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(12) **United States Patent**
Kimura et al.

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(45) **Date of Patent: Jul. 18, 2006**

(54) **INK JET RECORDING APPARATUS, CONTROL AND INK REPLENISHING METHOD EXECUTED IN THE SAME, INK SUPPLY SYSTEM INCORPORATED IN THE SAME, AND METHOD OF MANAGING INK AMOUNT SUPPLIED BY THE SYSTEM**

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(73) Assignee: **Seiko Epson Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 12 days.

(21) Appl. No.: **10/417,236**

(22) Filed: **Apr. 17, 2003**

(65) **Prior Publication Data**

US 2003/0202059 A1 Oct. 30, 2003

Related U.S. Application Data

(62) Division of application No. 10/068,008, filed on Feb. 8, 2002, now Pat. No. 6,883,905.

(30) **Foreign Application Priority Data**

Feb. 9, 2001	(JP)	P.2001-034187
Feb. 9, 2001	(JP)	P.2001-034188
Apr. 27, 2001	(JP)	P.2001-130997
Apr. 27, 2001	(JP)	P.2001-130998
Aug. 17, 2001	(JP)	P.2001-247677
Aug. 17, 2001	(JP)	P.2001-247678
Sep. 3, 2001	(JP)	P.2001-266043
Sep. 3, 2001	(JP)	P.2001-266044
Nov. 29, 2001	(JP)	P.2001-363784

(51) **Int. Cl.**
B41J 2/175 (2006.01)
B41J 2/195 (2006.01)

(52) **U.S. Cl.** **347/85**; 347/7

(58) **Field of Classification Search** 347/5, 347/7, 19, 84, 85, 86, 87
See application file for complete search history.

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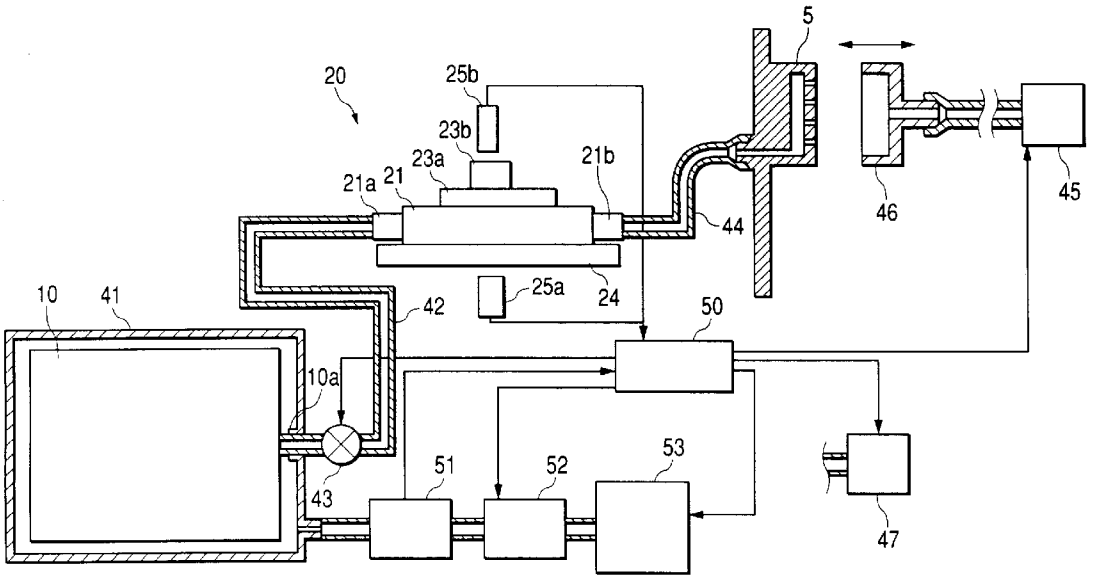
Primary Examiner—Anh T. N. Vo
(74) *Attorney, Agent, or Firm*—Sughrue Mion, PLLC

(57) **ABSTRACT**

In an ink jet recording apparatus, at least one main tank stores ink therein. A plurality of subtanks are communicated with each main tank. Each subtank stores ink supplied from the main tank. Each subtank is communicated with at least one recording head.

37 Claims, 18 Drawing Sheets



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347/86

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FIG. 1

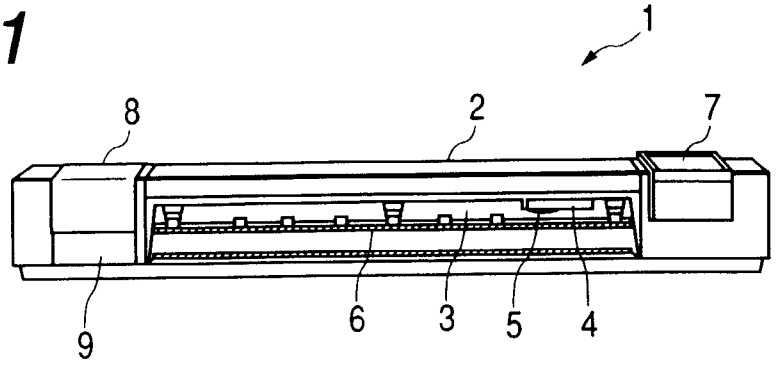

1
8
2
7
6
3
5
4
9

FIG. 2

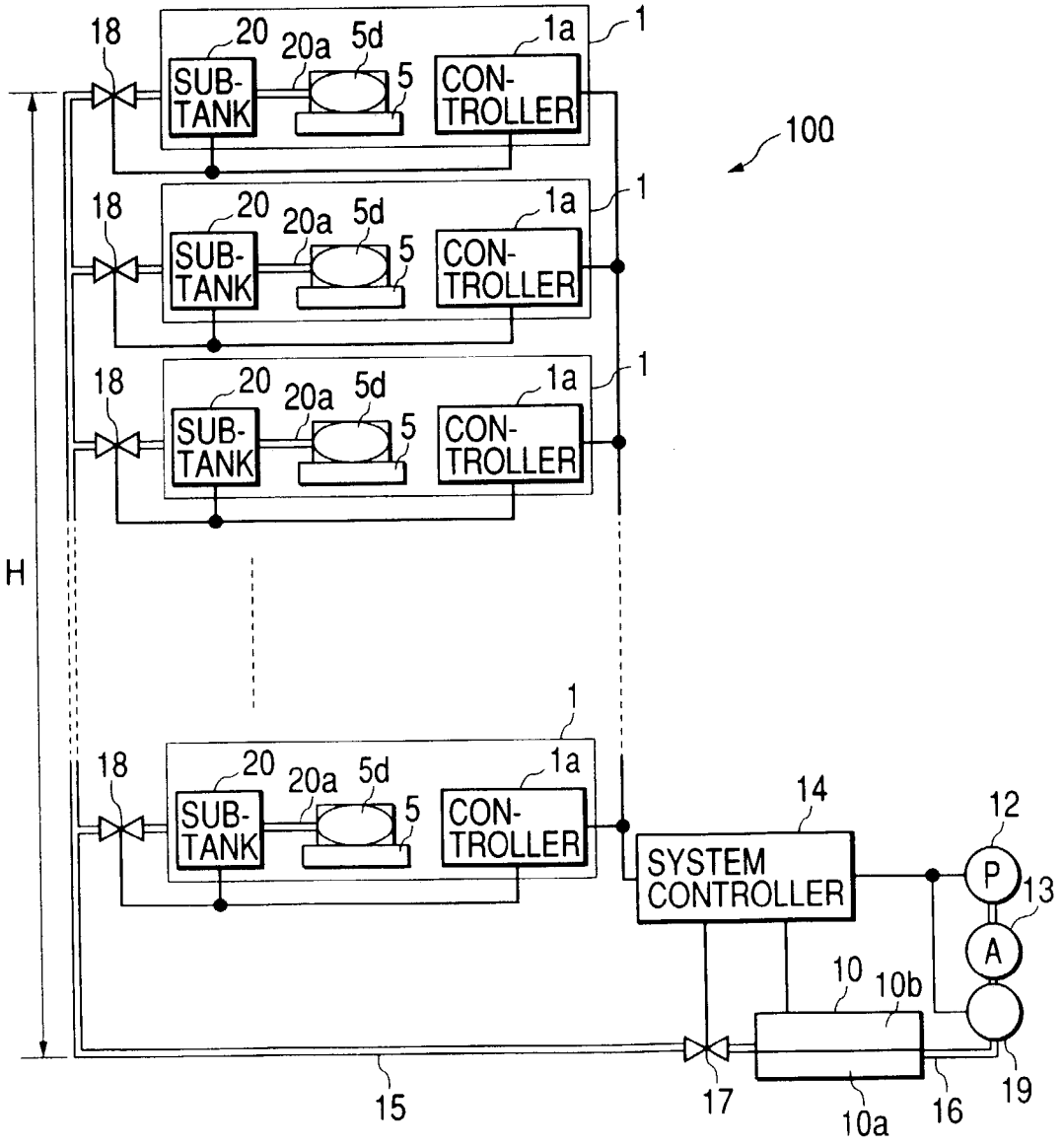

100
1
18
20
20a
5d
5
1a
SUB-TANK
CON-TROLLER
H
14
SYSTEM CONTROLLER
12
P
13
A
10
10b
10a
15
17
16
19

FIG. 3

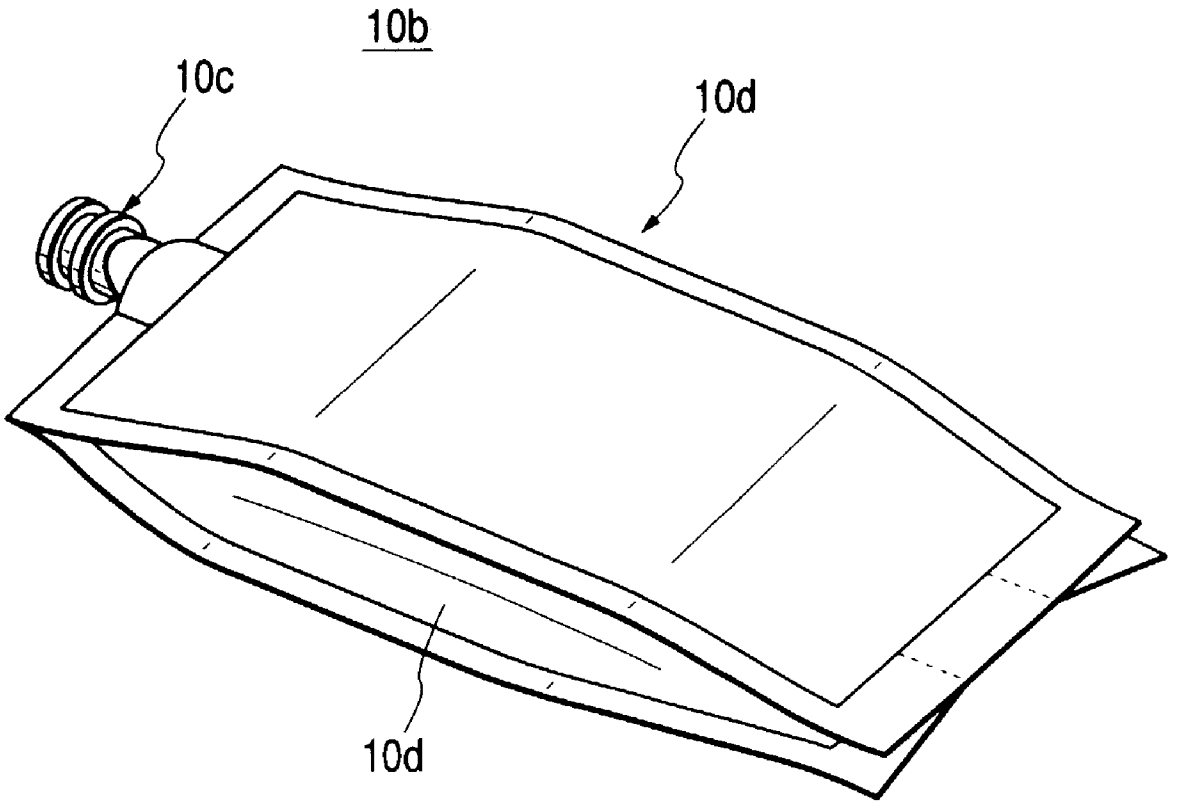


FIG. 4A

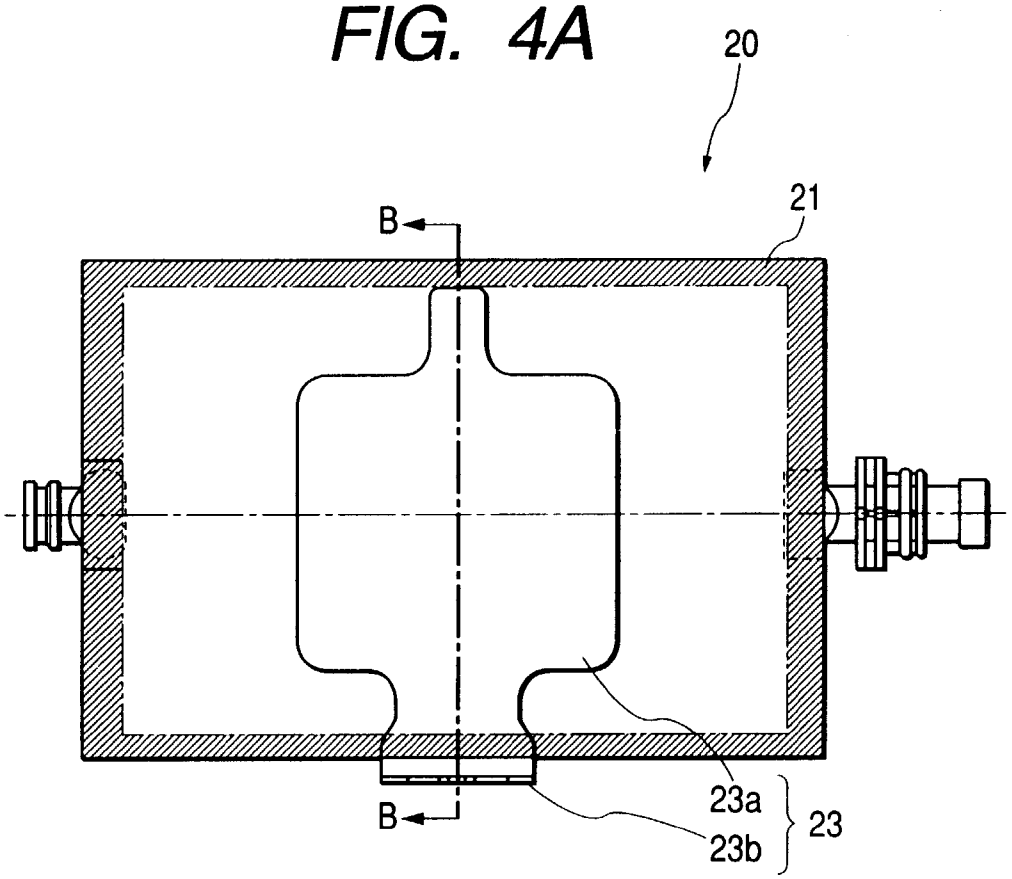


FIG. 4B

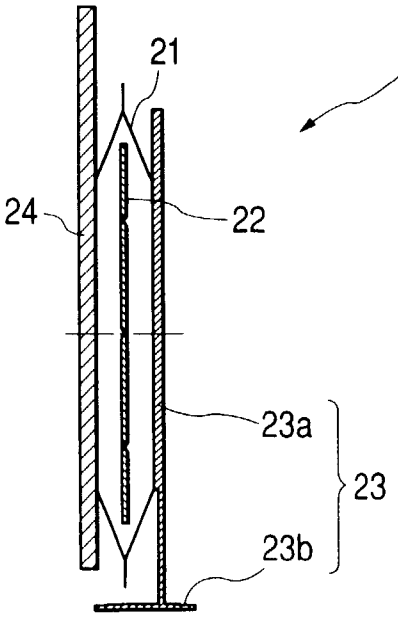


FIG. 5

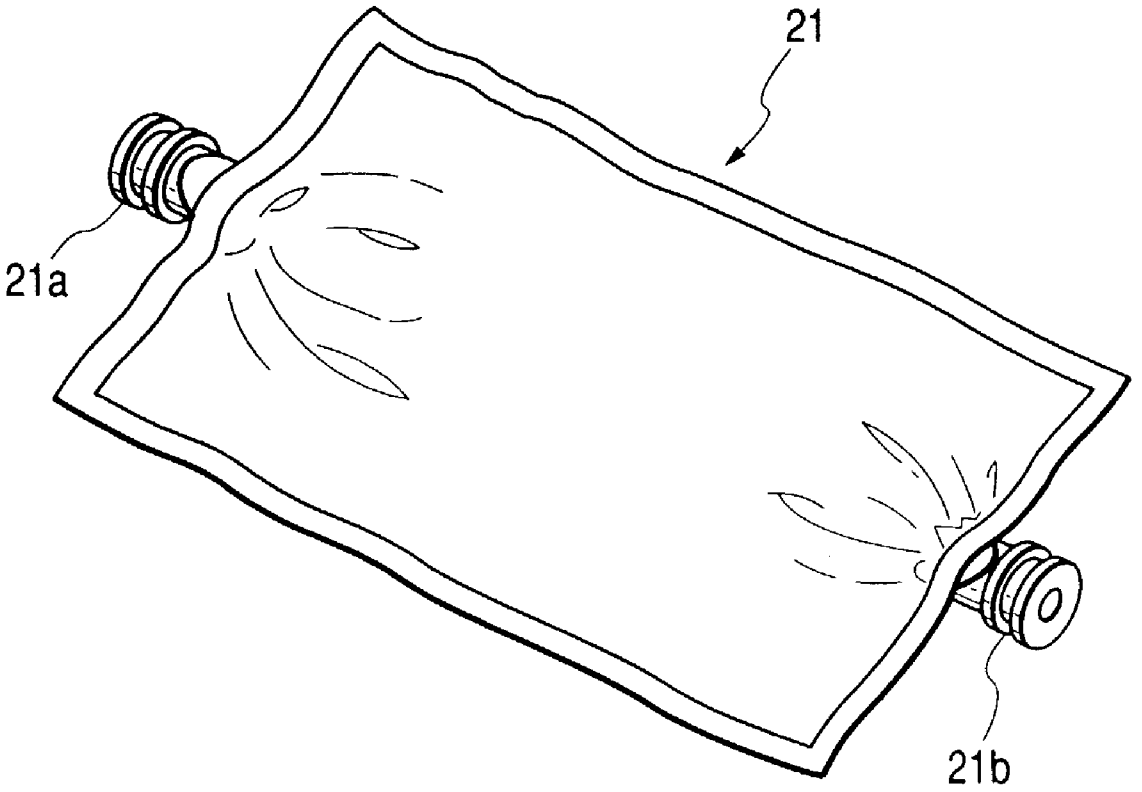


FIG. 6A

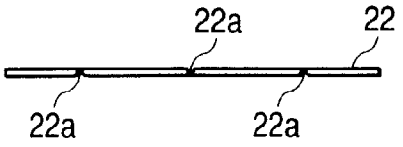


FIG. 6B FIG. 6C FIG. 6D

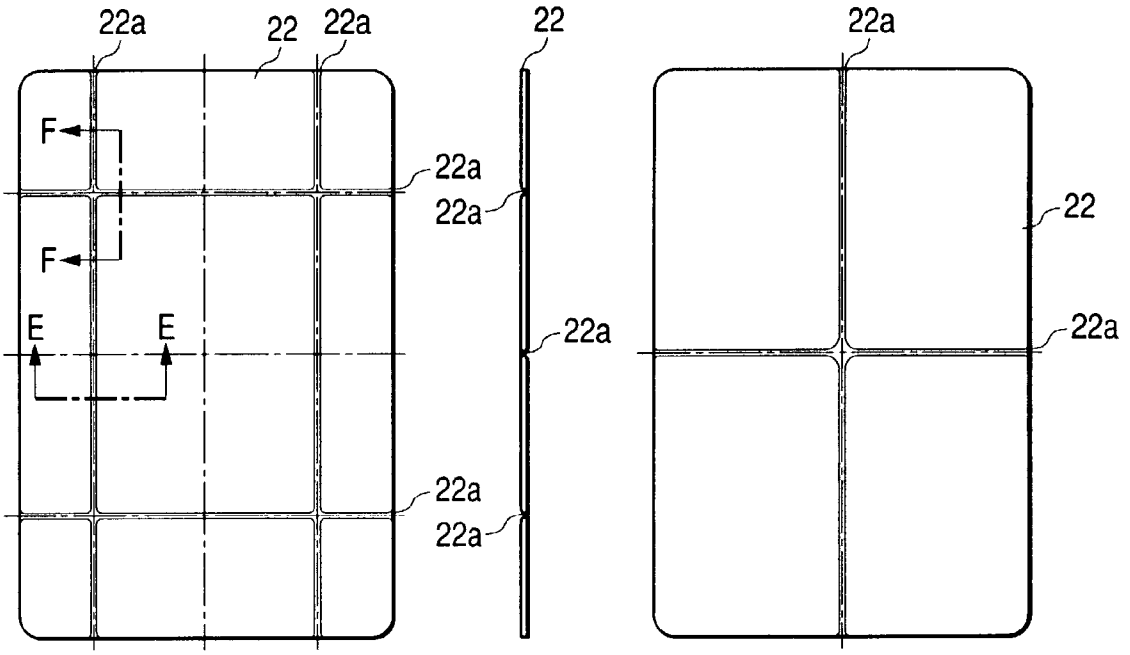


FIG. 6E

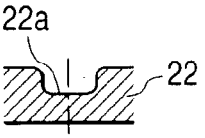


FIG. 6F

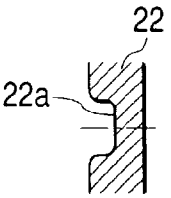


FIG. 7A

FIG. 7B

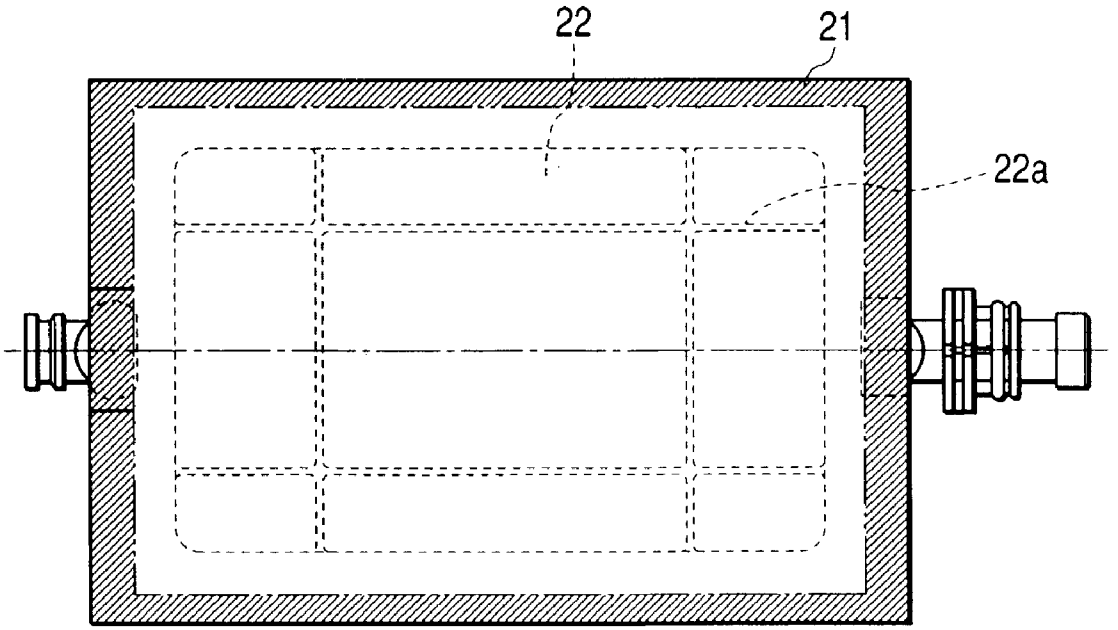


FIG. 8A

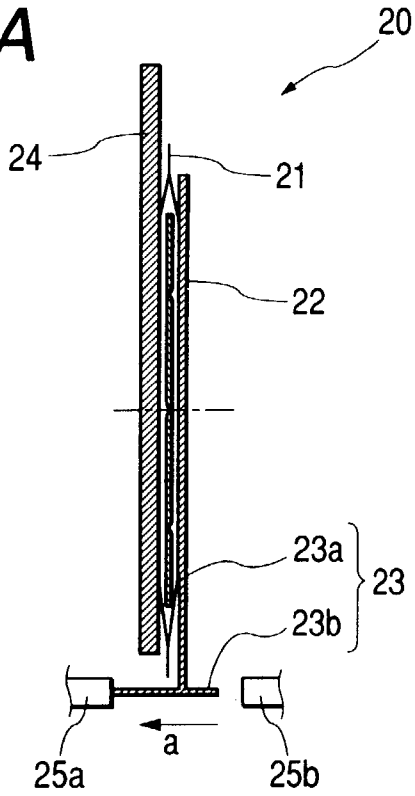


FIG. 8B

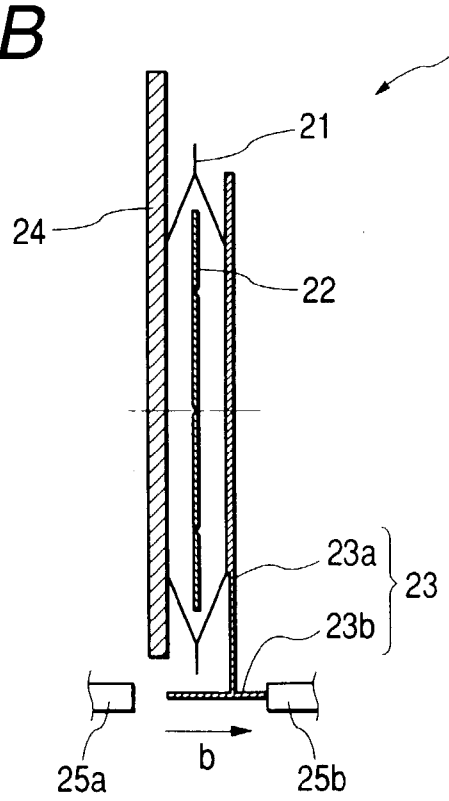


FIG. 9A

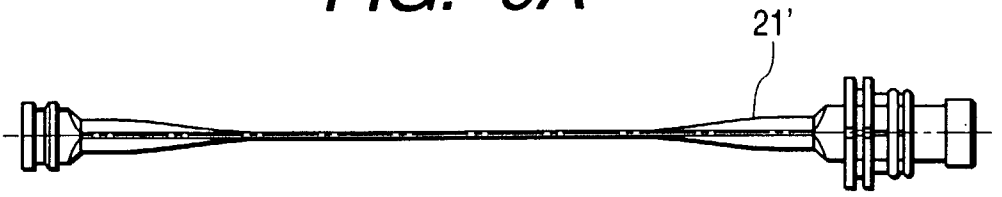


FIG. 9B

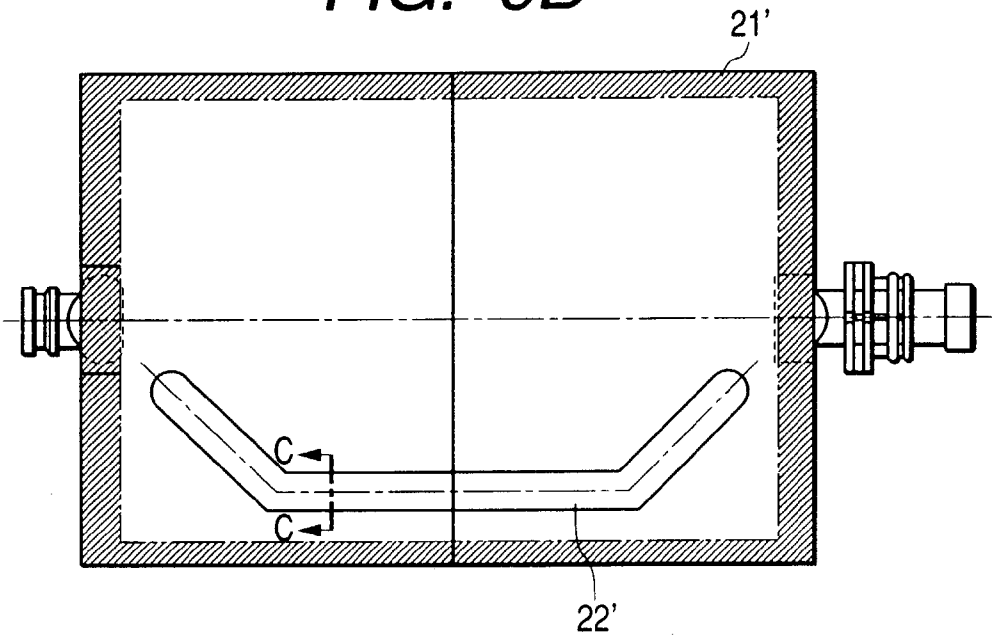


FIG. 9C

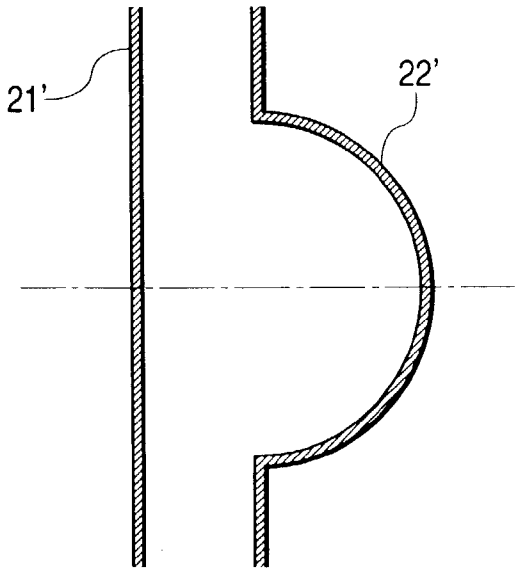


FIG. 10

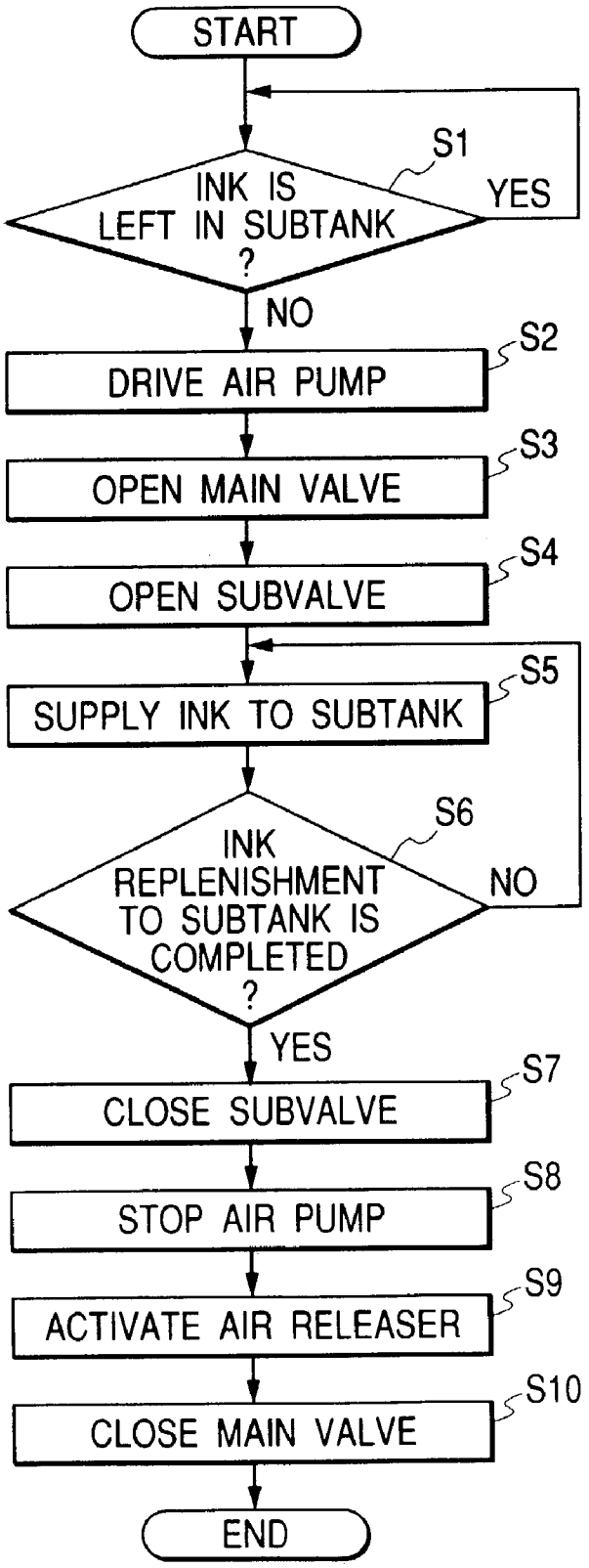

START
S1
INK IS LEFT IN SUBTANK ?
YES
NO
S2
DRIVE AIR PUMP
S3
OPEN MAIN VALVE
S4
OPEN SUBVALVE
S5
SUPPLY INK TO SUBTANK
S6
INK REPLENISHMENT TO SUBTANK IS COMPLETED ?
NO
YES
S7
CLOSE SUBVALVE
S8
STOP AIR PUMP
S9
ACTIVATE AIR RELEASER
S10
CLOSE MAIN VALVE
END

FIG. 11

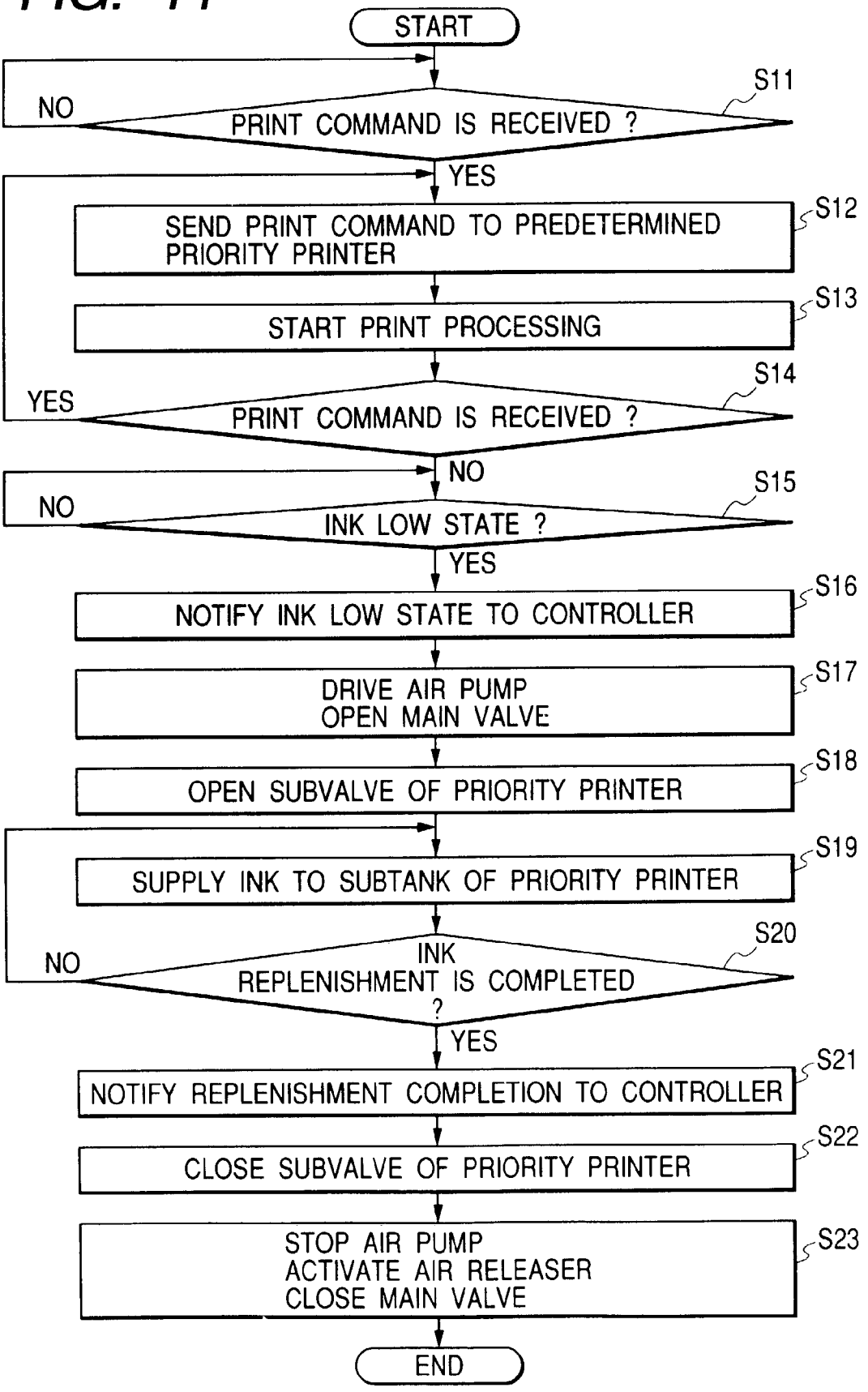

START
S11
NO
PRINT COMMAND IS RECEIVED ?
YES
SEND PRINT COMMAND TO PREDETERMINED PRIORITY PRINTER
S12
START PRINT PROCESSING
S13
S14
YES
PRINT COMMAND IS RECEIVED ?
NO
S15
NO
INK LOW STATE ?
YES
NOTIFY INK LOW STATE TO CONTROLLER
S16
DRIVE AIR PUMP
OPEN MAIN VALVE
S17
OPEN SUBVALVE OF PRIORITY PRINTER
S18
SUPPLY INK TO SUBTANK OF PRIORITY PRINTER
S19
S20
NO
INK REPLENISHMENT IS COMPLETED ?
YES
NOTIFY REPLENISHMENT COMPLETION TO CONTROLLER
S21
CLOSE SUBVALVE OF PRIORITY PRINTER
S22
STOP AIR PUMP
ACTIVATE AIR RELEASER
CLOSE MAIN VALVE
S23
END

FIG. 12

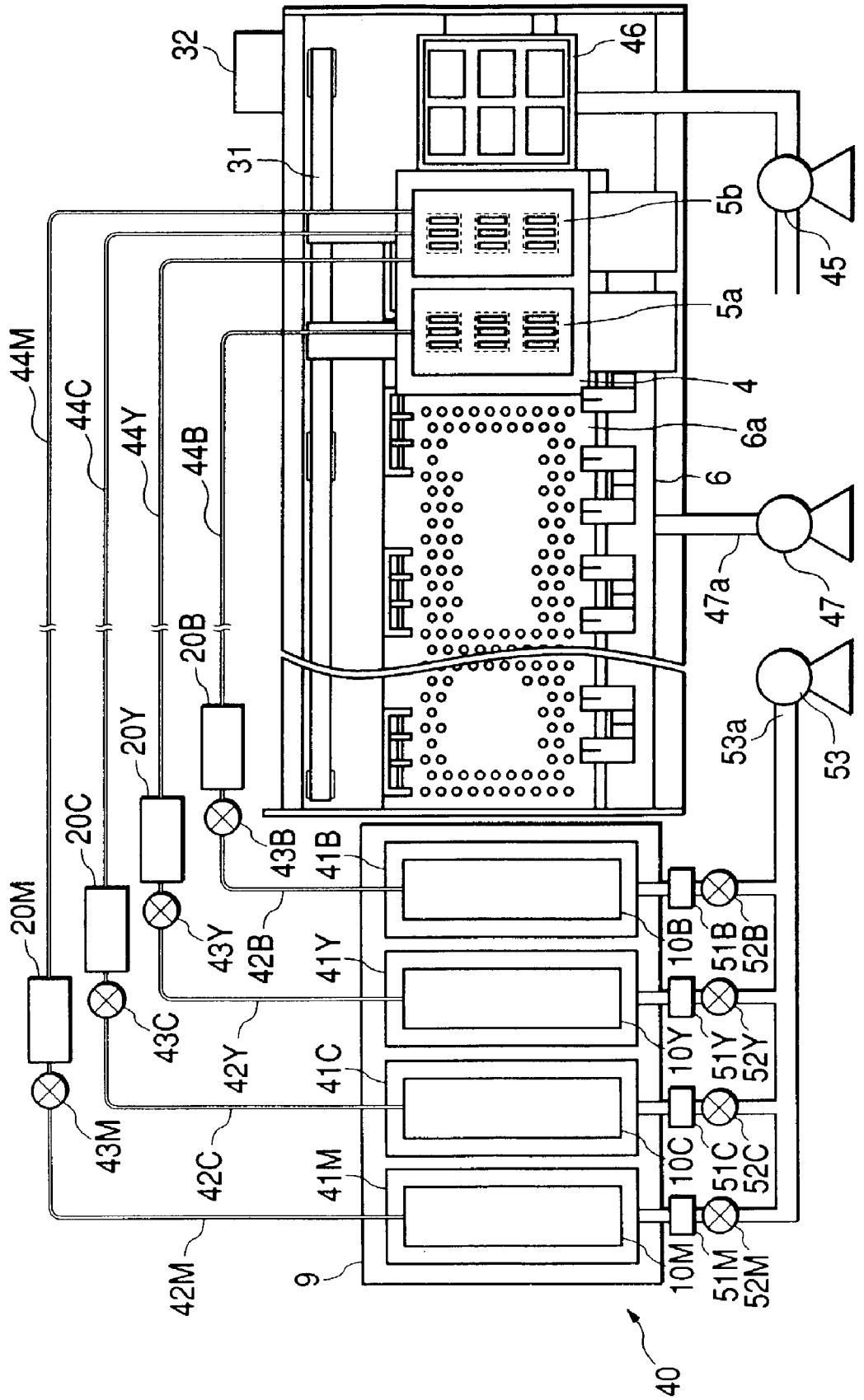

32
46
31
5b
45
5a
4
6a
6
44M
44C
44Y
44B
47a
47
20B
20Y
20C
53a
53
20M
43B
41B
10B
51B
52B
43Y
42B
41Y
43C
42Y
41C
10Y
51Y
52Y
43M
42C
41M
10C
51C
52C
42M
9
10M
51M
52M
40

FIG. 13

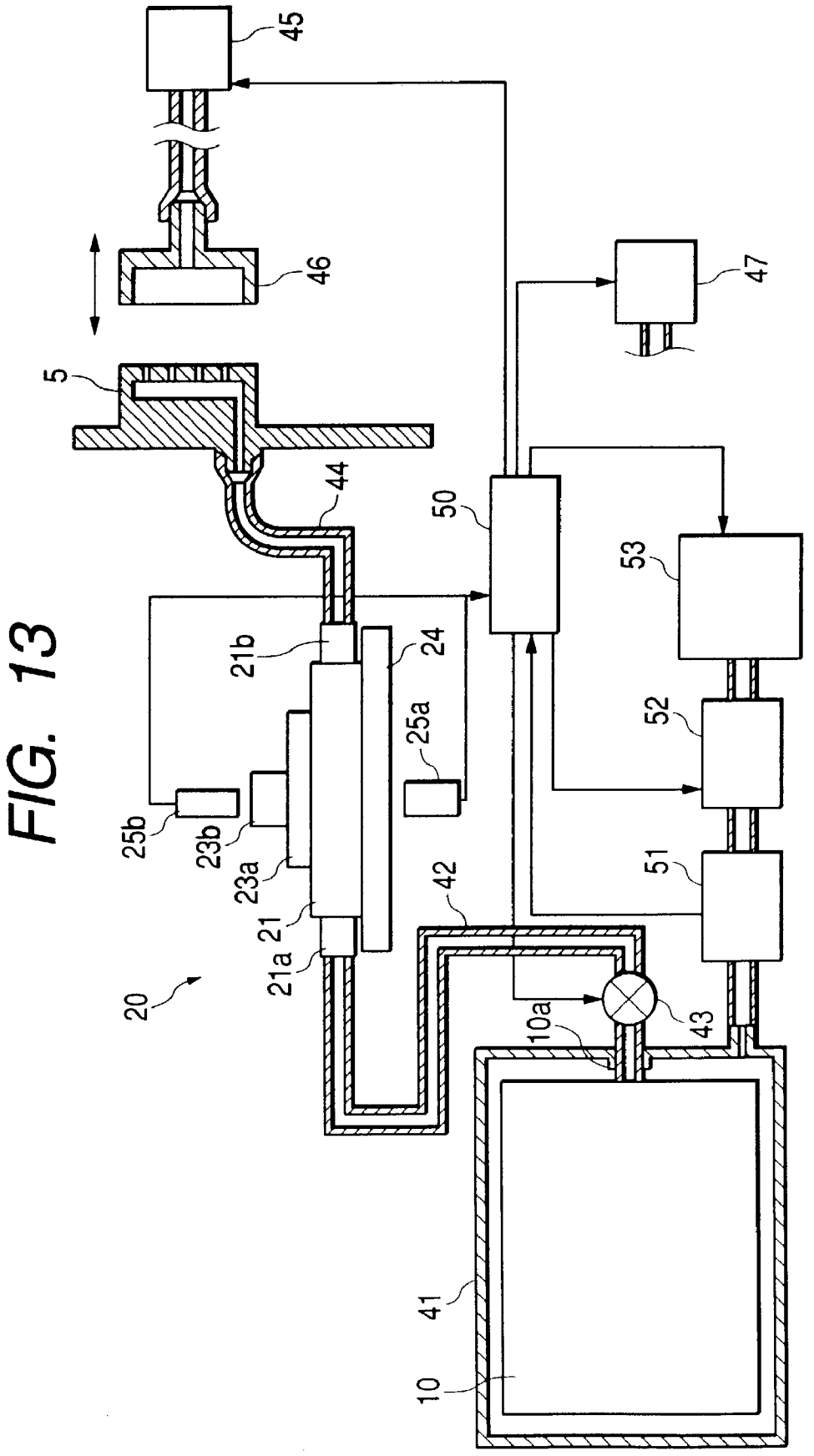

45
46
47
5
44
50
53
52
51
21b
24
25a
25b
23b
23a
21
21a
42
20
10a
43
41
10

FIG. 14

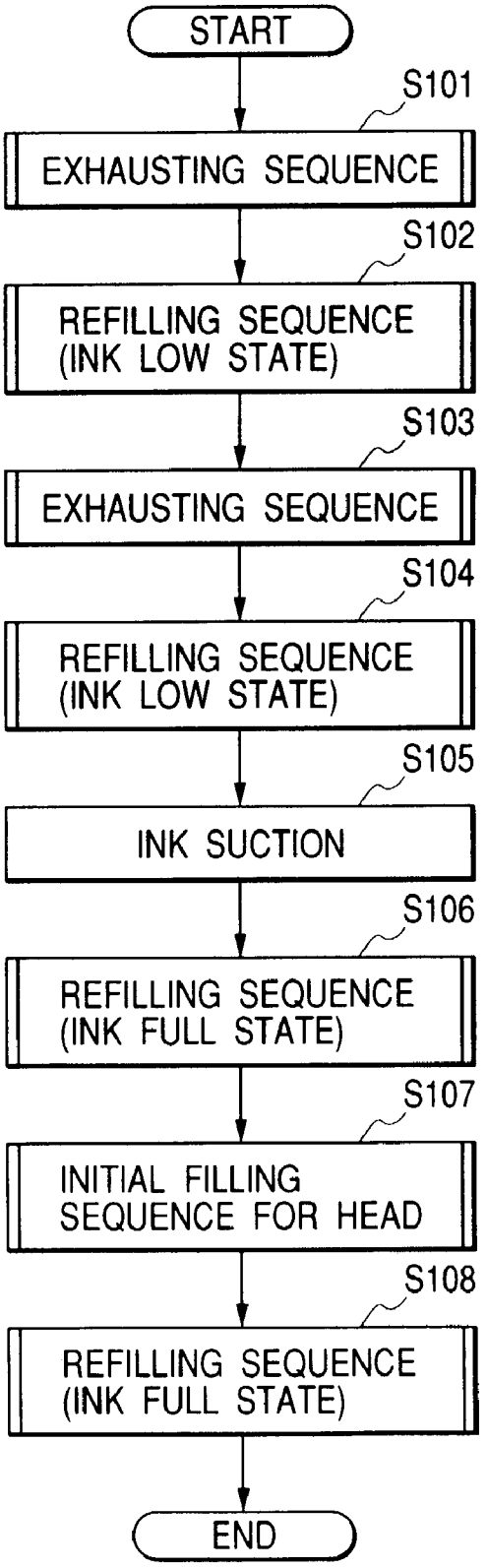

START
S101
EXHAUSTING SEQUENCE
S102
REFILLING SEQUENCE (INK LOW STATE)
S103
EXHAUSTING SEQUENCE
S104
REFILLING SEQUENCE (INK LOW STATE)
S105
INK SUCTION
S106
REFILLING SEQUENCE (INK FULL STATE)
S107
INITIAL FILLING SEQUENCE FOR HEAD
S108
REFILLING SEQUENCE (INK FULL STATE)
END

FIG. 15

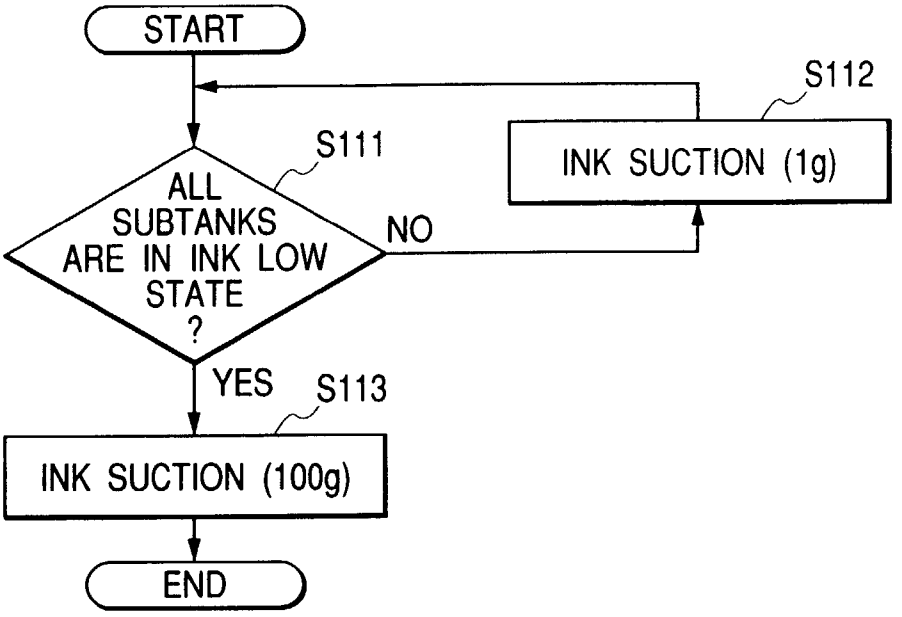

START
S112
INK SUCTION (1g)
S111
ALL SUBTANKS ARE IN INK LOW STATE ?
NO
YES
S113
INK SUCTION (100g)
END

FIG. 16

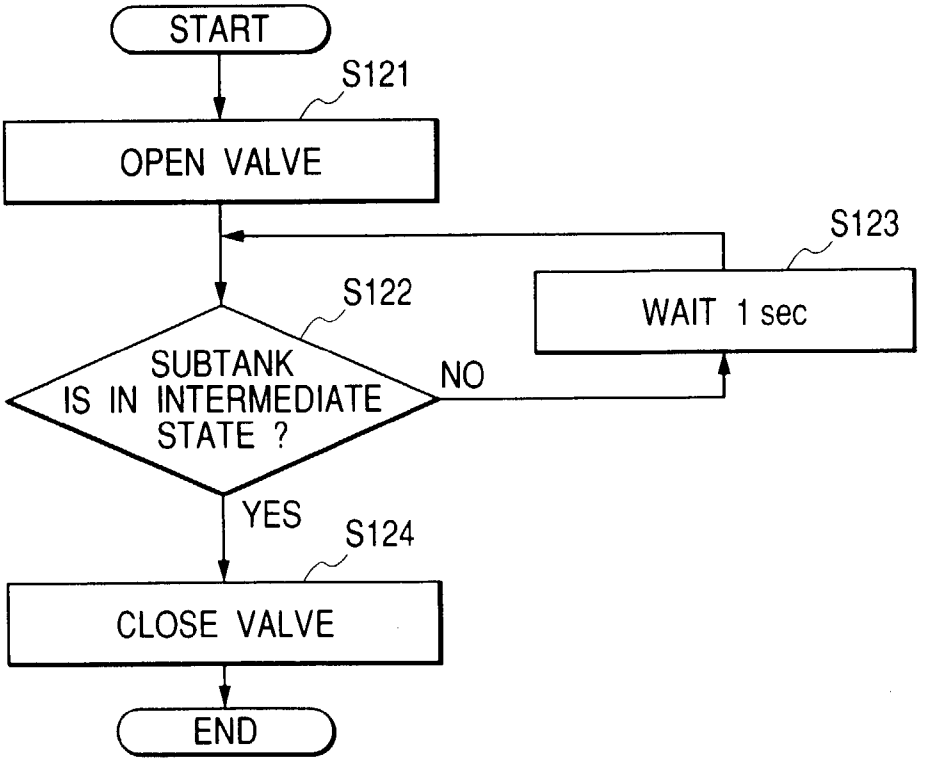

START
S121
OPEN VALVE
S123
WAIT 1 sec
S122
SUBTANK IS IN INTERMEDIATE STATE ?
NO
YES
S124
CLOSE VALVE
END

FIG. 17

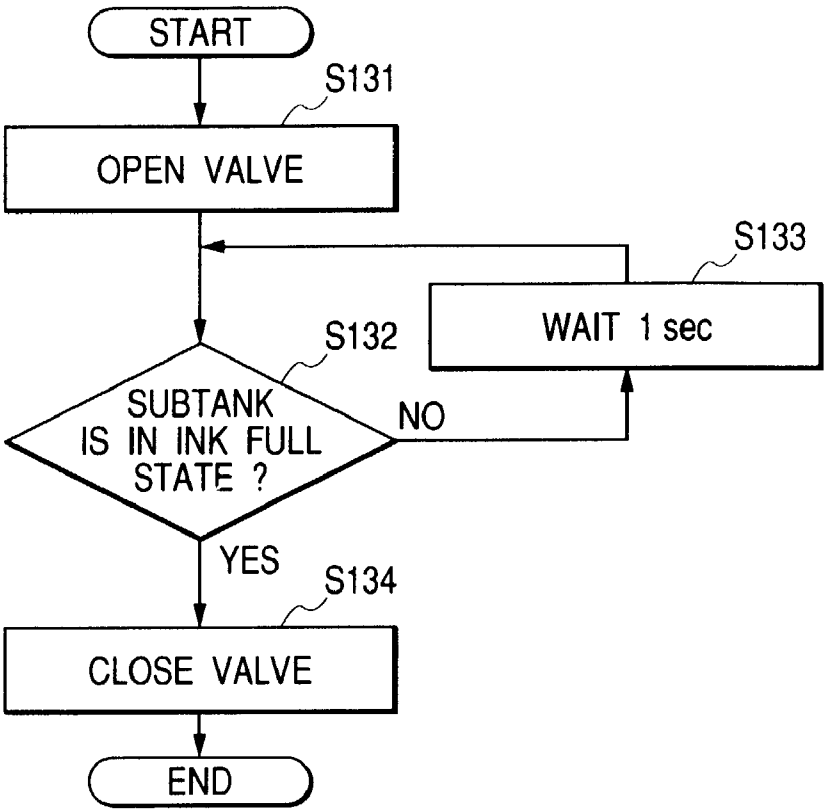

START
S131
OPEN VALVE
S133
WAIT 1 sec
S132
SUBTANK IS IN INK FULL STATE ?
NO
YES
S134
CLOSE VALVE
END

FIG. 18

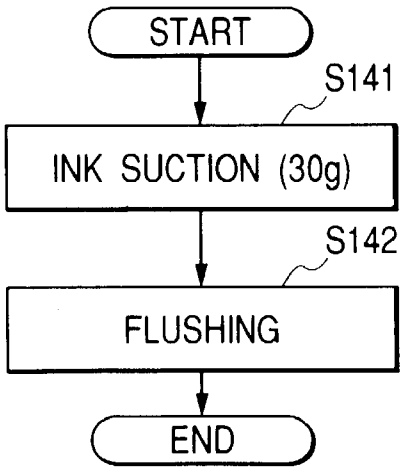

START
S141
INK SUCTION (30g)
S142
FLUSHING
END

FIG. 19

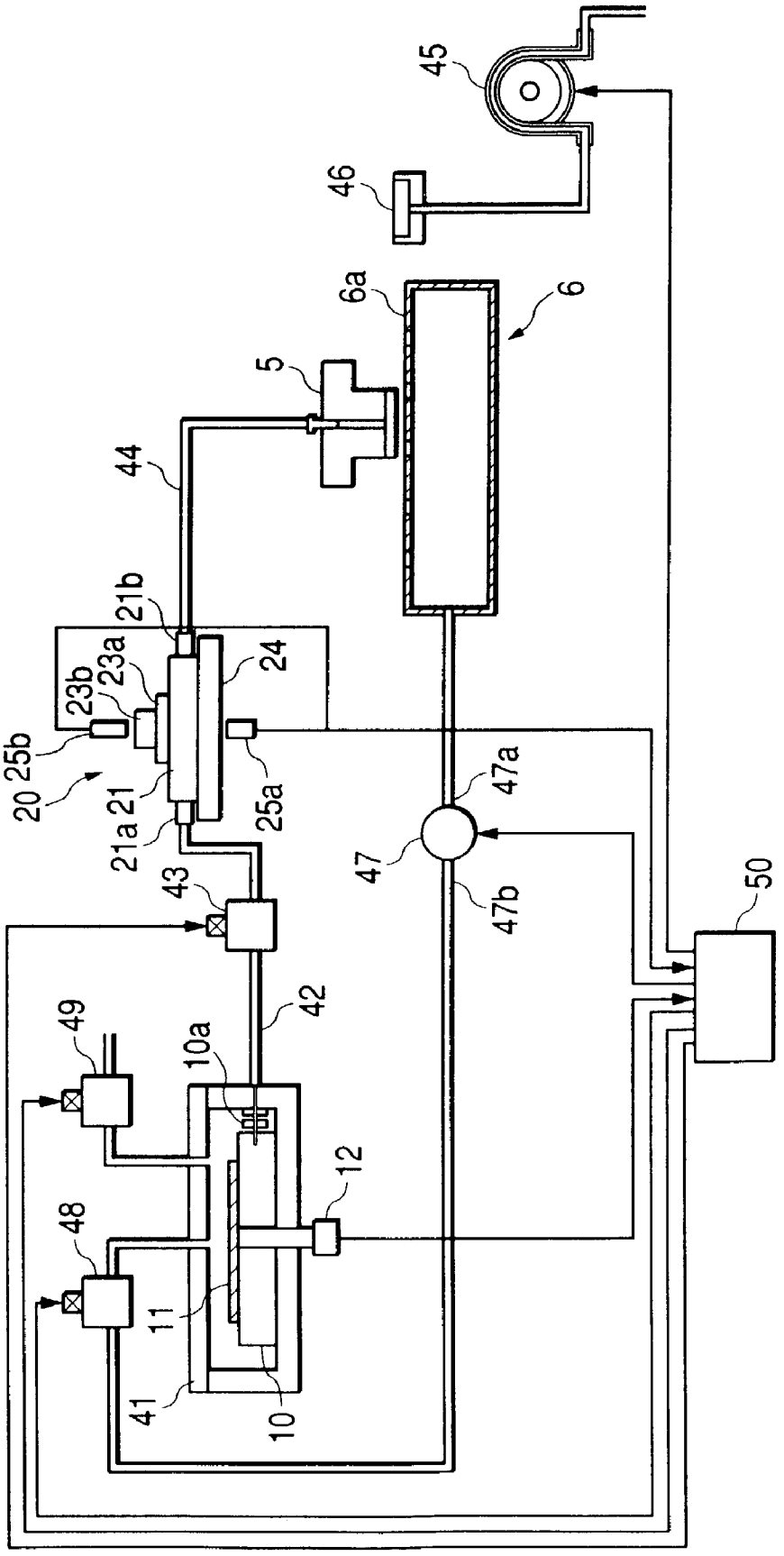

45
46
6a
6
5
44
21b
23a
24
23b
25b
20
21
21a
25a
47a
47
47b
43
50
42
49
10a
12
48
11
41
10

FIG. 20

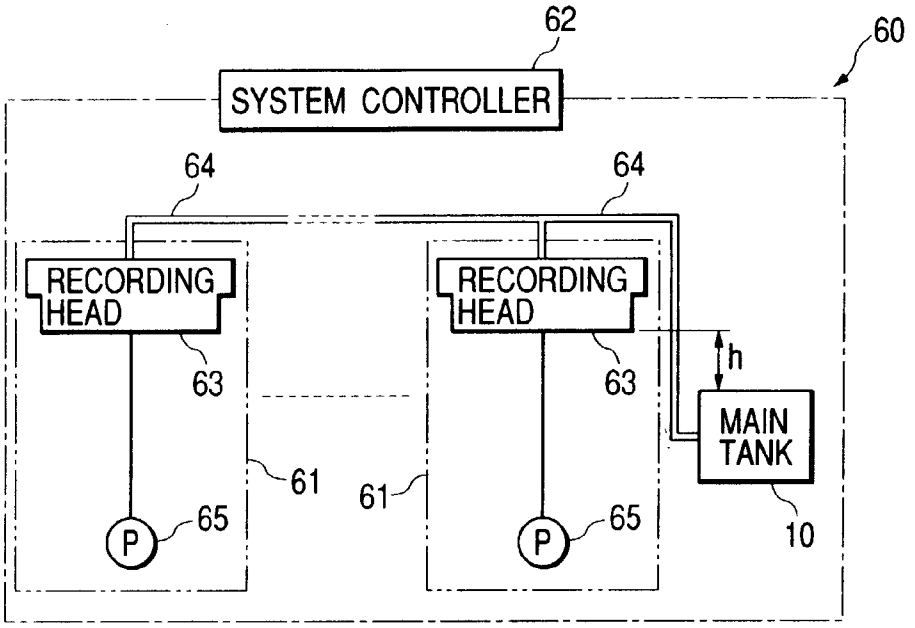

62
60
SYSTEM CONTROLLER
64
64
RECORDING HEAD
RECORDING HEAD
63
63
h
MAIN TANK
61
61
65
65
10
P
P

FIG. 21

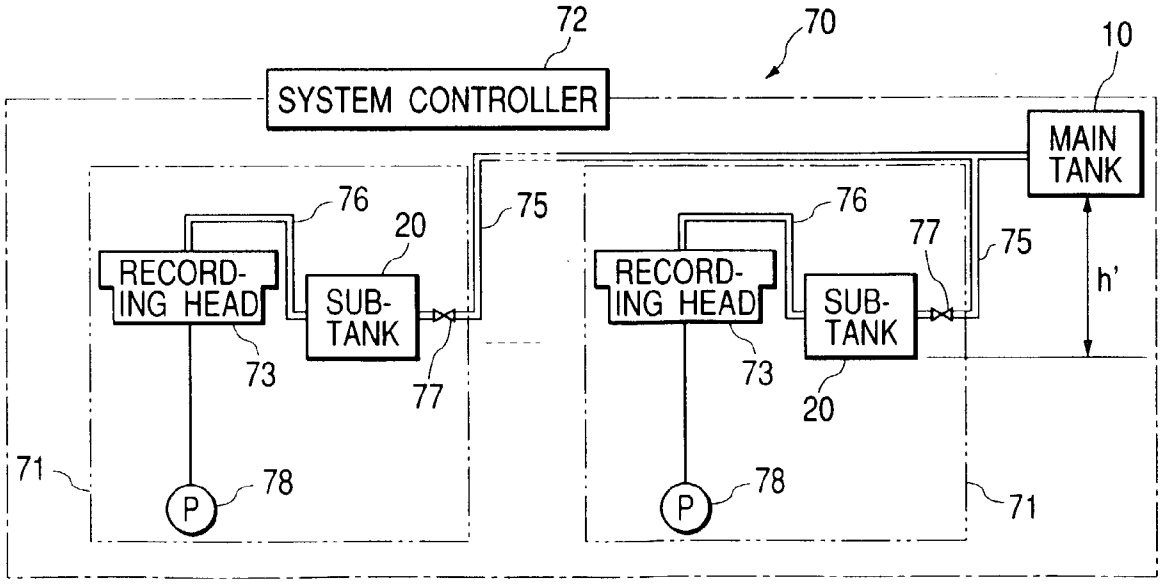

72
70
10
SYSTEM CONTROLLER
MAIN TANK
76
20
75
76
77
75
RECORD-ING HEAD
SUB-TANK
RECORD-ING HEAD
SUB-TANK
h'
73
77
73
20
71
78
78
71
P
P

FIG. 22

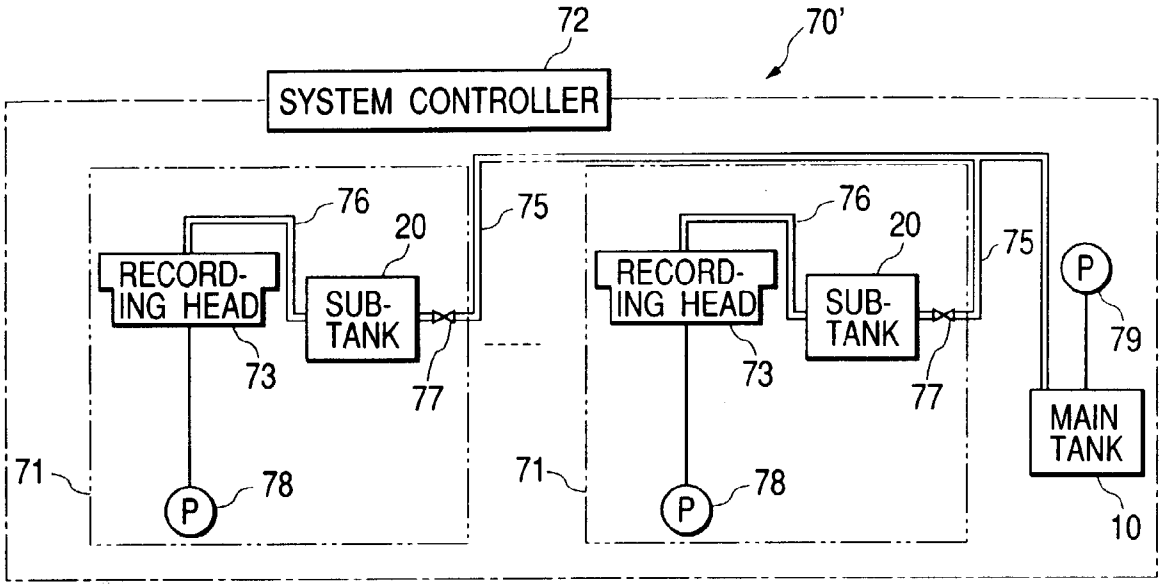
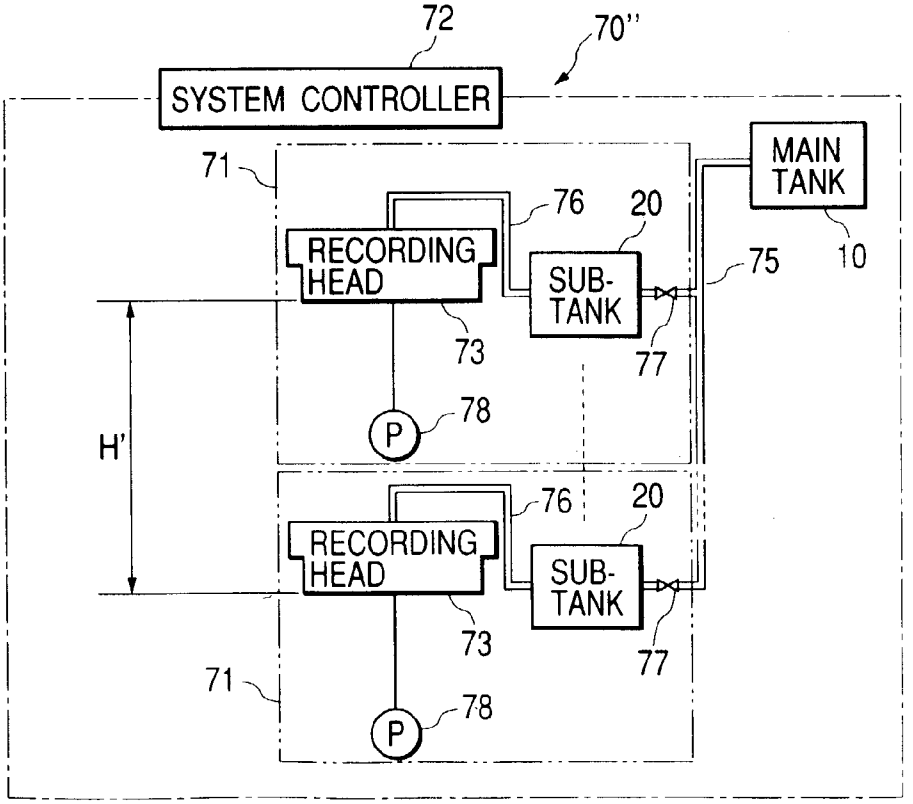

72
70'
SYSTEM CONTROLLER
RECORD-ING HEAD
SUB-TANK
76
20
75
73
77
71
78
P
79
MAIN TANK
10

FIG. 23


72
70''
SYSTEM CONTROLLER
71
RECORDING HEAD
SUB-TANK
76
20
75
73
77
78
P
H'
MAIN TANK
10

INK JET RECORDING APPARATUS, CONTROL AND INK REPLENISHING METHOD EXECUTED IN THE SAME, INK SUPPLY SYSTEM INCORPORATED IN THE SAME, AND METHOD OF MANAGING INK AMOUNT SUPPLIED BY THE SYSTEM

This is a divisional of application Ser. No. 10/068,008 filed Feb. 8, 2002 now U.S. Pat. No. 6,883,905; the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to an ink jet recording apparatus which records information on a recording medium with ink, a method of controlling the apparatus, and a method of replenishing ink stored in a main tank to a subtank for temporarily storing the replenished ink.

Further, the present invention relates to an ink supply system incorporated in the apparatus, and a method of managing the supplying ink amount executed by the ink supply system.

Recently, a digital camera provided with a CCD (charge coupled device) and a memory device has spread in place of a camera using a silver halide film. A picture taken by such a digital camera is recorded on a recording medium by a recording apparatus. As this recording apparatus, for example, an ink jet printer is used, and as a recording medium, for example, print paper is used. Under the circumstances, also in a laboratory where the silver halide film is developed and an image is printed on photographic paper thereby to make a photograph, an ink jet printer has been installed in order to print a digital image.

In this ink jet printer, a recording head, which pressurizes ink supplied from an ink tank and ejects an ink droplet, is reciprocated in the width direction of paper thereby to perform printing. The ink jet printer which can perform a large amount of printing by such the system includes a main ink tank having large volume (hereinafter referred to as a main tank) for each color, and a sub-ink tank (hereinafter referred to as a subtank) having small volume for each color, which is connected to each main tank by a tube. The subtank is airtightly formed of a flexible material having flexibility in the shape of a bag so as to be variable in volume.

As a method of increasing the number of prints per time in such a laboratory, it is considered that plural ink jet printers are operated. However, since many main tanks (multiplying the number of ink jet printers by the number of colors) are required, there is a problem on replacement of the main tanks.

In a case where ink is supplied from a single main tank for each color to print heads for each color of the plural ink jet printers, the number of the main tanks requires only the number of colors. However, in a case where the amount of ink ejection in the recording head is large, dynamic pressure in an ink supply passage becomes large, so that the ink supply runs short and printing quality lowers.

Further, since the dynamic pressure is produced due to the difference in length of the ink supply passage between the main tank and the print heads in the ink jet printer, the amount of the ink supply is different among the respective ink jet printers. For example, in a case where plural ink jet printers are laid horizontally, an ink jet printer located farthest from the main tank has the longest ink flowing passage. Therefore, in its ink jet printer, an ink supply time becomes longest. On the contrary, since an ink jet printer located nearest to the main tank has the shortest ink flowing passage, the ink supply time becomes shortest.

In a case where the main tank is arranged at the lowest position and plural ink jet printers are laid in the vertical direction, an ink jet printer located at the top has the longest ink flowing passage and also the largest pressure loss due to the head difference, so that the ink supply time becomes longest. On the contrary, an ink jet printer located at the lowest position has the shortest ink flowing passage and also the smallest pressure loss due to the head difference, so that the ink supply time becomes shortest.

Further, since the amount of ink consumption amount is large in the image printing by the plural ink jet printers, the amount management is important. Conventionally, such amount is managed every each ink jet printer.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide an ink jet recording apparatus in which a main tank can be replaced readily, and ink can be efficiently supplied to plural recording units without causing deterioration of the printing quality.

It is therefore another object of the invention to provide an ink supply system for reliably managing ink amount to be supplied, and a method of managing ink supplying amount performed by the ink supply system.

In order to achieve the above objects, according to the present invention, there is provided an ink jet recording apparatus, comprising:

at least one main tank, which stores ink therein; and

a plurality of subtanks, communicated with each main tank, each subtank storing ink supplied from the main tank, and being communicated with at least one recording head.

In this configuration, since ink is supplied from one main tank to the plural subtanks, even if the plural printers are used, the main tank is readily replaced. Further, the dynamic pressure in an ink supply passage between the main tank and each subtank does not affect to the recording of the recording head so that printing quality can be maintained.

Preferably, a plurality of main tanks are provided, so that the main tank can be quickly replaced for another main tank when the amount of the residual ink in a main tank is small without interrupting the recording operation. The empty main tank can be replaced with a new one thereafter.

Preferably, the subtanks are arranged in a vertical direction, so that the layout space of the plural recording apparatuses can be reduced, and the number of printers per a unit area can be increased.

Preferably, each subtank is airtightly formed by a material having flexibility so that a volume of the subtank is variable. Since it is not necessary to open an ink flowing passage to atmosphere, the recording can be performed while the deaeration state of ink is kept.

Here, it is preferable that each subtank contains a plate member which prevents inner surfaces of the subtank from being adhered with each other. Some troubles due to adhesion of the inner faces when the subtank is contracted.

Further, it is preferable that grooves are formed on surfaces of the plate member, so that ink supplied from the main tank can be smoothly introduced into the subtank by guiding the ink with the groove.

Preferably, the ink jet recording apparatus further comprises:

a first ink amount detector, which detects an ink amount stored in each subtank; and

a first supply amount controller, which controls a supply amount of ink flowing into each subtank, based on the detection of the first ink amount detector.

In this configuration, even if there is the different in height between the main tank and the subtank, the reversal flow between two tanks can be prevented.

Here, it is preferable that the first supply amount controller is provided as a first valve member. The first valve member is opened when the first ink amount detector detects an ink low state in which the ink amount stored in the subtank is a first predetermined level or less. The first valve member is closed when the first ink amount detector detects an ink full state in which the ink amount stored in the subtank is a second predetermined level or more. Since it is possible to prevent the ink in the subtank from running short, the ink can be sufficiently supplied to the plural recording apparatuses which consume a large amount of the ink.

Further, it is preferable that the apparatus further comprises a second supply amount controller, which controls a supply amount of ink flowing out of the main tank. Since the ink supplying passage from the main tank to the subtank can be closed on the main tank side, the main tank can be replaced without causing mixing of air in the ink supplying passage and ink leakage during the printing operation.

Here, it is preferable that the second supply amount controller is provided as a second valve member. The second valve member is first opened while the main tank is compressed, and then the first valve member is opened to supply ink to the subtank. When the pressurization control error or the control error of the first valve is occurred, the ink flow system can be arranged on the safety side by closing the second valve. Therefore, reliability of the ink supply control can be improved.

Further, it is preferable that the first valve member is first closed and the compressing of the main tank is canceled when the subtank is replenished, and the second valve member is then closed so that it is avoided a situation that the apparatus is deactivated while the ink supplying passage between the first valve member and the second valve member is kept in the pressurized state and the ink supplying passage is left as it is for a long time. Therefore, the ink leakage from the ink supplying passage can be prevented and safety can be improved.

Preferably, the subtank is communicated with a plurality of recording heads, so that the freedom of the design can be enhanced by the layout of the plural heads.

Preferably, the main tank and the subtanks are arranged so as to provide a head difference therebetween, to supply ink from the main tank to the subtanks. Since the main tank is always in a pressurized state due to the head difference, the ink can be supplied surely by the simple structure.

Preferably, the main tank is compressed to supply ink to the subtanks, so that the main tank can surely supply the ink even if it is arranged below the subtanks. Here, it is preferable that the main tank is compressed by a pump member.

Further, it is preferable that the pump member is connected to the main tank via an air releaser which opens the main tank to atmosphere. When the ink supply is not required, the pressurized state can be released so that breakdown of the apparatus due to keeping of the pressurized state can be eliminated. Accordingly, reliability can be improved, and safety in times of a pressurization control error and an ink supply error can be improved.

According to the present invention, there is also provided an ink jet recording apparatus, comprising:

at least one main tank, which stores in therein;

a plurality of recording sections, communicated with each main tank, each recording section including a subtank which stores ink supplied from the main tank, and at least one recording head communicated with the subtank; and

a system controller, which controls the main tank and the recording sections such that a recording section in which a time period required for supplying ink from the main tank to the subtank is shorter is controlled with a higher priority.

Preferably, a recording section in which a path length connecting the main tank and the subtank is shorter is controlled with a higher priority.

In a case where the amount of recording increases, since much ink can be distributed to the recording unit in which the ink supply finishes quickly the ink supply time can be reduced.

Preferably, each subtank is airtightly formed by a material having flexibility so that a volume of the subtank is variable. Since it is not necessary to open an ink flowing passage to atmosphere, the recording can be performed while the deaeration state of ink is kept.

Here, it is preferable that each subtank contains a plate member which prevents inner surfaces of the subtank from being adhered with each other. Some troubles due to adhesion of the inner faces when the subtank is contracted.

Further, it is preferable that grooves are formed on surfaces of the plate member, so that ink supplied from the main tank can be smoothly introduced into the subtank by guiding the ink with the groove.

Preferably, the ink jet recording apparatus further comprises:

a first ink amount detector, which detects an ink amount stored in each subtank; and

a first supply amount controller, which controls a supply amount of ink flowing into each subtank, based on the detection of the first ink amount detector.

In this configuration, even if there is the different in height between the main tank and the subtank, the reversal flow between two tanks can be prevented.

Here, it is preferable that the first supply amount controller is provided as a first valve member. The first valve member is opened when the first ink amount detector detects an ink low state in which the ink amount stored in the subtank is a first predetermined level or less. The first valve member is closed when the first ink amount detector detects an ink full state in which the ink amount stored in the subtank is a second predetermined level or more. Since it is possible to prevent the ink in the subtank from running short, the ink can be sufficiently supplied to the plural recording apparatuses which consume a large amount of the ink.

Further, it is preferable that the apparatus further comprises a second supply amount controller, which controls a supply amount of ink flowing out of the main tank. Since the ink supplying passage from the main tank to the subtank can be closed on the main tank side, the main tank can be replaced without causing mixing of air in the ink supplying passage and ink leakage during the printing operation.

Here, it is preferable that the second supply amount controller is provided as a second valve member. The second valve member is first opened while the main tank is compressed, and the first valve member is then opened to supply ink to the subtank. When the pressurization control error or the control error of the first valve is occurred, the ink flow system can be arranged on the safety side by closing the second valve. Therefore, reliability of the ink supply control can be improved.

Further, it is preferable that the first valve member is first closed and the compressing of the main tank is canceled

when the subtank is replenished, and the second valve is then closed so that it is avoided a situation that the apparatus is deactivated while the ink supplying passage between the first valve member and the second valve member is kept in the pressurized state and the ink supplying passage is left as it is for a long time. Therefore, the ink leakage from the ink supplying passage can be prevented and safety can be improved.

Preferably, the subtank is communicated with a plurality of recording heads, so that the freedom of the design can be enhanced by the layout of the plural heads.

Preferably, the main tank and the subtanks are arranged so as to provide a head difference therebetween, to supply ink from the main tank to the subtanks. Since the main tank is always in a pressurized state due to the head difference, the ink can be supplied surely by the simple structure.

Preferably, the main tank is compressed to supply ink to the subtanks, so that the main tank can surely supply the ink even if it is arranged below the subtanks. Here, it is preferable that the main tank is compressed by a pump member.

Further, it is preferable that the pump member is connected to the main tank via an air releaser which opens the main tank to atmosphere. When the ink supply is not required, the pressurized state can be released so that breakdown of the apparatus due to keeping of the pressurized state can be eliminated. Accordingly, reliability can be improved, and safety in times of a pressurization control error and an ink supply error can be improved.

According to the present invention, there is also provided a method of controlling the above ink jet recording apparatus to record information on a recording medium with ink.

According to the present invention, there is also provided a method of initially filling a subtank with ink stored in a main tank which is communicated with the subtank, comprising the steps of:

a) applying negative pressure to a recording head communicated with the subtank, to discharge air in the subtank while compressing the subtank,

b) opening a valve member provided between the main tank and the subtank, after the step a), to supply ink from the main tank to the subtank;

c) closing the valve member after the step b);

d) applying negative pressure to the recording head, after the step c), to discharge air and ink in the subtank while compressing the subtank; and

e) opening the valve member, after the step d), to supply ink from the main tank to the subtank.

Air in the flowing passage from the recording head through the subtank to the valve member can be exhausted by the first negative pressure application, and air in the flowing passage from the valve member to the main tank can be exhausted by the second negative pressure application. Therefore, air in the flowing passage from the recording head to the main tank can be eliminated, and deaeration of the ink filling the subtank can be improved.

Preferably, the initial filling method further comprises:

f) closing the valve member, after the step e);

g) applying negative pressure to the recording head, after the step f), to partly discharge ink in the subtank; and

h) opening the valve member, after the step g), to supply ink from the main tank to the subtank.

The ink flowing in the depressed subtank flows at a high speed bubbles and its deaeration is lost. However, by exhausting the predetermined amount of ink in the ink under this state and allowing new ink to flow in the subtank, the deaeration of the ink filling the subtank can be further improved.

Alternatively, the initial filling method further comprises:

f) closing the valve member, after the step e); and

g) applying negative pressure to the recording head, after the step f), to supply ink from the subtank to the recording head.

Since particularly the air in the recording head can be completely exhausted, the ejection performance of the ink droplet can be maintained.

Preferably, the steps c) to e) are repeated so air in the flowing passage from the recording head to the main tank can be completely eliminated, so that the deaeration of the ink filling the subtank can be improved more.

According to the present invention, there is also provided a method of initially filling a subtank with ink stored in a main tank which is communicated with the subtank, comprising the steps of:

a) applying negative pressure to a recording head communicated with the subtank, to discharge air in the subtank while compressing the subtank;

b) opening a valve member provided between the main tank and the subtank, after the step a), to supply ink from the main tank to the subtank;

c) closing the valve member after the step b); and

d) applying negative pressure to the recording head, after the step c), to supply ink from the subtank to the recording head.

According to the present invention, there is also provided an ink jet recording apparatus in which the initial filling methods are performed.

Preferably, the main tank is located above the subtank or is located below while being compressed, so that not only in a type in which the main tank is pressurized to supply the ink to the subtank but also in a type in which head difference is given between the main tank and the subtank to supply the ink, the air in the flowing passage from the recording head to the main tank can be eliminated. Accordingly, the deaeration of the ink filling the subtank can be improved.

Here, it is preferable that the subtank is airtightly formed by a material having flexibility so that a volume of the subtank is variable. The subtank contains a plate member which prevents inner surfaces of the subtank from being adhered with each other. In this configuration, uniformly pressurized state can be provided anywhere inside of the subtank so that remaining air therein can be eliminated.

According to the present invention, there is also provided an ink supply system, comprising:

at least one main tank, which stores ink therein;

a plurality of subtanks, communicated with each main tank, each subtank communicated with at least one recording section; and

a system controller, which monitors an ink amount consumed in each subtank to manage a residual ink amount in the main tank.

By only managing the ink in one main tank, ink supply to the plural recording units is stabilized.

Preferably, each subtank is airtightly formed by a material having flexibility so that a volume of the subtank is variable. Since it is not necessary to open an ink flowing passage to atmosphere, the recording can be performed while the deaeration state of ink is kept.

Here, it is preferable that each subtank contains a plate member which prevents inner surfaces of the subtank from being adhered with each other. Some troubles due to adhesion of the inner faces when the subtank is contracted.

Further, it is preferable that grooves are formed on surfaces of the plate member, so that ink supplied from the main tank can be smoothly introduced into the subtank by guiding the ink with the groove.

Preferably, the system controller starts to count the consumed ink amount of the subtank when an ink amount stored in the subtank becomes a predetermined level. Since the state of the ink consumption in the subtank is known during the recording operation by the recording unit, the ink management for each recording unit is facilitated.

Here, it is preferable that the system controller regards a total ink amount consumed in all the subtanks as an ink amount consumed in the main tank, so that the consumed ink amount in the main tank can be recognized exactly.

Preferably, the system controller obtains the consumed ink amount of each subtank every time when the subtank is replenished with ink supplied from the main tank. Accuracy between the total of the counted ink consumption amount in the subtank and the consumed ink amount in the main tank can be improved. Further, since the ink is supplied every each subtank, the subtanks other than the subtank to which the ink is supplied are used for recording, so that interruption during the recording operation by the recording unit can be reduced.

Preferably, the system controller selectively supplies ink to at least one subtank which requires an ink replenishment, and obtains the consumed ink amount of the at least one subtank. Loss in supply time of ink from the main tank to the subtank can be reduced.

Preferably, the system controller obtains the consumed ink amount of each subtank, and supplies ink to all the subtanks simultaneously. The loss of the ink supplying time from the main tank to the subtanks can be reduced.

Preferably, a flow rate of ink flowing into the subtank is greater than a flow rate of ink flowing out from the recording section associated with the subtank. The ink supply from the main tank to the subtank is surely performed, and it is possible to prevent the situation in which the recording unit cannot perform the recording operation.

Preferably, the system controller starts to supply ink to the subtank when the ink amount consumed in the subtank exceeds a threshold level. When the consumed ink amount in the subtank is small, since the system controller can operate so as not to supply the ink from the main tank, loss due to interruption of the recording operation by the recording unit, which is caused by the ink supply, can be reduced.

Here, it is preferable that the threshold level includes a first threshold level selected while the recording section performs recording, and a second threshold level which is smaller than the first threshold level selected while the recording is not performed. The loss reduction can be effectively attained.

Further, it is preferable that each subtank is provided with at least one detector which detects a residual ink amount therein. The system controller stops the ink supply when the detection of the detector is effected. The ink supply amount can be exactly recognized, and the ink cost can be reduced.

Preferably, each subtank is provided with at least one detector which detects a residual ink amount therein. The system controller starts to supply ink to the subtank when the detector detects that the residual ink amount is a predetermined level or less. Since the detection accuracy of the amount of the residual ink in the subtank can be improved, the ink supply from the main tank to the subtank can be efficiently performed.

Here, it is preferable that a plurality of detectors are provided with each subtank. The system controller starts to supply ink to the subtank when the detection of one detector is effected, and stops the ink supply when the detection of another detector is effected. The exact amount of the residual ink can be recognized.

Further, it is preferable that the detector is solely provided, so that a cost of the residual ink amount detector can be reduced.

Here, it is preferable that the system controller supplies ink to the subtank during the detection of the detector is effected, so that the supply time can be reduced.

Alternatively, it is preferable that the system controller supplies ink to the subtank for a predetermined time period when the detection of the detector is effected, so that the ink supply amount can be increased.

Preferably, a valve member is provided between the main tank and each subtank. The valve member is closed when the detector detects that the residual ink amount is a predetermined level or more. Since the amount of the residual ink in the subtank can be surely detected, troubles not occurred in the ink supply from the main tank to the subtank.

Here, it is preferable that each valve member is closed independently from another valve members. Alternatively, it is preferable that each valve member is closed selectively. Alternatively, all the valve members are closed simultaneously. Hereby, the ink supply from the main tank to the subtank can be readily performed.

Here, it is preferable that all the valve members are closed when at least one detector among the detectors of the subtanks detects that one subtank is almost empty. It is possible prevent, for example, the situation in which the ink moves from the upper recording unit to the lower recording unit due to the head difference when the valves of all the subtanks are open.

Preferably, the system controller supplies ink from the main tank to each subtank every time when the system is activated. The loss due to the interruption of the recording operation by the recording unit, which is caused by the ink supply from the main tank to the subtank, can be reduced.

Preferably, the system controller supplies ink from the main tank to each subtank every time when a predetermined time period elapses. Even if the apparatus is regularly activated, the ink supply from the main tank to the subtank can be surely performed.

Preferably, the system controller supplies ink from the main tank to the subtank after obtaining the consumed ink amount of each subtank to calculate a residual ink amount in the main tank, every time when the recording section performs recording. The total of the consumed ink amount in the subtanks becomes equal to the consumed ink amount of the main tank, and the ink supply from the main tank to the subtank can be surely performed.

Preferably, the system controller obtains the consumed ink amount of each subtank every time when the recording section performs recording to calculate a residual ink amount in the main tank. An ink end state is effected in all the recording section when the residual ink amount in the main tank is a predetermined level or less. The total of the consumed ink amount in the subtanks becomes equal to the consumed ink amount of the main tank, and the ink supply from the main tank to the subtank can be surely performed.

Here, it is preferable that the recording section continues the recording until a predetermined amount of ink in the subtank is consumed after the ink end state is effected. The amount of the residual ink in the main tank is exactly counted, and the ink in the subtank is not used uselessly.

Preferably, the system controller sequentially compares the ink amount consumed in each subtank and a residual ink

amount in the main tank. The system controller supplies ink to the compared subtank when the consumed ink amount in the compared subtank is less than the residual ink amount. An ink end state is effected when the consumed ink amount is greater than the residual ink amount. The ink supply from the main tank to the subtank can be surely performed.

Here, it is preferable that the ink supply is once performed even when the ink end state is effected, so that the ink in the main tank can be consumed as much as possible even if there is the unevenness in the amount of the residual ink in the main tank.

Further, it is preferable that the ink supply is performed until any change is not occurred in the detector, even when the ink end state is effected. The influence of the unevenness in the consumed ink amount can be eliminated.

Preferably, the system controller sequentially compares the ink amount consumed in each subtank and a residual ink amount in the main tank. The system controller supplies ink to the compared subtank when the consumed ink amount of the compared subtank is less than the residual ink amount. The system controller does not supply ink to the compared subtank when the consumed ink amount of the compared subtank is greater than the residual ink amount. An ink end state is effected when there is at least one subtank to which ink is not supplied, so that the useless ink amount can be reduced.

Preferably, the main tank is provided with a first detector which detects a residual ink amount in the main tank. An ink end state is effected when the first detector detects that the residual ink amount is a predetermined amount or less.

Here, it is preferable that each subtank is provided with a second detector which detects a residual ink amount therein. The system controller stops the ink supply when the second detector detects that the subtank is almost full when the ink end state is effected. The system constitution can be simplified.

Preferably, the ink supply system further comprises a memory for storing a residual ink amount in the main tank, so that the ink amount in the main tank can be managed with higher accuracy even if the main tank is replaced.

According to the present invention, there is also provided a method of managing an ink amount supplied from main tank to the subtanks which are provided in the above ink systems.

According to the present invention, there is also provided an ink supply system, comprising:

at least one main tank, which stores ink therein,

a plurality of recording heads, communicated with each main tank while providing a head difference therebetween; and

a system controller, which monitors an ink amount consumed in each recording head to manage a residual ink amount in the main tank.

By only monitoring the amount of ink consumption of each recording head, it is possible to prevent the ink in the main tank from running short. Further, as long as the ink remains in the main tank, ink supply to each recording head is always performed. Therefore, by the simple control system, high quality recording can be performed.

Preferably, the ink supply system further comprises a memory for storing a residual ink amount in the main tank, so that the ink amount in the main tank can be managed with higher accuracy even if the main tank is replaced.

According to the present invention, there is also provided a method of managing an ink amount supplied from main tank to the subtanks which are provided in the above ink systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing in detail preferred exemplary embodiments thereof with reference to the accompanying drawings, wherein:

FIG. **1** is a front view showing an exterior constitution of an ink jet recording apparatus according to a first embodiment of the invention;

FIG. **2** is a diagram showing the schematic constitution of the ink jet recording apparatus according to the first embodiment;

FIG. **3** is a perspective view showing the detailed structure of an ink pack of a main tank in the ink jet recording apparatus in FIG. **2**;

FIG. **4**A is a plan view showing the detailed structure of a subtank in the ink jet recording apparatus in FIG. **2**;

FIG. **4**B is a section view taken along a line B—B in FIG. **4**A;

FIG. **5** is a perspective view showing the detailed structure of an ink pack of the subtank;

FIG. **6**A is a short side view of an adhesion guard;

FIG. **6**B is a top plan view of the adhesion guard;

FIG. **6**C is a long side view of an adhesion guard;

FIG. **6**D is a bottom plan view of the adhesion guard;

FIG. **6**E is a section view taken along a line E—E in FIG. **6**B;

FIG. **6**F is a section view taken along a line F—F in FIG. **6**B;

FIG. **7**A is a side view showing the layout state of the adhesion guard in the subtank;

FIG. **7**B is a plan view showing the layout state of the adhesion guard in the subtank;

FIGS. **8**A and **8**B are section views showing the operation of an ink amount detector of the subtank;

FIG. **9**A is a side view showing a modified example of the subtank;

FIG. **9**B is a plan view showing the modified example of the subtank;

FIG. **9**C is an enlarged section view taken along a line C—C in FIG. **9**B;

FIG. **10** is a flowchart showing an ink replenishing operation performed in the ink jet recording apparatus;

FIG. **11** is a flowchart showing another ink replenishing operation performed in the ink jet recording apparatus;

FIG. **12** is a diagram showing the schematic constitution of the ink jet recording apparatus according to a second embodiment of the invention;

FIG. **13** is a diagram showing the detailed constitution of a recording section of the ink jet recording apparatus in FIG. **12**;

FIG. **14** is a flowchart showing an initial ink filling operation performed in the recording section in FIG. **13**;

FIGS. **15** to **18** are first flowcharts showing the detailed operations in the initial ink filling operation;

FIG. **19** is a diagram showing the detailed constitution of a recording section of an ink jet recording apparatus according to a third embodiment of the invention;

FIG. **20** is a diagram showing the schematic constitution of an ink supply system in an ink jet recording apparatus according to a fourth embodiment of the invention;

FIG. **21** is a diagram showing the schematic constitution of an ink supply system in an ink jet recording apparatus according to a fifth embodiment of the invention;

FIG. **22** is a diagram showing the schematic constitution of an ink supply system in an ink jet recording apparatus according to a sixth embodiment of the invention; and

FIG. **23** is a diagram showing the schematic constitution of an ink supply system in an ink jet recording apparatus according to a seventh embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below in detail with reference to the accompanying drawings.

In a printer **1** shown in FIG. **1** that is one of the ink jet recording apparatus according to a first embodiment, a frame **2** is so formed as to define a window **3** having a width in which print paper can pass through. A recording head **5** mounted on a carriage **4** that reciprocates in the main scanning direction is arranged at the upper portion of the window **3**, and a paper guide **6** for supporting the print paper is arranged at the lower portion of the window **3**. On the right side of the frame **2**, an operation panel **7** for operating a control unit included in the printer is arranged, and on the left side of the frame **2**, an ink tank container **9** is arranged, which is covered with a cover **8** that can be opened and closed. An ink tank is detachably accommodated therein.

Usually, the recording head **5** in the printer **1** is composed of a black ink recording head that ejects black ink and a color ink recording head that ejects ink of each of plural colors such as yellow, cyan, and magenta, so that a full color image can be printed. The recording head for each color is connected to a subtank of the corresponding color with a pipe line. Under this constitution, while the print paper is intermittently fed in the sub-scanning direction by the predetermined amounts, the carriage **4** is moved in the main scanning direction, and ink supplied from the subtank to the recording head **5** is ejected on the print paper as ink droplets thereby to perform printing.

As shown in FIG. **2**, an ink jet recording system **100** according to this embodiment includes a plurality of the printers **1**, a single main tank **10**, an air pump **12**, an accumulator **13**, an air releaser **19**, and a system controller **14**. The plural printers **1** are vertically arranged with the difference in height H.

The main tank **10** is divided into an air chamber **10***a* and an ink pack **10***b*. The ink pack **10***b* is connected to a subtank **20** provided for each printer **1** by a pipe line **15**, and ink stored therein is supplied to the subtank **20** of each printer **1**. The subtank **20** is connected through a damper **5***d* to the recording head **5** by a pipe line **20***a*, so that ink stored therein is supplied to the recording head **5**.

The air pump **12** is connected to the air chamber **10***a* of the main tank **10** by a pipe line **16**, through the accumulator **13** and the air releaser **19**, so that intake air is supplied to the air chamber **10***a* of the main tank **10**. The accumulator **13** stabilizes pressure fluctuation in the air pump **12**. To operate the ink jet recording system **100**, however, the accumulator **13** is not essential. The air releaser **19** release air within the pipe line **16** and the air chamber **10***a* to atmosphere to thereby cancel the pressurized state produced by the air pump **12**.

An electromagnetic valve **17** (hereinafter, main valve) is provided for the pipe line **15** in the vicinity of the main tank **10**, and an electromagnetic valve **18** (hereinafter, subvalve) is provided for the pipe line **15** in the vicinity of each subtank **20**. The system controller **14** is electrically connected to a controller **1***a* of each printer **1**, the main tank **10**, the air pump **12**, the main valve **17**, and the air releaser **19**, to perform driving each printer **1**, the air pump **12** and the air releaser **19**, to check the residual amount of ink in the main tank **10**, and to open/close the main valve **17**. Further, the controller **1***a* of each printer **1** is electrically connected to the subvalve **18** and the subtank **20**, to open/close the subvalve **18** and to check the residual amount of ink in the sub-main tank **20**.

In FIG. **2**, for convenience, the main tank **10**, the pipe lines **15**, **16**, and the subtanks **20** are not shown every each color ink. As a matter of fact, the main tank **10** and the subtanks **20** are provided every each color and connected to each other by the pipe lines **15**, **16** for each color.

As described above, since ink is supplied from one main tank **10** to the plural subtanks **20**, even if the plural printers **1** are provided, the maintenance work is completed by only exchanging the one main tank, so that the work performance can be improved. The dynamic pressure in the pipe line **15** between the main tank **10** and the subtank **20** does not give the influence to the operation of the recording head **5**, so that the print quality can be maintained. Although the plural printers **1** are arranged with the difference in height H, the subtank **20** in each printer **1** is arranged such that head difference between the subtank **20** and the recording head **5** is made constant.

Further, a plurality of main tanks may be provided in the recording system **100**. In this case, when the amount of the residual ink therein becomes low, an operating tank can be quickly switched for another main tank. Therefore, while the switched main tank is used, the original main tank **10** can be replaced with a new main tank filled with ink.

Further, a plurality of recording heads may be provided with respect to the subtank **20**. However, in this case, the number of nozzles per a recording head and the ink amount ejected in a unit time period should be considered such that a dynamic pressure generated in the pipe line **20***a* when the plural recording heads are operated is below a problematic level, while considering also a static pressure defined by the layout of the recording heads an the subtank **20** in the vertical direction. The design freedom is enhanced with the plural recording heads if the above condition is satisfied.

As shown in FIG. **3**, the ink pack **10***b* is an airtight pack made of a flexible material and having a size so as to be variable in volume in accordance with the ink amount stored therein, for example, about 1000 cc. On one short side thereof, a connection port **10***c* connected to the pipe line **15** is provided. A center portion on the other short side is deposited in order to prevent excess expansion. On long sides, gores **10***d* are provided to positively gain an expandable capacity.

As a material of the ink pack **10***b* of the main tank **10**, for example, an aluminum laminating film can be used in order to secure gas barrier property, in which an aluminum foil is interposed as a middle layer between two films, for example, a nylon film on the outer side and a polyethylene film on the inner side. Further, a translucent film can be also used, in which silicon oxide is evaporated on a surface of a polymer film such as polyester or nylon thereby to form a silicon oxide layer is formed, and a polymer film such as polyethylene having good heat-welding property is laminated on these surfaces.

As shown in FIGS. **4**A and **4**B, the subtank **20** includes an ink pack **21** in which ink is stored, an adhesion guard **22** for preventing mutual adhesion of the inner surfaces of the ink pack **21**, an ink amount detector **23** for detecting the amount of ink in the ink pack **21**, and a fixing plate **24** on which the ink pack **21** is fixed.

On one surface of the ink pack **21**, the ink amount detector **23** is bonded; and on the other surface of the ink pack **21**, the fixing plate **24** is bonded. The ink amount detector **23**

includes a plate-shaped bonded part **23***a* that is bonded on one surface of the ink pack **21**, and a plate-shaped detector part **23***b* that is integrally formed at the lower portion of this bonded part **23***a* so as to perpendicularly extend from the surface of the bonded part **23***a*.

As shown in FIG. **5**, the ink pack **21** is an airtight pack made of a flexible material and having a size so as to be variable in volume in accordance with the ink amount stored therein, for example, about 5 to 300 cc. On the opposed sides thereof, an inlet **21***a* connected to the pipe line **15** and an outlet **21***b* connected to the pipe line **20***a* are provided.

As a composing material of the ink pack **21** of the subtank **20**, for example, an aluminum laminating film can be used in order to secure gas barrier property, in which an aluminum foil is interposed as a middle layer between two films, for example, a nylon film on the outer side and a polyethylene film on the inner side. Further, a translucent film can be also used, in which silicon oxide is evaporated on a surface of a polymer film such as polyester or nylon thereby to form a silicon oxide layer is formed, and a polymer film such as polyethylene having good heat-welding property is laminated on these surfaces.

Since the ink pack **21** of the subtank **20** has flexibility, even if the ink supply from the main tank **10** to the subtank **20** is forcedly performed, the ink does not leak from the recording head **5** and meniscus of a nozzle of the recording head **5** is not damaged. Further, since the ink is not exposed to atmosphere, it is not oxidized, so that restriction in an inner diameter and a length of an ink flowing passage from the main tank **10** to the subtank **20** are eliminated. Therefore, printing can be performed while the deaeration state of the ink is maintained. Moreover, the amount of the residual ink can be detected by the change in thickness of the ink pack.

Here, the ink pack **21** of the subtank **20** may be formed of a hard material. In this case, a member such as a detector that can detect the liquid surface in the ink pack **21** of the subtank **20** is used for detection of the residual ink amount.

Besides, when initial ink filling from the main tank **10** to the subtank **20** is performed, even if the ink pack **21** is evacuated once, it is possible to prevent the mutual adhesion of the inner surfaces of the ink pack **21** by the adhesion guard **22**. Therefore, the initial ink filling can be smoothly performed. Further, even if the subtanks **20** of the plural colors are provided, reversal flow of the ink of the different color from the recording head **5**, which is produced when one of their ink packs **21** is closed, can be prevented.

As shown in FIG. **7**B, the adhesion guard **22** is a rectangular plastic plate that is slightly smaller than the inner shape of the ink pack **21**. As shown in FIG. **6**B, on one surface of the adhesion guard **22**, grid-like grooves **22***a* having a rectangular cross-section are formed, and on the other surface of the adhesion guard **22**, as shown in FIG. **6**D, grooves **22***a* having the similar rectangular cross-section are formed crosswise.

As shown in FIGS. **7**A and **7**B, the adhesion guard **22** is housed in the ink pack **21** in a free state. Since the inner surface of the ink pack **21** does not interfere with the adhesion guard **22** when it expands or contracts by filling or consumption of ink, the error operation of the ink amount detector **23** can be prevented. Further, since the ink supplied from the main tank **10** flows along the grooves **22***a* into the ink pack **21**, the ink pack **21** can be initially filled with the ink smoothly.

As shown in FIGS. **8**A and **8**B, switches **25***a* and **25***b* are arranged on both sides of the detector part **23***b* of the ink amount detector **23**, that is, on both sides in the direction where the ink pack **21** expands or contracts in accordance with the ink amount stored therein. The switch **25***a* is activated when the ink pack **21** is contracted, by the detector part **23***b* moving in an arrow-a direction, so that it is that the ink pack **21** becomes substantially empty (an ink low state), for example, the amount of ink left therein is 10 g or less.

On the other hand, the switch **25***b* is activated when the ink pack **21** is expanded, by the detector part **23***b* moving in an arrow-b direction, so that it is detected that the ink pack **21** becomes substantially full (an ink full state), for example, the amount of ink therein is 20 g or more. A state where both the switches **25***a* and **25***b* are not activated, that is, a state where the ink amount in the ink pack **21** is between the ink low state and the ink full state is an ordinary state.

An ink pack **21'** shown in FIGS. **9**A and **9**B as a modified example is not provided with the rectangular plate-shaped adhesion guard **22**, but a adhesion guard **22'** formed as a convex having a semi-circular cross-section by press-molding on one surface of the ink pack **21** to which the ink amount detector **23** is bonded. Since the adhesion guard **22'** is formed by thus deforming one surface of the ink pack **21**, it is not necessary to prepare the rectangular adhesion guard **22** that is a separate member from the ink pack **21**. Further, since the adhesion guard **22'** can be formed simultaneously with formation of the ink pack **21'**, a cost of the subtank **20** can be reduced.

As described above, the rectangular plate-shaped adhesion guard **22**, as shown in FIG. **4**B, is housed in the ink pack **21** in the free state, and the adhesion guard **22'** having the semi-circular and convex section, as shown in FIG. **9**C, is formed so as to avoid the bonding surface of the bonded part **23***a* of the ink amount detector **23** to the one surface of the ink pack **21'**. Therefore, each of the adhesion guards **22** and **22'** does not interfere with the detector part **23***b* of the ink amount detector **23**. Accordingly, since the ink amount in the ink packs **22** and **22'** can be always detected with high accuracy, bad printing due to a shortage of ink supply can be prevented.

An ink replenishing operation performed in the thus configured recording system **100** will be described with reference to FIG. **10**. The system controller **14**, upon reception of a print command from a host computer (not shown), sends the command to the controller **1***a* of each printer **1** so that the controller **1***a* of each printer **1** starts a print processing on the basis of the received print command. First, it is checked the amount of the residual ink in the subtank **20** (step S**1**).

When the controller **1***a* of one printer **1** detects the small amount of the residual ink in the subtank **20**, it is notified to the system controller **14**. Then, the system controller **14** drives the air pump **12** (step S**2**), opens the main valve **17** (step S**3**), and opens the subvalve **18** through the controller **1***a* of the printer **1** (step S**4**).

The air pump **12** supplies air to the air chamber **10***a* of the main tank **10** thereby to pressurize the ink in the ink pack **10***b* of the main tank **10**, and supplies the ink to the subtank **20** of the printer **1** thereby to replenish the subtank **20** with the ink (step S**5**). Hereby, since it is possible to prevent the ink in the subtank **20** from running short, the ink can be sufficiently supplied to the plural printers **1** that consume a large amount of ink.

Thereafter, when the controller **1***a* of the printer **1** detects the completion of ink replenishment in the subtank **20** (step S**6**), it is notified to the system controller **14**. Then, the system controller **14** closes the subvalve **18** through the controller **1***a* of the printer **1** (step S**7**), stops drive of the air pump **12** (step S**8**), activates the air releaser **19** to open the insides of the pipe line **16** and the air chamber **10***a* to

atmosphere so that the pressurized state produced by the air pump **12** (step S**9**) is canceled. Lastly, the main valve **17** (step S**10**) is closed.

Since the pressurized state can be canceled by the air releaser **19** when the ink supply is not required, breakdown of the apparatus caused by keeping of the pressurized state can be eliminated, reliability can be improved. Moreover, safety can be secured even if a pressurizing control error or an ink supply error is occurred.

The above operation is repeated while the ink jet recording system **100** is activated. When the system controller **14** detects the small amount of the residual ink in the ink pack **10***b* of the main tank **10**, it is notified to the host computer through a display or the like. Hereby, the user replaces the subject ink pack **10***b* with a new one.

Accordingly, since the user manages only the ink in the ink pack **10***b* of one main tank **10**, the residual amount check of ink is facilitated. Further, since the pipe line **15** from the main tank **10** to the subtank **20** can be closed by the main valve **17** on the main tank **10** side, the ink pack **10***b* of the main tank **10** can be replaced even during the printing operation, without causing the air invasion or ink leakage in the pipe line **15**.

Since the ink is forcedly supplied to each subtank **20** by the air pump **12**, and the head difference between the subtank **20** and the recording head **5** and the pipe line **20***a* in each printer **1** are arranged such that the ink supply from the subtank **20** to the recording head **5** can be stably performed, the printers **1** can be arranged in the horizontal direction, the vertical direction, or three-dimensionally (their combination), even if the main tank is arranged in any position. In a case where the printers **1** are arranged in the vertical direction, the layout space of the plural printers **1** can be reduced. In other words, the number of printers per a unit area can be increased.

Alternatively, another ink replenishing operation shown in FIG. **11** may be adopted. The system controller **14**, upon reception of a print command, for example, from a host computer (not shown) (step S**11**), sends the print command to a controller **1***a* of a printer **1** in which the ink supplying time from the main tank **10** to the printer **1** is shortest, that is, a printer **1** in which a length of the pipe line **15** connecting the main tank **10** and the printer **1** is shortest (hereinafter referred to as a first priority printer) (step S**12**). Then, the controller **1***a* of the first priority printer **1** starts a printing operation on the basis of the received print command, and checks the amount of the residual ink in the subtank **20** (step S**13**).

Further, the system controller **14**, upon reception of a print command from the host computer (step S**14**), sends the print command to a controller **1***a* of a printer **1** in which a length of the pipe line **15** connecting the main tank **10** and the printer **1** is secondly shortest (hereinafter referred to as a second priority printer) (step S**12**). Then, the controller **1***a* of the second priority printer **1** starts a printing operation on the basis of the received print command, and checks the amount of the residual ink in the subtank **20** (step S**13**). Hereafter, a third priority printer, a fourth priority printer . . . are similarly controlled (steps S**11** to S**14**).

Since the printers **1** are sequentially controlled in accordance with the priority based on the ink supplying time (the length of the pipe line **15**), in a case where the printing amount increases, the somewhat large amount of printing can be assigned to the printer **1** in which the ink supply completes quickly (i.e., a higher priority printer). Therefore, the total ink supply time can be reduced.

When the controller **1***a* of the first priority printer **1** that is most preferentially controlled checks whether the amount of the residual ink in the subtank **20** comes to the small amount, namely, whether the subtank **20** is in the ink low state (step S**15**). When the ink low state is detected, it is notified to the system controller **14** (step S**16**). Then, the system controller **14** drives the air pump **12**, opens the main valve **17** (step S**17**), and further opens the subvalve **18** through the controller **1***a* of the first priority printer **1** (step S**18**).

The air pump **12** supplies air to the air chamber **10***a* of the main tank **10** thereby to pressurize ink in the ink pack **10***b* of the main tank **10**, and supplies the ink to the subtank **20** of the first priority printer **1** thereby to replenish the subtank **20** with the ink (step S**19**). Thereafter, the controller **1***a* of the first priority printer **1**, when detects the completion of ink replenishment in the subtank **20** (step S**20**), notifies that to the system controller **14** (step S**21**).

Then, the system controller **14** closes the subvalve **18** through the controller **1***a* of the above printer **1** (step S**22**), stops drive of the air pump **12**, activates the air releaser **19** to open the insides of the pipe line **16** and the air chamber **10***a* to the atmosphere so that the pressurized state produced by the air pump **12** is released. Lastly the controller **1***a* closes the main valve **17** (step S**23**). Hereafter, the ink is similarly supplied to the second priority printer, the third priority printer . . . (steps S**15** to S**23**)

The above operation is repeated while the ink jet recording system **100** is activated. When the system controller **14** detects the ink low state of the ink pack **10***b* of the main tank **10**, it is notified to the host computer through a display or the like. Hereby, the user replaces the ink pack **10***b* of the subject ink tank **10** for a new one.

Also according to the above configuration, the same advantages discussed with reference to FIG. **10** can be attained.

Here, the air pump **12** may be removed. In such a configuration, a main tank **10** is arranged at the top of the system, and each of printers **1** is arranged below the main tank **10** with difference of height. Due to the head difference between the main tank **10** and the subtank **20** of each printer **1**, by opening the main valve **17**, the ink can be surely supplied to the subtank in which the subvalve **18** is opened.

In an ink jet recording system according to a second embodiment of the invention, as shown in FIG. **12**, a carriage **4** is constituted so that it can be reciprocated by a carriage drive motor **32** through a timing belt **31**. On this carriage **4**, a recording head **5***a* that ejects a droplet of black ink supplied from an ink supply system **40** and a recording head **5***b* that ejects a droplet of each color ink of yellow, cyan, and magenta are mounted.

The ink supply system **40** includes: main tanks **10**B, **10**Y, **10**C and **10**M in which ink of each color is stored; subtanks **20**B, **20**Y, **20**C and **20**M in which the ink of each color supplied from the main tanks **10**B, **10**Y, **10**C and **10**M are temporarily stored; and pressure chambers **41**B, **41**Y, **41**C and **41**M that are arranged in the ink tank container **9** for housing the main tanks **10**B, **10**Y, **10**C and **10**M therein. The respective pressure chambers **41**B, **41**Y, **41**C and **41**M are connected to an ejection port **53***a* of a pressure pump **53** through pressure detectors **51**B, **51**Y, **51**C and **51**M and electromagnetic valves for pressure release **52**B, **52**Y, **52**C and **52**M (hereinafter, releaser valves).

There are provided pipe lines **42**B, **42**Y, **42**C and **42**M that connect the main tanks **10**B, **10**Y **10**C and **10**M with the subtanks **20**B, **20**Y, **20**C and **20**M. Electromagnetic valves

43B, 43Y, 43C and 43M (hereinafter, simply referred as valves) connected to the pipe lines 42B, 42Y 42C and 42M; and ink supplying tubes 44*b*, 44Y, 44C and 44M that connects the subtanks 20B, 20Y, 20C and 20M to the recording heads 5*a* and 5*b*.

In a non-printing region on a right side of a sheet guide member 6, a capping unit 46 is arranged, which causes a suction pump 45 to apply negative pressure to the recording heads 5*a* and 5*b* for preventing the clogging caused by dried ink in the recording heads 5*a*, 5*b* at the non-printing time or initial ink filling time of the recording heads 5*a* and 5*b*.

As is specifically shown in FIG. 13, in the main tank 10 (10B, 10Y, 10C. 10M), a connection port 10*a* is connected to the pipe line 42 (42B, 42Y, 42C. 42M). In the subtank 20 (20B, 20Y, 20C, 20M), an Inlet 21*a* is connected to the pipe line 42, and an outlet 21*b* is connected to the ink supplying tube 44 (44*b*, 44Y, 44C, 44M).

A controller 50 is electrically connected to: the pressure detector 51 (51B, 51Y, 51C, 51M) that detects the pressure applied to the main tank 10; the releaser valve 52 (52B, 52Y, 52C, 52M); the pressure pump 53; the valves 43 (43B, 43Y, 43C, 43M); switches 25*a*, 25*b* activated by displacement of an ink amount detector 23 provided with the subtank 20; and suction pumps 45 and 47. The controller 50 controls check of the amount of ink in the main tank 10 and in the subtank 20, drives of the suction pumps 45, 47 and the pressure pump 53, and opens or closes the valves 43 and 52. In FIG. 13, for convenience, the main tank 10, the subtank 20, the pressure chamber 41, the pipe line 42, the valve 43 and the ink supplying tube 44 are not shown every each color ink, but shown for only one color ink.

An initial ink filling operation performed in the recording system will be described with reference to flowcharts of FIGS. 13 to 18. In the initial state, the valves 43 for all the colors are closed. Further, in the subtanks 20 for all the colors, air and carrier liquid entering in an assembly process has entered. Firstly, the controller 50, upon reception of an initial filling command from a host computer (not shown), exhausts the air and carrier liquid in each subtank 20 (step S101 in FIG. 14).

Namely, the recording head 5 is moved to the non-printing region to seal the recording head 5 with the capping unit 46. Next, the suction pump 45 is operated to apply the negative pressure of the capping unit 46 through the recording head 5 to each ink supplying tube 44 and each subtank 20, and the air and the carrier liquid that remain in these members are exhausted to the capping unit 46.

The suction amount of the suction pump 45 at this time is set to not a fixed value but a variable value varying according to the amount of ink in each subtank 20. Namely, the control unit judges whether the amount of ink in each subtank 20 is 10 g or less, (step S111 in FIG. 15), that is, whether the ink amount is in an ink low state. When the ink amount is not in the ink low state, the controller 50 sets the suction amount of the suction pump 45 to a small amount, for example, 1 g, and drives the suction pump 45 till the subtank 20 enters in the ink low state (step S112 in FIG. 15). In this time, since the carrier liquid enters in each subtank 20 in place of ink, the controller performs judgment from the amount of carrier liquid.

When the amount of the carrier liquid in each subtank 20 comes to the ink low state, the controller 50 sets the suction amount of the suction pump 45 to a large amount, for example, 100 g, and drives the suction pump 45 thereby to make each subtank 20 in a high negative pressure state. Accordingly, each subtank 20 is compressed by atmospheric pressure thereby to completely exhaust the air and the carrier liquid to the capping apparatus 46 (step S113 in FIG. 15).

In a case where the suction amount of the suction pump 45 is set to a considerably large value, its suction amount may be set as a fixed value. Further, a threshold value of the number of loops between the steps S111 and S112 may be previously set in case the loops are excessively repeated due to some trouble. When the number of loops is over the threshold value, the operation proceeds to the step S113.

Next, the controller 50 supplies ink in each main tank 10 to each subtank 20 (step S102 in FIG. 14). Namely, the controller 50 opens each valve 43, and allows the ink in each main tank 10 to flow into each subtank 20 that is in the high negative pressure state (step S121 in FIG. 16). Next, the controller 50 judges whether the amount of ink in each subtank 20 is in a state between the ink low state and an ink full state (an intermediate state), for example, 20 g or more (step S122 in FIG. 16). When the ink amount is not the intermediate state, the controller 50 waits for one second (step S123 in FIG. 16). Hereby, the amount of ink in each subtank 20 increases gradually, and when it comes to the intermediate state, the controller 50 closes each valve 43 (step S124 in FIG. 16).

In this embodiment, the pressure pump 53 operates thereby to pressurize each main tank 10. However, in a system in which each main tank 10 is not pressurized since each subtank 20 is in the high negative pressure state, priming to each sub-subtank 20 is performed by this negative pressure and each pipe line 42 can be filled with the ink, so that the ink supply from each main tank 10 to each subtank 20 can be performed.

Further, enough time period for the amount of ink in each subtank 20 to come to the intermediate state may be previously set in case where a loop between the steps S122 and S123 is excessively repeated due to some trouble. In a case where the time when the ink amount has come to the intermediate state is over the preset time period, the operation proceeds to the step S124 forcedly. However, in this case, even if the ink is not supplied from each main tank 10 to each subtank 20, the initial filling is continued. Therefore, in order to prevent this situation, a fetal error (breakdown) or an ink end error (state where there is no ink in each main tank 10) may be established when the time period for which the ink amount has come to the intermediate state is over the preset time period.

Here, since the ink supplied from each main tank 10 to each subtank 20 includes air that has existed in each pipe line 42, this air must be also exhausted. Therefore, the controller 50 exhausts the air and the ink in each subtank 20 (step S103 in FIG. 14). Namely, the suction pump 45 is operated thereby to apply the negative pressure of the capping device 46 to each ink supplying tube 44 and each subtank 20 through the recording head 5, so that the air and the ink in these members are exhausted to the capping unit 46.

Namely, the operations explained with reference to FIGS. 15 and 16 are again executed to completely exhaust the air and the ink to the capping unit 46. In order to exhaust the air contained in the ink in each subtank 20 more completely, the steps S103 and S104 may be repeated plural times.

Here, in a case where each valve 43 is opened when each subtank 20 is in the high negative pressure state, the ink flows suddenly from each main tank 10 to each subtank 20 and bubbles, so that the deaeration lowers. Therefore, the controller 50 exhausts the bubbling ink in the ink in each subtank 20, for example, 30–80%, preferably 50% of the total ink amount. Namely, the suction pump 45 is operated

to suck the ink in each subtank **20** and exhaust it to the capping unit **46** (Step S**105** in FIG. **14**).

Next, the controller **50** supplies the ink in each main tank **10** to each subtank **20** (step S**106** in FIG. **14**). Namely, the controller **50** opens each valve **43**, and allows the ink in each main tank **10** to flow into each subtank **20** (step S**131** in FIG. **17**). Next, the controller **50** judges whether the amount of ink in each subtank **20** is in the ink full state (step S**132** in FIG. **17**). When the ink amount is not in the ink full state, the controller **50** waits for one second (step S**133** in FIG. **17**).

When the amount of ink in each subtank **20** comes to the ink full state, the controller **50** closes each valve **43** (step S**134** in FIG. **17**). In the step S**131**, since each subtank **20** is not in the negative pressure state, the ink stored therein does not bubble. Hereby, the ink that has bubbled in each subtank **20** can be completed exhausted, and, with ink supplied till the ink amount comes to the ink full state, the aerated ink can be diluted.

Here, in order to secure print quality immediately after the initial filling, since it is necessary to dissolve in the ink the air bubbles remaining in a portion in the recording head **5** where the flow stagnates, the predetermined amount of deaerated ink must be allowed to flow. Therefore, the controller **50** performs an initial ink filling operation for the recording head **5** (step S**107** in FIG. **14**). Namely, the suction pump **45** is operated thereby to suck and exhaust 50% of the total ink amount in each subtank **20** to the capping unit **46** (step S**141** in FIG. **18**).

And, the controller **50** performs a flushing operation of ejecting the ink in the capping unit **46** by driving the recording head **5** (step S**142** in FIG. **18**). Hereby, the minute air bubbles stuck around an actuator of the recording head **5** separate from the actuator and dissolve. Further, at the flushing time, it is not necessary to seal the recording head **5** with the capping unit **46**, but the recording head **5** may be only positioned on the capping unit **46**.

Next, the controller **50**, in order to compensate the ink consumed by the initial filling in the recording head **5**, supplies ink in each main tank **10** to each subtank **20** (step S**108** in FIG. **14**). Namely, the operations explained with reference to FIG. **17** is again executed.

By the above steps, the initial filling processing in each subtank **20** and the initial filling processing in the recording head **5** are completed. The steps S**105**,S**106** and the steps S**107**,S**108** may be performed according to necessity.

In this embodiment, the ink jet printer **1** has one subtank **20** for one main tank **10**. However, the invention can be applied also to an ink jet recording apparatus having plural subtanks **20** (recording heads **5**) for one main tank **10**, which will be described below as a third embodiment.

In FIG. **19**, parts having the same constitution as the constitution shown in FIG. **13** are denoted by the same reference numerals, and their detailed explanation is omitted. A main tank **10**, to which an residual ink amount detector plate **11** is attached, is housed in a pressure chamber **41** (**41**B, **41**Y, **41**C, **41**M). The pressure chamber **41** is connected through an electromagnetic valve **48** (**48**B, **48**Y, **48**C, **48**M; hereinafter referred as a main valve) to an outlet port **47***b* of a suction pump **47** in order to arbitrarily adjust pressure therein, and connected through an electromagnetic valve **49** for pressure release (hereinafter referred as a releaser valve). An inlet port of the suction pump **47** is connected to a paper guide **6** to fix a print paper thereon. An electromagnetic valves **43** (**43**B, **43**Y, **43**C and **43**M; hereinafter, referred as a subvalve) is connected to a pipe line **42** (**42**B, **42**Y, **42**C and **42**M).

A controller **50** is electrically connected to: a detector **12** that detects movement of the residual ink amount detector plate **11** of the main tank **10**; switches **25***a* and **25***b* that operate by the movement of an ink amount detector **23** provided with a subtank **20**; each of valves **43**, **48** and **49**; and each of suction pumps **45** and **47**. The controller **50** controls check of the amount of residual ink in the main tank **10** and the amount of ink in the subtank **20**, drives each suction pumps **45**, **47**, and opens or closes the respective valves **43**, **48** and **49**. In FIG. **19**, for convenience, the main tank **10**, the subtank **20**, the pressure chamber **41**, the pipe line **42**, the subvalve **43** and an ink supplying tube **44** are not shown every each color ink, but shown for only one color ink.

Thus by using air-intake and air-outlet of the suction pump **47**, both of fixing of the print paper and pressurization of the main tank **10** are simultaneously performed, so that the pressure pump **53** shown in FIGS. **12** and **13** is not required. The size and cost of the printer **1** can be accordingly downsized.

FIG. **20** shows an ink supply system **60** in an ink jet recording system according to a fourth embodiment of the invention. This ink supply system **60** includes one main tank **10**, plural ink jet printers **61**, and a system controller **62** that control the whole of the system.

The main tank **10** is located in a lower position than a recording head **63** of each ink jet printer **61** and arranged so that a head difference h is given between the recording head **63** and the main tank **10**. Further, the main tank **10** is connected to each recording head **63** by a pipe line **64** to always supply ink storing therein to each recording head **63** directly. At this time, since the negative pressure state is required in order to make a meniscus of a nozzle of the recording head **63**, the head difference between the main tank **10** and each recording head **63** is made constant. By locating the main tank **10** in the lower position than the recording head **63**, it is possible to prevent the meniscus formed in the nozzle of each recording head **63** from being damaged.

A suction pump **65** is connected to each recording head **63**, and sucks air in the ink flowing passage extending from the nozzle of each recording head **63**. According to this constitution, clogging due to dust in the ink flowing passage or clogging due to dried ink in a nozzle opening can be resolved. The system controller **62** monitors the consumed ink amount in each recording head **63** and manages the amount of the residual ink in the main tank **10**.

In FIG. **20**, for convenient, the main tank **10**, the recording heads **63**, and the pipe line **64** are not shown every each color ink in a four-color type of black, cyan, magenta and yellow used in color printing, in a six-color type of black, cyan, light cyan, magenta, light magenta and yellow, or in a seven-color type of black, cyan, light cyan, magenta, light magenta, yellow and dark yellow. Actually, the main tank **10** and the recording head **63** are partitioned every each color and they are connected to each other by the pipe line **64** for each color.

Although the ink jet printer **61** includes one recording head **63** that ejects each of the above colors, one ink jet printer **61** may be provided with plural recording heads **63**.

FIG. **21** shows an ink supply system **70** in an ink jet recording system according to a fifth embodiment of the invention. This ink supply system **70** includes one main tank **10**, plural ink jet printers **71**, and a system controller **72** that controls the whole of the system.

Each ink jet printer **71** includes one subtank **20** and one recording head **73**. Since the negative pressure state is

required in order to make a meniscus of a nozzle of the recording head **73**, the head difference between the subtank **20** and the corresponding recording head **73** is made constant.

The main tank **10** is located in the higher position than each subtank **20** so that a head difference h' is given between the main tank **10** and each subtank **20**, and connected to each subtank **20** by a pipe line **75**. The subtank **20** is connected to the recording head **73** by a pipe line **76**. The capacity of the main tank **10** has several times of the total capacity of the subtanks **20**. An electromagnetic valve **77** (hereinafter, simply referred as valve) is connected to the pipe line **75**. A suction pump **78** is connected to the recording head **73** to apply negative pressure in an ink flowing passage extending from the nozzle of the recording head **73**, thereby to decompress ink in the main tank **10**. In cooperation with the head differential pressure, the ink is once led into the subtank **20**.

After the recording head **73** is replenished with ink in the subtank **20**, the system controller **72** closes the valve **77** and ejects the ink from the recording head **73** thereby to execute printing. For this time, the system controller **72** monitors the amount of ink in each subtank **20**, and replenishes each subtank **20** with ink in the main tank **10**.

As in FIG. **22** which shows an ink supply system **70'** in an ink jet recording system according to a sixth embodiment of the invention, an air pump **79** may be connected to a main tank **10** to compress ink in the main tank **10** to replenish the subtanks **20**. According to this configuration, ink can be supplied to the subtank **20** more quickly than the system in FIG. **21**. Moreover, the layout position of the main tank **10** is not limited as in the system in FIG. **21**.

As in FIG. **23** which shows an ink supply system **70"**in an ink jet recording system according to a seventh embodiment of the invention, ink jet printers **71** may be arranged vertically to reduce the layout area of the system. A main tank **10** is arranged in a top position, and each subtank **20** and each recording head **73** are arranged below the main tank **10** with difference of height H'. According to this constitution, ink in the main tank **10** is naturally supplied to the subtank **20** once due to head difference and fills the subtank **20**. Thereafter, the ink in the subtank **20** is supplied to the recording head **73**. However, as in the system in FIG. **22**, an air pump **79** may be connected to the main tank **10** to compress ink in the main tank **10** to replenish the subtank **20**. In this case, limitations in position of the main tank **10** are eliminated.

In FIGS. **21** to **23**, for convenience, the main tank **10**, the subtanks **20**, the recording heads **73**, and the pipe lines **75**, **76**, are not shown every each color ink. As a matter of fact, the main tank **10**, the subtanks **20**, the recording heads **73** are partitioned according to each color and connected to one another by the pipe lines **75**, **76** for each color. Further, although the ink jet printer **71** includes one recording head **73** that ejects each of the above colors, one ink jet printer **71** may be provided with plural recording heads **73**.

As a method of monitoring the amount of ink in each subtank **20** performed by the system controller **72**, for example, a soft counting is used. This soft counting is a method of, when the ink in the subtank **20** is consumed by printing of the ink jet printer **71** or cleaning of the recording head **73**, accumulatively recording the consumed ink amount of each subtank **20** in a non-volatile memory device provided in the printer body. According to this method, it is possible to monitor a state of the consumed ink amount in the subtank **20** during the printing operation by the recording head **73**, so that ink management of each recording head **73** is facilitated.

The soft counting may be reset when the subtank **20** falls into a predetermined condition, for example, when a thickness of the subtank becomes a predetermined level detected by a mechanical switch (an ink high state), or when pressure in the subtank does not come to positive pressure. After then, it is counted the ink amount consumed by printing, cleaning, flushing or the like.

Hereby, since the consumed ink amount in the subtank **20** becomes nearly equal to the counted ink amount, when ink is supplied to the subtank **20** and the subtank **20** becomes the ink high state, the supplied ink amount is nearly the same as the counted ink amount. Totalizing the consumed ink amount of each subtank **20**, the consumed ink amount of the main tank **10** can be exactly obtained.

Methods of supplying ink to the subtank **20** on the basis of this soft counting will be described below.

As a first example, each time ink is supplied to each subtank **20**, the consumed ink amount of each subtank **20** is totalized, or it is totalized and reset. Hereby, accuracy between the total of the counted ink amount in the subtank **20** and the consumed ink amount in the main tank **10** can be improved. Further, since the ink is supplied every each subtank **20**, the subtanks other than the subtank subjected to the ink supply can be used in printing, so that interruption of printing by the recording head **73** can be reduced.

As a second example, ink is supplied selectively to only a subtank requiring the ink supply, and the consumed ink amount of subtank **20** is totalized, or it is totalized and reset.

As a third example, when the consumed ink amount of each subtank **20** is totalized, ink is supplied simultaneously to all the subtanks.

In the second and third examples, loss of the supply time of ink from the main tank **10** to the subtank **20** can be reduced.

The flowing amount of ink supplied from the main tank **10** to the subtank **20** is so determined as to be the largest flowing amount of ink ejection of the recording head **73** or more. Hereby, even during the recording operation, since the amount of ink supplied from the main tank **10** to the subtank **20** is larger than the amount of ink ejection, it is possible to avoid impossibility of printing in the recording head **73**. However, in a case where the valve **77** is opened during the recording operation, pressure fluctuation in the ink flowing passage is produced and the printing state changes. Therefore, it is necessary to pay an attention to the ink supply during the recording operation.

Methods of triggering the ink supply to each subtank **20** performed by the system controller **72** will be described below.

As a first example, when the apparatus is activated, the printing is performed or finished, the print paper is discharged, if the consumed ink amount in the subtank **20** is over the predetermined threshold value, ink is supplied from the main tank **10** to the subtank **20**. This threshold value is set to a large value during printing by the recording head **73**, and set to a small value except for that time. Hereby, the ink supply can be controlled so that ink is not supplied from the main tank **10** when the consumed ink amount in the subtank **20** is small. Therefore, time loss due to the interruption of printing in the recording head **73**, which is caused by the ink supply, can be reduced.

As a second example, a residual ink amount detector that detects the amount of the residual ink in each subtank **20** is provided. Here, the system controller **72** supplies ink from the main tank **10** to the subtank **20** when the detected value indicates that the residual ink amount lowers a predetermined level, for example, when the ink high state is can-

celed, or the ink low state in which the negative pressure state where at least printing can be performed is effected. Hereby, since the detecting accuracy of the residual ink amount in the subtank **20** can be improved, the ink supply from the main tank **10** to the subtank **20** can be efficiently performed.

Here, for example, the ink amount detector **23** shown in FIG. **4** is attached to the subtank **20** and fixed to the fixing plate **24**. By this constitution, since the ink amount detector **23** moves in accordance with the expansion or contraction of the subtank **20** due to the variation of the ink amount therein, the movement of the ink amount detector **23** may be detected by a mechanical, electrical, or optical detector, or a linear scale is attached to the ink amount detector **23** to monitor the residual ink amount and the consumed ink amount in the subtank **20**. Hereby, unevenness of the consumed ink amount detected by soft counting can be suppressed.

For example, two or more residual ink amount detectors may be provided. Here, the ink supply is started after the detection of one detectors is effected, and the ink supply is terminated after the detection of the other is effected. Hereby, the exact residual ink amount can be recognized.

Alternatively, the residual ink amount detector may be single. Hereby, a cost of the residual ink amount detector can be reduced. In this case, the ink supply is performed during the detection of the residual ink amount detector is effected. Hereby, the ink supplying time can be reduced. Alternatively, the ink is supplied for a predetermined time after the detection of the residual ink amount detector is effected. Hereby, the supplying amount can be increased. Alternatively, the ink is supplied after the consumed ink amount of the subtank **10** exceeds the threshold value till the detection of the residual ink amount detector is effected. Hereby, the ink-supplying amount can be recognized most exactly, and the cost can be reduced.

The ink supply from the main tank **10** to the subtank **20** is performed each time the apparatus is activated. Hereby, the time loss due to the interruption of printing in the recording head **73**, which is caused by the ink supply, can be reduced. Further, the ink supply from the main tank **10** to the subtank **20** is performed each time a predetermined time period elapses. Hereby, even in a case where the apparatus is regularly activated so that the ink supply at the time of activation cannot be performed, the ink supply from the main tank **10** to the subtank **20** can be surely performed. Alternatively, the ink supply may be performed each time the apparatus is activated and each time the predetermined time period elapses.

Ink of the amount consumed per a day may be supplied from the main tank **10** to the subtank **20** at once. Hereby, the ink supplying operation is performed only when the apparatus is activated. Therefore, the interruption of the recording operation due to the ink supplying operation can be eliminated, and efficiency of the recording processing can be improved. Here, the order of the ink supply from the main tank **10** to the subtank **20** is not particularly limited. For example, regardless of height of the layout of the subtank **20**, length of the supplying passage, or the consuming amount, the ink may be supplied from an arbitrary subtank **20**.

Methods of terminating the ink supply performed by the system controller **72** will be described below.

As a first example, each time printing is performed by the recording head **73**, the consumed ink amount of each subtank **20** is totalized thereby to calculate the residual ink amount in the main tank **10**, and ink is supplied from the main tank **10** to the subtank **20**. When the system controller **72** judges an ink end state of the main tank **10**, all the recording heads **73** is brought into an ink end state. Hereby, the total of the consumed ink amount in the subtanks **20** becomes equal to the consumed ink amount of the main tank **10**, so that the ink supply from the main tank **10** to the subtank **20** can be surely performed.

In this case, after the ink end state of the main tank **10** is detected, recording is performed by the recording head **73** till the consumed ink amount of each subtank **20** becomes a predetermined value or more. Hereby, the amount of the residual ink in the main tank **10** is exactly counted, and the ink in the subtank **20** is not used uselessly.

As a second example, when the ink is supplied from the main tank **10** to the subtank **20**, the system controller **72** compares the consumed ink amount in each subtank **20** and the residual ink amount in the main tank **10**. When the consumed ink amount is smaller than the ink residual ink, the ink is supplied; and when the consumed ink amount is larger than the ink residual ink, the system controller **72** judges the main tank **10** is in the ink end state so that. Hereby, the ink supply from the main tank **10** to the subtank **20** can be surely performed. When the consumed ink amount is larger than the ink residual ink, the system controller **72** may compare the consumed ink amount of all the subtanks **20** with the residual ink amount of the main tank **10** without performing ink supply. If the former is larger than the latter, the system controller **72** judges the main tank **10** is the ink end state. Hereby, the useless ink amount can be reduced.

Alternatively, even when the consumed ink amount is larger than the ink residual ink, the ink supply ink may be performed only once before the ink end state is judged. Hereby, even in a case where there is unevenness in the residual ink amount in the main tank **10**, the ink in the main tank **10** can be consumed as much as possible. Alternatively, even when the consumed ink amount is larger than the ink residual ink, the ink is supplied; and in a case where the residual ink detector does not change, the system controller **72** judges the main tank **10** is in the ink end state. Hereby, an influence by unevenness of the consumed ink amount can be eliminated.

As a method of supplying ink to the subtank **20** not using the soft counting method, when the system controller **72** judges the residual ink amount to be the ink high state, that is, to be nearly full from the detection value by the ink amount detector **23**, the valve **77** is closed thereby to stop the ink supply from the main tank **10** to the subtank **20**. Hereby, even if the apparatus is deactivated on the way, the residual ink amount in the subtank **20** can be surely detected. Therefore, a disadvantage is not produced in the ink supply from the main tank **10** to the subtank **20**.

This method is performed every each subtank **20**, in only the predetermined subtank **20**, or simultaneously in all the subtanks **20**. Hereby, the ink supply from the main tank **10** to the subtank **20** can be readily performed. Here, in a case where this method is performed in all the subtanks **20** simultaneously, there is the following disadvantage. When the valves **77** of the all the subtanks **20** are open, the ink moves from the upper subtank **20** to the lower subtank **20**, for example, by the head difference. If the apparatus is deactivated in a state where the ink in the upper subtank **20** is empty, the corresponding recording head **73** cannot perform printing.

To avoid such a situation, the valve **77** is closed when the system controller **72** judges the subtank **20** becomes the ink low state based on the detection value by the ink amount detector **23**.

An ink end detector may be provided with the main tank **10**. In this case, the system controller **72** judges the ink end

state upon reception of a detection signal from the ink end detector. After the main tank **10** is replaced with a new one, ink is supplied to the subtank **20** till the ink amount detector **23** detects that the subtank **20** is in the ink full state. Hereby, the system constitution can be simplified.

According to the above configurations, since only ink in the single main tank **10** is managed, the ink supply to the plural recording heads **73** is stabilized, and printing quality can be improved.

Besides, a memory device for storing the residual ink amount in the main tank **10** may be attached to the main tank **10**, whereby ink management can be performed more specifically.

In each of the above embodiments, although the subtank **20** is provided with the adhesion guard **22**, it may be omitted from the subtank **20**.

Although the printer is explained as an example, a facsimile machine and a copying machine may be adopted as an ink jet recording apparatus if a main tank and a subtank are provided therein.

The invention claimed is:

1. An ink supply system, comprising:
- a main tank, which stores ink therein;
- a plurality of subtanks, communicated with the main tank;
- at least one recording section, communicated with at least one of the subtanks; and
- a system controller, which is coupled to each of the subtanks and the main tank and monitors an ink amount consumed in each subtank to manage a residual ink amount in the main tank; and
- wherein the system controller starts to count the consumed ink amount of the subtank when an ink amount stored in the subtank reaches a predetermined level.

2. The ink supply system as set forth in claim **1**, wherein each subtank is airtightly formed by a material having flexibility so that a volume of the subtank is variable.

3. The ink supply system as set forth in claim **2**, wherein each subtank contains a plate member which prevents inner surfaces of the subtank from being adhered with each other.

4. The ink jet recording apparatus as set forth in claim **3**, wherein grooves are formed on surfaces of the plate member.

5. The ink supply system as set forth in claim **1**, wherein the system controller equates a total ink amount consumed in all the subtanks as an ink amount consumed in the main tank.

6. The ink supply system as set forth in claim **1**, wherein the system controller obtains the consumed ink amount of each subtank every time when the subtank is replenished with ink supplied from the main tank.

7. The ink supply system as set forth in claim **1**, wherein the system controller selectively controls the supply of ink to at least one subtank, and obtains the consumed ink amount of the at least one subtank.

8. The ink supply system as set forth in claim **1**, wherein the system controller obtains the consumed ink amount of each subtank, and controls the supply of ink to all the subtanks simultaneously.

9. The ink supply system as set forth in claim **1**, wherein a flow rate of ink flowing into the subtank is greater than a flow rate of ink flowing out from the recording section associated with the subtank.

10. The ink supply system as set forth in claim **1**, wherein the system controller starts to supply ink to the subtank when the ink amount consumed in the subtank exceeds a threshold level.

11. The ink supply system as set forth in claim **10**, wherein the threshold level includes a first threshold level selected while the recording section performs recording, and a second threshold level which is smaller than the first threshold level selected while the recording is not performed.

12. The ink supply system as set forth in claim **10**, wherein:
- each of the subtanks is provided with at least one detector which detects a residual ink amount therein; and
- the system controller stops the ink supply to each of the subtanks when a detection by the detector is effected.

13. The ink supply system as set forth in claim **1**, wherein:
- each subtank is provided with at least one detector which detects a residual ink amount therein; and
- the system controller controls the supply of ink to the subtank when the detector detects that the residual ink amount is a predetermined level or less.

14. The ink supply system as set forth in claim **13**, wherein:
- a first detector and a second detector are provided with each subtank; and
- the system controller controls the supply of ink to an associated one of the subtanks when a detection by the first detector is effected, and stops the ink supply of ink to associated one of the subtanks when a detection by the second detector is effected.

15. The ink supply system as set forth in claim **13**, wherein the detector is solely provided.

16. The ink supply system as set forth in claim **15**, wherein the system controller controls the supply of ink to an associated one of the subtanks during a detection by the detector.

17. The ink supply system as set forth in claim **15**, wherein the system controller controls the supply of ink to an associated one of the subtanks for a predetermined time period when a detection by the detector is effected.

18. The ink supply system as set forth in claim **13**, wherein:
- a valve member is provided between the main tank and each of the subtank; and
- the valve member is closed when the detector detects that the residual ink amount is a predetermined level or more.

19. The ink supply system as set forth in claim **18**, wherein each valve member is closed independently from another valve members.

20. The ink supply system as set forth in claim **18**, wherein each valve member is closed selectively by said system controller.

21. The ink supply system as set forth in claim **18**, wherein all the valve members are closed simultaneously.

22. The ink supply system as set forth in claim **21**, wherein all the valve members are closed when at least one detector among the detectors of the subtanks detects that one subtank is almost empty.

23. The ink supply system as set forth in claim **1**, wherein the system controller controls the supply of ink from the main tank to each of the subtanks every time when the system is activated.

24. The ink supply system as set forth in claim **1**, wherein the system controller controls the supply of ink from the main tank to each subtanks every time when a predetermined time period elapses.

25. The ink supply system as set forth in claim **1**, wherein the system controller controls the supply of ink from the main tank to the subtank after obtaining the consumed ink

amount of each subtank to calculate a residual ink amount in the main tank, every time when the recording section performs recording.

26. The ink supply system as set forth in claim **1**, wherein:

the system controller obtains the consumed ink amount of each subtank every time when the recording section performs recording to calculate a residual ink amount in the main tank; and

an ink supply end state is effected in all the recording section communicated with each of the subtanks when the residual ink amount in the main tank is a predetermined level or less.

27. The ink supply system as set forth in claim **26**, wherein the recording section continues the recording until a predetermined amount of ink in the subtank is consumed after the ink end state is effected.

28. The ink supply system as set forth in claim **1**, wherein:

the system controller sequentially compares the ink amount consumed in each subtank and a residual ink amount in the main tank;

the system controller supplies ink to the compared subtank when the consumed ink amount of the compared subtank is less than the residual ink amount; and

an ink supply end state is effected when the consumed ink amount of the compared subtank is greater than the residual ink amount.

29. The ink supply system as set forth in claim **28**, wherein the ink supply is once performed even when the ink supply end state is effected.

30. The ink supply system as set forth in claim **28**, wherein the ink supply is performed until any change is not occurred in the detector, even when the ink supply end state is effected.

31. The ink supply system as set forth in claim **1**, wherein:

the system controller sequentially compares the ink amount consumed in each subtank and a residual ink amount in the main tank;

the system controller supplies ink to the compared subtank when the consumed ink amount of the compared subtank is less than the residual ink amount;

the system controller does not supply ink to the compared subtank when the consumed ink amount of the compared subtank is greater than the residual ink amount; and

an ink supply end state is effected when there is at least one subtank to which ink is not supplied.

32. The ink supply system as set forth in claim **1**, wherein:

the main tank is provided with a first detector which detects a residual ink amount in the main tank; and

an ink supply end state is effected when the first detector detects that the residual ink amount is a predetermined amount or less.

33. The ink supply system as set forth in claim **32**, wherein:

each subtank is provided with a second detector which detects a residual ink amount therein; and

the system controller stops the ink supply when the second detector detects that the subtank is almost full when the ink supply end state is effected.

34. The ink supply system as set forth in claim **1**, further comprising a memory coupled to said system controller for storing a determined residual ink amount in the main tank.

35. A method of managing an ink amount supplied from main tank to the subtanks which are provided in the ink system as set forth in claim **1**.

36. The ink supply system as set forth in claim **1**, wherein said system contains a plurality of the recording sections, and further comprises a plurality of printer units, each of which comprises one of the subtanks and one of the recording sections.

37. The ink supply system as set forth in claim **36**, wherein the subtank in one of the printer units and the subtank in another one of the printer units are communicated with the main tank in a parallel manner.

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