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(54) **FLUID EJECTION SYSTEM, FLUID EJECTION SYSTEM DRIVE METHOD, AND SURGICAL APPARATUS**

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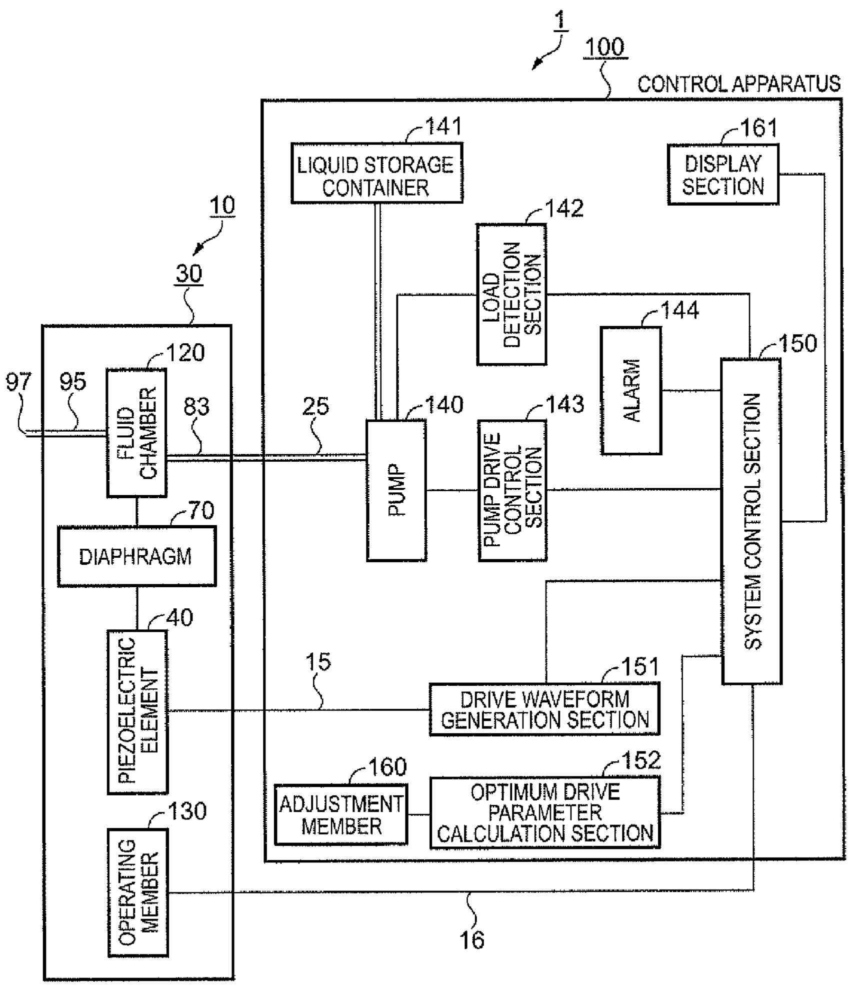
(57) **ABSTRACT**

A fluid ejection system includes: a pulsation generation section which, including a fluid chamber, a diaphragm which changes a volume of the fluid chamber, and a piezoelectric element which drives the diaphragm, pulsatively ejects a fluid from a nozzle; and a control apparatus including a pressure generation section which supplies the fluid to the fluid chamber at a predetermined pressure, a drive waveform generation section which inputs a drive waveform into the piezoelectric element, and a load detection section which detects a load of the pressure generation section, wherein in the event that the load detection section has detected a load abnormality of the pressure generation section, a fluid discharge pressure amplitude of the pulsation generation section or a fluid supply pressure of the pressure generation section is made higher than at a normal drive time.



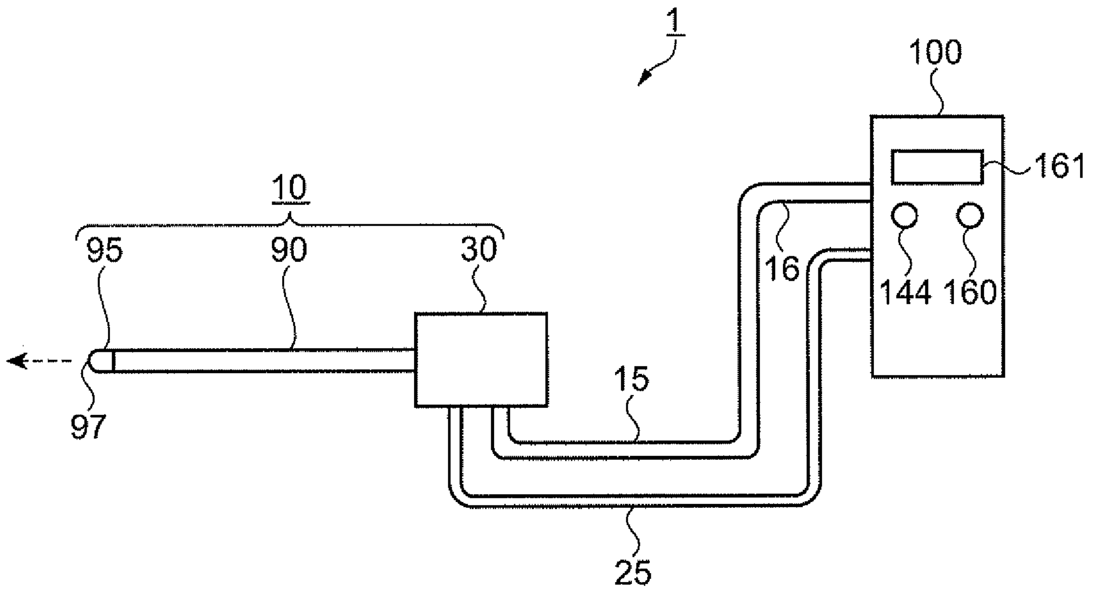

1
100
161
10
95
90
30
16
144
160
15
97
25

FIG. 1

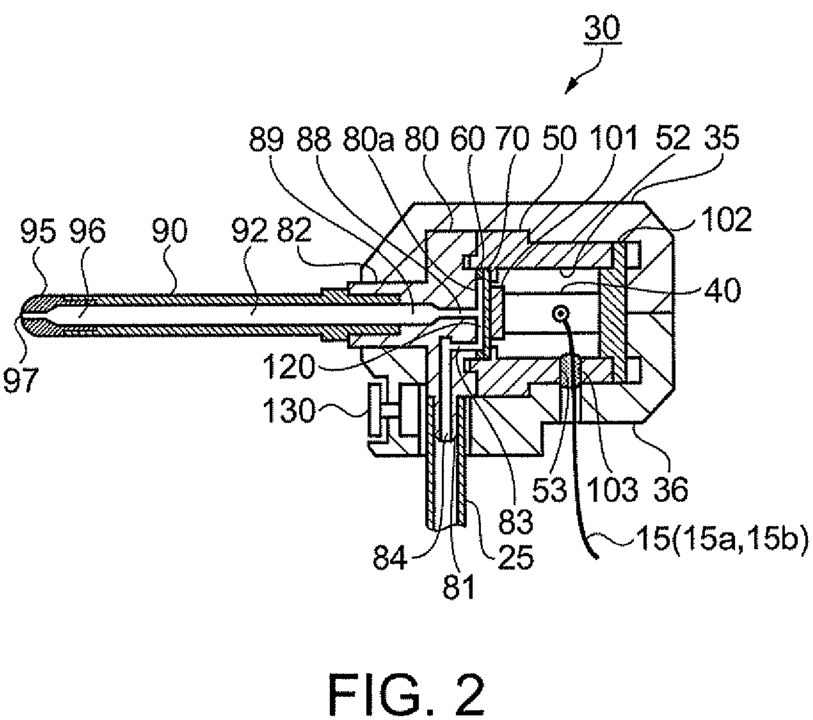

30
89
88
80a
80
60
70
50
101
52
35
102
95
96
90
92
82
40
120
97
130
53
103
36
83
84
25
81
15(15a,15b)

FIG. 2

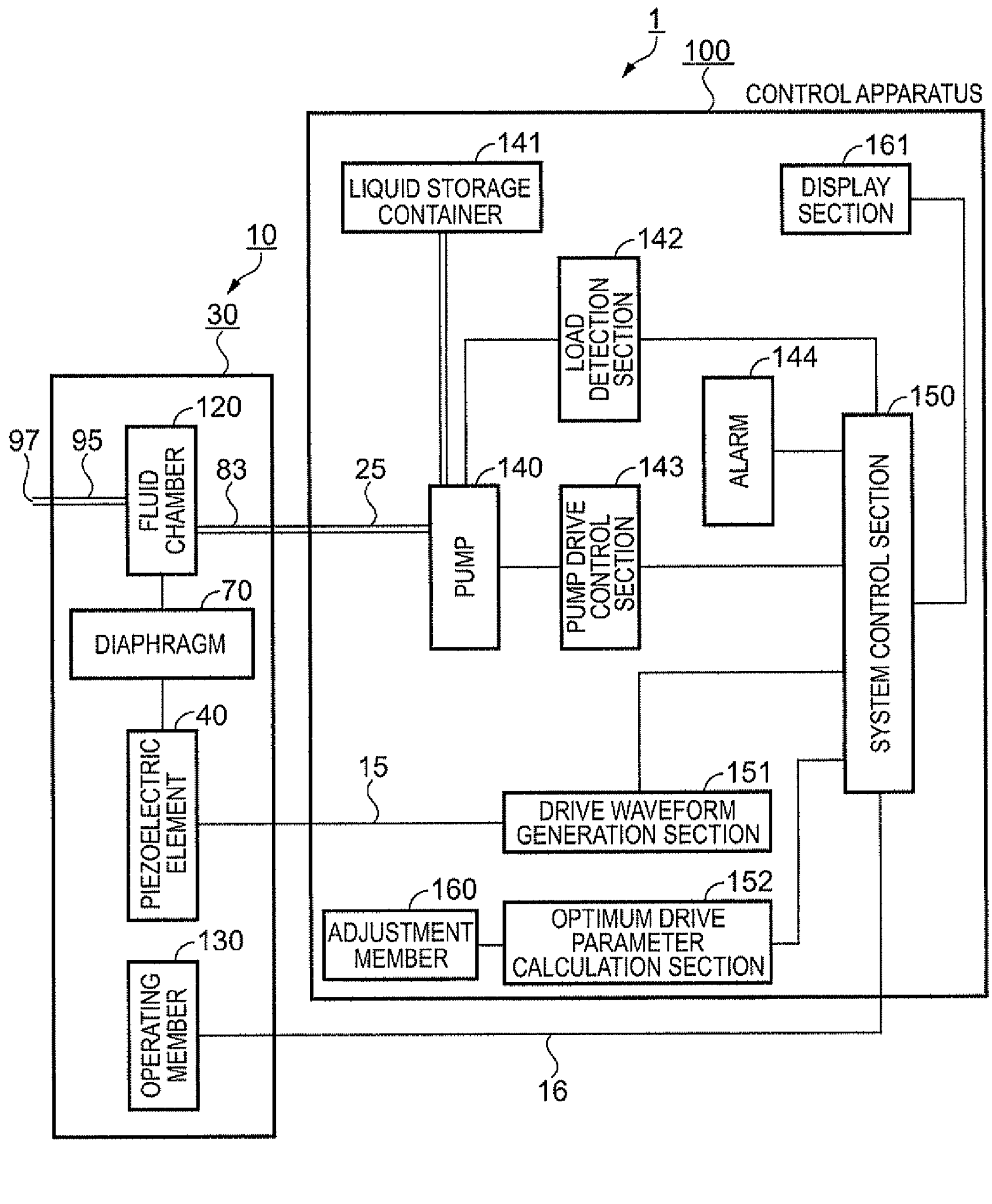

1
100
CONTROL APPARATUS
141
LIQUID STORAGE CONTAINER
161
DISPLAY SECTION
10
142
LOAD DETECTION SECTION
30
144
ALARM
150
120
97
95
FLUID CHAMBER
83
25
140
143
PUMP
PUMP DRIVE CONTROL SECTION
SYSTEM CONTROL SECTION
70
DIAPHRAGM
40
PIEZOELECTRIC ELEMENT
15
151
DRIVE WAVEFORM GENERATION SECTION
160
ADJUSTMENT MEMBER
152
OPTIMUM DRIVE PARAMETER CALCULATION SECTION
130
OPERATING MEMBER
16

FIG. 3

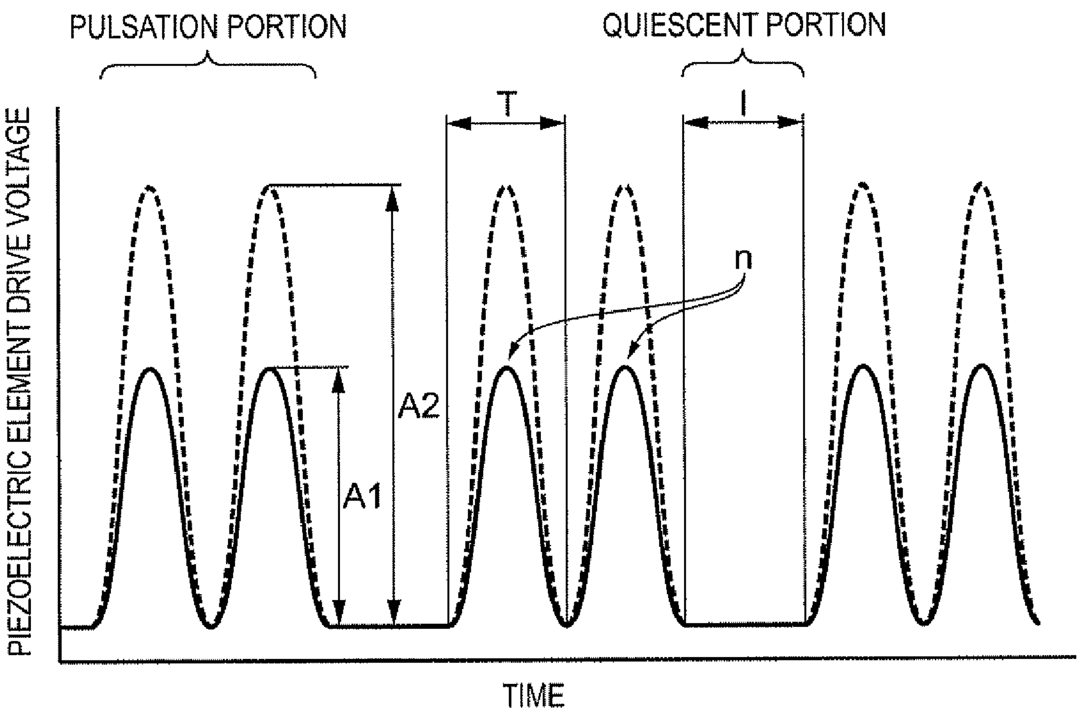

PULSATION PORTION
QUIESCENT PORTION
T
I
n
A2
A1
PIEZOELECTRIC ELEMENT DRIVE VOLTAGE
TIME

FIG. 4

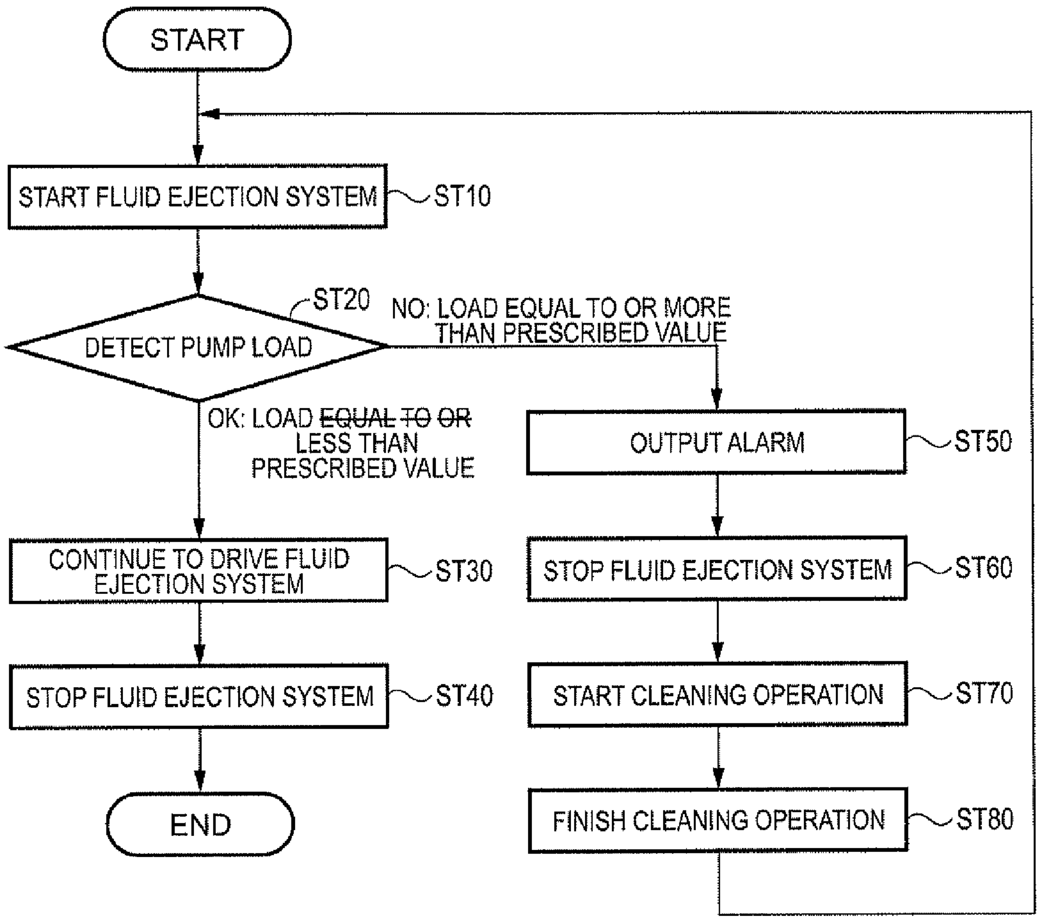

START
START FLUID EJECTION SYSTEM
ST10
ST20
DETECT PUMP LOAD
NO: LOAD EQUAL TO OR MORE THAN PRESCRIBED VALUE
OK: LOAD ~~EQUAL TO OR~~ LESS THAN PRESCRIBED VALUE
OUTPUT ALARM
ST50
CONTINUE TO DRIVE FLUID EJECTION SYSTEM
ST30
STOP FLUID EJECTION SYSTEM
ST60
STOP FLUID EJECTION SYSTEM
ST40
START CLEANING OPERATION
ST70
END
FINISH CLEANING OPERATION
ST80

FIG. 5

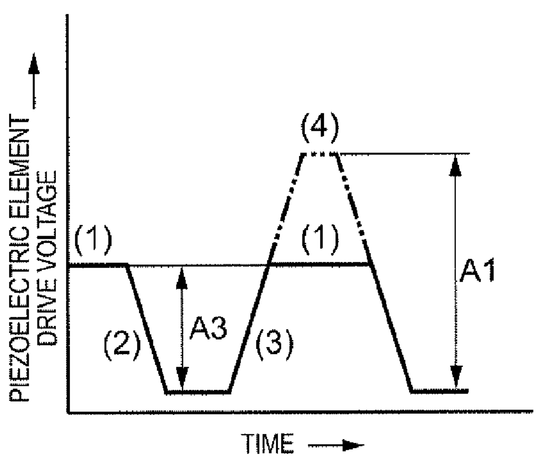

PIEZOELECTRIC ELEMENT DRIVE VOLTAGE
(4)
(1)
(1)
A1
(2)
A3
(3)
TIME

FIG. 6

FIG. 7A

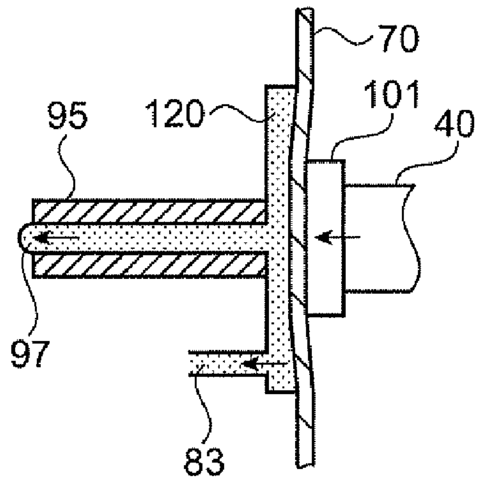



FIG. 7B

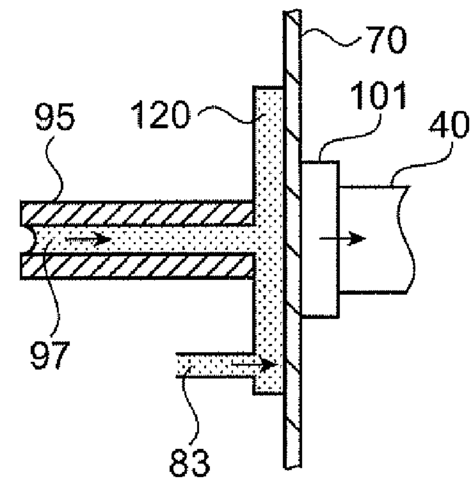
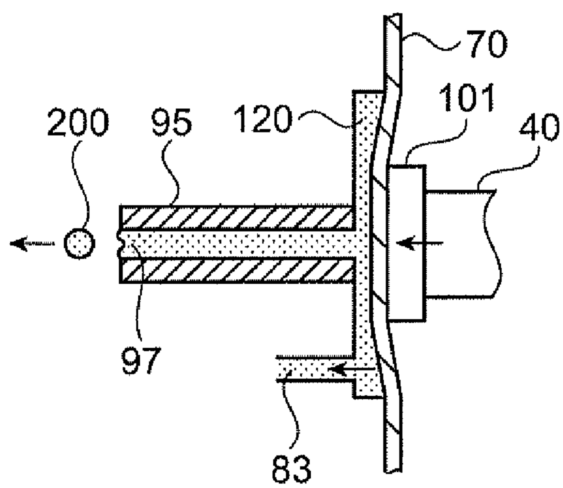



FIG. 7C



# FLUID EJECTION SYSTEM, FLUID EJECTION SYSTEM DRIVE METHOD, AND SURGICAL APPARATUS

[0001] Japanese Patent Application No. 2008-279336 filed on Oct. 30, 2008, is hereby incorporated by reference in its entirety.

## BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to a fluid ejection system including a fluid ejection apparatus and a control apparatus which carries out a control of the fluid ejection apparatus, a method of driving the fluid ejection system, and a surgical apparatus using the fluid ejection system and its drive method.

[0004] 2. Related Art

[0005] With a surgery using an ejected fluid, it is possible to incise an organ parenchyma while saving a vasculature of a blood vessel or the like. Furthermore, as an incidental damage to a body tissue other than an incision site is light, a burden on a patient is low. Also, as there is little bleeding, the bleeding does not hinder a vision of a surgical field, thus enabling a rapid surgery, which is clinically applied particularly to a hepatic resection or the like which is hindered by bleeding from microvessels.

[0006] As a fluid ejection apparatus which incises or excises a body tissue, one has been known which, by changing the volume of a fluid chamber by means of a diaphragm, discharges a fluid from a nozzle as high-speed droplets in a pulse form (refer to, for example, JP-A-2005-152127).

[0007] When incising or excising a body tissue using this kind of fluid ejection apparatus, it is conceivable that the leading extremity of the nozzle comes into contact with a body tissue, blood, and a body fluid, and it is expected that these will cause a nozzle leading extremity clogging.

[0008] Also, as the diameter of a fluid ejection opening is extremely small at around 0.1 to 0.2 mm, and the diameter of an outlet channel communicating with the nozzle from the fluid chamber is also extremely small at around 0.3 mm, it is also conceivable that a clogging occurs in a channel from the fluid chamber to the nozzle.

## SUMMARY

[0009] An advantage of some aspect of the invention is to solve at least a part of the problem described above and the invention can be realized as the following aspects or application examples.

### Application Example 1

[0010] A fluid ejection system includes a pulsation generation section which, including a fluid chamber, a diaphragm which changes a volume of the fluid chamber, and a piezoelectric element which drives the diaphragm, pulsatively ejects a fluid from a nozzle; and a control apparatus including a pressure generation section which supplies the fluid to the fluid chamber at a predetermined pressure, a drive waveform generation section which inputs a drive waveform into the piezoelectric element, and a load detection section which detects a load of the pressure generation section. In the event that the load detection section has detected a load abnormality of the pressure generation section, a fluid discharge pressure amplitude of the pulsation generation section or a fluid supply pressure of the pressure generation section is made higher than at a normal drive time.

[0011] The normal drive time means a drive status when actually using the fluid ejection system.

[0012] In the event that the pulsation generation section is driven normally (in conformity to a design value), the load of the pressure generation section falls within an approximately constant range. Herein, in the event that a clogging or the like occurs in a channel from the fluid chamber to the nozzle, the load of the pressure generation section increases.

[0013] According to this application example, by detecting that the load of the pressure generation section has increased (a load abnormality), it is determined that the heretofore described clogging has occurred. Therein, it is possible to eliminate the clogging by making the fluid discharge pressure amplitude of the pulsation generation section higher than at the normal drive time, and clean the channel from the fluid chamber to the nozzle.

[0014] Also, it is also possible to eliminate the clogging by making the fluid supply pressure of the pressure generation section higher.

### Application Example 2

[0015] In the fluid ejection system according to the heretofore mentioned application example, it is preferable that the drive waveform is configured of a pulsation portion and a quiescent portion, and that, in the event that the load detection section has detected a load abnormality of the pressure generation section, the amplitude of the pulsation portion is made larger than the amplitude at the normal drive time.

[0016] In the event that the drive waveform is configured of the pulsation portion formed of a whole number of sequential waveforms, and the quiescent portion in which no waveform is output, by appropriately selecting an amplitude (a potential) and frequency of the pulsation portion, an ejection of a fluid group forms a pulsation necessary for an excision capability. Also, a quiescent time enables a control of a flow rate.

[0017] Therein, in the event that a load abnormality of the pressure generation section has been detected, it being possible to increase an amount of displacement of a diaphragm by making the amplitude of the pulsation portion still larger than the amplitude at the normal drive time, and make the fluid discharge pressure amplitude higher than at the normal drive time by increasing an amount of a volume contraction of the fluid chamber, it is possible to eliminate the clogging.

### Application Example 3

[0018] In the fluid ejection system according to the heretofore mentioned application example, it is preferable that the drive waveform input in the event that the load detection section has detected a load abnormality of the pressure generation section is configured of a continuous pulsation portion.

[0019] In this way, it being possible to increase the number of pulsations per unit time of the fluid by eliminating the quiescent portion from the drive waveform, and continuously inputting the pulsation portion, it is possible to increase a capability to eliminate the clogging.

### Application Example 4

[0020] In the fluid ejection system according to the heretofore mentioned application example, it is desirable that a frequency of the drive waveform input in the event that the load detection section has detected a load abnormality of the pressure generation section approximately matches a resonant frequency of a pressure wave propagated through a space from the fluid chamber to the nozzle.

**[0021]** The fluid discharged from the fluid chamber, by the pressure wave thereof being propagated from the fluid chamber to the nozzle, is ejected from the nozzle as pulse-like (pulsation) droplets at a high speed. At the same time, one portion of the pressure wave is reflected at a nozzle position, and directed toward the fluid chamber. Consequently, by matching the frequency of the drive waveform with the resonant frequency of the pressure wave propagated between the fluid chamber and nozzle, the amplitude of the pressure wave increases due to the resonance, and it is possible to increase the clogging elimination capability.

Application Example 5

**[0022]** In the fluid ejection system according to the heretofore mentioned application example, it is preferable that, in the event that the load detection section has detected a load abnormality of the pressure generation section, the amplitude of the pulsation portion is made larger than the amplitude at the normal drive time, and the pressure at which the pressure generation section supplies the fluid to the fluid chamber is made higher than that at the normal drive time.

**[0023]** When the amplitude of the pulsation portion is made larger, the amount of the volume contraction of the fluid chamber increases, as previously described. By this means, as well as the fluid discharge pressure becoming higher, the discharge amount increases. Therein, as the amount of fluid supplied to the fluid chamber is increased by increasing the pressure at which the fluid is supplied by the pressure generation section, it is possible to supply a sufficient amount of liquid to the pulsation generation section in response to an increase in the discharge amount.

Application Example 6

**[0024]** In the fluid ejection system according to the heretofore mentioned application example, it is preferable that a load of the pressure generation section is detected as a change in a drive speed of a fluid delivery device of the pressure generation section.

**[0025]** Herein, the pressure generation section being, for example, a pump, it is possible to employ a fluid delivery device such as a piston pump or a gear pump.

**[0026]** In the event that a clogging occurs in the channel from the fluid chamber to the nozzle, the pressure inside this channel rises. Then, the load of the pressure generation section increases, and the drive speed of the fluid delivery device of the pump decreases. Consequently, it is possible to easily carry out a clogging determination by detecting the decrease in the drive speed.

**[0027]** A change in the drive speed of the fluid delivery device can be easily and accurately measured by a linear encoder in the case of the piston pump, or a rotary encoder in the case of the gear pump.

Application Example 7

**[0028]** In the fluid ejection system according to the heretofore mentioned application example, it is desirable that the load detection section, in the event that the drive speed has become equal to or less than a prescribed value, determines that there is a load abnormality of the pressure generation section.

**[0029]** By so doing, it is possible to accurately detect that a clogging has occurred in the channel from the fluid chamber to the nozzle.

Application Example 8

**[0030]** In the fluid ejection system according to the heretofore mentioned application example, it is desirable that the load detection section is a pressure sensor provided inside the pressure generation section.

**[0031]** In the event that a clogging occurs in the channel from the fluid chamber to the nozzle, the pressure inside the channel rises, causing an output load of the pressure generation section, and the internal pressure of the pressure generation section rises. Therein, it is possible to directly detect a load by using the pressure sensor.

Application Example 9

**[0032]** In the fluid ejection system according to the heretofore mentioned application example, it is preferable that it further includes an alarm which, in the event that the load detection section has detected a load abnormality of the pressure generation section, informs of the abnormality.

**[0033]** By providing the alarm in this way, it is possible to inform a user (a surgeon) that a clogging has occurred, and stop surgery immediately.

Application Example 10

**[0034]** In the fluid ejection system according to the heretofore mentioned application example, it is preferable that, in the event that the load detection section has detected a load abnormality of the pressure generation section, the drive of the pulsation generation section and pressure generation section is stopped.

**[0035]** By so doing, it is possible to prevent a failure of the fluid ejection system, including the pulsation generation section and pressure generation section, accompanying a pressure rise due to their continuing to be driven even in the event that a load abnormality of the pressure generation section has been detected, and increase safety.

Application Example 11

**[0036]** In the fluid ejection system according to the heretofore mentioned application example, it is preferable that it further includes an operating member which, after the load detection section has detected a load abnormality of the pressure generation section, and the drive of the pulsation generation section and pressure generation section has been stopped, switches in such a way as to make the fluid discharge pressure of the pulsation generation section or the fluid supply pressure of the pressure generation section higher than at the normal drive time.

**[0037]** By so doing, as it is possible to carry out a clogging removal while confirming a condition by the surgeon consciously carrying out a switching operation after detecting an abnormality such as a clogging, and stopping the drive, it does not happen that a high pressure liquid ejection is unconsciously started, so it is possible to increase the safety.

Application Example 12

**[0038]** In the fluid ejection system according to the heretofore mentioned application example, it is desirable that the operating member is provided on the pulsation generation section.

**[0039]** With the fluid ejection system of the heretofore mentioned application example, the pulsation generation section is gripped when operated. Consequently, by providing the operating member on the pulsation generation section, it is possible for the surgeon him or herself to carry out the switching operation at hand, and remove a clogging.

Application Example 13

**[0040]** In the fluid ejection system according to the heretofore mentioned application example, it is desirable that, in an idle period of the pulsation generation section, the drive waveform is configured of a combination of a midpoint potential, at which the piezoelectric element is charged to the extent that the fluid is moved to a position in which it reaches the leading extremity of the nozzle, and a potential at which the piezoelectric element is discharged.

**[0041]** When incising or excising a body tissue using the pulsation generation section, it is conceivable that the leading extremity of the nozzle comes into contact with a body tissue, blood, and a body fluid. At this time, it happens that these become dry in the idle period of the pulsation generation section during surgery, causing a clogging at the nozzle leading extremity.

**[0042]** Therein, in the drive idle period, by constantly repeating a movement of the liquid to the extent that the liquid is not discharged from the nozzle, it is possible to suppress the clogging in a channel from the nozzle leading extremity and nozzle to the fluid chamber.

Application Example 14

**[0043]** A fluid ejection system drive method according to this application example is a method of driving a fluid ejection system including: a pulsation generation section which, including a fluid chamber, a diaphragm which changes a volume of the fluid chamber, and a piezoelectric element which drives the diaphragm, pulsatively ejects a fluid from a nozzle; and a control apparatus including a pressure generation section which supplies the fluid to the fluid chamber at a predetermined pressure, a drive waveform generation section which inputs a drive waveform into the piezoelectric element, and a load detection section which detects a load of the pressure generation section. The method includes a step of, during a normal drive of the fluid ejection system, detecting a load of the pressure generation section, which supplies the fluid to the pulsation generation section at the predetermined pressure, by means of the load detection section; a step of outputting an alarm in the event that the load of the pressure generation section has become equal to or more than a prescribed value; a step of stopping the drive of the pulsation generation section and pressure generation section; a cleaning step in which a fluid discharge pressure of the pulsation generation section or a fluid supply pressure of the pressure generation section is made higher than at a normal drive time; and a step of restoring the normal drive after finishing the cleaning step.

**[0044]** According to this application example, in the event that a load of the pressure generation section has been detected due to a clogging, and the load of the pressure generation section has become equal to or more than the prescribed value, it is possible to carry out a cleaning (remove a clogging) by increasing the fluid discharge pressure or discharge amount of the pulsation generation section in comparison with at the normal drive time, and it is possible to maintain the normal drive and safety.

**[0045]** Also, there is an advantage in that, as it is possible to continuously use the pulsation generation section without discarding it due to a failure caused by a clogging, it is possible to reduce a running cost.

Application Example 15

**[0046]** A surgical apparatus according to this application example includes the fluid ejection system described in the heretofore mentioned application example, and is driven by the previously described fluid ejection system drive method.

**[0047]** According to this application example, in the event that a clogging has occurred in the pulsation generation section during surgery, it is possible to easily remove the clogging and, as well as it being possible to maintain a stable pulsation discharge, it is possible to increase the safety, and perform surgery with ease.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0048]** The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

**[0049]** FIG. **1** is an illustration showing an outline configuration of a fluid ejection system according to Embodiment 1.

**[0050]** FIG. **2** is a sectional view showing a main configuration of a pulsation generation section according to Embodiment 1, taken along a direction of a channel of a liquid.

**[0051]** FIG. **3** is a configuration diagram showing a main system configuration of the fluid ejection system according to Embodiment 1.

**[0052]** FIG. **4** is an illustration illustrating one example of a drive waveform according to Embodiment 1.

**[0053]** FIG. **5** is an illustration showing a method of driving the fluid ejection system according to Embodiment 1.

**[0054]** FIG. **6** is an illustration showing a drive waveform input during an idle period according to Embodiment 5.

**[0055]** FIGS. **7**A to **7**C are fragmentary sectional views schematically representing a behavior of a pulsation generation section according to Embodiment 5.

## DESCRIPTION OF EXEMPLARY EMBODIMENTS

**[0056]** Hereafter, a description will be given, based on the drawings, of embodiments of the invention.

**[0057]** FIGS. **1** to **5** show a fluid ejection system according to Embodiment 1, and FIGS. **6** and **7**A to **7**C show Embodiment 5.

**[0058]** The drawings to be referred to in the following description are schematic diagrams in which the vertical and horizontal scales of members and portions differ from actual ones, for the convenience of illustration.

**[0059]** Also, the fluid ejection system according to some aspects of the invention can be variously employed for a drawing using ink or the like, a washing of a miniature object and structure, a cutting off or cutting out of an object, an electronic instrument cooling device, a surgical knife, and the like, but in the embodiments to be described hereafter, a description will be given exemplifying with a surgical apparatus suitable in incising or excising a body tissue. Consequently, a fluid used in the embodiments being a liquid such as water, saline, or a chemical, the fluid may be expressed as the liquid.

Embodiment 1

**[0060]** FIG. **1** is an illustration showing an outline configuration of the fluid ejection system according to Embodiment 1. In FIG. **1**, the fluid ejection system **1** is configured of a control apparatus **100**, which includes a liquid storage container storing a liquid, a fluid delivery device of a pump acting as a pressure generation section, and a drive waveform generation section (which are not shown), a fluid ejection apparatus **10** which pulsatively ejects the liquid supplied from the fluid delivery device, and a fluid supply tube **25** (hereafter expressed simply as a tube **25**) which brings the fluid ejection apparatus **10** into communication with the pump.

**[0061]** Also, the control apparatus **100** and fluid ejection apparatus **10** are electrically connected by a drive signal cable **15** and operation switching signal cable **16**.

**[0062]** The liquid storage container, the pump, the drive waveform generation section, and a system control section, which controls the whole of the system, are included inside the control apparatus **100**, and a display section **161**, which displays a drive condition and drive status, an adjustment member **160**, which sets an optimum drive waveform, and an alarm **144**, are provided on the external side.

**[0063]** The fluid ejection apparatus **10** includes a pulsation generation section **30**, which causes the supplied liquid to pulsate at a high pressure and high frequency, and a connection channel pipe **90**, which is connected to the pulsation generation section **30**. A nozzle **95** including a fluid ejection opening **97**, which is formed by reducing the sectional area of the channel, is inserted in the leading extremity of the connection channel pipe **90**.

**[0064]** Next, a description will be given of a liquid flow in the fluid ejection system **1**. The liquid stored in the liquid storage container included in the control apparatus **100** is supplied by the pump at a certain pressure to the pulsation generation section **30** via the tube **25**.

**[0065]** The pulsation generation section **30**, being provided with a fluid chamber **120** (refer to FIG. **2**) and the fluid chamber **120**'s volume changing unit, by driving the volume changing unit, generates a pulsation, and ejects the liquid in a pulse form from the fluid ejection opening **97**. A detailed description of the pulsation generation section **30** will be given hereafter, referring to FIGS. **2** to **4**.

**[0066]** A discharge pressure of the pump at a normal drive time is set to approximately three atmospheres (0.3 MPa) or less. When performing surgery using the fluid ejection system **1**, a main portion which a surgeon grips is the pulsation generation section **30**. Consequently, it is preferable that the tube **25** connected to the pulsation generation section **30** is as flexible as possible. For that purpose, it is preferable that it is made a flexible and thin tube, and that the pressure is made low within a range in which it is possible to send the liquid to the pulsation generation section **30**.

**[0067]** Next, a description will be given of a structure of the fluid ejection apparatus **10** according to Embodiment 1.

**[0068]** FIG. **2** is a sectional view showing a main configuration of the pulsation generation section according to Embodiment 1, taken along a liquid channel direction. In FIG. **2**, the fluid ejection apparatus **10** is configured of the pulsation generation section **30**, the connection channel pipe **90** connected to the pulsation generation section **30**, and the nozzle **95** inserted in the connection channel pipe **90**.

**[0069]** The pulsation generation section **30** includes a ring shaped spacer **60** closely clamped between the mutually opposed surfaces of a first machine casing **80** and second machine casing **50**, and a diaphragm **70** which, acting as the volume changing unit, is made of a disk shaped sheet metal, and the fluid chamber **120** is configured by a wall surface **80*a*** of the first machine casing **80**, the diaphragm **70**, and the inner peripheral wall surface of the spacer **60**.

**[0070]** A tube connection pipe **81** is protruded from the outer side surface of the first machine casing **80**, and an inflow connection channel **84** is opened in the tube connection pipe **81**. The inflow connection channel **84** is brought into communication with an inlet channel **83** communicating with the flow chamber **120**.

**[0071]** The tube **25** is pressed into the tube connection pipe **81**. The tube **25** is connected to the pump provided inside the control apparatus **100** (refer to FIG. **1**), and the liquid is supplied into the flow chamber **120** via the inflow connection channel **84** and inlet channel **83**.

**[0072]** Also, an outlet channel **88** is opened, and furthermore, an outlet connection channel **89** communicating with the outlet channel **88** is opened, in an approximate center of the wall surface **80*a*** so as to be approximately perpendicular to the wall surface **80*a*** of the first machine casing **80**.

**[0073]** A connection channel pipe insertion portion **82** is protruded in a direction opposite to the fluid chamber **120**, and the outlet connection channel **89** communicating with the outlet channel **88** is provided, in the first machine casing **80**. The connection channel pipe **90** is pressed into and fixed in the connection channel pipe insertion portion **82**.

**[0074]** Apart from the connection channel pipe **90** being pressed into and fixed in the connection channel pipe insertion portion **82**, it is also acceptable to adopt a removable structure in which threaded portions are formed in the connection channel pipe **90** and connection channel pipe insertion portion **82**, and the connection channel pipe **90** is screwed into and fixed in the connection channel pipe insertion portion **82**.

**[0075]** The connection channel **92** communicating with the outlet connection channel **89** is opened in the connection channel pipe **90**, and the nozzle **95** is pressed into a leading extremity of the connection channel pipe **90** opposite the outlet channel **88**. The nozzle **95** includes a nozzle channel **96** communicating with the connection channel **92**, and the fluid ejection opening **97**.

**[0076]** Herein, the outlet connection channel **89**, connection channel **92**, and nozzle channel **96** have approximately the same sectional area, and this sectional area is larger than the sectional area of the outlet channel **88**. Also, the sectional area of the fluid ejection opening **97** is reduced in comparison with the sectional area of the connection channel **92**, and furthermore, reduced in comparison with that of the outlet channel **88**.

**[0077]** The sectional area represents the sectional area of the channel when sectioned perpendicular to a liquid flow direction.

**[0078]** In this embodiment, the diameter of the outlet channel **88** is set to 0.3 mm, the diameter of the connection channel **92** to 1.0 mm, and the diameter of the fluid ejection opening

**97** within a range of 0.1 to 0.2 mm. Also, the channel length from the fluid chamber **120** to the fluid ejection opening **97** is appropriately set within a range of 100 to 200 mm.

**[0079]** Meanwhile, the second machine casing **50**, being a cylindrical member, has opened therein a cylindrical hole **52** passing through the second machine casing **50**. One of the openings of the hole **52** is sealed with a lower plate **102**. A piezoelectric element **40** acting as a drive source is disposed inside the hole **52**. The piezoelectric element **40**, being a stacked piezoelectric element, configures a columnar actuator.

**[0080]** One extremity of the piezoelectric element **40** is closely fixed to the diaphragm **70** across an upper plate **101**, and the other extremity to the inner surface of the lower plate **102**.

**[0081]** Drive electrodes (not shown) are provided one on each of the opposed side surfaces of the piezoelectric element **40**, and the drive signal cable **15** formed of connection leads **15***a* and **15***b* coated in insulation is connected to the drive electrodes.

**[0082]** The drive signal cable **15**, being extended outward through a through hole **53** opened in a side surface of the second machine casing **50**, is connected to a drive waveform generation section **151** (refer to FIG. **3**) included in the control apparatus **100**. The through hole **53** is sealed with a seal member **103** in a condition in which the drive signal cable **15** is put through the through hole **53**.

**[0083]** The pulsation generation section **30**, having its periphery hermetically sealed, is covered with a contour member which is attachable to and detachable from the pulsation generation section **30**. In this embodiment, the contour member is configured of an upper casing **35** and lower casing **36** as a case member.

**[0084]** The upper casing **35** and lower casing **36** hold the pulsation generation section **30** in such a way as to sandwich the connection channel pipe insertion portion **82** of the first machine casing **80** and the cylindrical portion of the second machine casing **50**. The upper casing **35** and lower casing **36** are fixed by unshown fixing screws. Consequently, the upper casing **35** and lower casing **36** are of a structure such that they are attachable to and detachable from the pulsation generation section **30**.

**[0085]** Also, a packing (not shown) acting as a seal member, being provided between the mutually opposed end faces of the upper casing **35** and lower casing **36**, hermetically seals the pulsation generation section **30**.

**[0086]** An operating member **130** is provided on the pulsation generation section **30**. The operating member **130** being a switch, it is possible to select a push button type, a slide type, a rotary type, or the like, but the push button type switch is more preferable from the aspect of a space saving and a simple operation. The operating member **130**, being disposed in such a way that everything other than an operation section is embedded in the lower casing **36**, is connected to the control apparatus **100** by the operation switching signal cable **16** (refer to FIG. **1**).

**[0087]** Next, a description will be given of a system configuration of the fluid ejection system **1**.

**[0088]** FIG. **3** is a configuration diagram showing a main system configuration of the fluid ejection system according to this embodiment. The fluid ejection apparatus **10** is configured of the fluid chamber **120**, the diaphragm **70** acting as the volume changing unit which changes the volume of the fluid chamber **120**, the piezoelectric element **40** which drives the diaphragm **70**, and the operating member **130**.

**[0089]** The control apparatus **100** includes the liquid storage container **141** (hereafter expressed simply as the container **141**), and a load detection section **142** which, including the pump **140** communicating with the container **141**, and a pump drive control section **143** which controls a drive of the pump **140**, detects a load fluctuation of the pump **140**.

**[0090]** As the pump **140**, it is possible to employ a liquid delivery device such as a piston pump or a gear pump, and it is brought into communication with the fluid chamber **120** by the tube **25**. The load detection section **142** includes a linear encoder in the case of the piston pump, and a rotary encoder in the case of the gear pump, and detects a load fluctuation of the pump **140** as a change in piston drive speed or gear rotation speed.

**[0091]** There is provided the alarm **144** which, in the event that a clogging has occurred in the pulsation generation section **30**, and the load (drive speed) of the pump **140** has become equal to or more than a prescribed value, determines that the load is abnormal, and gives an alarm. The alarm **144** can employ a sound of a buzzer or the like, or a light alert.

**[0092]** Also, the control apparatus **100** includes an optimum drive parameter calculation section **152** which calculates a drive waveform corresponding to the hardness of an excised tissue, the adjustment member **160** which inputs the excised tissue hardness, and the drive waveform generation section **151** which, based on an optimum drive parameter, generates a drive waveform to be input into the piezoelectric element **40**. The control apparatus **100** further includes the system control section **150** which governs the overall control of each system component, and the display section **161**. The display section **161** displays a drive condition such as the excised tissue hardness, a drive status, and the like.

**[0093]** A rotary switch being suitable as the adjustment member **160**, by rotating a dial thereof, a drive condition such as the excised tissue hardness is selected, and input into the optimum drive parameter calculation section **152**. An amplitude (a potential), cycle, waveform quantity (pulse quantity), quiescent time, and the like, of a pulsation portion compatible with the selected and input excised tissue hardness or the like, are calculated in the optimum drive parameter calculation section **152**, and input into the piezoelectric element **40**, via the drive signal cable **15**, as an optimum drive waveform in the drive waveform generation section **151**.

**[0094]** Next, a description will be given, referring to the drawing, of one example of a drive waveform.

**[0095]** FIG. **4** illustrates one example of a drive waveform according to this embodiment. Firstly, a description will be given of a drive waveform at the normal drive time. It is taken that the drive waveform in this illustration is configured of a pulsation portion configured of a whole number of sequential sinusoidal waveforms in which a piezoelectric element drive voltage starts with a phase $-\pi/2$, and a quiescent portion (expressed as a quiescent time I).

**[0096]** In the drawing, the drive waveform expressed by the solid line represents the normal drive time, and the waveform of the pulsation portion is expressed by an amplitude A**1**, a cycle T, and a number n of sequential sine waves. In this illustration, the number of sine waves is taken to be two. The waveform of this pulsation portion being of a burst wave, it is possible, in the drive waveform generation section **151**, to generate it easily by specifying the heretofore mentioned parameter.

**[0097]** The drive waveform not being limited to that of the sine wave, it is also acceptable that it is of a combination of rectangular waves.

**[0098]** Continuing, a description will be given of an operation of the fluid ejection system **1**. Firstly, a description will be given of a normal drive status (refer to FIGS. **1** to **3**).

**[0099]** The liquid is constantly supplied to the inlet channel **83** at a certain fluid pressure by the pump **140**. As a result, when the piezoelectric element **40** carries out no operation, the liquid flows into the fluid chamber **120** due to a difference between a discharge pressure of the pump **140** and the whole fluid resistance value on the inlet channel side.

**[0100]** Herein, supposing that the illustrated drive waveform is input into the piezoelectric element **40**, and the piezoelectric element **40** expands rapidly, the pressure inside the fluid chamber **120** rises rapidly and reaches several tens of atmospheres in the event that inlet channel side and outlet channel side combined inertances L**1** and L**2** have a sufficient size. As this pressure is far larger than a pressure applied to the inlet channel **83** by the pump **140**, an inflow of the liquid into the fluid chamber **120** from the inlet channel **83** decreases due to the pressure, and an outflow from the outlet channel **88** increases.

**[0101]** However, as the inlet channel side combined inertance L**1** is larger than the outlet channel side combined inertance L**2**, an increased amount of liquid discharged from the outlet channel **88** is larger than a decreased amount of flow rate in which the liquid flows from the inlet channel **83** into the fluid chamber **120**. For this reason, a pulse-like fluid discharge, that is, a pulsation flow, occurs in the outlet channel **88**.

**[0102]** A pressure fluctuation (that is, a pressure wave) at this discharge time is propagated through the connection channel **92** of the connection channel pipe **90**, and the liquid is ejected in a pulse form from the fluid ejection opening **97** of the nozzle **95** (for both of which refer to FIG. **2**) at the leading extremity. As the diameter of the fluid ejection opening **97** is reduced in comparison with the diameter of the outlet channel **88**, the liquid is ejected as higher-pressure and higher-speed pulse-like droplets.

**[0103]** Meanwhile, the interior of the fluid chamber **120** attains a vacuum condition immediately after the pressure rise, due to an interaction between the decrease in the amount of liquid inflow from the inlet channel **83** and the increase in the liquid outflow from the outlet channel **88**. As a result, a flow of the liquid in the inlet channel **83** moving toward the interior of the fluid chamber **120** at the same speed as that before the piezoelectric element **40** operates is restored, after a certain time has elapsed, due to both the pressure of the pump and the vacuum condition inside the fluid chamber **120**. In the event that there is an expansion of the piezoelectric element **40** after the flow of the liquid inside the inlet channel **83** has been restored, it is possible to continuously eject the liquid from the nozzle **95** in the pulse form.

**[0104]** In a tissue excision by a pulsating fluid ejection, when a pulsation intensity is high (that is, a fluid discharge pressure amplitude is large), it is possible to excise a high hardness tissue. The fluid discharge pressure amplitude can be realized by increasing an amplitude A of a piezoelectric element drive voltage. Meanwhile, however, an amount of fluid ejected per unit time is also increased at the same time. As a result, an excision depth per unit time is also increased at the same time.

**[0105]** When the surgeon does not want the increase in the excision depth per unit time, it is necessary to increase the amplitude A, and at the same time, reduce the number n of sequential sine waves to an appropriate value, increase the quiescent time I, or the like.

**[0106]** In this embodiment, on the dial shaped adjustment member **160** being rotationally operated, and the excised tissue hardness being selected and set, the fluid ejection section drive voltage amplitude A, which is one of control parameters, changes, and at the same time, an adjustment is made by the optimum drive parameter calculation section **152** in such a way that the quiescent time I, which is another control parameter, changes, and the excision depth does not change.

**[0107]** It is also acceptable to use an optimum drive parameter table in place of the optimum drive parameter calculation section **152**. The excised tissue hardness is selected by the adjustment member **160**, and an optimum drive parameter is selected from the optimum drive parameter table, generating a drive waveform. It is more preferable that information on the optimum drive parameter selected is displayed in the display section **161**.

**[0108]** The optimum drive parameter table is a table in which are combined control parameters such as a surgery type, the diameter of the fluid ejection opening **97**, an excised tissue hardness, and an excision depth.

**[0109]** However, when a body tissue is incised or excised using the fluid ejection system **1** as the surgical apparatus, as a distance between the nozzle **95** and a surgical site is several millimeters or less, it is conceivable that the leading extremity of the nozzle **95** comes into contact with a body tissue, blood, and a body fluid, and it is expected that these will cause a nozzle leading extremity clogging.

**[0110]** Also, as the diameter of the fluid ejection opening **97** is extremely small at around 0.1 to 0.2 mm, and the outlet channel **88** communicating with the nozzle from the fluid chamber **120** is also extremely small at around 0.3 mm, it is also conceivable that a clogging occurs in a channel from the fluid chamber **120** to the fluid ejection opening **97**. Consequently, a removal of these cloggings, that is, a cleaning, is needed.

**[0111]** Continuing, a description will be given of a drive method relating to a cleaning of the channel from the fluid chamber **120** to the fluid ejection opening **97**.

**[0112]** FIG. **5** is an illustration showing the drive method relating to the cleaning of this embodiment. A description will be given, referring to FIGS. **2** to **4** too, in accordance with the process shown in FIG. **5**.

**[0113]** Firstly, the fluid ejection system **1** is started, starting a normal drive (ST**10**). While the fluid ejection system is being driven, a load fluctuation of the pump **140** is being detected by the load detection section **142** (ST**20**). As previously described, a load fluctuation is detected as a change in the drive speed of the fluid delivery device of the pump **140**.

**[0114]** Herein, in the event that the pulsation generation section **30** is driven normally (in conformity to a design value), the load of the pump **140** falls within an approximately constant range, and the fluid delivery device continues to be driven within a certain drive speed range.

**[0115]** Herein, in the event that a clogging occurs in the channel from the fluid chamber **120** to the fluid ejection opening **97**, the pressure inside the channel increases. Then, the load of the pump **140** increases, and the drive speed decreases. Consequently, by setting a correlation between the drive load and drive speed of the fluid delivery device, it is possible to detect a change in the load as a fluctuation in the speed.

**[0116]** In the event that the load of the pump **140** is less than the prescribed value, the fluid ejection system **1** continues to be driven as it is (ST**30**) and, when the surgery is finished, the fluid ejection system is stopped (ST**40**).

**[0117]** In the event that the load of the fluid delivery device of the pump **140** has become equal to or more than the prescribed value (that is, in the even that the drive speed has become equal to or less than the prescribed value), a signal is input into the system control section **150** from the load detection section **142**, and an alarm is output using a sound, light, or the like by the alarm **144** (ST**50**). Together with the alarm output from the alarm **144**, a drive stop command is output to the drive waveform generation section **151** and pump drive control section **143** from the system control section **150**, stopping the fluid ejection system **1** (ST**60**).

**[0118]** In the event that an alarm has been output, the surgeon determines that a clogging has occurred, and starts a cleaning operation. A cleaning start operation, after the pulsation generation section **30** has been moved away from a living body, is carried out by means of a switch input from the operating member **130** provided on the pulsation generation section **30**. A cleaning start command from the operating member **130** is input into the system control section **150** via the operation switching signal cable **16**, and the pump **190** and pulsation generation section **30** are started based on the system control section **150** drive start command, starting the cleaning operation (ST**170**).

**[0119]** At this time, the liquid discharge pressure amplitude of the pulsation generation section **30** is made higher than at the normal drive time. The liquid discharge pressure amplitude of the pulsation generation section **30** can be made higher by making the amplitude of the pulsation portion of the drive waveform larger than at the normal drive time.

**[0120]** The drive waveform in that case is illustrated by the broken line in FIG. **4**. In this illustration, an amplitude A**2** is made approximately twice as high as the amplitude A**1** at the normal drive time. By this means, the amount of expansion of the piezoelectric element **40** increases, and the amount of volume contraction of the fluid chamber **120** increases. By this means, the pulsation becomes stronger, and the liquid discharge pressure amplitude increases, meaning that it is possible to remove the clogging.

**[0121]** The surgeon, when determining that the clogging has been removed, operates the operating member **130** again, stops the pulsation generation section **30** and pump **140**, and finishes the cleaning operation (ST**80**).

**[0122]** The determination of the clogging removal is carried out by observing a discharge condition of the liquid from the liquid ejection opening **97**.

**[0123]** Continuing, the operating member **130** is operated, and a start command from the system control section **150** is input, starting the fluid ejection system **1** (specifically, the pulsation generation section **30** and pump **140**). A drive waveform output at this time is the drive waveform at the normal drive time (refer to FIG. **4**). Then, the process in and after ST**20** is repeated.

**[0124]** It is possible to employ a method whereby a pump load is detected by the load detection section **142** during the cleaning operation, and the cleaning operation is continued in the event that the load is equal to or more than the prescribed value, while the cleaning operation is stopped (a system stop) in the event that the load is less than the prescribed value.

**[0125]** With this kind of method, a setting is such that a detection reference value of the load detection section **192** is matched with the pump drive speed at a cleaning operation time.

**[0126]** A restart of the fluid ejection system is carried out by operating the operating member **130**. Consequently, it is preferable that the operating member **130** is a one-circuit two-contact type switch.

**[0127]** Also, in the cleaning operation, it is preferable that, as well as the amplitude of the pulsation portion of the drive waveform being made larger, the liquid supply pressure of the pump **140** is made higher. By this means, it is possible to increase a liquid supply amount per unit time. This is because, as the liquid discharge amount increases due to the amplitude of the pulsation portion of the drive waveform being made larger, there is a need to increase the liquid supply amount.

**[0128]** With the heretofore described drive waveform at the cleaning operation time according to this embodiment, the amplitude (potential) thereof is changed with the cycle T and quiescent time I thereof remaining the same as those of the pulsation portion at the normal drive time, but it is also acceptable that the cycle T is changed, or the quiescent time I is changed.

**[0129]** Consequently, according to the fluid ejection system of this embodiment, by detecting that the load of the pump **140** has increased, it is determined that a clogging has occurred in the channel from the fluid chamber **120** to the fluid ejection opening **97**. Therein, it is possible to eliminate the clogging by making the fluid discharge pressure amplitude of the pulsation generation section **30** higher than at the normal drive time, and clean the channel from the fluid chamber **120** to the fluid ejection opening **97**.

**[0130]** With the fluid discharge pressure amplitude, by making the amplitude of the pulsation portion still larger than the amplitude at the normal drive time, the amount of displacement of the diaphragm **70** is increased, increasing the amount of the volume of the fluid chamber **120** contracted by the diaphragm **70**, as a result of which it is possible to increase the pressure inside the fluid chamber **120**.

**[0131]** When the amplitude of the pulsation portion is made higher, the amount of the volume contraction of the fluid chamber **120** increases, as previously described. By this means, as well as the fluid discharge pressure amplitude becoming higher, the discharge amount increases. Therein, as the amount of fluid supplied to the fluid chamber **120** increases by increasing the fluid supply pressure applied by the pump **140**, it is possible to supply a sufficient amount of liquid to the pulsation generation section **30** in response to an increase in the discharge amount.

**[0132]** Also, a change in load of the pump **140** is detected as a change in the drive speed of the fluid delivery device of the pump **140**. In the event that a clogging occurs in the channel from the fluid chamber **120** to the fluid ejection opening **97**, the pressure inside this channel rises. Then, the load of the pump **140** increases, and the drive speed decreases. Consequently, it is possible to carry out a clogging determination by detecting a decrease in the drive speed.

**[0133]** Also, there is provided the alarm **144** which informs of an abnormality in the event that the load detection section **142** has detected an increase in the load of the pump **140** which is equal to or more than the prescribed value. By providing the alarm **144** in this way, it is possible to inform the surgeon of the fact that a clogging has occurred, and stop the surgery immediately.

**[0134]** It is also acceptable that the detection of a load abnormality of the pump **140** is done by a method which determines it to be abnormal when it is detected instantaneously, or by a method which determines it to be abnormal when it continues for, for example, several seconds.

**[0135]** In this embodiment, the alarm **144** is disposed in the control apparatus **100**, but it is also acceptable that it is disposed in the pulsation generation section **30**. However, it is preferable that the pulsation generation section **30**, as it is the portion which the surgeon grips, is made as light and small as possible. For this reason, it is more preferable to dispose it in the control apparatus **100**. Alternatively, it is also acceptable that the alarm **144** is disposed independently in a position which is distant from the control apparatus **100**, the pulsation generation section **30** and easy to recognize.

**[0136]** Also, in the event that the load detection section **142** has detected a load abnormality of the pump **140**, as well as an alarm being given, the drive of the pulsation generation section **30** and pump **140** is stopped. By so doing, it is possible to prevent a failure of the fluid ejection system **1**, including the pulsation generation section **30** and pump **140**, accompanying a pressure rise due to their continuing to be driven in the event that a load abnormality of the pump **140** has been detected, and increase safety.

**[0137]** Also, the pulsation generation section **30** includes the operating member **130**. After a clogging has been detected, and the pulsation generation section has stopped, the surgeon consciously carries out a switching operation of the operating member **130**, causing a cleaning operation. By so doing, it not happening that a high pressure liquid ejection is unconsciously started, it is possible to increase the safety.

**[0138]** Furthermore, according to this embodiment, there is also an advantage in that, as it is possible to continuously use the pulsation generation section **30** without discarding it due to a failure caused by a clogging, it is possible to reduce a running cost.

## Embodiment 2

**[0139]** Continuing, a description will be given of a fluid ejection system according to Embodiment 2. Although the drawings are omitted, a description will be given referring to FIG. **4**. The drive waveform at the normal drive time of the fluid ejection system according to this embodiment is configured of a pulsation portion and quiescent portion, as expressed by the solid line in FIG. **4**.

**[0140]** In this embodiment, the drive waveform input at the cleaning operation time in the event that the load detection section **142** has detected an increase in load (a load abnormality) of the pump **140** is configured of a continuous waveform. That is, it is configured of only a continuous pulsation portion without the quiescent time I.

**[0141]** Also, the amplitude of the pulsation portion is larger than at the normal drive time, and the pulsation portion of the amplitude A**2** expressed in FIG. **4** forms a continuous drive waveform.

**[0142]** By eliminating the quiescent portion from the drive waveform, and continuously inputting the pulsation portion, it is possible to increase the number of pulsations per unit time at the cleaning operation time. Furthermore, the amplitude of the pulsation portion is made larger than at the normal drive time, thereby increasing the fluid discharge pressure. By this means, it is possible to increase a capability to eliminate a clogging.

**[0143]** It is more preferable, at this time, to increase the fluid supply pressure in response to the fluid discharge pressure.

## Embodiment 3

**[0144]** Continuing, a description will be given, referring to FIG. **2**, of Embodiment 3. Embodiment 3 has a feature wherein the frequency of a drive waveform input in the event that the load detection section **142** has detected an increase in load (a load abnormality) of the pump **140** approximately matches the resonant frequency of a pressure wave propagated through a space from the fluid chamber **120** to the nozzle **95**.

**[0145]** The liquid converted into a pulsation flow by the pulsation generation section **30**, by the pressure wave propagated from the fluid chamber **120** to the nozzle **95**, is ejected from the nozzle **95** as pulse-like droplets at a high speed. At the same time, one portion of the pressure wave is reflected at a nozzle position, and directed toward the fluid chamber **120**. Specifically, the pressure wave reciprocates in a portion, whose sectional area is extremely small, of a channel from the fluid chamber **120** to the nozzle **95**.

**[0146]** In this embodiment, a distance from the fluid chamber **120** to the nozzle **95** is set to be 100 to 200 mm. Also, the propagation speed of the pressure wave from the fluid chamber **120** to the nozzle **95** is approximately 1500 m per second. Herein, supposing that the distance from the fluid chamber **120** to the nozzle **95** is 150 mm, it is 300 mm there and back, and the resonant frequency of the pressure wave is 5 kHz. Consequently, the frequency of the drive waveform is taken to be 5 kHz.

**[0147]** By matching the resonant frequency of the pressure wave with the frequency of the drive waveform in this way, the amplitude of the pressure wave increases due to the resonance, and it is possible to increase the clogging elimination capability.

## Embodiment 4

**[0148]** Continuing, a description will be given of Embodiment 4. Although the illustration is omitted, a description will be given referring to FIG. **3**. Embodiment 4 has a feature wherein a pressure sensor is included inside the pump **140**.

**[0149]** In the event that a clogging occurs in the channel from the fluid chamber **120** to the fluid ejection opening **97**, the pressure inside the channel rises, causing an output load of the pump **140**. As a result, the internal pressure of the pump **140** rises. Therein, the pressure sensor is disposed in a fluid chamber (a pressure chamber) inside the pump **140**.

**[0150]** Then, a difference between an internal pressure of the pump **140** at the normal drive time and at a clogging occurrence time is set in advance and, in the event that a rise in the pressure is equal to or more than a prescribed value, a cleaning operation is started. The cleaning operation can be carried out in accordance with the process described in the illustration shown in FIG. **5**.

[0151] By so doing, it is possible to directly detect a change in the internal pressure of the pump **140** accompanying the clogging.

Embodiment 5

[0152] Continuing, a description will be given, referring to the drawings, of a fluid ejection system according to Embodiment 5. Embodiment 5 has a feature wherein a drive waveform is formed such that it is possible to prevent a clogging due to a drying or the like in the channel from the fluid chamber **120** to the fluid ejection opening **97** while temporarily halting the fluid ejection system halfway through a surgery.

[0153] FIG. **6** is an illustration showing a drive waveform input during an idle period according to this embodiment, and FIGS. **7**A to **7**C are fragmentary sectional views schematically representing a behavior of the pulsation generation section in response to the drive waveform. In FIG. **6**, one cycle of the drive waveform is configured of a combination of, firstly, an area **1** in which a midpoint potential is held for a certain time, continuing, an area **2** in which the piezoelectric element **40** is discharged, and an area **3** in which the piezoelectric element **40** is charged with the midpoint potential after a certain time elapses.

[0154] A description will be given of a behavior of the liquid in each area. FIG. **7**A represents a condition in which the midpoint potential (indicated by a potential A**3**) shown by **1** in FIG. **6** is applied to the piezoelectric element **40**. In this condition, the amount of charge of the piezoelectric element **40** is intermediate with respect to a full charge, and the amount of expansion is also intermediate with respect to a full charge amount. Consequently, the amount of the volume of the fluid chamber **120** contracted by the diaphragm **70** is also of an intermediate value.

[0155] In the case of this kind of midpoint potential, the liquid, rather than being discharged from the fluid ejection opening **97** of the nozzle **95**, remains to the extent that one portion thereof peeps out of the leading extremity.

[0156] On the discharge potential (a potential −A**3**) expressed by **2** in FIG. **6** being applied in this condition, the piezoelectric element **40** is discharged, attaining the condition represented in FIG. **7**B. That is, a condition is attained in which the diaphragm **70** expands the volume of the fluid chamber **120**.

[0157] Then, the pressure of the fluid chamber **120** decreases instantaneously, and the liquid in the nozzle **95** is retracted into the fluid chamber **120** by an amount by which the volume of the fluid chamber **120** has increased.

[0158] On the midpoint potential (the potential A**3**) shown in **3** of FIG. **6** being applied, the condition of FIG. **7**A is attained in this condition. On this kind of drive waveform being repeatedly continued, the liquid in the nozzle **95** repeats the conditions of FIGS. **7**A and **7**B in the fluid ejection opening **97**.

[0159] With the drive waveform when discharging the liquid, as expressed by **4** in FIG. **6**, a potential A**1** higher than the midpoint potential is applied to the piezoelectric element **40**. In this kind of case, as represented in FIG. **7**C, the piezoelectric element **40** expands by being fully charged, the volume of the fluid chamber **120** is contracted to the maximum by the diaphragm **70**, and the liquid is discharged as droplets **200** in the pulse form.

[0160] When incising or excising a body tissue, it is conceivable that the leading extremity of the nozzle **95** comes into contact with a body tissue, blood, and a body fluid. At this time, it happens that these become dry in an idle period of the pulsation generation section **30**, causing a clogging at the nozzle **95** leading extremity (or in the fluid ejection opening **97**).

[0161] Therein, in the pulsation generation section drive idle period (a surgery suspension period), by constantly repeating a movement of the liquid to the extent that the liquid is not discharged from the nozzle **95**, it is possible to suppress the clogging in the channel from the fluid ejection opening **97** to the fluid chamber **120**.

[0162] FIG. **6** illustrates the case in which the drive waveform is of a rectangular wave, but it is also acceptable that the drive waveform is of a combined sine wave.

[0163] Also, in the drive using the drive waveform of Embodiment 5 too, by implementing the clogging removals described in Embodiment 1 to Embodiment 4, it is possible to use the fluid ejection system with more ease.

[0164] The fluid ejection system **1** according to some aspects of the invention can be variously employed for a drawing using ink or the like, a washing of a miniature object and structure, a cutting off or cutting out of an object, a surgical knife, and the like, but is suitable as a surgical instrument with which a body tissue is incised or excised.

What is claimed is:

**1**. A fluid ejection system comprising:

a pulsation generation section which, including a fluid chamber, a diaphragm which changes a volume of the fluid chamber, and a piezoelectric element which drives the diaphragm, pulsatively ejects a fluid from a nozzle; and

a control apparatus including a pressure generation section which supplies the fluid to the fluid chamber at a predetermined pressure, a drive waveform generation section which inputs a drive waveform into the piezoelectric element, and a load detection section which detects a load of the pressure generation section, wherein

in the event that the load detection section has detected a load abnormality of the pressure generation section, a fluid discharge pressure amplitude of the pulsation generation section or a fluid supply pressure of the pressure generation section is made higher than at a normal drive time.

**2**. The fluid ejection system according to claim **1**, wherein

the drive waveform is configured of a pulsation portion and a quiescent portion, and

in the event that the load detection section has detected a load abnormality of the pressure generation section, the amplitude of the pulsation portion is made larger than the amplitude at the normal drive time.

**3**. The fluid ejection system according to claim **1**, wherein

the drive waveform input in the event that the load detection section has detected a load abnormality of the pressure generation section is configured of a continuous pulsation portion.

**4**. The fluid ejection system according to claim **1**, wherein

a frequency of the drive waveform input in the event that the load detection section has detected a load abnormality of the pressure generation section approximately matches a resonant frequency of a pressure wave propagated through a space from the fluid chamber to the nozzle.

5. The fluid ejection system according to claim 2, wherein in the event that the load detection section has detected a load abnormality of the pressure generation section, the amplitude of the pulsation portion is made larger than the amplitude at the normal drive time, and the pressure at which the pressure generation section supplies the fluid to the fluid chamber is made higher than that at the normal drive time.

6. The fluid ejection system according to claim 1, wherein the load detection section detects a load of the pressure generation section as a change in a drive speed of a fluid delivery device of the pressure generation section.

7. The fluid ejection system according to claim 6, wherein the load detection section, in the event that the drive speed has become equal to or less than a prescribed value, determines that there is a load abnormality of the pressure generation section.

8. The fluid ejection system according to claim 1, wherein the load detection section is a pressure sensor provided inside the pressure generation section.

9. The fluid ejection system according to claim 1, further comprising:

an alarm which, in the event that the load detection section has detected a load abnormality of the pressure generation section, informs of the abnormality.

10. The fluid ejection system according to claim 1, wherein in the event that the load detection section has detected a load abnormality of the pressure generation section, the drive of the pulsation generation section and pressure generation section is stopped.

11. The fluid ejection system according to claim 1, further comprising:

an operating member which, after the load detection section has detected a load abnormality of the pressure generation section, and the drive of the pulsation generation section and pressure generation section has been stopped, switches in such a way as to make the fluid discharge pressure of the pulsation generation section or the fluid supply pressure of the pressure generation section higher than at the normal drive time.

12. The fluid ejection system according to claim 11, wherein

the operating member is provided on the pulsation generation section.

13. The fluid ejection system according to claim 1, wherein

in an idle period of the pulsation generation section, the drive waveform is configured of a combination of a midpoint potential, at which the piezoelectric element is charged to the extent that the fluid is moved to a position in which it reaches the leading extremity of the nozzle, and a potential at which the piezoelectric element is discharged.

14. A method of driving a fluid ejection system including: a pulsation generation section which, including a fluid chamber, a diaphragm which changes a volume of the fluid chamber, and a piezoelectric element which drives the diaphragm, pulsatively ejects a fluid from a nozzle; and a control apparatus including a pressure generation section which supplies the fluid to the fluid chamber at a predetermined pressure, a drive waveform generation section which inputs a drive waveform into the piezoelectric element, and a load detection section which detects a load of the pressure generation section, the method comprising:

a step of, during a normal drive of the fluid ejection system, detecting a load of the pressure generation section, which supplies the fluid to the pulsation generation section at the predetermined pressure, by means of the load detection section;

a step of outputting an alarm in the event that the load of the pressure generation section has become equal to or more than a prescribed value;

a step of stopping the drive of the pulsation generation section and pressure generation section;

a cleaning step in which a fluid discharge pressure of the pulsation generation section or a fluid supply pressure of the pressure generation section is made higher than at a normal drive time; and

a step of restoring the normal drive after finishing the cleaning step.

15. A surgical apparatus comprising the fluid ejection system according to claim 1.

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