

Liquid Jet Recorder and Recording Method

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to a liquid jet recorder which discharges liquid to form droplets and deposit the droplets on a record medium such as a paper to make a record, and more particularly to a liquid
10 jet recorder and a recording method for imparting thermal energy to liquid to form droplets.

Description of the Prior Art

In a liquid jet recording method, droplets of recording liquid formed in one of various methods are
15 deposited on a record medium such as a paper.

Among the recorders which employ such recording method, a liquid jet recorder which utilizes heat as an energy to form droplets has a structure suitable to a high density multi-orifice recording head.

20 The liquid jet recorder which utilizes the heat as the droplet discharge energy comprises droplet forming means for forming the droplets of the recording liquid by heating the recording liquid to cause a rapid change in volume of the recording liquid to cause the
25 liquid to be discharged from orifices, and a recording head having an electro-thermal energy transducer (heater) which is heated upon application of an electrical signal to heat the recording liquid.

1 On the other hand, among the recording liquids
used in the liquid jet recorders, aqueous recording
liquid is preferable from standpoints of a recording
characteristic and safety. The aqueous recording
5 liquid consists of recording agent ingredient such as
pigment or dye and solvent ingredient such as water or
water and water soluble organic solvent for dissolving
or dispersing the recording agent ingredient.

 In the recorder which utilizes the heat as the
10 droplet discharge energy and the recorder which uses
other droplet forming method, the orifices at the end
of the nozzle from which the recording liquid is
discharged are usually opened to the atmosphere
externally of the recorder irrespective of the
15 operation of the recorder.

 As a result, if the non-record state lasts for
a long time, water and other solvent such as volatile
organic solvent are evaporated into the atmosphere
through the orifices because the recording liquid is
20 aqueous and the recording agent ingredient and
non-volatile solvent remain in the recording liquid.
Thus, the viscosity of the recording liquid increases
beyond a range suitable for the discharge of the
recording liquid. As a result, immediately after the
25 record operation was resumed, the droplets are not
discharged in spite of the application of a discharge
signal and initial print portion of the recorded image
includes a low quality print.

1 In a known recording method, the recording
liquid is always heated by applying to the heater an
electrical signal of a level insufficient to cause the
droplets to be discharged even when the droplet
5 discharge signal is not applied so that the temperature
of the recording liquid is always maintained in a
predetermined range to assure good discharge condition
of the droplets to the increase of viscosity of the
recording liquid at a low temperature.

10 For example, Japanese Patent Application
Laid-Open No. 187364/1983 discloses a liquid jet recorder
for forming flying droplets by heating liquid by an
electro-thermal transducer and discharging the droplets
to make a record. It includes detection means for
15 detecting an external temperature and means for varying
a duty cycle of a drive signal for pre-heating the
electro-thermal transducer in accordance with the
output from the detection means.

 In the recorder of this type, since the
20 electrical signal is applied to the heater so that the
recording liquid is always kept at a high temperature
during a relatively long non-record or stop period, the
solvent ingredient in the recording liquid is easily
evaporated and the droplets are not discharged when the
25 record operation is resumed. In addition, since the
vicinity of the heater is always kept heated, the
durability of the members around the heater is short or

1 the recording liquid stored around the heater during
the non-print period is modified by the heat and the
color of the recording liquid changes or precipitate
is generated in the recording liquid and it clogs the
5 orifices.

SUMMARY OF THE INVENTION

It is an object of the present invention to
provide a liquid jet recorder and a recording method
10 for adjusting a viscosity of recording liquid within a
range suitable for good droplet discharge condition
and assuring good and stable droplet discharge
condition when a record operation is resumed after a
long non-print or stop period.

15 It is another object of the present invention
to provide a liquid jet recorder and a recording
method for securing good and stable droplet discharge
condition without reducing durability of members
around a heater of the recorder and without modifying
20 recording liquid stored around the heater during the
non-print period by an affect of heat.

It is other object of the present invention to
provide a liquid jet recorder and a recording method
which use a thermal energy to form droplets and assure
25 good and stable droplet discharge condition by using
droplet forming means as recording liquid heating means
to adjust viscosity of the recording liquid.

5 The present invention provides a liquid jet recorder
having an electro-thermal energy transducer used to
heat liquid upon application of an electrical signal
to form flying droplets, including discharge signal
generating means for causing the electro-thermal
energy transducer to discharge droplets and heating
signal generating means for generating a high
frequency electrical signal to be applied to the
electro-thermal energy transducer within a range
10 insufficient for discharging of the droplets.

15 The present invention also provides a liquid droplet
recording method for making a record by applying an
electrical signal to an electro-thermal energy
transducer to heat liquid to discharge a liquid
droplet, characterised in that when a predetermined
time period has elapsed from discharge of a droplet, a
high frequency electrical signal of a level
insufficient to discharge a droplet is applied to the
20 transducer by heating signal generating means.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Fig. 1 is a perspective view of a recording head of a
liquid jet recorder of the present invention,

Fig. 2 is a partial enlarged view of a vicinity of
nozzle of the recording head shown in Fig. 1,

1 Fig. 3 shows changes in time of temperature
of heats generated when three different electrical
signals are applied to the electro-thermal energy
transducer, and

5 Figs. 4 and 5 flow charts in a mechanism
for controlling record operation of the present
recorder.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

10 The recorder of the present invention is
explained with reference to a liquid jet recording
head which utilizes heat as an energy to form droplets.

 Fig. 1 is a perspective view of a recording
head in the liquid jet recorder of the present
15 invention and Fig. 2 is a partial enlarged view of a
vicinity of a nozzle of the recording head shown in
Fig. 1.

 Numeral 1 denotes a supply tube which connects
a recording liquid main tank (not shown) and a sub-tank
2 for temporarily storing therein recording liquid in
20 the recording head and supplies the recording liquid
from the main tank to the sub-tank 2, numeral 3 denotes
a suction tube connected to a recovery pump (not shown),
numeral 4 denotes a supply pipe unit for supplying the
25 recording liquid from the sub-tank 2 to a liquid
chamber 5, numeral 6 denotes a retainer for the supply
pipe unit 4, numeral 7 denotes a nozzle having a

1 plurality of orifices 12 arranged longitudinally to
discharge the recording liquid as shown in Fig. 2,
numeral 8 denotes an electrical wiring unit including
a flexible printed circuit board (FPC) for applying an
5 electrical signal to a heater 13 to apply a thermal
energy to the recording liquid in a liquid flow path
14 shown in Fig. 2, numeral 9 denotes a base plate on
which the supply pipe unit 4, liquid chamber 5, nozzle
7, supply pipe retainer 6 and FPC 8 are mounted,
10 numeral 10 denotes a bushing to support periphery of
the nozzle and numeral 11 denotes a front plate.

In the present embodiment, droplet forming
means for forming droplets is constructed by the orifices
12 and the liquid flow path 14 having a portion thereof
15 connected to the orifices 12 and in which the heat from
the heater is applied to the recording liquid, and
liquid heating means is constructed by the heater 13
and the FPC 8 for applying the electrical signal to
the heater 13 as required. While not shown in the
20 drawing, the recorder includes discharge signal
generating means for generating an electrical signal
to discharge droplets and a heating signal generating
means for generating a recording liquid heating
electrical signal to be described later.

25 In order to make a record by the present
recorder, the recording liquid is filled in to the
sub-tank 2, the liquid chamber 5 and the liquid flow

1 path 14 from the main tank through the supply tube 1
and the supply pipe unit 4. A recording signal is
applied to the heater 13 through the FPC 8, that is,
the electrical signal from the droplet discharge
5 signal generating means is applied to the heater 13.
As a result, the heater 13 generates a heat and a
thermal energy is applied to the recording liquid in
the liquid flow path 14 in the vicinity of the heater
13 and air bubbles are generated in the recording
10 liquid due to momentary increase in volume of the
recording liquid. Thus, the recording liquid down-
stream of the heater 13 is discharged from the
orifices 12 and droplets of the recording liquid are
formed. The droplets of the recording liquid are
15 deposited on a record medium such as a paper fed in
front of the nozzle 7 to make a record.

In the liquid jet recorder of the present
invention, the recording liquid heating signal is
applied to the heater 13 in the record operation, that
20 is, immediately before the electrical signal is applied
to the heater 13 to discharge the droplets for
recording.

The recording liquid heating signal in the
present recorder serves to heat the recording liquid
25 by the heater 13 to a temperature which assures a
proper viscosity of the recording liquid to attain
good recording liquid discharge condition, to an

1 extent insufficient for discharging of the droplets.
The signal is generated by the heating signal
generating means.

5 The heating time of the recording liquid by
the heater 13 heated by the application of the heating
electrical signal is preferably as short as possible
within a range in which the recording liquid is heated
to the predetermined temperature.

By heating the recording medium in a short
10 heating time, the heater 13 and the members around the
heater are less affected by the heat leading to the
degradation to extend the lifetime of those components.
Further, the diffusion of the heat from the heater to
the periphery of the heater is minimized and the
15 amount of recording liquid to be heated is reduced,
the affect of the heat to the recording liquid in the
liquid flow path or the liquid chamber is eliminated and
the promotion of the evaporation of the solvent ingre-
dient of the recording liquid from the orifices by long
20 time heating is prevented. The heating time of the
recording liquid is determined depending on a
temperature characteristic of the recording liquid such
as a heat capacity, a structure of the recorder and a
temperature suitable to the recording liquid to be
25 discharged.

Taking the above requirements in to
consideration, when the heating electrical signal is

1 applied in the liquid jet recorder of the present
invention, voltage, frequency and pulse width of the
signal are selected in accordance with a condition of
application of the droplet discharge signal, a
5 temperature characteristic of the recording liquid
used, a temperature characteristic of the viscosity of
the recording liquid and a change of viscosity of the
recording liquid in a non-print or stop period.

There are various methods to control the
10 electrical signal to produce the heating electrical
signal. In a method which uses an electrical signal
circuit incorporated in the recorder, the discharge
signal generating means is shared by the heating
electrical signal generating means and the electrical
15 signal from the discharge signal generating means is
tailored in the following manner to produce the
heating electrical signal.

A relation between the frequency, voltage and
pulse width of the applied electrical signal and the
20 heating temperature is shown in Fig. 3 in which
electrical signals having voltage of 23.5 volts, pulse
width of 5 μ s and frequencies of 10 KHz, 5 KHz and
2 KHz, respectively, are applied to the heater.

In order to achieve the above object,
25 a) the pulse width of the droplet discharge
signal is reduced and the frequency is increased,

1 b) the voltage of the droplet discharge
signal is reduced and the frequency is increased, or

 c) the pulse width and the voltage of the
droplet discharge signal are reduced and the frequency
5 is increased.

 Particular values in those methods vary with
the properties of the recording liquid used and the
characteristics of the recorder and are not uniformly
defined. In the method a), the pulse width of the
10 heating electrical signal is preferably $1/1.25 - 1/100$
and more preferably $1/2 - 1/20$ of the pulse width of
the droplet discharge signal. The frequency of the
heating electrical signal is preferably $2 - 100$ times
and more preferably $5 - 50$ times as high as the
15 frequency of the droplet discharge signal. In the
method b), the voltage of the heating electrical signal
is preferably $1/1.25 - 1/10$ and more preferably
 $1/1.4 - 1/2.4$ of the voltage of the droplet discharge
signal, and the frequency of the heating electrical
20 signal is preferably $2 - 100$ times and more preferably
 $5 - 50$ times as high as the frequency of the droplet
discharge signal. In the method c), the voltage of the
heating electrical signal is preferably $1/1.25 - 1/10$
and more preferably $1/1.4 - 1/2.4$ of the voltage of the
25 droplet discharge signal, the pulse width of the
heating electrical signal is preferably $1/1.25 - 1/100$
and more preferably $1/2 - 1/20$ of the pulse width of

1 the droplet discharge signal, and the frequency of the
heating electrical signal is preferably 2 - 100 times
and more preferably 5 - 50 times as high as the
frequency of the droplet discharge signal.

5 The droplet discharge signal generating means
and the heating electrical signal generating means may
be independently and separately provided.

The heating electrical signal may be applied
immediately before the droplet discharge signal is
10 applied to the heater, or may be applied immediately
before the droplet discharge signal is applied after
the non-print period with the recorder being powered
on or stop period with the recorder being powered off.

If the viscosity of the recording liquid in
15 the liquid flow path is possibly not within the
suitable range under the environment of use of the
recorder such as temperature, the heating electrical
signal is applied immediately before the droplet
discharge signal is applied to the heater so that the
20 viscosity of the recording liquid at the time of
discharge is adjusted to a proper value. When the
viscosity of the recording liquid is kept in the proper
range under the environment of use of the recorder such
as temperature but the next droplet is not discharged
25 for a predetermined period (non-print mode) or the
recorder is in a stop mode, the viscosity of the
recording liquid may increase by the evaporation of the

1 solvent into the atmosphere. Thus, the non-print or
stop period is counted and if the record operation is
resumed after more than the predetermined length of
non-print or stop period, the heating electrical
5 signal is applied to the heater.

The above predetermined length of the
non-print or stop period, that is, the time period in
which the viscosity of the recording liquid in the
liquid flow path, particularly around the orifices
10 goes beyond the preferable range depends on the
characteristics of the recorder, the properties of the
recording liquid and the environment conditions such
as temperature and humidity of the location at which
the recorder is installed. Accordingly, it is
15 determined in accordance with a particular recorder
and the operation condition thereof.

In the recorder of the present invention,
after the heating electrical signal was applied to the
heater, non-print droplet discharge signal may be
20 applied to the heater and then the print droplet
discharge signal may be applied to the heater.

In the recorder of the present invention, the
non-print droplet discharge signal causes the droplet
to be discharged but the droplet is recovered by the
25 recorder and not used for printing on the record
medium.

1 By applying the non-print droplet discharge
signal to the heater after the heating electrical
signal was applied to the heater, even if the
non-print period or the stop period is very long and
5 the viscosity of the recording liquid increases by the
evaporation of the solvent, the heater is heated by
the heating electrical signal and the high viscosity
recording liquid is heated and the temperature thereof
rises. As a result, the viscosity of the recording
10 liquid is lowered to an extent to enable discharging
of the droplet although the droplet formed may not be
good. Then, as the droplet discharge signal is
applied to the heater, the recording liquid near the
heater is discharged out of the liquid flow path and
15 the recording liquid having the viscosity which is
within the suitable range for discharging is supplied
to the vicinity of the heater. The good discharge
condition of the recording liquid is thereafter
maintained.

20 The non-print droplet discharge signal is
applied under the condition that the recording liquid
having the viscosity which is beyond the suitable
range for discharging is discharged by the application
of the heating electrical signal to the heater and the
25 discharged droplet is removed from the liquid flow
path.

1 Figs. 4 and 5 show flow charts in a control
unit for the recorder of the present invention. In
Figs. 4 and 5, t indicates an upper limit of the
non-print time in which pre-heating is not required,
5 that is, the operation to apply the heating electrical
signal to heat the recording liquid to the extent that
the recording liquid is not discharged is not required,
and T indicates an upper limit of the non-print time
in which pre-heating is required. After the time
10 period T , the pre-heating and pre-discharging are
required. The pre-discharging means the non-print
droplet discharging.

 In the control unit shown in Fig. 4, when a
print signal or the print droplet discharge signal is
15 applied after power-on, the pre-heating and the
pre-discharging are conducted in this order before the
print droplet is discharged. Then, the discharge
signal generating means generates the discharge
electrical signal which is applied to the heater to
20 discharge to recording liquid. If the non-print time
exceeds t , the pre-heating is effected, and if the
non-print time exceeds T , the pre-heating and the
pre-discharging are effected.

 In the control unit shown in Fig. 5, when the
25 power is turned on, the pre-heating and the pre-
discharging are effected, and if the printing is not
effected after the power-on, the non-print time is

1 counted and if it exceeds t , the pre-heating is
effected. If it exceeds T , the pre-heating and the
pre-discharging are effected. The control for the
non-print period after printing is similar to that of
5 Fig. 4.

In the recorder of the present invention
described above, the thermal energy is utilized to
form the droplet and the discharge energy generating
means (heater) is shared by the means for heating the
10 recording liquid to the extent that it is not
discharged. These means may be separately and
independently provided or where the heat is not used
to form the droplet, recording liquid heating means
such as a heater may be provided to carry out the
15 control described above.

In the liquid jet recorder of the present
invention described above, the recording liquid heating
signal and, if necessary, the non-print droplet
discharge electrical signal are applied to the heater
20 13 immediately before the droplet discharge electrical
signal is applied so that the viscosity of the
recording liquid to be discharged is adjusted to a
range suitable to obtain good droplet discharge
condition. Thus, even if the record operation is
25 resumed after a long non-print or stop period, the
good and stable droplet discharge condition is always
attained.

1 Since the recording liquid is not frequently
 heated by the recording liquid heating signal and the
 heating time is very short, the durability of the
 member around the heater of the recorder is not
5 lowered by the affect of the heat and the recording
 liquid stored in the vicinity of the heater during the
 non-print period is not modified by the heat and the
 good and stable droplet discharge condition is
 attained.

10 In the present recorder which utilizes the
 thermal energy to form the droplet, the recording
 liquid heating means for primarily adjusting the
 viscosity of the recording liquid is shared by the
 droplet forming means. Accordingly, no separate
15 recording liquid heating means is required and the
 good and stable droplet discharge condition is always
 attained.

Example 1

 In the liquid jet recorder of the present
20 invention having the recording head as shown in Fig. 1
 in which 24 orifices (having size of 50 x 40 μ m are
 arranged in a vertical line at a pitch of 0.141 mm,
 the recording liquid having the following composition
 is filled, and after 1-hour non-print period under
25 25 °C and 30% RH, the print operation is resumed by
 applying a heating electrical signal having a voltage
 of 23.5 V, a pulse width of 5 μ s and a frequency of

1 10 KHz to the heater immediately before a droplet
discharge electrical signal having a voltage of 23.5 V,
a pulse width of 10 μ s and a frequency of 2 KHz is
applied. The number of non-discharged droplets to the
5 print signals is counted until all of the 24 orifices
discharge the print droplets to evaluate the recorder
for the non-discharging of the droplets after the
non-print period. The result is shown in Table 1.

The composition of the recording liquid used
10 is shown below.

[Composition of the recording liquid]

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

15 Comparative Example 1

In a recorder having a construction similar to
that of the Example 1 but only the print droplet
electrical signal is applied to the heater, the
recording liquid used in the Example 1 is filled, and
20 after 1-hour non-print time under 25 °C and 30% RH,
the record operation is resumed by applying the
droplet discharge electrical signal having a voltage
of 23.5 V, a pulse width of 10 μ s and a frequency of
2 KHz to the heater. The recorder is evaluated for
25 the non-discharging after the non-print period as was
done in the Example 1. The result is shown in Table 1.

1 Example 2

The recorder used in the Example 1 is used. The non-print period is 12 hours. After the heating electrical signal was applied, the droplet discharge
5 electrical signal comprising 100 pulses is applied to the heater to discharge the non-print droplets. Then, the print droplet discharge electrical signal is applied to the heater. The other steps are equal to those of the Example 1. The recording liquid used in
10 the Example 1 is used and the recorder is evaluated in the same manner as the Example 1. The result is shown in Table 1.

Comparative Example 2

Except for the non-print time of 12 hours, the
15 record is made in the same manner as the comparative Example 1 and the evaluation is done in the same manner as the Example 1. The result is shown in Table 1.

Table 1

20		Number of non-discharged droplets counted until all of 24 orifices discharge droplets	Non-print time (hour)
	Example 1	0	1
	Example 2	0	12
25	Comparative Example 1	1000	1
	Comparative Example 2	Two of 24 orifices do not discharge droplets	12



1 CLAIMS:

1. A liquid jet recorder having an electro-thermal energy transducer used to heat liquid upon application of an electrical signal to form a flying
5 droplet, comprising:

discharge signal generating means for causing said electro-thermal energy transducer to discharge the droplet; and

heating signal generating means for generating a
10 high frequency electrical signal to be applied to said electro-thermal energy transducer within a range insufficient for discharging of the droplet.

2. A liquid jet recorder according to Claim 1
15 wherein said discharge signal generating means and said heating signal generating means are common.

3. A liquid jet recorder according to Claim 1 wherein said discharge signal generating means and
20 said heating signal generating means are separate from each other.

4. A liquid jet recorder according to Claim 1 wherein a pulse width of said high frequency electrical
25 signal is $1/1.25$ to $1/100$ of a pulse width of the droplet discharge signal.



5. A liquid jet recorder according to claim 1 wherein a voltage of said high frequency electrical signal is $1/1.25$ to $1/10$ of a voltage of the droplet discharge signal.

5

6. A liquid jet recorder according to claim 1 wherein a frequency of said high frequency electrical signal is 2 to 100 times as high as a frequency of the droplet discharge signal.

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7. A liquid droplet recording method for making a record by applying an electrical signal to an electro-thermal energy transducer to heat liquid to discharge a liquid droplet, characterised in that when a predetermined time period has elapsed from discharge of a droplet, a high frequency electrical signal of a level insufficient to discharge a droplet is applied to the transducer by heating signal generating means.

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8. A recording method according to claim 7 wherein a non-print droplet discharge signal is applied to the transducer to discharge a non-print droplet after said high frequency electrical signal has been applied.

25

9. A recording method according to claim 8 wherein said non-print droplet is discharged a predetermined time after said predetermined time period.



1 10. A recording method according to Claim 7
wherein said discharge signal generating means and
said heating signal generating means are common.

5 11. A recording method according to Claim 7
wherein said discharge signal generating means and
said heating signal generating means are separate from
each other.

10 12. A recording method according to Claim 1
wherein a pulse width of said high frequency electrical
signal is $1/1.25$ to $1/100$ of a pulse width of the
droplet discharge signal.

15 13. A recording method according to Claim 7
wherein a voltage of said high frequency electrical
signal is $1/1.25$ to $1/10$ of a voltage of the droplet
discharge signal.

20 14. A recording method according to Claim 7
wherein a frequency of said high frequency electrical
signal is 2 to 100 times as high as a frequency of the
droplet discharge signal.



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15. A recording method substantially as herein described with reference to the accompanying drawings.

16. A liquid jet recording device substantially as herein described with reference to the accompanying drawings.
