to provide a fluid feed channel to thus maintain the chambers filled with fluid.

In accordance with yet another important aspect of the invention, the fluid feed channels are provided with an orifice at the distal end having a cross-sectional area smaller than the cross-sectional area of said fluid channel so as to serve as a restrictor to control the flow of fluid passing therethrough.

In accordance with yet another important aspect of the invention, the chambers of the ink jets may include a diaphragm coupled to the waveguide such that the diaphragm contracts and expands in response to the state of energization of the transducer in a direction having at least a component parallel with the axis of the orifice.

In accordance with yet still another important aspect of the invention, each waveguide abutts the transducer and is held thereon by means of a metal or ceramic ferrule that fits both the transducer end and the waveguide end.

In accordance with another important aspect of the invention, each acoustic waveguide is elongated such that the overall length along the axis of elongation greatly exceeds the dimension of the waveguide transverse to the axis.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Fig. 1 is a sectional view of an ink jet array representing a preferred embodiment of the invention;

Fig. 1a is a sectional view taken along line 1a-1a of Fig. 1;

Fig. 2 is a partially enlarged view of the array shown in Fig. 1;

Fig. 2a is a sectional view taken along line 2a-2a of Fig. 2;

Fig. 2b is a sectional view taken along line 2b-2b of Fig. 2;

Fig. 2c is a sectional view taken along line 2c-2c of Fig. 2;

Fig. 3 is a partially schematic diagram of yet another embodiment of the invention;

Fig. 4 is a partially schematic diagram of still another embodiment of the invention;

Fig. 5 is a partially schematic diagram of still another embodiment of the invention;

Fig. 6 is a sectional view of another embodiment of the invention; and

Fig. 6a is a sectional view taken along line 6a-6a of Fig. 6.

Referring to Fig. 1, an ink jet array comprising a plurality of jets 10 are arranged in a line so as to asynchronously eject ink droplets 12 on demand. The jets 10 comprise chambers 14 having outlet orifices 16 from which the droplets 12 are ejected. The chambers expand and contract in response to the state of energization of transducers 18, which are coupled to the chambers 14 by acoustic waveguides 20. The waveguides 20 may actually penetrate into said chamber by a distance d_i as shown in Fig. 2. The use of the waveguides 20, which are coupled to the transducer 18 by a ceramic or metal ferrule 21, permits the jets 10 to be more closely spaced without imposing limitations on the spacing of the transducers 18. More particularly, the centers of the chambers may be spaced by a distance d_c which is substantially less than the distance between the centers of the transducers d_t. This allows the creation of a rather dense ink jet array regardless of the configuration or size of the transducers 18.

Acoustic pulses are transmitted along the waveguide 20 in the following manner. When the transducer 18 is energized, the ends thereof move in an axial direction, i.e., the direction parallel with the axis of elongation of the waveguide 20, in an amount determined by the voltage applied to the transducer 18. Since one end of the transducer 18 is affixed to a solid back piece, the other end will move against the abutting end of the waveguide 20. The abutting end of the waveguide 20 will then be driven in the same direction by an amount corresponding to the end of the transducer 18. If the driving pulse is sharp, e.g., the voltage takes a short time to reach its final value, the end of the transducer will move fast; the end of the waveguide will move fast in a similar manner, and only part of the waveguide 20 will be able to follow the fast motion. The rest of the waveguide will stay at rest. The end of the waveguide that was initially deformed will relax by pushing an elastically deforming consecutive portion along the waveguides 20. This successive displacement of the elastic deformation ultimately reaches the distal end of the waveguide 20. The last portion thereof causes the fluid within the chamber 14 to be compressed and thus causes the ejection of fluid droplets from the orifice. The physical properties used —————— are those of a true waveguide traveling along the waveguide length and not those of a piston whereby one end of the rod is moved and the other end will move in unison.

The chambers 14 are coupled to a passageway 24 in the waveguide 20 which is terminated at the distal end 22 by an opening 26. The opening 26 is of a reduced cross-sectional area as compared with the cross-sectional area of the waveguide a greater distance from the orifice 16 (i.e., the passageway tapers) so as to provide a restrictor at the inlet to the chamber 14. Ink enters the passageway 24 in the waveguide 20 through an opening 28, as perhaps best shown in Figs. 2, 2a and 2c. The remainder of the waveguide 20 may be filled with a suitable material 30 such as a metal piece or epoxy encapsulant.

During the operation of the ink jet array as shown in Figs. 1 and 2, the distal end 22 of the waveguide 20 expands and contracts the volume of the chamber 14 in a direction 32 having at least a component parallel with the axis of the orifice 16. It will, or course, be appreciated that the waveguides 20 necessarily extend in a direction having at least component parallel with the direction of the expansion and contraction of the ends 22 of the waveguides 20.

It will be appreciated that the waveguides 20 as shown in Fig. 1 are elongated. As utilized herein, the waveguides 20 are considered elongated as long as the overall length along the axis of acoustic propagation greatly exceeds the dimension of the waveguide transverse to the axis, e.g., more than 10 times greater.

As best shown in Fig. 2, the waveguides 20 actually penetrate into the chambers 14. The position of the waveguides 20 in the chambers 14 may be preserved by maintaining a close tolerance between the external dimension of the waveguides 20 and the walls of the chamber 14 as formed in a block 34. The block 34 may comprise a variety of materials including plastics, metals and/or ceramics.

Referring again to Fig. 1 in combination with Fig. 1a, it will be appreciated that the transducers 18 are potted within a potting material 36 which may comprise elastomers or foams. The waveguides 20 are also encapsulated or potted within a material 38 as shown in Figs. 1 and 2. As also shown in Fig. 2b, each waveguide 20 may be surrounded by a sleeve 40, which assists in attenuating fluxural vibrations or resonances in the waveguide 20. In the alternative, sleeve 40 may be eliminated and the potting material 38 may be relied upon to attenuate resonances. A suitable potting material 38 includes elastomers, polyethylene or polystyrene. The potting material 38 is separated from the chamber block 34 by a gasket 41 which may comprise an elastomer.

It will, or course, be appreciated that the transducers 18 must be energized in order to transmit an acoustic pulse along the waveguides 20. Although no leads have been shown as coupled to the transducers 18, it will be appreciated that such leads will be provided for energization of the transducers 18.

By referring now to Figs. 1 and 2, it will be appreciated that ink flows through the inlet ports 28 in each of the waveguides 20 from a chamber 42 which communicates through a channel 44 to a pump 46. The pump 46 supplies ink under the appropriate regulated pressure from a supply 48 to the chamber 42. The pressure regulation afforded by the pump 46 is important, particularly in a typewriter environment, since considerable liquid sloshing and accompanying changes in liquid pressure within the chamber 42 and a passageway 44 may occur. As shown in Fig. 1, the end of the ink jet array is capped by a member 50 which covers foot members 52 at the ends of the transducers 22 as well as the end of the pump 46.

As shown in Fig. 1, some of the waveguides 24 individually extend in a substantially straight line to the respective chambers 14. Others may be bent or curved toward the chambers 14. As shown in Fig. 3, a somewhat different transducer construction is utilized. More particularly, an integral transducer 118 having a plurality of legs 118(a-f) coupled to, for example, five jets 110 of the type shown in Fig. 1 through waveguides 120. Here again, the configuration of the transducer block 118 is immaterial so far as the density of the array of ink jets is concerned. Moreover, the disposition of the array of ink jets 110 may be changed vis-a-vis the transducer block 118. As shown, the arrangement of transducers 118(a-f) is offset laterally (shown as below) with respect to the axis x through the orifice of the jet 110 located at one extremity (shown as the upper extremity) of the array. As shown in Fig. 3 and in Fig. 1, the ink jet arrays are well suited for use in a printer application requiring last character visibility because of the skewing of the transducers to one side of the array of jets 10. Referring now to Fig. 4, a plurality of transducers 218 and jets 210 are mounted on a two-tiered head 200. Once again, the jets 210 are very closely spaced so as to achieve a dense array while the transducers 218 are more substantially spaced. As a result, the waveguides

220 fan in or converge from the transducers 218 to the jets 210. Fig. 5 shows an arrangement whereby two or more heads 200 shown in Fig. 4 are sandwiched together to thus form heads that have multiple rows of jets 210 with the purpose of multiplying the writing capability of the heads and thereby increasing the resolution of the characters generated.

As clearly shown in Figs. 1, 3 and 4, the overall lengths of the waveguides vary. This allows the distance between the transducers to be maximized so as to minimize cross talk between transducers as well as between waveguides.

Referring now to Figs. 6 and 6a, a somewhat different embodiment is shown wherein the acoustic waveguides 20 are coupled to the chambers 14 in a somewhat different manner. In particular, the ends of the chambers 14 remote from the orifices 16 are terminated by a diaphragm 60 including protrusions 62 which abut the waveguides 20. Ink is capable of flowing into the chambers 14 through orifices 65 shown in Fig. 6a adjacent a restrictor plate 64. The openings 65 communicate with a reservoir 66 in the manner disclosed in the aforesaid application. For this purpose, the block 34 includes lands 68 which form the restrictor openings 65 to the chamber 14 in combination with the restrictor plate 64.

In operation, the pulse from a transducer travels along each of the waveguides 20 in the embodiment shown in Fig. 6 until such time as it reaches a projection 62 on the diaphragm 60. This deforms the diaphragm 60 into and out of the chamber 14 associated with that particular waveguide 20 so as to change the volume of that chamber and expell droplets of ink 12 from the orifices 16. It will, therefore, be appreciated that the diaphragm 60 expands and contracts in a direction generally corresponding to and parallel with the axis of elongation of the waveguides 20 at the projection 62. It will be appreciated that the fluidic reaction of this embodiment including the chamber 14 may be reparable from the waveguides 20 at the diaphragm 62 in accordance with one important object of the invention.

Acoustic waveguides suitable for use in the various embodiments of this invention include waveguides made of such material as tungsten, stainless steel or titanium, or other hard materials such as ceramics, or glass fibers. In choosing an acoustic waveguide, it is particularly important that the transmissibility of the waveguide material be a maximum for acoustic waves and its strength also be a maximum.

The mechanism by which the waveguides operate in conjunction with the transducer may be described as follows. An electrical pulse arrives at the transducer. The transducer first retracts (fill cycle) and then expands. The retraction, followed by expansion results in displacements at the transducer face, which are imposed at the end of the waveguide which is touching the transducer. Depending on the rise-time of the pulse, part of the end of the waveguide will be compressed elastically. This initial compression will launch a compressional impulse along the waveguide with a speed equal to the speed of sound in the material of the waveguide. At a later time (corresponding to approximately 2μ sec in a 2.54 cm steel guide), the impulse will arrive at the distal end of the waveguide; it will, thus, alter the volume of the chamber and generate droplets.

The physical mechanism involved in truning the pulse generated by the transducer into a mechanical impulse may be explained using a unit step excitation analysis or a unit impulse excitation analysis as follows:

Here, a constant force F_o, is assumed to be applied suddenly at time = 0 to a waveguide that is at rest initially. The usual equation of motion is:

$$m \frac{d^2x}{dt^2} + c \frac{dx}{dt} + kx = Fo \quad \text{for } t>o$$

with the solution of:

$$x = \frac{Fo}{k} + Xe^{-\beta Wnt} \sin(\sqrt{1-\beta^2} Wnt + \phi).$$

This must satisfy the initial conditions $X = \frac{dx}{dt} = o$ at $t = o$

$$tg\ \phi = \frac{\sqrt{1-\beta^2}}{\beta} \quad \text{and} \quad X = -\frac{Fo}{k\sqrt{1-\beta^2}}$$

Then:

$$\therefore x = \frac{Fo}{k} \left[1 - \frac{e^{-\beta Wnt}}{\sqrt{1-\beta^2}} \sin(\sqrt{1-\beta^2}\ Wnt + \phi)\right].$$

Here: Wn = frequency of the transient ($W = 2\ \Pi\ f$).
β = damping factor (lossiness)
t = time (sec)
F_o = force applied (impulse) in dynes
m = mass (gr).
k = spring constant assuming the guide deformation remains within the elastic limit of the material.
$k = \frac{EA}{l}$ where: E = Young's Modulus in $\frac{(dy)}{cm^2}$
A = cross section area in (cm^2)
l = length in (cm).
also, $\frac{C}{2m} = \beta Wn$, where C is the damping.

An impulse, I, is defined as a large force acting for a very short time which can never be rigorously realized in practice. However, it is useful to assume this case because it provides insight into the understanding of waveguide operation. Thus, as stated: $\lim \frac{I}{\Delta t} \to \infty$ $\Delta t \to o$

This impulse produces an initial velocity in the small short portion mass (m) adjacent to the transducer end. This velocity is $v_o = I/m$, and the displacement may be considered equal to zero. Thus, the differential equation for t>o with the right side equal to O the solution:

$$x = Xe^{-\beta Wnt} \sin(\sqrt{1-\beta^2}\, Wnt - \phi)$$

is fitted to:

$$\frac{dx}{dt} = \frac{I}{m} \text{ (at } t=o\text{) and } x=o$$

Then:

$$X = \frac{I}{\sqrt{km(1-\beta^2)}} \text{ for } \phi = o$$

Thus, the displacement, x, at any time, t, is:

$$X = \frac{I}{\sqrt{km(1-\beta^2)}}\, e^{-\beta Wnt} \sin \sqrt{1-\beta^2}\, Wnt$$

With peak displacement given by:

$$t_g\left(\sqrt{1-\beta^2}\, Wnt\right) = \frac{\sqrt{1-\beta^2}}{\beta}$$

The kinetic energy provided by unit impulse on the first end of the waveguide is derived as follows:

An impulse, I, from the transducer hits the portion of mass in the waveguide and generates thereon a velocity, V. Assuming the waveguide had an initial velocity, V_o, we have, for a velocity change:

$$m(V - V_o) = I$$

multiplying both sides by $1/2\ (V + V_o)$:

$$1/2\ mV^2 - 1/2\ mV_o = I[1/2(V-V_o)]$$

If no initial velocity is assumed ($V_o = 0$),

$$1/2\ mV^2 = 1/2\ IV = \text{kinetic energy (in CGS units)}.$$

The foregoing is a general description of how a single (impulse) is introduced into a waveguide. In what follows, an analysis is made on what happens when an impulse travels along a waveguide.

When a mechanical impulse of amplitude, $\underline{\alpha}$, travels along a waveguide medium, it will have a particle velocity v at a time, t, and a displacement position, x. The displacement, b, at a time, t, of a particle whose initial position is, x, will be:

$$b = \alpha \sin 2\Pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) = \alpha \sin 2\Pi\left(ft - \frac{x}{\lambda}\right)$$

Here: T = period (sec)

f = frequency (sec^{-1})

λ = wave length (impulse leading edge, pulse width, trailing edge)

α = particle displacement amplitude.

Since:

$$v = f\lambda \qquad \text{and } w = 2\Pi f$$

Then:

$$b = \alpha \sin \frac{2}{\lambda}\,(Vt-X) = \alpha \sin w\left(t-\frac{x}{v}\right)$$

The particle velocity is:

$$\frac{db}{dt} = \alpha w \cos w\left(t - \frac{x}{v}\right)$$

Assuming a ——— layer of thickness, dx, whose mass is ρdx (where ρ = density). The kinetic energy (KE) of this layer is:

$$dE = \frac{\rho dx}{2}\left(\frac{db}{dt}\right)^2 = \frac{1}{2}\,\rho dx \alpha^2 w^2 \cos^2 w\left(t-\frac{x}{v}\right)$$

where dE is a small increment of the kinetic energy.

The KE of the whole wave system is:

$$E = \frac{1}{2}\,\rho\alpha^2 w^2 \int \cos^2 w\left(t-\frac{x}{v}\right) dx$$

The total energy of the impulse motion per unit volume is:

$$E - 1/2\rho\alpha^2 w^2 \text{ (=energy density)} = 2\Pi^2\rho^2\alpha^2 f^2$$

Thus, in thin wires, one gets large displacements and the energy is transmittable if it stays within the wire.

The intensity of the pulse is: I = energy transmission per second per unit area of wave front. Then it equals energy density E x velocity V.

$$I = \frac{1}{2}\rho \alpha^2 w^2 v = \alpha^2 w^2 (\rho v)$$

The varying compressional pressure P at any point relates to particle velocity in the medium as follows:

$$P = \rho v \frac{db}{dt} \therefore \frac{P}{\left(\frac{db}{dt}\right)} = \rho v = K \text{ (constant, depending on the material)}$$

The energy loss from the guide into the environment is calculated by:

$$R = \frac{R_2 - R_1}{R_2 + R_1}$$

where R is the total reflected energy from the environment surrounding the waveguide and the material of the waveguide, R_1 is the reflected energy from the material, and R_2 is the reflected energy in the environment surrounding the waveguide.

Making $R_1 = \rho_1 C_1$ where ρ_1 = density of the waveguide material in $\left(\frac{gr}{cm^3}\right)$ and C_1 = wave velocity in said material.

For steel: $R_1 = \rho_1 C_1 = 7.9 \times 5.2 \times 10^5 = 4.1 \times 10^6$.

For air: $R_2 = \rho_2 C_2 = .35 \times 10^5$. ρ_2 is the density of air or material surrounding the waveguide.

Hence, 1 - R = .0164.

which is the amount lost from the waveguide per unit length and which is quite small.

The energy attenuation due to bending is calculated by A.E.H. Love in his Treatise of the Mathematical Theory of Elasticity: Dover (1944). From this calculation, it may be concluded that all of the energy would be transmitted along a bent waveguide if the bending radius is equal to or greater than a quarter wave of the vibrating power for the material of the waveguide.

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CLAIMS

1. An ink jet apparatus characterised by an ink jet chamber (14) including an inlet port (28) for receiving ink in said chamber and an outlet orifice (16) for ejecting ink droplets from said chamber; a transducer (18) located separately from said chamber; and an elongated, preferably solid, acoustic waveguide (20) coupled between said ink jet chamber (14) and said transducer (18) for transmitting acoustic pulses generated at said transducer (18) to said chamber (14) for changing the volume of said chamber (14) in response to the state of energization of said transducer (18).

2. An ink jet apparatus according to claim 1, characterised in that said chamber (14) includes a diaphragm (60) coupled to said waveguide (20), said diaphragm (60) being deformed into and out of said chamber in response to said state of energization.

3. An ink jet apparatus according to claim 1, characterised in that said waveguide (20) penetrates into said chamber (14).

4. An ink jet apparatus according to claim 1 or 3, characterised in that at least a portion of said waveguide (20) includes a passageway (24) for coupling ink from a reservoir (42) to the chamber (14).

5. An ink jet apparatus according to claim 4, characterised in that said waveguide (20) extends through said reservoir (42), said inlet port (28) being located in an intermediate portion along the waveguide (20) at said reservoir (42).

6. An ink jet apparatus according to claim 4 or 5, characterised in that said passageway (24) has a lesser cross-section over said orifice (16) than at said inlet port (28).

7. An ink jet apparatus according to any preceding claim, characterised in that sad waveguide is curved along the axis of elongation.

8. An ink jet apparatus according to any preceding claim, characterised in that said waveguide (20) abuts the transducer (18).

9. An ink jet apparatus according to any preceding claim, characterised in that said pulses are transmitted to said chamber (14) in a direction having at least a component parallel with the axis of the orifice.

10. An ink jet apparatus according to any preceding claim, characterised by a plurality of ink jet chambers (14), a plurality of transducers (18) and a plurality of elongated acoustic waveguides (20), each coupled between a respective said ink jet chamber (14) and a respective said transducer (18).

11. An ink jet apparatus according to claim 10, characterised in that said plurality of waveguides (20) are removably coupled to said ink jet chambers (14).

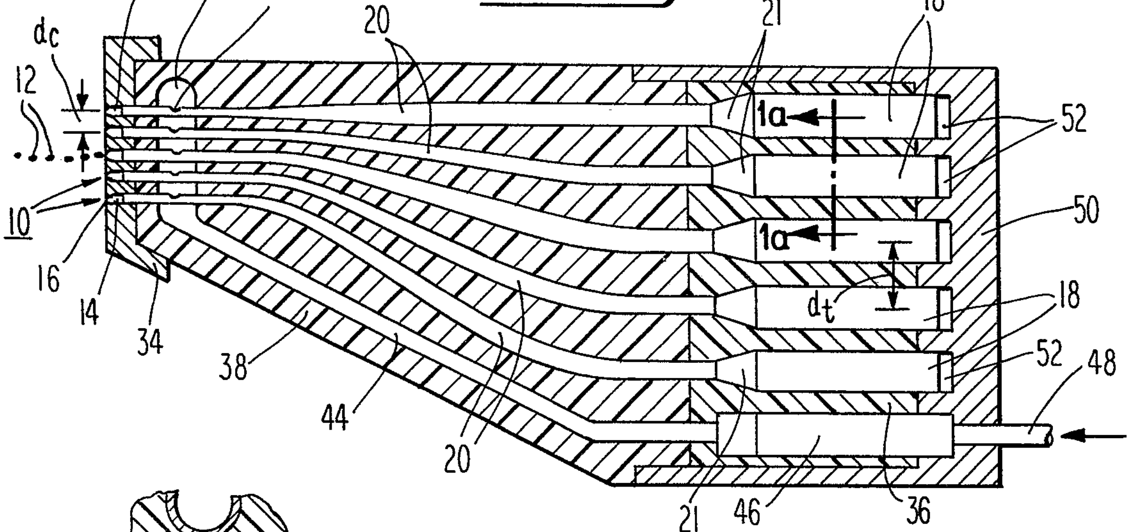
12. An ink jet apparatus according to claim 10 or 11 characterised in that said waveguides (20) are of differing lengths along the axes of elongation.

13. An ink jet apparatus according to any one of claims 10 to 12, characterised in that said waveguides (20) converge towards an array of said chambers (14).

14. An ink jet apparatus according to claim 13, characterised in that the distance between the two furthest-apart chambers of said array of chambers (14) is substantially less than that between the two furthest-apart transducers (18) of said plurality.

15. An ink jet apparatus according to claim 13 or 14, characterised by an arrangement of said transducers (18) which is offset laterally with respect to the axis of an orifice (16) at one extremity of said apparatus.

Fig. 1



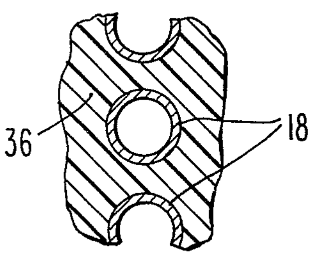


Fig. 1a

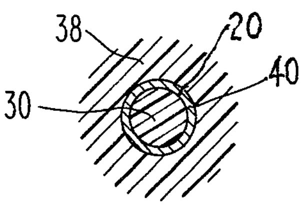


Fig. 2b

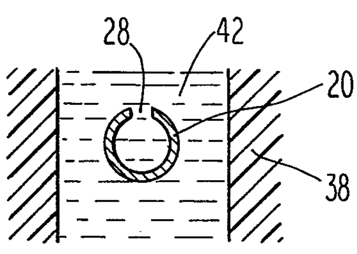


Fig. 2a

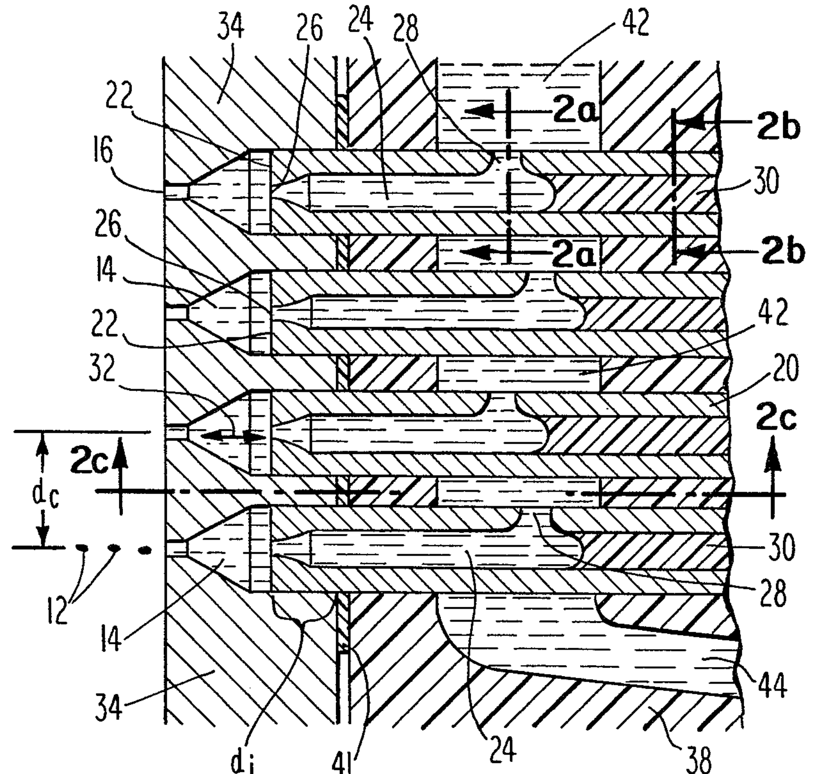


Fig. 2

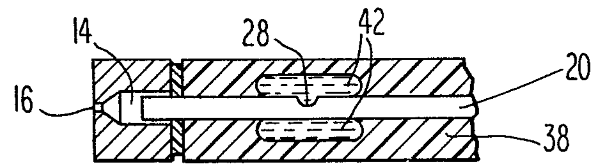


Fig. 2c

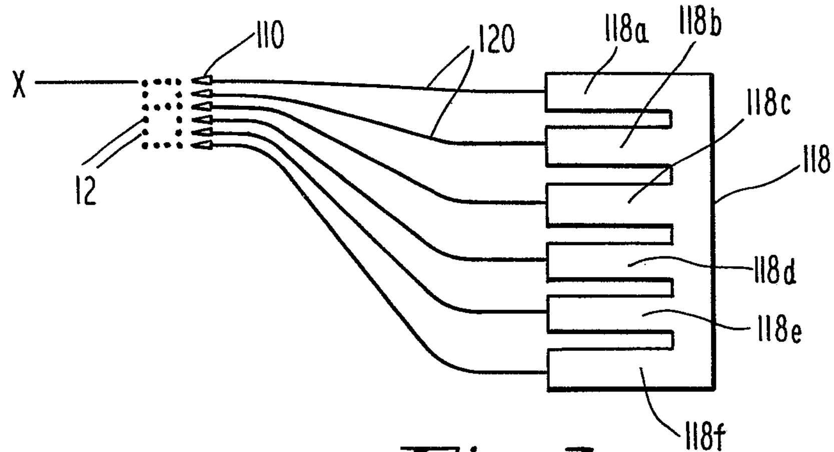


Fig. 3

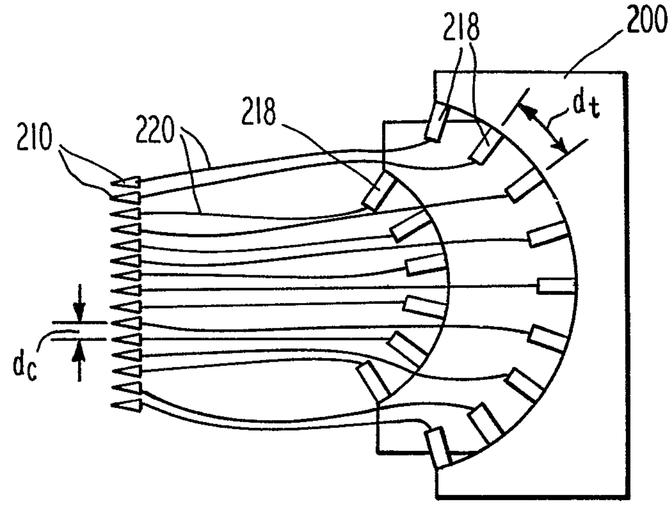


Fig. 4

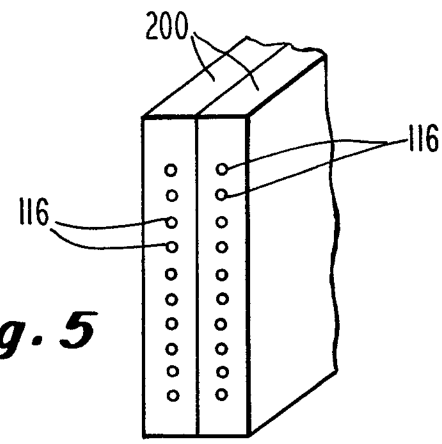


Fig. 5

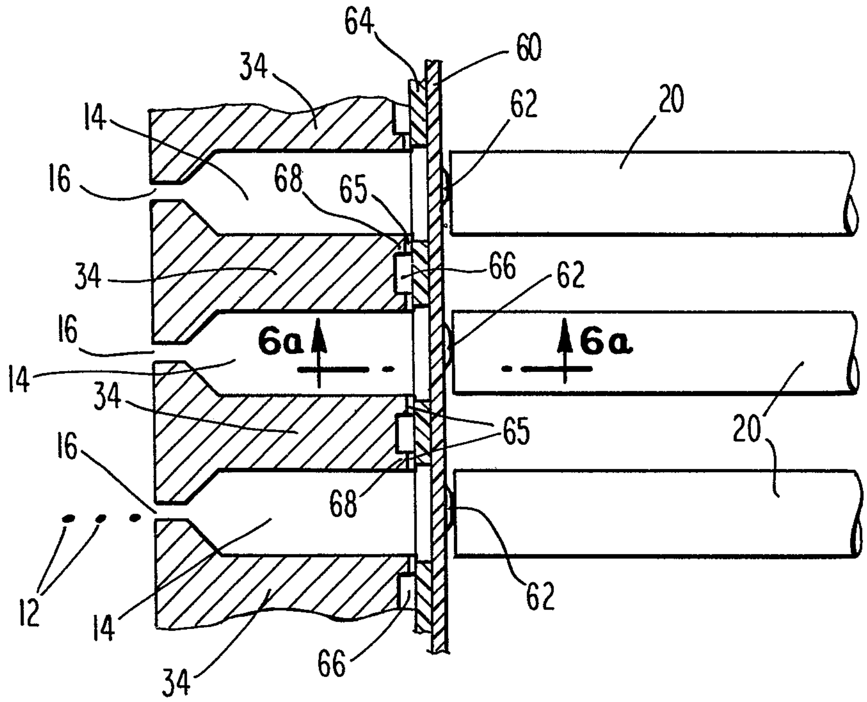

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Fig. 6

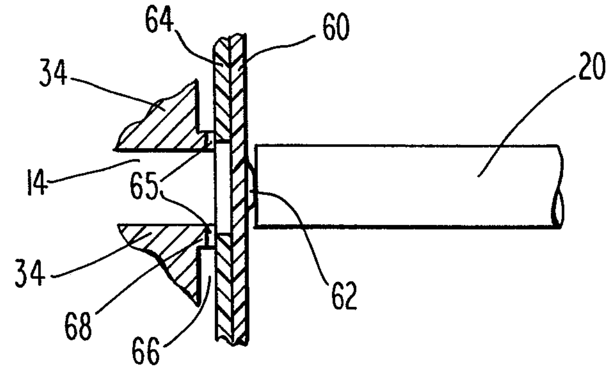
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Fig. 6a