

COMMONWEALTH OF AUSTRALIA

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610020

CONVENTION APPLICATION FOR A STANDARD PATENT

We, SUMITOMO BAKELITE COMPANY LIMITED, a corporation organized under the laws of Japan of 2-2, Uchisaiwaicho-1-chome, Chiyoda-ku, Tokyo, Japan, hereby apply for the grant of a Standard Patent for an invention entitled

"SURGICAL OPERATION DEVICE"

which is described in the accompanying complete specification.

Details of basic application:-

Number of basic application:- 01-106044

Name of Convention country in which basic application was filed:- Japan

Date of basic application:- 27 April 1989

Our address for service is: F.B. RICE & CO.,
28A Montague St,
Balmain N.S.W. 2041

Dated this 12 day of October 1989

SUMITOMO BAKELITE COMPANY
LIMITED

By: 

Registered Patent Attorney

TO: The Commissioner of Patents,
COMMONWEALTH OF AUSTRALIA

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APPLICATION ACCEPTED AND AMENDMENTS

ALLOWED

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DECLARATION IN SUPPORT

In support of the (Convention) Application made by: SUMITOMO BAKELITE COMPANY LIMITED, a corporation organized under the laws of Japan, of 2-2, Uchisaiwaicho-1-chome, Chiyoda-ku, Tokyo, Japan, for a patent for an invention entitled: "SURGICAL OPERATION DEVICE"

I (We), Hisao AOKI, of and care of the applicant company do solemnly and sincerely declare as follows:

- a) I am (We are) the applicant(s) for the patent
- OR
- b) I am (We are) authorised by the applicant(s) for the patent to make this declaration on its behalf.

Delete the following if not a Convention Application.
The basic application(s) as defined by section 141 (142) of the Act was (were) made

on April 27, 1989 in Japan
or in
or in

by SUMITOMO BAKELITE COMPANY LIMITED

The basic application(s) referred to in this paragraph is (are) the first application(s) made in a Convention country in respect of the invention the subject of the application.

- a) I am (We are) the actual inventor(s) of the invention.
- OR
- b) Morito IDEMOTO, Naohiko INOUE and Yasuo NOGUCHI,
of: 10-2-405, Ichiba Kamicho, Tsurumi-ku, Yokohama, Japan;
32-36, Hirado-2-chome, Totsuka-ku, Yokohama, Japan;
70-17-709, Nasecho, Totsuka-ku, Yokohama, Japan; respectively.

is (are) the actual inventor(s) of the invention and the facts upon which the applicant company is (are) entitled to make the application are as follows:

The applicant is the assignee of the invention from the inventors.

Declared at Tokyo, Japan this 9th day of October, 1989.
SUMITOMO BAKELITE COMPANY LIMITED.

Signed *Hisao Aoki* Status Representative Director

Declarant's Name Hisao AOKI

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(57) Claim

1. A surgical operation device comprising:
 - an ultrasonic piezoelectric transducer for generating ultrasonic mechanical vibrations;
 - an oscillation feedback type oscillator for applying high frequency power to the transducer;
 - a mechanical vibration transmitter connected to the ultrasonic piezoelectric transducer for transmitting and amplifying said ultrasonic mechanical vibrations;
 - a sucking unit adapted to remove tissue fragments from an operation section; and
 - an irrigator adapted to supply a liquid to the operation section;
- wherein the piezoelectric transducer includes a bolted Langevin type transducer; and
- wherein the feedback circuit of the oscillation feedback type oscillator includes an oscillation voltage detector detecting a signal proportional to the oscillation voltage applied to the ultrasonic piezoelectric transducer, a phase comparator providing an output proportional to the comparative voltage phases of an output of the oscillation voltage detector and a

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reference signal, a low pass filter through which the phase comparator is passed, a differential amplifier receiving the output of the filter, and a voltage controlled oscillator receiving the output of the differential amplifier, providing the power to the transducer and supplying the reference signal to the phase comparator.

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Complete Specification for the invention entitled:

"SURGICAL OPERATION DEVICE"

The following statement is a full description of this invention
including the best method of performing it known to us:-

1 BACKGROUND OF THE INVENTION

The present invention relates to surgical operation devices for crushing, severing and/or cutting the organization of an organism using ultrasonic vibrations.

5 Known operation devices which use ultrasonic waves are devices for crushing and/or cutting the organization of an organism in the fields of orthopedic and general surgical operations, devices for operating cataract in the field of ophthalmology and ultrasonic operation
10 devices for scaling the teeth in the field of dental surgery. Any of these devices includes an ultrasonic oscillator, an ultrasonic piezoelectric transducer, an ultrasonic wave transmitter which constitute a single resonant system which oscillates ultrasonically at a
15 particular resonant frequency. Usually, the operation section of the ultrasonic vibration transmitter contacts an organism, so that a mechanical load acts on the operation section. The load on the oscillator fluctuates in accordance with contact state. Therefore, the oscillating
20 frequency and mechanical resonant frequency of the oscillator differ from each other and it is difficult to maintain the amplitude and vibrating speed of the operation section at constant appropriate conditions.

In order to cope with such fluctuations of the
25 load, an oscillation feedback oscillation is known in

1 which if an ultrasonic vibration transmitter is connected
and driven with a constant current or voltage, in order
to cope with fluctuations of the load, the mechanical
Q of the resonant system is high, so that the amplitude
5 and vibrating speed of the operation section is maximum
at the mechanical resonant frequency. This amplitude
and vibrating speed are extracted by using an appropriate
device or method proportional to the amplitude and fed
back to the input terminal of an amplifier to maintain
10 oscillation at all times even if the mechanical resonant
frequency fluctuates. An oscillator is used in which
a pickup device is attached to a piezoelectric
transducer to obtain a voltage in proportion to vibra-
tion and to feed back the voltage to the input terminal
15 of the amplifier. The attachment of the pickup device
to the transducer renders structurally complicated and
large-sized a handpiece including the transducer. This
is against miniaturization and lightening of the
handpiece as an operation device for medical treatment
20 manipulated by the operator.

There is proposed a method in which a voltage
in proportion to the vibration is extracted by an
electrical circuit. In this case, an oscillator is
used in which an oscillating voltage detector is used
25 as a feedback circuit. A voltage in proportion to the
vibration is extracted as an output voltage 105 to a
transducer 104 from a matching circuit 102 by an
oscillating voltage detecting motional bridge 107 of a

1 feedback circuit 103 and fed back to the input terminal
106 of an amplifier 101, as shown in FIGs. 19 and 20.
If a load is applied to the operation section before
oscillation starts, the mechanical resonant frequency
5 of the resonant system including the piezoelectric
transducer and the ultrasonic vibration transmitter
greatly tends to be a spurious frequency at the start-up.
In addition, under such condition, the oscillation is
fixed by the feedback circuit 103 in the spurious mode,
10 so that it is difficult to restore the predetermined
mechanical resonant frequency. If the difference between
the mechanical resonant frequency and the oscillating
frequency is out of the narrow resonant frequency of
the matching circuit 102 of the oscillator or of
15 filters of the amplifier 101 by fluctuations of the load
on the vibrating operation section, feedback would not
be effected and oscillation would stop undesirably.

An ultrasonic oscillator including a feedback
circuit using a PLL (Phase-Locked Loop) ^{USA 4 275 363} ~~Japanese~~ Patent
20 ~~Publication JP-A-61-10194~~ uses the feature of the PLL
to cause a piezoelectric transducer to sweep frequencies
in a predetermined range to lock the oscillating frequency
to the mechanical resonant frequency. If the resonant
system is driven which includes an ultrasonic vibration
25 transmitter connected to the piezoelectric transducer
and has a greatly changing load thereon, the direct
supply of a feedback signal from the transducer to a
phase comparator of the PLL makes it impossible to



1 discriminate between the spurious frequency and the
optimum resonant frequency generated when the amplitude
and vibrating speed of the operation section are maximum
and the vibration may be likely to be fixed in the
5 spurious mode. Thus, especially, it is difficult to
vibrate an ultrasonic vibration transmitter in large
load fluctuation and especially used for severing and/or
cutting a hard organization.

While a magnetostrictive transducer is often
10 used as a power transducer, the efficiency of its
electro-mechanical conversion is low, radiation loss
from the transducer is high and the transducer would
be deteriorated unless it is cooled by water, for example.
Thus, a power electrostrictive bolted Langevin transducer
15 higher in electro-mechanical conversion efficiency than
the magnetostrictive transducer has been invented.
The Langevin transducer is low in heat generation
compared to the magnetostrictive transducer, so that a
special-purpose cooling mechanism is not needed.
20 FIG. 21 schematically illustrates a Langevin transducer
in which one of metal blocks 108, 109 has a bolt portion
and the other has a nut portion. The bolt portion has
ring-like polarized electrostrictive transducers 112,
113 and electrodes 114, 115, 116 fitted alternately
25 thereon and tightened by the other (nut) of the blocks
108 and 109. High-frequency power is applied across
the electrode plates 114, 115 and 116 from the oscillator
to cause ultrasonic vibrations. At this time, the metal

1 block 108 contacting the ultrasonic vibration transmitter
117 which directly contacts the organization of an
organism may be used grounded. According to classifica-
tion of dangerous degree of electrical shocks this system
5 is a B-type medical device, so that it cannot be applied
directly to human hearts.

One example of the structure of a conventional
handpiece using an ultrasonic vibration transmitter to
crush, suck and eliminate a soft organization will be
10 described somewhat in detail with reference to FIG. 22.
An ultrasonic vibration transmitter 119 is connected
to an ultrasonic vibration source 118 as by screws.
The transmitter 119 includes a constant cross-sectional
area (for example, cylindrical) portion 126 of a 1/4
15 wavelength, a tapered portion and a minimum-diameter
pipe-like operation section 122 for generation of
ultrasonic vibrations. The transmitter 119 has a
longitudinally extending internal path 120 through
which cellular fragments crushed and emulsified by the
20 operation section 122 and an irrigation solution supplied
to a position where operation is effected are sucked and
eliminated to the outside.

The distribution of stress on the transmitter
119 is expressed by a stress line 123 in FIG. 22(b).
25 The internal stress produced when ultrasonic vibrations
occur is zero at the end of the ultrasonic vibration
source 118 and the operation section 122. The maximum
point on the stress line 123 appears at the minimum

1 cross section area 121 of the tapering portion. FIG.
22(c) illustrates the amplitude corresponding to the
stress. The amplitude amplification rate is directly
proportional to the ratio of cross section area S_1 the
5 cylindrical portion 126 to cross section area S_2 of
the operation section 122, S_1/S_2 . Similarly, the
internal stress is also proportional directly to the
cross section area ratio between portion 126 and 121.

A large amplitude is required to crush the
10 organization of an organism, especially, calcification
so that it is necessary to increase the cross section
area ratio in the ultrasonic vibration transmitter
119. As a result, a metal fatigue and hence breakage
due to ultrasonic vibration may occur at the minimum
15 tapering end 121 to which the maximum stress applies.
Thus, if a high-amplitude handpiece is designed which
prevents a breakage at the minimum cross section area
121, it would be greatly deformed and not suitable for
practical use.

20 If a position where operation is effected
is deep in a living body and the operating field is
very narrow, very difficult operation is forced to thereby
take a long time, which is an obstacle to an appropriate
and accurate operation.

25 When a hard organization is conventionally
severed and cut, Kerrison forceps, chisels, raspatories,
surgical burs, etc., are used. Operation devices such
as Kerrison forceps and line saws are low in operation

1 efficiency, take much time, take much energy from the
operator, and require fine operation and high techniques.
An air-driven surgical bur rotates a drill to sever and
cut the affected portion of a living body, so that
5 small vibrations are transmitted to the hand of the
operator from an area where the bur contacts the hard
organization during operation, and hence a fine opera-
tion is difficult. In addition, the activeness of the
organization of an organism would be lost by frictional
10 heat due to rotation of the drill. Furthermore, the
rotational movement of the drill would damage the
organization of blood vessel and nerves in a hard
organization only by touching the organization.

SUMMARY OF THE INVENTION

15 In order to solve such problems with the
conventional surgical operation devices, the present
invention provides a surgical operation device which
includes an ultrasonic oscillator capable of widely
tracing the mechanical resonant frequency in accordance
20 with load fluctuation and starting with an appropriate
frequency, a bolted CF-type Langevin transducer of a
reduced leakage current, an ultrasonic vibration trans-
mitter of high fatigue strength and for a soft organiza-
tion, and an ultrasonic vibration transmitter for
25 severing and/or cutting a hard organization efficiently.

~~The present invention provides a surgery
operation device comprising:~~



The present invention provides a surgical operation device comprising:

an ultrasonic piezoelectric transducer for generating ultrasonic mechanical vibrations;

5 an oscillation feedback type oscillator for applying high frequency power to the transducer;

a mechanical vibration transmitter connected to the ultrasonic piezoelectric transducer for transmitting and amplifying said ultrasonic mechanical vibrations;

10 a sucking unit adapted to remove tissue fragments from an operation section; and

an irrigator adapted to supply a liquid to the operation section;

15 wherein the piezoelectric transducer includes a bolted Langevin type transducer; and

wherein the feedback circuit of the oscillation feedback type oscillator includes an oscillation voltage detector detecting a signal proportional to the oscillation voltage applied to the ultrasonic piezoelectric transducer, a phase comparator providing an output proportional to the comparative voltage phases of an output of the oscillation voltage detector and a reference signal, a low pass filter through which the phase comparator is passed, a differential amplifier receiving the output of the filter, and a voltage controlled oscillator receiving the output of the differential amplifier, providing the power to the transducer and supplying the reference signal to the phase comparator.

20

25



1 ~~an ultrasonic piezoelectric transducer for~~
generating ultrasonic vibrations;
an oscillation feedback type oscillator for
supplying high-frequency power to the transducer;
5 a vibration transmitter connected to the
resonator for transmitting and amplifying a mechanical
vibration at an ultrasonic frequency;
a sucking unit; and
an irrigator;
10 wherein the piezoelectric transducer includes
a bolted Langevin type transducer; and
wherein the feedback circuit of the oscillation
feedback oscillator includes an oscillation voltage
detector, a phase comparator, a low pass filter, a dif-
15 ~~ferential amplifier, and a voltage controlled oscillator.~~

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of one embodiment
of a surgical operation device according to the present
invention;

20 FIGS. 2 - 4 are a block diagram and a circuit
diagram of an oscillation feedback type oscillator;

FIG. 5 illustrates the structure of a bolted
CF-type Langevin transducer;

25 FIGS. 6 - 14B illustrate the shape, vibration
and distribution of stress of an ultrasonic vibration
transmitter as one embodiment of the present invention;

FIGS. 15A - 17B illustrate one embodiment of a



1 severing/cutting ultrasonic vibration transmitter;

FIG. 18 illustrates the shape of a handpiece with a switch;

FIGs. 19 and 20 are a block diagram and a
5 circuit diagram, respectively, of a conventional oscillator; and

FIGs. 21 and 22 illustrate the shape, and amplitude, distribution of stress of the conventional ultrasonic vibration transmitter.

10 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described in detail with reference to the drawings. FIG. 1 is a block diagram of a surgical operation device as one embodiment of the present invention. The device has an
15 ultrasonic function, an irrigation function, and a sucking function. The irrigation function is to cause an irrigator 14 to supply a liquid which does not damage the tissues, for example, physiological saline solution, to operation sections at the end of handpiece 12 or 13
20 via a tube 203 to cool the operation sections and their ambient organism organizations using the liquid, and to generate a cavitation due to the ultrasonic vibrations of the operation sections to crush tissues. The sucking function is to cause a sucking unit 20 to suck
25 and eliminate fragments of tissues crushed by the operation sections at the end of the handpiece 12 or 13 out of the living body. A negative pressure (vacuum)

1 generated by a vacuum pump 19 is adjusted by a pressure
adjuster valve 17 and a pressure meter 16 to an
appropriate sucking pressure so that the fragments
of tissues are stored in a bottle 18 via a tube 204.

5 The ultrasonic function is to cause an oscillation
feedback type oscillator 1 to generate an electrical
energy of ultrasonic frequency (18 - 38 KHz), to apply
the electric energy to bolted Langevin type resonators
in the handpiece 12 or 13 to generate mechanical ultra-
10 sonic vibrations, and to cause the vibration transmitters
connected to the transducers to increase the vibration
amplitude and speed to thereby crush, sever and cut the
affected portion of a living body using ultrasonic
vibrations of the operation sections.

15 The oscillation feedback type oscillator 1
according to the present invention has a circuit to
maintain an ultrasonic vibration of a predetermined
resonant frequency even if the load on the operation
section fluctuates greatly, namely, even if a hard
20 organization is severed/cut. In the oscillator 1, a
predetermined AC source current is rectified by a
rectifier 2 to provide direct current sources for driving
circuit elements in the oscillator 1. A current flows
from the rectifier 2 to an overload control circuit 3,
25 and an amplitude adjuster 4. The overload control
circuit 3 interrupts a current using a device such as a
thyristor when a current exceeding a maximum predetermined
value flows through the unit 3. The threshold current is

1 preferably 1.5 - 3A although not limited. The amplitudes
of the ultrasonic vibrations generated by the handpiece
12 or 13 are adjusted by varying the output voltage of
the amplitude adjuster 4.

5 In oscillation, a signal of a reference
frequency output from the feedback circuit 11, namely, a
signal of the resonant frequency of the handpieces is
inputted to and amplified by the amplifier 5 and the
resulting signal is delivered through a filter 6 and a
10 transformer 7 to an amplifier 8. The filter 6 includes
a bandpass filter centered at the resonant frequency
and preferably passes therethrough a band of a resonant
frequency $\pm 1 - 3$ KHz although not especially limited.
The signal voltage is enhanced by the transformer 7 and
15 the resulting voltage is applied to the amplifier 8
which amplifies the signal current of the resonant
frequency from the transformer 7 in accordance with the
current from the amplitude adjuster 4. The resulting
signal is enhanced by a transformer 9 and is delivered
to a matching circuit 10 which performs impedance
matching between the handpiece 12 or 13 and the oscil-
lator 1. The output from the matching circuit 10 is
delivered to the feedback circuit 11. The amplifier
8 is preferably a SEPP circuit or a B-class push-pull
25 circuit although not especially limited.

FIG. 2 illustrates the details of the feedback
circuit 11. The output 21 from the matching circuit
10 is supplied to the handpiece 12 or 13 via an oscillation

1 voltage detector 22 which includes a motional bridge 29,
a base clipper 30, a voltage adjuster 31 and an input
level converter 32, as shown in FIG. 3. The output 21
from the matching circuit 10 is applied across two
5 terminals on a diagonal line of the motional bridge 29
to drive a bolted Langevin type transducer 34 included
in the handpiece 12 or 13 connected in a branch of the
bridge. A resistor 201 cooperating with a capacitor 202
to form a parallel circuit of the motional bridge 29
10 may be removed if a plurality of capacitors are connected
in series to adjust a breakdown voltage. The output
from other two terminals of the motional bridge 29
through a base clipper 30, a voltage adjuster 31, and
an input level converter 32 is applied to an input 33
15 of a phase comparator 23 as an input signal having an
appropriate input level. A power supply V_{DD} 36 provides
a power to the active elements of the voltage adjuster
31 and converter 32. The oscillation voltage detector
22 provides a stabilized feedback signal irrespective
20 of the state of the loads on the handpiece 12 or 13.
The output signal from the oscillation voltage detector
22 is delivered to the phase comparator 23 of a PLL 28
where the feedback signal is compared with a reference
signal of substantially the same frequency as the
25 resonant frequency generated by a voltage controlled
oscillator (VCO) 26 with reference to phase, and
the phase difference is intergrated into a saw-tooth
wave by a low pass filter 24 like a lag filter of

1 capacitors and resistors. The resulting saw-tooth signal
is amplified by a differential amplifier 25 the output
from which is inputted to the VCO 26. The feedback
signal 27 substantially locked by a control voltage
5 from the VCO 26 is fed back to the amplifier 5 and then
to the PLL 28 again via the filter 6, transformer 7,
amplifier 8, transformer 9, matching circuit 10 and
oscillation voltage detector 22. This operation is
repeated to bring about a locked state or a resonant
10 frequency state. Thus, even if the operation section
at the end of the ultrasonic vibration transmitter of
the handpiece 12 or 13 has a load thereon from prior to
vibration thereof, namely, even if the resonant
frequency is very difficult to generate, access to an
15 optimum resonant frequency or locked state is repeated
and finally an ultrasonic operation at the resonant
frequency is brought about. Therefore, even if the opera-
tion section is embedded either in a large-load hard
organization or in a soft calcified organization, a
20 vibration of a stabilized amplitude is easily obtained.
The phase comparator 23, low pass filter 24 and dif-
ferential amplifier 25 are preferably those shown in
FIG. 4, although not especially limited. The VCO 26
is preferably made of crystal, LC, CR or ceramics,
25 although not especially limited.

FIG. 5 shows a bolted Langevin type transducer
as one embodiment of the present invention. The
transducer 36 includes ring-like electrostrictive

1 elements, 43, 44, 35 ring-like electrodes 45, 37, 46, 47
alternating with the electrostrictive elements,
insulator ceramic rings 41 and 42 outside the end
electrodes 45 and 47, a metal block 49 having a bolt
5 portion which extends through the ceramic rings 41, 42
electrostrictive elements 43, 44, 35 and electrodes
45, 37, 46, 47 and a metal block nut 48 which cooperates
with the bolted metal block 49 to tighten the elements
therebetween. By supplying a current of a predetermined
10 high frequency to leads 40 and 50 to the respective
electrodes, ultrasonic vibrations occur at the ends
38 and 39 of the transducer 36.

In the present invention, any electrostrictive
device may be used if it can withstand the tightening
15 pressure. The preferable material is PZT (plumbous
zirconate titanate). The insulator ceramics used may
be ones of electrical resistance of more than 10^{13} Ω cm
and of less than a dielectric constant of 20, for
example, Al_2O_3 or ZrO_2 ceramics, but not limited to them.
20 The materials of the metal blocks used may be stainless
steel, titanium alloy, aluminum alloy, etc., but not
limited to them.

While the direction and amplitude of vibrations
of the transducer are not especially limited, it is
25 desirable to design the overall length of the transducer
so as to be an integral times one half of the resonating
vibration wavelength to obtain high energy efficiency.
Provision of a fluid path in the transducer 36 serves to

1 cool the transducer.

FIG. 6 illustrates a handpiece as one example of the present invention. It includes an ultrasonic vibration source 51 and a vibration transmitter 62 engaged threadedly with the source. The vibration transmitter 62 include a connection portion 53 and an operation section 56 engaged threadedly with the connection portion. A fluid path 52 extends longitudinally through the ultrasonic vibration source 51, connection portion 53 and operation section 56 at the outer end 57 fo which the amplitude of vibrations appears as a side 61 shown in FIG. 8. The amplitude of the mechanical vibrations of an ultrasonic frequency generated by the ultrasonic vibration source 51 is amplified by a change in the cross section area of the connection portion 53 and operation section 56, the resulting signal is transmitted to the operation end 57 to crush part of the organization of an organism and the fragments of the crushed organization are sucked and discharged via the fluid path 52.

20 The connection portion 53 has a constant cross-sectional area (cylindrical stem) portion 58 extending from the adjacent end of the ultrasonic vibration source 51 to a position where a node of vibration 60 shown in FIG. 8 is formed and a tapering portion integral with the cylindrical portion engaged threadedly at 54 with a tapering base of the operation section 56 so as to form a merged tapering section. Therefore, as shown in

1 FIG. 7, the maximum stress is produced at a position
close to the contact face 55 of larger cross section
area than the conventional handpiece (see FIGs. 21
and 22) and reduced by 20 - 50% even if the outer shape
5 of the vibration transmitter 62 is the same as the
conventional one. The threads are preferably fine, but
the pitch itself is influenced by the size of the threads
and not especially limited. In addition to threaded
engagement, welding or pinning may be employed. The
10 position of the contact face 55 where the operation
section 56 and connection portion 53 are connected is
determined by the material of the connection portion
53 in a position from the node 60 of vibration in the
connection portion 53. The length of the tapering
15 portion of the connection portion 53 is preferably $1/3 -$
 $1/10$ of the wavelength of vibration.

By employing the density of the connection
portion 53 material higher than that of the operation
section 56, the amplitude amplification rate increases
20 in direct proportion to the ratio in density of the
connection portion material to the operation section 56
material to thereby provide a larger amplitude than the
conventional one even if the stresses produced at the
operation section 56 and connection portion 53 are the
25 same as those in the conventional operation section and
connection portion. For example, if the connection
portion 53 and operation section 56 are made of stainless
steel and titanium alloy, respectively, the ratio in

1 density of the stainless steel and titanium alloy is
9:5 and appears as an increase of 180% in the amplitude
amplification rate and the amplitude increases by 180%
even if the connection portion and operation section is
5 the same in shape as the conventional one.

FIG. 9 illustrates an embodiment of the
invention in which the fluid path 64 extending through
the ultrasonic vibration source 63 and connection portion
65 is larger in cross section area than the fluid path
10 66 in the operation section 67. Therefore, the size of
fragments of the organism organization crushed by the
operation end 68 is smaller than the cross sectional
area of the fluid path 64, so that even when the
fragments pass through the fluid path 64 smaller in
15 amplitude than the operation end 68, they easily pass
through the fluid path 64 by vacuum suction to thereby
prevent the clogging of the fluid path. The cross-
sectional area of the fluid path 64 is preferably 1.3 -
2.3 times that of the fluid path 66, but not limited.

20 FIG. 10 illustrates an embodiment having a
plurality of vibrating nodes 72 and 74. FIG. 11 shows
an embodiment in which the junction 77 between the
ultrasonic vibration source 76 and connection portion
78 is between the sides of vibrations 80 and 81.

25 FIG. 12 shows an embodiment in which the operation
section 87 has a plurality of vibration sides 88 and
nodes 89. FIG. 13 shows an embodiment in which the
operation section 94 has a plurality of sides 97 and

1 nodes 98 and in which the ultrasonic vibrations source
91 is connected to the connection portion 93 between
a node 96 and a side 95 of vibration. The embodiments
of FICs. 10 - 13 are each a handpiece which reduces
5 the stress and increases the amplification rate, is
excellent in durability and provides a large amplitude.

FIG. 14A illustrates an embodiment in which
the connection portion 53 is bent with reference to the
longitudinal axis. FIG. 14B illustrates an embodiment
10 in which the operation section 56 is bent at an
angle of 5 - 120 degrees to the longitudinal axis of
the connection portion.

FIG. 15A illustrates a vibration transmitter
210 to cut a hard organization. An irrigation liquid
15 is red from an inlet 213 through an irrigation path
212 to an outlet 214 and ejected therefrom against
the operation end 211, the organization of an organism
portion to be cut, and its neighborhood. The irrigation
liquid prevents the generation of frictional heat in the
20 portion to be cut and in the vibration transmitter 210
and hence the deterioration of the vibration transmitter.
As shown in FIG. 15B, the use of a rugged wedge-like
blade 215 formed on the operation section serves to
start vibrations easily even if it is stucked into a
25 hard organization, and the cutting efficiency is doubled
compared to a regular wedge-like blade. Although the
dimensions of the rugged shape of the blade is not
specially limited, the thickness of the blade is preferably

1 1.0 - 2.5 mm and the crest-crest or valley-valley pitch
is preferably 1 - 5 mm. The number of crests or
valleys in the blade is preferably 3 - 10 depending on
the size of the operation section 211. While the
5 material of the vibration transmitter 210 is not
particularly limited, it is preferably titanium alloy.
The operation section 211 may be a removable one of
titanium alloy or ceramic.

FIGs. 16A - 16H illustrate embodiments of
10 the operation section for severing and cutting purposes.
FIG. 16A illustrates a conical operation section 216.
FIG. 16B illustrates a ball-like operation section
218. FIG. 16C illustrates a prismatic operation section
219. FIG. 16D illustrates a ring-like operation section
15 220. FIG. 16E illustrates a scoop-like operation section
221. FIG. 16F illustrates a fork-like operation section
222. FIG. 16G illustrates a spoon-like operation section
223. Each operation section has an outlet 217 for an
irrigation liquid, so that the generation of heat in
20 the operation section and thermal damage to the organiza-
tion around the operation section are prevented. The
operation sections produced from a hard organization
by severing and cutting are washed away to ensure the
field of view of operation is ensured. While the
25 material of the operation section is not especially
limited, stainless steel, titanium alloy or ceramics
are preferable. The number of outlets 217 is not
especially limited. The operation section may be of a

1 removable type.

FIG. 16H illustrates an embodiment in which the operation section 233 has a plurality of openings 231 for the suction path 232 to cut a mass of calcium depositing on a soft organization and to suck calcium fragments away. Provision of the plurality of openings 231 serves to suck small fragments of calcium to thereby prevent clogging of the suction path.

FIG. 17A illustrates an embodiment in which the operation section 226 is of a blade type, and the connection portion 225 of the vibration transmitter 224 is bent relative to the longitudinal axis of the handpiece. The bend angle is not especially limited, but is preferably 5 - 45 degrees. FIG. 17B illustrates one example of a bent blade-like operation section 228 of the vibration transmitter 227. The bent angle is not limited, but is preferably 5 - 30 degrees.

FIG. 18 illustrates an embodiment in which switches 229 are provided on a handpiece 231 to turn on and off ultrasonic vibrations. The switch 229 is a waterproof momentary touch switch giving a clicking sensation and preferably made of a fluororubber, and the surface diameter of the switch 229 is preferably 5 - 15 mm, but not especially limited. The material of the handpiece 231 is preferably a plastic material such as heat-resisting polysulfone, polyamide, polyimide, polyamidoimide, PTFE, ETFE, epoxy or phenol resin or a metal such as an aluminum alloy, titanium alloy or stainless steel

1 alloy. It preferably has a heat resistance higher
than 130°C.

According to the present invention, the
mechanical resonant frequency can be traced over a
5 wide range in correspondence to fluctuations of a load
during vibration. The vibration starts at an
appropriate mechanical resonant frequency irrespective
of the state of the loads on the handpieces at the start-
up whereas the conventional ultrasonic oscillator can
10 only start to oscillate when it has no load or
substantially no load (for example, when the surgery
device is placed in water). According to the inventive
device, the handpiece includes a CF type transducer the
leakage current of which is very small, for example, less
15 than 10 μ A compared to a conventional bolted Langevin
type transducer, so that the device is also usable in
heart operation. The ultrasonic vibration transmitter
in the present invention has a composite structure of
the connection portion and operation section excellent
20 in durability compared to the conventional transmitter.
Severing/cutting a hard organization can be effected
without damaging its ambient organization thermally,
while it is difficult for the conventional surgical bur
to do so. Provision of touch switches on the handpieces
25 facilitates the manipulation by the operator and
contributes advantageously to microsurgery which requires
fine manipulation. As just mentioned above, the surgical
operation device according to the present invention is

1 suitable for crushing and removing soft organizations
and a calcium mass and a calcified organization in the
field of brain surgery, heart surgery, digestive surgery
or severing and cutting a hard organization in the field
5 of mouth surgery, orthopedic surgery, plastic surgery,
etc.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A surgical operation device comprising:
 - an ultrasonic piezoelectric transducer for generating ultrasonic mechanical vibrations;
 - an oscillation feedback type oscillator for applying high frequency power to the transducer;
 - a mechanical vibration transmitter connected to the ultrasonic piezoelectric transducer for transmitting and amplifying said ultrasonic mechanical vibrations;
 - a sucking unit adapted to remove tissue fragments from an operation section; and
 - an irrigator adapted to supply a liquid to the operation section;wherein the piezoelectric transducer includes a bolted Langevin type transducer; and
wherein the feedback circuit of the oscillation feedback type oscillator includes an oscillation voltage detector detecting a signal proportional to the oscillation voltage applied to the ultrasonic piezoelectric transducer, a phase comparator providing an output proportional to the comparative voltage phases of an output of the oscillation voltage detector and a reference signal, a low pass filter through which the phase comparator is passed, a differential amplifier receiving the output of the filter, and a voltage controlled oscillator receiving the output of the differential amplifier, providing the power to the transducer and supplying the reference signal to the phase comparator.
2. A surgical operation device according to claim 1, wherein the oscillation voltage detector includes a motional bridge, a base clipper, a voltage adjuster, and an input level converter, and wherein the low pass filter includes a lag filter.
3. A surgical operation device according to claim 1, wherein the bolted Langevin type transducer includes a stack of alternating one or more ring-like electrostrictive elements and ring-like electrodes one larger in number than the electrostrictive elements and



connected electrically in parallel, a pair of insulators holding the stack therebetween, a pair of metal blocks placed outside the corresponding insulators and a bolt tightening those elements by extending through the center of those elements.

4. A surgical operation device according to claim 3 wherein the insulators each include a ceramic material having an electrical resistance higher than 10^{13} Ω cm.

5. A surgical operation device according to claim 1, wherein the ultrasonic vibration transmitter transmits and amplifies a mechanical vibration of an ultrasonic frequency and includes a connecting portion which comprises a stem portion of a constant cross section area and a tapering portion extending from the stem portion, and an operation section connected removably to the tapering portion wherein a node of vibration occurs at the junction between the stem portion and the tapering portion and a side of the vibration occurs at a free end of the operation section.

6. A surgical operation device according to claim 5, wherein the means for connecting the connecting portion and operation section includes a thread.

7. A surgical operation device according to claim 5, wherein the bolted Langevin type transducer and the ultrasonic vibration transmitter or the ultrasonic vibration transmitter have a fluid path extending therethrough.

8. A surgical operation device according to claim 7, wherein the cross sectional area of the fluid path in the connecting portion is equal to, or larger than, that of the fluid path in the operation section.

9. A surgical operation device according to claim 5, wherein the material and density of the connecting portion are equal to, or higher than, those of the operation section.

10. A surgical operation device according to claim 5, wherein a forward portion of the operation section is bent at angles of 5 - 120 degrees to the longitudinal axis of the device.

11. A surgical operation device according to claim 1, wherein the ultrasonic vibration transmitter includes an operation section of a blade form contacting the organization of an organism and has a fluid path extending therethrough, one end of the path being open in the operation section.

12. A surgical operation device according to claim 11, wherein the ultrasonic vibration transmitter includes a connecting portion extending at an angle, or parallel, to the direction of mechanical vibrations at an ultrasonic frequency and an operation section contacting the organization of an organism.

13. A surgical operation device according to claim 11, wherein the end portion of the ultrasonic vibration transmitter including the operation section extends at an angle to the direction of mechanical

vibrations at an ultrasonic frequency.

14. A surgical operation device according to claim 1, including a switch provided on the side of a handpiece including a bolted Langevin type transducer and an ultrasonic vibration transmitter.

15. A surgical operation device as defined in any one of the preceding claims wherein the bolted Langevin type transducer includes a stack of alternating one or more electrostrictive elements and electrodes, said electrodes being one larger in number than said electrostrictive elements, and connected electrically in parallel, a pair of blocks placed outside the stack and a bolt tightening the electrostrictive elements and electrodes together.

16. A surgical operation device being substantially as described herein with reference to any one or combination of the figures 1-18 inclusive.

Dated this 5th day of February 1991

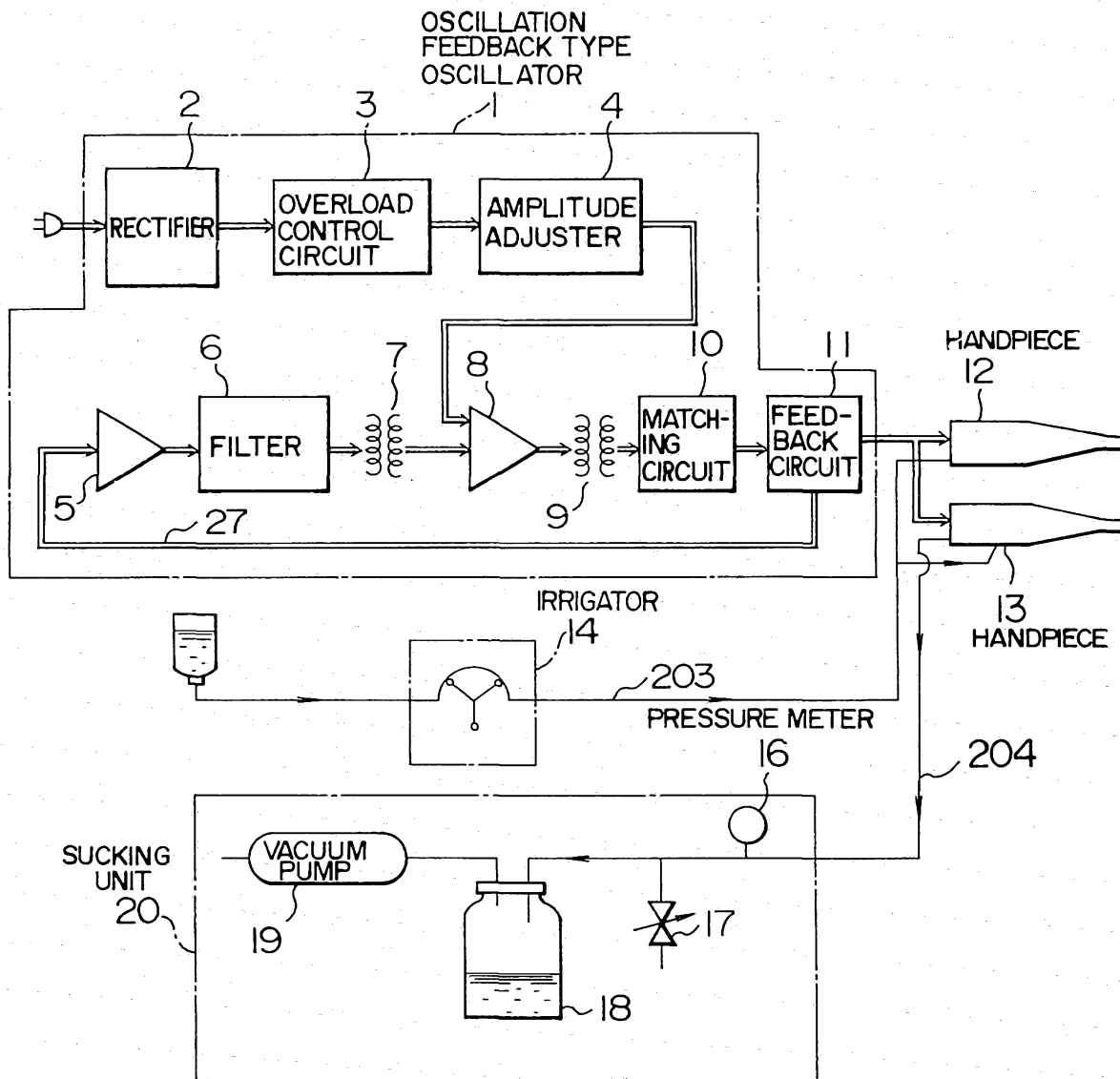
SUMITOMO BAKELITE COMPANY
LIMITED

Patent Attorneys for the
Applicant
F.B. RICE & CO.



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

FIG. 1



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FIG. 2

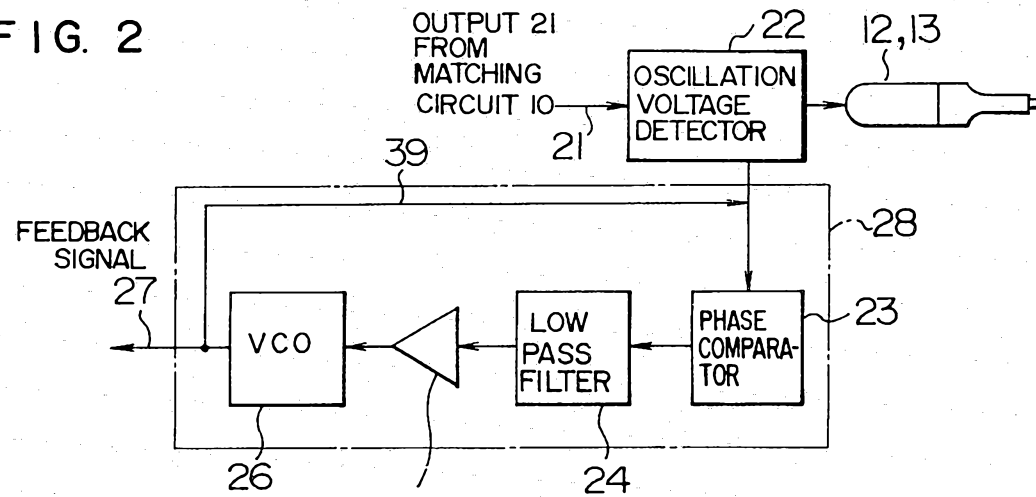
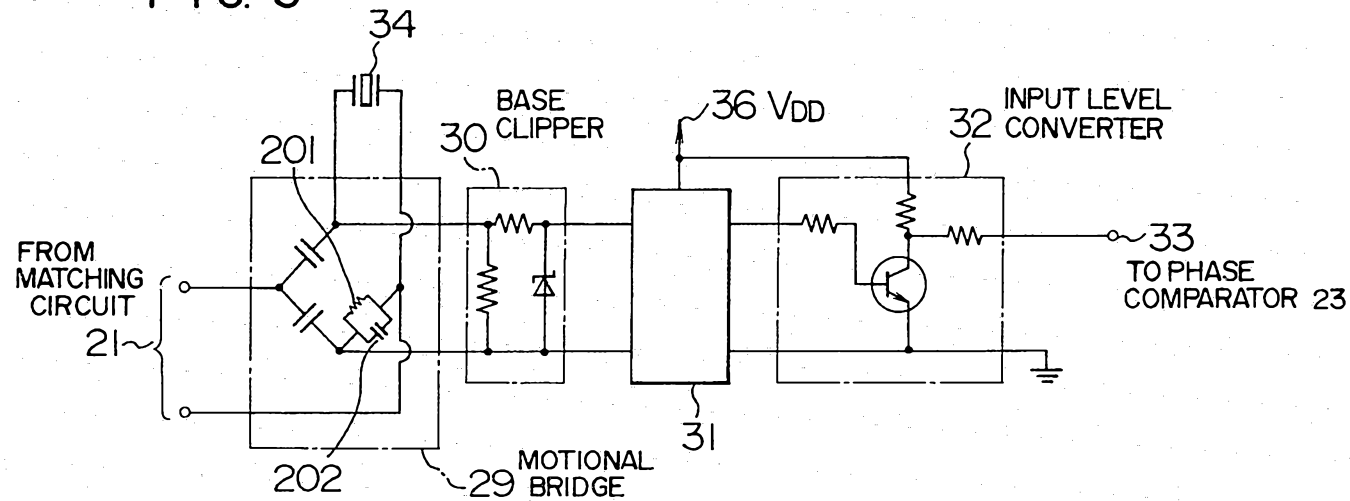


FIG. 3



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FIG. 4

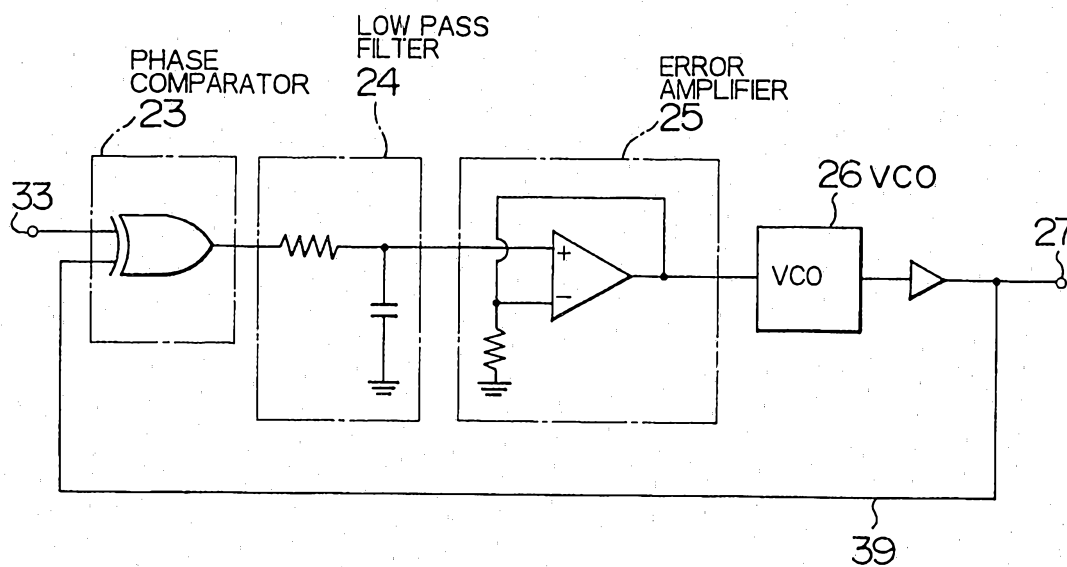


FIG. 5

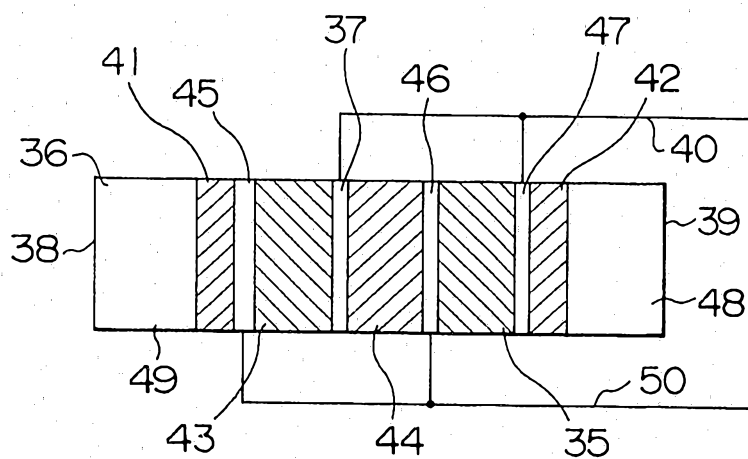


FIG. 6

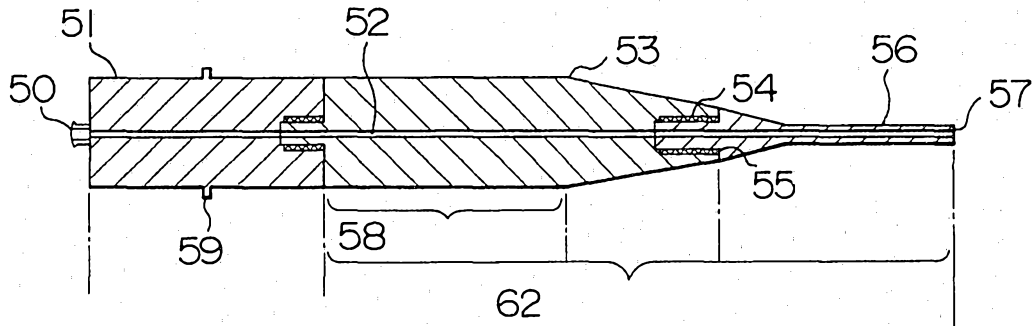


FIG. 7

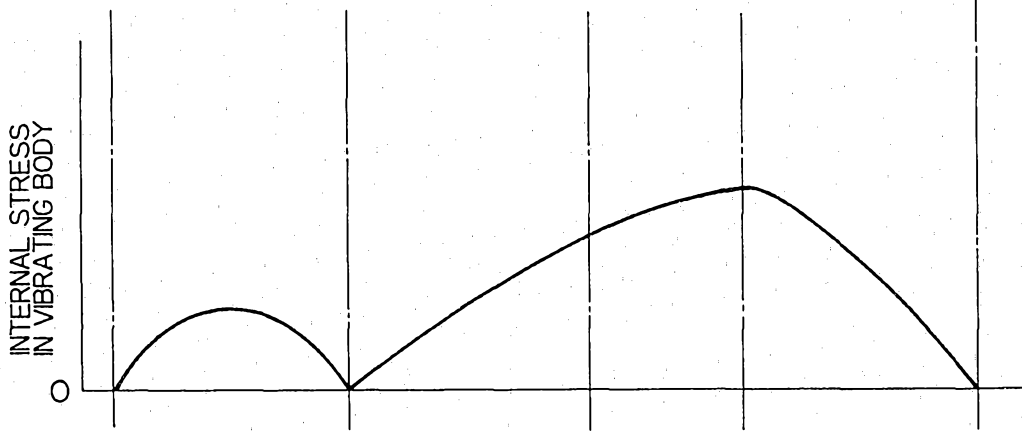


FIG. 8

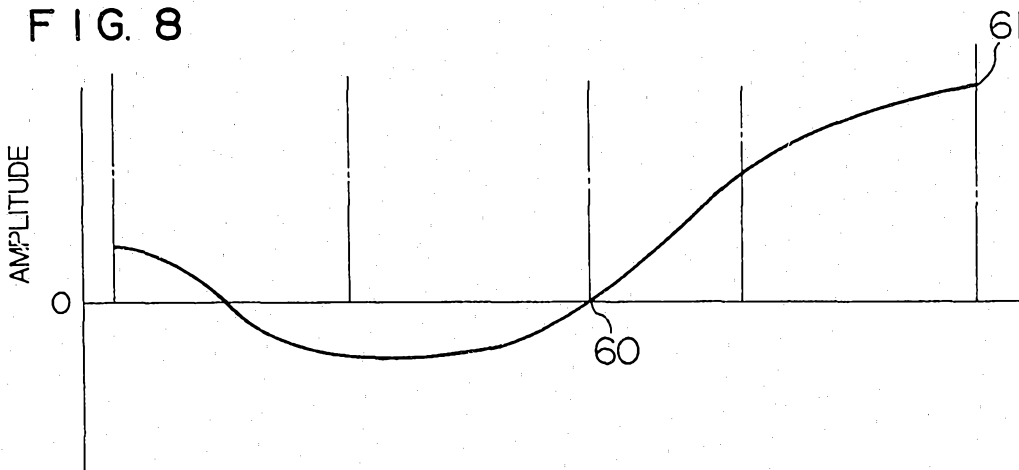


FIG. 9

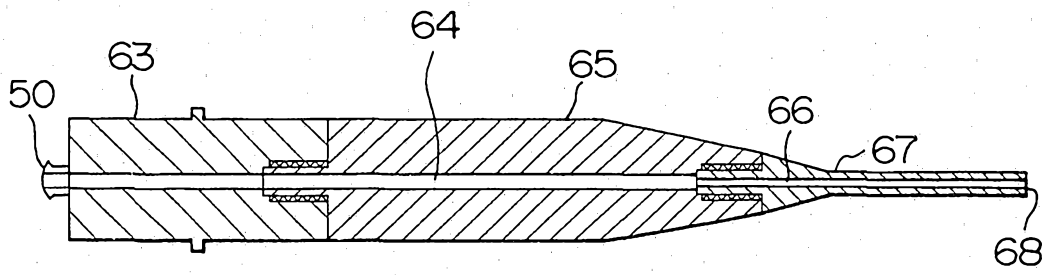


FIG. 10

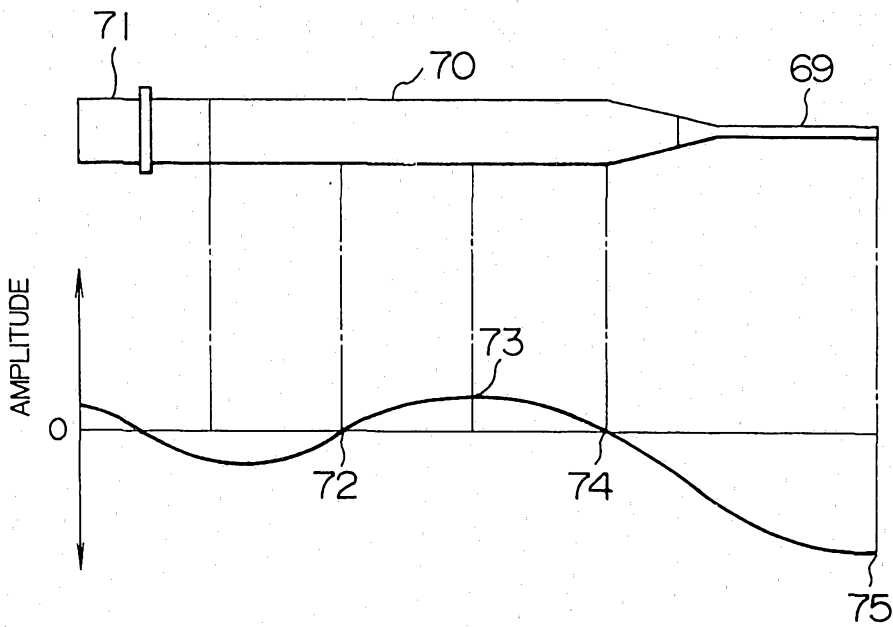


FIG. 11

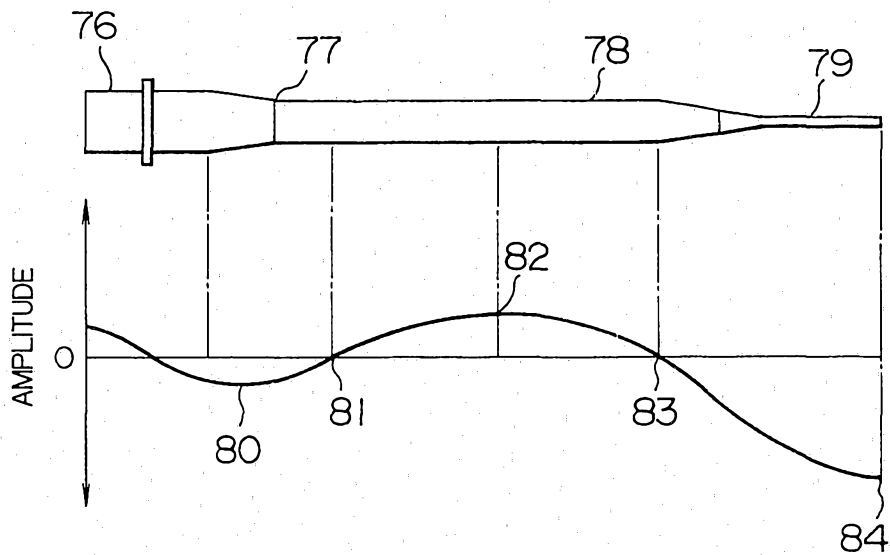


FIG. 12

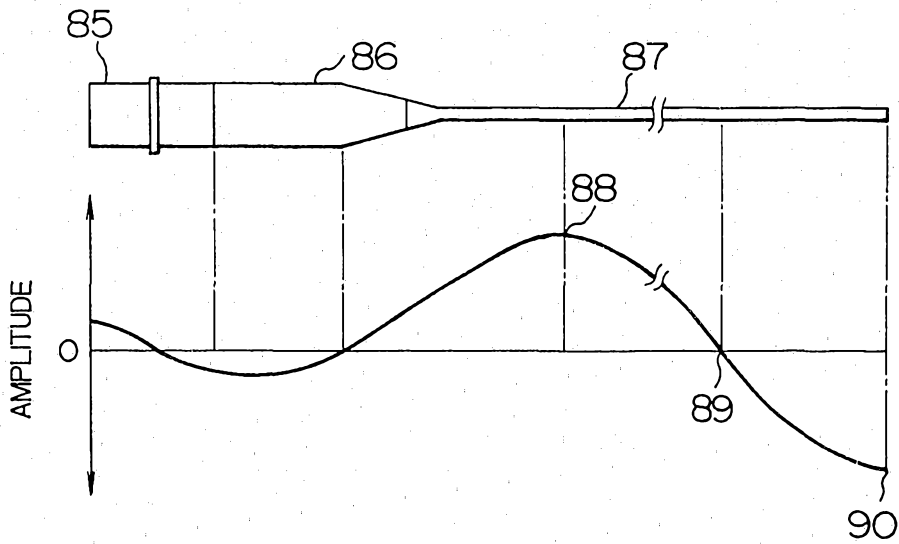


FIG. 13

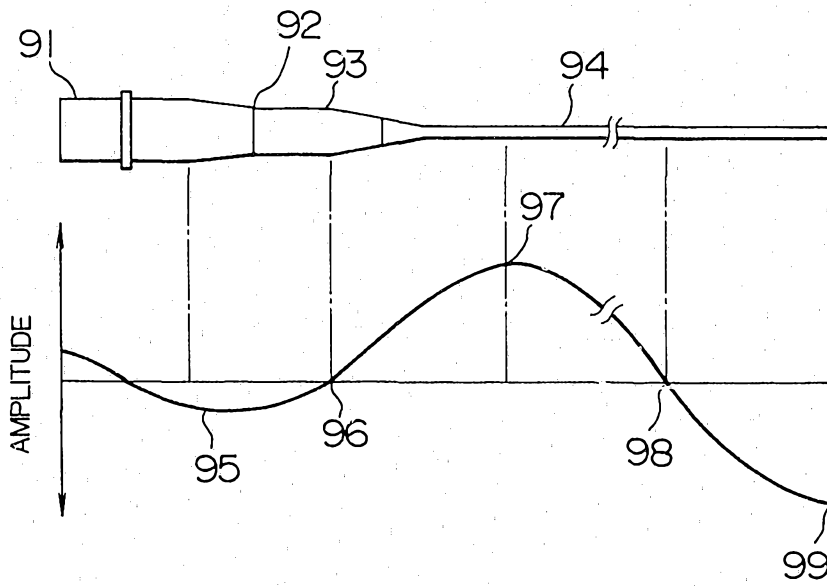


FIG. 14A

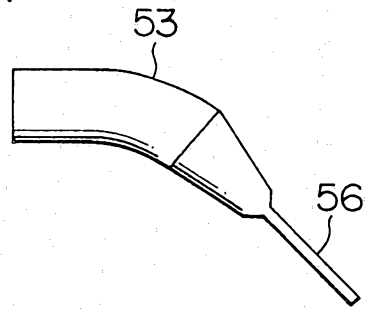


FIG. 14B

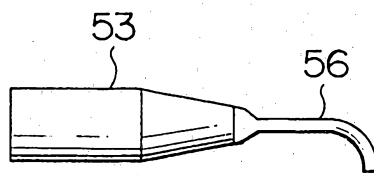


FIG. 15A

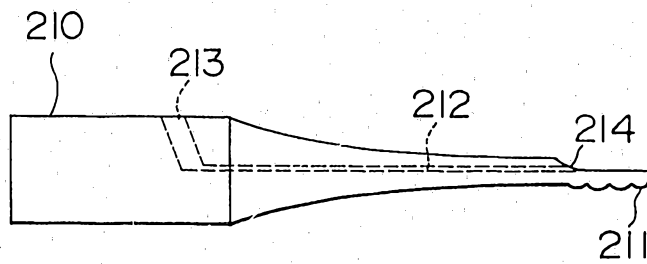


FIG. 15B

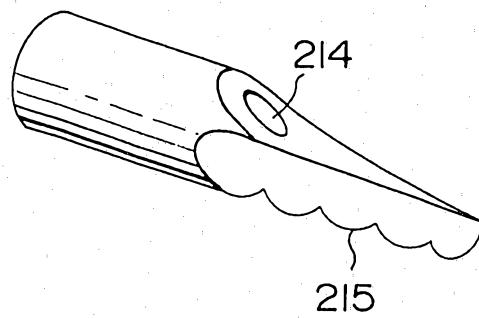


FIG. 16A

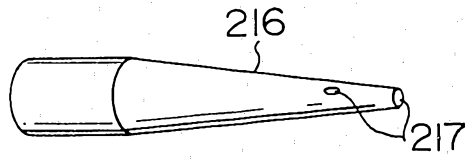


FIG. 16B

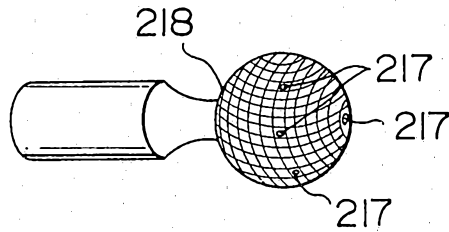


FIG. 16C

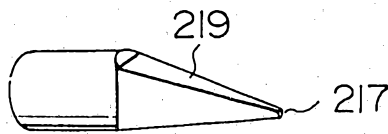


FIG. 16D

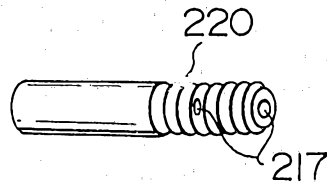


FIG. 16E

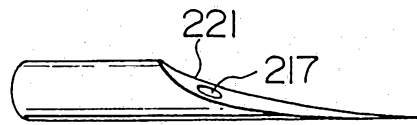


FIG. 16F

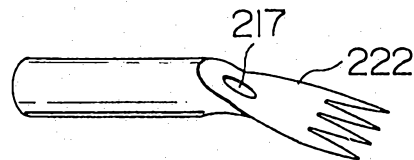


FIG. 16G

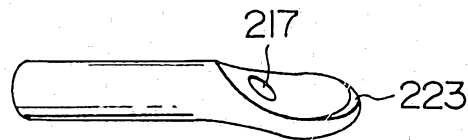


FIG. 16H

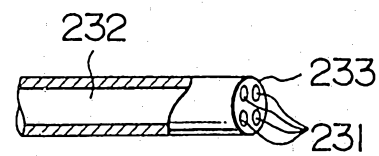


FIG. 17A

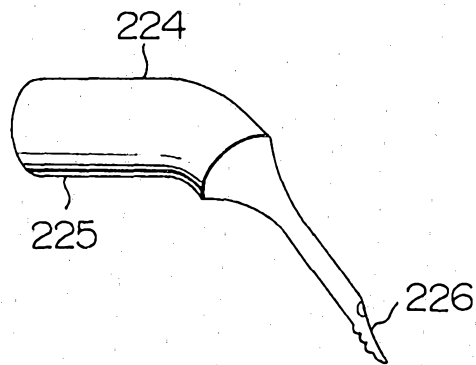


FIG. 17B

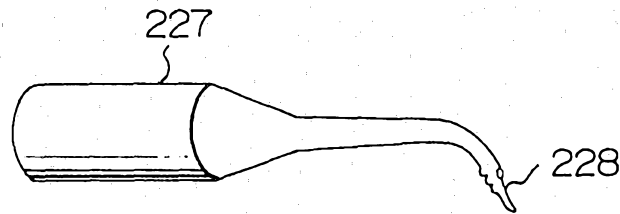


FIG. 18

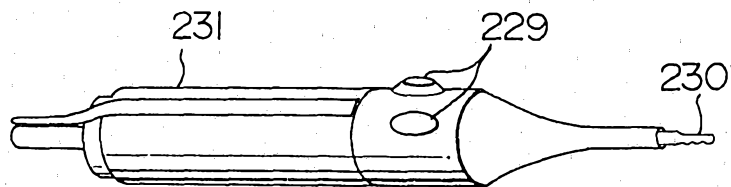


FIG. 19
PRIOR ART

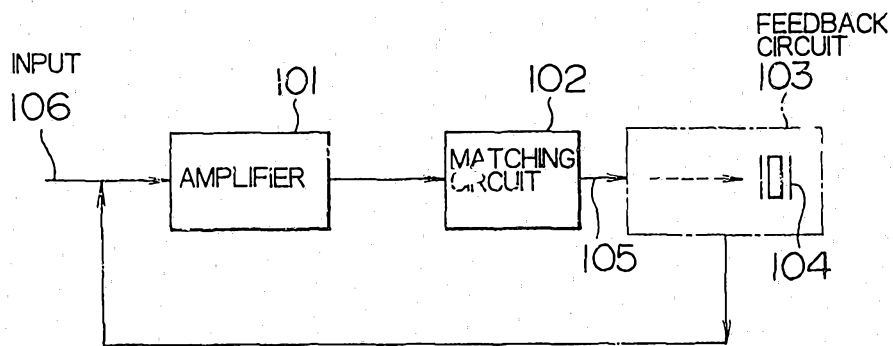


FIG. 20
PRIOR ART

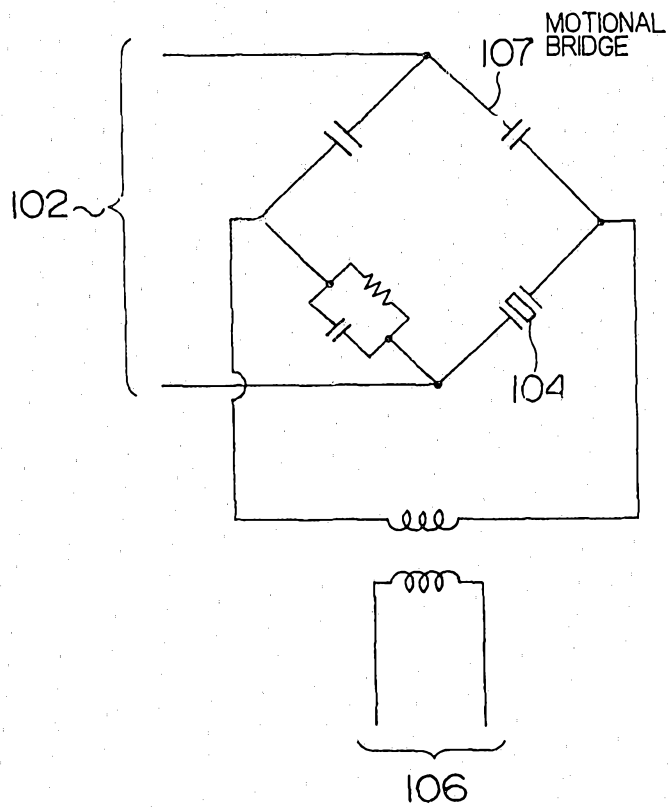


FIG. 21
PRIOR ART

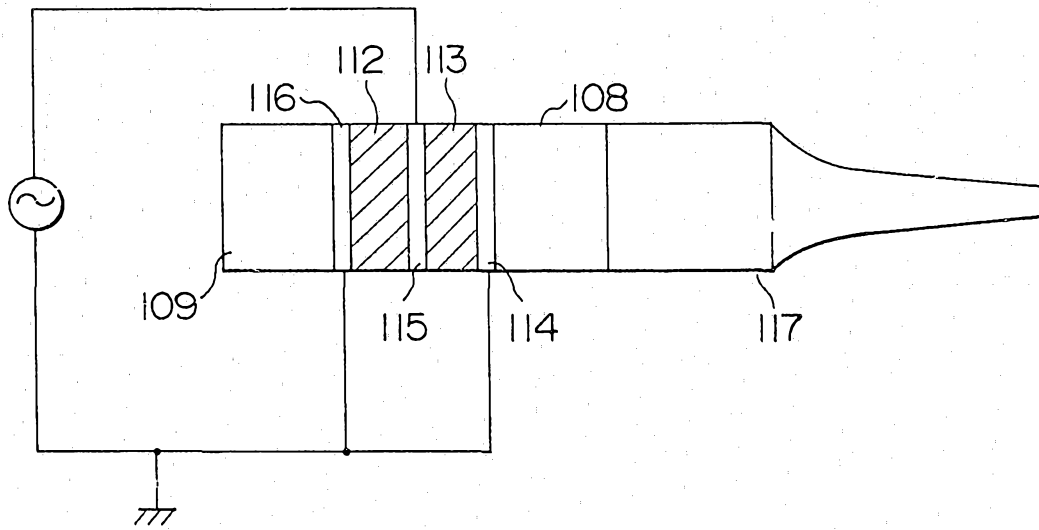


FIG. 22
PRIOR ART

