

1 TITLE OF THE INVENTION

Liquid-Discharge Recording Apparatus and a
Method of Operation thereof.

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to a
liquid-discharge recording apparatus and, more
particularly, to a liquid-discharge recording apparatus
having the mechanism to maintain a viscosity of an ink
10 to be emitted so as to be fitted for emission at least
when the ink is emitted.

Description of the Prior Art

According to liquid-discharge recording
apparatuses, a recording liquid (for example, ink) is
15 held in an ink vessel, the ink is led to a recording
head unit from this ink vessel, a nozzle provided in
the recording head unit is driven in response to a
print pattern signal, and at the same time the ink is
emitted from a discharge opening at the head of the
20 nozzle, thereby performing the recording such as the
printing or the like on a recording material such as a
paper or the like. The ink emitted forms a jet liquid
droplet and is deposited on the recording material.

As methods of emitting the ink onto the
25 recording material, the method whereby an electro-
mechanical converter such as, e.g., a piezoelectric
device or the like is used, the method whereby an

1 electrothermal energy converter is used, and the like
are known. According to the method whereby the
electrothermal energy converter is used, the ink in
the nozzle is heated by the electrothermal energy
5 converter to cause a change in pressure of the ink,
thereby emitting the ink.

In the liquid-discharge recording apparatuses
to which the above-mentioned emitting methods and other
conventional emitting methods are applied, it is a
10 general manner that the discharge opening at the head
of the nozzle to emit the ink is always open into the
open air irrespective of whether the apparatus is
operating or not. Therefore, in the case where the
recording is not performed for a long time, the water
15 and volatile organic solvent or the like which are the
components of the ink evaporate into the open air from
the inks remaining at the discharge opening and in the
portion near the discharge opening. Thus, the viscosity
of the residual ink increases and exceeds a range of
20 viscosity necessary for emission, causing a problem
such that no ink is emitted in spite of the fact that a
print signal is applied immediately after the apparatus
operated and the recording was restarted.

In addition, there is also another problem such
25 that a temperature of the ink decreases at low
temperatures in winter season or the like, so that the
viscosity of the ink also increases.

1 To solve the problem of the increase of the
viscosity of the ink mentioned above, there has been
proposed the method whereby the ink is heated just
before the recording is restarted, namely, just before
5 the ink is again emitted, and the temperature of the
ink is increased, thereby reducing the viscosity and
maintaining it to a predetermined viscosity range.

 However, for such a preheating, the heating
condition is largely changed due to the circumstances
10 under which the recording apparatus is used. Namely,
there is a drawback such that if the preheating
condition is determined so as to obtain good emission
of the ink droplets even under low temperature
environment (for example, 5°C), the viscosity of the
15 ink becomes too low due to the heating under high
temperature environment (e.g., 35°C), so that the ink
viscosity is out of the range necessary for good
emission. On the contrary, in the case where the
preheating condition is set so as to derive a good ink
20 viscosity under high temperature environment, the
necessary viscosity cannot be derived under low
temperature environment.

 Further, even when the environmental temperature
is constant, the heating condition is also largely
25 changed depending on the use state of the recording
apparatus. Namely, due to the use of the recording
apparatus, all of the thermal energy applied from the

1 electrothermal energy converter to emit the ink
droplets from the discharge opening, for example, is
not necessarily used to form the ink droplets but a
part of this thermal energy increases the temperature
5 of the peripheral members of the electrothermal energy
converter. Therefore, the temperature of the portion
where the discharge opening is formed immediately after
the completion of the recording is largely changed as
compared with the temperature before the start of the
10 recording, so that there is a problem such that, for
instance, when the ink is heated at the restart of the
recording just after the end of the recording, the ink
is overheated and the viscosity overdecreases.

As another method for preventing the occurrence
15 of the problem due to the increase of the viscosity of
the ink, there has been proposed the method whereby the
ink is always heated when the apparatus is used and the
ink temperature is always kept constant in consideration
of a change in temperature of the external environment
20 and thereby to cope with the foregoing problem
(Japanese Patent Unexamined Publication No. 187364/
1983). As the ink heating means in this case, there
are considered the method whereby the electrothermal
energy converter which is used to form the flight ink
25 droplets is used, and the method whereby another
electrothermal energy converter is separately provided
to always heat the ink.

1 However, the use of only the above methods
also causes the problem such that it takes a time to
heat the ink when the recording is restarted. Namely,
in the case of using the electrothermal energy
5 converter provided to form the ink droplets, it is
possible to apply the electrical signal only within a
range such as not to form any ink droplet. Therefore,
an electrical signal of a high level cannot be applied
and the heating time inevitably becomes long. In the
10 case of using the electrothermal energy converter
separately provided, such a limitation does not occur;
however, since the heat is concentrated to only a
single portion, the peripheral portion is influenced by
the heat and the durability deteriorates. Thus, even
15 in this case as well, an electrical signal of a fairly
high level cannot be applied.

In addition to the foregoing heating methods,
there has been further proposed the method whereby the
recording head provided with the discharge opening in
20 the recording apparatus is located at the home position
when the recording is interrupted and this discharge
opening is covered by a cap at the home position.

However, the use of both the heating of the ink
and the capping of the discharge opening causes the
25 viscosity of the ink to exceed the viscosity range
necessary to emit the ink, so that the emission of the
ink and the formation of the ink droplets are not

always accurately performed. Further, in the case where the recording is interrupted for a long time, there is a risk that the portion of the ink which evaporates will leak from the cap, so that the concentration of the remaining ink near the discharge opening increases.

The problem with which the present invention is concerned is the provision of a liquid discharge recording apparatus in which effective use is made of both heating means for maintaining the viscosity of the ink and capping means for preventing evaporation when the recording is interrupted.

In one aspect, the invention provides a liquid-discharge recording apparatus comprising:

a recording head having an opening for discharging a liquid;

discharging means for discharging liquid from the opening;

heating means for heating liquid in said recording head prior to a recording process;

capping means for covering the discharge opening;
and

control means operable to control the heating
means so that the heating means is deactivated at all
5 times when the capping means covers the discharge
opening.

In a second aspect the invention provides a
liquid-discharge recording apparatus comprising:

10 a recording head having an opening for
discharging liquid;

heating means for heating liquid in said
recording head, said heating means comprising
electrothermal energy converting means for generating
15 energy which is used to discharge liquid in response
to an emission signal and which is used to heat the
liquid without discharging the liquid in response to a
heating signal;

capping means for covering the discharge opening;
20 and

control means operable to control the heating
signal so that the heating means is deactivated
whenever the capping means covers the discharge
opening.

In a third aspect the invention provides a method of operating a liquid-discharge recording apparatus in which there is provided a recording head having a discharge opening for emitting a liquid, and heating means in said recording head for heating the liquid prior to a recording process and capping means for covering said discharge opening, wherein the heating means is deactivated whenever an internal side of the capping means is not substantially communicated to the atmosphere.

In a fourth aspect the invention provides a method of operating a liquid discharge recording apparatus comprising: a recording head having an opening for discharging a liquid; heating means comprising electrothermal energy converting means for generating energy which is used to discharge liquid in response to an emission signal and which is used to heat liquid without discharging liquid in response to a heating signal; and capping means for covering the opening, wherein the heating means is deactivated at all times when the opening is substantially not communicated to the atmosphere.

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Reference is directed to United Kingdom Patent Application No 8828777.6 (GB 2208829A) which is divided from this application.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Fig. 1 is a schematic perspective view of a recording head unit of a liquid-discharge recording apparatus for explaining the first embodiment of the present invention;

 Fig. 2 is an enlarged diagram of a nozzle unit
15 of Fig. 1;

 Fig. 3 is a flowchart showing the heating and pre-ink-jet controls in the apparatus of Fig. 1;

 Fig. 4 is a schematic perspective view of a recording head unit for use in another example;

20 Fig. 5 is a schematic perspective view of a recording head unit in a liquid-discharge recording apparatus for use in the second embodiment;

 Fig. 6 is an enlarged perspective view of a nozzle unit in Fig. 5;

25 Fig. 7 is a rear perspective view of the main part of a liquid-discharge recording apparatus according to the third embodiment;

1 Fig. 8 is a front perspective view of a
recording head unit in Fig. 7;

Fig. 9 is a timing chart showing examples of
operation timings of capping means and heating means;
5 and

Fig. 10 is a flowchart showing an example of an
operation procedure for controlling the operation of
the heating means on the basis of the operation of the
capping means.

10

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the case of the first embodiment of a
liquid-discharge recording apparatus according to the
present invention, a temperature sensor to detect a
15 temperature of a recording head unit in which a
discharge opening is formed is provided and the heating
condition is selected on the basis of a detection
signal of this temperature sensor.

An electrothermal energy converter for heating
20 can also serve as an electrothermal energy converter
for emission. Namely, in the recording apparatus of
the type in which ink droplets are formed by heating
and expanding the ink by the electrothermal energy
converter for emission, two roles for emitting and
25 heating can be achieved by changing a level of an
electrical signal which is applied to the electro-
thermal energy converter. In this case, as compared

1 with the case where another electrothermal energy
converter for heating is separately provided, only the
minimum portion which needs to be heated can be heated,
so that the influence of the heat to the peripheral
5 portion of the electrothermal energy converter can be
suppressed to the minimum degree.

Various kinds of controlling methods can be
considered with regard to how to control the
electrothermal energy converter for heating in
10 dependence on the temperature of the head unit detected
by the temperature sensor. However, it is the most
general method that the electrical signal for heating
is applied to the electrothermal energy converter for
heating until the temperature of the recording head
15 unit near the nozzle becomes a predetermined
temperature.

The heating is ordinarily performed immediately
before the recording is started. It is desirable that
the control of the electrothermal energy converter for
20 heating is carried out by changing the level of the
electrical signal in consideration of the recording
interruption or stop period before the recording is
started.

The first embodiment of the invention will then
25 be described hereinbelow with reference to Figs. 1 to 3.
Fig. 1 is a schematic perspective view of the recording
head unit of the liquid-discharge recording apparatus

1 according to the first embodiment. Fig. 2 is an
enlarged diagram of the nozzle unit in Fig. 1.

In Fig. 1, an ink is led from a main tank (not
shown) for storage of the ink to a sub-tank 2 for
5 temporary storage of the ink by an ink supply tube 1.
The ink a quality of which deteriorated and which could
not be used is inhaled into a recovery pump (not shown)
from the sub-tank 2 or the like through a suction tube
3. The sub-tank 2 is communicated with a liquid
10 chamber 5 provided behind a nozzle unit 4 through an
ink supply tube unit 6, thereby allowing the ink to be
supplied and inhaled. In Fig. 2, twenty-four nozzles
7 are vertically arranged in front of the liquid
chamber 5. The head of each of the nozzles 7 forms a
15 discharge opening 8. The ink is emitted from the
discharge opening 8 toward a recording material. Those
plurality of nozzles 7 constitute the nozzle unit 4.
The nozzle unit 4 is fixed to a bushing 10 locating at
the center of a front plate 9 arranged in front of the
20 recording head. An electrothermal energy converter 11
for both emitting ink droplets and heating the ink is
provided in each nozzle 7. Electrical signals are
supplied to the converters 11 through an electrical
wiring section 12. The wiring section 12 and supply
25 tube unit 6 are together supported to a base plate 13.
A temperature sensor 14 consisting of a thermistor is
attached near the liquid chamber 5 provided for the
base plate 13.

1 A control method of the liquid-discharge
recording apparatus having the above-mentioned
arrangement will then be explained with reference to
Fig. 3. As described above, the electrothermal energy
5 converter 11 is used for both emitting and heating.
The heating of the ink is carried out in two kinds of
heating modes; namely, the first heating mode in that
the heating is performed at the restart of the
recording after the stop of the recording when a power
10 supply of the apparatus is OFF; and the second heating
mode in that the heating is performed at the restart of
the recording after the stop of the recording when the
power supply of the apparatus is ON. In this example,
the pre-ink-jet of ink droplets is also carried out
15 prior to performing the actual printing. The applying
levels of the foregoing first and second heating
electrical signals and of the emitting electrical
signal are shown in Table 1.

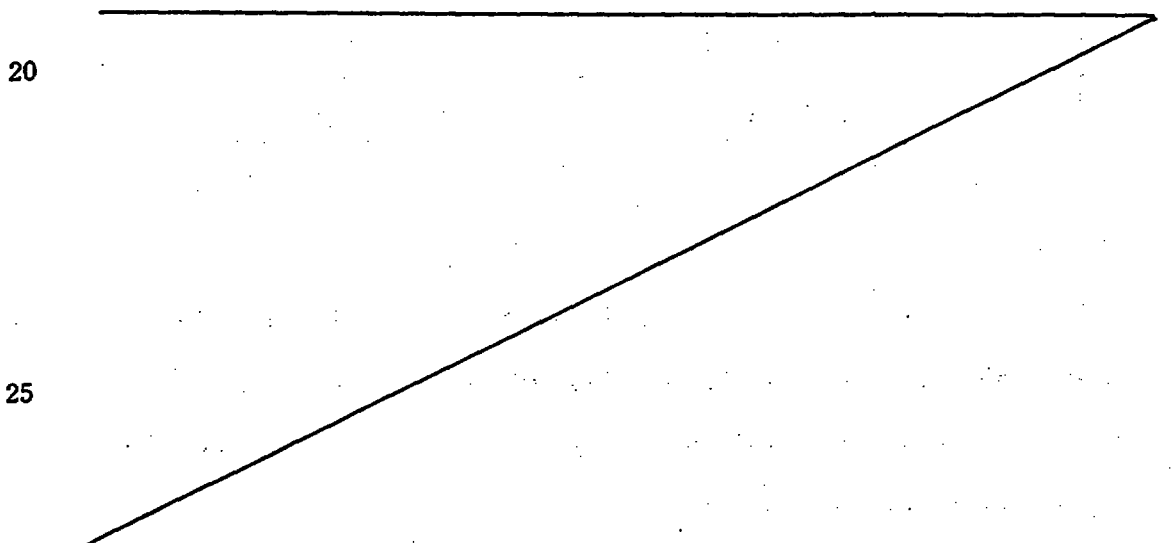


TABLE 1

	Voltage (V)	Pulse width (μsec)	Frequency (kHz)	Applying time, the number of pulses, etc.
5	23.5	2	16	Apply until the recording head temperature becomes 45°C
	23.5	2	35	Apply for one second
10	23.5	10	2	
	23.5	10	2	Apply 100 pulses
15	23.5	10	2	Apply 100 pulses

TABLE 2 (Compositions of the ink)

20	C.I. direct black 19	2 weight parts
	Diethylene glycol	30 weight parts
	Water	70 weight parts

Namely, after the recording was stopped in the
 25 OFF state of the power supply of the apparatus, when
 this power supply is turned on, the first heating is
 performed and the first heating electrical signal of a

1 voltage 23.5 V, a pulse width 2 μ sec, and a frequency
16 kHz is applied until the temperature of the
recording head becomes 45°C. Thereafter, to perform
the pre-ink-jet which is not used for printing, the
5 first pre-ink-jet electrical signal of a voltage 23.5 V,
a pulse width of 10 μ sec, and a frequency 2 kHz is
applied by 100 pulses. The apparatus waits for a
printing signal after completion of the preliminary
emission of the ink. When the printing signal is
10 applied, if the temperature of the recording head
exceeds 20°C, the second pre-ink-jet is carried out.
This is because a consideration is made to the case
where the recording interruption period after the end
of the first pre-ink-jet becomes long. The second
15 pre-ink-jet is performed by applying 100 pulses of the
second pre-ink-jet electrical signal of a voltage
25.5 V, a pulse width 10 μ sec, and a frequency 2 kHz.
After completion of the second pre-ink-jet, the
inherent emission of ink droplets is carried out and
20 the recording is started. When the temperature of the
recording head is below 20°C, the second heating is
performed and the recording head temperature is
controlled so as to become 20°C or more. This second
heating is executed by applying the second heating
25 electrical signal of a voltage 23.5 V, a pulse width
2 μ sec, and a frequency 35 kHz for one second.

1 To explain the effect of this embodiment, the
inventors of this application have performed the
experiments to compare the embodiment and Comparison
Examples 1 and 2, which will be explained later.

5 Experimental conditions:

 The environmental condition under which the
liquid-discharge recording apparatus is used was set to
two kinds: one is the condition at 10°C and 20%RH; and
the other is the condition at 40°C and 20%RH. The
10 compositions of the ink used are shown in Table 2. The
condition before the recording is restarted is set to
three kinds: the first condition is that the recording
was interrupted for five seconds when the power supply
of the apparatus was ON; the second condition is that
15 the recording was interrupted for one hour when the
power supply of the apparatus was ON; and the third
condition is that the recording was stopped for 72
hours when the power supply of the apparatus was OFF.
The dimensions of each of the 24 discharge openings are
20 50 x 40 μ m and the recording unit in which they are
vertically arranged in a line at regular intervals of
0.141 mm was used. It has been confirmed that when the
signal to emit the ink droplets was applied for five
minutes just before the recording is interrupted or
25 stopped, the ink droplets were accurately emitted.

 The control was performed in accordance with
the flowchart of Fig. 3 as the experimental condition
of the embodiment.

1 For Comparison Example 1, the recording was
restarted without performing the first and second
heating operations nor executing the first and second
emitting operations.

5 For Comparison Example 2, in the case of
restarting the recording in the recording stop state,
the signal of the same voltage, pulse width, and
frequency as those of the first heating electrical
signal of the embodiment was heated for twenty seconds,
10 and the same signals as the electrical signals for the
pre-ink-jet of the embodiment were applied, and the
heating and pre-ink-jet were carried out. In the case
of restarting the recording in the recording inter-
ruption state, the electrical signal of the same
15 voltage, pulse width, and frequency as those of the
second heating electrical signal of the embodiment was
applied for one second and the heating was performed.

The results of those three experiment examples
are shown in Table 3 for comparison.

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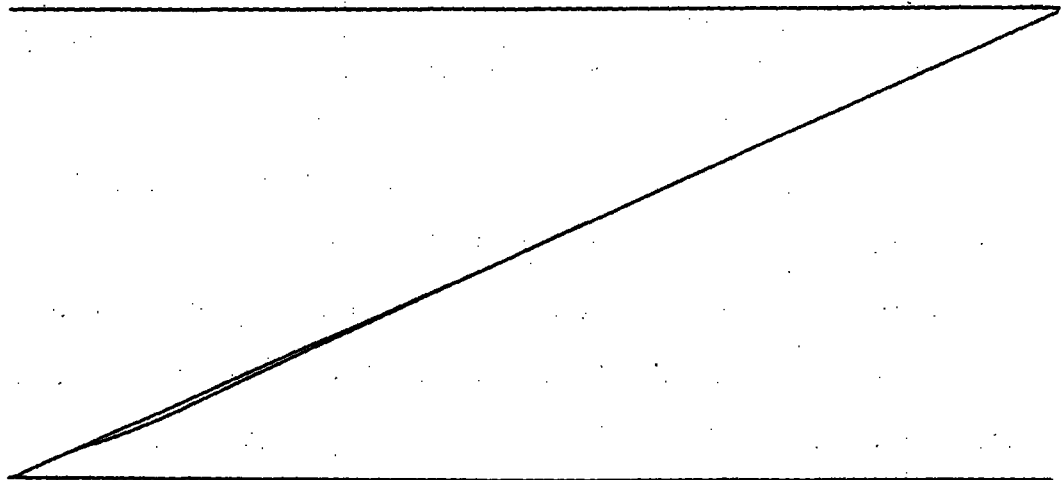


TABLE 3

The number of ink droplets which are not emitted until the ink droplets are emitted from all of 24 discharge openings

5	Recording inter- ruption or stop period	Environ- ment	Experi- ment 1	Comparison Example 1	Comparison Example 2
	Recording inter- ruption when the power supply of the recording apparatus is ON (5 seconds)	10°C 20%RH	o	o	o
10		40°C 20%RH	o	o	No droplet is emitted from 5 discharge openings
	Recording inter- ruption when the power supply of the recording apparatus is ON (1 hour)	10°C 20%RH	o	2,000	o
15		40°C 20%RH	o	o	o
	Recording stop when the power supply of the recording apparatus is OFF (72 hours)	10°C 20%RH	o	No droplet is emitted from 3 discharge openings	o
20		40°C 20%RH	o	o	No droplet is emitted from 5 discharge openings

It has been found from the results of the experiments shown in Table 3 that the case of the embodiment of the invention in which the control was performed in accordance with the flowchart of Fig. 3 is superior to Comparison Examples 1 and 2.

1 In the above embodiment, when the power supply
of the apparatus is turned on in the recording stop
state, the heating electrical signal is applied until
the temperature of the recording head becomes a set
5 value, and in the case where the recording is restarted
in the recording interruption state, the content
(voltage, pulse width, frequency, applying time) of the
heating electrical signal is determined in accordance
with the temperature of the recording head. Further,
10 as a modified form of this embodiment, the recording
stop or interruption period of the apparatus is counted
and the supply of the heating electrical signal may be
controlled on the basis of the count data of the
recording stop or interruption period and the
15 temperature data of the recording head. In addition,
as shown in Fig. 4, the electrothermal energy converter
for heating may be replaced by an external heater 15
which is separately provided.

 In the case of the second embodiment of a
20 liquid-discharge recording apparatus of the present
invention, the foregoing object is accomplished by a
constitution comprising: first heating signal
generating means which has an electrothermal energy
converter for heating a liquid to emit the liquid in
25 response to the supply of an electrical signal and
which generates an electrical signal which is applied
within a range such as not to emit any liquid to the

1 electrothermal energy converter; and second heating
signal generating means for generating an electrical
signal which is applied to an electrothermal energy
converter provided to heat the liquid separately from
5 the foregoing electrothermal energy converter, wherein
the first and second heating signal generating means
are constituted by the same means.

Namely, the electrothermal energy converter
provided to form the ink droplets and the electrothermal
10 energy converter separately provided to preheat are
used to preheat the ink.

The liquid-discharge recording apparatus
according to the second embodiment of the invention
will then be described with reference to Figs. 5 and 6.
15 Fig. 5 is a schematic perspective view of a recording
head unit in the liquid-discharge recording apparatus
and Fig. 6 is an enlarged diagram of a nozzle unit in
Fig. 5.

In Fig. 5, the ink is led from a main tank
20 (not shown) for storage of the ink to a sub-tank 502
for temporary storage of the ink through an ink supply
tube 501. The ink a quality of which deteriorated and
which could not be used is inhaled to a recovery pump
(not shown) from the sub-tank 502 or the like through a
25 suction tube 503. The sub-tank 502 is communicated
with a liquid chamber 505 (see Fig. 6) arranged behind
the nozzle unit 504 through an ink supply tube unit 506,

1 thereby allowing the ink to be supplied and inhaled.
In Fig. 6, a nozzle 507 is formed in front of the
liquid chamber 505. For example, twenty-four nozzles
507 are vertically arranged. The head of each nozzle
5 507 forms an ink discharge opening, namely, an orifice
508. The ink is emitted toward a recording material
from the orifice 508. Each nozzle 507 constitutes the
nozzle unit 504. The nozzle unit 504 is fixed to a
bushing 510 locating at the center of a front plate 509
10 arranged in front of the recording head.

An electrothermal energy converter 511 to emit
the ink and form ink droplets is provided in each
nozzle 507 and serves to emit the ink. Another
electrothermal energy converter 514 is arranged near
15 the liquid chamber 505. Electrical signals are supplied
to the electrothermal energy converters 511 and 514
through an electrical wiring section 512. The
electrical wiring section 512 and supply tube unit 506
are together supported by a base plate 513.

20 According to the liquid-discharge recording
apparatus shown in Figs. 5 and 6 described above, the
electrothermal energy converter 511 provided to form
the ink droplets and the electrothermal energy
converter 514 provided separately to preheat are
25 together used to preheat the ink. The use of both of
those converters makes it possible to reduce the
preheating time and to prevent the heat from being

1 concentrated to a single portion, so that the bad
influence on the peripheral parts can be prevented.
On one hand, the electrical signal which is applied is
determined in accordance with various conditions such
5 as the applying condition of the ink-jet signal in the
liquid-discharge recording apparatus, temperature
characteristic of the ink which is used, particularly,
the temperature characteristic of the viscosity of the
ink, viscosity change characteristic of the ink in the
10 recording interruption or stop state, and the like.
For example, it is necessary to individually control
the voltage, frequency, pulse width, and the like of
the electrical signal to predetermined values and then
apply the signal.

15 As the heating electrical signal generating
means for applying the electrical signals to those two
kinds of electrothermal energy converters 511 and 514,
one electrical signal generating means is commonly used.
The heating electrical signal to heat the electrothermal
20 energy converter 511 to form the ink droplets and the
heating electrical signal to heat (i.e., preheat) the
electrothermal energy converter 514 within a range such
as not to emit any ink droplet are together generated
from the common heating electrical signal generating
25 means.

Various kinds of timings to preheat the ink are
considered. As one of them, the preheating signal may

1 be applied immediately before the ink-jet signal is
applied. On one hand, the preheating signal may be
also always applied in the ON state of the power supply
of the recording apparatus although no recording is
5 performed (in the recording interruption state). Or,
the preheating signal may be applied for a temporary
period when the power supply is again turned on after
the state whereby the power supply of the recording
apparatus is OFF (after the recording stop state).
10 Further, the recording interruption period is
automatically counted in the recording interruption
state and after an expiration of the recording
interruption period longer than a predetermined time,
the preheating signal may be also applied.

15 To which extent the ink is preheated, namely,
to which degree the level of the preheating electrical
signal is controlled differs depending on various
conditions. Namely, various cases are considered in
dependence on the characteristic of the recording
20 apparatus, the physical property of the ink, and the
environmental condition such as the temperature,
humidity, and the like at the location where the
recording apparatus is installed and used. The level
of the preheating electrical signal may be properly
25 determined in accordance with the respective conditions
or the like.

1 Next, an explanation will be made with respect
to the results of the comparison experiments in the
cases where the recording is restarted after the ink
was preheated according to the embodiment of the
5 invention using the liquid-discharge recording
apparatus shown in Figs. 1 and 2 and where the
recording is restarted without performing the
preheating at all. As the ink used in the experiments,
the ink of the compositions shown in Table 2 was used.

10 The dimensions of each of the 24 orifices
(discharge openings) 507 are 50 x 40 μm . These
orifices are vertically arranged in a line at regular
intervals of 0.141 mm. The liquid-discharge (i.e.,
ink-jet) recording apparatus was used under the
15 environment at 25°C and 30%RH. The ink-jet recording
apparatus was kept in the recording interruption state
for one hour. In this example, the electrical signal
to heat (preheat) the ink was sent to the electro-
thermal energy converter 511 to form the ink droplets
20 (to emit the ink) during this interval and the heating
electrical signal was also sent to the other
electrothermal energy converter 514 which always
operates within a range such as not to emit any ink.
As the comparison example, the method whereby those
25 preheating operations are not performed at all was used.
Table 4 shows the voltages, pulse widths, and
frequencies of those heating electrical signals and of

- 1 the electrical signal to emit the ink (to form the ink droplets) to the electrothermal energy converter 511.

TABLE 4

5

	Voltage (V)	Pulse width (μsec)	Frequency kHz
Ink-jet electrical signal to the converter 511	23.5	10	2
Ink heating electrical signal to the converter 511	23.5	5	10
10 Heating electrical signal to the converter 514	23.5		

The results are as shown in Table 5.

TABLE 5

15

	Recording interruption period	The number of ink droplets which are not emitted until the ink droplets are emitted from all of 24 orifices
The embodiment	One hour	0
20 Comparison example	One hour	1000

In the case of the third embodiment of a liquid-discharge recording apparatus of the present invention, the viscosity of the ink is maintained by controlling the operation of heating means in response to the operation of capping means. Due to this, the unnecessary heating of the ink during the recording

25

1 interruption period can be prevented and the viscosity
range of the ink can be maintained to the necessary
range.

The ink heating means mentioned above includes
5 the means in which a heat generation level of an
electrothermal energy converter (heating device) which
is used to emit the ink and to form the ink droplets is
reduced and this converter is used, the means in which
a separate auxiliary heating device is used, and the
10 means in which both of those electrothermal energy
converter and auxiliary heating device are used. The
capping means, on one hand, is not limited to the
foregoing cap but an evaporating device containing an
ink evaporation component may be positioned at a
15 discharge opening.

An example of a structure of the liquid-discharge
recording apparatus according to the third embodiment of
the invention will then be explained with reference to
Figs. 7 and 8. The ink is supplied from a main tank
20 (not shown) for storage of the ink to a sub-tank 702
for temporary storage of the ink through a supply tube
arranged in a tube 701. A suction tube, which will be
explained hereinafter, to inhale the choked ink from a
discharge opening or the like is also arranged in the
25 tube 701 and connected to a suction pump (not shown).
The sub-tank 702 is communicated with a liquid chamber
arranged behind a nozzle, which will be explained

1 hereinafter, by a supply tube unit 703. A plurality
of nozzles are vertically arranged in front of the
liquid chamber. The heads of the nozzles are supported
by a bushing 704 and open. The bushing 704 is fixed
5 to a front plate 705 and constitutes a nozzle unit 706.
An electrothermal energy converter 707 provided in the
liquid chamber (not shown) is used to keep the
temperature of the ink constant. Electrical signals to
apply energies to the electrothermal energy converter
10 707 and to a heating device, provided in correspondence
to each discharge opening, for emitting the ink and
forming the ink droplets are supplied through an
electrical wiring section 708 consisting of an FPC
(flexible printed circuit). The electrical wiring
15 section 708, supply tube unit 703, and nozzle unit 706
are supported by a base plate 709. The case plate 709
and sub-tank 702 and the like constitute a recording
head unit as a whole. This recording head unit moves
along a shaft 710 and performs the recording operation.

20 This recording head unit is returned to a
predetermined home position when the recording is
interrupted. The nozzle unit 706 is covered with a cap
711 at the home position, thereby preventing the
evaporation component of the ink from being evaporated
25 from the head of the nozzle. No electrical signal is
applied to the electrothermal energy converter 707 at
the home position, so that the heating of the ink is

1 stopped. Due to this, it is possible to prevent that
the heating device 707 further operates in the state
in that the cap 711 was coupled and the viscosity
range of the ink exceeds the necessary range. It is
5 further possible to prevent that the evaporation
component of the ink which is heated and is likely to
be evaporated leaks from the cap 711 when the recording
is interrupted for a long time and the viscosity of the
ink contrarily increases.

10 In the above example, another heating device
707 different from a heating device which is provided
for a nozzle (not shown) and serves to form the ink
droplets was used as the ink heating means. However,
in this modified form, an electrical signal to this
15 heating device is set to a low level and applied,
thereby enabling the heating device to form the ink
droplets to be also used as the heating means for
keeping the ink temperature constant. On one hand,
although the cap 711 was used as the capping means at
20 the head of the nozzle in the foregoing example, in
another modified form, further, an evaporating device
containing an evaporation component of the ink may be
allowed to exist in the cap 711 and may be also used as
the capping means. In this case as well, it is
25 possible to prevent that the ink evaporation component
is evaporated at the home position when the recording
is interrupted and the ink viscosity increases.

1 Therefore, the further heating of the ink can be
stopped, so that the viscosity range of the ink can
optimized.

As the above-mentioned evaporating device, the
5 ink droplets emitted from the discharge opening may be
preliminarily emitted into an absorption material such
as a sponge or the like and the ink may permeate this
absorption material. In this case, it is preferable
to perform the pre-ink-jet immediately after the
10 recording head unit was returned to the home position.

The operation of the heating means for
maintaining the ink temperature to a predetermined
value as mentioned above is controlled by control means
in response to the operation of the capping means.

15 In this control means, the operation of the
capping means is discriminated by, for example, an
operation signal of the capping means or the ON/OFF of
a switch which operates interlockingly with the
movement of the capping means, or the like.

20 Fig. 9 is a timing chart showing an example of
the operation timing between the capping means and the
heating means. Under a fixed condition, it is possible
to control in a manner such that the heating means is
set to the inoperative mode (OFF state) when the
25 capping means is operating (ON state) as shown in Fig. 9.

Fig. 10 is a flowchart showing an example of an
operation procedure of the control means in the case

1 of controlling the heating means in response to the
operation of the capping means as shown in the timing
chart of Fig. 9.

5 In Fig. 10, when the power supply of the
apparatus is turned on, in step S1001, the ink
temperature is first detected by a temperature sensor
attached to the recording head unit, or the like, and
a check is made to see if it is necessary to heat the
ink or not. If YES, a check is then made in step
10 S1002 to see if the capping means is operating or not.
If the capping means is in the inoperative mode and no
operation signal is supplied, namely, if NO in step
S1002, the heating means is turned on to heat the ink
in step S1003. When the heating means is ON, the
15 operations in steps S1001 to S1003 are repeated and the
heating operation is continued until the ink temperature
reaches a predetermined value.

When it is determined that the ink temperature
has increased and reached the temperature at which the
20 heating is not required in step S1001, step S1004
follows irrespective of the presence and absence of the
capping operation signal and the heating means is
turned off to interrupt the heating.

On one hand, even if the ink temperature does
25 not increase to the predetermined value yet, when the
capping operation signal exists in step S1002, namely,
when the capping means is operating, step S1004 follows

1 and the heating means is turned off to interrupt the heating.

All of the above-described examples can be applied irrespective of the presence and absence of the sub-tank 2 or the presence and absence of the carriage, or the like.

As described above, the temperature of the recording head unit in which the ink discharge openings are formed is detected and the electrothermal energy converter for heating is controlled on the basis of this temperature. Therefore, the ink can be heated in consideration of the environmental condition under which the recording apparatus is used and of the recording interruption or stop period before the restart of the recording. In other words, since the operating environmental temperature and the recording interruption and stop periods are reflected in the temperature of the recording head unit, the optimum heating can be carried out by properly selecting the heating condition in accordance with the temperature of the recording head unit.

Further, as described above, ~~recording apparatus of the invention,~~ the preheating of the ink which is performed when the recording is restarted is carried out using both the electrothermal energy converter provided to form the ink droplets and

1 the electrothermal energy converter separately
provided to preheat the ink. Thus, the preheating
time can be reduced and it is further prevented that
the heat for preheating is concentrated to a single
5 portion, so that the bad influence on the peripheral
parts can be prevented.

In addition, as described above,
there is provided the control means for controlling the
operation of the heating means for holding the ink
10 temperature to a predetermined value on the basis of
the operation of the capping means for covering the ink
discharge opening. Therefore, it is possible to obtain
the liquid-discharge recording apparatus which can
automatically suppress that the ink viscosity changes
15 to a value out of a desired viscosity range and can
efficiently perform the recording with an excellent
quality.

CLAIMS

1. A liquid-discharge recording apparatus comprising:
a recording head having an opening for
5 discharging a liquid;
discharging means for discharging liquid from the
opening;
heating means for heating liquid in said
recording head prior to a recording process;
10 capping means for covering the discharge opening;
and
control means operable to control the heating
means so that the heating means is deactivated at all
times when the capping means covers the discharge
15 opening.

2. Apparatus according to claim 1 further comprising a
sub-tank for temporary storage of liquid from a main
tank, the sub-tank communicating with the discharge
20 opening.

3. Apparatus according to claim 2, wherein the
sub-tank communicates with the discharge opening via
a liquid chamber.
25

4. Apparatus according to claim 3, wherein a



plurality of discharge openings communicate with the liquid chamber.

5 5. Apparatus according to any preceding claim, wherein the discharging means is a member for generating thermal energy.

6. A liquid-discharge recording apparatus comprising:
a recording head having an opening for
10 discharging liquid;

heating means for heating liquid in said recording head, said heating means comprising electrothermal energy converting means for generating energy which is used to discharge liquid in response
15 to an emission signal and which is used to heat the liquid without discharging the liquid in response to a heating signal;

capping means for covering the discharge opening;
and

20 control means operable to control the heating signal so that the heating means is deactivated whenever the capping means covers the discharge opening.



7. Apparatus according to claim 6 further comprising another heating device different from the electrothermal energy converting means.

5 8. Apparatus according to claim 7, wherein the control means is operable to deactivate said other heating device.

10 9. Apparatus according to claim 7 or 8, wherein the control means is operable to activate both the electrothermal energy converting means and the other heating device.

15 10. Apparatus according to any preceding claim, further comprising means for detecting a temperature of the liquid in the recording head, and wherein the control means responds to temperature information detected by the temperature detecting means to cause the heating means, when not deactivated, to heat the
20 liquid.

11. Apparatus according to claim 10, wherein emission signal generating means generates an emission signal to which the electrothermal energy generating means is
25 responsive, and heating signal generating means forming part of the control means generates an



electrical signal which has a level within a range such as not to emit any liquid, said electrical signal being applied to the electrothermal energy converting means.

5

12. Apparatus according to claim 10 or 11, wherein the control means operates so that when a power supply of the apparatus is turned on and the heating means is not deactivated, the liquid in the recording head
10 reaches a set temperature.

13. An apparatus according to claim 12, wherein control means is arranged to apply to the electrothermal energy converting means a first signal
15 when a recording is restarted after a recording interruption in the state in that a power supply of said apparatus is ON and a second signal when said power supply of said apparatus is turned on.

20 14. A liquid-discharge recording apparatus according to Claim 1 substantially as hereinbefore described with reference to Figures 7 to 10 of the accompanying drawings.



15. Apparatus according to claim 1, wherein a single such heating means is provided for a single such recording head.

5 16. A method of operating a liquid-discharge recording apparatus in which there is provided a recording head having a discharge opening for emitting a liquid, and heating means in said recording head for heating the liquid prior to a recording process and
10 capping means for covering said discharge opening, wherein the heating means is deactivated whenever an internal side of the capping means is not substantially communicated to the atmosphere.

15 17. A method of operating a liquid discharge recording apparatus comprising: a recording head having an opening for discharging a liquid; heating means comprising electrothermal energy converting means for generating energy which is used to discharge liquid in
20 response to an emission signal and which is used to heat liquid without discharging liquid in response to a heating signal; and capping means for covering the opening, wherein the heating means is deactivated at
25 all times when the opening is substantially not communicated to the atmosphere.



18. Apparatus according to any of claims 1 to 15, wherein said capping means has an ink absorptive body.

