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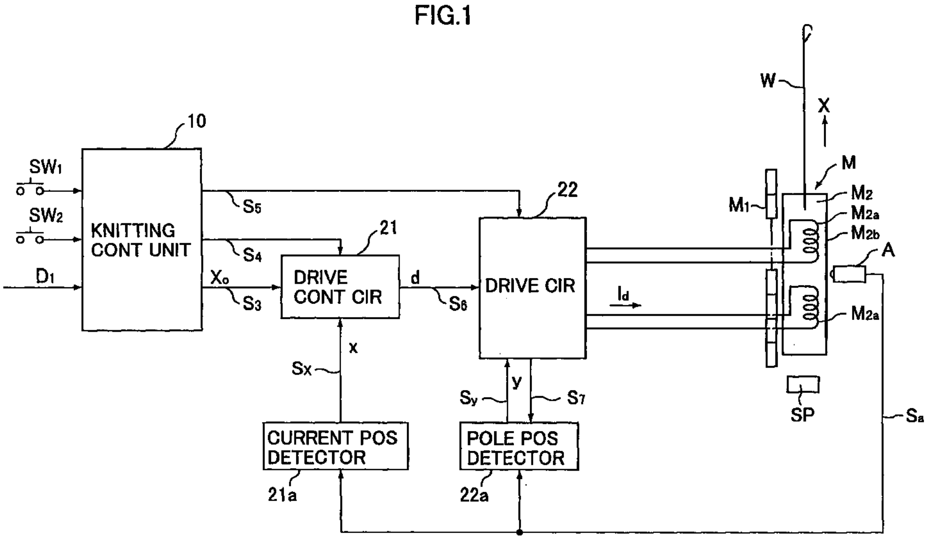
(54) A linear motor control device for driving knitting head components of a knitting machine

(57) A drive control circuit (21), a driving circuit (22) and a pole position detector (22a) are combined together and connected to a knitting control unit (10). When a stop switch (SW2) is operated, for instance, the knitting control unit (10) causes the drive control circuit (21) and the driving circuit (22) to move a knitting head assembly (W) to its rearward movement limit and outputs a clear signal (S5). Upon receiving the clear signal (S5), the driving circuit (22) outputs a reset signal (S7) to the pole position detector (22a), so that relative position (y) of magnetic poles of a stator (M1) and the movable part (M2) detected by the pole position detector (22a) by using a sensor (A) is properly corrected.

FIG.1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates to a linear motor control device for driving knitting head components of a knitting machine which can avoid knitting defective fabrics and knit high-quality fabrics in a stable way.

Description of the Prior Art

[0002] The prior art to which the invention is directed discloses a flat knitting machine in which knitting head components, such as a plurality of feeders and knitting needles on front and rear beds, are individually controlled by linear motors.

[0003] Positions of the individual linear motors, which are combined with respective drive control circuits and driving circuits, are controlled according to target position signals fed from a common knitting control unit. Each of the driving circuits is provided with a pole position detector for determining the relative position of magnetic poles of a stator and a movable part of the linear motor using a sensing signal fed from a sensor which detects travel of the movable part of the linear motor. The individual driving circuits reset their own pole position detectors by outputting a reset signal thereto at power-up. After resetting the pole position detectors, the driving circuits can drive the linear motors in a properly controlled manner by outputting driving currents to appropriate coils of the linear motors selected in accordance with the relative position of the magnetic poles of the stator and the movable part detected by the pole position detector.

[0004] According to the prior art cited above, it becomes impossible for each pole position detector to correctly detect the relative position of the magnetic poles of the stator and the movable part if the pulse-shaped sensing signal from the sensor is missed during the operation of the flat knitting machine. If resulting sensing errors accumulate, the linear motors would vibrate in a slight, rapid movement when they should keep the knitting head components in a stationary condition, or the linear motors would not run smoothly, making it difficult to achieve precision position control of the knitting head components. Should this occur, there arises a problem that the flat knitting machine could produce such defects as drop stitches and wale streaks in a finished fabric.

SUMMARY OF THE INVENTION

[0005] In view of the foregoing problem of the prior art, it is an object of the present invention to provide a linear motor control device for driving knitting head components of a knitting machine which can control the position of each knitting head component with constant high accuracy, without causing an excessive accumulation of errors in sensing the relative position of magnetic poles by resetting pole position detectors in according with a clear signal fed from a knitting control unit.

[0006] According to the invention, a linear motor control device for driving a knitting head component of a knitting machine comprises a drive control circuit which detects a positioning deviation of the knitting head component driven by a linear motor, a pole position detector for determining the relative position of magnetic poles of a stator and a movable part of the linear motor by using a sensor which detects travel of the movable part, and a driving circuit which outputs driving current to an appropriate coil of the linear motor based on a driving signal fed from the drive control circuit and a pole position signal fed from the pole position detector, wherein the pole position detector is reset on condition that the movable part is located at a specific position when a clear signal has been transmitted from a knitting control unit.

[0007] In one form of the invention, the pole position detector may be reset by a reset signal entered from the driving circuit.

[0008] The driving circuit may output the reset signal after verifying that the movable part is located at its rearward movement limit or that the movable part located at its rearward movement limit is forced rearward.

[0009] Alternatively, the driving circuit may output the reset signal after verifying that the clear signal entered from the knitting control unit has been continuously present for a specific time period.

[0010] According to the above-described construction of the invention, the pole position detector is reset each time the clear signal is transmitted from the knitting control unit on condition that the movable part is located at the specific position. The pole position detector can exactly determine the relative position of the magnetic poles of the stator and the movable part of the linear motor with minimum accumulation of sensing errors caused by potential loses of sensing signals from the sensor regardless of operating time of the knitting machine, and the drive control circuit and the driving circuit can correctly control the position of each knitting head component by controlling the linear motor. The knitting control unit produces the clear signal when the knitting head components have been set to specific positions, such as their rearward movement limits or forward movement limits, after power-on of the knitting machine, upon completion of knitting a particular quantity of fabric (e.g., one or more webs), or after manual stoppage of the knitting machine using a stop switch.

[0011] The specific position referred to above corresponds to the rearward movement limit or forward movement limits of the movable part, or any set position within the stroke of the movable part where its position can be exactly detected.

[0012] On the other hand, the drive control circuit determines a positioning deviation of the linear motor based on a comparison between a target position indicated in a target position signal fed from the knitting control unit and the current position of the movable part of the linear motor, and outputs the driving signal. It is to be noted that the target position varies with time up to a final target position in order to move the knitting head component according to a specific velocity pattern.

[0013] The reset signal for resetting the pole position detector is output from the driving circuit. It is possible to easily improve by setting appropriate conditions for the driving circuit.

[0014] For example, it is possible to ensure that the clear signal from the knitting control unit is not a wrong signal induced by noise by verifying that the movable part is currently located at its rearward movement limit. Such an arrangement helps to prevent outputting a "noise-induced" reset signal. When the driving signal from the drive control circuit indicates the duty factor of the linear motor driving current, the driving circuit can verify that the movable part is located at its rearward movement limit by sensing that the duty factor is 0%, for instance.

[0015] If the driving circuit outputs the reset signal and reset the pole position detector after verifying that the movable part located at its rearward movement limit is forced rearward, it becomes possible to prevent malfunctioning caused by noise even more effectively. In addition, since the movable part is correctly held at the rearward movement limit when the pole position detector is reset, it is possible to sense the relative position of the magnetic poles even more precisely subsequently.

[0016] If the driving circuit outputs the reset signal after verifying that the clear signal entered from the knitting control unit has been continuously present for a specific time period, it becomes possible to enhance the noise withstand capability as a whole since conditions for outputting the reset signal are made more stringent.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a general block diagram of a linear motor control device of a knitting machine according to a preferred embodiment of the invention;
FIG. 2 is a program flowchart showing the operation of a knitting control unit;
FIG. 3 is a program flowchart showing the operation of a driving circuit; and
FIG. 4 is a diagram depicting the operation of the linear motor control device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

[0018] A preferred embodiment of the invention is now described with reference to the accompanying drawings.

[0019] Referring to FIG. 1, a linear motor control device for driving knitting head components of a knitting machine comprises drive control circuits 21 and driving circuits 22 connected to a common knitting control unit 10, wherein one each drive control circuit 21 and driving circuit 22 are connected in series and provided for each combination of a knitting head assembly W and a linear motor M. It is to be noted that FIG. 1 shows only one set of the drive control circuit 21, the driving circuit 22, the linear motor M and the knitting head assembly W, wherein the knitting head assembly W is a set of a feeder and a knitting needle, for instance, which are driven by the linear motor M. Although the knitting machine of the present embodiment is a flat knitting machine, it may be other type of knitting machine in this invention.

[0020] The linear motor M is formed of a combination of a stator M1 made of permanent magnets which are arrayed such that their north and south poles are aligned alternately along the moving direction of the knitting head assembly W and a movable part M2 having a plurality of coils M2a. The stator M1 of the linear motor M is provided with a sensor A for detecting the travel of the movable part M2 by means of a scale M2b which is attached to the movable part M2. The knitting head assembly W is connected to the movable part M2 and a stopper SP which sets a limit on rearward movement of the movable part M2 and the knitting head assembly W is provided at the back of the movable part M2. The sensor A outputs a pulse-shaped sensing signal Sa at each successive graduation line on the scale M2b.

[0021] The knitting control unit 10 is associated with a start switch SW1 and a stop switch SW2, and knitting data D1 is entered to the knitting control unit 10 from a data unit which is not illustrated. A target position signal S3 and a control signal S4 output from the knitting control unit 10 are entered to the drive control circuit 21 while a clear signal S5 also output from the knitting control unit 10 is entered to the driving circuit 22.

[0022] The drive control circuit 21 is connected to a current position detector 21a. The sensing signal Sa is entered from the sensor A to the current position detector 21a while an output of the current position detector 21a is entered to the drive control circuit 21 as a current position signal Sx. An output of the drive control circuit 21 is entered to the driving circuit 22 as a driving signal S6. Outputs of the driving circuit 22 are delivered to the coils M2a of the movable part M2 of the linear motor M. Another output of the driving circuit 22 is entered to a pole position detector 22a as a reset signal S7. The sensing signal Sa from the sensor A is branched and entered also to the pole position detector 22a and an output of the pole position detector 22a is entered to the driving circuit 22 as a pole position signal Sy.

[0023] When the flat knitting machine has been powered on, the knitting data D1 is entered from the unillustrated data unit to the knitting control unit 10. When the start switch SW1 is turned on at this point, the knitting control unit 10 can output the target position signal S3 to the drive control circuit 21 according to the knitting data D1. The target position signals S3 thus output to the individual drive control circuits 21 indicate target positions xo for the respective knitting head assemblies W that vary with the lapse of time. The current position detector 21a outputs the current position signal Sx indicating current position x of the pertinent knitting head assembly W based on the sensing signal Sa from the sensor A, wherein the current position x is measured from an unillustrated knitting operation origin which is set at the front of the stopper SP in a forward-moving direction of the knitting head assembly W.

[0024] The drive control circuit 21 determines a positioning deviation $\Delta x = x - xo$ of the pertinent knitting head assembly W based on a comparison between the target position xo fed from the knitting control unit 10 and the current position x fed from the current position detector 21a and outputs a command value d specifying the value of driving current Id to be supplied to the linear motor M for eliminating the positioning deviation Δx. When the driving current Id is a pulse-width-modulated rectangular-shaped current, the command value d indicates the duty factor of the driving current Id, with plus (+) and minus (-) signs indicating the moving direction of the movable part M2 and the knitting head assembly W.

[0025] The pole position detector 22a, on the other hand, has a function of a counter. It counts the pulse-shaped sensing signal Sa fed from the sensor A in a positive or negative direction depending on the moving direction of the movable part M2, determines relative position y of magnetic poles of the stator M1 and the movable part M2 of the linear motor M and outputs it as the pole position signal Sy. Based on the driving signal S6 from the drive control circuit 21 and the pole position signal Sy from the pole position detector 22a, the driving circuit 22 selects one of the coils M2a and outputs the driving current Id of an appropriate flowing direction and amount, so that the linear motor M moves the knitting head assembly W to follow the target position xo which varies with the lapse of time and a desired fabric can be knit as a consequence.

[0026] When the flat knitting machine has been powered on, or when a particular amount of fabric specified in the knitting data D1 has been completed, the knitting control unit 10 operates according to a program flowchart shown in FIG. 2. In the latter case, the program of FIG. 2 is run at regular intervals determined by the amount of fabric to be knit.

[0027] First, the program causes the knitting control unit 10 to output target position signals S3 indicating target positions xo which set final target positions for the individual knitting head assemblies W at their rearward movement limits in step (1) of FIG. 2. Then, each drive control circuit 21 outputs a driving signal S6 containing a command value $d = b$ for a rearward-moving direction for the relevant knitting head assembly W to the driving circuit 22, causing the movable part M2 of the relevant linear motor M to move rearward during a time period $t = t0$ to t1 shown in FIG. 4 until it goes into contact with the stopper SP provided in the back. In FIG. 4, it is assumed that the movable part M2 is located at its knitting operation origin during a period $t<t0$. After a time period needed for the movable part M2 to retract up to its rearward movement limit has elapsed (step (2)), the program causes the knitting control unit 10 to output the control signal S4 to the drive control circuit 21 in step (3) so that the command value specified in the driving signal S6 from the drive control circuit 21 is zeroed ($d = 0$) at time $t = t1$. As an alternative to the aforementioned operation flow, the drive control circuit 21 may detect based on the current position signal Sx from the current position detector 21a that the movable part M2 has retracted to its rearward movement limit in step (2).

[0028] After a specified waiting time $T1 = t2 - t1$ has elapsed (step (4)), the program causes the knitting control unit 10 to output the clear signal S5 in step (5), and after a subsequent waiting time $T2a = t2a - t2$ has elapsed (step (6)), the program causes the knitting control unit 10 to output again the control signal S4. Upon receiving this control signal S4, the drive control circuit 21 outputs the driving signal S6 containing a command value $d = a$ in step (7) for the rearward-moving direction at time $t=t2a$, whereby the driving circuit 22 causes the movable part M2 currently positioned at its rearward movement limit to be forced against the stopper SP. Generally, it is preferable to achieve a relationship $0<a<b$ in order to force the movable part M2 against the stopper SP with appropriate force.

[0029] Subsequently, when a time period $T2b = t3 - t2a$ has elapsed (step (8)), the program eliminates the clear signal S5 in step (9). This means that the clear signal S5 is continuously output for a specified time period $T2 = t3 - t2$. When a time period $T3 = t4 - t3$ has elapsed (step (10)), the program causes the knitting control unit 10 to output target position signals S3 indicating target positions xo which set final target positions for the individual knitting head assemblies W at their knitting operation origins in step (11). Then, each drive control circuit 21 outputs a driving signal S6 containing a command value $d = -b$ for the frontward-moving direction, whereby the driving circuit 22 causes the pertinent knitting head assembly W to move frontward from its rearward movement limit to its knitting operation origin during a time period $t = t4$ to t5 and stay at the knitting operation origin thereafter ($t>t5$).

[0030] On the other hand, the driving circuit 22 operates according to a program flowchart shown in FIG. 3 upon receiving the clear signal S5 from the knitting control unit 10 at time $t = t2$.

[0031] Specifically, when the driving circuit 22 begins to operate at a leading edge of the clear signal S5, the program can recognize that the movable part

M2 of the linear motor M is at its rearward movement limit by verifying that the command value specified in the driving signal S6 is equal to zero (d = 0) in step (1) of FIG. 3. If the command value is not equal to zero in step (1), the program judges that the movable part M2 is not at its rearward movement limit and terminates operation flow of FIG. 3.

[0032] Next, the program monitors the clear signal S5 from the knitting control unit 10 to determine whether the clear signal S5 is continuously present for the specified time period T2 in steps (2) and (3). If the clear signal S5 disappears during the time period T2, the program terminates the operation flow of FIG. 3 without proceeding further. If the clear signal S5 is present for the time period T2 in steps (2) and (3) and normally disappears at the end of the time period T2 (step (4)), the program monitors the driving signal S6 to determine whether it indicates the command value $d = a$ for a monitoring time $T3a = t3a - t3 < T3$ in steps (5) and (6). Then, the program causes the driving circuit 22 to output the reset signal S7 to the pole position detector 22a in step (7) and terminates the operation flow of FIG. 3. At this point, the pole position detector 22a resets a count value of the sensing signal Sa fed from the sensor A in a condition in which the movable part M2 is forced against the stopper SP. Thereafter, the pole position detector 22a can exactly determine the relative position y of the magnetic poles of the stator M1 and the movable part M2 and output it as the pole position signal Sy.

[0033] The knitting control unit 10 operates as described above also when the stop switch SW2 is operated during fabric knitting operation, or when the flat knitting machine has been automatically stopped due to a certain cause. In such cases, however, the knitting control unit 10 holds the current target positions xo indicated by the individual target position signals S3 at the time that the stop switch SW2 is operated or the flat knitting machine is automatically stopped. Then, according to the aforementioned procedure, the knitting control unit 10 outputs the target position signals S3, control signals S4 and clear signals S5 and each driving circuit 22 outputs the reset signal S7 upon receiving the clear signal S5 to reset the pole position detector 22a. When the start switch SW1 is operated subsequently, the knitting control unit 10 stops to hold the individual target position signals S3 and permits the target positions xo to vary with the lapse of time according to the knitting data D1, whereby the drive control circuits 21 and the driving circuits 22 recommence to control the positions of the knitting head assemblies W by the respective linear motor M to resume the fabric knitting operation.

[0034] As described above, when the clear signal S5 is entered, the driving circuit 22 recognizes that the movable part M2 is at its rearward movement limit by verifying that the command value specified in the driving signal S6 is equal to zero (d = 0), verifies that the clear signal S5 is continuously present for the specified time period T2, verifies that the movable part M2 located at the rearward movement limit is forced rearward against the stopper SP based on the fact that the command value specified in the driving signal S6 is equal to a (d = a) after the clear signal S5 has disappeared and, then, outputs the reset signal S7. Since the driving circuit 22 outputs the reset signal S7 only when specific conditions have been met after the clear signal S5 was produced as seen above, the driving circuit 22 would not inadvertently reset the pole position detector 22a when a wrong clear signal S5 has occurred due to noise.

[0035] In one alternative form of the embodiment, however, the driving circuit 22 may output the reset signal S7 immediately after verifying that the command value specified in the driving signal S6 is equal to zero (d = 0) when the clear signal S5 has been entered. In another alternative, the driving circuit 22 may output the reset signal S7 after verifying that the command value in the driving signal S6 is equal to zero (d = 0) when the clear signal S5 has been entered and that the command value in the driving signal S6 is equal to a (d = a) when the clear signal S5 has disappeared. In another alternative, the driving circuit 22 may output the reset signal S7 after the clear signal S5 has been continuously present for the specified time period T2. Furthermore, the driving circuit 22 may output the reset signal S7 after verifying that the command value in the driving signal S6 is equal to zero (d =0) when the clear signal S5 has been entered and after the clear signal S5 has been continuously present for the specified time period T2.

[0036] Instead of outputting the reset signal S7 from the driving circuit 22, it may be output directly from the knitting control unit 10 to the pole position detector 22a. In this alternative form of the embodiment, the knitting control unit 10 should control the drive control circuit 21 and the driving circuit 22 and output the reset signal S7 according to a time chart shown in FIG. 4, for example, without outputting the clear signal S5.

[0037] In the foregoing discussion, the rearward movement limits of the movable part M2 and the knitting head assembly W defined by the stopper SP may be replaced by any set positions including their forward movement limits as long as the relative position y of the magnetic poles of the stator M1 and the movable part M2 can be physically defined in a correct way. If such set position is located other than at the rearward movement limit or forward movement limit of the movable part M2, the movable part M2 at the set position may be detected by a dedicated sensor provided in addition to the sensor A. More specifically, the knitting control unit 10 may cause the movable part M2 to move toward the set position and the dedicated sensor to detect the arrival of the movable part M2 to the set position in steps (1) and (2) of FIG. 2.

Claims

1. A linear motor control device for driving a knitting head component (W) of a knitting machine, said linear motor control device comprising:

a drive control circuit (21) which detects a positioning deviation (Δx) of the knitting head component (W) driven by a linear motor (M);
a pole position detector (22a) for determining the relative position of magnetic poles of a stator (M1) and a movable part (M2) of the linear motor (M) by using a sensor (A) which detects travel of the movable part (M2); and
a driving circuit (22) which outputs driving current (Id) to an appropriate coil (M2a; M2b) of the linear motor (M) based on a driving signal (S6) fed from said drive control circuit (21) and a pole position signal (Sy) fed from said pole position detector (22a);
wherein said pole position detector (22a) is reset on condition that the movable part (M2) is located at a specific position when a clear signal (S5) has been transmitted from a knitting control unit (10).

2. A linear motor control device according to claim 1, wherein said pole position detector (22a) is reset by a reset signal (S7) entered from said driving circuit (22).

3. A linear motor control device according to claim 2, wherein said driving circuit (22) outputs the reset signal (S7) after verifying that the movable part (M2) is located at its rearward movement limit.

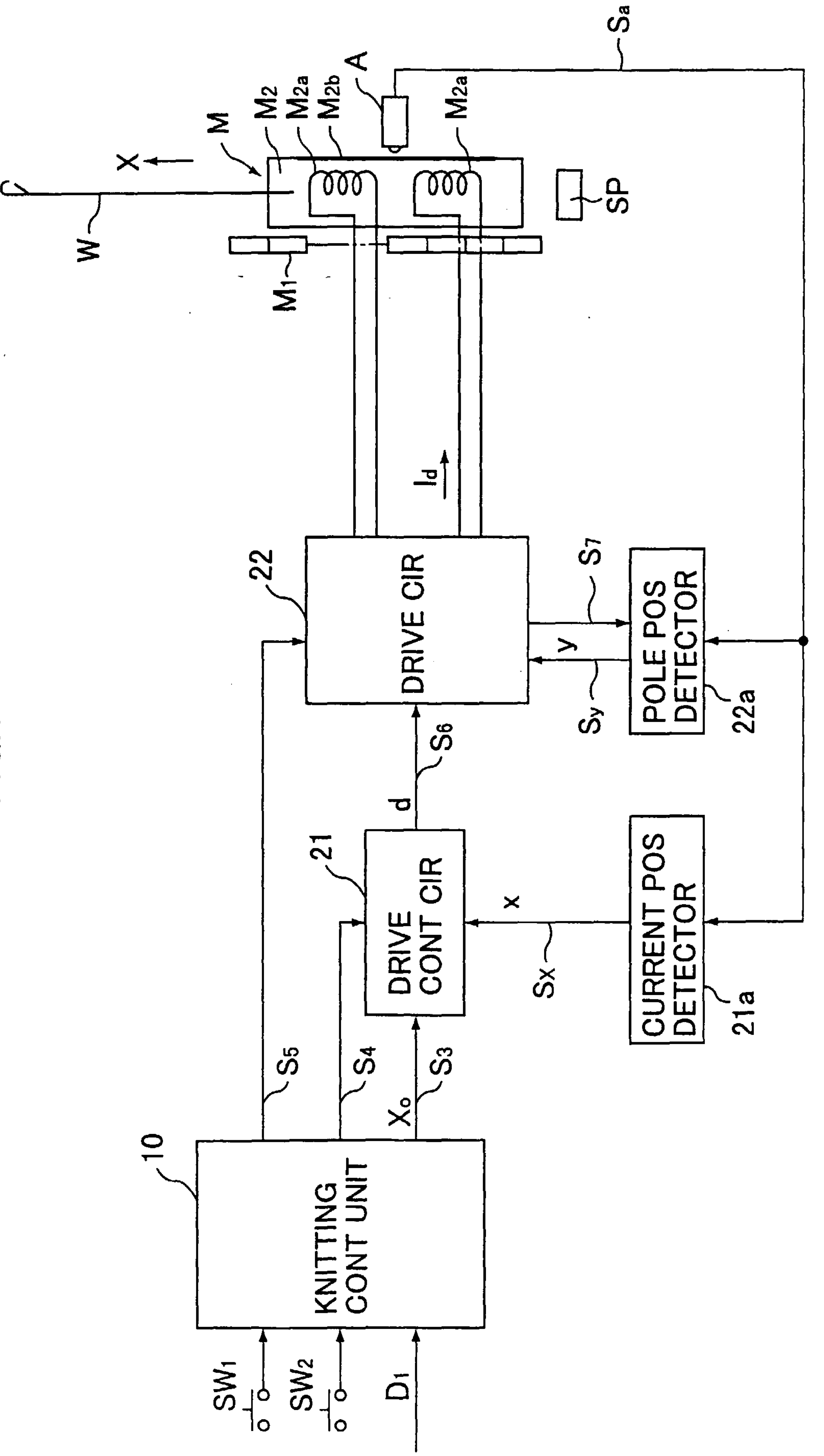
4. A linear motor control device according to claim 2, wherein said driving circuit (22) outputs the reset signal (S7) after verifying that the movable part (M2) located at its rearward movement limit is forced rearward.

5. A linear motor control device according claim 2, 3 or 4, wherein said driving circuit (22) outputs the reset signal (S7) after verifying that the clear signal (S5) entered from the knitting control unit (10) has been continuously present for a specific time period.

6. A linear motor control device according to claim 1, wherein said pole position detector (22a) is reset by a reset signal (S7) output from said driving circuit (22) after verifying that the driving signal (S6) containing a command value (d) which is zero output from said drive control circuit (21).

7. A linear motor control device according to claim 1, wherein said pole position detector (22a) is reset by a reset signal (S7) output from said driving circuit (22) upon verification that the clear signal (S5) has been output from said knitting control unit (10) for a certain time period after the driving signal (S6) containing a command value (d) which is zero is output from said drive control circuit (21).

8. A linear motor control device according to claim 1, wherein said pole position detector (22a) is reset by a reset signal (S7) output from said driving circuit (22) upon verification that the driving control circuit (21) outputs the driving signal (S6) containing a command value (d) corresponding to a further movement of the knitting head component (W) from its limit position after the clear signal (S5) has been output from said knitting control unit (10) for a certain time period after the driving signal (S6) is output from said drive control circuit (21) containing a command value (d) which is zero.


KNITTING CONT UNIT
10
SW₁
SW₂
D₁
S5
S4
S3
Xo
DRIVE CONT CIR
21
d
S6
x
Sx
CURRENT POS DETECTOR
21a
DRIVE CIR
22
S7
y
Sy
POLE POS DETECTOR
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Id
M
M1
M2
M2a
M2b
A
Sa
SP
W
X

FIG.1

FIG.2

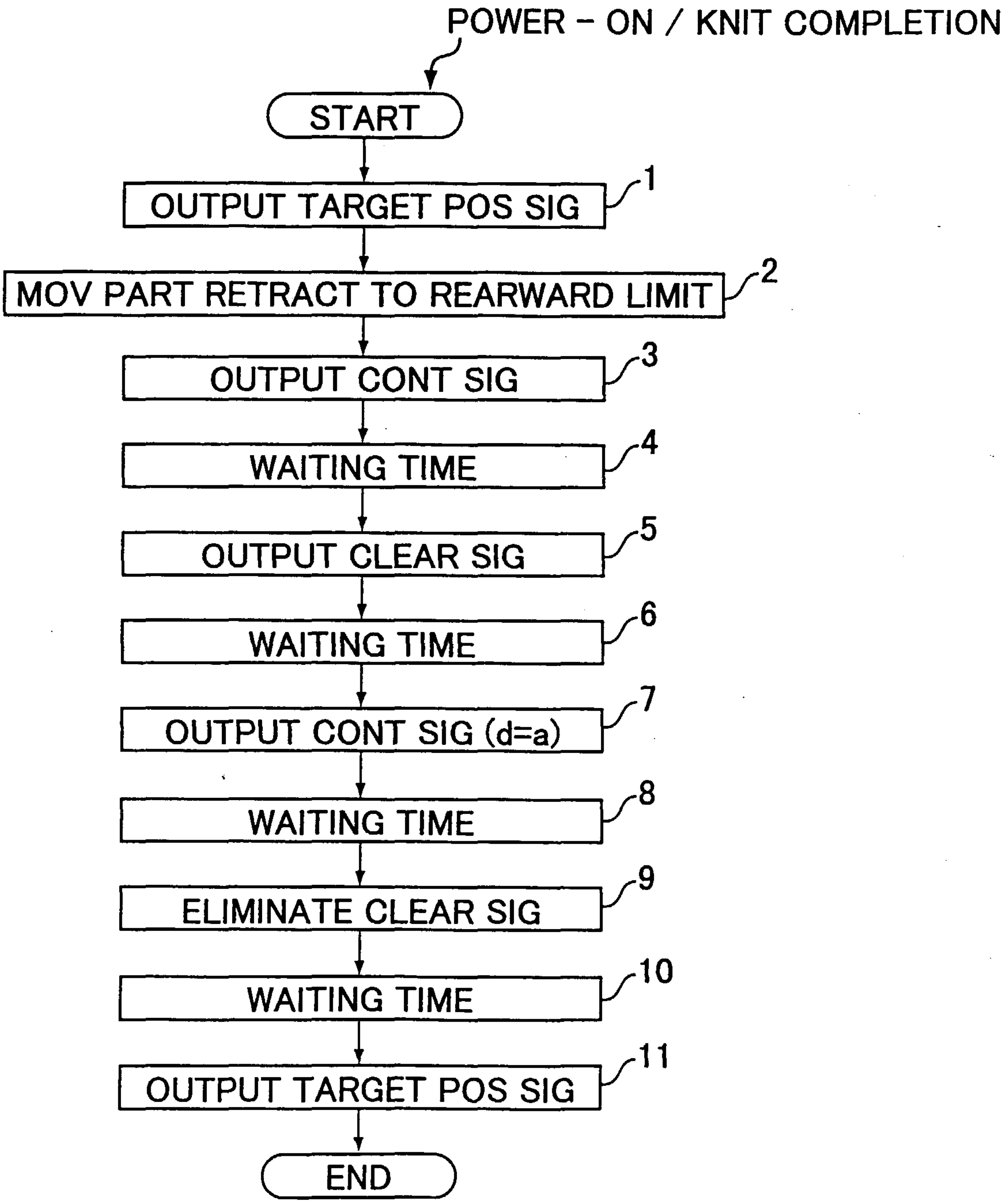

POWER - ON / KNIT COMPLETION
START
OUTPUT TARGET POS SIG
1
MOV PART RETRACT TO REARWARD LIMIT
2
OUTPUT CONT SIG
3
WAITING TIME
4
OUTPUT CLEAR SIG
5
WAITING TIME
6
OUTPUT CONT SIG (d=a)
7
WAITING TIME
8
ELIMINATE CLEAR SIG
9
WAITING TIME
10
OUTPUT TARGET POS SIG
11
END

FIG.3

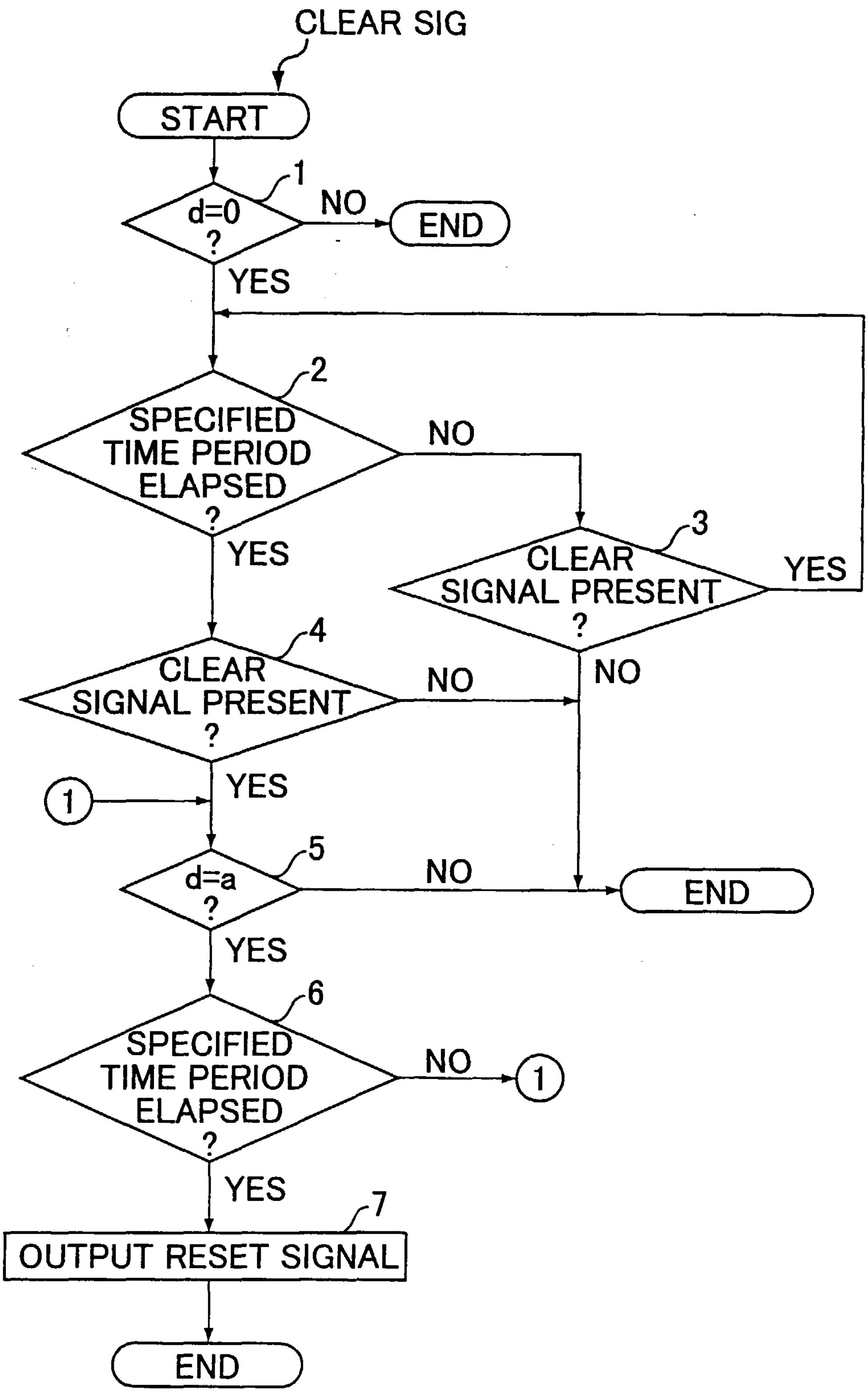
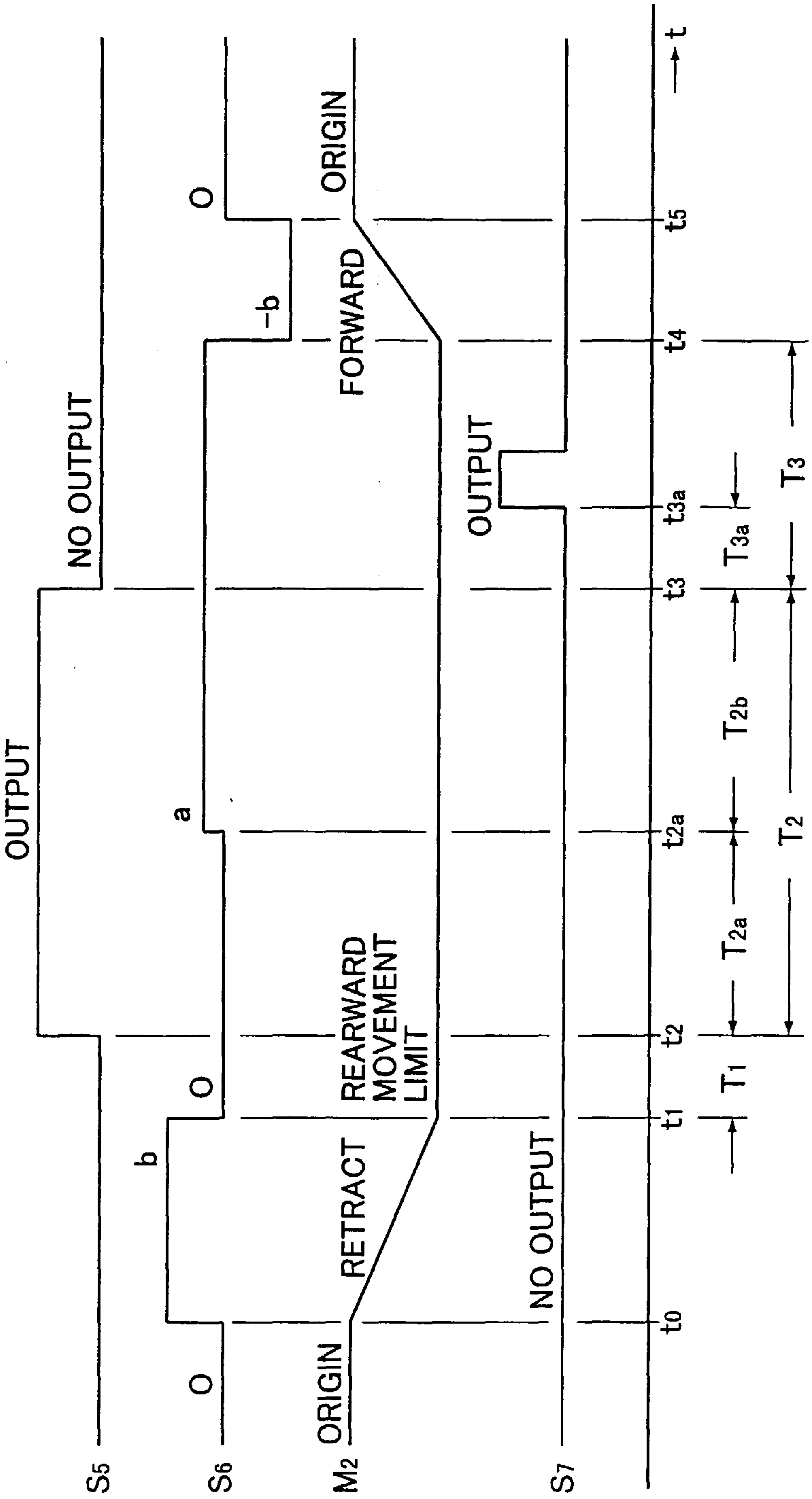

CLEAR SIG
START
1
d=0
?
NO
END
YES
2
SPECIFIED
TIME PERIOD
ELAPSED
?
NO
3
CLEAR
SIGNAL PRESENT
?
YES
NO
YES
4
CLEAR
SIGNAL PRESENT
?
NO
YES
1
5
d=a
?
NO
END
YES
6
SPECIFIED
TIME PERIOD
ELAPSED
?
NO
1
YES
7
OUTPUT RESET SIGNAL
END

FIG.4


S5
S6
M2
S7
OUTPUT
NO OUTPUT
O
b
a
-b
ORIGIN
RETRACT
REARWARD MOVEMENT LIMIT
FORWARD
NO OUTPUT
OUTPUT
t0
t1
t2
t2a
t3
t3a
t4
t5
t
T1
T2a
T2b
T2
T3a
T3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 11 1968

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.7)
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A	EP 0 821 091 A (TSUDAKOMA K.K.K.) 28 January 1998 (1998-01-28)		
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			D04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 September 2000	Van Gelder, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 11 1968

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18-09-2000

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