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(71) Applicant: **Hewlett-Packard Company**
Palo Alto, California 94304 (US)

(72) Inventors:
- **Branham, Bradley B.**
  Portland,OR 97210 (US)
- **Klopfenstein, Michael F.**
  Portland, OR 97205 (US)
- **Dickinson, Jay**
  Portland, OR 97221 (US)
- **Su, Wen-Li**
  Camas, WA 98607 (US)

(74) Representative: **Colgan, Stephen James et al**
CARPMAELS & RANSFORD
43 Bloomsbury Square
London WC1A 2RA (GB)

(54) Cleaning of printhead nozzles using vibration

(57) An invention for removing an agglomeration (82, 98) from an orifice (80, 100) of a printhead (54, 56, 102) used in a printing device (20) is disclosed. The invention may also be used to help prevent formation of agglomerations in printhead orifices.

An embodiment of the invention is an apparatus that includes a source (36) that supplies a signal and a transducer (62, 88) coupled to the source (36) and configured to convert the signal from the source (36) into a vibrational waveform (84, 94, 134, 136) selected to remove the agglomeration (82, 98) from the orifice (80, 100) of the printhead (54, 56, 102).

An embodiment of a method (150) in accordance with the present invention includes the steps of supplying a signal to a transducer coupled to the agglomeration (154), converting the signal into a vibrational waveform (154), and transmitting the vibrational waveform to the agglomeration to change a state of the agglomeration from a solid to a fluid to remove the agglomeration from the orifice of the printhead (154).

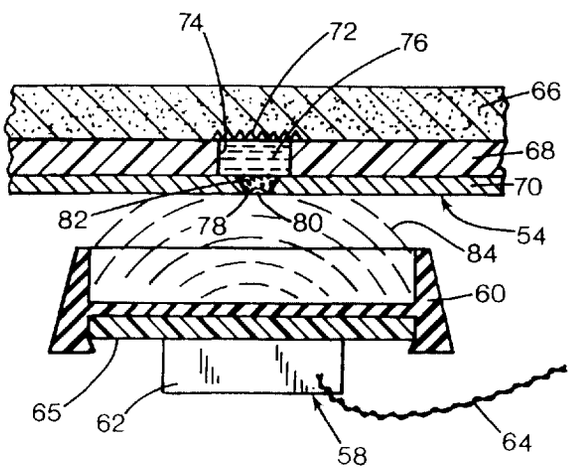

FIG. 3

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Description

Background and Summary of the Invention

[0001] The present invention relates to printing devices. More particularly, the present invention relates to removing one or more agglomerations from one or more orifices of a printhead used in a printing device. The invention may also be used to help prevent formation of agglomerations in printhead orifices.

[0002] Inkjet printers use pens which shoot drops of printing composition, referred to generally herein as "ink", onto a medium such as paper or transparencies. Each pen has a printhead formed with nozzles. Each nozzle has an orifice through which the ink drops are fired. To print an image, the printhead is propelled back and forth across the page by, for example, a carriage, while shooting drops of ink in a desired pattern as the printhead moves. The particular ink ejection mechanism within the printhead may take on a variety of different forms known to those skilled in the art, such as thermal printhead technology.

[0003] In a current thermal system, a barrier layer containing ink channels and vaporization chambers is located between an orifice plate and a substrate layer. This substrate layer typically contains linear arrays of heater elements, such as resistors, which are energized to heat ink within the vaporization chambers. Upon heating, the ink in the vaporization chamber turns into a gaseous state and forces or ejects an ink drop from a orifice associated with the energized resistor. By selectively energizing the resistors as the printhead moves across the page, the ink is expelled in a pattern onto the media to form a desired image (e.g., picture, chart or text).

[0004] To clean and protect the printhead, typically a "service station" mechanism is mounted on the printer chassis so the printhead can be moved over the station for maintenance. For storage, or during non-printing periods, service stations usually include a capping system which seals the printhead orifices from contaminants and drying. To facilitate priming, some printers have priming caps that are connected to a pumping unit to draw a vacuum on the printhead.

[0005] During operation of the printing device, agglomerations (i.e., occlusions or clogs in one or more printhead orifices caused by, for example, dried ink, dust, or printing composition aerosol) may occur. Some agglomerations may be periodically cleared by firing a number of drops of ink through each of the orifices in a clearing or purging process known as "spitting." The waste ink is collected in a spitting reservoir portion of the service station, known as a "spittoon." After spitting, uncapping, or occasionally during printing, most service stations have a flexible wiper that wipes the printhead surface to remove ink residue, as well as any paper dust or other debris that have collected on the printhead.

[0006] Other agglomerations, such as those that completely block an orifice, cannot be cleared by "spitting" and/or "wiping." In such cases, this printhead orifice fails to eject ink and print quality of the printing device is degraded. If a sufficient number of printhead orifices fail, print quality of the printing device is appreciably degraded. In extreme cases, the printhead may fail to print at all. In addition to degradation of print quality, the life of a printhead may be reduced due to overheating (ink flowing through a printhead and out nozzle orifices helps cool the printhead). Further, components of a printing device may be damaged by printing composition that is misdirected due to one or more partially clogged nozzle orifices. Alleviation of such agglomerations would be a welcome improvement.

[0007] Accordingly, the present invention is directed to providing such an improvement. Broadly characterized, the present invention relates to removing one or more agglomerations from an orifice of a printhead used in a printing device. The agglomerations include those that cannot be cleared by "spitting" and/or "wiping" as well as those that can be so cleared. The present invention may also be used to help prevent formation of agglomerations in printhead orifices.

[0008] An embodiment of the present invention is an apparatus for removing an agglomeration from an orifice of a printhead. The apparatus includes a source that supplies a signal and a transducer. The transducer is coupled to the source and configured to convert the signal from the source into a vibrational waveform selected to remove the agglomeration from the orifice of the printhead.

[0009] The above-described apparatus may include the following additional features and characteristics. The transducer may be acoustically coupled to the agglomeration, whereby the vibrational waveform is applied to the agglomeration by transmission of the vibrational waveform via air to change a state of the agglomeration from solid to fluid. The transducer may be mechanically coupled to the printhead, whereby the vibrational waveform oscillates the printhead thereby vibrating the agglomeration to change a state of the agglomeration from solid to fluid.

[0010] The apparatus may be included in a printing device which may be an inkjet printer. The transducer may be positioned on a printhead cap of the printing device.

[0011] The apparatus may include a sensor that detects the presence of the agglomeration in the orifice and notifies the source of the agglomeration which causes the source to supply the signal to the transducer. The printhead may include a substrate and the transducer may be formed from the substrate of the printhead.

[0012] The vibrational waveform may have a predetermined frequency selected to change a state of the agglomeration from solid to fluid. The vibrational waveform may have a range of frequencies selected to change a state of the agglomeration from solid to fluid. The waveform may have a predetermined shape (e.g., sinusoidal, sawtooth, square, etc.) selected to change

a state of the agglomeration from solid to fluid.

[0013] Another embodiment of an apparatus for removing an agglomeration from an orifice of a printhead in accordance with the present invention includes structure for removing an agglomeration from the orifice of the printhead. The structure for removing the agglomeration generates a vibrational waveform selected to change a state of the agglomeration from solid to fluid.

[0014] The above-described apparatus may include the following additional features and characteristics. The structure for removing an agglomeration may be acoustically coupled to the agglomeration, whereby the vibrational waveform is applied to the agglomeration by transmission of the vibrational waveform via air to change the state of the agglomeration from solid to fluid. The structure for removing an agglomeration may be mechanically coupled to the printhead, whereby the vibrational waveform oscillates the printhead thereby vibrating the agglomeration to change the state of the agglomeration from solid to fluid.

[0015] The vibrational waveform may have a predetermined frequency selected to change the state of the agglomeration from solid to fluid. The vibrational waveform may have a range of frequencies selected to change the state of the agglomeration from solid to fluid. The vibrational waveform may have a predetermined shape selected to change the state of the agglomeration from solid to fluid.

[0016] The apparatus may be included in a printing device which may be an inkjet printer. The structure for removing an agglomeration may be positioned on a printhead cap of the printing device.

[0017] The apparatus may further include structure for detecting the presence of an agglomeration in the orifice. The printhead may include a substrate and the structure for removing an agglomeration may be formed from the substrate of the printhead.

[0018] The structure for removing the agglomeration may include a transducer.

[0019] A further aspect of the present invention is a method for removing an agglomeration from an orifice of a printhead. An embodiment of the method includes the steps of supplying a signal to a transducer coupled to the agglomeration, converting the signal into a vibrational waveform, and transmitting the vibrational waveform to the agglomeration to change a state of the agglomeration from solid to fluid to remove the agglomeration from the orifice of the printhead.

[0020] The above-described method may include the following additional steps and characteristics. The vibrational waveform may be transmitted by acoustic coupling. Alternatively, the vibrational waveform may be transmitted by mechanical coupling to the printhead.

[0021] The method may include the step of modeling the agglomeration to optimize the vibrational waveform. The method may also include the step of selecting a predetermined frequency for the vibrational waveform. The method may also include the step of selecting a range of frequencies for the vibrational waveform.

[0022] The method may additionally include the step of selecting a shape of the vibrational waveform. The method may further include the steps of detecting a presence of an agglomeration in the orifice and supplying the signal to the transducer when the agglomeration is detected.

[0023] Other objects, advantages, and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0024] FIG. 1 is a fragmented, partially schematic, perspective view of an inkjet printing device in which the present invention may be used.

[0025] FIG. 2 is a bottom perspective view of an ink cartridge and also of an embodiment of a printhead orifice cleaner in accordance with the present invention on a cap of a service station of an inkjet printer.

[0026] FIG. 3 is an enlarged view taken along line 3-3 of FIG. 2 that shows a printhead of the ink cartridge of FIG. 2 and the operation of the present invention via acoustic coupling.

[0027] FIG. 4 is an enlarged view of the printhead of the ink cartridge of FIG. 2 and the operation of the present invention via mechanical coupling.

[0028] FIG. 5 is a diagram of an agglomeration in an orifice of a printhead that is causing the printhead to perform less than optimally.

[0029] FIG. 6 is a diagram of removal of the agglomeration shown in FIG. 5 from the orifice of the printhead in accordance with the present invention.

[0030] FIG. 7 is a diagram of the orifice cleared of the agglomeration shown in FIGs. 5 and 6.

[0031] FIGs. 8(a)-(f) illustrate an embodiment of a method of detecting and removing one or more agglomerations from one or more orifices of a printhead in accordance with the present invention.

[0032] FIG. 9 is a flowchart of an embodiment of a method of detecting and removing one or more agglomerations from an orifice of a printhead in accordance with the present invention.

Detailed Description of the Drawings

[0033] FIG. 1 illustrates an embodiment of a printing device 20, here shown as an inkjet printer, which may be used for printing business reports, correspondence, desktop publishing, and the like, in an industrial, office, home or other environment. A variety of inkjet printing devices are commercially available. Some of these include plotters, portable printing units, copiers, cameras, video printers, and facsimile machines, to name a few.

[0034] While it is apparent that the printer components may vary from model to model, the typical inkjet

printer 20 includes a chassis 22 surrounded by a housing or casing enclosure 24, typically of a plastic material. Sheets of media are fed through a print zone 25 by an adaptive media handling system 26. The media may be any type of suitable sheet material, such as paper, cardstock, transparencies, mylar, and the like, but, for convenience, the illustrated embodiment is described using paper as the medium. The media handling system 26 has a feed tray 28 for storing sheets of paper before printing. A series of conventional motor-driven paper drive rollers (not shown) may be used to move the media from tray 28 into the print zone 25 for printing. After printing, the sheet then lands on a pair of retractable output drying wing members 30. The wings 30 momentarily hold the newly printed sheet above any previously printed sheets still drying in an output tray portion 32 before pivotally retracting to the sides, as shown by curved arrows 33, to drop the newly printed sheet into the output tray 32. The media handling system 26 may include a series ofadjustment mechanisms for accommodating different sizes of media, including letter, legal, A-4, envelopes, etc., such as a sliding length adjustment lever 34, and an envelope feed slot 35. Printer 20 also has a printer controller, illustrated schematically as a microprocessor 36, that controls operation of printing device 20.

[0035] A carriage guide rod 38 is supported by chassis 22 to slideably support an inkjet carriage 40 for travel back and forth across the print zone 25 along a scanning axis 42 defined by the guide rod 38. A conventional carriage propulsion system may be used to drive carriage 40, including a position feedback system, which communicates carriage position signals to the controller 36. For instance, a carriage drive gear and motor assembly may be coupled to drive an endless belt secured in a conventional manner to carriage 40, with the motor operating in response to control signals received from the printer controller 36. To provide carriage positional feedback information to printer controller 36, an optical encoder reader may be mounted to carriage 40 to read an encoder strip extending along the path of carriage travel.

[0036] Carriage 40 is also propelled along guide rod 38 into a servicing region, as indicated generally by arrow 44, located within the interior of the casing 24. The servicing region 44 houses a service station 45, which may provide various conventional printhead servicing functions. For example, a service station frame 46 holds a group of printhead servicing appliances, such as one or more caps and wipers. In FIG. 1, a spittoon portion 48 of the service station is shown as being defined, at least in part, by the service station frame 46.

[0037] In print zone 25, a media sheet receives printing composition, referred to generally herein as "ink", from an inkjet cartridge, such as a black ink cartridge 50 and/or a color ink cartridge 52. The cartridges 50 and 52 are also often called "pens" by those in the art. The illustrated color pen 52 is a tri-color pen, although in some embodiments, a set of discrete monochrome pens may be used.

[0038] The illustrated pens 50, 52 each include reservoirs for storing a supply of ink. The pens 50, 52 have printheads 54, 56, respectively, each of which includes a plurality of nozzles formed therethrough in a manner well known to those skilled in the art. The illustrated printheads 54, 56 are thermal inkjet printheads, although other types of printheads may be used, such as piezoelectric printheads. The printheads 54, 56 typically include a substrate layer having a plurality of resistors which are associated with the nozzles. Upon energizing a selected resistor, a bubble of gas is formed to eject a drop of ink from an orifice of the nozzle onto a sheet of media in print zone 25. The printhead resistors are selectively energized in response to enabling or firing command control signals, which may be delivered by a conventional multi-conductor strip (not shown) from controller 36 to the printhead carriage 40, and through conventional interconnects between the carriage and pens 50, 52 to the printheads 54, 56.

[0039] FIG. 2 is a bottom perspective view of ink cartridge 50 and also of an embodiment of a printhead orifice cleaner 58 in accordance with present invention on a printhead cap 60 of service station 45 of inkjet printer 20. Printhead orifice cleaner 58 is used to remove one or more agglomerations from one or more orifices of printhead 54. Agglomerations are occlusions or clogs that partially or completely block an orifice of a printhead nozzle. Agglomerations can occur from things such as dried printing composition, dust, or printing composition aerosol.

[0040] Some agglomerations may be periodically cleared by firing a number of drops of ink through each of the orifices of printhead 54 in a clearing or purging process known as "spitting." The waste ink is collected in spittoon reservoir portion 48 of service station 45. "Wiping", described above, may also occur. Other agglomerations, such as those that completely clog an orifice, can not be cleared by "spitting" and/or "wiping." In such cases, this printhead orifice fails to eject ink and print quality of printing device 20 is degraded. If a sufficient number of printhead orifices fail, print quality is appreciably degraded. In extreme cases, printhead 54 may fail to print at all. In addition to degradation of print quality, the life of printhead 54 may be reduced due to overheating (ink flowing through printhead 54 and out nozzle orifices helps cool printhead 54). Further, components of printing device 20 may be damaged by printing composition that is misdirected due to one or more partially clogged nozzle orifices. The present invention is directed to removing agglomerations from printhead nozzle orifices to help eliminate or reduce these problems.

[0041] Printhead orifice cleaner 58 includes a piezoelectric transducer 62 that receives one or more signals from a source, such as controller 36, via line 64, which may be part of the above-described multi-conductor strip. Transducer 62 converts such signals into one or

more vibrational waveforms selected to remove one or more agglomerations from one or more nozzle orifices of printhead 54, as more fully discussed below. The frequency or frequencies of these vibrational waveforms may be selected based upon the particular characteristics of anticipated agglomerations. The shape or shapes of these vibrational waveforms (e.g., sinusoidal, sawtooth, square, etc.) may also be selected based upon the particular characteristics of anticipated agglomerations. Various additional factors may need to be accounted for in addition to the anticipated agglomerations such as printhead resonant frequency, printhead operating temperature, ambient temperature, and ambient humidity. The particular frequency and shape of a vibrational waveform may be controlled by the signals sent on line 64 and/or the characteristics of transducer 62.

[0042] FIG. 3 is an enlarged view of printhead 54 and printhead orifice cleaner 58 taken along line 3-3 of FIG. 2 that illustrates operation of printhead orifice cleaner 58 via acoustic coupling. Piezoelectric transducer 62 is attached to base component 65 of service station 45 to which printhead cap 60 is also attached, as shown. Printhead 54 includes a substrate 66 that may be made of silicon, a barrier 68 that may be made of a photo-exposed polymer, an orifice plate 70 that may be made of metal, and a resistor 72. Substrate 66, barrier 68, and orifice plate 70 define a printing composition reservoir or chamber 74 in which a quantity of printing composition 76 is disposed. A nozzle 78 is formed in orifice plate 70 and includes an orifice 80 though which printing composition 76 is ejected by energizing resistor 72, as discussed above. Although only one resistor, nozzle and orifice are shown for printhead 54, it is to be understood that printhead 54 includes a plurality of such resistors, nozzles and orifices.

[0043] An agglomeration 82 is shown that is blocking orifice 80 of nozzle 78. This agglomeration may be either partially or completely blocking printing composition 76 intended for a sheet of media. In the embodiment of the printhead orifice cleaner 58 of the present invention shown in FIG. 3, acoustic coupling is used to remove agglomeration 82 from orifice 80. With such acoustic coupling, contact between printhead 54 and printhead orifice cleaner 58 or printhead cap 60 does not occur. Rather, vibrational waveform 84 is generated by vibration of transducer 62, transmitted via air, and used to remove agglomeration 82.

[0044] Transducer 62 is configured to convert one or more signals from controller 36 received via line 64 into one or more vibrational waveforms. The frequency or frequencies of vibrational waveform 84 may be selected based upon the particular characteristics of anticipated agglomerations. The shape or shapes of vibrational waveform 84 may also be based upon the particular characteristics of anticipated agglomerations. That is, the anticipated agglomerations may be modeled to optimize vibrational waveform 84. Various additional factors may need to be accounted for in addition to the anticipated agglomerations such as printhead operating temperature, ambient temperature, and ambient humidity.

[0045] In an alternative embodiment of the present invention shown in FIG.4, a printhead orifice cleaner 86 uses mechanical coupling to remove agglomeration 82 from orifice 80. Printhead orifice cleaner 86 includes a piezoelectric transducer 88 that is attached to base component 65 of service station 45 to which printhead cap 60 is also attached, as shown. Transducer 88 receives one or more signals from a source, such as controller 36, via line 90, which may be part of the above-described multi-conductor strip, and converts such signals into one or more vibrational waveforms selected to remove one or more agglomerations from one or more nozzle orifices of printhead 54, as more fully discussed below.

[0046] As with acoustic coupling, the frequency or frequencies of these vibrational waveforms may be selected based upon the particular characteristics of anticipated agglomerations, as well as the fact that mechanical rather than acoustic coupling will occur. Also, the shape or shapes of these vibrational waveforms may also be based upon the particular characteristics of anticipated agglomerations. That is, the anticipated agglomerations may be modeled to optimize the vibrational waveform.

[0047] These frequencies and shapes may be the same or different than those used with acoustic coupling, shown above in FIG. 3. For example, for pigmented inks, the inventors have found that vibrational waveforms having a sinusoidal shape and a frequency in the range of 20 KiloHertz (KHz) to 22 KiloHertz (KHz) are effective in removing ink agglomerations from nozzle orifices where mechanical coupling, shown in FIG. 4, is used. Other shapes and/or frequencies may work as well for such ink agglomerations.

[0048] Various additional factors may need to be accounted for in addition to the anticipated agglomerations such as printhead resonant frequency, printhead operating temperature, ambient temperature, and ambient humidity. With regard to printhead resonant frequency, the frequency of the one or more vibrations is selected to take advantage of the resonant frequency of printhead 54 to amplify the energy supplied to the agglomeration to further facilitate the changing of state of the agglomeration from solid to fluid.

[0049] As noted above, in the embodiment of the printhead orifice cleaner 86 of the present invention shown in FIG. 4, mechanical coupling is used to remove agglomeration 82 from orifice 80. With such mechanical coupling, contact between printhead 54 and printhead orifice cleaner 86 occurs via printhead cap 60. Vibrational waveforms 92 and 94 are generated by vibration of transducer 88 and transmitted via cap 60 and orifice plate 70 to agglomeration 82. Transducer 88 is configured to convert one or more signals from controller 36 received via line 90 into such vibration. Acoustic vibrational waveforms 96 may be generated by vibration of

transducer 88 and transmitted via any air trapped between printhead 54 and 60. Such waveforms may also be used to help remove agglomeration 82.

[0050] Agglomerations are removed from printhead nozzle orifices in accordance with the present invention by changing a state of the agglomeration from a solid to a fluid. This may be accomplished as illustrated in FIGs. 5-7. FIG. 5 shows a diagram of an agglomeration 98 in an orifice 100 of a printhead 102. As with printhead 54, printhead 102 includes a substrate 104, a barrier 106, an orifice plate 108, a resistor 110, and a printing composition reservoir or chamber 112 in which a quantity of printing composition 114 is disposed. Although only one resistor, nozzle and orifice are shown for printhead 102, it is to be understood that printhead 102 includes a plurality of such resistors, nozzles and orifices.

[0051] A printhead orifice cleaner 115 in accordance with the present invention is incorporated directly into substrate 104. Controller 36 sends one or more signals to printhead orifice cleaner 115 via the above-described multi-conductor strip and interconnects between carriage 40 and ink cartridges disposed therein. Printhead orifice cleaner 115 converts such signals into vibrations of substrate 104 that remove agglomeration 98 from orifice 100, as more fully discussed below.

[0052] Agglomeration 98 is partially blocking orifice 100 of printhead 102 so that drops of ink 116, 118, and 120 are misdirected and not aligned. Additional stray droplets of ink 122, 124, 126, 128, 130, and 132 are also being ejected.

[0053] Vibrational waveforms, generally represented by arrows 134 and 136 in FIG 6, are generated by vibration of substrate 104, and transmitted via barrier 106 and orifice plate 108 to agglomeration 98. This transmission occurs by vibration of barrier 106 and orifice plate 108. Sufficient quantities of this vibrational waveform energy removes agglomeration 98 from orifice 100 by breaking agglomeration 98 into smaller masses which change state from solid to fluid as these masses dissolve into printing composition 114, as shown in FIG. 6 and generally indicated by arrows 138, 140, 142, 144, and 146. As shown in FIG. 7, after removing agglomeration 98 from orifice 100, drops of ink 138, 140, and 142 are ejected from orifice 100 in a directed and aligned manner without stray droplets.

[0054] FIGs. 8(a)-(f) illustrate an embodiment of a method of detecting and removing one or more agglomerations from one or more orifices of a printhead in accordance with the present invention. In accordance with this method, printhead 54 shots drops of ink 144 onto a media sheet 146 as shown in FIG. 8(a). The quality of printing is checked periodically, as shown in FIG. 8(b), by an optical device or sensor 148 which may be mounted, for example, on carriage 40. Optical device 148 feeds back information regarding the quality of printing to controller 36. If quality is less than expected, one or more agglomerations in one or more orifices of printhead 54 may be present.

[0055] Although an optical device 148 is shown as a way of detecting agglomerations, it should be noted that other devices may be used as well in accordance with the present invention. Theses devices may be used instead of optical device 148 or in conjunction with optical device 148. For example, rise in temperature of printhead 54 may indicate one or more orifices clogged with agglomerations because ink is not flowing out of printhead 54 in a sufficient quantity to cool printhead 54. A temperature sensor may be used on printhead 54 to detect such temperature increases. As an another example, agglomerations may be detected acoustically by a microphone because a printhead emits different sound waves when all orifices are clear of agglomerations than when one or more orifices are clogged with agglomerations. As a further example, agglomerations may be detected based upon changing electrical or magnetic characteristics of an orifice when an agglomeration is present.

[0056] Printhead orifice cleaner 86 is used to remove any such agglomerations as shown in FIG. 8(c). It should be noted that printhead orifice cleaner 58, printhead orifice cleaner 115, or other printhead orifice cleaners in accordance with the present invention may alternatively be used. The nozzles of printhead 54 may be further cleaned by "spitting" into spittoon portion 48 of service station 45 as shown in FIG. 8(d). Depending on the particular characteristics of a printhead, wiping, as described above, may also be desirable.

[0057] Printhead 54 resumes printing by shooting drops of ink 144 onto media sheet 146 as shown in FIG 8(e). The quality of printing is again checked periodically as shown in FIG. 8(f) by optical device 148. If quality is less than expected, printhead orifice cleaner 86 is used again, as generally indicated by arrow 150.

[0058] A flowchart of an embodiment of a method of detecting and removing one or more agglomerations from an orifice of a printhead 150 in accordance with the present invention is shown in FIG. 9. Method 150 includes the step of detecting one or more plugged orifices of a printhead caused by one or more agglomerations, as generally indicated by step 152 in FIG 9, and as discussed above in connection with FIG. 8. If at least one agglomeration is detected, controller 36 sends a signal to the transducer of the printhead orifice cleaner of the present invention to generate a first vibrational waveform, as generally indicated by step 154. Although not shown, spitting and/or wiping, as discussed above, may also occur.

[0059] If the one or more agglomerations are removed, printing resumes, as generally indicated by steps 156 and 158. If one or more of the orifices remain clogged, the transducer is vibrated differently to produce a second vibrational waveform to further attempt to remove the one or more agglomerations, as indicated by steps 156 and 160. This second vibrational waveform may be different than the first vibrational waveform (e. g., have a different frequency and/or shape). Addition-

ally, the second vibrational waveform may be applied for a different period of time than the first vibrational waveform. Alternatively, the first and second vibrational waveforms may be the same. Although not shown, spitting and/or wiping, as discussed above, may also occur.

[0060] If the agglomerations are removed, printing resumes, as generally indicated by steps 162 and 164. If not, then additional vibrational waveforms may be generated by controller 36 and the transducer to still further attempt to remove remaining agglomerations. Such additional vibrational waveforms are only generated if the number of previously attempts to remove the one or more agglomerations do not exceed a predetermined limit, as generally indicated by step 166. If the number of attempts to remove the one or more agglomerations do exceed the predetermined limit, an error signal is sent to controller 36, as indicated by step 168.

[0061] Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is intended by way of illustration and example only, and is not to be taken by way of limitation. For example, in alternative embodiments of the printhead orifice cleaner of the present invention, the transducer does not have to be a piezoelectric transducer. As another example, the transducer may be mechanically coupled to the printhead by locating it elsewhere other than as previously shown and described above, such as on the cartridge body or on the carriage. As an additional example, instead of changing a state of an agglomeration from solid to fluid, as described above, an agglomeration may be broken into smaller solid elements by vibrational energy and then spit out of an orifice into the spittoon portion of a service station. As a further example, adaptive decision control electronics (e.g., neural networks) may be used instead of or in combination with a controller. Such adaptive decision control-electronics could be used, for example, to change the vibrational waveform of the printhead orifice cleaner as often as necessary to optimize agglomeration removal based the particular type of agglomeration, as well as based upon other parameters, such as current printhead temperature, printhead resonant frequency, ambient temperature, and ambient humidity. As yet a further example, a method in accordance with the present invention may direct vibrational waveforms at the printhead in instances when one or more agglomerations have not been detected in an attempt to help prevent the formation of agglomerations or to remove undetected agglomerations. This may be done on a periodic basis such as during part of a service station routine or after a predetermined number of pages have been printed. Such periodic application of vibrational waveforms helps maintain the ink in a liquid state so that occurrence of agglomeration formation is reduced or eliminated. The spirit and scope of the present invention are to be limited only by the terms of the following claims.

Claims

1. An apparatus for removing an agglomeration (82, 98) from an orifice (80, 100) of a printhead (54, 56, 102), the apparatus comprising:

   a source (36) that supplies a signal; and
   a transducer (62, 88) coupled to the source (36) and configured to convert the signal from the source (36) into a vibrational waveform (84, 94, 134, 136) selected to remove the agglomeration (82, 98) from the orifice (80, 100) of the printhead (54, 56, 102).

2. The apparatus of Claim 1, wherein the transducer (62, 88) is acoustically coupled to the agglomeration (82, 98), whereby the vibrational waveform (84, 94, 134, 136) is applied to the agglomeration (82, 98) by transmission of the vibrational waveform (84, 94, 134, 136) via air to change a state of the agglomeration (82, 98) from solid to fluid.

3. The apparatus of Claim 1, wherein the transducer (62, 88) is mechanically coupled to the printhead (54, 56, 102), whereby the vibrational waveform (84, 94, 134, 136) oscillates the printhead (54, 56, 102) thereby vibrating the agglomeration (82, 98) to change a state of the agglomeration (82, 98) from solid to fluid.

4. The apparatus of Claim 1, further comprising a printing device (20).

5. The apparatus of Claim 4, wherein the transducer (62, 88) is positioned on a printhead cap (60) of the printing device (20).

6. The apparatus of Claim 1, further comprising a sensor (148) that detects the presence of the agglomeration (82, 98) in the orifice (80, 100) and notifies the source (36) of the agglomeration (82, 98) which causes the source (36) to supply the signal to the transducer (62, 88).

7. The apparatus of Claim 1, wherein the printhead (54, 56, 102) includes a substrate (66, 104), and further wherein the transducer (62, 88) is formed from the substrate (66, 104) of the printhead (54, 56, 102).

8. The apparatus of Claim 1, wherein the vibrational waveform (84, 94, 134, 136) has a predetermined frequency selected to change a state of the agglomeration from solid to fluid.

9. The apparatus of Claim 1, the vibrational waveform (84, 94, 134, 136) has a range of frequencies to change a state of the agglomeration (82, 98) from

solid to fluid.

10. The apparatus of Claim 1, wherein the vibrational waveform (84, 94, 134, 136) has a predetermined shape selected to change a state of the agglomeration from solid to fluid.

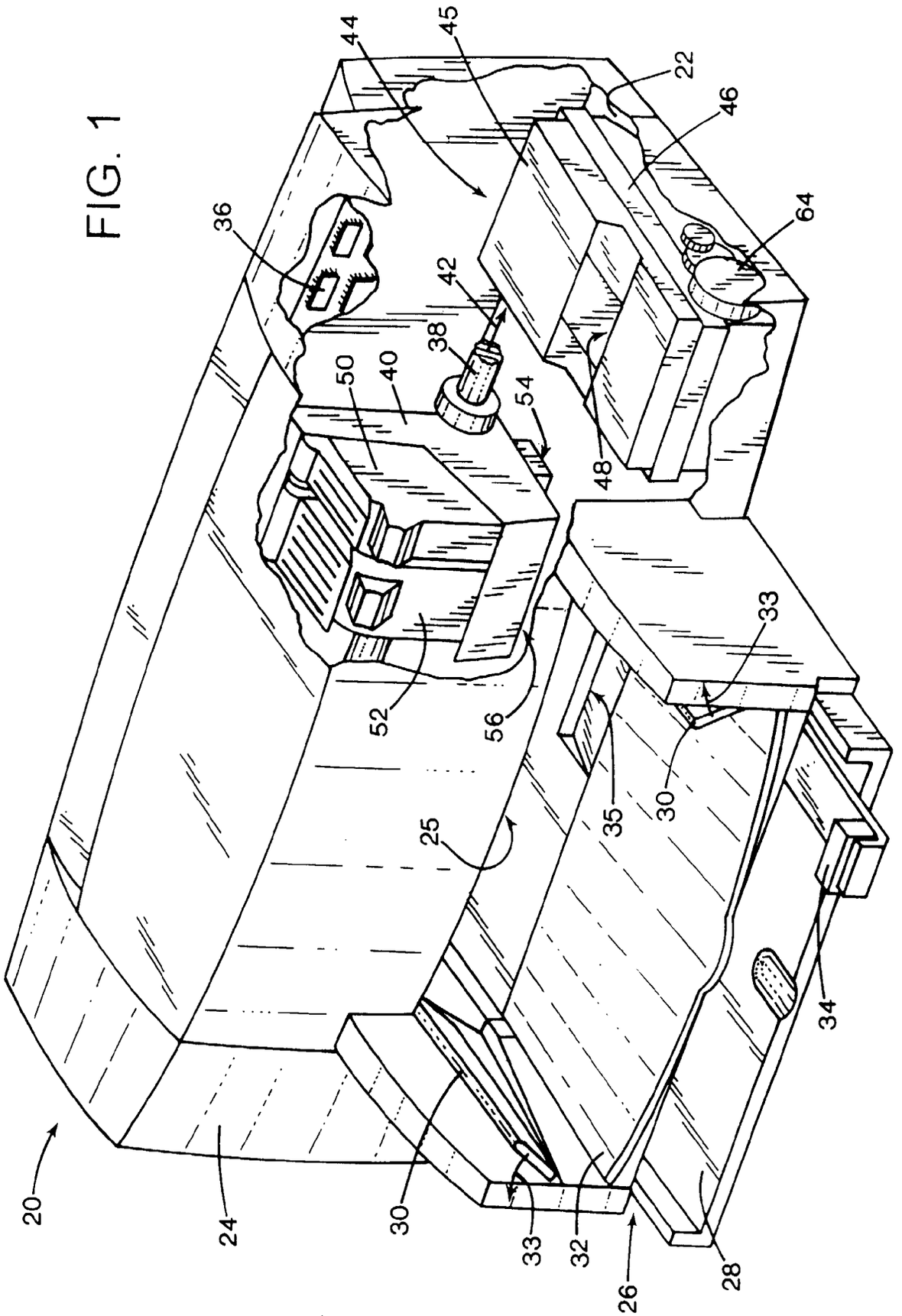
11. A method for removing an agglomeration from an orifice of a printhead (150), the method (150) comprising the steps of:

supplying a signal to a transducer coupled to the agglomeration (154);
converting the signal into a vibrational waveform (154); and
transmitting the vibrational waveform to the agglomeration to change a state of the agglomeration from solid to fluid to remove the agglomeration from the orifice of the printhead (154).

12. The method of Claim 11, further comprising the steps of :

detecting a presence of an agglomeration in the orifice (152); and
supplying the signal to the transducer when the agglomeration is detected (154).

FIG. 1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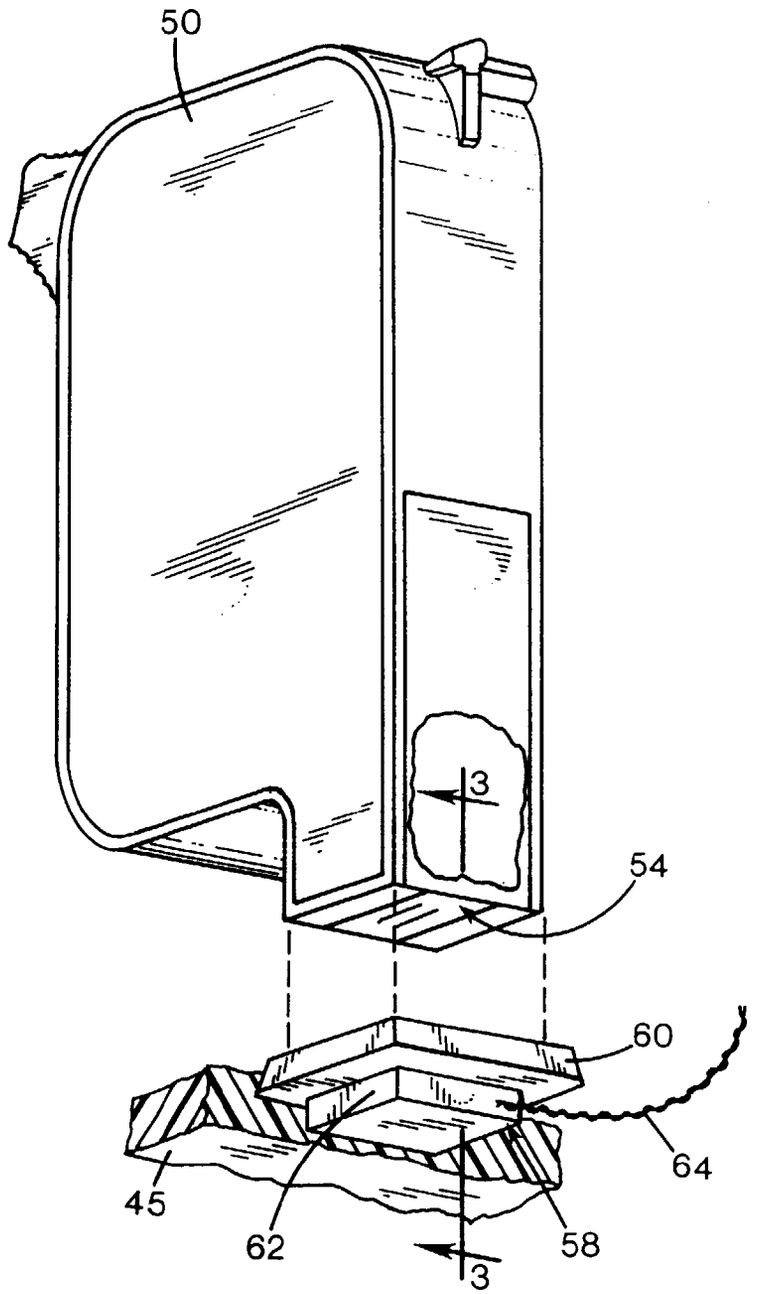
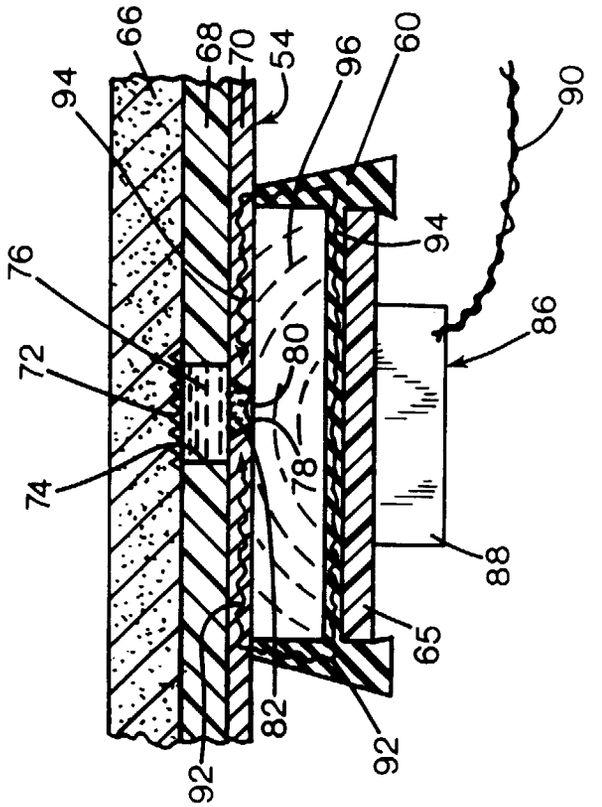


FIG. 2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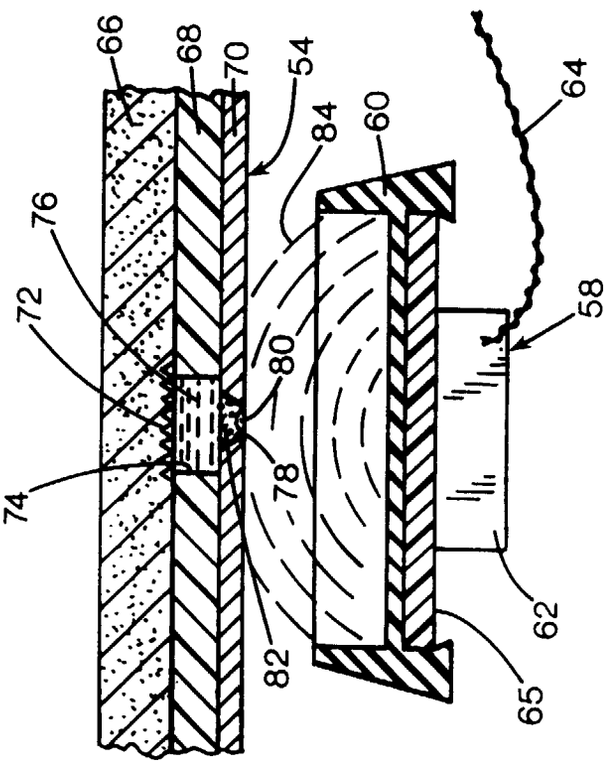
92

FIG. 4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62
82
65

FIG. 3

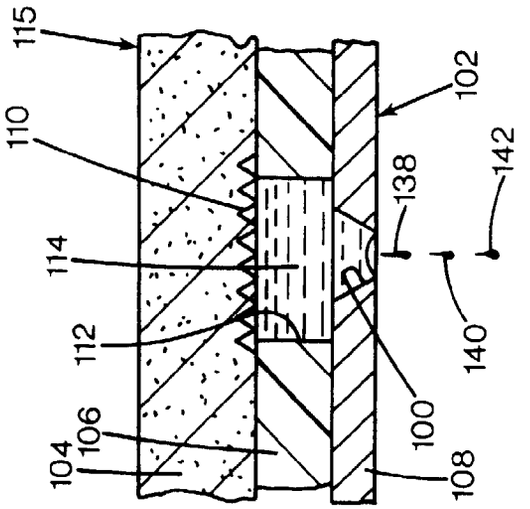


FIG. 7

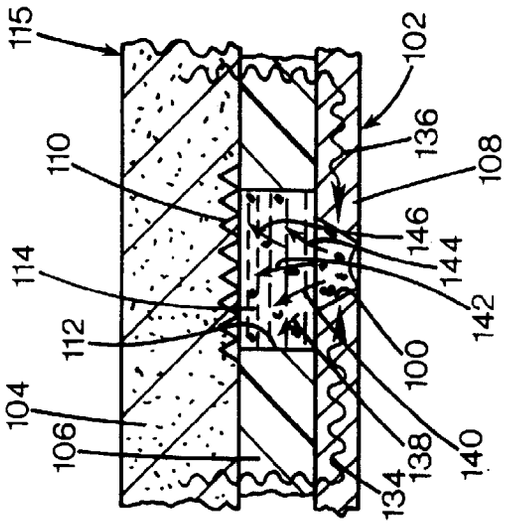


FIG. 6

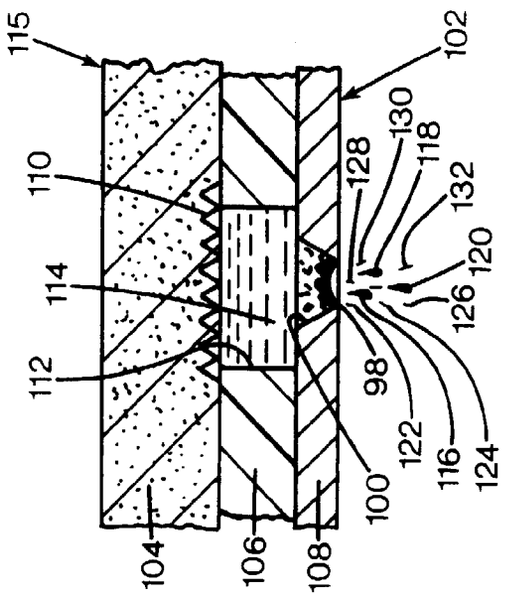


FIG. 5

FIG. 8

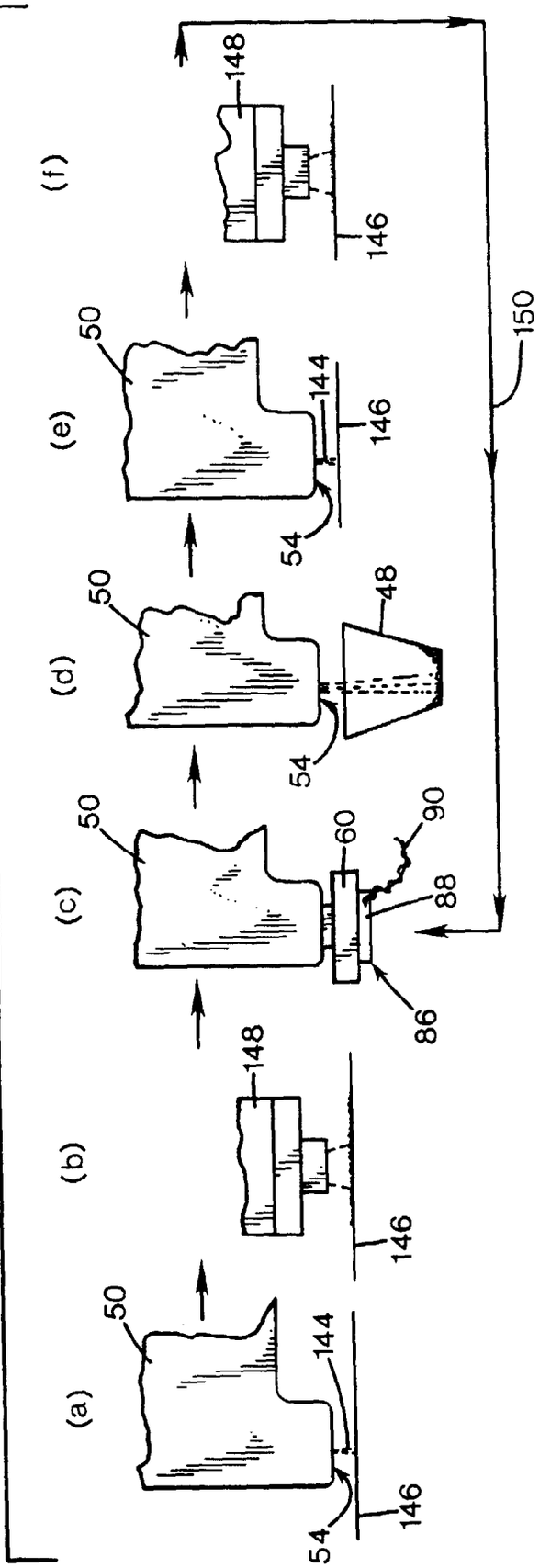
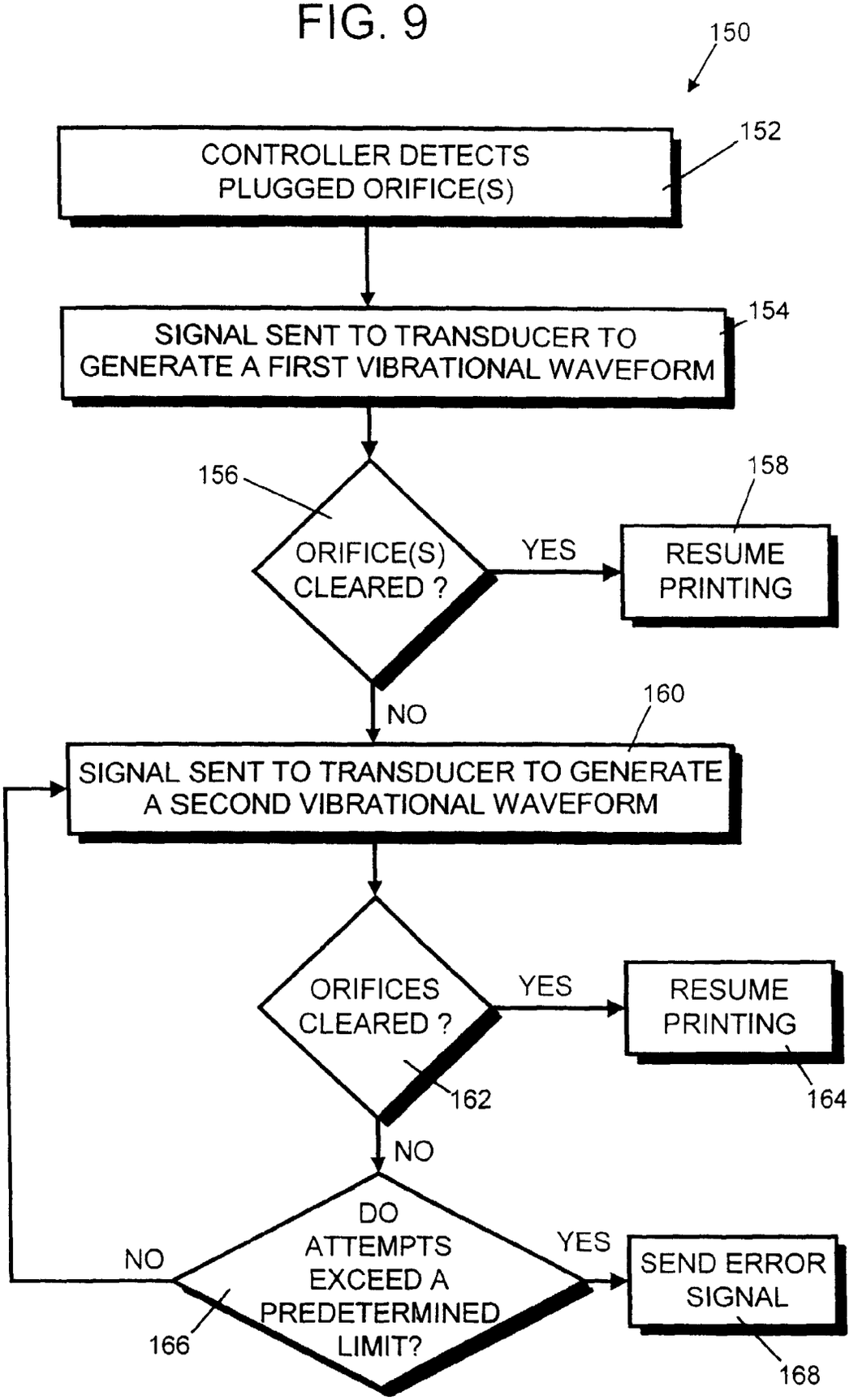


FIG. 9


150
CONTROLLER DETECTS PLUGGED ORIFICE(S)
152
SIGNAL SENT TO TRANSDUCER TO GENERATE A FIRST VIBRATIONAL WAVEFORM
154
156
ORIFICE(S) CLEARED ?
YES
158
RESUME PRINTING
NO
160
SIGNAL SENT TO TRANSDUCER TO GENERATE A SECOND VIBRATIONAL WAVEFORM
ORIFICES CLEARED ?
YES
RESUME PRINTING
162
164
NO
DO ATTEMPTS EXCEED A PREDETERMINED LIMIT?
NO
YES
SEND ERROR SIGNAL
166
168

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 7675

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Y	US 4 609 925 A (NOZU TAKETO ET AL) 2 September 1986	3,6,12	
A	* abstract * * column 5, line 32 - column 13, line 9; figures 4-17 *	7	
X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 330 (M-636), 28 October 1987 & JP 62 113555 A (CANON INC), 25 May 1987	1,4,5,11	
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X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 050 (M-562), 17 February 1987 & JP 61 215059 A (TOSHIBA CORP), 24 September 1986	1,3,4, 8-11	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	19 January 1999	Nielsen, M

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EUROPEAN SEARCH REPORT

Application Number
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			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	19 January 1999	Nielsen, M

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