

CFO 9044

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1 Method for Judging Discharge State of
Ink Jet Recording Head, and Ink Jet
Recording Apparatus Utilizing the Same

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an ink jet recording apparatus adapted for use in a printer, a facsimile, a word processor, a copying machine or
10 the like, and more particularly to a method for detecting the temperature characteristics of an ink jet recording head and judging the discharge state thereof.

Related Background Art

15 Recording apparatus for recording on a recording medium such as paper or a sheet for overhead projector, have been commercialized in the form employing a recording head of various recording methods. Such recording head is known, for example,
20 in the wire dot method, the thermal method, the thermal transfer method or the ink jet method. Particularly the ink jet method is attracting attention as a quiet recording method of a low running cost, since the ink is directly discharged
25 onto the recording medium.

In such ink jet recording apparatus, an ink tank containing ink is connected to the recording

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1 head through an ink supply pipe, and the ink is
supplied from such ink tank. Said ink tank may be
formed as an ink cartridge which is separate from the
recording head and is replaceably mounted in the
5 recording apparatus, or as an integral unit with the
recording head, which is integrally replaceably
mounted in the recording apparatus.

In such ink jet recording apparatus, if the
ink supply is interrupted because of the exhaustion
10 of ink, the ink discharge becomes no longer possible
so that the recording ability is lost. In order to
avoid such situation, there has been commercialized
the recording apparatus with a function of detecting
the remaining ink amount, thus generating an alarm
15 signal or requesting the replacement of the ink tank,
according to the amount of consumption of ink.

For detecting the remaining ink amount, there
has been proposed a method of counting the pulse
signals supplied for ink discharge and thereby
20 calculating the amount of ink consumption, a method
of inspecting the change in the resistance of ink
itself or of a member holding the ink, a method of
detecting the weight change of the ink tank, or a
method of forming a transparent area in an ink path
25 in the ink tank or in the recording head and
inspecting the presence or absence of ink in said ink
path by the observation of the user or by a



1 photosensor.

In the above-mentioned method utilizing the count of the ink discharge pulse signals, the remaining ink amount is detected by calculating the
5 ink amount used in recording, from the product of the number of applied pulses and the amount of discharge per ink droplet discharged by a pulse.

Also the method of remaining amount detection by inspecting the resistance of ink etc. utilizes
10 a fact that ordinary ink has a certain specific resistance due to the presence of water and other conductive substances therein, measures the resistance of the ink or the member holding the ink by means of a pair of electrodes provided for example
15 in the ink tank, and detects the remaining ink amount based on a fact that the resistance between said electrodes is correlated with the remaining ink amount.

Also the method utilizing the weight change
20 of the ink tank relies on the change of force applied to a spring provided in a member for mounting the ink tank, resulting from ink consumption, and detects the remaining ink amount by activating an electrical contact by the deformation of said spring.

25 However, such conventional methods as explained above have been associated with the following drawbacks.

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1 The limit remaining amount, at which the
recording operation becomes impossible, detected by
the above-mentioned methods, is influenced for
example by the unit-to-unit fluctuation of the
5 recording head in manufacture, and is not highly
reliable, so that the recording operation may be
disabled immediately after the warning for such limit
remaining amount or may still be properly conducted
even after such warning. According to the
10 experiments of the present inventors, such drawbacks
is particularly conspicuous in case ink is held in
the ink tank by means of an ink holding member such
as sponge.

Besides the amount of ink droplet discharge
15 per pulse is influenced not only by the unit-to-unit
fluctuation of the recording head but also by the
ambient temperature, so that the exact calculation
of the amount of ink consumption is difficult.
Furthermore, the detection by visual inspection or
20 by photosensor has been unable to provide sufficient
accuracy.

Furthermore, the configuration becomes
complex by the presence of the detection members such
as the spring or the photosensor, or the presence of
25 the transparent area, for the detection of the
remaining ink amount.

Furthermore, the above-mentioned conventional

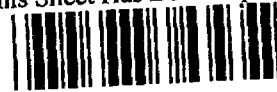




1 methods, though being capable of detecting the
disabled recording state resulting from the
interruption of ink supply caused by the ink
exhaustion, are unable to detect the disabled
5 recording state that may occur before the complete
exhaustion of ink. Such disabled recording state
before the ink exhaustion may be caused, for example,
by bubble formation, by air intrusion, in the ink
path between the ink tank and the recording head,
10 or by interruption of ink supply due to generation
or growth of a remaining bubble in a recording head
designed to generate a bubble for ink discharge, or
by destruction of meniscus at the ink discharge
opening due to vibration applied to the recording
15 apparatus or the recording head, thereby causing the
liquid to flow into the nozzle of the recording head
from said ink discharge opening.

SUMMARY OF THE INVENTION

20 In consideration of the foregoing, the
principal object of the present invention is to
provide an ink jet recording apparatus capable of
detecting the temperature characteristics for each
recording head and of effecting high precise
25 detection of the ink discharge state based on thus
detected temperature characteristics. Another object
of the present invention is to provide a method for



1 detecting the temperature characteristics of the ink
jet recording head, and a method for judging the
ink discharge state of the ink jet recording head.

The foregoing objects can be attained,
5 according to the present invention, by an ink jet
recording apparatus for effecting recording by
discharging ink from a discharge opening onto a
recording medium, comprising an electrothermal
converter provided in said recording head;
10 temperature detection means for detecting the
temperature of said recording head; and temperature
characteristic detection means for applying a
predetermined energy to said electrothermal
converter, detecting the temperature change of said
15 recording head resulting from said energy application
by means of said temperature detection means and
detecting the temperature characteristics of said
recording head based on the result of said detection.

Also according to the present invention,
20 there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising input means for
enabling the operator to instruct the execution of
25 detection of the ink discharge state of said
recording head, and ink discharge state detection
means for causing said recording head to discharge



1 ink and detecting the state of ink discharge thereof,
in response to the instruction of the operator
through said input means.

Also according to the present invention,
5 there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising ink discharge
state detection means for detecting the ink discharge
10 state of said recording head, and control means for
controlling said ink discharge state detection means,
in case defective ink discharge from said recording
head is detected by said means, thereby causing said
means to again detect the ink discharge state.

15 Also according to the present invention,
there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising an electrothermal
20 converter provided in said recording head;
temperature detection means for detecting the
temperature in the vicinity of said recording head;
and judging means for judging the ink discharge state
of said recording head, through comparison of the
25 temperature characteristics of said recording head
determined by the temperature change in the vicinity
of said recording head in response to a predetermined



1 energy applied to said electrothermal converter and
the temperature detected by said temperature
detection means.

Also according to the present invention,
5 there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising ink discharge
state detection means for detecting the ink discharge
10 state of said recording head, and memory means for
storing, in case said ink discharge state detection
means detects defective ink discharge from said
recording head, the recording data at least since the
latest detection of the satisfactory ink discharge
15 state.

Also according to the present invention,
there is provided a method for detecting the
temperature characteristics of an ink jet recording
head, comprising steps of applying a predetermined
20 energy to an electrothermal converter provided in the
recording head for effecting recording by discharging
ink from a discharge opening onto a recording medium,
detecting the temperature change in said recording
head resulting from said energy application, and,
25 based on said detection, detecting the temperature
characteristics of said recording head.

Also according to the present invention,



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1 there is provided a method for judging the discharge
state of an ink jet recording head, which comprises
judging the ink discharge state of said recording
head, based on the result of detection of the
5 temperature characteristics according to the above-
mentioned method.

According to the configuration of the present
invention, in an ink jet recording apparatus for
effecting recording by means of a recording head
10 capable of discharging ink from a discharge opening
onto a recording medium, a predetermined energy is
applied to an electrothermal converter provided in
said recording head, then the temperature change of
said recording head resulting from said energy
15 application is detected by said temperature detection
means, and, based on the result of said detection,
the temperature characteristic detection means
detects the temperature characteristics of said
recording head.

20 Also based on the result of detection of the
temperature characteristics of the recording head
obtained by said temperature characteristic detection
means, the judging means judges the ink discharge
state of said recording head.

25

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view of an



1 ink jet cartridge of the present invention;

Fig. 2 is an exploded perspective view of an ink jet cartridge of the present invention;

Figs. 3A, 3B and 3C are schematic views of
5 a recording part of the ink jet cartridge shown in Fig. 2;

Fig. 4 is a schematic perspective view of an ink jet recording apparatus of the present invention;

Fig. 5 is a block diagram of an ink jet
10 recording apparatus constituting a 1st embodiment;

Fig. 6 is a chart showing the temperature change in the vicinity of a heater board in case an electrical energy is applied to a discharge heater;

Figs. 7A and 7B are charts showing the amount
15 of temperature change in the vicinity of the heater board in the course of application of a predetermined energy to the discharge heater;

Figs. 8A and 8B are charts showing an example of ink discharge and non-discharge conditions
20 for the electrical energy in the present invention;

Fig. 9 is a chart showing temperature changes in the vicinity of the heater board in case two electrical energies of ink discharge condition and ink non-discharge condition are applied to the
25 discharge heater;

Fig. 10 is a chart showing constants obtained in case two electrical energies of ink discharge

1 condition and ink non-discharge condition are applied
to the discharge heater;

Fig. 11 is a flow chart showing a first
method of detecting the ink discharge state described
5 in the first embodiment;

Fig. 12 is a flow chart showing a second
method of detecting the ink discharge state described
in the first embodiment;

Fig. 13 is a flow chart showing a third
10 method of detecting the ink discharge state described
in the first embodiment;

Fig. 14 is a flow chart showing a method for
moving the recording head to a position opposed to
a cap, described in the first embodiment.

15 Figs. 15A and 15B are views showing the
structure and the principle of ink discharge of a
recording head employing a piezoelectric device;

Fig. 16 is a chart showing the temperature
change in the vicinity of the heater board during
20 and after the application of an electrical energy
to the discharge heater;

Fig. 17 is a chart showing the relationship
between the ambient temperature and the discharged
ink amount;

25 Fig. 18 is a schematic view of a recording
head provided with a plurality of temperature
sensors;





1 Fig. 19 is a flow chart showing an example
of detection of the ink discharge state in a
recording head provided with plural temperature
sensors;

5 Fig. 20 is a block diagram of the control
system of a recording apparatus constituting a sixth
embodiment;

 Fig. 21 is a flow chart showing the setting
of variable timing of detection of the ink discharge
10 state;

 Fig. 22 is a block diagram of the control
system of a recording apparatus constituting a
seventh embodiment;

 Fig. 23 is a flow chart showing the repeated
15 detection of the ink discharge state and steps before
said repeated detection; and

 Fig. 24 is a flow chart showing the function
of a recording apparatus capable of re-recording,
constituting a seventh embodiment.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now the present invention will be clarified
in detail by preferred embodiments thereof shown in
the attached drawings.

25 Fig. 1 is a perspective view of a head
cartridge 3 integrally composed of a recording head
1 and an ink tank 2, in which the present invention



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1 is applicable, and Fig. 2 is an exploded perspective
view of the head cartridge 3, wherein shown are a
heater board 110 provided with plural discharge
heaters formed in an array on a Si substrate and
5 electrical wirings for supplying electric power
thereto; a grooved cover plate 140 integrally
provided with plural nozzles, an orifice plate 141
having discharge openings corresponding thereto, and
a common liquid chamber for containing ink for supply
10 to said nozzles; a wiring board 120 which is
connected at an end to the heater board 110 for
example by wire bonding and is provided at the other
end with pads 121 for receiving electrical signals
from the main body of the recording apparatus; and a
15 metal base plate 130 on which said wiring board 120
and said heater board 110 are adhered for example
with an adhesive material.

The heater board 110 and the grooved cover
plate 140 are fixed to the base plate 130, by
20 pinching said heater board 110 and the grooved cover
plate 140 with a press spring 150 and engaging the
leg portion thereof with a hole 131 in the base plate
130. An ink supply member 160 is provided with an
ink supply pipe 161 and an ink pipe 162 connected
25 thereto. The ink supply pipe 161 is connected to an
ink supply hole 101 of an ink tank 100, while the ink
pipe 162 is connected to an ink receiving hole 142 of

1 the grooved cover plate 140, whereby there is formed
an ink path from the ink tank 100 to the discharge
openings of the orifice plate 141.

Fig. 3A shows the details of said heater
5 board 110, and Fig. 3B is a partially cut off
perspective view thereof. There is shown an array
111 of discharge heaters 111a, provided respectively
corresponding to nozzles, communicating with the
discharge openings of the orifice plate 141. By
10 applying a voltage to said array 111 of the discharge
heaters, the ink in the nozzles obtains thermal
energy and is discharged as droplets from the
discharge openings of the orifice plate 141, to
effect the recording operation. Heaters 112a, 112b
15 for temperature regulation can heat the vicinity of
the heater board 110. Temperature sensors 113a,
113b, which can be formed by the semiconductor film
forming technology in a similar manner as the heater
array 111 and the heaters 112a, 112b and
20 simultaneously therewith, can detect the temperature
in the vicinity of the heater array 111.

Hatched areas indicate the connecting
portions with the grooved cover plate 140. Each of
the discharge heaters constituting the array 111 is
25 an electrothermal converter of a resistance of 120 Ω ,
capable of providing an energy of about 3 W with a
driving voltage of 19 V. Also each of the heaters



1 112a, 112b, is composed of an electrothermal
converter of a resistance of 144 Ω , capable of
providing an energy of 4.W with a driving voltage of
24 V. Each of the temperature sensors 113a, 113b is
5 composed of a diode sensor, varying the output by
about 2.5 mV per one degree of temperature.

In the following there will be given an
explanation on the principle of ink discharge of the
recording head, adapted for use in the ink jet
10 recording apparatus of the present embodiment as
the recording means of the present invention.

The recording head, adapted for use in the
ink jet recording apparatus, is generally provided
with a fine liquid-discharging opening (orifice), a
15 liquid path, an energy action part provided in a
part of said liquid path, and energy generating means
for generating a droplet forming energy to be applied
to the liquid present in said energy action part, and
is rendered replaceable. Such energy generating
20 means can, for example, be a mechanism utilizing an
electromechanical converter such as a piezoelectric
element, a mechanism in which an irradiating
electromagnetic wave such as a laser beam is absorbed
in liquid to generate heat therein and a droplet is
25 discharged and is caused to fly by the action of heat
generation, or a mechanism in which liquid is heated
by an electrothermal converter to cause a droplet to



1 fly.

Among these mechanisms, the recording head of the ink jet recording utilizing the thermal energy for liquid discharge is capable of recording with a high resolving power, since the liquid discharging openings (orifices) for discharging recording liquid to form flying droplets can be arranged with a high density. Besides, the recording head utilizing the electrothermal converters as the energy generating means can be formed in a compact structure, and can also be easily formed as a long and flat or two-dimensional configuration, fully exploiting the advantages of the semiconductor technology and the microworking technology, showing remarkable progress and improvement in reliability in recent years. It has therefore been rendered possible to provide an ink jet recording head, which can be easily formed in a configuration with multiple nozzles and with a high density, and which has satisfactory mass producibility and a low manufacturing cost.

Such ink jet recording head employing an electrothermal converter for the energy generating means and produced with a semiconductor manufacturing process is generally provided with liquid paths respectively corresponding to ink discharge openings, in which an electrothermal converter is provided in each liquid path for applying thermal energy to the

1 liquid present in each liquid path thereby
discharging liquid from the corresponding ink
discharge opening and forming a flying droplet, and
in which the liquid is supplied to the liquid paths
5 from a common liquid chamber. With regard to the
method for forming the ink discharge part, the
present applicant has proposed, in the Japanese
Patent Laid-Open Application No. 62-253457, a method
of laminating, on a first substrate, a solid layer
10 for at least forming the liquid paths, a layer of a
material curable with actinic energy at least
utilized for forming the walls of the liquid paths,
and a second substrate, then laminating a mask on
said second substrate, effecting irradiation with
15 actinic energy ray from above said mask thereby
curing at least the walls of the liquid paths in said
curable material layer, and eliminating said solid
layer and the uncured portions of said curable
material layer from the space between the two
20 substrates, thereby forming at least the liquid
paths.

Fig. 3C is a schematic view of the ink jet
recording head explained above. The recording head
1801 is composed of electrothermal converters 1803,
25 electrodes 1804, liquid path walls 1805 and a cover
plate 1806, formed through a semiconductor
manufacturing process including the steps of etching,





1 evaporation, sputtering etc.

In such recording head 1801, recording liquid 1812 is supplied from an unrepresented liquid reservoir to a common liquid chamber 1808 through a liquid supply pipe 1807.

There is also provided a liquid supply pipe connector 1809. The recording liquid 1812 supplied into the common liquid chamber 1808 is supplied into the liquid paths 1810 by the capillary action, and is stably maintained at the ink discharge openings 1811 at the ends of the liquid paths, by meniscus formation. A current supply to the electrothermal converter 1803 heats the liquid present thereon, thereby generating a bubble by film boiling phenomenon, and a liquid droplet is discharged from the ink discharge opening 1811 by the growth of said bubble. The above-explained configuration allows to obtain an ink jet recording head of multiple liquid paths, such as 128 or 250 liquid paths, with a high liquid path density such as 16 path/mm.

Fig. 4 illustrates an example of the printer unit of the ink jet recording apparatus of the present embodiment. There are shown a head cartridge 201 including an ink jet recording head; a carriage 202 supporting the head cartridge 201 and effecting a scanning motion in a direction S; a hook 203 for mounting the head cartridge 201 onto the carriage 202;

1 a lever 204 for operating the hook 203; a support
plate 205 for supporting an electrical connecting part
for the head cartridge; a flexible printed circuit
(FPC) 206 for connecting said electrical connecting
5 part and a control unit of the main body; and a guide-
shaft 207 inserted in a bearing 208 of the carriage
202, for guiding the same in a direction S.

A timing belt 209, connected to the carriage
202 for moving the same in the direction S, is
10 supported by pulleys 210A, 210B positioned on both
ends of the apparatus. A pulley 210B receives the
driving force from a carriage motor 211, through a
transmission mechanism such as gears. A transport
roller 212 serves to define the recording face of the
15 recording medium such as paper, and to transport said
recording medium at the recording operation, and is
driven by a transport motor 213. There are also
provided a paper pan 214 for guiding the recording
medium to the recording position, and pinch rollers
20 215 provided in the feeding path of the recording
medium for pressing the same to the transport roller
212 and for transporting the same.

There are further provided a platen 216
opposed to the discharge openings of the head
25 cartridge 201 and serving to define the recording
face of the recording medium; discharge rollers 217
positioned at the downstream side of the recording



1 position in the advancing direction of the recording
medium and serving to discharge the recording medium
toward an unrepresented discharge exit; spurs 218
positioned corresponding to the discharge rollers 217
5 and serving to press the discharge rollers 217 across
the recording medium, thereby generating the
transporting force of the discharge rollers 217 on the
recording medium; and a releasing lever 219 for
releasing the biasing action of the pinch roller 215
10 and the spurs 218 for example at the setting of the
recording medium.

The platen 216 is supported at both ends,
rotatably about the shaft of the discharge rollers 217,
and is biased from the stop position of the lateral
15 plates 220 toward a front portion 221 of the paper pan
214. The transport roller 212 is in contact, in
plural portions 212A of a reduced diameter, with the
inside of the front portion 221 of said paper pan.

A cap 222, composed of an elastic material
20 such as rubber and so positioned as to oppose to the
face containing the ink discharge openings of the
recording head at the home position, is so supports
as to be contacted to or separated from said recording
head. Said cap 222 is used for protecting the
25 recording head in the non-recording state, or for the
discharge recovery operation for the recording head.

Such discharge recovery operation is conducted



1 for example by positioning the cap 222 opposite to
said face containing the ink discharge openings and
activating the energy generating elements, provided in
the nozzles of the recording head for ink discharge,
5 thereby discharging ink from all the discharge
openings and thus eliminating bubbles and dusts which
are the cause of defective discharge or viscosified
ink unsuitable for recording (operation called
preliminary discharge), or by covering said face
10 containing the discharge openings with the cap 222 and
forcedly sucking the ink from all the discharge
openings with a suction pump, thereby eliminating the
cause of defective discharge.

A pump 223 provides the suction force for
15 forced discharge of ink and is used for sucking the
ink received by the cap 222, at the discharge recovery
operation by such forced discharge or by the
preliminary discharge. A used ink tank 224, for
receiving the used ink sucked by the pump 223, is
20 connected with said pump 223 through a tube 228.

A blade 225, for wiping the face containing
the discharge openings of the recording head, is
supported movably between a position protruding
toward the recording head for effecting the wiping
25 operation in the course of carriage movement and a
retracted position not engaging with said face. There
are further provided a motor 226, and a cam device



1 227 for driving the pump 223 and moving the cap 222
and the blade 225 by the driving force transmitted
from said motor 226.

Fig. 5 is a block diagram showing an example
5 of the control system of the recording apparatus
explained above.

The capping position and the moved position
of the carriage 202 shown in Fig. 4 can be known by
a recovery system home position sensor 235 and a
10 carriage home position sensor 236. In Fig. 5, there
are shown an MPU 1000 for controlling various units
by executing a control sequence according to a
predetermined program; a ROM 1001 storing the program
corresponding to said control sequence; and a RAM used
15 as a work area in the execution of said control
sequence.

In the following there will be given a
detailed explanation on the measurement of the
temperature characteristics of the above-explained
20 recording head, and the method of detecting the
discharge state of ink, utilizing said measurement.
[Embodiment 1]

At first there will be explained a first
embodiment of the present invention.

25 Fig. 6 is a chart showing the temperature
change in the vicinity of the heater board 110 when
an electrical energy is given to the discharge heaters



1 111.

A curve A shows a state of normal ink discharge, while a curve B shows a state of absence of ink discharge due to insufficient ink filling in the liquid paths of nozzles in the recording head or in the common liquid chamber communicating thereto. It will be understood that the temperature change is larger in the absence of ink discharge (curve B) than in the presence of ink discharge (curve A). In general, the temperature of the heater board 110 is determined by the heat supply from the discharge heaters 111 constituting the heat source, and by the heat dissipation to the base plate 130 and the grooved cover plate 140. In the presence of ink discharge, the heat dissipation becomes larger because the ink is discharged to the outside with heat, and the difference in temperature characteristics results for this reason.

It is consequently possible to detect whether the ink discharge is possible, by detecting the temperature characteristics in the vicinity of the heater board 110 when a predetermined electrical energy inducing the ink discharge is applied to the discharge heaters 111.

More specifically, at first the temperature change dT_A is measured in the vicinity of the heater board 110 when the predetermined electrical energy



1 inducing the ink discharge is applied to the discharge
heaters 111 in a normal state in which the nozzles and
the common liquid chamber communicating thereto are
sufficiently filled with ink. Then the temperature
5 change dTB after a predetermined time is measured in
a state in which ink is absent in the nozzles and in
the common liquid chamber. When these measurements
are conducted on a plurality of heat cartridges and
are statistically processed, there are obtained
10 plottings as shown in Fig. 7A. In this manner there
are determined, in advance, the maximum value TA of
 dTA and the minimum value TB of dTB .

Fig. 11 is a flow chart showing the sequence
of detecting the ink discharge state, to be executed
15 by the MPU 1000, and a corresponding program is stored
in the ROM 1001. In the following there will be
explained a first method for detecting whether the
ink discharge is possible. At first the above-
mentioned predetermined electrical energy is applied
20 to the discharge heaters 111 (step S1). Then the
temperature change dT in the vicinity of the heater
board 110 is measured by the recording head
temperature sensor 113 (step S2), and is compared
with the values TA , TB (steps S3, S4). Based on said
25 comparison, the ink discharge state is identified as
normal if $dT \leq TB$ (step S6), or as abnormal if $dT >$
 TB (step S5). Since TA and TB are determined from the



1 measurements of a plurality of recording heads, there
is not encountered a situation $TA < dT < TB$.

The above-mentioned predetermined electrical
energy including ink discharge is, for example as
5 shown in Fig. 8A, composed of 1000 pulses of a pulse
duration of 7 μ sec and a frequency of 4 kHz, applied
to all of 64 nozzles, and said energy is defined as
E1. In this case TA , TB are respectively about 14.5°
and 15.5° .

10 In the following there will be explained a
second method which is applicable even in case the
temperature characteristics show a large fluctuation
among different head cartridges.

The above-explained method is not usable in
15 case the fluctuation among different head cartridges
is large so that the maximum value of dTA is larger
than the minimum value of dTB , namely in case of
 $TA > TB$ as shown in Fig. 7B. Such fluctuation in the
temperature characteristics may result from the
20 fluctuation in the thickness of the adhesive material
between the heater board 110 and the base plate 130,
or in the resistance of the discharge heaters 111, or
in the dimension or the physical properties of the
heater board and the base plate. Also in case the
25 ink discharge is conducted, such fluctuation may also
arise from the change in the amount of heat
dissipation by the in, due to variations in the



1 size of ink droplets and in the physical properties
of ink.

As the relationship $dTB > dTA$ stands for all
the head cartridges as explained in relation to Fig.
5 6, a value ($dTB - dTA$) is calculated for each head
cartridge and the minimum TD of said values is
statistically determined, based on the data partially
shown in Fig. 7B. Thus, a relationship $dTB - dTA \geq TD$
stands for any head cartridge. Also it is assumed in
10 general that the nozzles are in the normal ink filling
state at the start of the recording operation, because
of the automatic discharge recovery process.

Fig. 12 is a flow chart showing said second
method. At first, at the start of the recording
15 operation, at which the nozzles are in the normal ink
filling state, the above-mentioned predetermined
electrical energy is applied to the discharge heaters
111 (step S7), and the temperature change in the
vicinity of the heater board 110 is measured in order
20 to determined dTA (step S8). For detecting whether
the ink discharge is possible, the above-mentioned
predetermined electrical energy is applied to the
discharge heaters 111 (step S9), then the temperature
change dT in the vicinity of the heater board is
25 measured (step S10), and the ink discharge state is
identified as normal if $dT \leq dTA$ (step S14), or as
abnormal if $dT \geq dTA + TD$ (step S13).



1 When said predetermined electrical energy is
selected as E1 mentioned before, the TD becomes about
2°.

 However, since this method unconditionally
5 assumes that the temperature change in the vicinity
of the heater board 110 is equal to dTA when said
predetermined electrical energy is applied to the
discharge heaters 111 at the start of the recording
operation, there will be encountered an erroneous
10 detection if the ink filling state of the nozzles
becomes abnormal for some reason at the start of the
recording operation.

 In the following there will be explained a
third method for avoiding this drawback, by utilizing
15 reference temperature characteristics not related to
the ink filling state of the nozzles, measured for
each head cartridge.

 As already explained in relation to Fig. 6,
the difference in the temperature characteristics
20 resulting from the ink filling state of the nozzles
is caused by the heat dissipation at the ink
discharge. Therefore, for obtaining the reference
temperature characteristics mentioned above, there
can be conceived to provide the discharge heaters
25 with a low electrical energy that will not induce ink
discharge even at the normal ink filling state of the
nozzles.

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1 Said predetermined electrical energy not
inducing the ink discharge even in the normal ink
filling state of the nozzles can be, for example as
shown in Fig. 8B, 3000 pulses of a pulse duration of
5 2 μ sec and a frequency of 6 kHz applied to all of 64
nozzles, and said electrical energy is defined as E2. ---
When said electrical energy E2 is applied to the
discharge heaters 111, the temperature change in the
vicinity of the heater board 110 remains substantially
10 same regardless of the ink filling state of the
nozzles, because the heat is not dissipated by the ink
discharge.

Now, let us consider the relationship between
the reference temperature characteristics, obtained
15 by the application of the electrical energy E2 which
does not induce the ink discharge even in the normal
ink filling state of the nozzles and is exemplified
in Fig. 8B, and the temperature characteristics,
obtained by the application of the electrical energy
20 E1 as shown in Fig. 8A and inducing the ink discharge.

Fig. 9 is a chart showing the temperature
changes in the vicinity of the heater board 110, when
the above-mentioned two electrical energies are
applied to the discharge heaters 111.

25 A curve A shows a case with appropriate ink
filling in the nozzles and in the common liquid
chamber communicating therewith and with normal ink



1 discharge under the application of the electrical
energy E1, while a curve B indicates a case of absence
of ink in the nozzles and in said common liquid
chamber under the application of said electrical
5 energy E1. A curve C indicates the case of
application of the electrical energy E2, and the
curve remains substantially same regardless of the
ink filling state, as explained before. The
respective temperature changes are represented by
10 dTA, dTB and dTC.

When these measurements are conducted on
plural head cartridges, the values of dTA, dTB, dTC
are different among different head cartridges, but
following relations stand for each head cartridge:

15
$$dTA = K1 \times dTC \quad (K1 \text{ being constant for each cartridge})$$

$$dTB = K2 \times dTC \quad (K2 \text{ being constant for each cartridge})$$

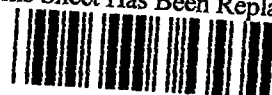
$$K1 < K2$$

20 Thus, if the constants K1, K2 are known, the
temperature changes dTA, dTB relating to the presence
or absence of ink can be calculated from the
temperature change dTC based on the reference
temperature characteristics.

25 Then, let us give further consideration on the
constants K1, K2.

Fig. 10 shows the constants K1, K2 in the





1 plural head cartridges Nos. 7 to 12, showing large
fluctuations in the temperature characteristics, in
the measurement shown in Fig. 7B. As will be seen
from Fig. 10, there stands a relationship:

5
$$K_{1\max} < K_{2\min}$$

between the maximum value $K_{1\max}$ of K_1 and the minimum
value $K_{2\min}$ of K_2 . Said relationship stands even in
the head cartridges with significant fluctuation in
the temperature characteristics, because the ratios
10 of the temperature changes dTA , dtB , dTC , based on the
temperature characteristics of each cartridge, are
considered instead of said temperature changes
themselves.

Therefore, there are obtained relationship:

15
$$dTA \leq K \times dTC$$

$$dtB \geq K \times dTC$$

for all the head cartridges by selecting a new
constant K so as to satisfy a relation:

$$K_{1\max} < K < K_{2\min} \quad (1).$$

20 Fig. 13 is a flow chart showing a detecting
sequence for the ink discharge state, based on the
above-mentioned relations. At first a predetermined
electrical energy E_2 not inducing the ink discharge
is applied to the discharge heaters (step S15), and
25 then the temperature change dTC of the recording head
is measured (step S16). Subsequently a predetermined
energy E_1 inducing the ink discharge is applied to



- 1 the discharge heaters (step S17), then the temperature
change dT of the recording head is measured (step S18)
and is compared with $K \times dTC$ (step S19), whereupon the
ink discharge state is identified as normal if
5 $dT \leq K \times dTC$ (step S20) or as abnormal if $dT \geq K \times dTC$
(step S21).

When the aforementioned electrical energies
 $E1$, $E2$ are adopted, the values of $K1_{max}$, $K2_{min}$ were
experimentally determined as about 1.45 and 1.75.

- 10 Consequently, in this case, the value K can be
selected for example as 1.6, in order to satisfy the
aforementioned relation (1).

- In the ink discharge state detecting methods
explained above, the temperature detection by the
15 temperature sensor is conducted during the application
of the electrical energy to the discharge heaters.
Since the temperature drops rapidly after the
application of the predetermined energy, there may
result an error in the detection if the detection is
20 repeated plural times after said energy application.
For this reason, the temperature detection is
preferably conducted during the energy application.

- However, if the energy application is executed
in the pulse form as shown in Figs. 8A and 8B, stable
25 detection is difficult because of an abrupt
temperature change or a noise generation when the
pulse signal is turned on. In the present embodiment,

1 therefore, the temperature detection in the course
of energy application is conducted in synchronization
with said pulses, when the pulse is turned off. Also
if the temperature detection has to be conducted
5 after the energy application, it is executed within
a limited or short time after the energy application.

In the following there will be explained the
recording process, with reference to Fig. 4, in a
recording apparatus capable of detection of the
10 temperature characteristics of the recording head
and detection of the ink discharge state utilizing
said temperature characteristics.

At first, when the power supply to the
recording apparatus is turned on, the recovery motor
15 226 is activated to set the recovery unit at the home
position of the recovery system and to retract the
cap 222. Then the carriage 202 is set at the home
position opposed to the cap 222. Then the cap 222
is again contacted with the nozzles of the recording
20 head, and the entry of the recording data signal is
awaited. In response to said entry, the transport motor
213 is activated to initiate the feeding of the recording
medium, such as paper, up to a front end position of
the desired recording. Then the cap 222 is retracted
25 and separated from the nozzles of the recording head,
and the carriage 202 is set at the home position



1 opposed to the cap 222. Subsequently the
predetermined preliminary discharge is executed, and
the carriage 202 is moved to a desired recording
start position. Said preliminary discharge in this
5 embodiment is executed prior to the recording
operation; and also in the course of the recording
operation, by the movement of the carriage 202 to said
home position again, after the lapse of a
predetermined period of T seconds from the preceding
10 preliminary discharge.

Thereafter desired recording operation is
executed by the discharge of ink droplets according
to ink discharge signals corresponding to the
recording data. After the recording of a page of the
15 recording medium, the recording medium is discharged,
and there are conducted the detection of the
temperature characteristics of the recording head and
of the ink discharge state. In the present
embodiment, the detection of the ink discharge state
20 is conducted after the recording of a page. Thus said
detection is executed after the recording of a page
if the recording data are less than a page, or after
the recording of each page if the recording data cover
plural pages.

25 Since the detection of the ink discharge state
involves ink discharging operation, it is executed, as
in the preliminary discharge explained before, at the



1 home position where the carriage is opposed to the cap
222. Fig. 14 is a flow chart showing said detection
process. When the detection sequence is initiated,
there is discriminated, by unrepresented position
5 detecting means, whether the head cartridge 201 is
located at the position opposed to the cap (step S22),
and, if not, the carriage is moved to the position
opposed to the cap 222 (steps S23, S24). If the step
S22 identifies that the head cartridge 201 is
10 positioned opposite to the cap, a step S24
discriminates whether the cap 222 is in contact with
the face including the ink discharge openings, and,
if in contact, the cap is opened (step S25). Said
detection is executed while the cap 222 is not
15 contacting said face including the ink discharge
openings, in order to prevent that the ink discharged
and received in the cap 222 comes into contact with
said face.

In the detection of the ink discharge state,
20 the ink discharge inducing energy, composed of 1000
pulses of a pulse duration of 7 μ sec and a frequency
of 4 kHz applied to all of 64 nozzles, causes the
discharge of ink of about 5 mg. In order to avoid
contamination of the interior of the recording
25 apparatus by the discharged ink, it is discharged
toward the cap. Also in the present embodiment, in
order to ensure the reception of ink into the cap, and



1. also for discarding the ink in the cap or in the pump
223 connected to the cap 222 in advance, the pump 223
is activated to effect suction while the cap 222 is
separated from the face containing the discharge
5 openings of the recording head. This operation is
executed before and after said detection of the ink
discharge state, whereby said detection can be
conducted without contamination of the apparatus with
ink.

10 If an abnormal discharge state is detected in
said detection of the ink discharge state, an
abnormality signal is generated to display a warning
message, to turn on a light-emitting diode, or to
inform an alarm by information means 1004 such as an
15 alarm buzzer. When the abnormal state is eliminated
by the user, there is executed a predetermined re-
starting procedure.

As explained in the foregoing, the detection
of the ink discharge state based on the temperature
20 characteristics of the recording head allows exact
detection without particular components therefor.
Also the present embodiment enables detection with an
inexpensive configuration, since the energy
application for said detection of the ink discharge
25 state is made to the ink discharge means, and since
the temperature detection is achieved by a temperature
sensor which is manufacturable simultaneously with the



1 ink discharge means.

Also the above-explained second and third methods for detecting the ink discharge state are applicable even when the temperature characteristics
5 of the recording head involve fluctuation. Consequently there can be provided advantages of alleviating the control of precision in the dimension and material of the heater board or base plate and in the thickness of the aforementioned adhesive material,
10 thus reducing the manufacturing cost, and advantages that such methods are applicable regardless of the kind, physical properties and droplet size of the ink.

Also as the detection of the ink discharge state is executed when the recording head is opposed
15 to an ink receiving member such as a cap, and as the ink is eliminated from said ink receiving member for example by the ink suction before and after said detection, the discharged ink can be securely captured and the contamination within the recording apparatus
20 can be minimized.

The above-explained embodiment employs a diode sensor for detecting the temperature, but other sensors are likewise usable as long as the temperature of the recording head can be detected. For example
25 the temperature can be detected by measuring the resistance of the electrothermal converters such as discharge heaters or other heaters. Also the



1 temperature sensor is provided on the heater board,
but such configuration is not limitative.

Furthermore, the recording apparatus may be
provided with an ink receiving member composed for
5 example of sponge, capable of absorbing and retaining
the ink, separately from the cap 222, and the ink
discharge for detecting the ink discharge state may be
conducted on such ink receiving member. Also
information by the informing means is given when an
10 abnormal result is obtained by the detection, but the
information may be provided in case said detection
indicates a normal state, and the result of said
detection may be provided by the recording apparatus
or by the host apparatus.

15 [Embodiment 2]

According to the invention described in the
first embodiment, an electrical energy is applied to
the ink discharge heater to effect the heating
thereof, in order to know the temperature
20 characteristics of the recording head. However the
heating means, to be used for heating the recording
head for obtaining said temperature characteristics,
is not limited to the discharge heaters, and there
will be explained another method in the present
25 embodiment. The recording head (head cartridge) of
the first embodiment is provided, as already explained
in relation to Figs. 3A to 3C, with heaters 112a, 112b for



1 temperature regulation of the recording head, in
addition to the discharge heaters. Consequently the
temperature characteristics of the recording head can
be detected, also by applying a predetermined
5 electrical energy to such heaters.

However, the ink discharge state cannot be
detected from the temperature characteristics obtained
by the heating of said heaters, since ink discharge is
not induced by said heating.

10 For this reason, the following method is
adopted for detecting the ink discharge state, in case
the above-mentioned heaters not constituting the ink
discharge means are used as the heating means for
obtaining the temperature characteristics of the
15 recording head.

As explained in the first embodiment, the
difference in the temperature characteristics arises
from whether the ink discharge is executed or not. It
is therefore conceived to drive the discharge heaters
20 also, for discharging the ink, in the course of
activation of the above-mentioned heaters. Thus there
can be obtained a temperature change of the heater
board, similar to that shown in Fig. 6, according to
the ink filling state in the nozzles and in the common
25 liquid chamber connecting thereto. Consequently the
method of the first embodiment can be likewise
applied, by integrally considering the heating with



1 the temperature-regulating heaters and that with the
discharge heaters. The temperature characteristics
not related to the ink filling state of the nozzles
can be obtained by activating the temperature-
5 regulating heaters only.

In the present embodiment, the detection of
the temperature characteristics is achieved by heaters
different from the discharge heaters. Consequently
the discharge heaters are used only for the ink
10 discharge, and the ink discharge means is not limited
to heaters. Thus the present embodiment is applicable
to the ink jet recording apparatus equipped with a
heater different from the heaters for ink discharge.
Ink discharge means not relying on the heater include
15 those employing an electromechanical converter such as
a piezoelectric element, and Figs. 15A and 15B
illustrate the cross-sectional view of such nozzle,
wherein illustrated a piezoelectric element 301, a
heater 302, and a discharge opening 303. Fig. 15B
20 illustrates the principle of ink discharge. Ink is
supplied from the left. A pulse supply to the
piezoelectric element 301 generates a mechanical
distortion therein, thus inducing ink discharge from
the discharge opening 303.

25 [Embodiment 3]

In the embodiments 1 and 2, the temperature
characteristics are determined by detecting the rise



1 in temperature of the recording head when an
electrical energy is applied to the ink discharging
heaters or the temperature-regulating heaters.
However, the method of temperature measurement is
5 not limited to such methods, and another method will
be explained in the present embodiment. The heater
board exhibits the temperature change as already
explained in Fig. 6, when the electrical energy is
applied to the heaters. After said energy
10 application, the temperature of the heater board
descends by heat dissipation, as shown in Fig. 16.
Said temperature descent is determined by the
temperature of the heater board at the end of
application of the electrical energy, and the
15 difference from the ambient temperature. Consequently
the temperature changes dT_a , dT_b within a
predetermined period dt after the end of application
of the electrical energy are correlated with the
temperature changes (increases) dT_A , dT_B caused by
20 said energy application. Therefore, the method of
the first embodiment can be still applied by measuring
 dT_a , dT_b and replacing the aforementioned values of
 dT_A , dT_B with thus measured values. In the method
of this embodiment, the detection of temperature
25 characteristics of the recording head is not affected
by the noises resulting from the activation of the
heaters, because said detection is executed after the



1 end of application of the electrical energy to said
heaters. Thus there is obtained an advantage that the
timing of temperature detection with the temperature
sensor can be arbitrarily selected.

5 [Embodiment 4]

The ink jet recording method is influenced by
a change in the physical properties of the ink, since
the principle of ink discharge utilizes such physical
properties. As a representative example, the amount
10 of ink discharge varies depending on the ambient
temperature. In general, the amount of ink discharge
in the ink jet recording decreases, as shown in Fig.
17, when the ambient temperature becomes lower,
because the ink viscosity increases at a lower
15 temperature.

If the ink discharge amount varies excessively
by the ambient temperature, a correction for the
ambient temperature may become necessary in the
foregoing embodiments, and the present embodiment
20 effects such correction for the temperature.

As already explained in the first embodiment,
the difference in the temperature characteristics
arises from the heat dissipation by the ink discharge.
Thus the above-mentioned temperature change ΔT_A
25 becomes larger or smaller respectively when the ink
discharge amount decreases or increases from the
normal amount. Stated differently, the variation in



1 dTA by the ambient temperature becomes no longer
negligible, if the ink discharge amount varies
significantly depending on the ambient temperature.

Thus, there will be explained a method of
5 preventing the excessive variation of dTA from the
reference value at a reference temperature, despite
of the variation of the ambient temperature. Such
temperature compensation can be achieved by increasing
or decreasing the energy applied to the heaters,
10 respectively when the ambient temperature is lower
or higher than the reference temperature. More
specifically, there is determined an applied energy
for providing the optimum dTA for each ambient
temperature, by collecting data of dTA for different
15 applied energies for each ambient temperature, and
the energy applied to the heaters is controlled
according to said data.

The applied energy may be varied by a change
in the pulse duration, the number of applied pulses
20 or the applied voltage.

It is also possible, instead of varying the
energy applied to the heaters, to vary the criteria
of judgment utilizing the detected temperature
characteristics (temperature change) according to
25 the ambient temperature.

For example, in the 3rd method of the first
embodiment, the value of the constant K_1 varies



1 depending on the ambient temperature. It is therefore
conceivable to calculate the constant K1 for each
ambient temperature and to determine the optimum
constant K for each ambient temperature.

5 [Embodiment 5]

In the following there will be explained an
application in which the recording head is provided
with plural temperature sensors.

Fig. 18 shows a configuration of the heater
10 board 110, in which, in the array of the discharge
heaters 111, a temperature sensor 113 is provided for
example for every eight discharge heaters. Thus, if
the heater board 110 has 64 discharge heaters, there
will be 8 temperature sensors 113 on the same heater
15 board. The outputs dT1 - dT8 of said eight
temperature sensors are transmitted to the printer
control unit shown in Fig. 5 and supplied to the MPU
1000. Based on each result of temperature detection,
there can be discriminated whether the ink discharge
20 state is normal or abnormal, according to the
detecting procedure explained in the first embodiment.

Each temperature sensor represents best the
temperature state in the vicinity of said sensor, so
that an abnormal ink discharge state, identified by
25 the temperature detection by a sensor, can be
considered to indicate abnormal ink discharge of the
ink discharge means in the vicinity of said sensor.



1 In the present embodiment with plural temperature
sensors, the abnormal state is informed by the
informing means 1004 if an abnormal state is found in
any of the detected temperature changes $dT1 - dT8$,
5 as shown in a flow chart in Fig. 19.

The control sequence of the present embodiment will be explained with reference to Fig. 19. At first a step S26 measures the temperature change $dT1$ by first temperature sensor 1. Based on said
10 measurement, a step S27 effects the temperature comparison as explained in the first embodiment, and, if a step S37 identifies an abnormal discharge state, a step S38 generates an alarm. On the other hand, if the discharge state is normal according to the
15 detection by the sensor 1, a step S28 measures the temperature change $dT2$ in a similar manner by a sensor 2. Thereafter the temperature detections are conducted to a sensor 8 in succession in a similar manner (steps S28 to S34), and the abnormality is
20 informed by said informing means if the abnormal discharge state is detected in any of said sensors. On the other hand, if all the results of said sensors are normal, the ink discharge state is identified as normal.

25 A more accurate detection of the ink discharge state is made possible by the use of such plural temperature sensors. In the present embodiment, there



1 is provided a temperature sensor for every eight
discharge heaters, but such configuration is not
limitative, and it is also possible to provide each
discharge heater with an individual temperature sensor
5 and to detect the ink discharge state for each
discharge heater by detecting the temperature
characteristics thereof. Also the abnormality is
informed in case any of the detected results is
abnormal, but such process can be arbitrarily selected
10 according to the characteristics of the recording
head or the structure of the recording apparatus.
Also this embodiment is applicable to the ink jet
recording head employing the aforementioned
electromechanical converters, if it is provided with
15 an electrothermal converter for temperature
regulation, separate from the ink discharge means.

[Embodiment 6]

The detection of the ink discharge state
according to the present invention is conducted, as
20 explained in the first embodiment, after the
completion of recording operation of every page,
but timing of such detection may be rendered variable,
as will be explained in the following.

Fig. 20 is a block diagram of a recording
25 apparatus in which the timing of said detection can
be set in variable manner. Input means 1005 is
provided, for entering said timing, separately from



1 the keyboard, but said keyboard may also be used for
said input means.

Since the detection of the ink discharge state
involves the ink discharge, the amount of ink
5 available for recording decreases, though slightly,
when such detection is executed. The configuration
in which the user can vary the timing of such
detection allows to economize the ink amount consumed
in such detection, and also allows to improve the
10 accuracy of detection by effecting the detections at
a short interval.

Fig. 21 is a flow chart for the setting of
the timing of said detection. As an example, the
detection is executed at an interval, in the automatic
15 mode, selected either by a number of days (steps S41,
S42), or by a number of hours (steps S43, S44), or
by a number of recorded sheets (steps S45, S46) or by
a number of recorded characters (steps S47, S48), or
executed, in the manual mode, in response to an
20 instruction entered from the input means 1005 (steps
S39, S40). In addition to such presettable intervals,
there may be selected a standard default interval,
stored in the control unit of the recording apparatus
(step S49).

25 The detection of the ink discharge state is
executed according to the timing or the interval thus
set.

This Sheet Has Been Replaced





1 Such settable timing of detection allows to
economize the ink consumption required in the
detection of the ink discharge state, and to improve
the accuracy of detection. In the present embodiment,
5 said manual mode is rendered selectable separately
from the automatic mode in which the detection is
executed at a preset interval, but it is also possible
to combine both modes whereby the detection is
normally executed at the present interval but is
10 additionally executed in response to an instruction
entered through the input means when necessary. Also
the present embodiment is applicable to any ink jet
recording apparatus, regardless of the means for
detecting the ink discharge state or of the ink
15 discharge means in the loaded recording head.

[Embodiment 7]

 In the following there will be explained an
ink jet recording apparatus capable of detecting the
ink discharge state, provided with memory means
20 capable of retaining a series of recording data, and
adapted to retain the recording data in case
abnormality is detected in said detection and to
repeat the recording operation according to thus
retained data. Fig. 22 is a block diagram of such
25 recording apparatus, in which provided input means
1005, capable of entering the timing of detection of
the ink discharge state and an instruction for

1 detection in the manual mode as explained in the
preceding embodiment, and memories 1006a, 1006b
capable of retaining a series of recording data. Said
memories may be provided only in either of the printer
5 unit and the control unit.

At first, with respect to the detection of the
ink discharge state of the present embodiment, there
will be explained the difference from the method of
the first embodiment, with reference to the flow
10 chart shown in Fig. 23. Said detection is executed
by the method already explained in the first
embodiment, but an improved accuracy of detection is
attained by executing, once abnormal discharge state
is detected, another detection of the discharge state
15 after an automatic discharge recovery operation
including the ink suction from the recording head
(step S59) and an ink discharge operation of a
predetermined amount (step S60), and the abnormality
is identified if the abnormality is detected in such
20 repeated detection also after the initial abnormality
detection.

Said discharge recovery operation and said
ink discharge of predetermined amount are executed
in order to confirm whether the initial abnormality
25 detection is due to the exhaustion of ink in the
recording head. More specifically, said operations
are executed in order to discriminate whether the





1 initial abnormality detection is due to bubble
formation in the ink path of the recording head or
interruption of ink supply for example by the meniscus
destruction resulting from vibration at the ink
5 discharge openings, that may occur prior to the
exhaustion of ink, or due to ink exhaustion in the
recording head.

If the ink is not yet exhausted, the ink
supply from the ink tank can be restored by the
10 discharge recovery operation including the suction
operation (step S59), and, the ink supply is secured
by the ink discharge of a predetermined amount in the
step S60. Thus the normal ink discharge state is
confirmed in the repeated detection. However, if
15 said detected abnormality is due to the ink
exhaustion, the secure ink supply cannot be restored
in the discharge recovery operation. Even if the ink
of a small amount is guided to the ink discharge means
by said suction operation from the ink tank, the ink
20 supply will be again interrupted in the succeeding
ink discharge operation of the predetermined amount,
so that the discharge abnormality is detected again
in the repeated detection.

Fig. 24 is a flow chart showing the control
25 sequence in which the recording data are retained in
the memory means 1006 shown in Fig. 22, whereby the
loss of the recording data, resulting from the

1 abnormality in discharge, can be prevented. When an
abnormality in ink discharge is detected (step S62),
the serial recording data that have been recorded at
said detection are stored in the memory means 1006
5 (step S63). Then the detection of abnormality is
informed (step S64), and the inspection of the
recording head is requested (step S65). Upon
detection of the completion of such inspection or of
the replacement of the recording head (step S66), and
10 in response to the entry of a command for re-recording
(step S67), there is discriminated whether a cassette
sheet feeder (CSF) is mounted on the recording
apparatus (step S68), and, if mounted, the sheet
feeding operation is conducted (step S69), but, if
15 not mounted, the sheet feeding is requested for
example by a message display (step S70). After the
sheet feeding operation is confirmed (branch YES in
step S71), the recording data are read from said
memory means 1006 (step S72) and the re-recording
20 operation is conducted, based on said recording data
(step S73).

In the present embodiment, the position of
the recording data, from which the re-recording is to
be started, can be instructed, so that the re-
25 recording is executed from a data position which
can be arbitrarily instructed according to the
location of the abnormality in the recording.



1 This embodiment is particularly suitable, among
various recording apparatus, for use in the
communication equipment such as the facsimile
apparatus, in which the necessity for re-recording
5 after the abnormality detection is high and the loss
of recording data is considered critical.

As explained in the foregoing, it is rendered
possible to improve the accuracy of detection, by
repeating the detection for ink discharge state, after
10 a discharge recovery operation including a sucking
operation and after a predetermined ink discharging
operation, and also to prevent the loss of recorded
data resulting from discharge abnormality, by
retaining the recording data.

15 In the present embodiment, the completion of
inspection of the recording head or of replacement
thereof may be entered by the user through the input
means. However, such information may be also obtained
automatically by detecting the replacement of the
20 recording head or the detachment and attachment
thereof.

The present invention has been explained by
embodiments of the recording apparatus equipped with
so-called serial-type recording head, but it is
25 likewise applicable to the recording apparatus
employing so-called full-line recording head.

The present invention is particularly suitably



1 usable in an ink jet recording head and recording
apparatus wherein thermal energy by an electrothermal
transducer, laser beam or the like is used to cause a
change of state of the ink to eject or discharge the
5 ink. This is because the high density of the picture
elements and the high resolution of the recording are
possible.

The typical structure and the operational
principle are preferably the ones disclosed in U.S.
10 Patent Nos. 4,723,129 and 4,740,796. The principle
and structure are applicable to a so-called on-demand
type recording system and a continuous type recording
system. Particularly, however, it is suitable for
the on-demand type because the principle is such that
15 at least one driving signal is applied to an
electrothermal transducer disposed on a liquid (ink)
retaining sheet or liquid passage, the driving signal
being enough to provide such a quick temperature rise
beyond a departure from nucleation boiling point, by
20 which the thermal energy is provided by the
electrothermal transducer to produce film boiling on
the heating portion of the recording head, whereby a
bubble can be formed in the liquid (ink) corresponding
to each of the driving signals. By the production,
25 development and contraction of the bubble, the liquid
(ink) is ejected through an ejection outlet to produce
at least one droplet. The driving signal is



1 preferably in the form of a pulse, because the
development and contraction of the bubble can be
effected instantaneously, and therefore, the liquid
(ink) is ejected with quick response. The driving
5 signal in the form of the pulse is preferably such
as disclosed in U.S. Patents Nos. 4,463,359 and
4,345,262. In addition, the temperature increasing
rate of the heating surface is preferably such as
disclosed in U.S. Patent No. 4,313,124.

10 The structure of the recording head may be
as shown in U.S. Patent Nos. 4,558,333 and 4,459,600
wherein the heating portion is disposed at a bent
portion, as well as the structure of the combination
of the ejection outlet, liquid passage and the
15 electrothermal transducer as disclosed in the above-
mentioned patents. In addition, the present invention
is applicable to the structure disclosed in Japanese
Laid-Open Patent Application No. 59-123670 wherein
a common slit is used as the ejection outlet for
20 plural electrothermal transducers, and to the
structure disclosed in Japanese Laid-Open Patent
Application No. 59-138461 wherein an opening for
absorbing pressure wave of the thermal energy is
formed corresponding to the ejecting portion. This
25 is because the present invention is effective to
perform the recording operation with certainty and
at high efficiency irrespective of the type of the



1 recording head.

The present invention is effectively applicable to a so-called full-line type recording head having a length corresponding to the maximum recording width. Such a recording head may comprise 5 a single recording head and plural recording head combined to cover the maximum width.

In addition, the present invention is applicable to a serial type recording head wherein 10 the recording head is fixed on the main assembly, to a replaceable chip type recording head which is connected electrically with the main apparatus and can be supplied with the ink when it is mounted in the main assembly, or to a cartridge type recording head 15 having an integral ink container.

The provisions of the recovery means and/or the auxiliary means for the preliminary operation are preferable, because they can further stabilize the effects of the present invention. As for such means, 20 there are capping means for the recording head, cleaning means therefor, pressing or sucking means, preliminary heating means which may be the electrothermal transducer, an additional heating element or a combination thereof. Also, means for 25 effecting preliminary ejection (not for the recording operation) can stabilize the recording operation.

As regards the variation of the recording head

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1 mountable, it may be a single corresponding to a
single color ink, or may be plural corresponding to
the plurality of ink materials having different
recording color or density. The present invention is
5 effectively applicable to an apparatus having at least
one of a monochromatic mode mainly with black, a multi-
color mode with different color ink materials and/or
a full-color mode using the mixture of the colors,
which may be an integrally formed recording unit or
10 a combination of plural recording heads.

Furthermore, in the foregoing embodiment, the
ink has been liquid. It may be, however, an ink
material which is solidified below the room
temperature but liquefied at the room temperature.
15 Since the ink is controlled within the temperature not
lower than 30 °C and not higher than 70 °C to
stabilize the viscosity of the ink to provide the
stabilized ejection in usual recording apparatus of
this type, the ink may be such that it is liquid
20 within the temperature range when the recording signal
is the present invention is applicable to other types
of ink. In one of them, the temperature rise due to
the thermal energy is positively prevented by
consuming it for the state change of the ink from the
25 solid state to the liquid state. Another ink material
is solidified when it is left, to prevent the
evaporation of the ink. In either of the cases, the



1 application of the recording signal producing thermal
energy, the ink is liquefied, and the liquefied ink
may be ejected. Another ink material may start to
be solidified at the time when it reaches the
5 recording material. The present invention is also
applicable to such an ink material as is liquefied
by the application of the thermal energy. Such an
ink material may be retained as a liquid or solid
material in through holes or recesses formed in a
10 porous sheet as disclosed in Japanese Laid-Open Patent
Application No. 54-56847 and Japanese Laid-Open
Patent Application No. 60-71260. The sheet is faced
to the electrothermal transducers. The most effective
one for the ink materials described above is the film
15 boiling system.

The ink jet recording apparatus may be used
as an output terminal of an information processing
apparatus such as computer or the like, as a copying
apparatus combined with an image reader or the like,
20 or as a facsimile machine having information sending
and receiving functions.

While the invention has been described with
reference to the structures disclosed herein, it is
not confined to the details set forth and this
25 application is intended to cover such modifications
or changes as may come within the purposes of the
improvements or the scope of the following claims.



1 As stated above, according to the invention,
since temperature characteristics is detected for
each recording head, the temperature characteristics
is applied to various uses so that it is possible to
5 obtain results not depend on difference of each
recording head. In addition by utilizing the
detection results of the temperature characteristics
an accurate detection of ink discharge state is
possible. Furthermore, according to the present
10 invention it is possible to detect the abnormal
state of the ink discharge which might occur before
ink is consumed up.

15

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1 WHAT IS CLAIMED IS:

1. An ink jet recording apparatus for effecting a recording operation by means of a recording head for discharging ink from discharge openings onto a recording medium, comprising:

an electrothermal converter provided on said recording head;

temperature detection means for detecting the temperature of said recording head; and

10 temperature characteristics detection means for applying a predetermined energy to said electrothermal converter, and detecting the temperature change of said recording head resulting from said energy application, by means of said
15 temperature detection means, thereby detecting the temperature characteristics of said recording head, based on the result of said detection.

2. An ink jet recording apparatus according to claim 1, further comprising:

judgment means for judging the ink discharge state of said recording head, based on the result of detection of the temperature characteristics of the recording head by said temperature characteristics
25 detection means.

3. An ink jet recording apparatus according





1 to claim 2, further comprising:

informing means for providing information,
based on the result of judgment of ink discharge state
by said judgment means.

5

4. An ink jet recording apparatus according to
to claim 2, wherein the temperature detection means
for said recording head are provided in plural units,
and the detection of the temperature characteristics
10 of the recording head and the judgment of the ink
discharge state are conducted according to the result
of temperature detection in a predetermined number
of temperature detection means among said plural
units.

15

5. An ink jet recording apparatus according
to claim 2, further comprising:

input means which allows the user to enter
an instruction for the execution of detection of said
20 ink discharge state, wherein said judgment means is
adapted to judge the ink discharge state in response
to the instruction entered by the user through said
input means.

25

6. An ink jet recording apparatus according
to claim 1, wherein said electrothermal converter is
a heater.





1 7. An ink jet recording apparatus according
to claim 6, wherein the predetermined amount of energy
applied to said electrothermal converter is capable
of inducing ink discharge.

5 8. An ink jet recording apparatus according
to claim 6, wherein the predetermined amount of energy
applied to said electrothermal converter is incapable
of inducing the ink discharge.

10 9. An ink jet recording apparatus according
to claim 6, wherein the predetermined amount of energy
applied to said electrothermal converter includes an
amount inducing the ink discharge and another amount
15 not inducing the ink discharge.

20 10. An ink jet recording apparatus according
to claim 1, wherein said electrothermal converter is
a heater for a purpose other than ink discharge.

25 11. An ink jet recording apparatus according
to claim 1, wherein said temperature characteristics
detection means is adapted to detect the temperature
characteristics of said recording head, based on the
temperature increase of said recording head detected
by said temperature detection means, when said
predetermined energy is applied to said electrothermal



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1 converter.

12. An ink jet recording apparatus according
to claim 1, wherein said temperature characteristics
5 detection means is adapted to detect the temperature
characteristics of said recording head, based on the
temperature descent of said recording head detected
by said temperature detection means, after the
application of said predetermined energy to said
10 electrothermal converter.

13. An ink jet recording apparatus according
to claim 1, wherein the application of said
predetermined energy to said electrothermal converter
15 is conducted by the supply of plural pulses of a
predetermined interval.

14. An ink jet recording apparatus according
to claim 13, wherein the detection of temperature
20 change in said recording head by said temperature
detection means is conducted in synchronization with
the cycles of said pulses.

15. An ink jet recording apparatus according
25 to claim 1, further comprising:

ambient temperature detection means for
detecting the ambient temperature of said recording



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1 head, wherein said temperature characteristics
detection means is adapted to correct the result of
detection of the temperature change in said recording
head, according to the ambient temperature detected
5 by said ambient temperature detection means.

16. An ink jet recording apparatus according
to claim 1, further comprising:

ambient temperature detection means for
10 detecting the ambient temperature of said recording
head, wherein said temperature characteristics
detection means is adapted to vary the amount of
energy applied to said electrothermal converter for
the purpose of detection of the temperature
15 characteristics of said recording head, based on the
ambient temperature detected by said ambient
temperature detection means.

17. An ink jet recording apparatus according
20 to claim 1, further comprising:

an ink receiving member for receiving the ink
discharged from the discharge opening of said
recording head, and

means for controlling the relative position
25 in such a manner said recording head becomes opposed
to said ink receiving member when the energy capable
of inducing ink discharge is applied to said





1 electrothermal converter, for the purpose of detecting
the temperature characteristics of said recording
head.

5 18. An ink jet recording apparatus according
to claim 1, further comprising:

an ink receiving member for receiving the
ink discharged from the discharge opening of said
recording head;

10 means for removing ink from said ink receiving
member; and

means for activating said ink removing means,
at the application of energy of an amount capable of
inducing ink discharge to said electrothermal
15 converter for the purpose of detecting the temperature
characteristics of said recording head, before and/or
after of said energy application.

19. An ink jet recording apparatus according
20 to claim 1, wherein the temperature characteristics
of said recording head include the temperature change
therein when the energy of an amount not inducing the
ink discharge is applied to said electrothermal
converter.

25

20. An ink jet recording apparatus according





1 to claim 1, wherein the temperature characteristics
of said recording head include the temperature change
therein when the energy of an amount capable of
inducing ink discharge is applied to said
5 electrothermal converter, in a state in which said
recording head is filled with ink.

21. An ink jet recording apparatus according
to claim 1, wherein the temperature characteristics
10 of said recording head include the temperature change
therein when the energy of an amount capable of
inducing ink discharge is applied to said
electrothermal converter, in a state in which said
recording head is not filled with ink.

15 22. An ink jet recording apparatus according
to claim 1, wherein said recording head is adapted to
induce a state change including bubble generation in
the ink, by means of thermal energy, and to effect
20 ink discharge based on said state change.

23. An ink jet recording apparatus for
effecting a recording operation by means of a
recording head for discharging ink from discharge
25 openings onto a recording medium, comprising:

input means for enabling the operator to
instruct the execution of detection of the ink





1 discharge state of said recording means; and
ink discharge state detection means for
detecting the ink discharge state of said recording
head, by causing the ink discharge from said recording
5 head, in response to the instruction of the operator
entered through said input means.

24. An ink jet recording apparatus according
to claim 23, wherein said input means is adapted to
10 enter a predetermined timing for detecting the ink
discharge state, and said ink discharge state
detection means is adapted to detect the ink discharge
state according to the entered timing.

15 25. An ink jet recording apparatus according
to claim 23, wherein said recording head is equipped
with an electrothermal converter for heating the ink
for the purpose of inducing ink discharge.

20 26. An ink jet recording apparatus according
to claim 23, further comprising an electrothermal
converter for a purpose other than ink heating.

25 27. An ink jet recording apparatus according
to claim 23, wherein said recording head is adapted
to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect





1 ink discharge based on said state change.

28. An ink jet recording apparatus for
effecting a recording operation by means of a
5 recording head for discharging ink from discharge
openings onto a recording medium, comprising:

ink discharge state detection means for
detecting the ink discharge state of said recording
head; and

10 control means for controlling said ink
discharge state detection means to effect the
detection of the ink discharge state again, in case
said detection means detects a defective state of ink
discharge from said recording head.

15

29. An ink jet recording apparatus according
to claim 28, further comprising:

discharge recovery process means for restoring
the ink discharge from said recording head;

20

wherein, when said ink discharge state
detection means detects a defective state of ink
discharge from said recording head, said control means
is adapted to so control said discharge recovery
process means to effect a discharge recovery process
25 by sucking ink from said recording head, and then to
so control said ink discharge state detection means
to again detect the ink discharge state.





1 30. An ink jet recording apparatus according
to claim 28, further comprising:

discharge recovery process means for restoring
the ink discharge from said recording head;

5 wherein, when said ink discharge state
detection means detects a defective state of ink
discharge from said recording head, said control
means is adapted to so control said discharge recovery
process means as to effect a discharge recovery
10 process by sucking ink from said recording head, then
to cause said recording head to discharge ink of a
predetermined amount, and to so control said ink
discharge state detection means to again detect the
ink discharge state.

15

31. An ink jet recording apparatus according
to claim 28, wherein said recording head is adapted
to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect
20 ink discharge based on said state change.

32. An ink jet recording apparatus for
effecting a recording operation by means of a
recording head for discharging ink from discharging
25 openings onto a recording medium, comprising:

ink discharge state detection means for





1 detecting the ink discharge state of said recording
head; and

memory means for storing, when said ink
discharge state detection means detects a defective
5 state in the ink discharge from said recording head,
the recording data at least starting from the
preceding detection of satisfactory state of the ink
discharge.

10 33. An ink jet recording apparatus according
to claim 32, further comprising:

means capable of instructing the recording
data, in case the recording operation is restarted
based on the recording data stored in said memory
15 means, in case said ink discharge state detection
means detects a defective state of the ink discharge
from said recording head.

20 34. An ink jet recording apparatus according
to claim 32, further comprising:

means for enabling said recording head to
again record the predetermined recording data, based
on the recording data stored in said memory means,
in case said ink discharge state detection means
25 detects a defective state of the ink discharge from
said recording head.





1 35. An ink jet recording apparatus according
to claim 31, wherein said recording head is adapted
to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect
5 ink discharge based on said state change.

 36. A method for detecting the temperature
characteristics of an ink jet recording head,
comprising steps of:
10 applying a predetermined energy to an
electrothermal converter provided in the recording
head for effecting recording by discharging ink from
a discharge opening onto a recording medium;
 detecting the temperature change in said
15 recording head, resulting from said energy
application; and
 detecting, based on the result of said
detection, the temperature characteristics of said
recording head.

20

 37. A method according to claim 36, wherein
the state of ink discharge from said recording head
is judged according to the result of detection of the
temperature characteristics of the recording head.

25

 38. An ink jet recording apparatus for
effecting a recording operation by means of a





1 recording head for discharging ink from discharge
openings onto a recording medium, comprising:

an electrothermal converter provided on said
recording head;

5 temperature detection means for detecting the
temperature in the vicinity of said recording head;
and

judgment means for judging the ink discharge
state of said recording head, through the comparison
10 between the temperature characteristics of said
recording head based on the temperature change in the
vicinity of said recording head at the application
of a predetermined energy to said electrothermal
converter, and the temperature detected by said
15 temperature detection means.

39. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
are represented by a temperature change A in the
20 normal ink discharge state and a temperature change
B in an abnormal ink discharge state.

40. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
25 are represented by a temperature ΔT_A in the normal
ink discharge state at the application of said
predetermined energy to said electrothermal converter,





1 and a temperature difference TD between said
temperature dTA and a temperature at an abnormal
discharge state lacking the ink discharge.

5 41. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
are represented, based on a temperature dTC when said
electrothermal converter is given an energy in a range
not inducing ink discharge from said discharge
10 opening.

42. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
are represented by a value obtained by applying the
15 predetermined energy to said electrothermal converter
in a plurality of recording heads and statistically
processing the temperature detected in the vicinity
of said recording head.

20 43. An ink jet recording apparatus according
to claim 42, wherein said temperature characteristics
are represented by a maximum temperature TA enabling
the normal ink discharge from said recording head
when the predetermined energy is applied to said
25 electrothermal converter in a plurality of recording
heads, and a minimum temperature TB of the abnormal
discharge state in which the ink is not discharged



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1 from said recording head.

44. An ink jet recording apparatus according
to claim 42, wherein said temperature characteristics
5 are represented by the temperature dTA enabling
the normal ink discharge from said recording head
at the application of the predetermined energy to
said electrothermal converter in a plurality of
recording heads, and the minimum value TD of the
10 temperature difference (dT_B - dT_A) between the
temperature dT_B of the abnormal discharge state in
which the ink is not discharged from said recording
head and said temperature dT_A.

15 45. An ink jet recording apparatus according
to claim 42, wherein said temperature characteristics
are represented by a temperature dTA enabling the
normal ink discharge from said recording head, said
temperature being detected at the application of a
20 predetermined energy E₁ to the electrothermal
converter in a plurality of the recording heads, and
by a ratio of a temperature dT_B in an abnormal
discharge state in which the ink is not discharged
from said recording head, to a temperature dT_C

25 detected by said temperature detection means when
an energy E₂ not inducing the ink discharge from said
recording head is applied.



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1 46. An ink jet recording apparatus according
to claim 38, further comprising:

 informing means for providing information,
based on the result of judgment of ink discharge state
5 by said judgment means.

 47. An ink jet recording apparatus according
to claim 38, comprising said temperature detection
means in plural units, wherein the judgment of the
10 ink discharge state is conducted according to the
result of detection in a predetermined number of
temperature detection means among said plural units.

 48. An ink jet recording apparatus according
15 to claim 38, further comprising:

 input means which allows the user to enter an
instruction for the execution of detection of said ink
discharge state, wherein said judgment means is
adapted to judge the ink discharge state in response
20 to the instruction entered by the user through said
input means.

 49. An ink jet recording apparatus according
to claim 38, wherein said recording head is adapted
25 to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect
ink discharge based on said state change.



50. An ink jet recording apparatus including means for detecting the temperature characteristics of an ink jet recording head wherein the result of detection is utilised for detecting the ink discharge state.

5

51. An ink jet recording apparatus including means for detecting the temperature characteristics on plural recording heads, and means for effecting statistical processing to enable exact detection of the ink discharge
10 state, unaffected by the individual difference of the recording heads.

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1 ABSTRACT OF THE DISCLOSURE

 The temperature characteristics of an ink
jet recording head are detected, and the result of
detection is utilized for detecting the ink discharge
5 state. Also a statistical processing on the
temperature characteristics detected on plural
recording heads enables exact detection of the ink
discharge state, not effected by the individual
difference of the recording heads. Also there is
10 detected the abnormality in ink discharge, that may
occur prior to the exhaustion of ink in the ink tank.

15

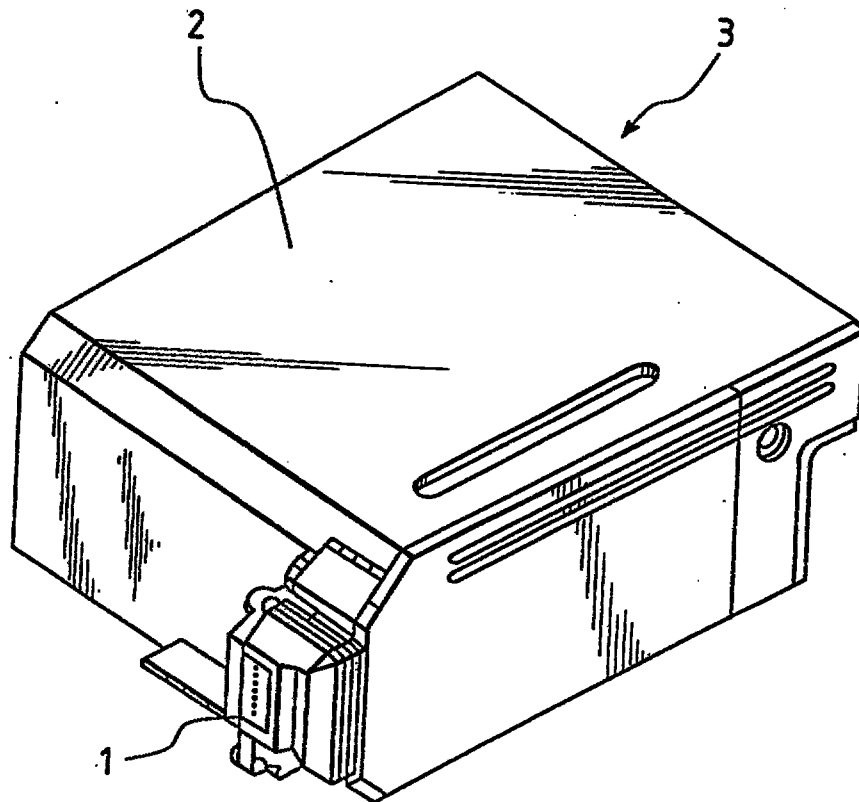
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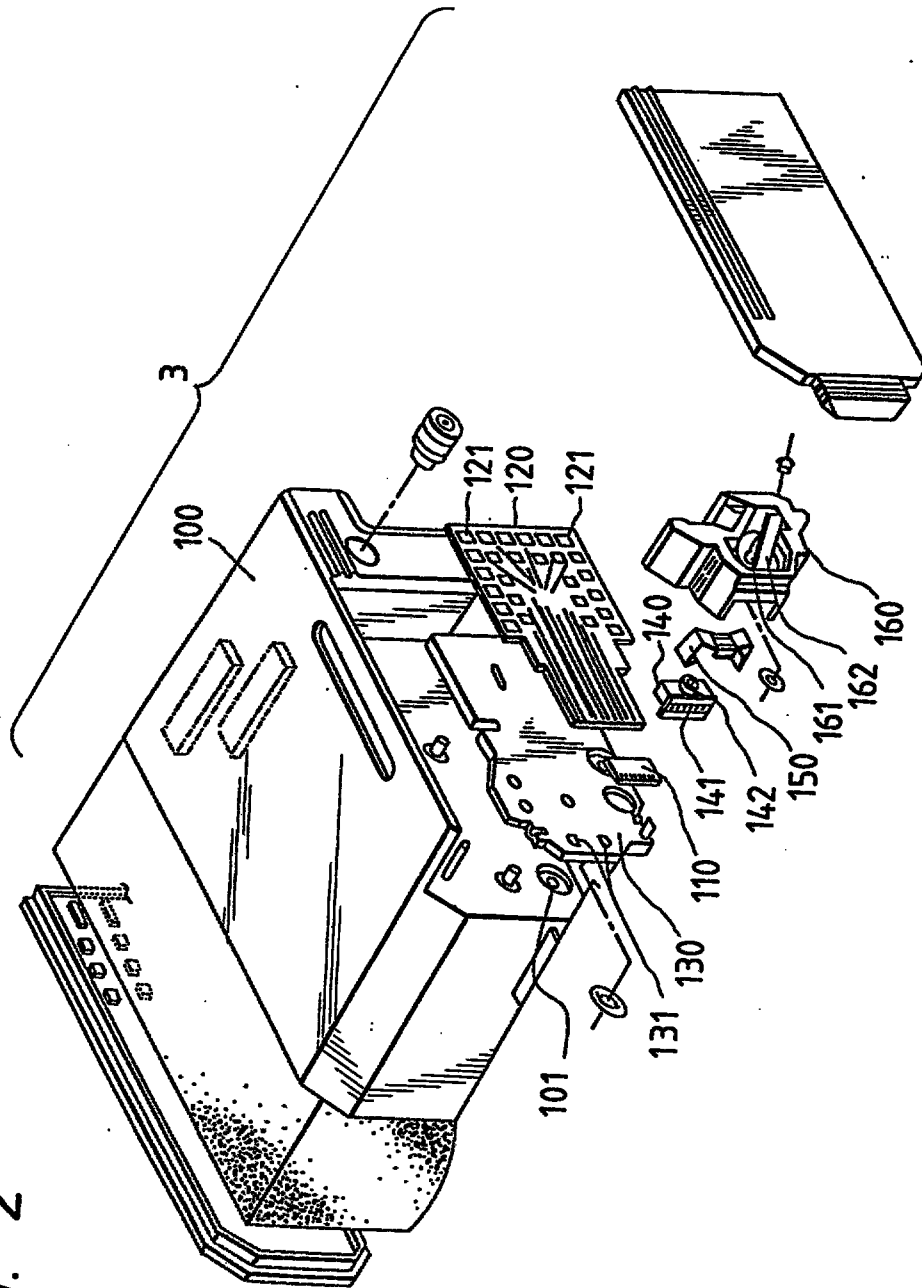
FIG. 1



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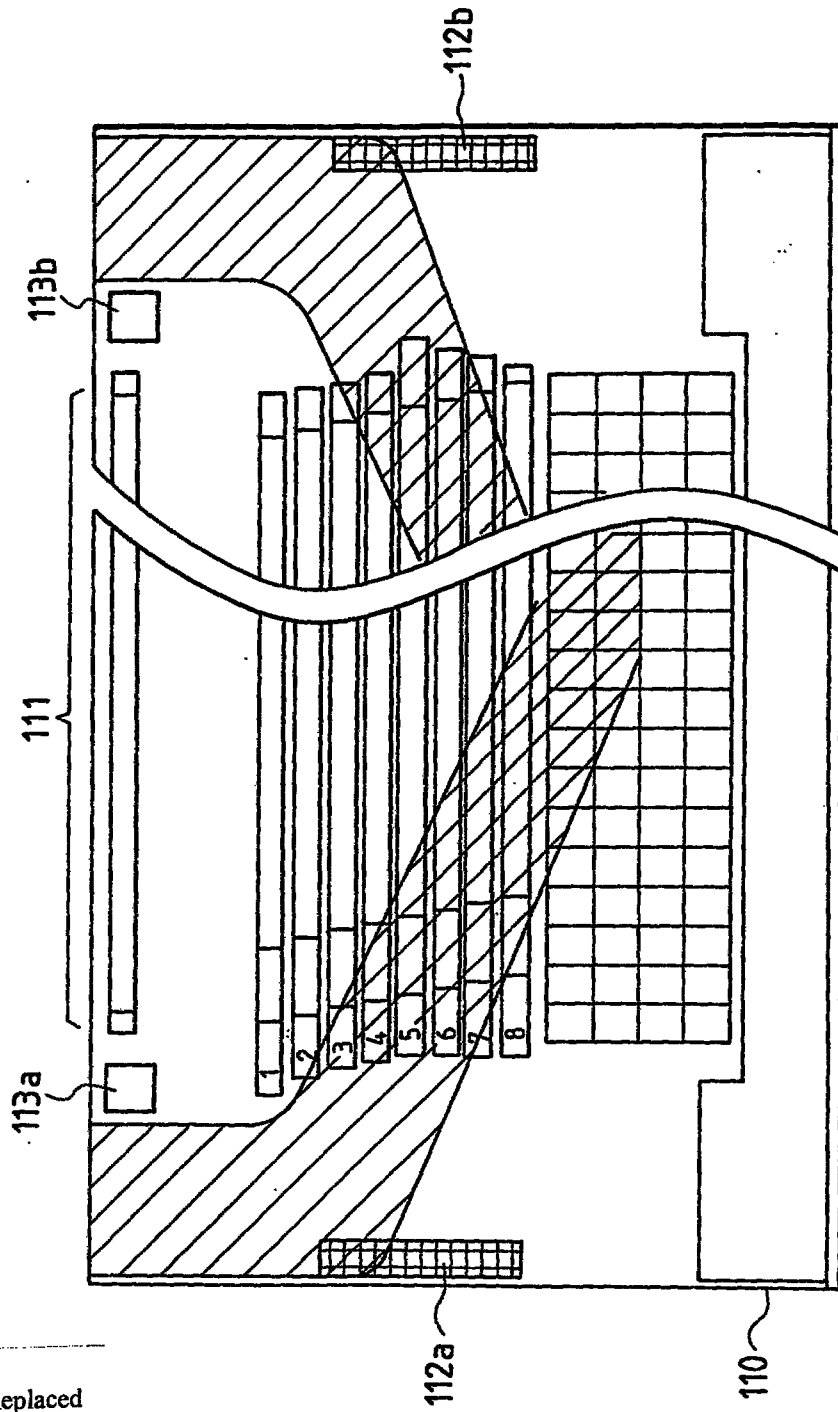
FIG. 2



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FIG. 3A



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FIG. 3B

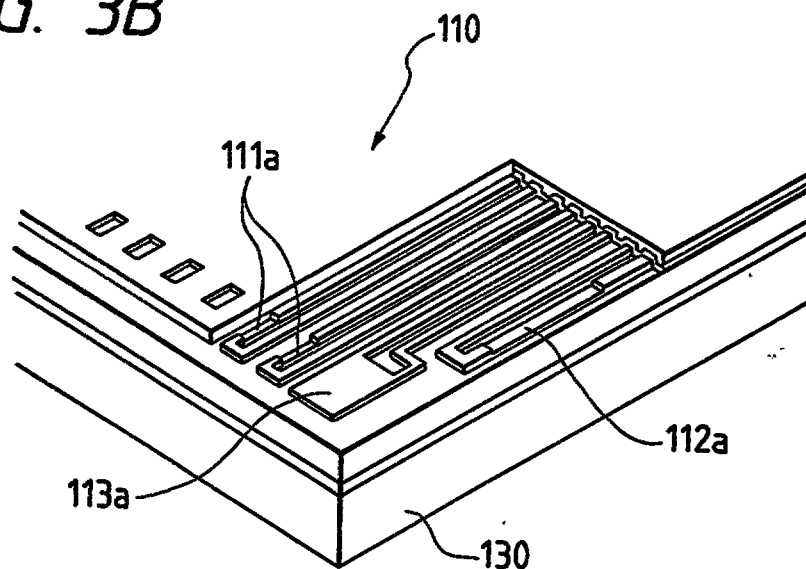
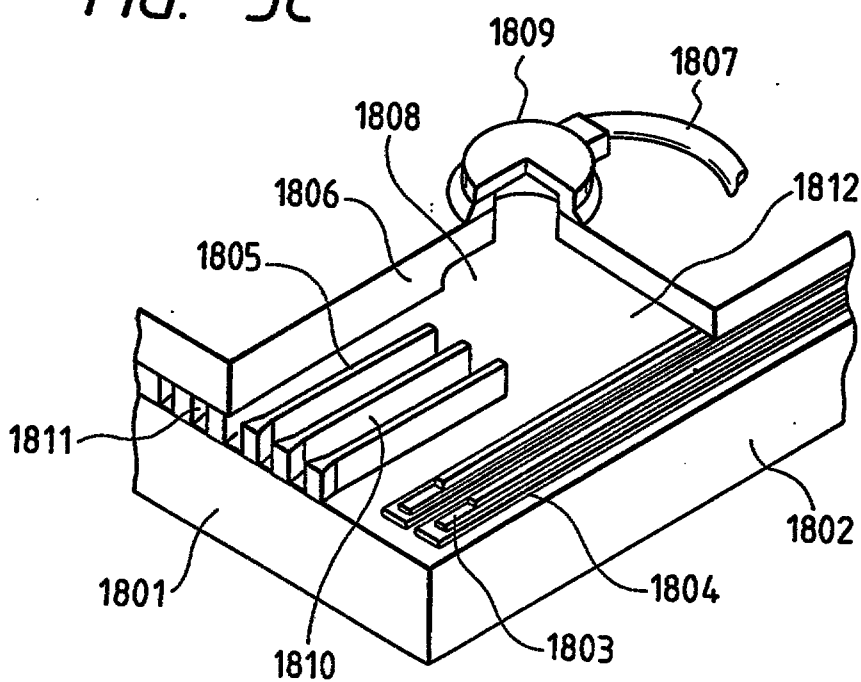
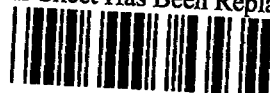


FIG. 3C



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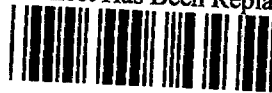


FIG. 4

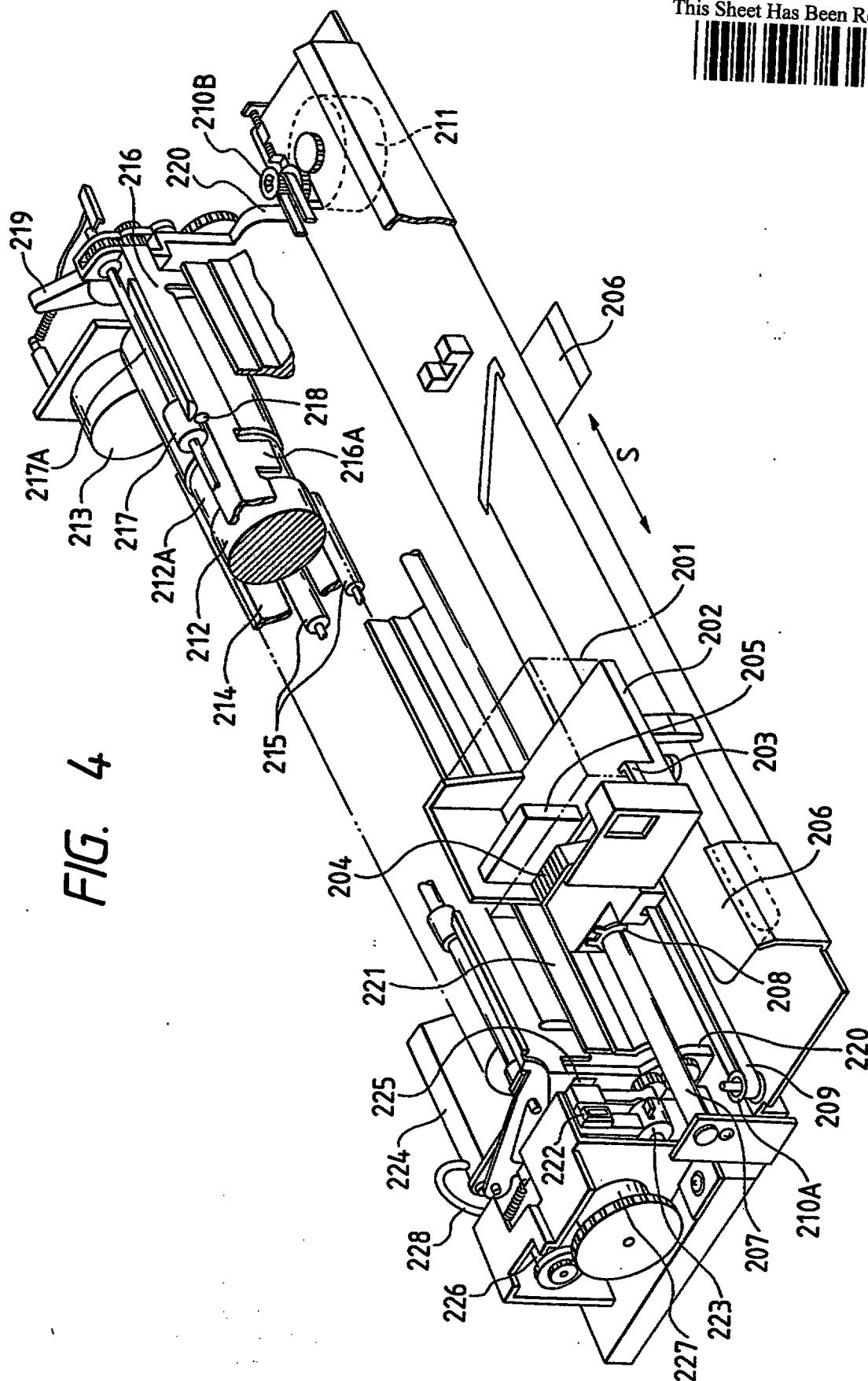
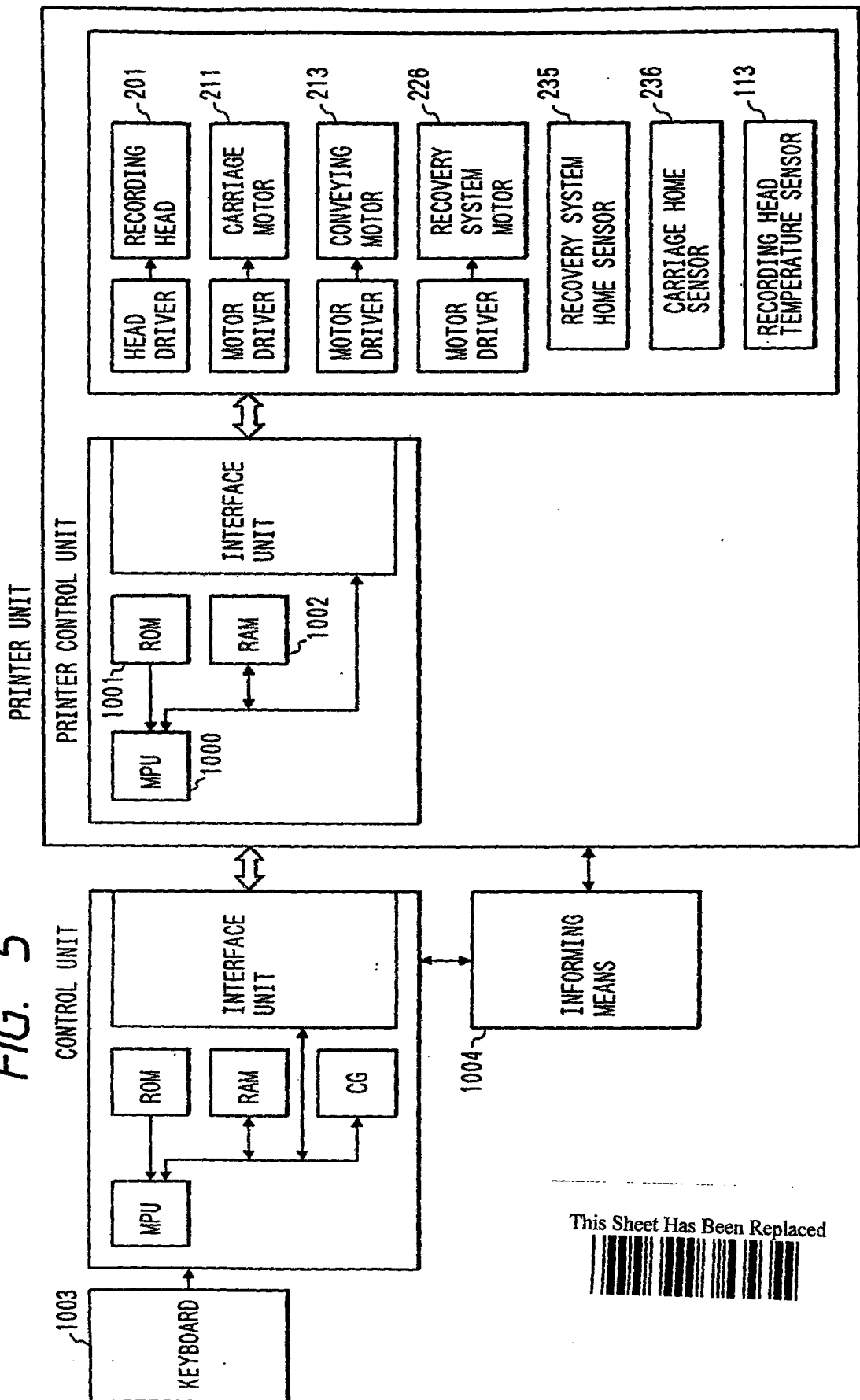


FIG. 5



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FIG. 6

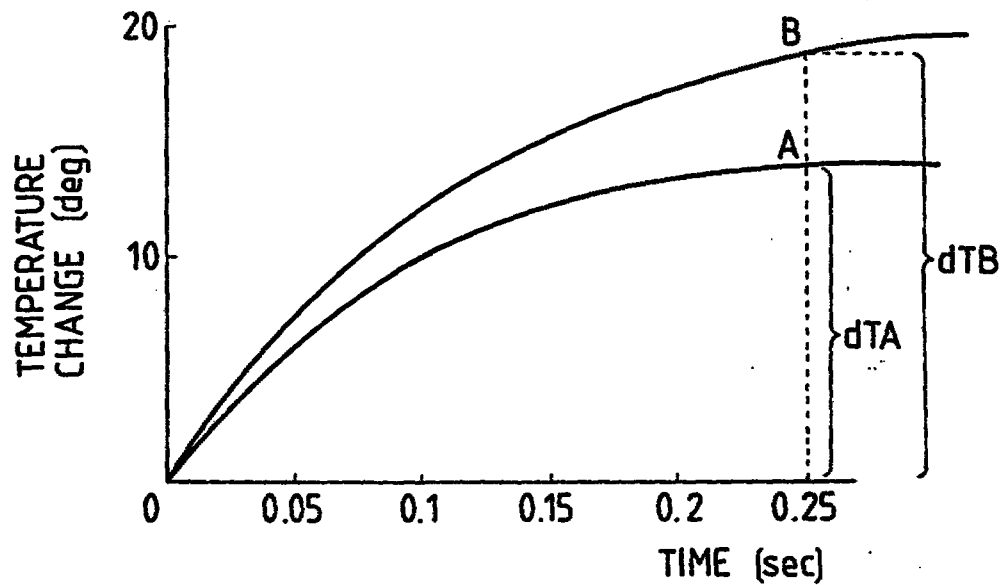


FIG. 7A

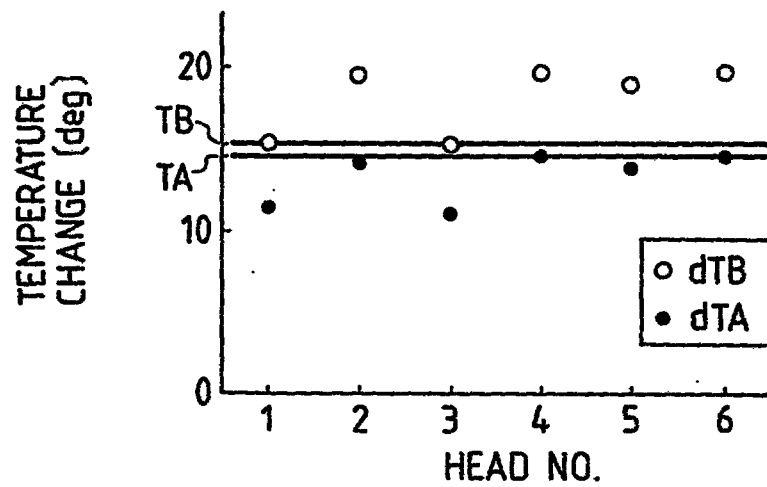
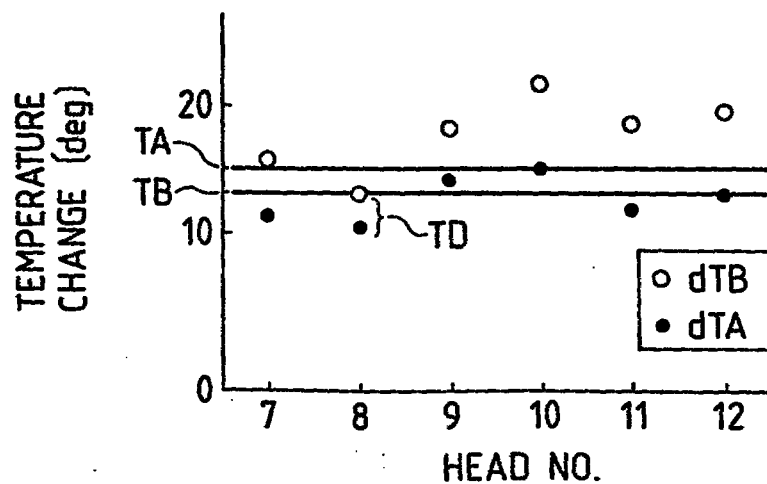


FIG. 7B





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FIG. 8A

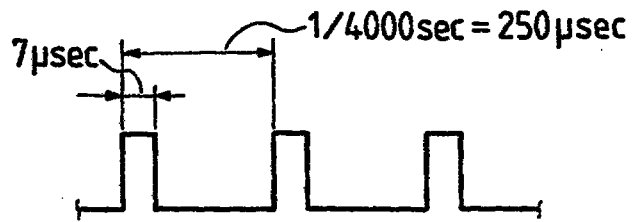


FIG. 8B

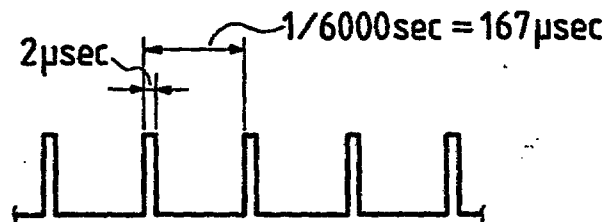


FIG. 9

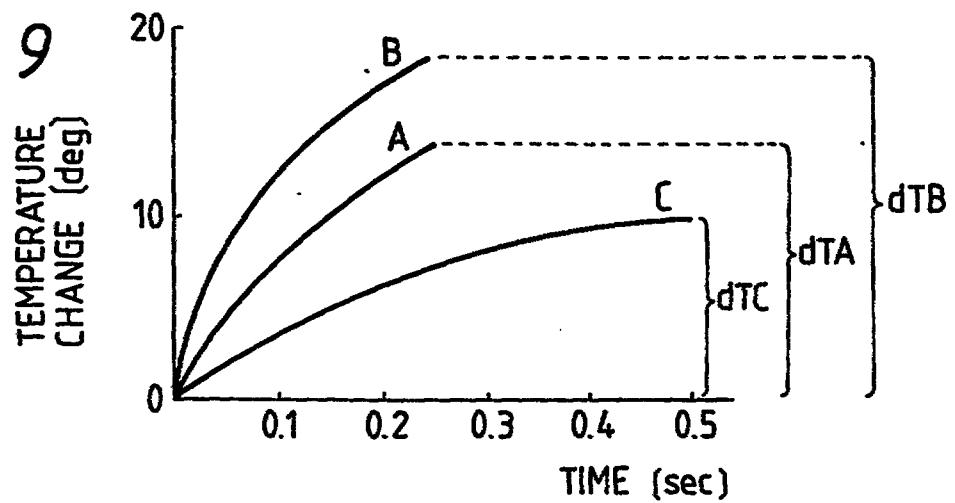


FIG. 10

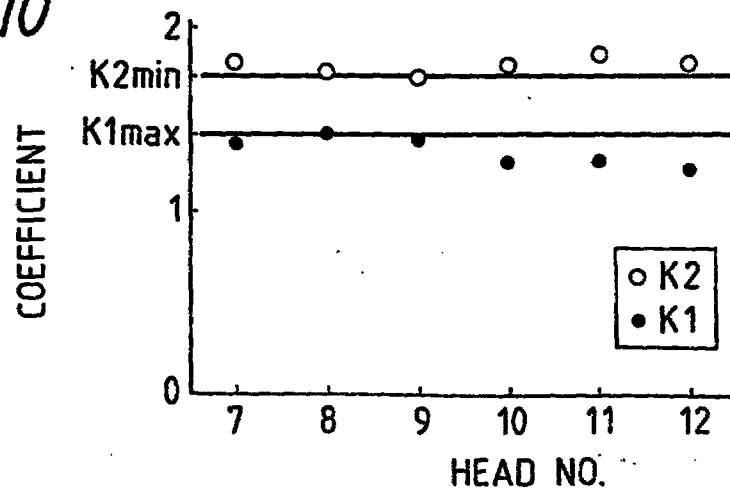
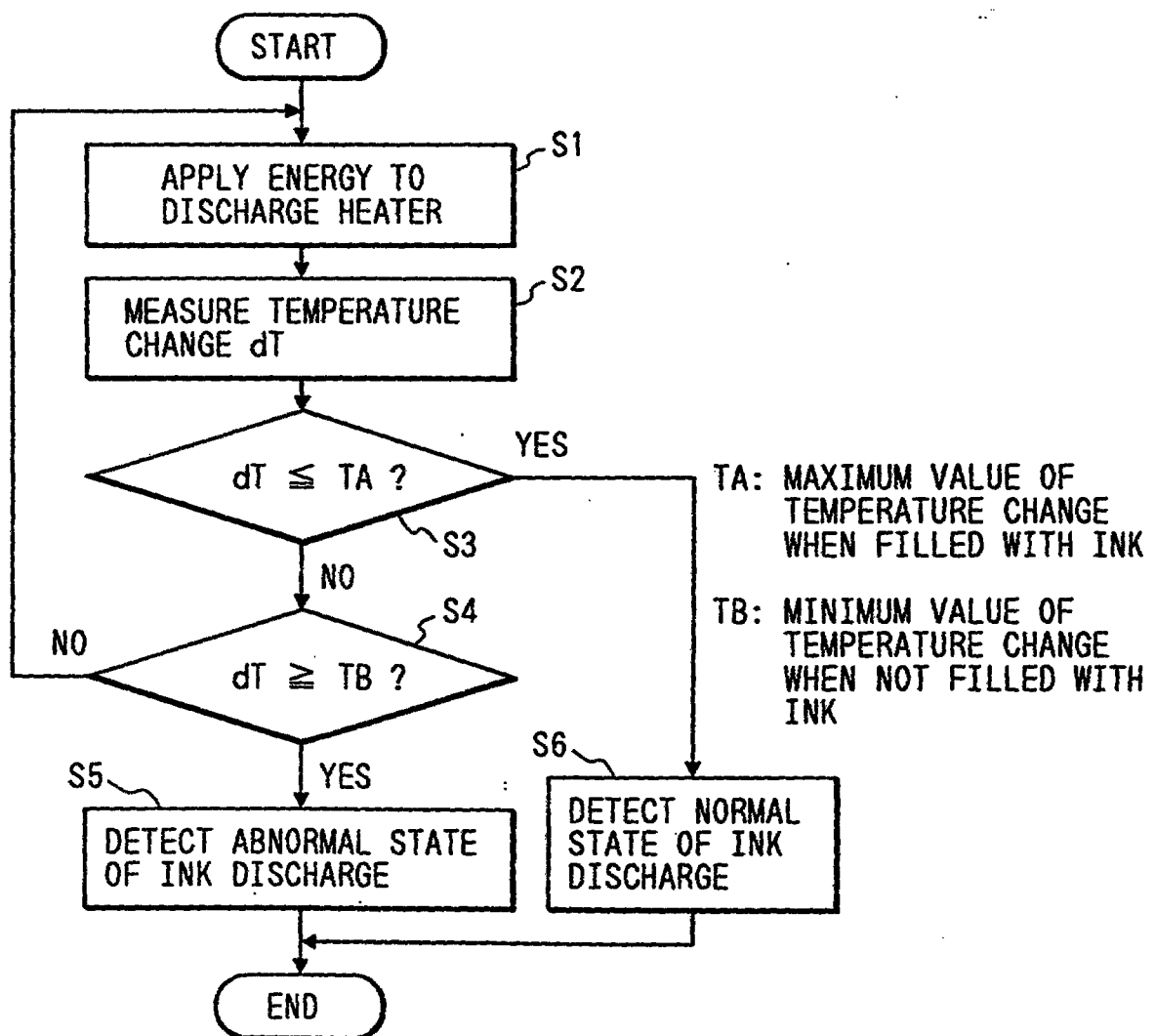


FIG. 11



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FIG. 12

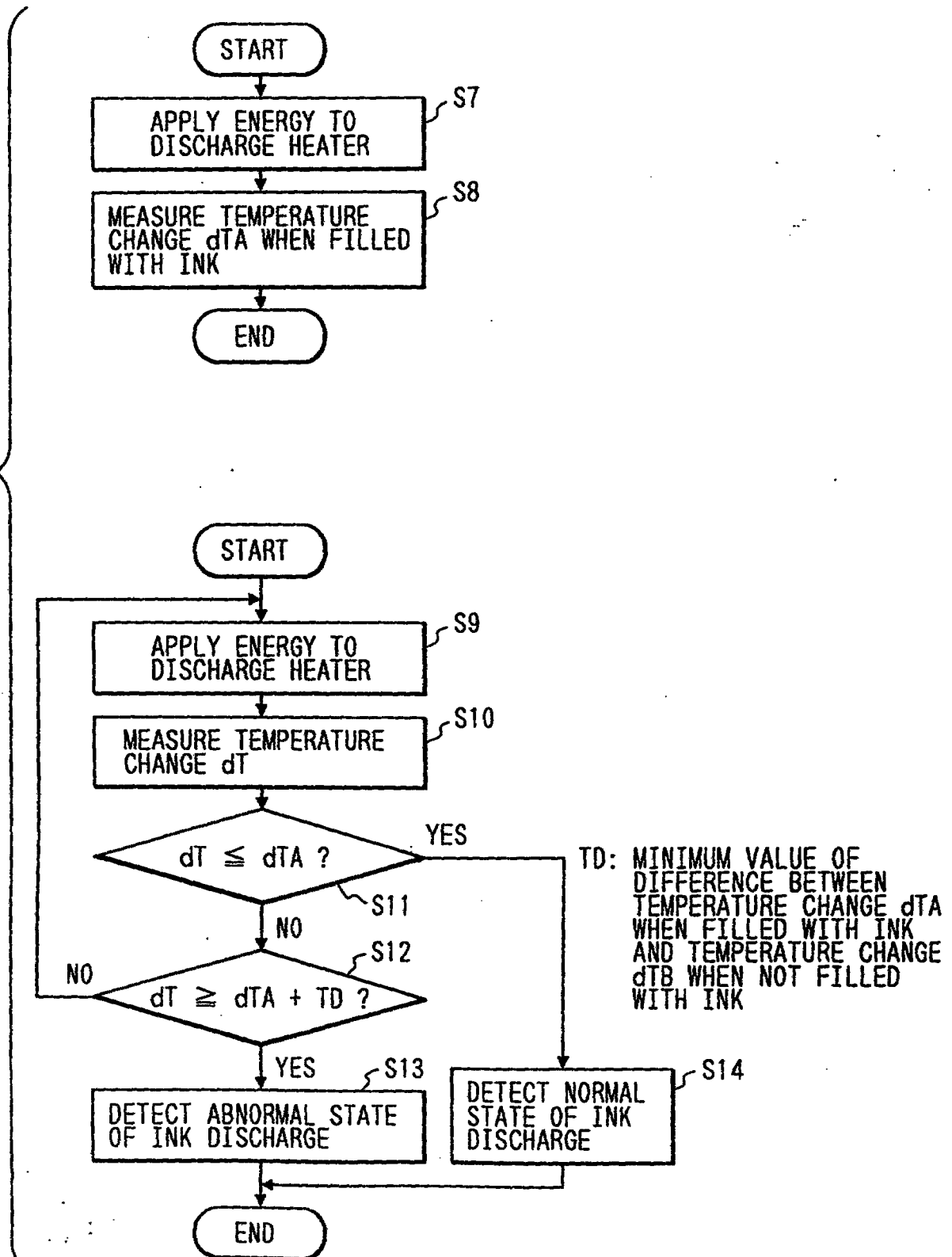
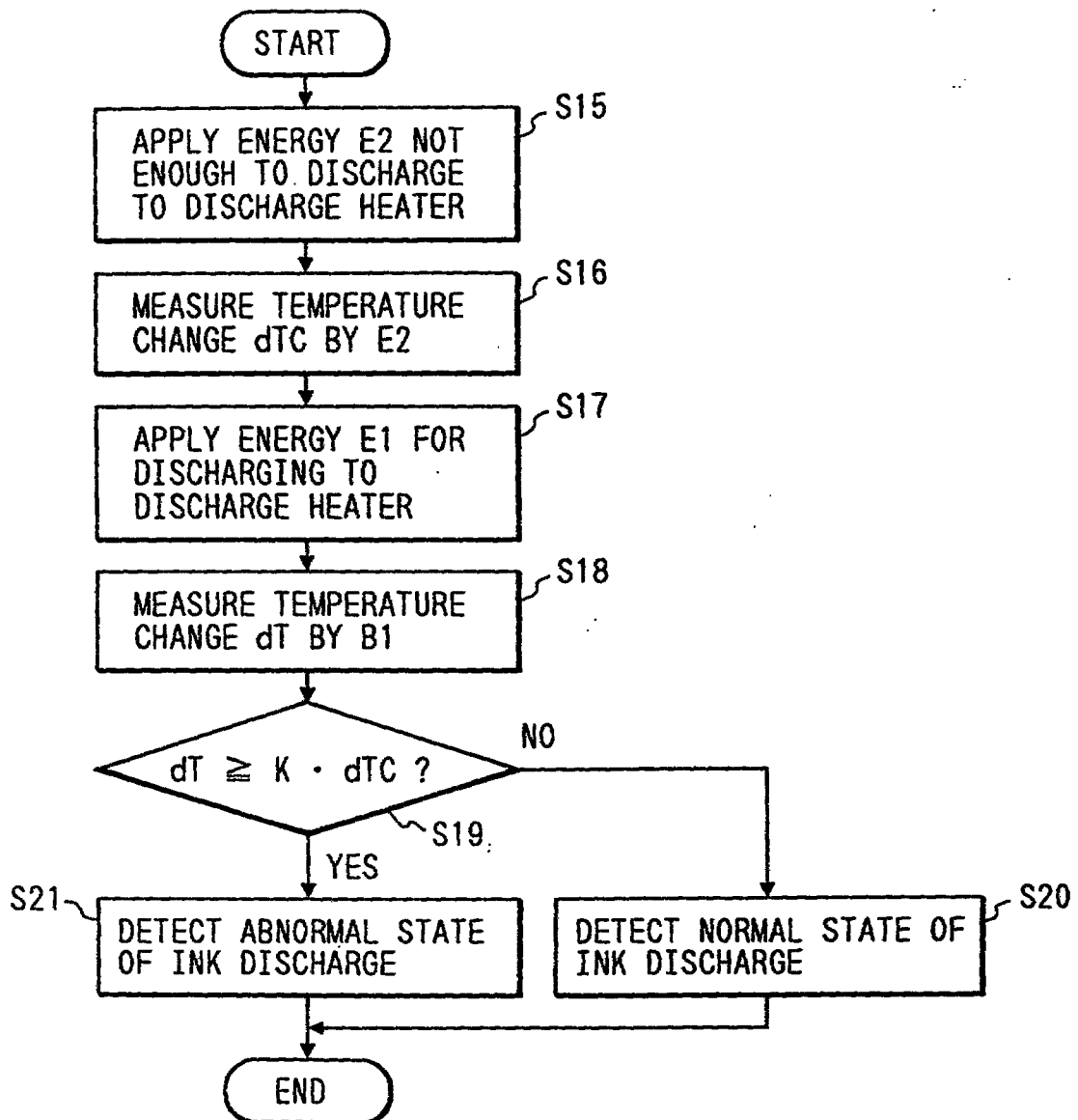


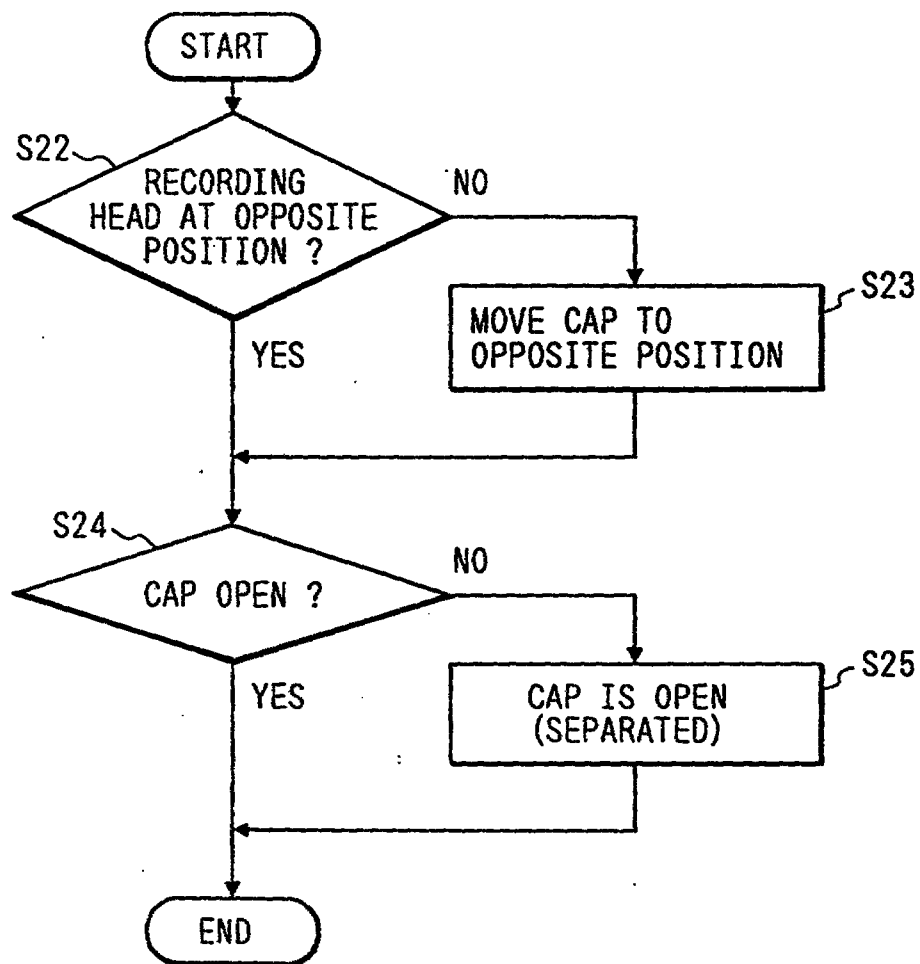
FIG. 13



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FIG. 14



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FIG. 15A

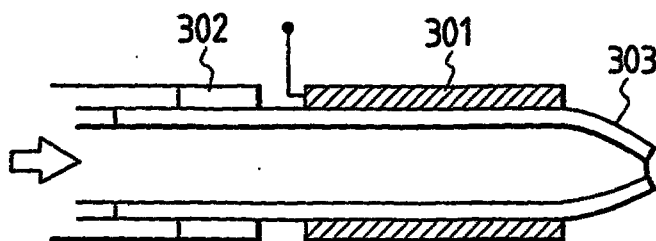


FIG. 15B

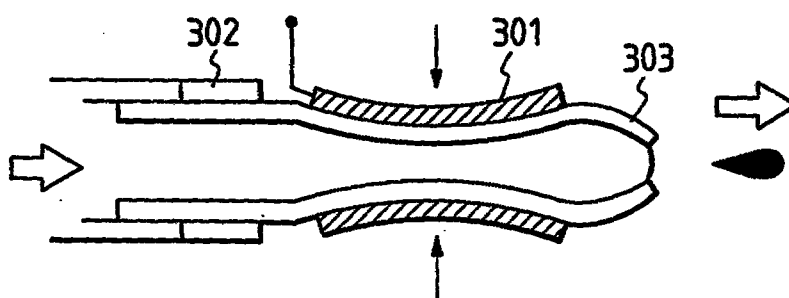


FIG. 16

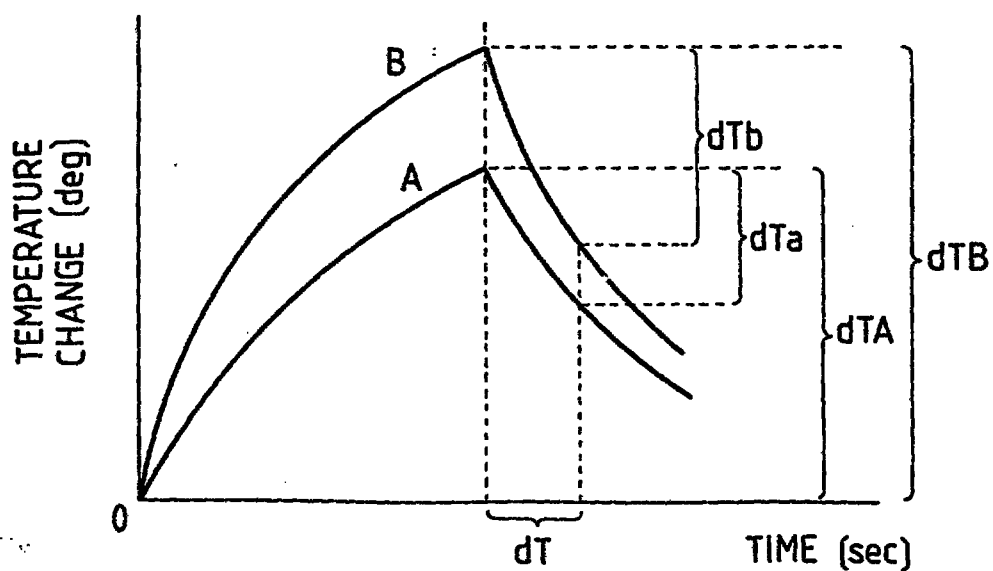




FIG. 17

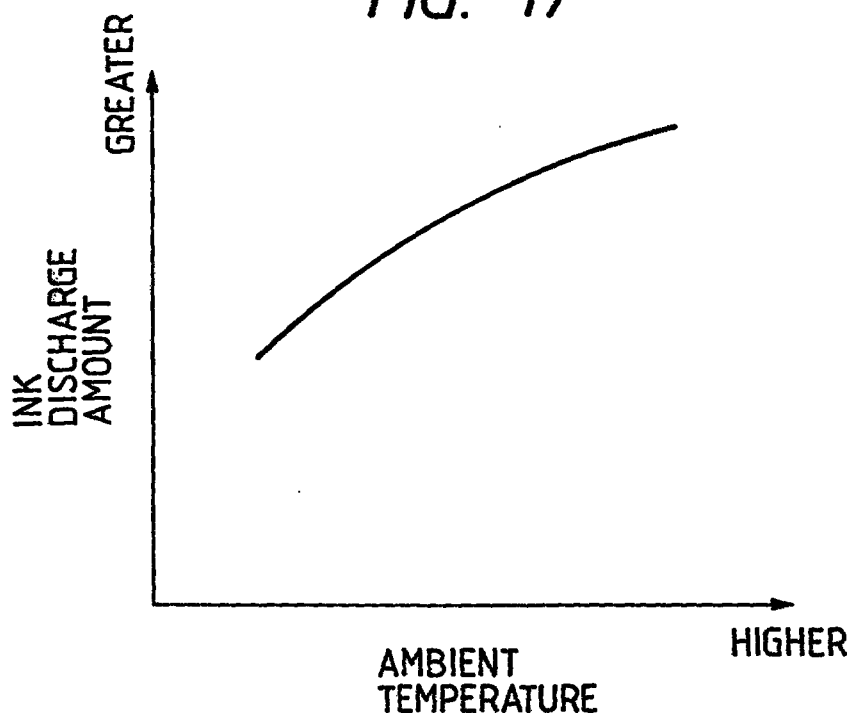
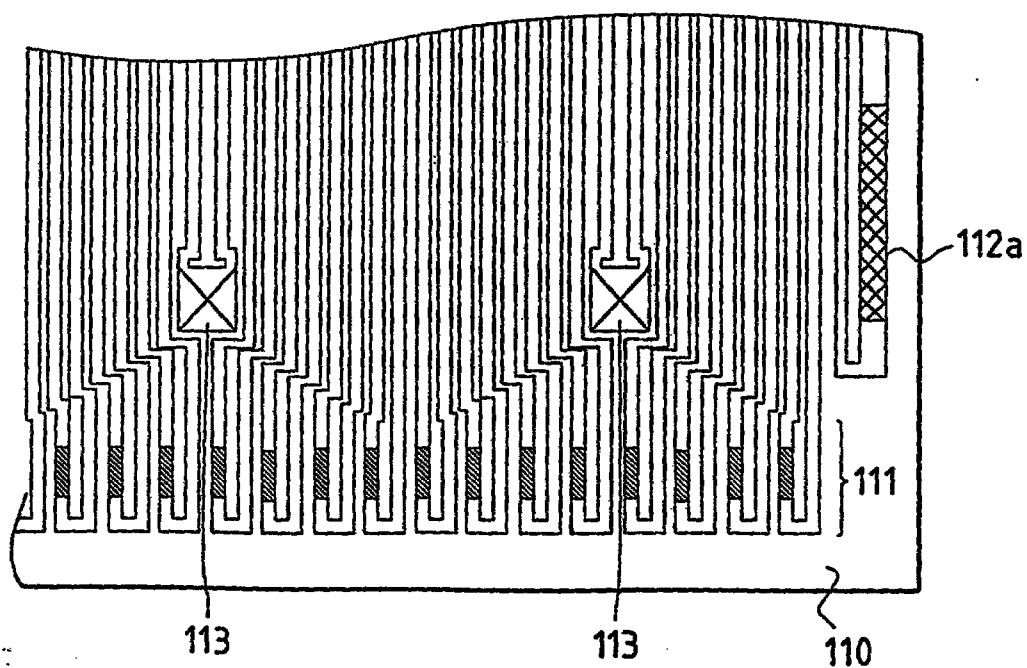


FIG. 18





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FIG. 19

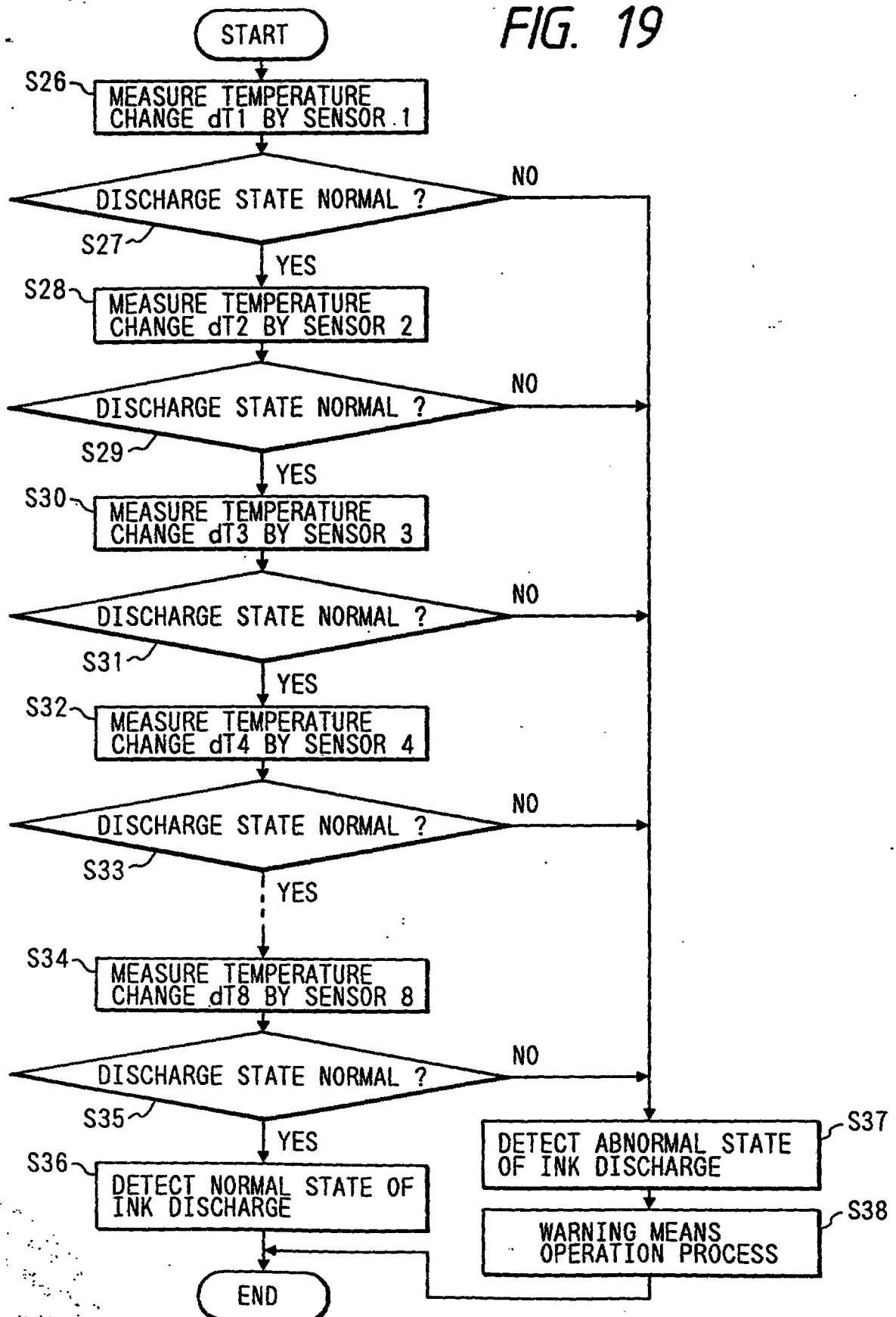
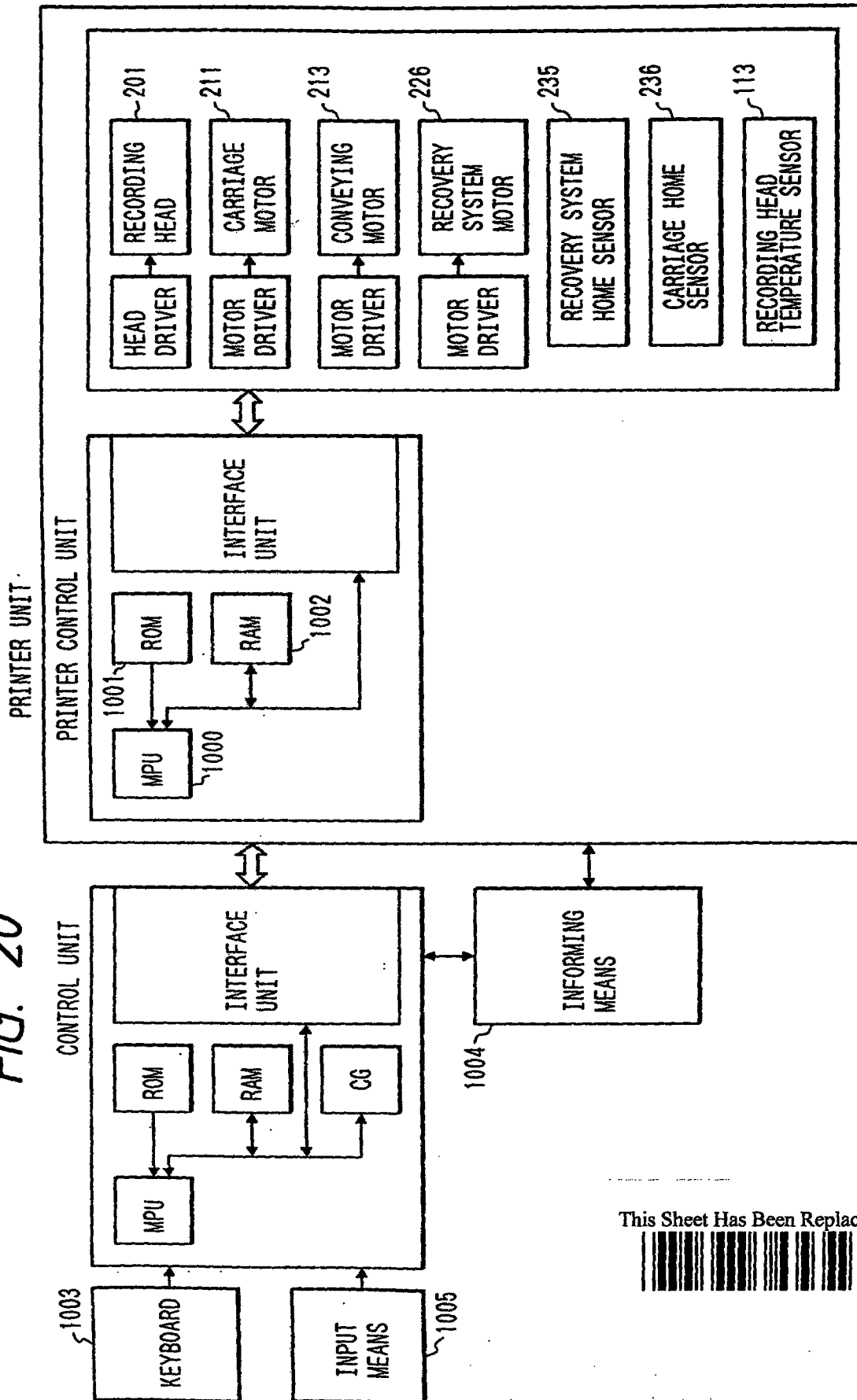


FIG. 20



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FIG. 21

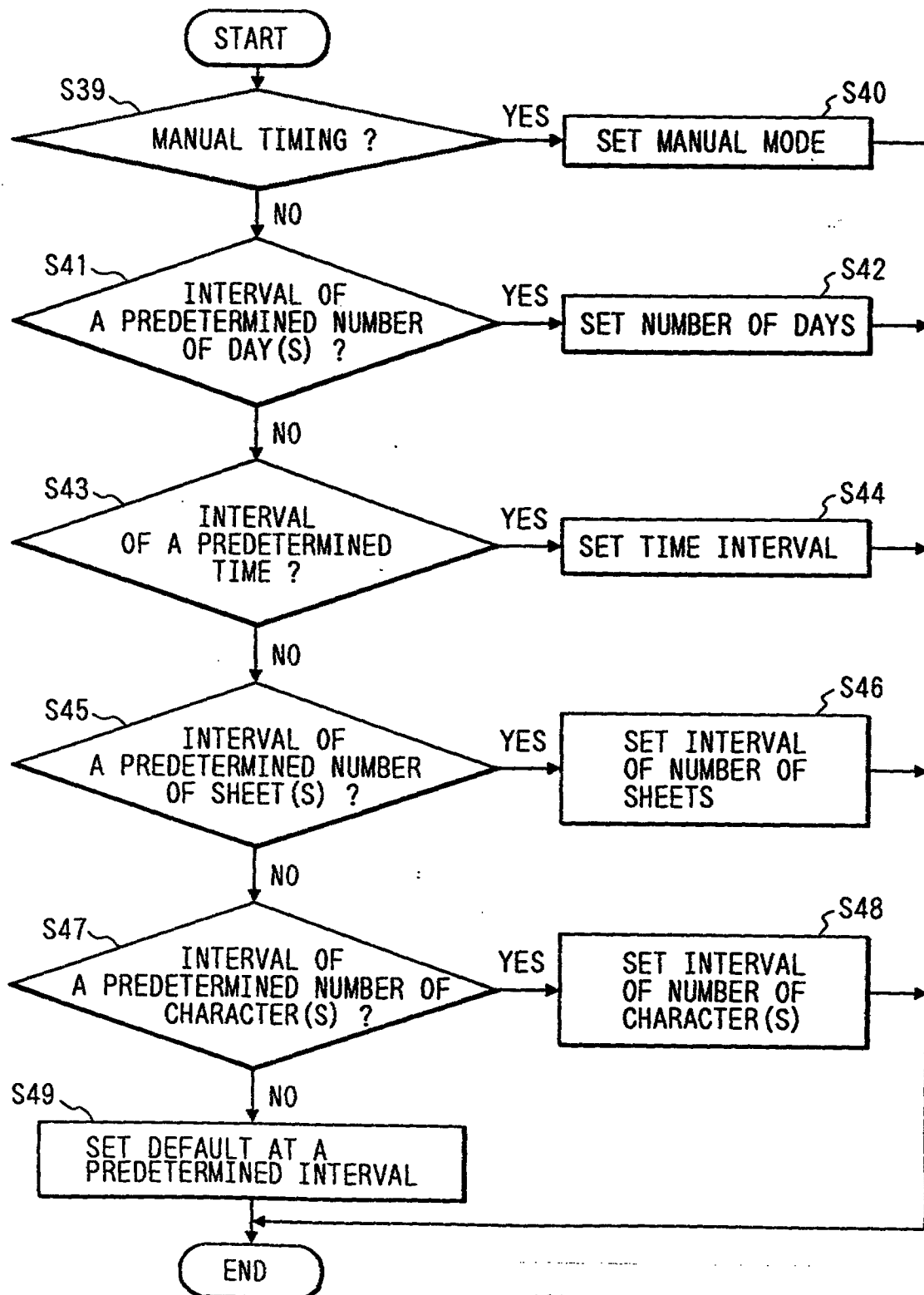
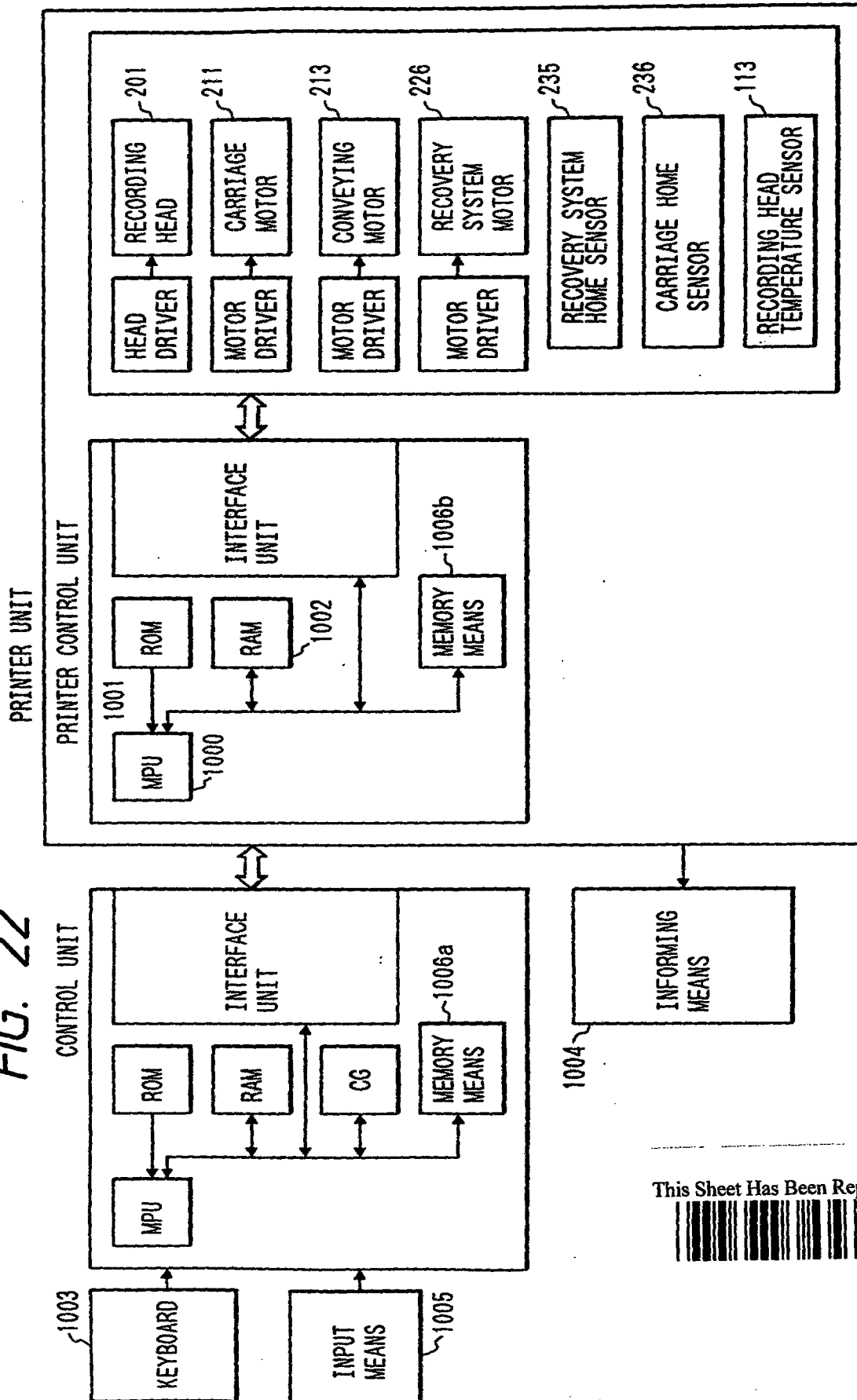


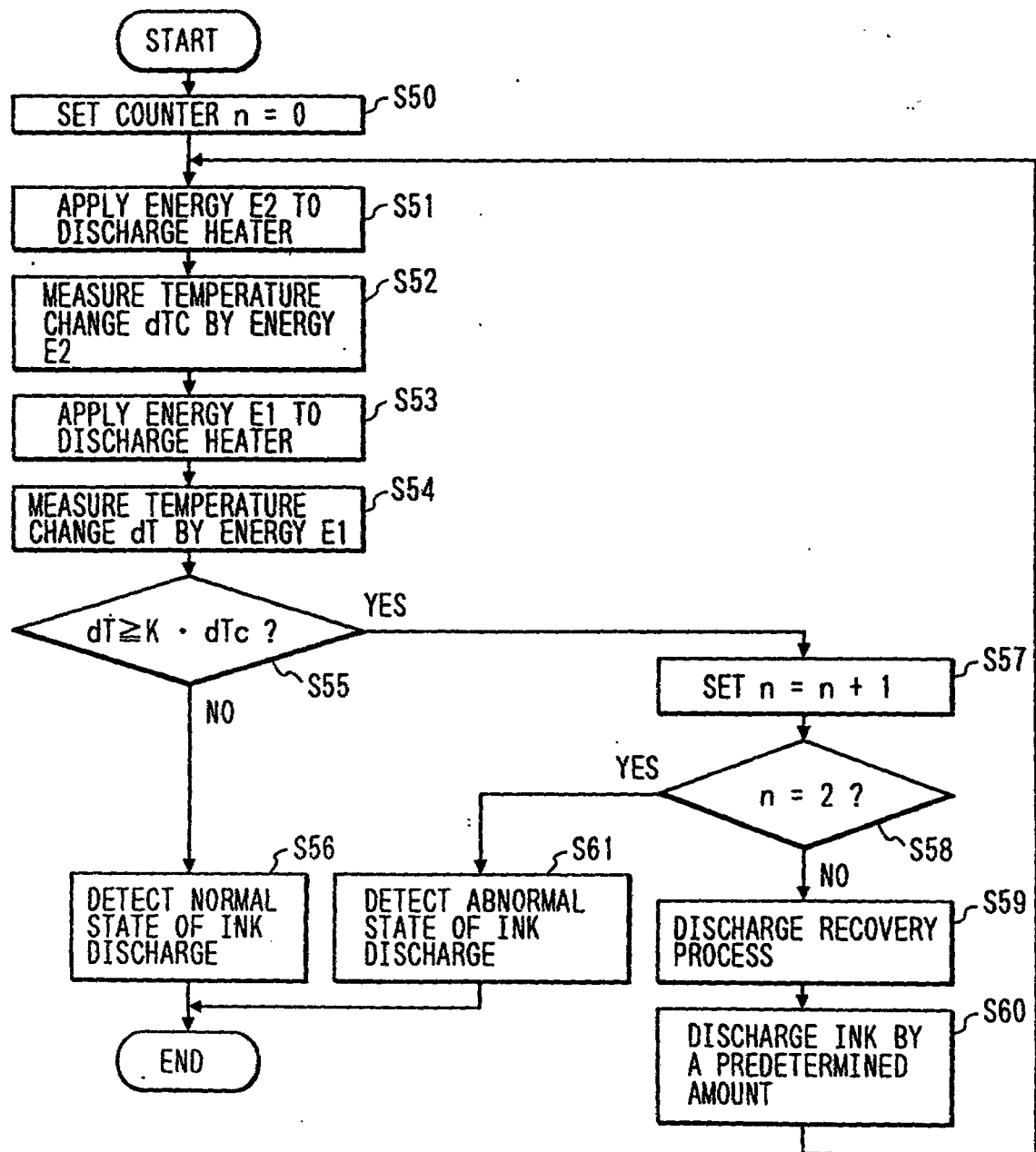
FIG. 22



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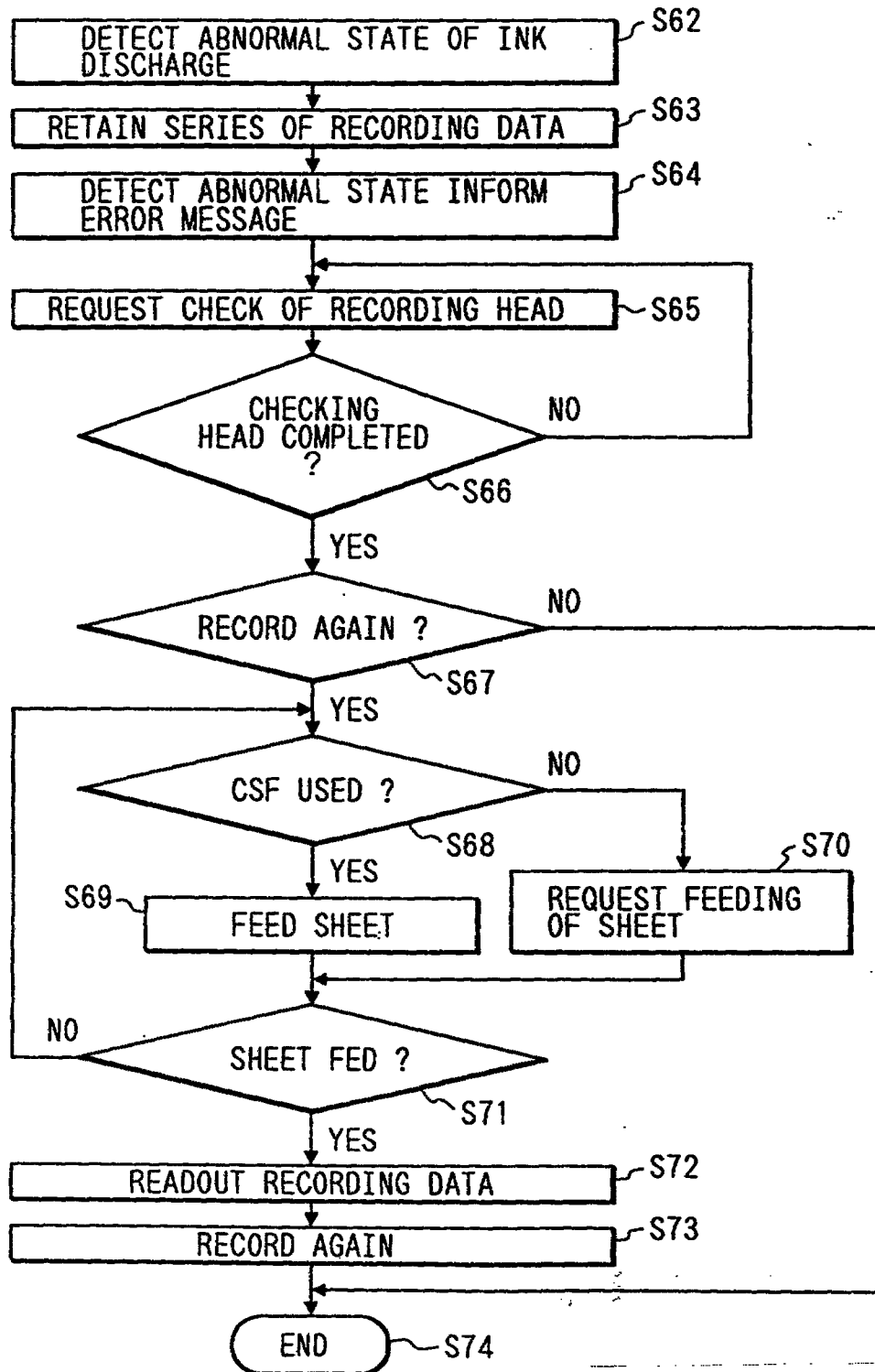
FIG. 23



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FIG. 24



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- 1 Method for Judging Discharge State of
Ink Jet Recording Head, and Ink Jet
Recording Apparatus Utilizing the Same

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an ink jet
recording apparatus adapted for use in a printer,
a facsimile, a word processor, a copying machine or
10 the like, and more particularly to a method for
detecting the temperature characteristics of an ink
jet recording head and judging the discharge state
thereof.

Related Background Art

- 15 Recording apparatus for recording on a
recording medium such as paper or a sheet for
overhead projector have been commercialized in the
form employing a recording head of various recording
methods. Such recording head is known, for example,
20 in the wire dot method, the thermal method, the
thermal transfer method or the ink jet method.
Particularly the ink jet method is attracting
attention as a quiet recording method of a low
running cost, since the ink is directly discharged
25 onto the recording medium.

In such ink jet recording apparatus, an ink
tank containing ink is connected to the recording

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1 head through an ink supply pipe, and the ink is
supplied from such ink tank. Said ink tank may be
formed as an ink cartridge which is separate from the
recording head and is replaceably mounted in the
5 recording apparatus, or as an integral unit with the
recording head, which is integrally replaceably
mounted in the recording apparatus.

In such ink jet recording apparatus, if the
ink supply is interrupted because of the exhaustion
10 of ink, the ink discharge becomes no longer possible
so that the recording ability is lost. In order to
avoid such situation, there has been commercialized
the recording apparatus with a function of detecting
the remaining ink amount, thus generating an alarm
15 signal or requesting the replacement of the ink tank,
according to the amount of consumption of ink.

For detecting the remaining ink amount, there
has been proposed a method of counting the pulse
signals supplied for ink discharge and thereby
20 calculating the amount of ink consumption, a method
of inspecting the change in the resistance of ink
itself or of a member holding the ink, a method of
detecting the weight change of the ink tank, or a
method of forming a transparent area in an ink path
25 in the ink tank or in the recording head and
inspecting the presence or absence of ink in said ink
path by the observation of the user or by a

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1 photosensor.

 In the above-mentioned method utilizing the
count of the ink discharge pulse signals, the
remaining ink amount is detected by calculating the
5 ink amount used in recording, from the product of the
number of applied pulses and the amount of discharge
per ink droplet discharged by a pulse.

 Also the method of remaining amount detection
by inspecting the resistance of ink etc. utilizes
10 a fact that ordinary ink has a certain specific
resistance due to the presence of water and other
conductive substances therein, measures the
resistance of the ink or the member holding the ink
by means of a pair of electrodes provided for example
15 in the ink tank, and detects the remaining ink amount
based on a fact that the resistance between said
electrodes is correlated with the remaining ink
amount.

 Also the method utilizing the weight change
20 of the ink tank relies on the change of force applied
to a spring provided in a member for mounting the ink
tank, resulting from ink consumption, and detects the
remaining ink amount by activating an electrical
contact by the deformation of said spring.

25 However, such conventional methods as
explained above have been associated with the
following drawbacks.

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1 The limit remaining amount, at which the
recording operation becomes impossible, detected by
the above-mentioned methods, is influenced for
example by the unit-to-unit fluctuation of the
5 recording head in manufacture, and is not highly
reliable, so that the recording operation may be
disabled immediately after the warning for such limit
remaining amount or may still be properly conducted
even after such warning. According to the
10 experiments of the present inventors, such drawbacks
is particularly conspicuous in case ink is held in
the ink tank by means of an ink holding member such
as sponge.

Besides the amount of ink droplet discharge
15 per pulse is influenced not only by the unit-to-unit
fluctuation of the recording head but also by the
ambient temperature, so that the exact calculation
of the amount of ink consumption is difficult.
Furthermore, the detection by visual inspection or
20 by photosensor has been unable to provide sufficient
accuracy.

Furthermore, the configuration becomes
complex by the presence of the detection members such
as the spring or the photosensor, or the presence of
25 the transparent area, for the detection of the
remaining ink amount.

Furthermore, the above-mentioned conventional

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1 methods, though being capable of detecting the
disabled recording state resulting from the
interruption of ink supply caused by the ink
exhaustion, are unable to detect the disabled
5 recording state that may occur before the complete
exhaustion of ink. Such disabled recording state
before the ink exhaustion may be caused, for example,
by bubble formation, by air intrusion, in the ink
path between the ink tank and the recording head,
10 or by interruption of ink supply due to generation
or growth of a remaining bubble in a recording head
designed to generate a bubble for ink discharge, or
by destruction of meniscus at the ink discharge
opening due to vibration applied to the recording
15 apparatus or the recording head, thereby causing the
liquid to flow into the nozzle of the recording head
from said ink discharge opening.

SUMMARY OF THE INVENTION

20 In consideration of the foregoing, the
principal object of the present invention is to
provide an ink jet recording apparatus capable of
detecting the temperature characteristics for each
recording head and of effecting high precise
25 detection of the ink discharge state based on thus
detected temperature characteristics. Another object
of the present invention is to provide a method for

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1 detecting the temperature characteristics of the ink
jet recording head, and a method for judging the
ink discharge state of the ink jet recording head.

The foregoing objects can be attained,
5 according to the present invention, by an ink jet
recording apparatus for effecting recording by
discharging ink from a discharge opening onto a
recording medium, comprising an electrothermal
converter provided in said recording head;
10 temperature detection means for detecting the
temperature of said recording head; and temperature
characteristic detection means for applying a
predetermined energy to said electrothermal
converter, detecting the temperature change of said
15 recording head resulting from said energy application
by means of said temperature detection means and
detecting the temperature characteristics of said
recording head based on the result of said detection.

Also according to the present invention,
20 there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising input means for
enabling the operator to instruct the execution of
25 detection of the ink discharge state of said
recording head, and ink discharge state detection
means for causing said recording head to discharge

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1 ink and detecting the state of ink discharge thereof,
in response to the instruction of the operator
through said input means.

Also according to the present invention,
5 there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising ink discharge
state detection means for detecting the ink discharge
10 state of said recording head, and control means for
controlling said ink discharge state detection means,
in case defective ink discharge from said recording
head is detected by said means, thereby causing said
means to again detect the ink discharge state.

15 Also according to the present invention,
there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising an electrothermal
20 converter provided in said recording head;
temperature detection means for detecting the
temperature in the vicinity of said recording head;
and judging means for judging the ink discharge state
of said recording head, through comparison of the
25 temperature characteristics of said recording head
determined by the temperature change in the vicinity
of said recording head in response to a predetermined

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1 energy applied to said electrothermal converter and
the temperature detected by said temperature
detection means.

Also according to the present invention,
5 there is provided an ink jet recording apparatus for
effecting recording by means of a recording head
capable of discharging ink from a discharge opening
onto a recording medium, comprising ink discharge
state detection means for detecting the ink discharge
10 state of said recording head, and memory means for
storing, in case said ink discharge state detection
means detects defective ink discharge from said
recording head, the recording data at least since the
latest detection of the satisfactory ink discharge
15 state.

Also according to the present invention,
there is provided a method for detecting the
temperature characteristics of an ink jet recording
head, comprising steps of applying a predetermined
20 energy to an electrothermal converter provided in the
recording head for effecting recording by discharging
ink from a discharge opening onto a recording medium,
detecting the temperature change in said recording
head resulting from said energy application, and,
25 based on said detection, detecting the temperature
characteristics of said recording head.

Also according to the present invention,

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1 there is provided a method for judging the discharge
state of an ink jet recording head, which comprises
judging the ink discharge state of said recording
head, based on the result of detection of the
5 temperature characteristics according to the above-
mentioned method.

According to the configuration of the present
invention, in an ink jet recording apparatus for
effecting recording by means of a recording head
10 capable of discharging ink from a discharge opening
onto a recording medium, a predetermined energy is
applied to an electrothermal converter provided in
said recording head, then the temperature change of
said recording head resulting from said energy
15 application is detected by said temperature detection
means, and, based on the result of said detection,
the temperature characteristic detection means
detects the temperature characteristics of said
recording head.

20 Also based on the result of detection of the
temperature characteristics of the recording head
obtained by said temperature characteristic detection
means, the judging means judges the ink discharge
state of said recording head.

25

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view of an

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1 ink jet cartridge of the present invention;

Fig. 2 is an exploded perspective view of an
ink jet cartridge of the present invention;

Figs. 3A, 3B and 3C are schematic views of
5 a recording part of the ink jet cartridge shown in
Fig. 2;

Fig. 4 is a schematic perspective view of an
ink jet recording apparatus of the present invention;

Fig. 5 is a block diagram of an ink jet
10 recording apparatus constituting a 1st embodiment;

Fig. 6 is a chart showing the temperature
change in the vicinity of a heater board in case an
electrical energy is applied to a discharge heater;

Figs. 7A and 7B are charts showing the amount
15 of temperature change in the vicinity of the heater
board in the course of application of a predetermined
energy to the discharge heater;

Figs. 8A and 8B are charts showing an
example of ink discharge and non-discharge conditions
20 for the electrical energy in the present invention;

Fig. 9 is a chart showing temperature changes
in the vicinity of the heater board in case two
electrical energies of ink discharge condition and
ink non-discharge condition are applied to the
25 discharge heater;

Fig. 10 is a chart showing constants obtained
in case two electrical energies of ink discharge

1 condition and ink non-discharge condition are applied
to the discharge heater;

 Fig. 11 is a flow chart showing a first
method of detecting the ink discharge state described
5 in the first embodiment;

 Fig. 12 is a flow chart showing a second
method of detecting the ink discharge state described
in the first embodiment;

 Fig. 13 is a flow chart showing a third
10 method of detecting the ink discharge state described
in the first embodiment;

 Fig. 14 is a flow chart showing a method for
moving the recording head to a position opposed to
a cap, described in the first embodiment.

15 Figs. 15A and 15B are views showing the
structure and the principle of ink discharge of a
recording head employing a piezoelectric device;

 Fig. 16 is a chart showing the temperature
change in the vicinity of the heater board during
20 and after the application of an electrical energy
to the discharge heater;

 Fig. 17 is a chart showing the relationship
between the ambient temperature and the discharged
ink amount;

25 Fig. 18 is a schematic view of a recording
head provided with a plurality of temperature
sensors;

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1 Fig. 19 is a flow chart showing an example
of detection of the ink discharge state in a
recording head provided with plural temperature
sensors;

5 Fig. 20 is a block diagram of the control
system of a recording apparatus constituting a sixth
embodiment;

 Fig. 21 is a flow chart showing the setting
of variable timing of detection of the ink discharge
10 state;

 Fig. 22 is a block diagram of the control
system of a recording apparatus constituting a
seventh embodiment;

 Fig. 23 is a flow chart showing the repeated
15 detection of the ink discharge state and steps before
said repeated detection; and

 Fig. 24 is a flow chart showing the function
of a recording apparatus capable of re-recording,
constituting a seventh embodiment.

20

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now the present invention will be clarified
in detail by preferred embodiments thereof shown in
the attached drawings.

25 Fig. 1 is a perspective view of a head
cartridge 3 integrally composed of a recording head
1 and an ink tank 2, in which the present invention

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1 is applicable, and Fig. 2 is an exploded perspective
view of the head cartridge 3, wherein shown are a
heater board 110 provided with plural discharge
heaters formed in an array on a Si substrate and
5 electrical wirings for supplying electric power
thereto; a grooved cover plate 140 integrally
provided with plural nozzles, an orifice plate 141
having discharge openings corresponding thereto, and
a common liquid chamber for containing ink for supply
10 to said nozzles; a wiring board 120 which is
connected at an end to the heater board 110 for
example by wire bonding and is provided at the other
end with pads 121 for receiving electrical signals
from the main-body of the recording apparatus; and a
15 metal base plate 130 on which said wiring board 120
and said heater board 110 are adhered for example
with an adhesive material.

The heater board 110 and the grooved cover
plate 140 are fixed to the base plate 130, by
20 pinching said heater board 110 and the grooved cover
plate 140 with a press spring 150 and engaging the
leg portion thereof with a hole 131 in the base plate
130. An ink supply member 160 is provided with an
ink supply pipe 161 and an ink pipe 162 connected
25 thereto. The ink supply pipe 161 is connected to an
ink supply hole 101 of an ink tank 100, while the ink
pipe 162 is connected to an ink receiving hole 142 of

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1 the grooved cover plate 140, whereby there is formed
an ink path from the ink tank 100 to the discharge
openings of the orifice plate 141.

Fig. 3A shows the details of said heater
5 board 110, and Fig. 3B is a partially cut off
perspective view thereof. There is shown an array
111 of discharge heaters 111a, provided respectively
corresponding to nozzles, communicating with the
discharge openings of the orifice plate 141. By
10 applying a voltage to said array 111 of the discharge
heaters, the ink in the nozzles obtains thermal
energy and is discharged as droplets from the
discharge openings of the orifice plate 141, to
effect the recording operation. Heaters 112a, 112b
15 for temperature regulation can heat the vicinity of
the heater board 110. Temperature sensors 113a,
113b, which can be formed by the semiconductor film
forming technology in a similar manner as the heater
array 111 and the heaters 112a, 112b and
20 simultaneously therewith, can detect the temperature
in the vicinity of the heater array 111.

Hatched areas indicate the connecting
portions with the grooved cover plate 140. Each of
the discharge heaters constituting the array 111 is
25 an electrothermal converter of a resistance of 120 Ω ,
capable of providing an energy of about 3 W with a
driving voltage of 19 V. Also each of the heaters

1 112a, 112b, is composed of an electrothermal
converter of a resistance of $144\ \Omega$, capable of
providing an energy of 4.W with a driving voltage of
24 V. Each of the temperature sensors 113a, 113b is
5 composed of a diode sensor, varying the output by
about 2.5 mV per one degree of temperature.

In the following there will be given an
explanation on the principle of ink discharge of the
recording head, adapted for use in the ink jet
10 recording apparatus of the present embodiment as
the recording means of the present invention.

The recording head, adapted for use in the
ink jet recording apparatus, is generally provided
with a fine liquid-discharging opening (orifice), a
15 liquid path, an energy action part provided in a
part of said liquid path, and energy generating means
for generating a droplet forming energy to be applied
to the liquid present in said energy action part, and
is rendered replaceable. Such energy generating
20 means can, for example, be a mechanism utilizing an
electromechanical converter such as a piezoelectric
element, a mechanism in which an irradiating
electromagnetic wave such as a laser beam is absorbed
in liquid to generate heat therein and a droplet is
25 discharged and is caused to fly by the action of heat
generation, or a mechanism in which liquid is heated
by an electrothermal converter to cause a droplet to

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1 fly.

Among these mechanisms, the recording head of the ink jet recording utilizing the thermal energy for liquid discharge is capable of recording with a high resolving power, since the liquid discharging openings (orifices) for discharging recording liquid to form flying droplets can be arranged with a high density. Besides, the recording head utilizing the electrothermal converters as the energy generating means can be formed in a compact structure, and can also be easily formed as a long and flat or two-dimensional configuration, fully exploiting the advantages of the semiconductor technology and the microworking technology, showing remarkable progress and improvement in reliability in recent years. It has therefore been rendered possible to provide an ink jet recording head, which can be easily formed in a configuration with multiple nozzles and with a high density, and which has satisfactory mass producibility and a low manufacturing cost.

Such ink jet recording head employing an electrothermal converter for the energy generating means and produced with a semiconductor manufacturing process is generally provided with liquid paths respectively corresponding to ink discharge openings, in which an electrothermal converter is provided in each liquid path for applying thermal energy to the

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1 liquid present in each liquid path thereby
discharging liquid from the corresponding ink
discharge opening and forming a flying droplet, and
in which the liquid is supplied to the liquid paths
5 from a common liquid chamber. With regard to the
method for forming the ink discharge part, the
present applicant has proposed, in the Japanese
Patent Laid-Open Application No. 62-253457, a method
of laminating, on a first substrate, a solid layer
10 for at least forming the liquid paths, a layer of a
material curable with actinic energy at least
utilized for forming the walls of the liquid paths,
and a second substrate, then laminating a mask on
said second substrate, effecting irradiation with
15 actinic energy ray from above said mask thereby
curing at least the walls of the liquid paths in said
curable material layer, and eliminating said solid
layer and the uncured portions of said curable
material layer from the space between the two
20 substrates, thereby forming at least the liquid
paths.

Fig. 3C is a schematic view of the ink jet
recording head explained above. The recording head
1801 is composed of electrothermal converters 1803,
25 electrodes 1804, liquid path walls 1805 and a cover
plate 1806, formed through a semiconductor
manufacturing process including the steps of etching,

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1 evaporation, sputtering etc.

In such recording head 1801, recording liquid 1812 is supplied from an unrepresented liquid reservoir to a common liquid chamber 1808 through a liquid supply pipe 1807.

There is also provided a liquid supply pipe connector 1809. The recording liquid 1812 supplied into the common liquid chamber 1808 is supplied into the liquid paths 1810 by the capillary action, and is stably maintained at the ink discharge openings 1811 at the ends of the liquid paths, by meniscus formation. A current supply to the electrothermal converter 1803 heats the liquid present thereon; thereby generating a bubble by film boiling phenomenon, and a liquid droplet is discharged from the ink discharge opening 1811 by the growth of said bubble. The above-explained configuration allows to obtain an ink jet recording head of multiple liquid paths, such as 128 or 250 liquid paths, with a high liquid path density such as 16 path/mm.

Fig. 4 illustrates an example of the printer unit of the ink jet recording apparatus of the present embodiment. There are shown a head cartridge 201 including an ink jet recording head; a carriage 202 supporting the head cartridge 201 and effecting a scanning motion in a direction S; a hook 203 for mounting the head cartridge 201 onto the carriage 202;

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1 a lever 204 for operating the hook 203; a support
plate 205 for supporting an electrical connecting part
for the head cartridge; a flexible printed circuit
(FPC) 206 for connecting said electrical connecting
5 part and a control unit of the main body; and a guide
shaft 207 inserted in a bearing 208 of the carriage
202, for guiding the same in a direction S.

A timing belt 209, connected to the carriage
202 for moving the same in the direction S, is
10 supported by pulleys 210A, 210B positioned on both
ends of the apparatus. A pulley 210B receives the
driving force from a carriage motor 211, through a
transmission mechanism such as gears. A transport
roller 212 serves to define the recording face of the
15 recording medium such as paper, and to transport said
recording medium at the recording operation, and is
driven by a transport motor 213. There are also
provided a paper pan 214 for guiding the recording
medium to the recording position, and pinch rollers
20 215 provided in the feeding path of the recording
medium for pressing the same to the transport roller
212 and for transporting the same.

There are further provided a platen 216
opposed to the discharge openings of the head
25 cartridge 201 and serving to define the recording
face of the recording medium; discharge rollers 217
positioned at the downstream side of the recording

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1 position in the advancing direction of the recording
medium and serving to discharge the recording medium
toward an unrepresented discharge exit; spurs 218
positioned corresponding to the discharge rollers 217
5 and serving to press the discharge rollers 217 across
the recording medium, thereby generating the
transporting force of the discharge rollers 217 on the
recording medium; and a releasing lever 219 for
releasing the biasing action of the pinch roller 215
10 and the spurs 218 for example at the setting of the
recording medium.

The platen 216 is supported at both ends,
rotatably about the shaft of the discharge rollers 217,
and is biased from the stop position of the lateral
15 plates 220 toward a front portion 221 of the paper pan
214. The transport roller 212 is in contact, in
plural portions 212A of a reduced diameter, with the
inside of the front portion 221 of said paper pan.

A cap 222, composed of an elastic material
20 such as rubber and so positioned as to oppose to the
face containing the ink discharge openings of the
recording head at the home position, is so supports
as to be contacted to or separated from said recording
head. Said cap 222 is used for protecting the
25 recording head in the non-recording state, or for the
discharge recovery operation for the recording head.

Such discharge recovery operation is conducted

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1 for example by positioning the cap 222 opposite to
said face containing the ink discharge openings and
activating the energy generating elements, provided in
the nozzles of the recording head for ink discharge
5 thereby discharging ink from all the discharge
openings and thus eliminating bubbles and dusts which
are the cause of defective discharge or viscosified
ink unsuitable for recording (operation called
preliminary discharge), or by covering said face
10 containing the discharge openings with the cap 222 and
forcibly sucking the ink from all the discharge
openings with a suction pump, thereby eliminating the
cause of defective discharge.

A pump 223 provides the suction force for
15 forced discharge of ink and is used for sucking the
ink received by the cap 222, at the discharge recovery
operation by such forced discharge or by the
preliminary discharged. A used ink tank 224, for
receiving the used ink sucked by the pump 223, is
20 connected with said pump 223 through a tube 228.

A blade 225, for wiping the face containing
the discharge openings of the recording head, is
supported movably between a position protruding
toward the recording head for effecting the wiping
25 operation in the course of carriage movement and a
retracted position not engaging with said face. There
are further provided a motor 226, and a cam device

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1 227 for driving the pump 223 and moving the cap 222
and the blade 225 by the driving force transmitted
from said motor 226.

Fig. 5 is a block diagram showing an example
5 of the control system of the recording apparatus
explained above.

The capping position and the moved position
of the carriage 202 shown in Fig. 4 can be known by
a recovery system home position sensor 235 and a
10 carriage home position sensor 236. In Fig. 5, there
are shown an MPU 1000 for controlling various units
by executing a control sequence according to a
predetermined program; a ROM 1001 storing the program
corresponding to said control sequence; and a RAM used
15 as a work area in the execution of said control
sequence.

In the following there will be given a
detailed explanation on the measurement of the
temperature characteristics of the above-explained
20 recording head, and the method of detecting the
discharge state of ink, utilizing said measurement.
[Embodiment 1]

At first there will be explained a first
embodiment of the present invention.

25 Fig. 6 is a chart showing the temperature
change in the vicinity of the heater board 110 when
an electrical energy is given to the discharge heaters

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1 111.

A curve A shows a state of normal ink discharge, while a curve B shows a state of absence of ink discharge due to insufficient ink filling in the liquid paths of nozzles in the recording head or in the common liquid chamber communicating thereto. It will be understood that the temperature change is larger in the absence of ink discharge (curve B) than in the presence of ink discharge (curve A). In general, the temperature of the heater board 110 is determined by the heat supply from the discharge heaters 111 constituting the heat source, and by the heat dissipation to the base plate 130 and the grooved cover plate 140. In the presence of ink discharge, the heat dissipation becomes larger because the ink is discharged to the outside with heat, and the difference in temperature characteristics results for this reason.

It is consequently possible to detect whether the ink discharge is possible, by detecting the temperature characteristics in the vicinity of the heater board 110 when a predetermined electrical energy inducing the ink discharge is applied to the discharge heaters 111.

More specifically, at first the temperature change dT_A is measured in the vicinity of the heater board 110 when the predetermined electrical energy

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1 inducing the ink discharge is applied to the discharge
heaters 111 in a normal state in which the nozzles and
the common liquid chamber communicating thereto are
sufficiently filled with ink. Then the temperature
5 change dTB after a predetermined time is measured in
a state in which ink is absent in the nozzles and in
the common liquid chamber. When these measurements
are conducted on a plurality of heat cartridges and
are statistically processed, there are obtained
10 plottings as shown in Fig. 7A. In this manner there
are determined, in advance, the maximum value TA of
 dTA and the minimum value TB of dTB .

Fig. 11 is a flow chart showing the sequence
of detecting the ink discharge state, to be executed
15 by the MPU 1000, and a corresponding program is stored
in the ROM 1001. In the following there will be
explained a first method for detecting whether the
ink discharge is possible. At first the above-
mentioned predetermined electrical energy is applied
20 to the discharge heaters 111 (step S1). Then the
temperature change dT in the vicinity of the heater
board 110 is measured by the recording head
temperature sensor 113 (step S2), and is compared
with the values TA , TB (steps S3, S4). Based on said
25 comparison, the ink discharge state is identified as
normal if $dT \leq TB$ (step S6), or as abnormal if $dT \geq$
 TB (step S5). Since TA and TB are determined from the

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1 measurements of a plurality of recording heads, there
is not encountered a situation $TA < dT < TB$.

The above-mentioned predetermined electrical
energy including ink discharge is, for example as
5 shown in Fig. 8A, composed of 1000 pulses of a pulse
duration of 7 μ sec and a frequency of 4 kHz, applied
to all of 64 nozzles, and said energy is defined as
E1. In this case TA, TB are respectively about 14.5°
and 15.5°.

10 In the following there will be explained a
second method which is applicable even in case the
temperature characteristics show a large fluctuation
among different head cartridges.

The above-explained method is not usable in
15 case the fluctuation among different head cartridges
is large so that the maximum value of dTA is larger
than the minimum value of dTB, namely in case of
TA > TB as shown in Fig. 7B. Such fluctuation in the
temperature characteristics may result from the
20 fluctuation in the thickness of the adhesive material
between the heater board 110 and the base plate 130,
or in the resistance of the discharge heaters 111, or
in the dimension or the physical properties of the
heater board and the base plate. Also in case the
25 ink discharge is conducted, such fluctuation may also
arise from the change in the amount of heat
dissipation by the in, due to variations in the

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1 size of ink droplets and in the physical properties
of ink.

As the relationship $dTB > dTA$ stands for all
the head cartridges as explained in relation to Fig.
5 6, a value $(dTB - dTA)$ is calculated for each head
cartridge and the minimum TD of said values is
statistically determined, based on the data partially
shown in Fig. 7B. Thus, a relationship $dTB - dTA \geq TD$
stands for any head cartridge. Also it is assumed in
10 general that the nozzles are in the normal ink filling
state at the start of the recording operation, because
of the automatic discharge recovery process.

Fig. 12 is a flow chart showing said second
method. At first, at the start of the recording
15 operation, at which the nozzles are in the normal ink
filling state, the above-mentioned predetermined
electrical energy is applied to the discharge heaters
111 (step S7), and the temperature change in the
vicinity of the heater board 110 is measured in order
20 to determined dTA (step S8). For detecting whether
the ink discharge is possible, the above-mentioned
predetermined electrical energy is applied to the
discharge heaters 111 (step S9), then the temperature
change dT in the vicinity of the heater board is
25 measured (step S10), and the ink discharge state is
identified as normal if $dT \leq dTA$ (step S14), or as
abnormal if $dT \geq dTA + TD$ (step S13).

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1 When said predetermined electrical energy is
selected as E1 mentioned before, the TD becomes about
2°.

 However, since this method unconditionally
5 assumes that the temperature change in the vicinity
of the heater board 110 is equal to dTA when said
predetermined electrical energy is applied to the
discharge heaters 111 at the start of the recording
operation, there will be encountered an erroneous
10 detection if the ink filling state of the nozzles
becomes abnormal for some reason at the start of the
recording operation.

 In the following there will be explained a
third method for avoiding this drawback, by utilizing
15 reference temperature characteristics not related to
the ink filling state of the nozzles, measured for
each head cartridge.

 As already explained in relation to Fig. 6,
the difference in the temperature characteristics
20 resulting from the ink filling state of the nozzles
is caused by the heat dissipation at the ink
discharge. Therefore, for obtaining the reference
temperature characteristics mentioned above, there
can be conceived to provide the discharge heaters
25 with a low electrical energy that will not induce ink
discharge even at the normal ink filling state of the
nozzles.

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1 Said predetermined electrical energy not
inducing the ink discharge even in the normal ink
filling state of the nozzles can be, for example as
shown in Fig. 8B, 3000 pulses of a pulse duration of
5 2 μ sec and a frequency of 6 kHz applied to all of 64
nozzles, and said electrical energy is defined as E2.
When said electrical energy E2 is applied to the
discharge heaters 111, the temperature change in the
vicinity of the heater board 110 remains substantially
10 same regardless of the ink filling state of the
nozzles, because the heat is not dissipated by the ink
discharge.

Now, let us consider the relationship between
the reference temperature characteristics, obtained
15 by the application of the electrical energy E2 which
does not induce the ink discharge even in the normal
ink filling state of the nozzles and is exemplified
in Fig. 8B, and the temperature characteristics,
obtained by the application of the electrical energy
20 E1 as shown in Fig. 8A and inducing the ink discharge.

Fig. 9 is a chart showing the temperature
changes in the vicinity of the heater board 110, when
the above-mentioned two electrical energies are
applied to the discharge heaters 111.

25 A curve A shows a case with appropriate ink
filling in the nozzles and in the common liquid
chamber communicating therewith and with normal ink

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1 discharge under the application of the electrical
energy E1, while a curve B indicates a case of absence
of ink in the nozzles and in said common liquid
chamber under the application of said electrical
5 energy E1. A curve C indicates the case of
application of the electrical energy E2, and the
curve remains substantially same regardless of the
ink filling state, as explained before. The
respective temperature changes are represented by
10 dTA, dTB and dTC.

When these measurements are conducted on
plural head cartridges, the values of dTA, dTB, dTC
are different among different head cartridges, but
following relations stand for each head cartridge:

15
$$dTA = K1 \times dTC \quad (K1 \text{ being constant for each cartridge})$$

$$dTB = K2 \times dTC \quad (K2 \text{ being constant for each cartridge})$$

$$K1 < K2$$

20 Thus, if the constants K1, K2 are known, the
temperature changes dTA, dTB relating to the presence
or absence of ink can be calculated from the
temperature change dTC based on the reference
temperature characteristics.

25 Then, let us give further consideration on the
constants K1, K2.

Fig. 10 shows the constants K1, K2 in the

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1 plural head cartridges Nos. 7 to 12, showing large
fluctuations in the temperature characteristics, in
the measurement shown in Fig. 7B. As will be seen
from Fig. 10, there stands a relationship:

5 $K_{1\max} < K_{2\min}$

between the maximum value $K_{1\max}$ of K_1 and the minimum
value $K_{2\min}$ of K_2 . Said relationship stands even in
the head cartridges with significant fluctuation in
the temperature characteristics, because the ratios
10 of the temperature changes dTA , dTB , dTC , based on the
temperature characteristics of each cartridge, are
considered instead of said temperature changes
themselves.

Therefore, there are obtained relationship:

15 $dTA \leq K \times dTC$

$$dTB \geq K \times dTC$$

for all the head cartridges by selecting a new
constant K so as to satisfy a relation:

$$K_{1\max} < K < K_{2\min} \quad (1).$$

20 Fig. 13 is a flow chart showing a detecting
sequence for the ink discharge state, based on the
above-mentioned relations. At first a predetermined
electrical energy E_2 not inducing the ink discharge
is applied to the discharge heaters (step S15), and
25 then the temperature change dTC of the recording head
is measured (step S16). Subsequently a predetermined
energy E_1 inducing the ink discharge is applied to

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- 1 the discharge heaters (step S17), then the temperature
change dT of the recording head is measured (step S18)
and is compared with $K \times dTC$ (step S19), whereupon the
ink discharge state is identified as normal if
5 $dT \leq K \times dTC$ (step S20) or as abnormal if $dT \geq K \times dTC$
(step S21).

When the aforementioned electrical energies
 $E1$, $E2$ are adopted, the values of $K1_{max}$, $K2_{min}$ were
experimentally determined as about 1.45 and 1.75.

- 10 Consequently, in this case, the value K can be
selected for example as 1.6, in order to satisfy the
aforementioned relation (1).

In the ink discharge state detecting methods
explained above, the temperature detection by the
15 temperature sensor is conducted during the application
of the electrical energy to the discharge heaters.
Since the temperature drops rapidly after the
application of the predetermined energy, there may
result an error in the detection if the detection is
20 repeated plural times after said energy application.
For this reason, the temperature detection is
preferably conducted during the energy application.

However, if the energy application is executed
in the pulse form as shown in Figs. 8A and 8B, stable
25 detection is difficult because of an abrupt
temperature change or a noise generation when the
pulse signal is turned on. In the present embodiment,

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1 therefore, the temperature detection in the course
of energy application is conducted in synchronization
with said pulses, when the pulse is turned off. Also
if the temperature detection has to be conducted
5 after the energy application, it is executed within
a limited or short time after the energy application.

In the following there will be explained the
recording process, with reference to Fig. 4, in a
recording apparatus capable of detection of the
10 temperature characteristics of the recording head
and detection of the ink discharge state utilizing
said temperature characteristics.

At first, when the power supply to the
recording apparatus is turned on, the recovery motor
15 226 is activated to set the recovery unit at the home
position of the recovery system and to retract the
cap 222. Then the carriage 202 is set at the home
position opposed to the cap 222. Then the cap 222
is again contacted with the nozzles of the recording
20 head, and the entry of the recording data signal is
awaited. In response to said entry, the transport motor
213 is activated to initiate the feeding of the recording
medium, such as paper, up to a front end position of
the desired recording. Then the cap 222 is retracted
25 and separated from the nozzles of the recording head,
and the carriage 202 is set at the home position

1 opposed to the cap 222. Subsequently the
predetermined preliminary discharge is executed, and
the carriage 202 is moved to a desired recording
start position. Said preliminary discharge in this
5 embodiment is executed prior to the recording
operation; and also in the course of the recording
operation, by the movement of the carriage 202 to said
home position again, after the lapse of a
predetermined period of T seconds from the preceding
10 preliminary discharge.

Thereafter desired recording operation is
executed by the discharge of ink droplets according
to ink discharge signals corresponding to the
recording data. After the recording of a page of the
15 recording medium, the recording medium is discharged,
and there are conducted the detection of the
temperature characteristics of the recording head and
of the ink discharge state. In the present
embodiment, the detection of the ink discharge state
20 is conducted after the recording of a page. Thus said
detection is executed after the recording of a page
if the recording data are less than a page, or after
the recording of each page if the recording data cover
plural pages.

25 Since the detection of the ink discharge state
involves ink discharging operation, it is executed, as
in the preliminary discharge explained before, at the

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1 home position where the carriage is opposed to the cap
222. Fig. 14 is a flow chart showing said detection
process. When the detection sequence is initiated,
there is discriminated, by unrepresented position
5 detecting means, whether the head cartridge 201 is
located at the position opposed to the cap (step S22),
and, if not, the carriage is moved to the position
opposed to the cap 222 (steps S23, S24). If the step
S22 identifies that the head cartridge 201 is
10 positioned opposite to the cap, a step S24
discriminates whether the cap 222 is in contact with
the face including the ink discharge openings, and,
if in contact, the cap is opened (step S25). Said
detection is executed while the cap 222 is not
15 contacting said face including the ink discharge
openings, in order to prevent that the ink discharged
and received in the cap 222 comes into contact with
said face.

In the detection of the ink discharge state,
20 the ink discharge inducing energy, composed of 1000
pulses of a pulse duration of 7 μ sec and a frequency
of 4 kHz applied to all of 64 nozzles, causes the
discharge of ink of about 5 mg. In order to avoid
contamination of the interior of the recording
25 apparatus by the discharged ink, it is discharged
toward the cap. Also in the present embodiment, in
order to ensure the reception of ink into the cap, and

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1. also for discarding the ink in the cap or in the pump
223 connected to the cap 222 in advance, the pump 223
is activated to effect suction while the cap 222 is
separated from the face containing the discharge
5 openings of the recording head. This operation is
executed before and after said detection of the ink
discharge state, whereby said detection can be
conducted without contamination of the apparatus with
ink.

10 If an abnormal discharge state is detected in
said detection of the ink discharge state, an
abnormality signal is generated to display a warning
message, to turn on a light-emitting diode, or to
inform an alarm by information means 1004 such as an
15 alarm buzzer. When the abnormal state is eliminated
by the user, there is executed a predetermined re-
starting procedure.

As explained in the foregoing, the detection
of the ink discharge state based on the temperature
20 characteristics of the recording head allows exact
detection without particular components therefor.
Also the present embodiment enables detection with an
inexpensive configuration, since the energy
application for said detection of the ink discharge
25 state is made to the ink discharge means, and since
the temperature detection is achieved by a temperature
sensor which is manufacturable simultaneously with the

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1 ink discharge means.

Also the above-explained second and third
methods for detecting the ink discharge state are
applicable even when the temperature characteristics
5 of the recording head involve fluctuation.
Consequently there can be provided advantages of
alleviating the control of precision in the dimension
and material of the heater board or base plate and in
the thickness of the aforementioned adhesive material,
10 thus reducing the manufacturing cost, and advantages
that such methods are applicable regardless of the
kind, physical properties and droplet size of the ink.

Also as the detection of the ink discharge
state is executed when the recording head is opposed
15 to an ink receiving member such as a cap, and as the
ink is eliminated from said ink receiving member for
example by the ink suction before and after said
detection, the discharged ink can be securely captured
and the contamination within the recording apparatus
20 can be minimized.

The above-explained embodiment employs a diode
sensor for detecting the temperature, but other
sensors are likewise usable as long as the temperature
of the recording head can be detected. For example
25 the temperature can be detected by measuring the
resistance of the electrothermal converters such as
discharge heaters or other heaters. Also the

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1 temperature sensor is provided on the heater board,
but such configuration is not limitative.

Furthermore, the recording apparatus may be
provided with an ink receiving member composed for
5 example of sponge, capable of absorbing and retaining
the ink, separately from the cap 222, and the ink
discharge for detecting the ink discharge state may be
conducted on such ink receiving member. Also
information by the informing means is given when an
10 abnormal result is obtained by the detection, but the
information may be provided in case said detection
indicates a normal state, and the result of said
detection may be provided by the recording apparatus
or by the host apparatus:

15 [Embodiment 2]

According to the invention described in the
first embodiment, an electrical energy is applied to
the ink discharge heater to effect the heating
thereof, in order to know the temperature
20 characteristics of the recording head. However the
heating means, to be used for heating the recording
head for obtaining said temperature characteristics,
is not limited to the discharge heaters, and there
will be explained another method in the present
25 embodiment. The recording head (head cartridge) of
the first embodiment is provided, as already explained
in relation to Figs. 3A to 3C, with heaters 112a, 112b for

1 temperature regulation of the recording head, in
addition to the discharge heaters. Consequently the
temperature characteristics of the recording head can
be detected, also by applying a predetermined
5 electrical energy to such heaters.

However, the ink discharge state cannot be
detected from the temperature characteristics obtained
by the heating of said heaters, since ink discharge is
not induced by said heating.

10 For this reason, the following method is
adopted for detecting the ink discharge state, in case
the above-mentioned heaters not constituting the ink
discharge means are used as the heating means for
obtaining the temperature characteristics of the
15 recording head.

As explained in the first embodiment, the
difference in the temperature characteristics arises
from whether the ink discharge is executed or not. It
is therefore conceived to drive the discharge heaters
20 also, for discharging the ink, in the course of
activation of the above-mentioned heaters. Thus there
can be obtained a temperature change of the heater
board, similar to that shown in Fig. 6, according to
the ink filling state in the nozzles and in the common
25 liquid chamber connecting thereto. Consequently the
method of the first embodiment can be likewise
applied, by integrally considering the heating with

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1 the temperature-regulating heaters and that with the
discharge heaters. The temperature characteristics
not related to the ink filling state of the nozzles
can be obtained by activating the temperature-
5 regulating heaters only.

In the present embodiment, the detection of
the temperature characteristics is achieved by heaters
different from the discharge heaters. Consequently
the discharge heaters are used only for the ink
10 discharge, and the ink discharge means is not limited
to heaters. Thus the present embodiment is applicable
to the ink jet recording apparatus equipped with a
heater different from the heaters for ink discharge.
Ink discharge means not relying on the heater include
15 those employing an electromechanical converter such as
a piezoelectric element, and Figs. 15A and 15B
illustrate the cross-sectional view of such nozzle,
wherein illustrated a piezoelectric element 301, a
heater 302, and a discharge opening 303. Fig. 15B
20 illustrates the principle of ink discharge. Ink is
supplied from the left. A pulse supply to the
piezoelectric element 301 generates a mechanical
distortion therein, thus inducing ink discharge from
the discharge opening 303.

25 [Embodiment 3]

In the embodiments 1 and 2, the temperature
characteristics are determined by detecting the rise

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1 in temperature of the recording head when an
electrical energy is applied to the ink discharging
heaters or the temperature-regulating heaters.
However, the method of temperature measurement is
5 not limited to such methods, and another method will
be explained in the present embodiment. The heater
board exhibits the temperature change as already
explained in Fig. 6, when the electrical energy is
applied to the heaters. After said energy
10 application, the temperature of the heater board
descends by heat dissipation, as shown in Fig. 16.
Said temperature descent is determined by the
temperature of the heater board at the end of
application of the electrical energy, and the
15 difference from the ambient temperature. Consequently
the temperature changes dT_a , dT_b within a
predetermined period dt after the end of application
of the electrical energy are correlated with the
temperature changes (increases) dTA , dtB caused by
20 said energy application. Therefore, the method of
the first embodiment can be still applied by measuring
 dT_a , dT_b and replacing the aforementioned values of
 dTA , dtB with thus measured values. In the method
of this embodiment, the detection of temperature
25 characteristics of the recording head is not affected
by the noises resulting from the activation of the
heaters, because said detection is executed after the

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1 end of application of the electrical energy to said
heaters. Thus there is obtained an advantage that the
timing of temperature detection with the temperature
sensor can be arbitrarily selected.

5 [Embodiment 4]

The ink jet recording method is influenced by
a change in the physical properties of the ink, since
the principle of ink discharge utilizes such physical
properties. As a representative example, the amount
10 of ink discharge varies depending on the ambient
temperature. In general, the amount of ink discharge
in the ink jet recording decreases, as shown in Fig.
17, when the ambient temperature becomes lower,
because the ink viscosity increases at a lower
15 temperature.

If the ink discharge amount varies excessively
by the ambient temperature, a correction for the
ambient temperature may become necessary in the
foregoing embodiments, and the present embodiment
20 effects such correction for the temperature.

As already explained in the first embodiment,
the difference in the temperature characteristics
arises from the heat dissipation by the ink discharge.
Thus the above-mentioned temperature change ΔT_A
25 becomes larger or smaller respectively when the ink
discharge amount decreases or increases from the
normal amount. Stated differently, the variation in

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1 dTA by the ambient temperature becomes no longer
negligible, if the ink discharge amount varies
significantly depending on the ambient temperature.

Thus, there will be explained a method of
5 preventing the excessive variation of dTA from the
reference value at a reference temperature, despite
of the variation of the ambient temperature. Such
temperature compensation can be achieved by increasing
or decreasing the energy applied to the heaters,
10 respectively when the ambient temperature is lower
or higher than the reference temperature. More
specifically, there is determined an applied energy
for providing the optimum dTA for each ambient
temperature, by collecting data of dTA for different
15 applied energies for each ambient temperature, and
the energy applied to the heaters is controlled
according to said data.

The applied energy may be varied by a change
in the pulse duration, the number of applied pulses
20 or the applied voltage.

It is also possible, instead of varying the
energy applied to the heaters, to vary the criteria
of judgment utilizing the detected temperature
characteristics (temperature change) according to
25 the ambient temperature.

For example, in the 3rd method of the first
embodiment, the value of the constant K_1 varies

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1 depending on the ambient temperature. It is therefore
conceivable to calculate the constant K1 for each
ambient temperature and to determine the optimum
constant K for each ambient temperature.

5 [Embodiment 5]

In the following there will be explained an
application in which the recording head is provided
with plural temperature sensors.

Fig. 18 shows a configuration of the heater
10 board 110, in which, in the array of the discharge
heaters 111, a temperature sensor 113 is provided for
example for every eight discharge heaters. Thus, if
the heater board 110 has 64 discharge heaters, there
will be 8 temperature sensors 113 on the same heater
15 board. The outputs dT1 - dT8 of said eight
temperature sensors are transmitted to the printer
control unit shown in Fig. 5 and supplied to the MPU
1000. Based on each result of temperature detection,
there can be discriminated whether the ink discharge
20 state is normal or abnormal, according to the
detecting procedure explained in the first embodiment.

Each temperature sensor represents best the
temperature state in the vicinity of said sensor, so
that an abnormal ink discharge state, identified by
25 the temperature detection by a sensor, can be
considered to indicate abnormal ink discharge of the
ink discharge means in the vicinity of said sensor.

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1 In the present embodiment with plural temperature
sensors, the abnormal state is informed by the
informing means 1004 if an abnormal state is found in
any of the detected temperature changes $dT1 - dT8$,
5 as shown in a flow chart in Fig. 19.

The control sequence of the present embodiment
will be explained with reference to Fig. 19. At first
a step S26 measures the temperature change $dT1$ by
first temperature sensor 1. Based on said
10 measurement, a step S27 effects the temperature
comparison as explained in the first embodiment, and,
if a step S37 identifies an abnormal discharge state,
a step S38 generates an alarm. On the other hand, if
the discharge state is normal according to the
15 detection by the sensor 1, a step S28 measures the
temperature change $dT2$ in a similar manner by a sensor
2. Thereafter the temperature detections are
conducted to a sensor 8 in succession in a similar
manner (steps S28 to S34), and the abnormality is
20 informed by said informing means if the abnormal
discharge state is detected in any of said sensors.
On the other hand, if all the results of said sensors
are normal, the ink discharge state is identified as
normal.

25 A more accurate detection of the ink discharge
state is made possible by the use of such plural
temperature sensors. In the present embodiment, there

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1 is provided a temperature sensor for every eight
discharge heaters, but such configuration is not
limitative, and it is also possible to provide each
discharge heater with an individual temperature sensor
5 and to detect the ink discharge state for each
discharge heater by detecting the temperature
characteristics thereof. Also the abnormality is
informed in case any of the detected results is
abnormal, but such process can be arbitrarily selected
10 according to the characteristics of the recording
head or the structure of the recording apparatus.
Also this embodiment is applicable to the ink jet
recording head employing the aforementioned
electromechanical converters, if it is provided with
15 an electrothermal converter for temperature
regulation, separate from the ink discharge means.

[Embodiment 6]

The detection of the ink discharge state
according to the present invention is conducted, as
20 explained in the first embodiment, after the
completion of recording operation of every page,
but timing of such detection may be rendered variable,
as will be explained in the following.

Fig. 20 is a block diagram of a recording
25 apparatus in which the timing of said detection can
be set in variable manner. Input means 1005 is
provided, for entering said timing, separately from

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1 the keyboard, but said keyboard may also be used for
said input means.

Since the detection of the ink discharge state
involves the ink discharge, the amount of ink
5 available for recording decreases, though slightly,
when such detection is executed. The configuration
in which the user can vary the timing of such
detection allows to economize the ink amount consumed
in such detection, and also allows to improve the
10 accuracy of detection by effecting the detections at
a short interval.

Fig. 21 is a flow chart for the setting of
the timing of said detection. As an example, the
detection is executed at an interval, in the automatic
15 mode, selected either by a number of days (steps S41,
S42), or by a number of hours (steps S43, S44), or
by a number of recorded sheets (steps S45, S46) or by
a number of recorded characters (steps S47, S48), or
executed, in the manual mode, in response to an
20 instruction entered from the input means 1005 (steps
S39, S40). In addition to such presettable intervals,
there may be selected a standard default interval,
stored in the control unit of the recording apparatus
(step S49).

25 The detection of the ink discharge state is
executed according to the timing or the interval thus
set.

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1 Such settable timing of detection allows to
economize the ink consumption required in the
detection of the ink discharge state, and to improve
the accuracy of detection. In the present embodiment,
5 said manual mode is rendered selectable separately
from the automatic mode in which the detection is
executed at a preset interval, but it is also possible
to combine both modes whereby the detection is
normally executed at the present interval but is
10 additionally executed in response to an instruction
entered through the input means when necessary. Also
the present embodiment is applicable to any ink jet
recording apparatus, regardless of the means for
detecting the ink discharge state or of the ink
15 discharge means in the loaded recording head.

[Embodiment 7]

 In the following there will be explained an
ink jet recording apparatus capable of detecting the
ink discharge state, provided with memory means
20 capable of retaining a series of recording data, and
adapted to retain the recording data in case
abnormality is detected in said detection and to
repeat the recording operation according to thus
retained data. Fig. 22 is a block diagram of such
25 recording apparatus, in which provided input means
1005, capable of entering the timing of detection of
the ink discharge state and an instruction for

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1 detection in the manual mode as explained in the
preceding embodiment, and memories 1006a, 1006b
capable of retaining a series of recording data. Said
memories may be provided only in either of the printer
5 unit and the control unit.

At first, with respect to the detection of the
ink discharge state of the present embodiment, there
will be explained the difference from the method of
the first embodiment, with reference to the flow
10 chart shown in Fig. 23. Said detection is executed
by the method already explained in the first
embodiment, but an improved accuracy of detection is
attained by executing, once abnormal discharge state
is detected, another detection of the discharge state
15 after an automatic discharge recovery operation
including the ink suction from the recording head
(step S59) and an ink discharge operation of a
predetermined amount (step S60), and the abnormality
is identified if the abnormality is detected in such
20 repeated detection also after the initial abnormality
detection.

Said discharge recovery operation and said
ink discharge of predetermined amount are executed
in order to confirm whether the initial abnormality
25 detection is due to the exhaustion of ink in the
recording head. More specifically, said operations
are executed in order to discriminate whether the

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1 initial abnormality detection is due to bubble
formation in the ink path of the recording head or
interruption of ink supply for example by the meniscus
destruction resulting from vibration at the ink
5 discharge openings, that may occur prior to the
exhaustion of ink, or due to ink exhaustion in the
recording head.

If the ink is not yet exhausted, the ink
supply from the ink tank can be restored by the
10 discharge recovery operation including the suction
operation (step S59), and, the ink supply is secured
by the ink discharge of a predetermined amount in the
step S60. Thus the normal ink discharge state is
confirmed in the repeated detection. However, if
15 said detected abnormality is due to the ink
exhaustion, the secure ink supply cannot be restored
in the discharge recovery operation. Even if the ink
of a small amount is guided to the ink discharge means
by said suction operation from the ink tank, the ink
20 supply will be again interrupted in the succeeding
ink discharge operation of the predetermined amount,
so that the discharge abnormality is detected again
in the repeated detection.

Fig. 24 is a flow chart showing the control
25 sequence in which the recording data are retained in
the memory means 1006 shown in Fig. 22, whereby the
loss of the recording data, resulting from the

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1 abnormality in discharge, can be prevented. When an
abnormality in ink discharge is detected (step S62),
the serial recording data that have been recorded at
said detection are stored in the memory means 1006
5 (step S63). Then the detection of abnormality is
informed (step S64), and the inspection of the
recording head is requested (step S65). Upon
detection of the completion of such inspection or of
the replacement of the recording head (step S66), and
10 in response to the entry of a command for re-recording
(step S67), there is discriminated whether a cassette
sheet feeder (CSF) is mounted on the recording
apparatus (step S68), and, if mounted, the sheet
feeding operation is conducted (step S69), but, if
15 not mounted, the sheet feeding is requested for
example by a message display (step S70). After the
sheet feeding operation is confirmed (branch YES in
step S71), the recording data are read from said
memory means 1006 (step S72) and the re-recording
20 operation is conducted, based on said recording data
(step S73).

In the present embodiment, the position of
the recording data, from which the re-recording is to
be started, can be instructed, so that the re-
25 recording is executed from a data position which
can be arbitrarily instructed according to the
location of the abnormality in the recording.

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1 This embodiment is particularly suitable, among
various recording apparatus, for use in the
communication equipment such as the facsimile
apparatus, in which the necessity for re-recording
5 after the abnormality detection is high and the loss
of recording data is considered critical.

As explained in the foregoing, it is rendered
possible to improve the accuracy of detection, by
repeating the detection for ink discharge state, after
10 a discharge recovery operation including a sucking
operation and after a predetermined ink discharging
operation, and also to prevent the loss of recorded
data resulting from discharge abnormality, by
retaining the recording data.

15 In the present embodiment, the completion of
inspection of the recording head or of replacement
thereof may be entered by the user through the input
means. However, such information may be also obtained
automatically by detecting the replacement of the
20 recording head or the detachment and attachment
thereof.

The present invention has been explained by
embodiments of the recording apparatus equipped with
so-called serial-type recording head, but it is
25 likewise applicable to the recording apparatus
employing so-called full-line recording head.

The present invention is particularly suitably

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1 usable in an ink jet recording head and recording
apparatus wherein thermal energy by an electrothermal
transducer, laser beam or the like is used to cause a
change of state of the ink to eject or discharge the
5 ink. This is because the high density of the picture
elements and the high resolution of the recording are
possible.

The typical structure and the operational
principle are preferably the ones disclosed in U.S.
10 Patent Nos. 4,723,129 and 4,740,796. The principle
and structure are applicable to a so-called on-demand
type recording system and a continuous type recording
system. Particularly, however, it is suitable for
the on-demand type because the principle is such that
15 at least one driving signal is applied to an
electrothermal transducer disposed on a liquid (ink)
retaining sheet or liquid passage, the driving signal
being enough to provide such a quick temperature rise
beyond a departure from nucleation boiling point, by
20 which the thermal energy is provided by the
electrothermal transducer to produce film boiling on
the heating portion of the recording head, whereby a
bubble can be formed in the liquid (ink) corresponding
to each of the driving signals. By the production,
25 development and contraction of the bubble, the liquid
(ink) is ejected through an ejection outlet to produce
at least one droplet. The driving signal is

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1 preferably in the form of a pulse, because the
development and contraction of the bubble can be
effected instantaneously, and therefore, the liquid
(ink) is ejected with quick response. The driving
5 signal in the form of the pulse is preferably such
as disclosed in U.S. Patents Nos. 4,463,359 and
4,345,262. In addition, the temperature increasing
rate of the heating surface is preferably such as
disclosed in U.S. Patent No. 4,313,124.

10 The structure of the recording head may be
as shown in U.S. Patent Nos. 4,558,333 and 4,459,600
wherein the heating portion is disposed at a bent
portion, as well as the structure of the combination
of the ejection outlet, liquid passage and the
15 electrothermal transducer as disclosed in the above-
mentioned patents. In addition, the present invention
is applicable to the structure disclosed in Japanese
Laid-Open Patent Application No. 59-123670 wherein
a common slit is used as the ejection outlet for
20 plural electrothermal transducers, and to the
structure disclosed in Japanese Laid-Open Patent
Application No. 59-138461 wherein an opening for
absorbing pressure wave of the thermal energy is
formed corresponding to the ejecting portion. This
25 is because the present invention is effective to
perform the recording operation with certainty and
at high efficiency irrespective of the type of the

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1 recording head.

The present invention is effectively applicable to a so-called full-line type recording head having a length corresponding to the maximum recording width. Such a recording head may comprise a single recording head and plural recording head combined to cover the maximum width.

In addition, the present invention is applicable to a serial type recording head wherein the recording head is fixed on the main assembly, to a replaceable chip type recording head which is connected electrically with the main apparatus and can be supplied with the ink when it is mounted in the main assembly, or to a cartridge type recording head having an integral ink container.

The provisions of the recovery means and/or the auxiliary means for the preliminary operation are preferable, because they can further stabilize the effects of the present invention. As for such means, there are capping means for the recording head, cleaning means therefor, pressing or sucking means, preliminary heating means which may be the electrothermal transducer, an additional heating element or a combination thereof. Also, means for effecting preliminary ejection (not for the recording operation) can stabilize the recording operation.

As regards the variation of the recording head

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1 mountable, it may be a single corresponding to a
single color ink, or may be plural corresponding to
the plurality of ink materials having different
recording color or density. The present invention is
5 effectively applicable to an apparatus having at least
on of a monochromatic mode mainly with black, a multi-
color mode with different color ink materials and/or
a full-color mode using the mixture of the colors,
which may be an integrally formed recording unit or
10 a combination of plural recording heads.

Furthermore, in the foregoing embodiment, the
ink has been liquid. It may be, however, an ink
material which is solidified below the room
temperature but liquefied at the room temperature.
15 Since the ink is controlled within the temperature not
lower than 30 °C and not higher than 70 °C to
stabilize the viscosity of the ink to provide the
stabilized ejection in usual recording apparatus of
this type, the ink may be such that it is liquid
20 within the temperature range when the recording signal
is the present invention is applicable to other types
of ink. In one of them, the temperature rise due to
the thermal energy is positively prevented by
consuming it for the state change of the ink from the
25 solid state to the liquid state. Another ink material
is solidified when it is left, to prevent the
evaporation of the ink. In either of the cases, the

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1 application of the recording signal producing thermal
energy, the ink is liquefied, and the liquefied ink
may be ejected. Another ink material may start to
be solidified at the time when it reaches the
5 recording material. The present invention is also
applicable to such an ink material as is liquefied
by the application of the thermal energy. Such an
ink material may be retained as a liquid or solid
material in through holes or recesses formed in a
10 porous sheet as disclosed in Japanese Laid-Open Patent
Application No. 54-56847 and Japanese Laid-Open
Patent Application No. 60-71260. The sheet is faced
to the electrothermal transducers. The most effective
one for the ink materials described above is the film
15 boiling system.

The ink jet recording apparatus may be used
as an output terminal of an information processing
apparatus such as computer or the like, as a copying
apparatus combined with an image reader or the like,
20 or as a facsimile machine having information sending
and receiving functions.

While the invention has been described with
reference to the structures disclosed herein, it is
not confined to the details set forth and this
25 application is intended to cover such modifications
or changes as may come within the purposes of the
improvements or the scope of the following claims.

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1 As stated above, according to the invention,
since temperature characteristics is detected for
each recording head, the temperature characteristics
is applied to various uses so that it is possible to
5 obtain results not depend on difference of each
recording head. In addition by utilizing the
detection results of the temperature characteristics
an accurate detection of ink discharge state is
possible. Furthermore, according to the present
10 invention it is possible to detect the abnormal
state of the ink discharge which might occur before
ink is consumed up.

15

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1 WHAT IS CLAIMED IS:

1. An ink jet recording apparatus for effecting a recording operation by means of a recording head for discharging ink from discharge
5 openings onto a recording medium, comprising:

an electrothermal converter provided on said recording head;

temperature detection means for detecting the temperature of said recording head; and

10 temperature characteristics detection means for applying a predetermined energy to said electrothermal converter, and detecting the temperature change of said recording head resulting from said energy application, by means of said
15 temperature detection means, thereby detecting the temperature characteristics of said recording head, based on the result of said detection.

2. An ink jet recording apparatus according
20 to claim 1, further comprising:

judgment means for judging the ink discharge state of said recording head, based on the result of detection of the temperature characteristics of the recording head by said temperature characteristics
25 detection means.

3. An ink jet recording apparatus according



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1 to claim 2, further comprising:

informing means for providing information,
based on the result of judgment of ink discharge state
by said judgment means.

5

4. An ink jet recording apparatus according
to claim 2, wherein the temperature detection means
for said recording head are provided in plural units,
and the detection of the temperature characteristics
10 of the recording head and the judgment of the ink
discharge state are conducted according to the result
of temperature detection in a predetermined number
of temperature detection means among said plural
units.

15

5. An ink jet recording apparatus according
to claim 2, further comprising:

input means which allows the user to enter
an instruction for the execution of detection of said
20 ink discharge state, wherein said judgment means is
adapted to judge the ink discharge state in response
to the instruction entered by the user through said
input means.

25

6. An ink jet recording apparatus according
to claim 1, wherein said electrothermal converter is
a heater.



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1 7. An ink jet recording apparatus according
to claim 6, wherein the predetermined amount of energy
applied to said electrothermal converter is capable
of inducing ink discharge.

5

8. An ink jet recording apparatus according
to claim 6, wherein the predetermined amount of energy
applied to said electrothermal converter is incapable
of inducing the ink discharge.

10

9. An ink jet recording apparatus according
to claim 6, wherein the predetermined amount of energy
applied to said electrothermal converter includes an
amount inducing the ink discharge and another amount
not inducing the ink discharge.

15

10. An ink jet recording apparatus according
to claim 1, wherein said electrothermal converter is
a heater for a purpose other than ink discharge.

20

11. An ink jet recording apparatus according
to claim 1, wherein said temperature characteristics
detection means is adapted to detect the temperature
characteristics of said recording head, based on the
temperature increase of said recording head detected
by said temperature detection means, when said
predetermined energy is applied to said electrothermal

25



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1 converter.

12. An ink jet recording apparatus according
to claim 1, wherein said temperature characteristics
5 detection means is adapted to detect the temperature
characteristics of said recording head, based on the
temperature descent of said recording head detected
by said temperature detection means, after the
application of said predetermined energy to said
10 electrothermal converter.

13. An ink jet recording apparatus according
to claim 1, wherein the application of said
predetermined energy to said electrothermal converter
15 is conducted by the supply of plural pulses of a
predetermined interval.

14. An ink jet recording apparatus according
to claim 13, wherein the detection of temperature
20 change in said recording head by said temperature
detection means is conducted in synchronization with
the cycles of said pulses.

15. An ink jet recording apparatus according
25 to claim 1, further comprising:

ambient temperature detection means for
detecting the ambient temperature of said recording



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1 head, wherein said temperature characteristics
detection means is adapted to correct the result of
detection of the temperature change in said recording
head, according to the ambient temperature detected
5 by said ambient temperature detection means.

16. An ink jet recording apparatus according
to claim 1, further comprising:

ambient temperature detection means for
10 detecting the ambient temperature of said recording
head, wherein said temperature characteristics
detection means is adapted to vary the amount of
energy applied to said electrothermal converter for
the purpose of detection of the temperature
15 characteristics of said recording head, based on the
ambient temperature detected by said ambient
temperature detection means.

17. An ink jet recording apparatus according
20 to claim 1, further comprising:

an ink receiving member for receiving the ink
discharged from the discharge opening of said
recording head, and

means for controlling the relative position
25 in such a manner said recording head becomes opposed
to said ink receiving member when the energy capable
of inducing ink discharge is applied to said





1 electrothermal converter, for the purpose of detecting
the temperature characteristics of said recording
head.

5 18. An ink jet recording apparatus according
to claim 1; further comprising:

an ink receiving member for receiving the
ink discharged from the discharge opening of said
recording head;

10 means for removing ink from said ink receiving
member; and

means for activating said ink removing means,
at the application of energy of an amount capable of
inducing ink discharge to said electrothermal
15 converter for the purpose of detecting the temperature
characteristics of said recording head, before and/or
after of said energy application.

19. An ink jet recording apparatus according
20 to claim 1, wherein the temperature characteristics
of said recording head include the temperature change
therein when the energy of an amount not inducing the
ink discharge is applied to said electrothermal
converter.

25

20. An ink jet recording apparatus according



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1 to claim 1, wherein the temperature characteristics
of said recording head include the temperature change
therein when the energy of an amount capable of
inducing ink discharge is applied to said
5 electrothermal converter, in a state in which said
recording head is filled with ink.

21. An ink jet recording apparatus according
to claim 1, wherein the temperature characteristics
10 of said recording head include the temperature change
therein when the energy of an amount capable of
inducing ink discharge is applied to said
electrothermal converter, in a state in which said
recording head is not filled with ink.

15

22. An ink jet recording apparatus according
to claim 1, wherein said recording head is adapted to
induce a state change including bubble generation in
the ink, by means of thermal energy, and to effect
20 ink discharge based on said state change.

23. An ink jet recording apparatus for
effecting a recording operation by means of a
recording head for discharging ink from discharge
25 openings onto a recording medium, comprising:

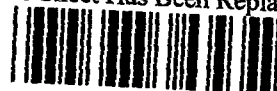
input means for enabling the operator to
instruct the execution of detection of the ink



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1 discharge state of said recording means; and
ink discharge state detection means for
detecting the ink discharge state of said recording
head, by causing the ink discharge from said recording
5 head, in response to the instruction of the operator
entered through said input means.

24. An ink jet recording apparatus according
to claim 23, wherein said input means is adapted to
10 enter a predetermined timing for detecting the ink
discharge state, and said ink discharge state
detection means is adapted to detect the ink discharge
state according to the entered timing.

15 25. An ink jet recording apparatus according
to claim 23, wherein said recording head is equipped
with an electrothermal converter for heating the ink
for the purpose of inducing ink discharge.

20 26. An ink jet recording apparatus according
to claim 23, further comprising an electrothermal
converter for a purpose other than ink heating.

25 27. An ink jet recording apparatus according
to claim 23, wherein said recording head is adapted
to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect



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1 ink discharge based on said state change.

28. An ink jet recording apparatus for
effecting a recording operation by means of a
5 recording head for discharging ink from discharge
openings onto a recording medium, comprising:

ink discharge state detection means for
detecting the ink discharge state of said recording
head; and

10 control means for controlling said ink
discharge state detection means to effect the
detection of the ink discharge state again, in case
said detection means detects a defective state of ink
discharge from said recording head.

15

29. An ink jet recording apparatus according
to claim 28, further comprising:

discharge recovery process means for restoring
the ink discharge from said recording head;

20 wherein, when said ink discharge state
detection means detects a defective state of ink
discharge from said recording head, said control means
is adapted to so control said discharge recovery
process means to effect a discharge recovery process
25 by sucking ink from said recording head; and then to
so control said ink discharge state detection means
to again detect the ink discharge state.

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1 30. An ink jet recording apparatus according
to claim 28, further comprising:

discharge recovery process means for restoring
the ink discharge from said recording head;

5 wherein, when said ink discharge state
detection means detects a defective state of ink
discharge from said recording head, said control
means is adapted to so control said discharge recovery
process means as to effect a discharge recovery
10 process by sucking ink from said recording head, then
to cause said recording head to discharge ink of a
predetermined amount, and to so control said ink
discharge state detection means to again detect the
ink discharge state.

15

31. An ink jet recording apparatus according
to claim 28, wherein said recording head is adapted
to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect
20 ink discharge based on said state change.

32. An ink jet recording apparatus for
effecting a recording operation by means of a
recording head for discharging ink from discharging
25 openings onto a recording medium, comprising:

ink discharge state detection means for



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1 detecting the ink discharge state of said recording
head; and

memory means for storing, when said ink
discharge state detection means detects a defective
5 state in the ink discharge from said recording head,
the recording data at least starting from the
preceding detection of satisfactory state of the ink
discharge.

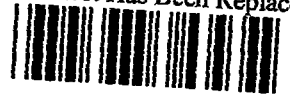
10 33. An ink jet recording apparatus according
to claim 32, further comprising:

means capable of instructing the recording
data, in case the recording operation is restarted
based on the recording data stored in said memory
15 means, in case said ink discharge state detection
means detects a defective state of the ink discharge
from said recording head.

20 34. An ink jet recording apparatus according
to claim 32, further comprising:

means for enabling said recording head to
again record the predetermined recording data, based
on the recording data stored in said memory means,
in case said ink discharge state detection means
25 detects a defective state of the ink discharge from
said recording head.





1 35. An ink jet recording apparatus according
to claim 31, wherein said recording head is adapted
to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect
5 ink discharge based on said state change.

 36. A method for detecting the temperature
characteristics of an ink jet recording head,
comprising steps of:
10 applying a predetermined energy to an
electrothermal converter provided in the recording
head for effecting recording by discharging ink from
a discharge opening onto a recording medium;
 detecting the temperature change in said
15 recording head, resulting from said energy
application; and
 detecting, based on the result of said
detection, the temperature characteristics of said
recording head.

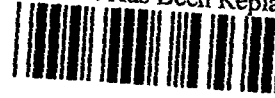
20 37. A method according to claim 36, wherein
the state of ink discharge from said recording head
is judged according to the result of detection of the
temperature characteristics of the recording head.

25 38. An ink jet recording apparatus for
effecting a recording operation by means of a



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1 recording head for discharging ink from discharge
openings onto a recording medium, comprising:

an electrothermal converter provided on said
recording head;

5 temperature detection means for detecting the
temperature in the vicinity of said recording head;
and

judgment means for judging the ink discharge
state of said recording head, through the comparison
10 between the temperature characteristics of said
recording head based on the temperature change in the
vicinity of said recording head at the application
of a predetermined energy to said electrothermal
converter, and the temperature detected by said
15 temperature detection means.

39. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
are represented by a temperature change A in the
20 normal ink discharge state and a temperature change
B in an abnormal ink discharge state.

40. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
25 are represented by a temperature dTA in the normal
ink discharge state at the application of said
predetermined energy to said electrothermal converter,





1 and a temperature difference TD between said
temperature dTA and a temperature at an abnormal
discharge state lacking the ink discharge.

5 41. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
are represented, based on a temperature dTC when said
electrothermal converter is given an energy in a range
not inducing ink discharge from said discharge
10 opening.

42. An ink jet recording apparatus according
to claim 38, wherein said temperature characteristics
are represented by a value obtained by applying the
15 predetermined energy to said electrothermal converter
in a plurality of recording heads and statistically
processing the temperature detected in the vicinity
of said recording head.

20 43. An ink jet recording apparatus according
to claim 42, wherein said temperature characteristics
are represented by a maximum temperature TA enabling
the normal ink discharge from said recording head
when the predetermined energy is applied to said
25 electrothermal converter in a plurality of recording
heads, and a minimum temperature TB of the abnormal
discharge state in which the ink is not discharged



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1 from said recording head.

44. An ink jet recording apparatus according
to claim 42, wherein said temperature characteristics
5 are represented by the temperature dTA enabling
the normal ink discharge from said recording head
at the application of the predetermined energy to
said electrothermal converter in a plurality of
recording heads, and the minimum value TD of the
10 temperature difference (dTB - dTA) between the
temperature dTB of the abnormal discharge state in
which the ink is not discharged from said recording
head and said temperature dTA.

15 45. An ink jet recording apparatus according
to claim 42, wherein said temperature characteristics
are represented by a temperature dTA enabling the
normal ink discharge from said recording head, said
temperature being detected at the application of a
20 predetermined energy E1 to the electrothermal
converter in a plurality of the recording heads, and
by a ratio of a temperature dTB in an abnormal
discharge state in which the ink is not discharged
from said recording head, to a temperature dTC
25 detected by said temperature detection means when
an energy E2 not inducing the ink discharge from said
recording head is applied.

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1 46. An ink jet recording apparatus according
to claim 38, further comprising:

 informing means for providing information,
based on the result of judgment of ink discharge state
5 by said judgment means.

 47. An ink jet recording apparatus according
to claim 38, comprising said temperature detection
means in plural units, wherein the judgment of the
10 ink discharge state is conducted according to the
result of detection in a predetermined number of
temperature detection means among said plural units.

 48. An ink jet recording apparatus according
15 to claim 38, further comprising:

 input means which allows the user to enter an
instruction for the execution of detection of said ink
discharge state, wherein said judgment means is
adapted to judge the ink discharge state in response
20 to the instruction entered by the user through said
input means.

 49. An ink jet recording apparatus according
to claim 38, wherein said recording head is adapted
25 to induce a state change including bubble generation
in the ink, by means of thermal energy, and to effect
ink discharge based on said state change.



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50. An ink jet recording apparatus including means for detecting the temperature characteristics of an ink jet recording head wherein the result of detection is utilised for detecting the ink discharge state.

5

51. An ink jet recording apparatus including means for detecting the temperature characteristics on plural recording heads, and means for effecting statistical processing to enable exact detection of the ink discharge
10 state, unaffected by the individual difference of the recording heads.



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METHOD FOR JUDGING DISCHARGE STATE OF INK JET
RECORDING HEAD, AND INK JET RECORDING APPARATUS
UTILIZING THE SAME

ABSTRACT

The temperature characteristics of an ink jet recording head are detected, and the result of detection is utilized for detecting the ink discharge state. Also a statistical processing on the temperature characteristics detected on plural recording heads enables exact detection of the ink discharge state, not effected by the individual difference of the recording heads. Also there is detected the abnormality in ink discharge, that may occur prior to the exhaustion of ink in the ink tank.

FIGURE 2

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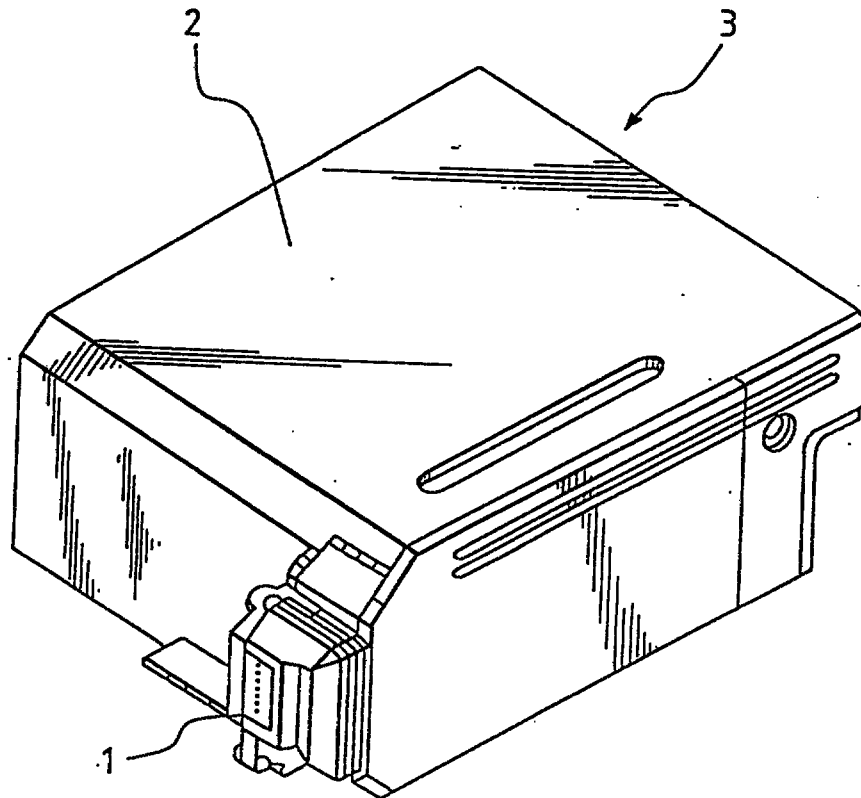


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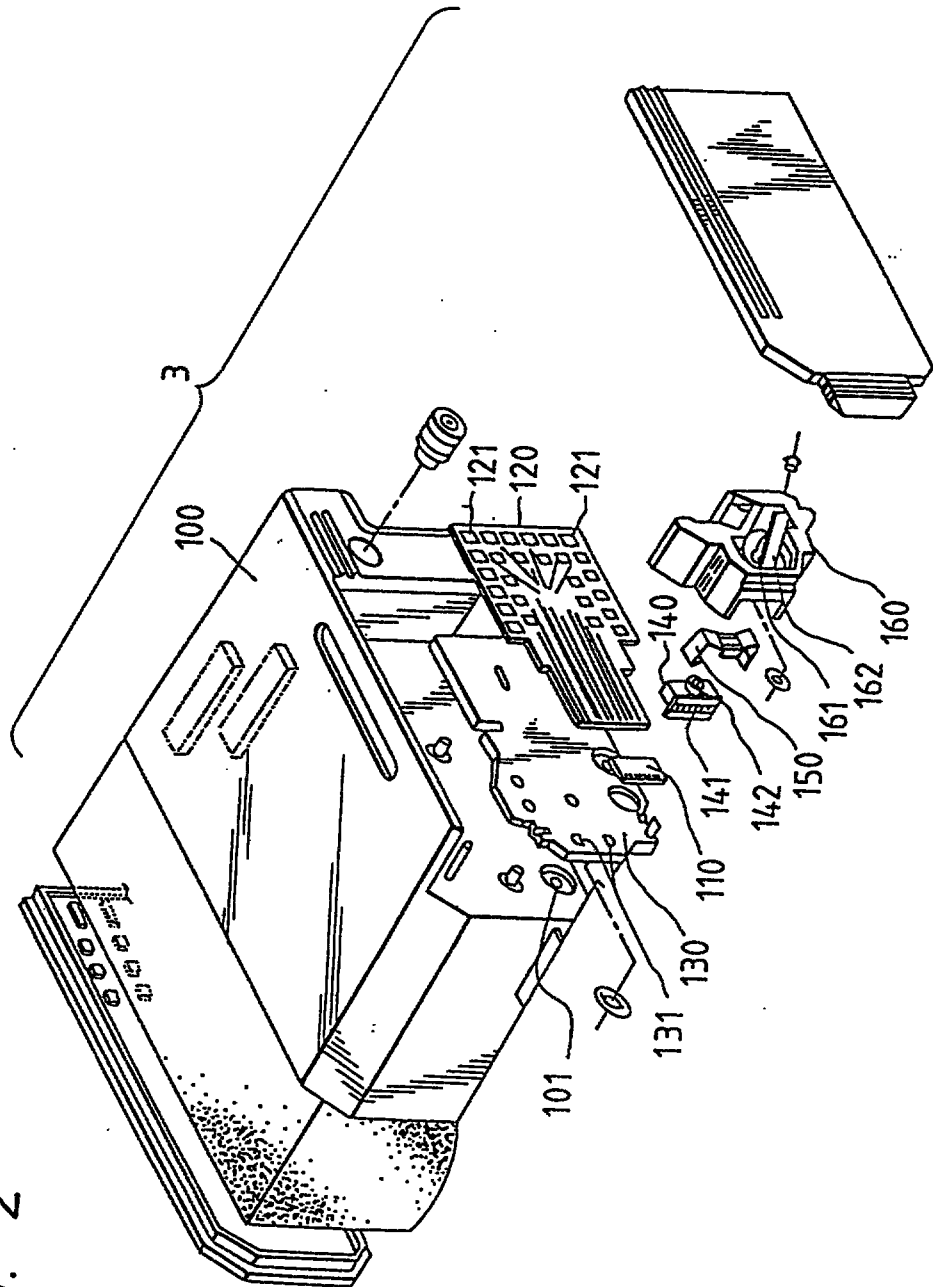
FIG. 1



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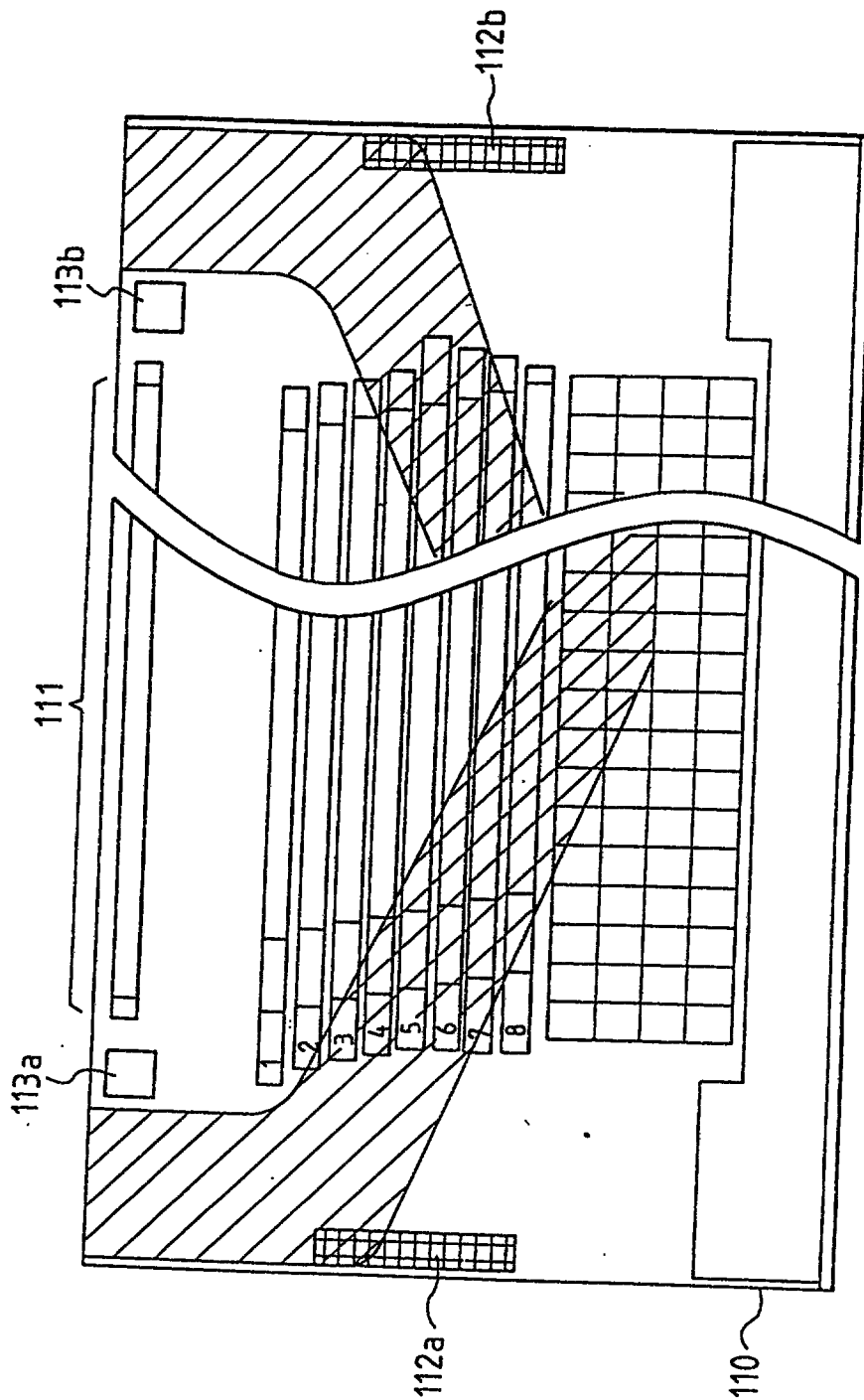
FIG. 2



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FIG. 3A



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FIG. 3B

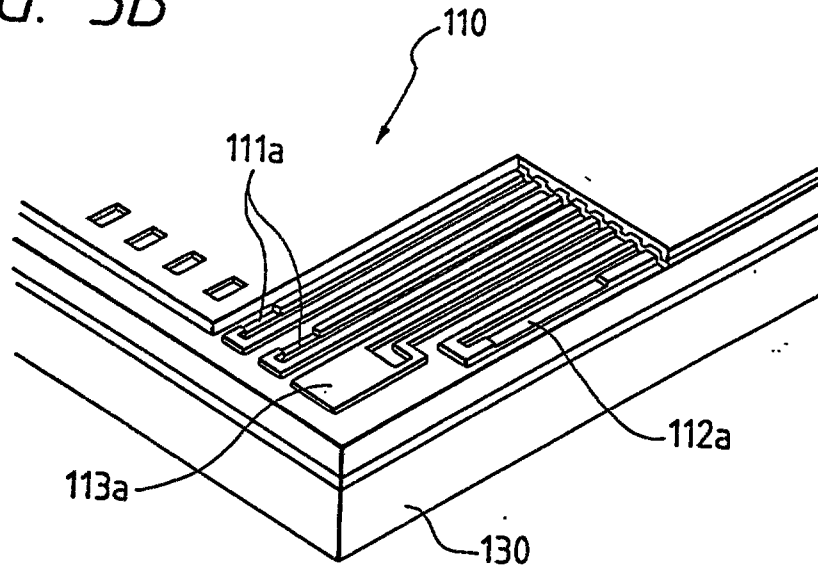
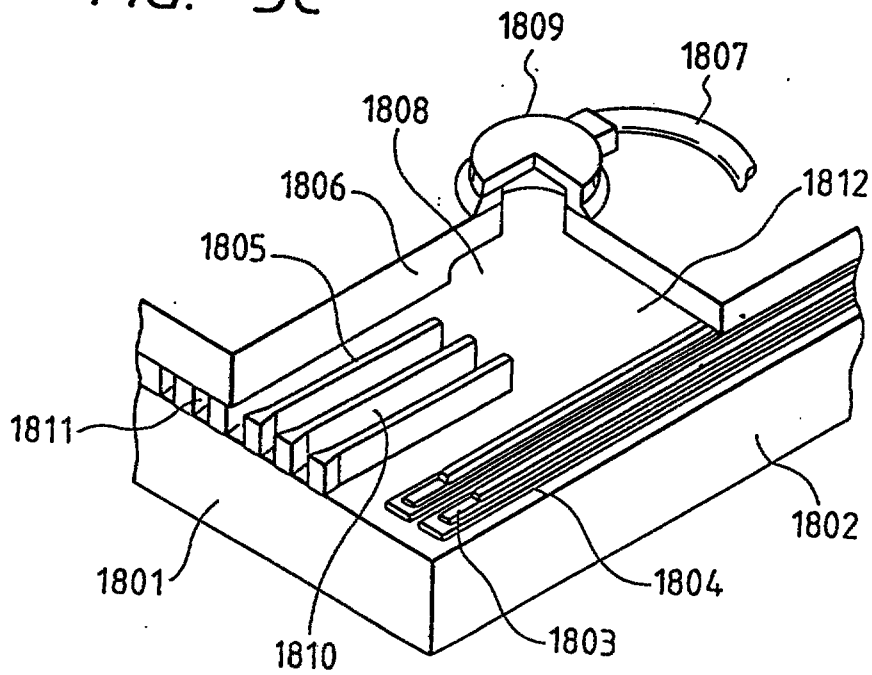


FIG. 3C



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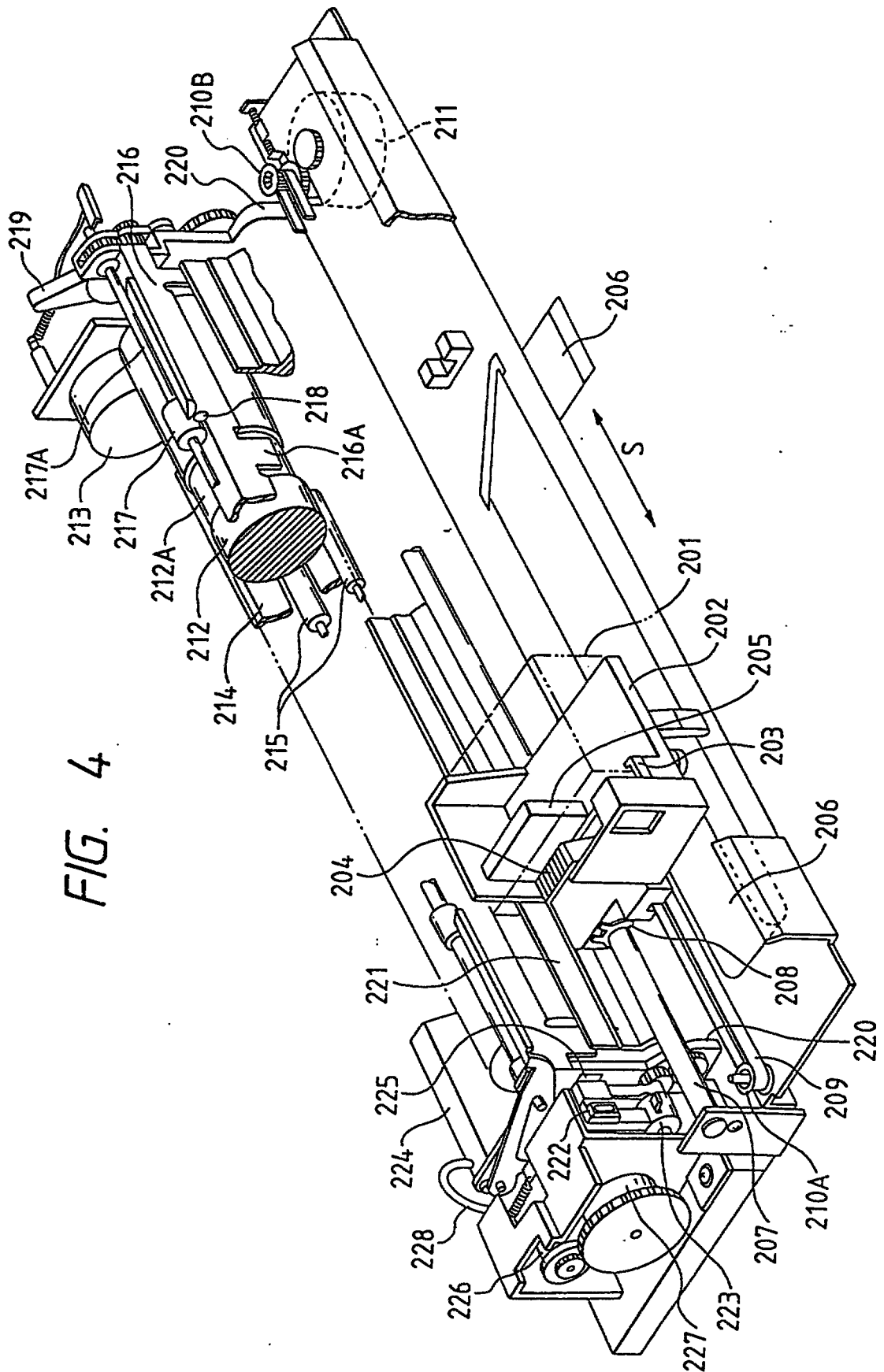
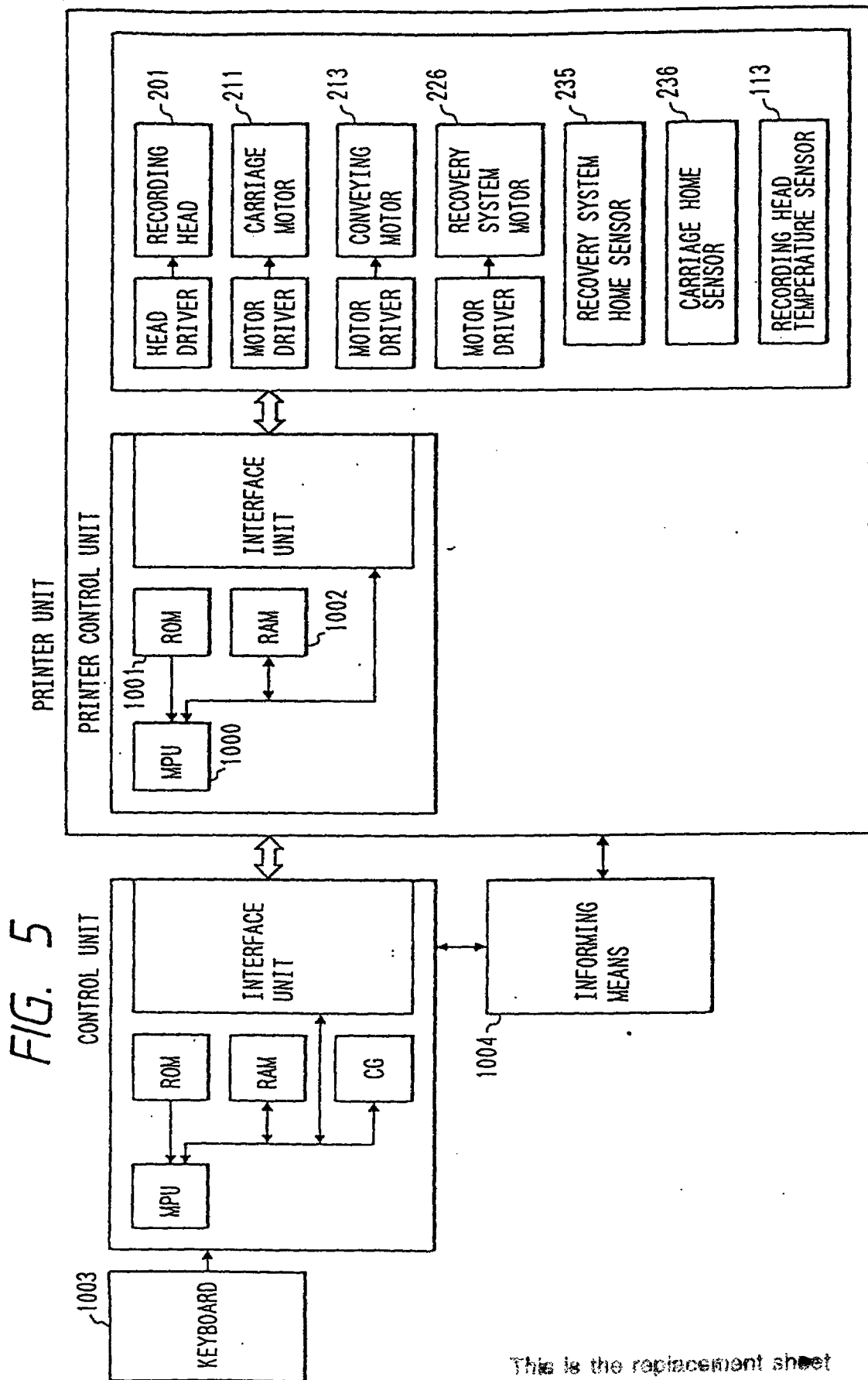


FIG. 4

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FIG. 6

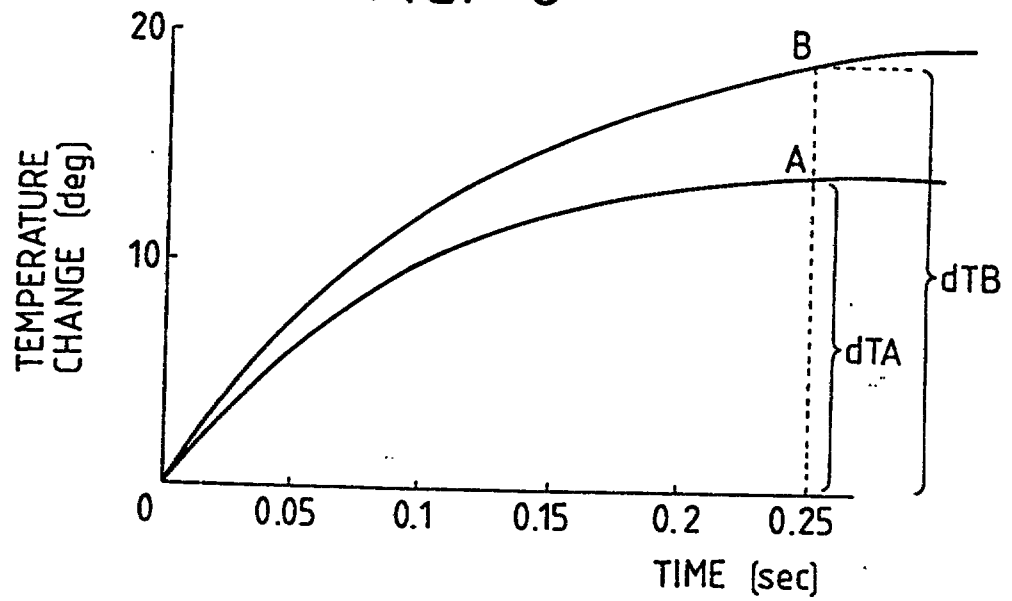


FIG. 7A

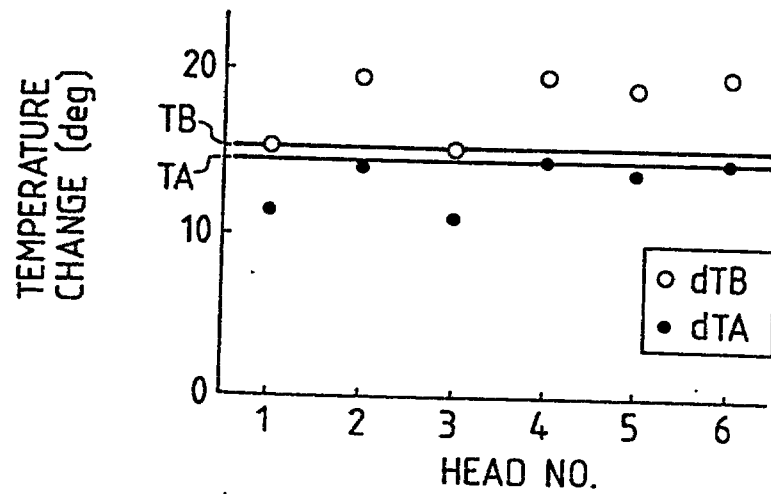
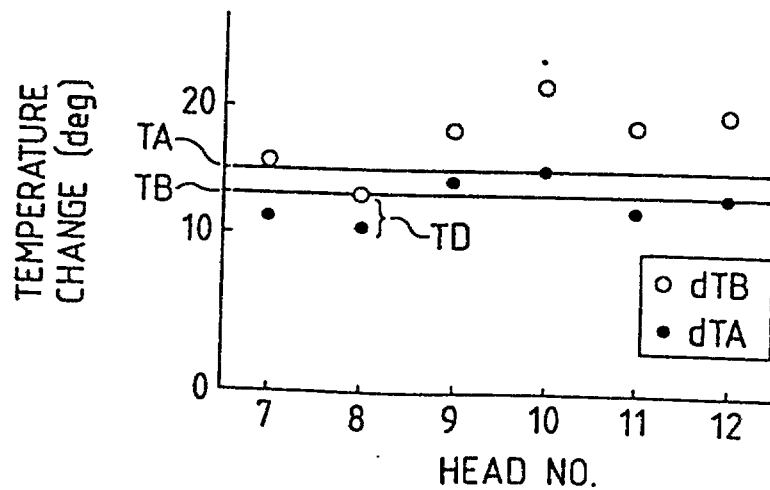


FIG. 7B



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FIG. 8A

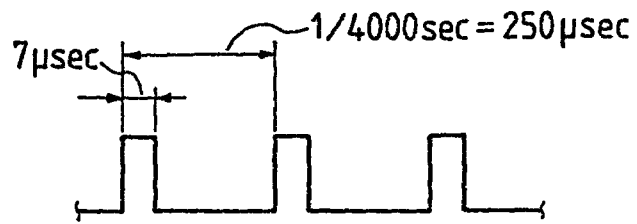


FIG. 8B

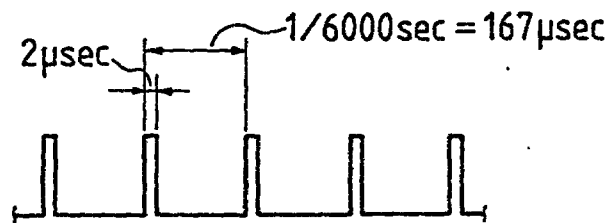


FIG. 9

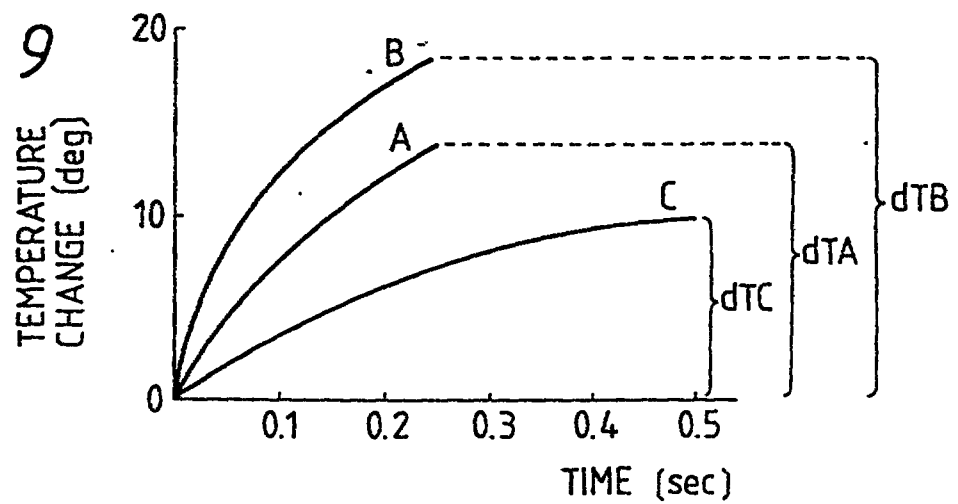
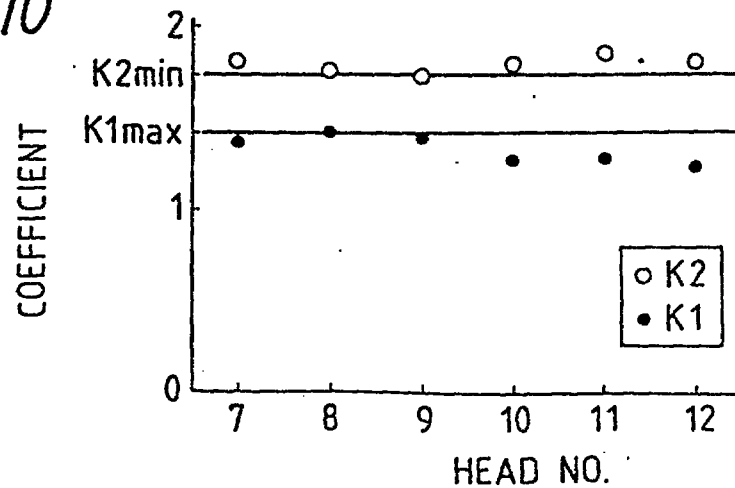


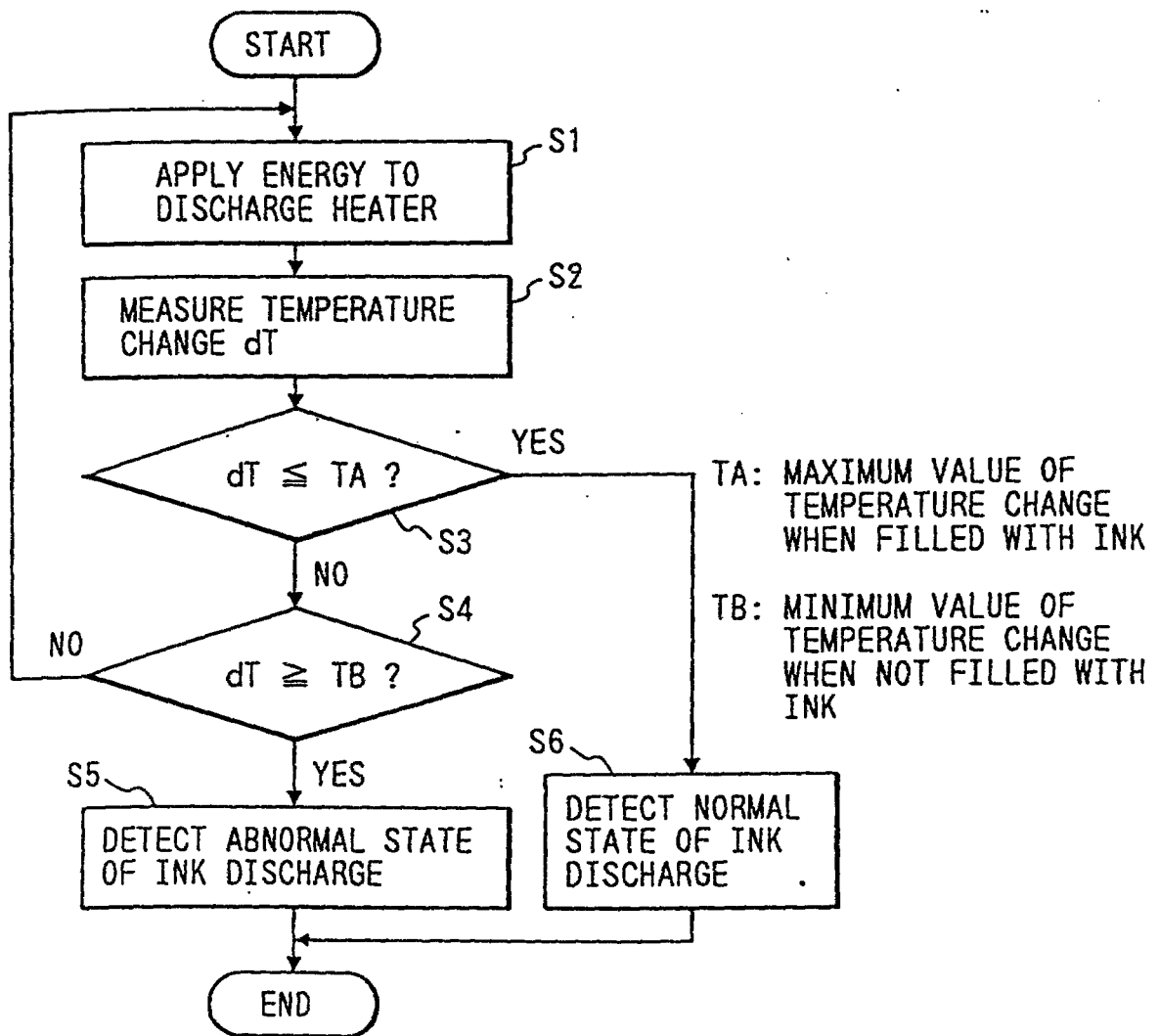
FIG. 10



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FIG. 11

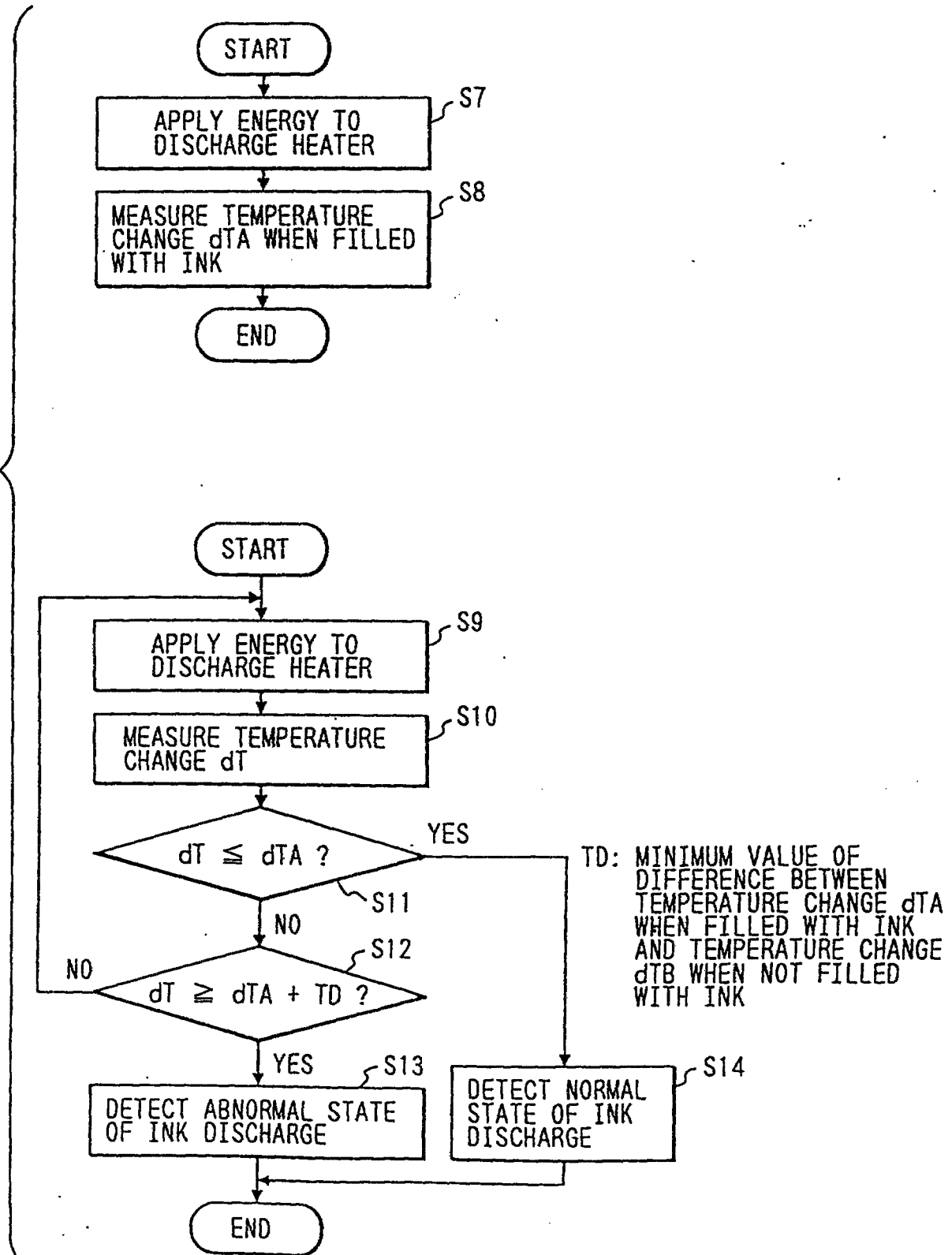


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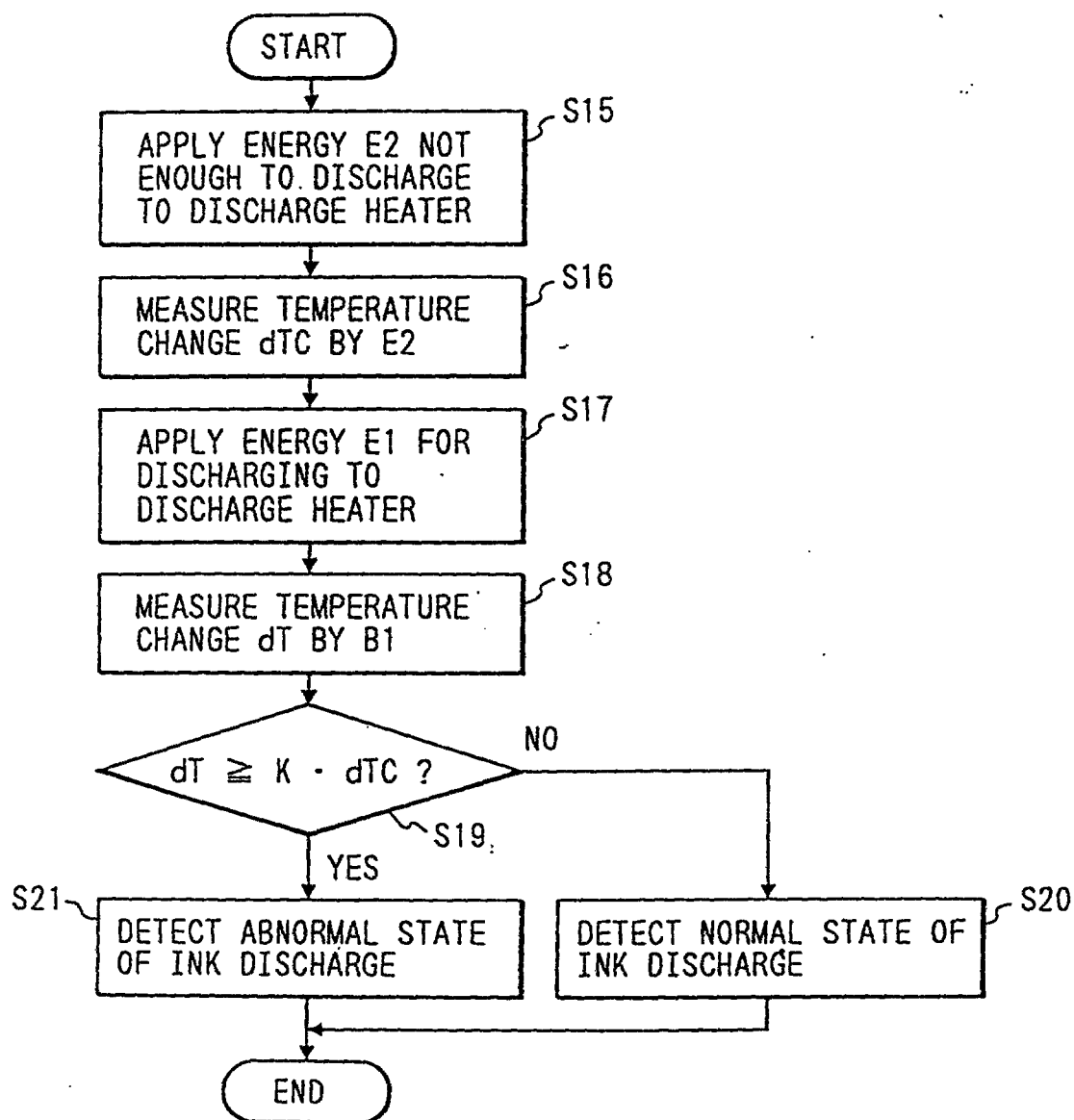
FIG. 12



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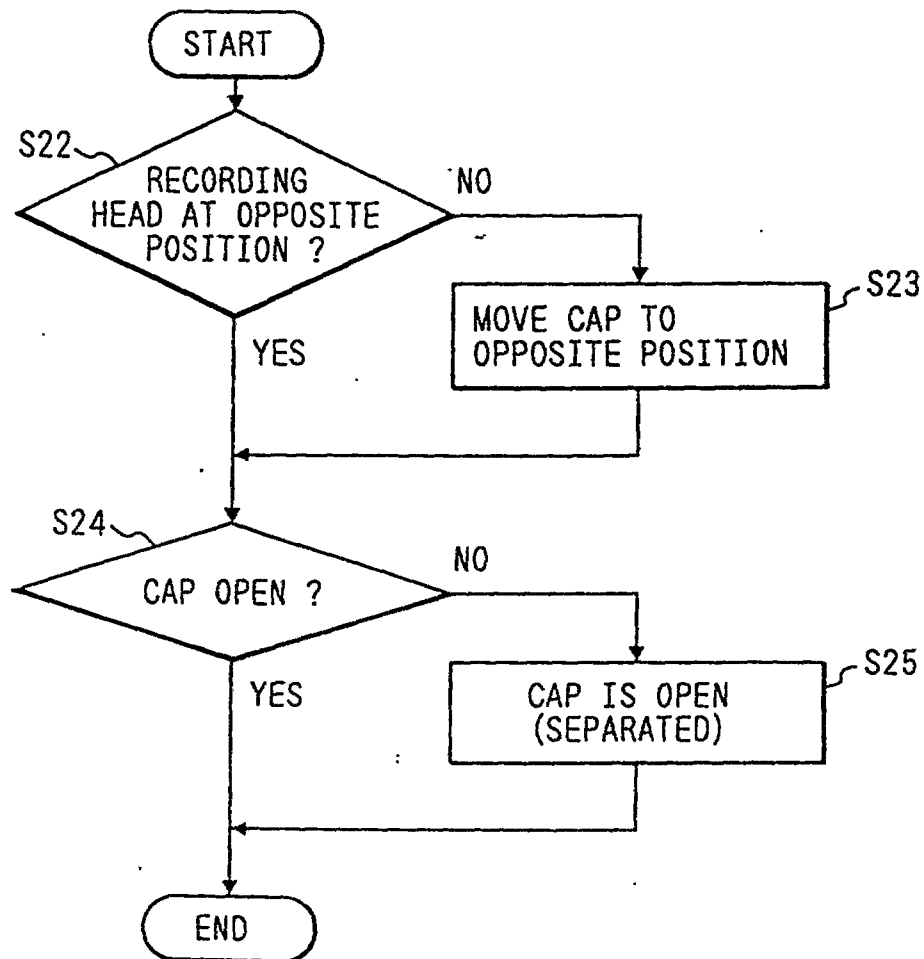
FIG. 13



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FIG. 14



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FIG. 15A

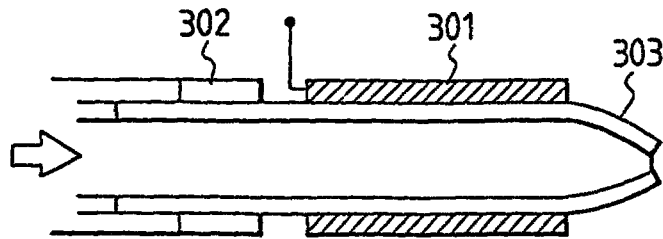


FIG. 15B

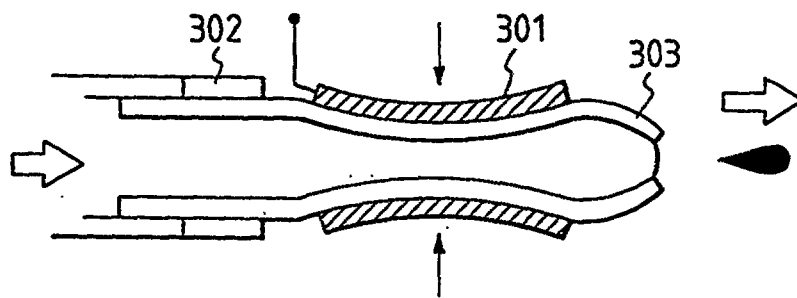
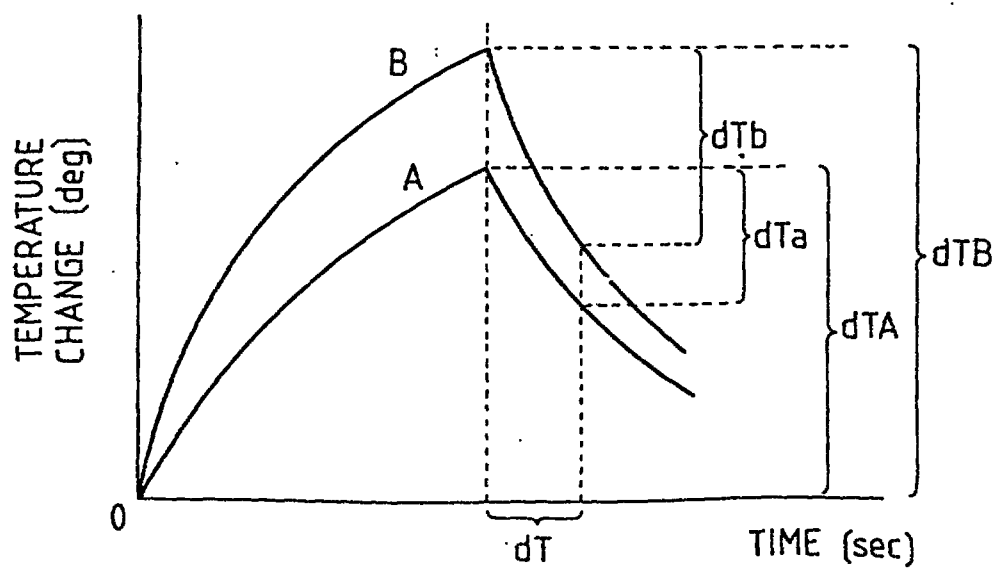


FIG. 16



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FIG. 17

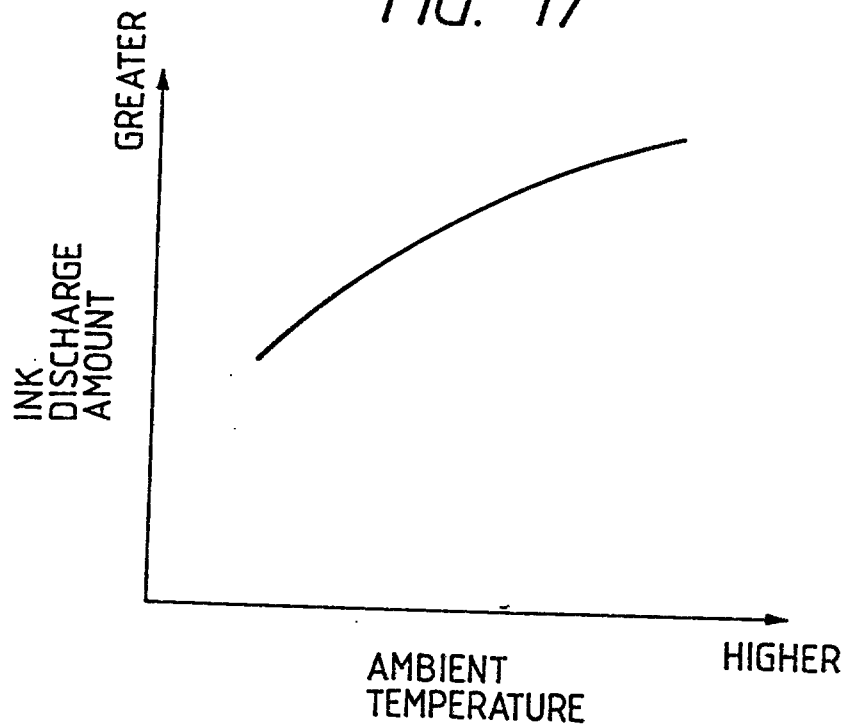
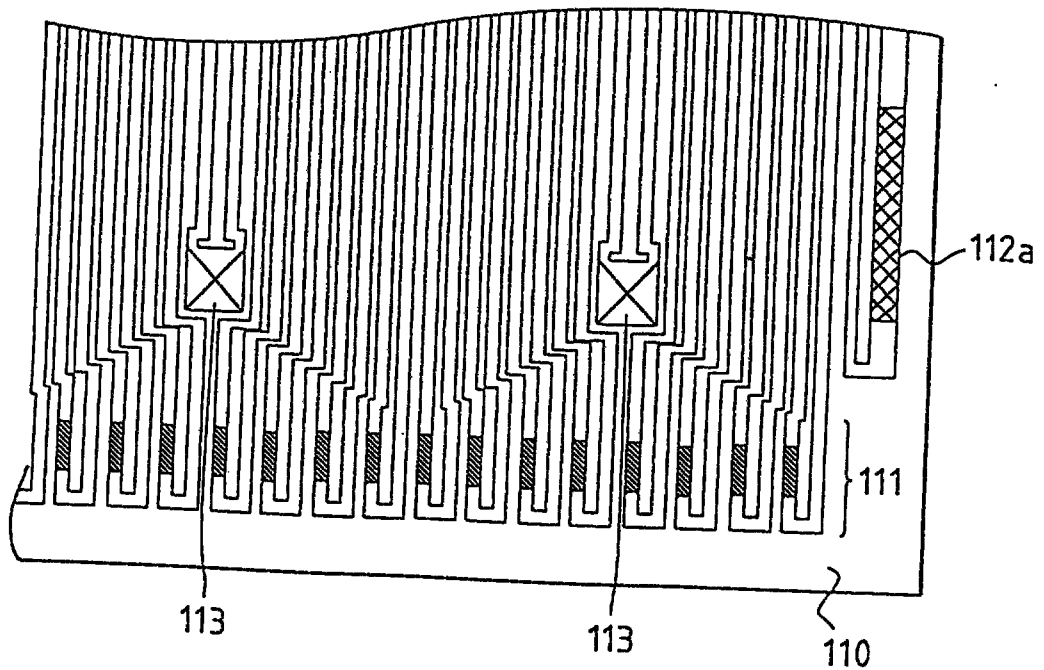


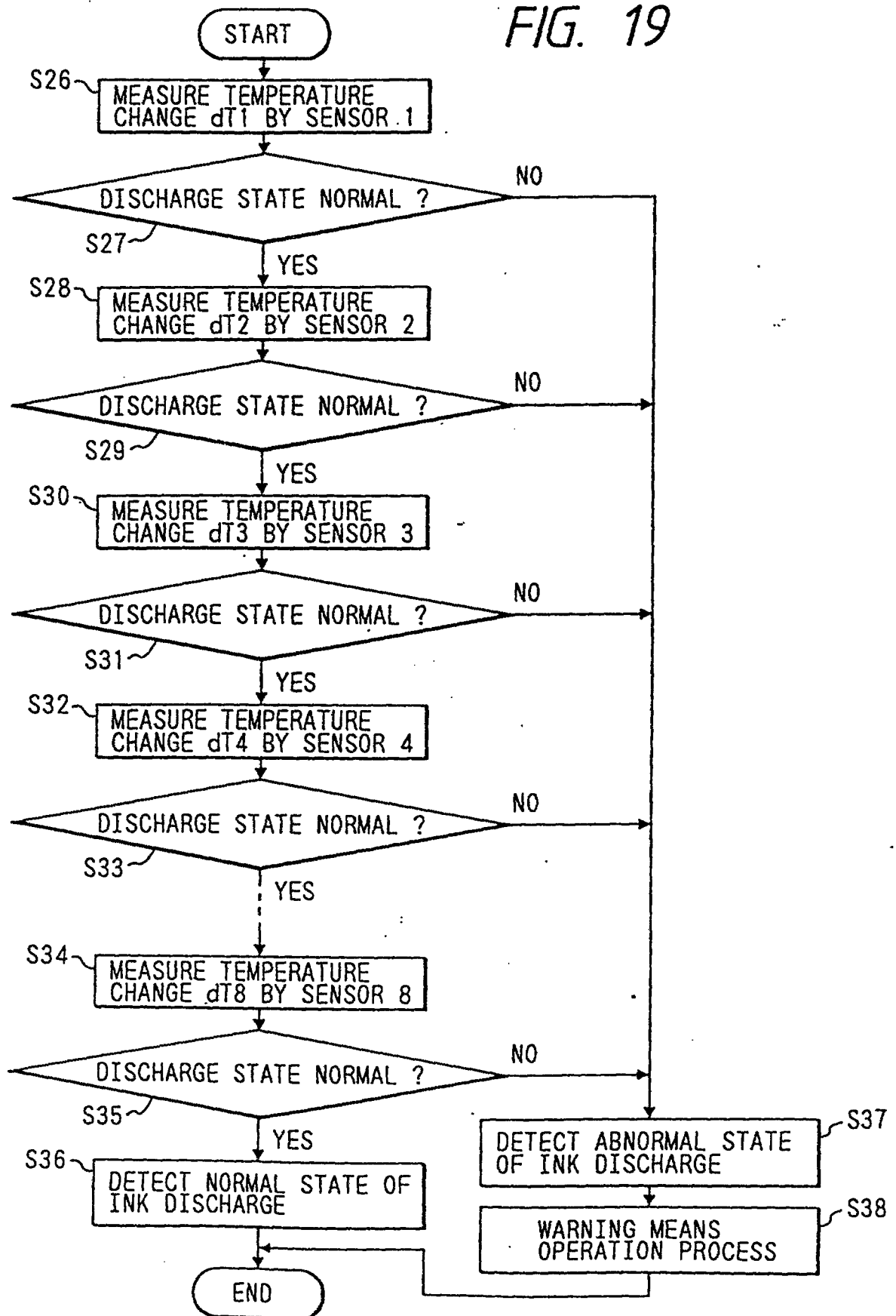
FIG. 18



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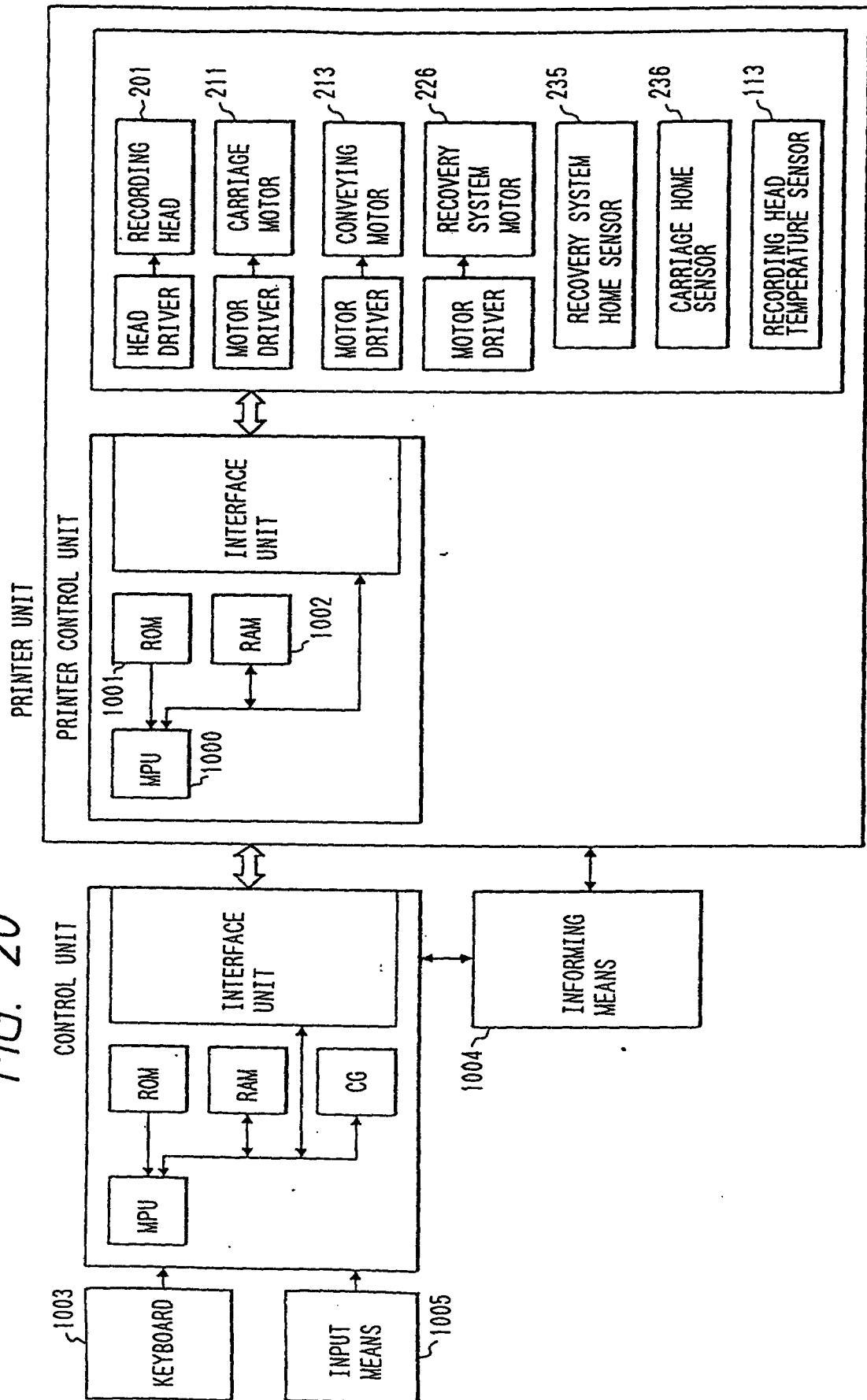
FIG. 19



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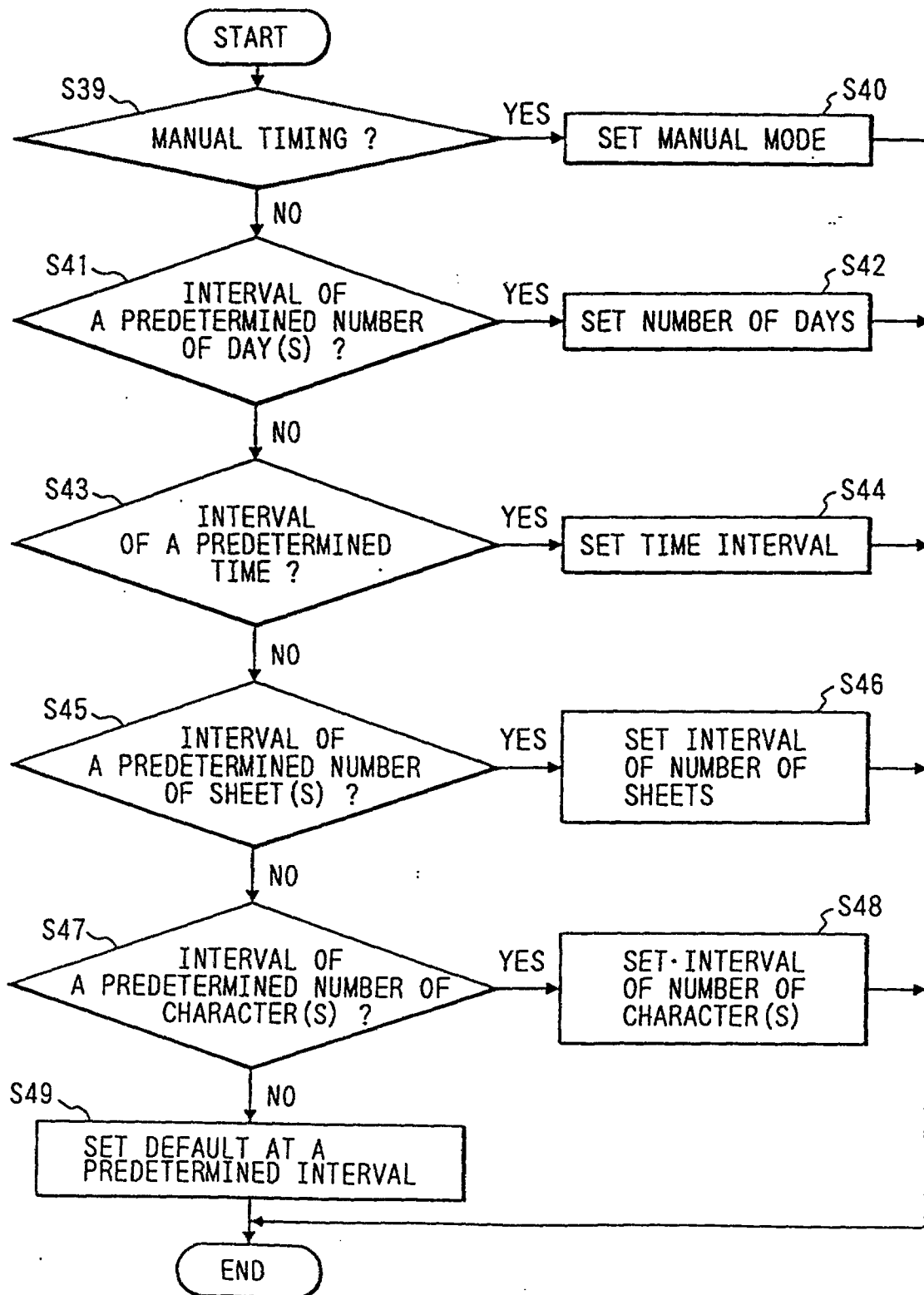
FIG. 20



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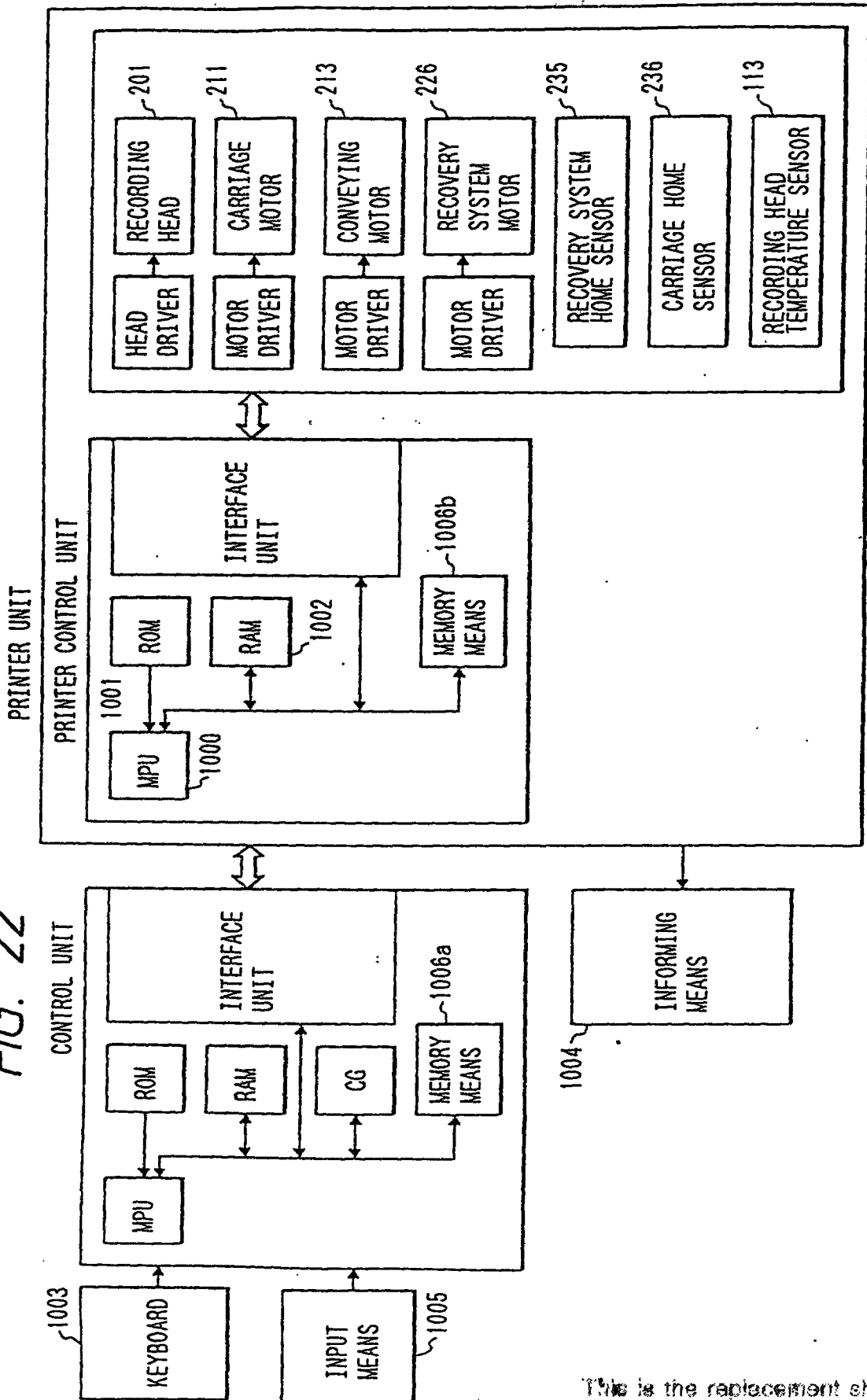
FIG. 21



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FIG. 22



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FIG. 23

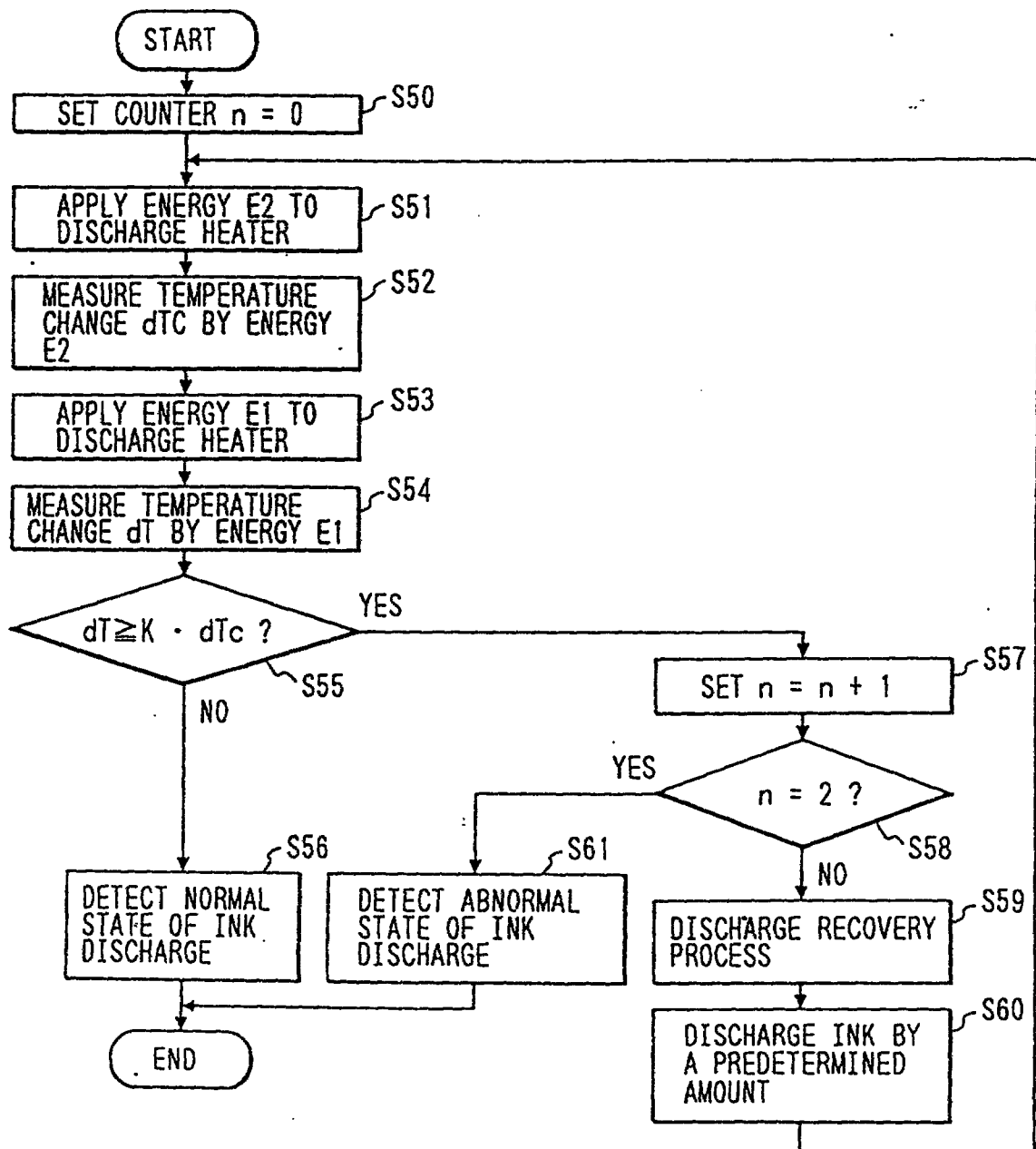
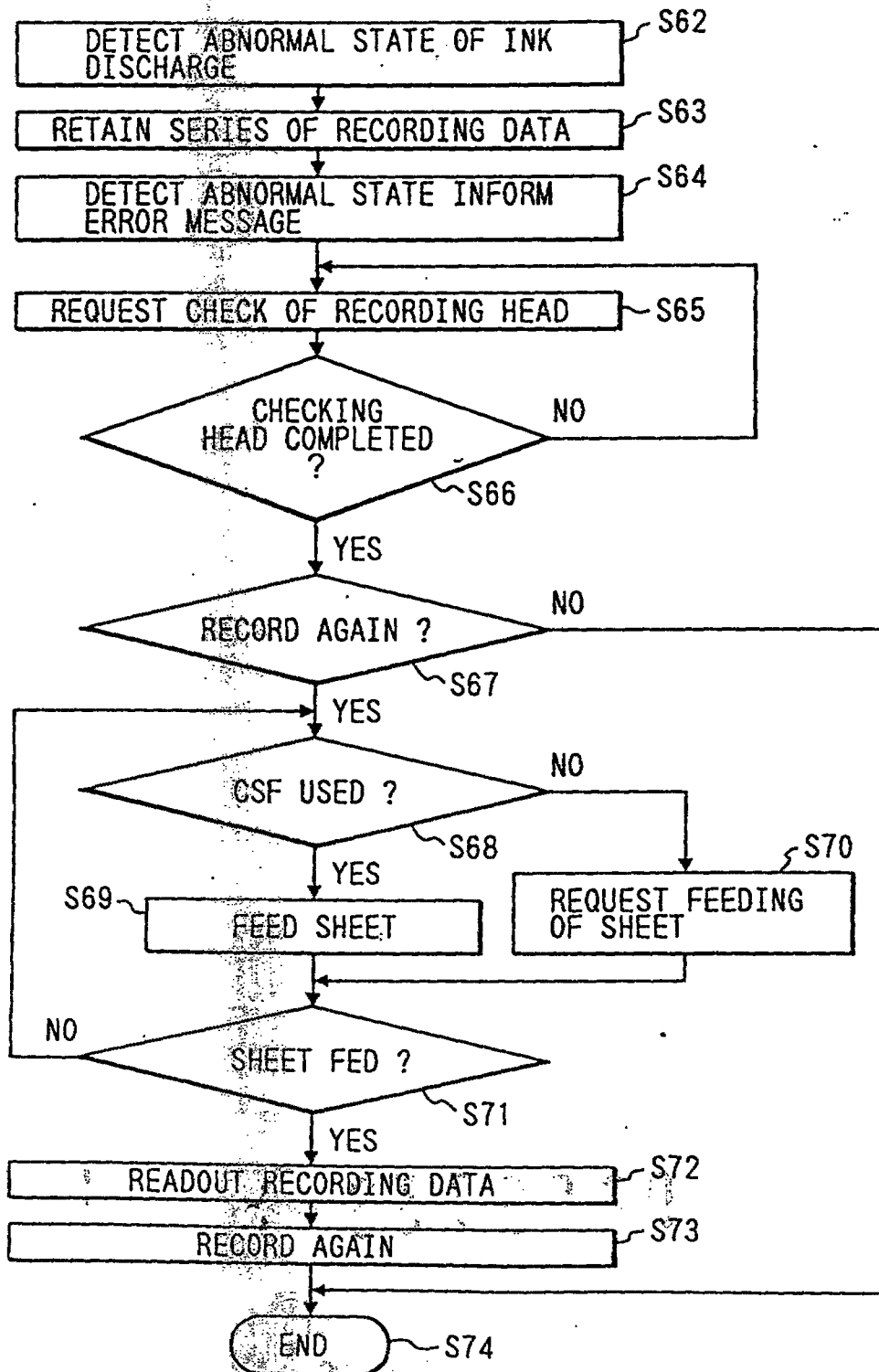


FIG. 24



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REPLACEMENT SHEETS		SG
☐ Description :	paged	to paged
☒ Claim(s) :	paged <u>55</u>	to paged <u>75</u>
☐ Drawing(s) :	paged	to paged
☒ Abstract :	paged <u>75</u>	to paged <u>75</u>
DATE OF RECEIPT		<u>23/11/25</u>

WHAT IS CLAIMED IS:

1. An ink jet recording apparatus for effecting a recording operation by means of a recording head for discharging ink from discharge openings onto a recording medium, comprising:

an electrothermal converter provided on said recording head;

temperature detection means for detecting the temperature of said recording head; and

temperature characteristics detection means for applying a predetermined energy to said electrothermal converter, and detecting the temperature change of said recording head resulting from said energy application, by means of said temperature detection means, thereby detecting the temperature characteristics of said recording head, based on the result of said detection.

2. An ink jet recording apparatus according to claim 1, further comprising:

judgment means for judging the ink discharge state of said recording head, based on the result of detection of the temperature characteristics of the recording head by said temperature characteristics detection means.

3. An ink jet recording apparatus according

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to claim 2, further comprising:

informing means for providing information,
based on the result of judgment of ink discharge state
by said judgment means.

4. An ink jet recording apparatus according
to claim 2, wherein the temperature detection means
for said recording head are provided in plural units,
and the detection of the temperature characteristics
of the recording head and the judgment of the ink
discharge state are conducted according to the result
of temperature detection in a predetermined number
of temperature detection means among said plural
units.

5. An ink jet recording apparatus according
to claim 2, further comprising:

input means which allows the user to enter
an instruction for the execution of detection of said
ink discharge state, wherein said judgment means is
adapted to judge the ink discharge state in response
to the instruction entered by the user through said
input means.

6. An ink jet recording apparatus according
to claim 1, wherein said electrothermal converter is
a heater.

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7. An ink jet recording apparatus according to claim 6, wherein the predetermined amount of energy applied to said electrothermal converter is capable of inducing ink discharge.

8. An ink jet recording apparatus according to claim 6, wherein the predetermined amount of energy applied to said electrothermal converter is incapable of inducing the ink discharge.

9. An ink jet recording apparatus according to claim 6, wherein the predetermined amount of energy applied to said electrothermal converter includes an amount inducing the ink discharge and another amount not inducing the ink discharge.

10. An ink jet recording apparatus according to claim 1, wherein said electrothermal converter is a heater for a purpose other than ink discharge.

11. An ink jet recording apparatus according to claim 1, wherein said temperature characteristics detection means is adapted to detect the temperature characteristics of said recording head, based on the temperature increase of said recording head detected by said temperature detection means, when said predetermined energy is applied to said electrothermal

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converter.

12. An ink jet recording apparatus according to claim 1, wherein said temperature characteristics detection means is adapted to detect the temperature characteristics of said recording head, based on the temperature descent of said recording head detected by said temperature detection means, after the application of said predetermined energy to said electrothermal converter.

13. An ink jet recording apparatus according to claim 1, wherein the application of said predetermined energy to said electrothermal converter is conducted by the supply of plural pulses of a predetermined interval.

14. An ink jet recording apparatus according to claim 13, wherein the detection of temperature change in said recording head by said temperature detection means is conducted in synchronization with the cycles of said pulses.

15. An ink jet recording apparatus according to claim 1, further comprising:

ambient temperature detection means for detecting the ambient temperature of said recording

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head, wherein said temperature characteristics detection means is adapted to correct the result of detection of the temperature change in said recording head, according to the ambient temperature detected by said ambient temperature detection means.

16. An ink jet recording apparatus according to claim 1, further comprising:

ambient temperature detection means for detecting the ambient temperature of said recording head, wherein said temperature characteristics detection means is adapted to vary the amount of energy applied to said electrothermal converter for the purpose of detection of the temperature characteristics of said recording head, based on the ambient temperature detected by said ambient temperature detection means.

17. An ink jet recording apparatus according to claim 1, further comprising:

an ink receiving member for receiving the ink discharged from the discharge opening of said recording head, and

means for controlling the relative position in such a manner said recording head becomes opposed to said ink receiving member when the energy capable of inducing ink discharge is applied to said

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electrothermal converter, for the purpose of detecting the temperature characteristics of said recording head.

18. An ink jet recording apparatus according to claim 1; further comprising:

an ink receiving member for receiving the ink discharged from the discharge opening of said recording head;

means for removing ink from said ink receiving member; and

means for activating said ink removing means, at the application of energy of an amount capable of inducing ink discharge to said electrothermal converter for the purpose of detecting the temperature characteristics of said recording head, before and/or after of said energy application.

19. An ink jet recording apparatus according to claim 1, wherein the temperature characteristics of said recording head include the temperature change therein when the energy of an amount not inducing the ink discharge is applied to said electrothermal converter.

20. An ink jet recording apparatus according

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to claim 1, wherein the temperature characteristics of said recording head include the temperature change therein when the energy of an amount capable of inducing ink discharge is applied to said electrothermal converter, in a state in which said recording head is filled with ink.

21. An ink jet recording apparatus according to claim 1, wherein the temperature characteristics of said recording head include the temperature change therein when the energy of an amount capable of inducing ink discharge is applied to said electrothermal converter, in a state in which said recording head is not filled with ink.

22. An ink jet recording apparatus according to claim 1, wherein said recording head is adapted to induce a state change including bubble generation in the ink, by means of thermal energy, and to effect ink discharge based on said state change.

23. An ink jet recording apparatus according to claim 2, further comprising:

input means instructable by an operator so as to execute determination of the ink ink discharge condition of said recording head,

wherein said judgement means judges whether an ink discharge condition is excellent or not on the basis of the instruction by the operator through said input means.

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24. An ink jet recording apparatus according to claim 23, wherein said input means is adapted to enter a predetermined timing for detecting the ink discharge state, and said ink discharge state detection means is adapted to detect the ink discharge state according to the entered timing.

25. An ink jet recording apparatus according to claim 23, wherein said recording head is equipped with an electrothermal converter for heating the ink for the purpose of inducing ink discharge.

26. An ink jet recording apparatus according to claim 23, further comprising an electrothermal converter for a purpose other than ink heating.

27. An ink jet recording apparatus according to claim 23, wherein said recording head is adapted to induce a state change including bubble generation in the ink, by means of thermal energy, and to effect

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ink discharge based on said state change.

28. An ink jet recording apparatus according to claim 2, further comprising:

control means for allowing said judgement means to judge once whether an ink discharge condition is excellent or not if said judgement means judges that the ink discharge condition from said recording head is not excellent.

29. An ink jet recording apparatus according to claim 28, further comprising:

discharge recovery process means for restoring the ink discharge from said recording head;

wherein, when said ink discharge state detection means detects a defective state of ink discharge from said recording head, said control means is adapted to so control said discharge recovery process means to effect a discharge recovery process by sucking ink from said recording head, and then to so control said ink discharge state detection means to again detect the ink discharge state.

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30. An ink jet recording apparatus according to claim 28, further comprising:

discharge recovery process means for restoring the ink discharge from said recording head;

wherein, when said ink discharge state detection means detects a defective state of ink discharge from said recording head, said control means is adapted to so control said discharge recovery process means as to effect a discharge recovery process by sucking ink from said recording head, then to cause said recording head to discharge ink of a predetermined amount, and to so control said ink discharge state detection means to again detect the ink discharge state.

31. An ink jet recording apparatus according to claim 28, wherein said recording head is adapted to induce a state change including bubble generation in the ink, by means of thermal energy, and to effect ink discharge based on said state change.

32. An ink jet recording apparatus according to claim 2, further comprising:

memory means for storing recording data proceeding from at least previously when the ink discharge condition is excellent if said judgement means judges that the ink discharge condition from said recording head is not excellent.

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33. An ink jet recording apparatus according to claim 32, further comprising:

means capable of instructing the recording data, in case the recording operation is restarted based on the recording data stored in said memory means, in case said ink discharge state detection means detects a defective state of the ink discharge from said recording head.

34. An ink jet recording apparatus according to claim 32, further comprising:

means for enabling said recording head to again record the predetermined recording data, based on the recording data stored in said memory means, in case said ink discharge state detection means detects a defective state of the ink discharge from said recording head.

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35. An ink jet recording apparatus according to claim 32, wherein said recording head is adapted to induce a state change including bubble generation in the ink, by means of thermal energy, and to effect ink discharge based on said state change.

36. A method for detecting the temperature characteristics of an ink jet recording head, comprising steps of:

applying a predetermined energy to an electrothermal converter provided in the recording head for effecting recording by discharging ink from a discharge opening onto a recording medium;

detecting the temperature change in said recording head, resulting from said energy application; and

detecting, based on the result of said detection, the temperature characteristics of said recording head.

37. A method according to claim 36, wherein the state of ink discharge from said recording head is judged according to the result of detection of the temperature characteristics of the recording head.

38. An ink jet recording apparatus for effecting a recording operation by means of a

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recording head for discharging ink from discharge openings onto a recording medium, comprising:

an electrothermal converter provided on said recording head;

temperature detection means for detecting the temperature in the vicinity of said recording head; and

judgment means for judging the ink discharge state of said recording head, through the comparison between the temperature characteristics of said recording head based on the temperature change in the vicinity of said recording head at the application of a predetermined energy to said electrothermal converter, and the temperature detected by said temperature detection means.

39. An ink jet recording apparatus according to claim 38, wherein said temperature characteristics are represented by a temperature change A in the normal ink discharge state and a temperature change B in an abnormal ink discharge state.

40. An ink jet recording apparatus according to claim 38, wherein said temperature characteristics are represented by a temperature ΔT_A in the normal ink discharge state at the application of said predetermined energy to said electrothermal converter,

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and a temperature difference TD between said temperature dTA and a temperature at an abnormal discharge state lacking the ink discharge.

41. An ink jet recording apparatus according to claim 38, wherein said temperature characteristics are represented, based on a temperature dTC when said electrothermal converter is given an energy in a range not inducing ink discharge from said discharge opening.

42. An ink jet recording apparatus according to claim 38, wherein said temperature characteristics are represented by a value obtained by applying the predetermined energy to said electrothermal converter in a plurality of recording heads and statistically processing the temperature detected in the vicinity of said recording head.

43. An ink jet recording apparatus according to claim 42, wherein said temperature characteristics are represented by a maximum temperature TA enabling the normal ink discharge from said recording head when the predetermined energy is applied to said electrothermal converter in a plurality of recording heads, and a minimum temperature TB of the abnormal discharge state in which the ink is not discharged

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from said recording head.

44. An ink jet recording apparatus according to claim 42, wherein said temperature characteristics are represented by the temperature dTA enabling the normal ink discharge from said recording head at the application of the predetermined energy to said electrothermal converter in a plurality of recording heads, and the minimum value TD of the temperature difference ($dTB - dTA$) between the temperature dTB of the abnormal discharge state in which the ink is not discharged from said recording head and said temperature dTA .

45. An ink jet recording apparatus according to claim 42, wherein said temperature characteristics are represented by a temperature dTA enabling the normal ink discharge from said recording head, said temperature being detected at the application of a predetermined energy $E1$ to the electrothermal converter in a plurality of the recording heads, and by a ratio of a temperature dTB in an abnormal discharge state in which the ink is not discharged from said recording head, to a temperature dTC detected by said temperature detection means when an energy $E2$ not inducing the ink discharge from said recording head is applied.

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46. An ink jet recording apparatus according to claim 38, further comprising:

informing means for providing information, based on the result of judgment of ink discharge state by said judgment means.

47. An ink jet recording apparatus according to claim 38, comprising said temperature detection means in plural units, wherein the judgment of the ink discharge state is conducted according to the result of detection in a predetermined number of temperature detection means among said plural units.

48. An ink jet recording apparatus according to claim 38, further comprising:

input means which allows the user to enter an instruction for the execution of detection of said ink discharge state, wherein said judgment means is adapted to judge the ink discharge state in response to the instruction entered by the user through said input means.

49. An ink jet recording apparatus according to claim 38, wherein said recording head is adapted to induce a state change including bubble generation in the ink, by means of thermal energy, and to effect ink discharge based on said state change.

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50. An ink jet recording apparatus including means for detecting the temperature characteristics of an ink jet recording head wherein the result of detection is utilised for detecting the ink discharge state.

51. An ink jet recording apparatus including means for detecting the temperature characteristics on plural recording heads, and means for effecting statistical processing to enable exact detection of the ink discharge state, unaffected by the individual difference of the recording heads.

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METHOD FOR JUDGING DISCHARGE STATE OF INK JET
RECORDING HEAD, AND INK JET RECORDING APPARATUS
UTILIZING THE SAME

ABSTRACT

The temperature characteristics of an ink jet recording head are detected, and the result of detection is utilized for detecting the ink discharge state. Also a statistical processing on the temperature characteristics detected on plural recording heads enables exact detection of the ink discharge state, not effected by the individual difference of the recording heads. Also there is detected the abnormality in ink discharge, that may occur prior to the exhaustion of ink in the ink tank.

FIGURE 2

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