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(54) **Hydraulic systems for ink jet printers.**

(57) A hydraulic system, suitably an ink supply system for an ink jet printer, wherein an upstanding tube (59) of a viscometer (55) is connected to supply line for liquid and a ball is movably upwardly and downwardly within the tube. A valve (57) controls a flow of liquid from the supply line to the tube (59). Control means cause the valve to open and allow liquid to flow into the tube so that the ball (58) is moved to an upper part of the tube. The valve is then closed and the time taken for the ball to fall through a predetermined distance through liquid within the tube is determined. This line represents the viscosity of the liquid within the system. If the value of viscosity determined from the time taken for the ball to descend is different from an optimum value, the control means operating a charging means which add a component to the liquid so as to move the viscosity towards the optimum value.

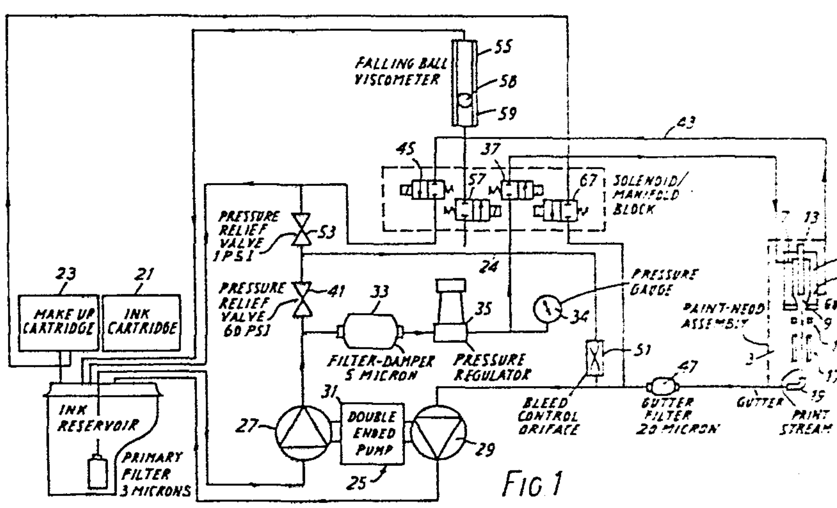

FIG 1

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TITLE MODIFIED
see front page

IMPROVEMENTS IN HYDRAULIC SYSTEMS

This invention relates to hydraulic systems, suitably to ink supply systems for ink jet printers.

In a continuous ink jet printer, ink is conveyed from a reservoir to a print head where the ink is forced through a nozzle at high pressure and broken up into droplets by an ultrasonic vibrator. Droplets emerging from the nozzle are charged by amounts which suit their print positions on a target and the charged droplets are then deflected on to the target by an electrostatic field. Uncharged droplets are returned to the reservoir.

During operation of the printer, volatile solvents are lost from the ink by evaporation so that the composition and physical properties of the ink are changed. It is desirable therefore that the composition of the ink should be monitored and that any deficiency in the proportion of solvents should be made good.

Problems arising from loss of solvents or other components arise in other hydraulic systems.

According to the present invention there is provided a hydraulic system comprising a viscometer which includes an upstanding tube connected to a supply line for liquid and an element which is movable upwardly and downwardly within the tube, and control means which are adapted to control the flow of liquid from the supply line to the tube, the element being moved to an upper part of the tube by a sufficient upwards flow of liquid from the supply line and descending through the liquid when the upwards flow of liquid is terminated, and the control means being further adapted to determine the time taken for the element to descend through a predetermined distance through liquid within the tube, which time is representative of the viscosity of the liquid in the tube.

Preferably, means are provided for charging the liquid in the system with a component which causes a change in the viscosity thereof, the control means being arranged to effect a comparison between a desired viscosity and the viscosity represented by the said time taken for the element to descend through the liquid and to generate a control signal for activating the charging means if the comparison reveals a difference between the two viscosities, whereby the liquid is charged with the said component and the difference between the two viscosities is reduced.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic drawing of an ink jet printer including an ink system according to the invention;

Figure 2 is a viscometer included in the system of Figure 1;

Figure 3 is a block diagram of an electrical control circuit associated with the printer of Figure 1; and

Figures 4A to 4D are graphs relating to the operation of the printer of Figure 1.

Referring to Figure 1 of the drawings, an ink system according to the invention is designed to convey ink between a reservoir 1 and a print head 3 of an ink jet printer. Included in the head 3 is an ink container 5 having an inlet 7 at an upper end thereof, an outlet orifice 9 at a lower end, and a bleed outlet 11. A vibrator 13, connected to a piezoelectric transducer (not shown), extends downwardly into the container 5. As hereinafter described, ink in the container 5 is subjected to a pressure which forces a jet of ink through the orifice 9. Vibration of the vibrator 13 ensures that the jet breaks up into droplets of uniform size. Below the container 5 there is an electrode 15 for charging droplets by an amount which suits their print positions on a target and a pair of electrodes 17 for deflecting charged droplets on to the target (not shown). The charge applied to each droplet, and hence the location at which it strikes the target, depends of course upon the instantaenous magnitude of the potential applied to the electrode 15. This potential is determined by an output from a print microprocessor (not shown). A gutter 19 is provided for collecting uncharged droplets, which are not deflected on to the target.

In the present system, the reservoir 1 is provided with a cartridge 21 containing ink for replenishing the ink stored within the reservoir. Also mounted on the reservoir 1 is a make-up cartridge 23 containing solvents for adding to ink within the system, as hereinafter described.

A double ended pump 25 serves to pump ink from the reservoir 1 to the print head 3 and to return unused ink from the head to the reservoir. The pump 25 includes a first gear pump 27, which is connected into the high pressure side of the system, and a second pump 29, which is on the suction side. Rotary parts of the pumps 27 and 29 are coupled to respective opposed shafts of a motor 31.

The pump 27, which is a gear pump of the suction shoe type, has an inlet connected to the reservoir 1 and an outlet connected to the head 3 via a filter damper 33, a pressure regulator 35 and a jet run solenoid valve 37. The filter damper 33 serves both to filter ink from the reservoir 1 and to dampen cyclical variations in the rate of flow of ink from the pump 27. The pressure regulator 35 maintains the pressure of ink supplied to the head 3 at a predetermined value. A visual indication of this pressure is provided by a pressure gauge 39. To ensure that the pressure of ink does not rise above 60 pounds per square inch, a pressure relief valve 41 connects the output of the pump 27 to the reservoir 1 by means hereinafter described.

A bleed line 43 is provided for returning a mixture of ink and air from the containers of the head 3 to the reservoir 1 at the beginning of a printing operation. Connected into the line 43 is a bleed solenoid valve 45.

On the suction side of the system, the pump 29 has an inlet connected to the gutter 19 via a gutter filter 47 and an outlet connected directly to the reservoir 1. The pump 29 is a gear pump of the cavity plate type.

To ensure that the pump 29 applies sufficient suction to the head 3 and is adequately lubricated, the inlet to the pump is connected to the outlet of the pump 27 via a bleed line 49 and the pressure relief valve 41. Included in the line 49 is a bleed control orifice 51 which is preset to allow a predetermined flow of ink to the pump 29. The junction between the bleed line 49 and the valve 41 is connected to the reservoir 1 by a further pressure relief valve 53, which opens if the pressure of ink in the line 49 exceeds 1 pound per square inch.

Operation of the motor 31 and the valves 37 and 45 is controlled by a main microprocessor (not shown) which is linked to the print microprocessor.

In use of the present system, it is important to replace volatile solvents lost from the ink by evaporation in the head 3. Such loss of solvents is detected by detecting changes in the viscosity of the ink, which varies with changes in composition. Means are then provided for adding fresh solvents as necessary.

Referring now to Figures 1 and 2, a viscometer 55 has its inlet connected to the bleed line 49 by a normally closed solenoid valve 57 and its outlet directly connected to the reservoir 1. The viscometer 55 includes a stainless steel ball 58 which is movable upwardly and downwardly within an upstanding tube 59 of ground glass. At an upper end of the tube 59 there is a flared portion 61, whilst a seat 63 for the ball 57 is provided near to a lower end of the tube. A ball detector coil 65 surrounds a section of the tube 59 immediately above the seat 63.

The ink make up cartridge 23, referred to above, contains solvents which are added to the ink when a loss of solvents is detected by the viscometer 55. Solvents from the cartridge 23 are supplied to the line between the pump 29 and the gutter 19 via a normally closed make-up solenoid valve 67.

Associated with the viscometer 55 and the valve 67 is an electrical control circuit, shown in Figure 3 of the drawings.

The control circuit of Figure 3 includes a single chip microcomputer 69 having inputs which are supplied with data representing the current and desired viscosities of ink in the system and outputs which supply control signals for removing any discrepancy between current and desired viscosities. Thus, a first input to the microcomputer 69 is connected to a cartridge memory device 71 which stores data relating to various kinds of ink and the viscosities thereof for optimum printing results. A second input to the microcomputer is connected to a sensor 73, whose input is connected to the ball detector coil 65, referred to above. Further inputs are connected to a temperature sensor 75 and associated analogue/digital converter 77 and to a timer 79. Outputs from the microcomputer 69 are connected to the make-up solenoid valve 67 and to the solenoid valve 57, respectively.

The microcomputer 69 is programmed to activate the viscometer 55, to interpret data relating to viscosity and associated parameters applied to the inputs thereof, and to provide control signals for actuating the make-up solenoid valve 67, as hereinafter described.

In using the present system, the solenoid valves 57 and 67 are normally closed and the jet run solenoid valve 37 is normally open. Initially, the bleed solenoid valve 45 is also open.

Accordingly, when the motor 31 is first energised, ink from the reservoir 1 is pumped to the container 5 in the head 3 via the filter damper 33, the pressure regulator 35 and the jet run solenoid valve 37. The pressure applied to ink within the container 5 forces a jet of ink downwardly via the orifice 9 to the gutter 19. A mixture of ink and air is returned to the reservoir 1 via the bleed outlet 11 of the container 5, the bleed line 43 and the bleed solenoid valve 45. When all of the air has been exhausted from the container 5, the bleed solenoid valve 45 is closed.

Printing can now be commenced by energising the piezoelectric transducer so that the vibrator 13 causes the jet of ink from the orifice 7 to be broken up into droplets of uniform size and by energising the charging electrode 15 and the deflecting electrodes 17.

With the motor 31 energised, ink at an initial pressure of 1 p.s.i. is supplied from the outlet of the pump 27 to the inlet to the pump 29 via the pressure relief valve 41, the bleed line 49 and the bleed control orifice 51. This supply of ink seals internal clearances within the pump 29. Accordingly, the efficiency of the pump 29 as an air pump is increased, a higher suction is applied to the gutter 19, and a mixture of air and unused liquid is drawn from the gutter. As described above, the orifice 51 is pre-set to allow a predetermined flow of ink along the bleed line 49, this predetermined flow being sufficient to ensure that the pump 29 is adequately lubricated.

Once every 15 minutes during operation of the system, the microcomputer 69 initiates a check on the viscosity of ink in the system. As a first stage in the check, a signal from the micro-computer 69 is applied to the solenoid valve 57, causing the valve to open and to allow ink to flow from the bleed line 49 to the viscometer 55. Ink flows upwardly through the tube 59 of the viscometer 55, forcing the steel ball 58 upwardly into the flared portion 61 at the top of the tube. The ball remains in the flared portion 61, supported by the upwards flow of ink, whilst ink continues to flow upwardly past the ball and then outwardly from the tube 59 to the reservoir 1. The presence of the flared portion 61 means there is sufficient space for any solid particles in the ink to pass between the wall of the tube 59 and to return to the reservoir 1.

Approximately one minute after the solenoid valve 57 has been opened, the microcomputer 69 activates the timer 79 and at the same time applies a further signal to the valve 57, causing the valve to close. With the upwards flow of ink terminated, the ball 58 descends slowly within the tube 59 at a rate dependent upon the viscosity of ink in the tube. When the ball 58 has moved downwardly through a predetermined distance, it enters the ball detector coil 65. Movement of the ball 58 through the coil 65 is sensed by the sensor 73, which applies an input signal to the microcomputer 69.

Within the microcomputer 69, a computation of the viscosity of the ink is made from data representing the time between the closing of solenoid valve 57 and the arrival of the ball 58 at the coil 65, data representing the ambient temperature or the temperature of the ink, supplied by the temperature sensor 75 and the analogue digital converter 77, and data stored in the memory device 71 and representing the relationship between the viscosity of the ink, the time taken for the ball 58 to descend through the tube 59 and the ambient temperature.

A comparison is then made between the computed viscosity and data representing the optimum viscosity, also stored in the memory device 71.

Assuming there is a difference between the computed and optimum viscosities, an output signal is applied from the microcomputer 69 to the solenoid valve 67. The valve 67 is then opened for a predetermined interval of time and a predetermined volume of solvents flows from the make-up cartridge 23 to the line connecting the pump 29 to the gutter 19.

A similar computation of viscosity is made at intervals of 15 minutes. Each time there is a discrepancy between the computed and optimum viscosities, a fresh volume of solvents is supplied from the make-up cartridge 23. If the computed viscosity equals the optimum viscosity, the solenoid valve 67 remains closed so that no solvents are added.

One ink suitable for use in the ink jet printer of Figures 1 to 3 is known as "Coates Black MEK".

As shown in Figure 4A, this ink has a viscosity which varies linearly with temperature between 20°C and 45°C, the viscosity falling from approximately 3.8 c.p. at a temperature of 20°C to approximately 2.0 c.p. at 45°C. There is also a linear relationship between the viscosity of this ink and the time taken for the ball to fall through the predetermined distance within the tube 59 of the viscometer 59, as shown in the graph forming Figure 4B.

Referring now to Figure 4C, the printer of Figures 1 to 3 was first operated over a period of 12 hours with the microcomputer 69 disconnected from the solenoid valve 57. This meant that the valve 57 remained closed so that there was no checking of the viscosity of ink in the system and no supply of fresh solvents from the make-up cartridge 23. As shown in Figure 4C, the viscosity increased at a fairly constant rate throughout the 12 hour period, starting at approximately 3.85 c.p.and ending at approximately 4.65 c.p.

Referring now to Figure 4D, the printer was then operated over a second 12 hour period with the microcomputer 69 re-connected to the solenoid valve 57. The valve 57 was therefore opened and the viscosity checked in the manner described above. It will be seen from Figure 4D that the effect of periodically checking the viscosity and adding fresh solvent, when necessary, is to restrict variation in the viscosity and values between 3.9 and 4.0 c.p.

In a further printing operation carried out by the above printer the ambient temperature was 28^{o}C and the time for the ball to fall through the predetermined distance, assuming the viscosity was at its optimum value, was 72 secs. In practice, the measured time of descent was 74 secs. Accordingly, a charge of 8 ccs of solvent was added to the ink after the first check by the control means. This reduced the viscosity by 0.04 c.p. and reduced the ball descent time to 73 secs, as measured at the next check.

In operation at normal running temperatures it was found that approximately 16 ccs out of a total volume of solvent of 1.75

litres were lost from the system during each hour. The control means described above compensate by adding the appropriate additional volumes of solvent.

CLAIMS:

1. A hydraulic system comprising a viscometer which includes an upstanding tube connected to a supply line for liquid and an element which is movable upwardly and downwardly within the tube, and control means which are adapted to control the flow of liquid from the supply line to the tube, the element being moved to an upper part of the tube by a sufficient upwards flow of liquid from the supply line and descending through the liquid when the upwards flow of liquid is terminated, and the control means being further adapted to determine the time taken for the element to descend through a predetermined distance through liquid within the tube, which time is representative of the viscosity of the liquid in the tube.

2. A system as claimed in claim 1, wherein the tube has a circular section and the element is a ball.

3. A system as claimed in any one of the preceding claims, wherein a small clearance is provided between the element and a side wall of a lower part of the tube whilst there is sufficient space for solid particles in the liquid to pass between the element and a side wall of said upper part of the tube.

4. A system as claimed in claim 1, 2 or 3, wherein the control means include a coil disposed coaxially of the tube, means for supplying an electrical current to the coil, and means for sensing a change in the said current caused by a movement of the element

downwardly through the coil.

5. A system as claimed in any one of the preceding claims, further comprising means for charging the liquid in the system with a component which causes a change in the viscosity thereof, the control means being arranged to effect a comparison between a desired viscosity and the viscosity represented by the said time taken for the element to descend through the liquid and to generate a control signal for activating the charging means if the comparison reveals a difference between the two viscosities, whereby the liquid is charged with the said component and the difference between the two viscosities is reduced.

6. A system as claimed in claim 5, wherein the control means include a store containing data relating to various liquids which can be used in the system and the viscosity of each liquid which ensures optimum operation of the system, and means for effecting a comparison between the stored data and the viscosity represented by the said time taken for the element to descend through the predetermined distance.

7. A system as claimed in claim 6, wherein the control means further includes means for sensing the temperature of the liquid in the system or the ambient temperature, and the store includes further data representing the variation of the viscosity of each of said liquids with temperature, the control means being adapted to effect a comparison between the viscosity represented by the said

time taken for the element to descend through the predetermined distance and the viscosity desired at the temperature sensed by the temperature sensing means.

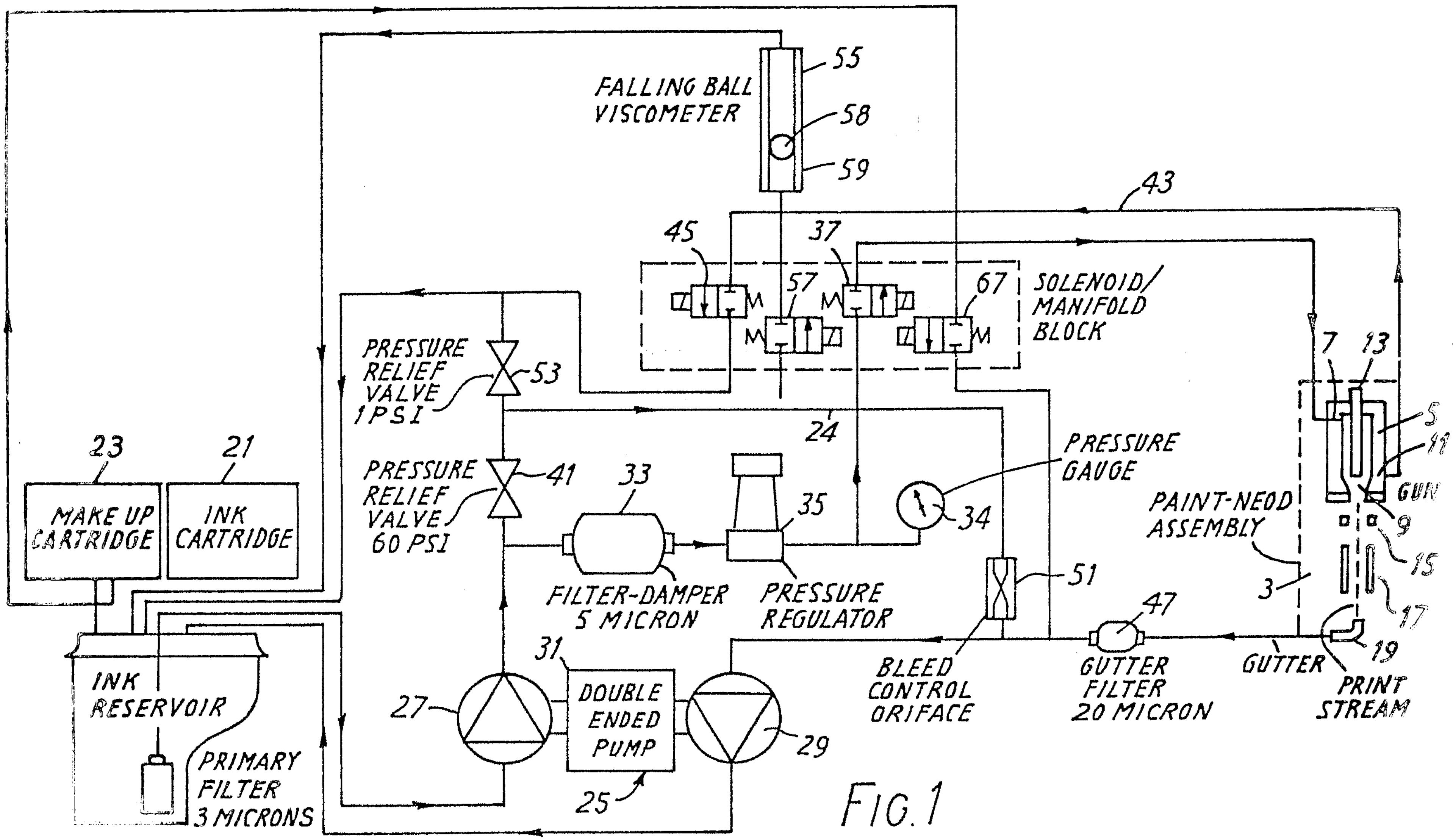
8. An ink jet printer including a hydraulic system as claimed in any one of the preceding claims, the printer further comprising an ink reservoir, a printing head, a pump means for supplying ink from the reservoir to the head and for returning unused ink from the head to the reservoir, the viscometer of the system being connected in a supply line between the pump means and the head or between the pump means and the reservoir.

9. A method of determining the viscosity of a liquid in a hydraulic system, comprising providing a flow of liquid along a supply line in the system, allowing an upwards flow of liquid from the supply line into an upstanding tube of a viscometer connected to the supply line, whereby an element within the tube is moved to an upper part of the tube, terminating the upwards flow of liquid from the supply line so that the element descends through the liquid in the tube, determining the time taken for the element to descend through a predetermined distance, and computing the viscosity of the liquid from the said time and other parameters.

10. A method as claimed in claim 10, further comprising effecting a comparison between a desired viscosity and the viscosity represented by the said time, and, if the comparison reveals a different between the two viscosities, charging the liquid with a component which causes the viscosity of the liquid to move towards

the desired viscosity.

11. A method as claimed in claim 10 or 11, wherein the flow of liquid is a flow of ink along a supply line in an ink jet printer.



FALLING BALL VISCOMETER
55
58
59
43
45
37
57
67
SOLENOID/ MANIFOLD BLOCK
7
13
5
11
GUN
9
15
17
19
PAINT-NEOD ASSEMBLY
3
PRESSURE RELIEF VALVE 1PSI
53
PRESSURE RELIEF VALVE 60 PSI
41
24
PRESSURE GAUGE
34
33
35
FILTER-DAMPER 5 MICRON
PRESSURE REGULATOR
51
47
BLEED CONTROL ORIFACE
GUTTER FILTER 20 MICRON
GUTTER
PRINT STREAM
23
21
MAKE UP CARTRIDGE
INK CARTRIDGE
INK RESERVOIR
PRIMARY FILTER 3 MICRONS
27
31
DOUBLE ENDED PUMP
29
25

FIG.1

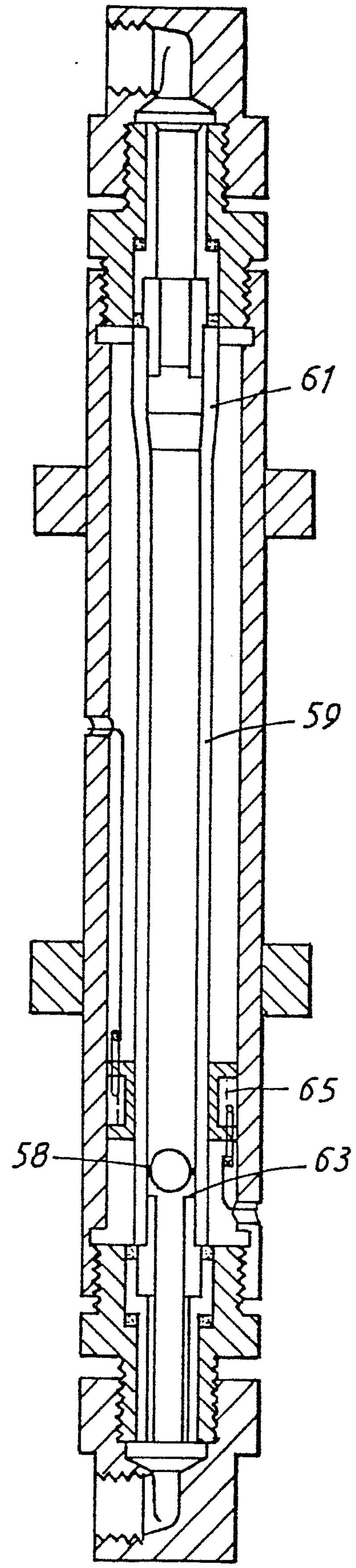
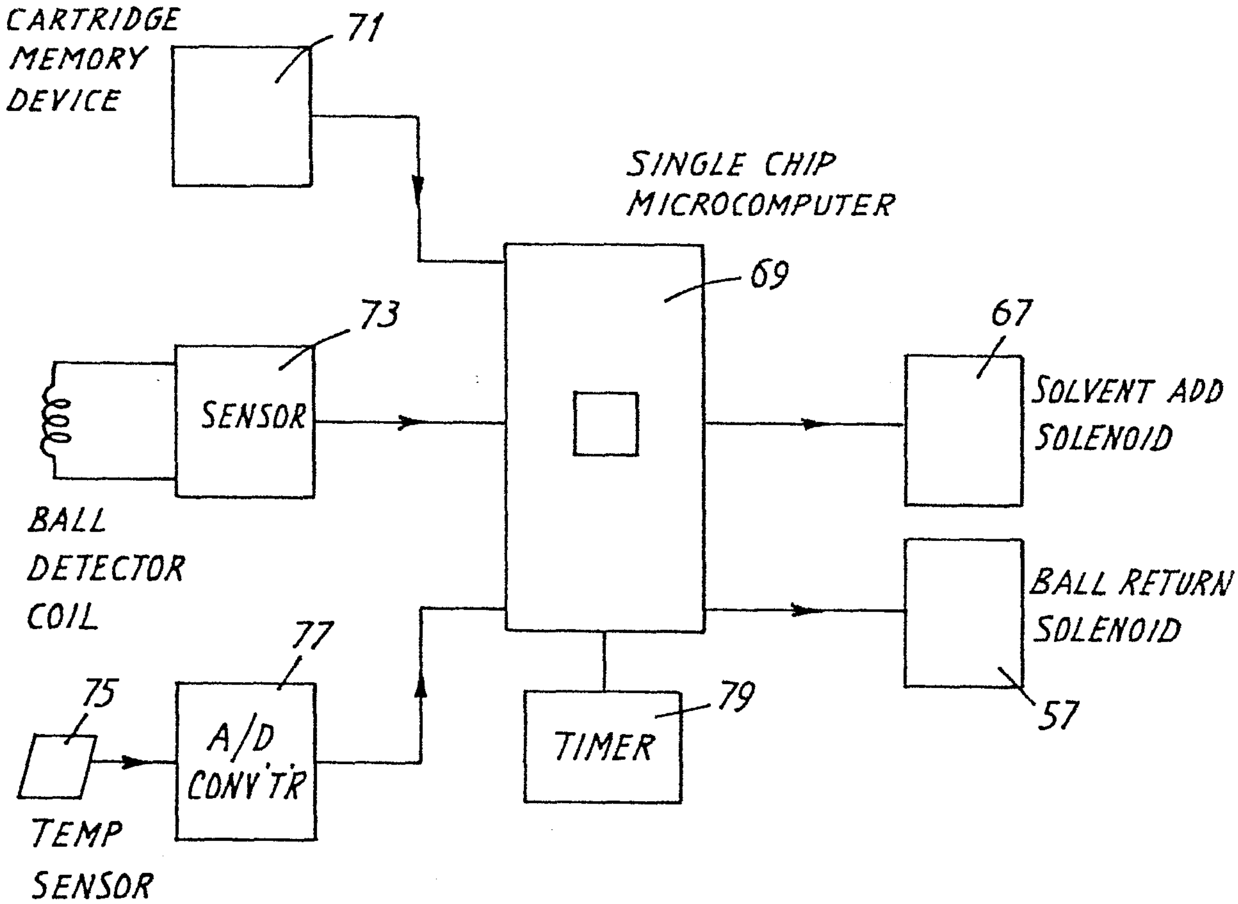


FIG. 2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COIL
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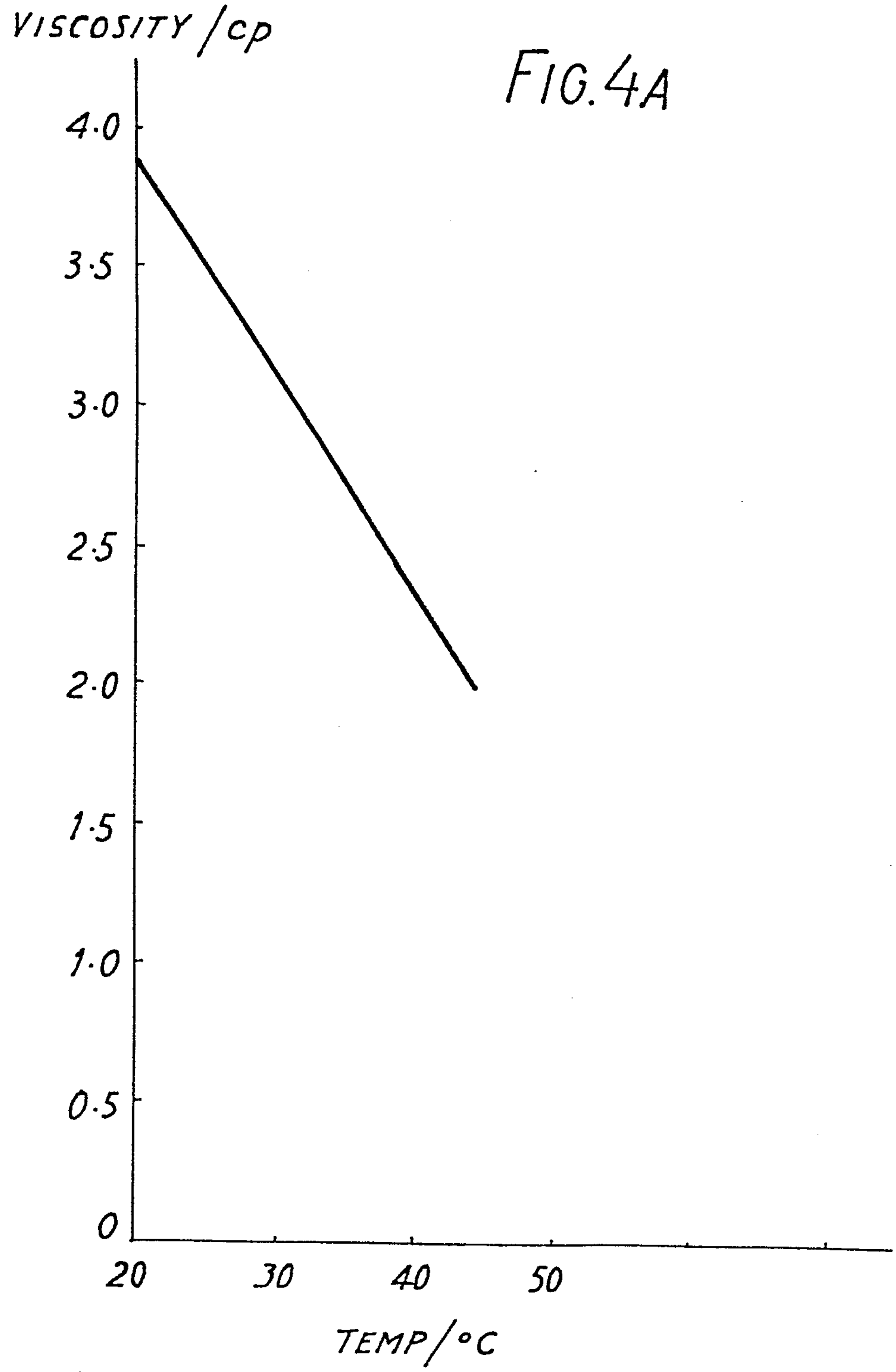
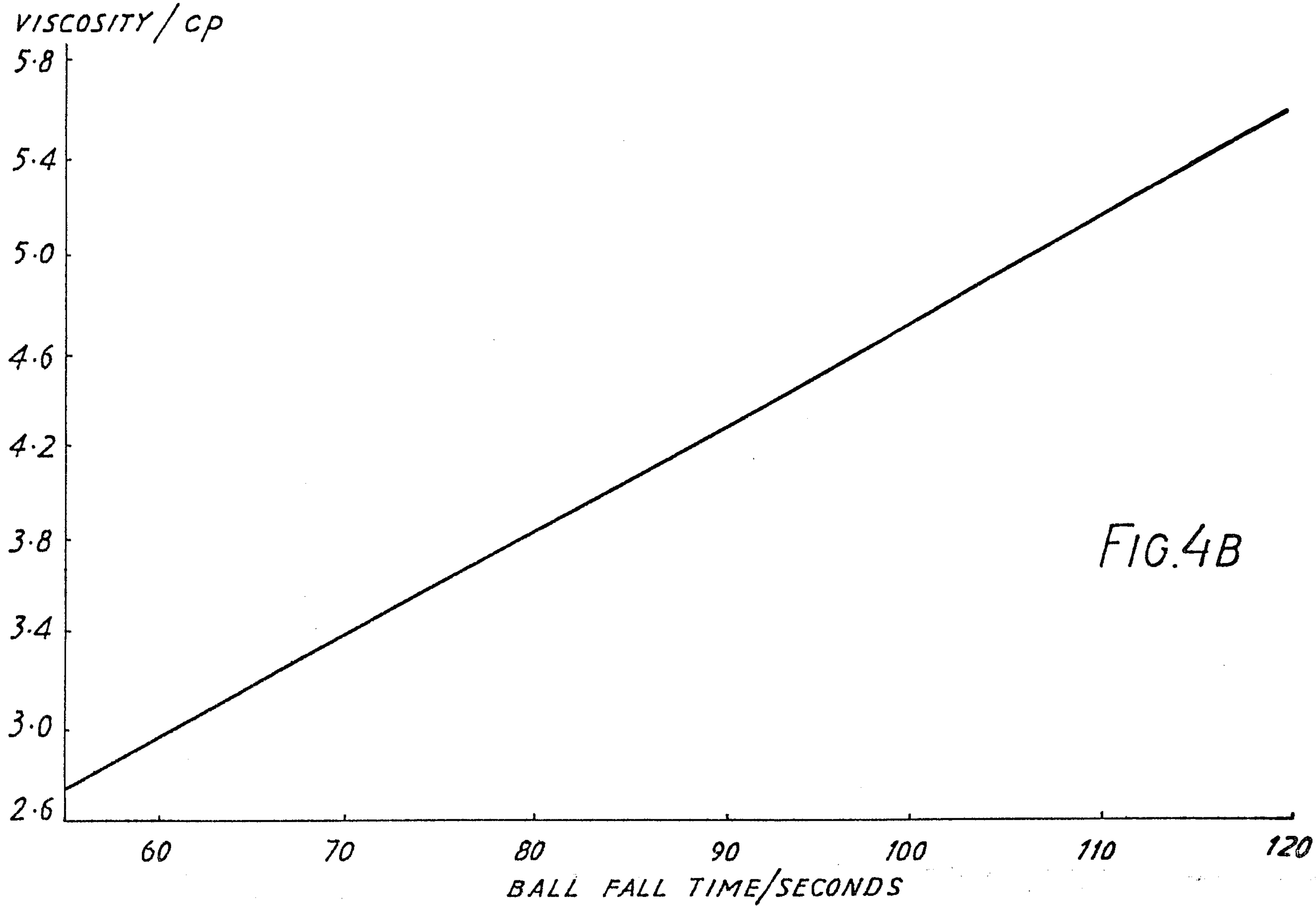
SOLENOID
BALL RETURN
SOLENOID
57
77
75
A/D
CONV'TR
TEMP
SENSOR
TIMER
79

FIG.3

FIG. 4A




VISCOSITY / CP
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5·4
5·0
4·6
4·2
3·8
3·4
3·0
2·6
60
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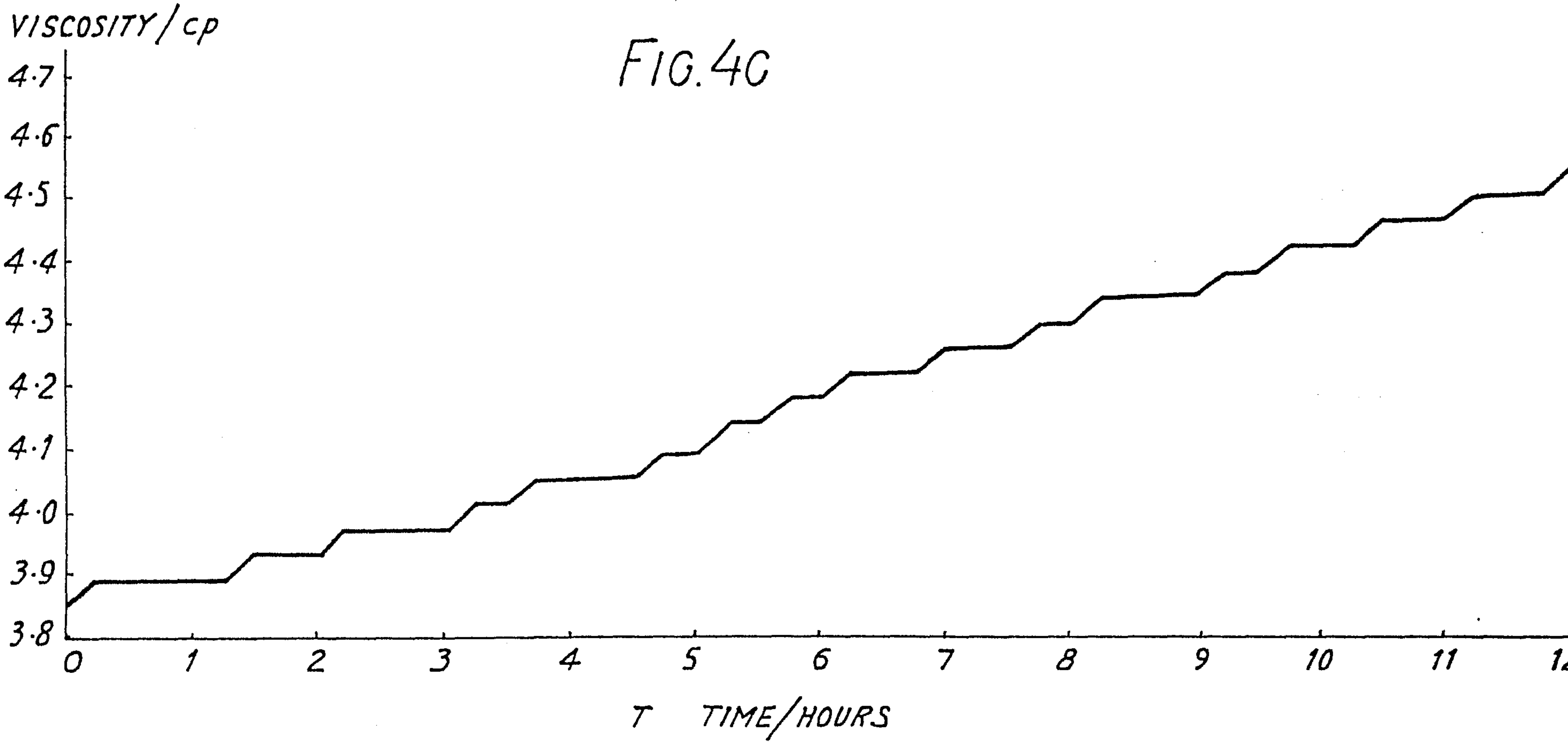
80
90
100
110
120
BALL FALL TIME/SECONDS

FIG.4B

FIG. 4C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4·1
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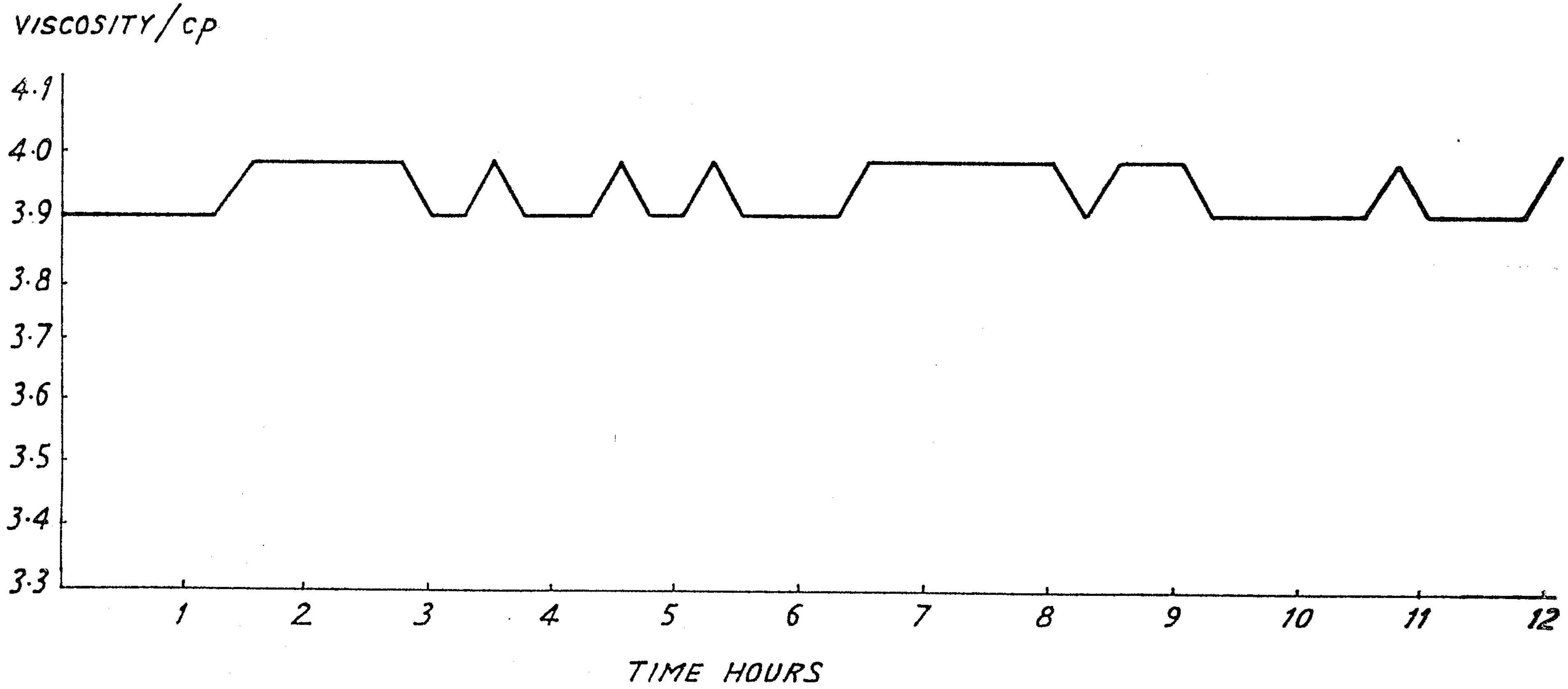
11
12
T TIME/HOURS

FIG. 4D


VISCOSITY/CP
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6
7
8
9
10
11
12
TIME HOURS

European Patent Office

EUROPEAN SEARCH REPORT

0142265
Application number

EP 84306916.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl 4)
A	DE - A1 - 3 111 987 (SHARP) --		B 41 J 27/00 B 41 J 3/04
A	DE - A1 - 3 125 194 (SHARP) ----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 41 J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	18-01-1985	MEISTERLE

CATEGORY OF CITED DOCUMENTS

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