United States Patent [19]

Gachot et al.

[11] **3,844,178**

[45] **Oct. 29, 1974**

[54] **STEPPING MOTOR OF THE FLUID PRESSURE TYPE**

[76] Inventors: **Jean Gachot,** 179 Avenue de la Division Leclerc, Enghien-les-Bains; **Siméon Lekarski,** 138 Boulevard de la Republique, Saint-Cloud, both of France

[22] Filed: **June 2, 1972**

[21] Appl. No.: **259,033**

[30] **Foreign Application Priority Data**

June 3, 1971 France 71.20155
May 3, 1972 France 72.15665

[52] **U.S. Cl.** **74/128,** 92/58, 92/32
[51] **Int. Cl.** **F16h 27/00,** F01b 13/00
[58] **Field of Search** 92/58, 72, 32; 91/35, 36; 74/88, 128, 162, 144

[56] **References Cited**

UNITED STATES PATENTS

2,134,072 10/1938 Christensen .... 92/98 D
2,715,925 8/1955 Morgan 74/144
2,874,544 2/1959 Switzer .... 60/97 SE
3,378,196 4/1968 Gudnestad 74/128
3,661,059 5/1972 Hunter et al. 91/499

FOREIGN PATENTS OR APPLICATIONS

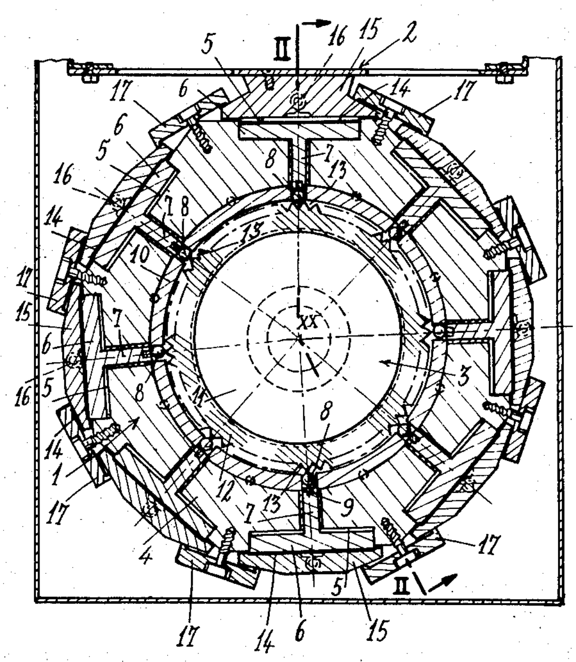
499,958 3/1951 Belgium 74/128

Primary Examiner—Edgar W. Geoghegan
Attorney, Agent, or Firm—Young & Thompson

[57] **ABSTRACT**

A step by step motor whose rotor is rotated by fluid pressure relatively to a stator. The invention provides a plurality of rows of rolling elements, either on the rotor or on the stator, arranged to co-operate with grooves formed in the other member, and actuating means for each row of rolling elements, the elements of successive rows being displaced with respect to the bottom of the grooves over an angular distance which varies by an increment corresponding to one step. Among other applications, control possibilities are provided for valves and machine-tool tables.

6 Claims, 11 Drawing Figures



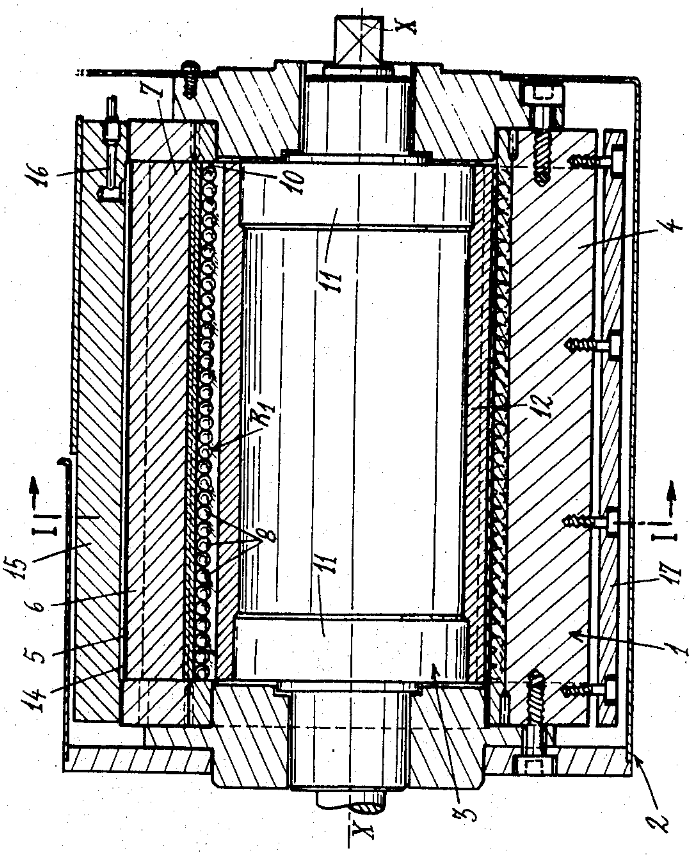


Fig. 2

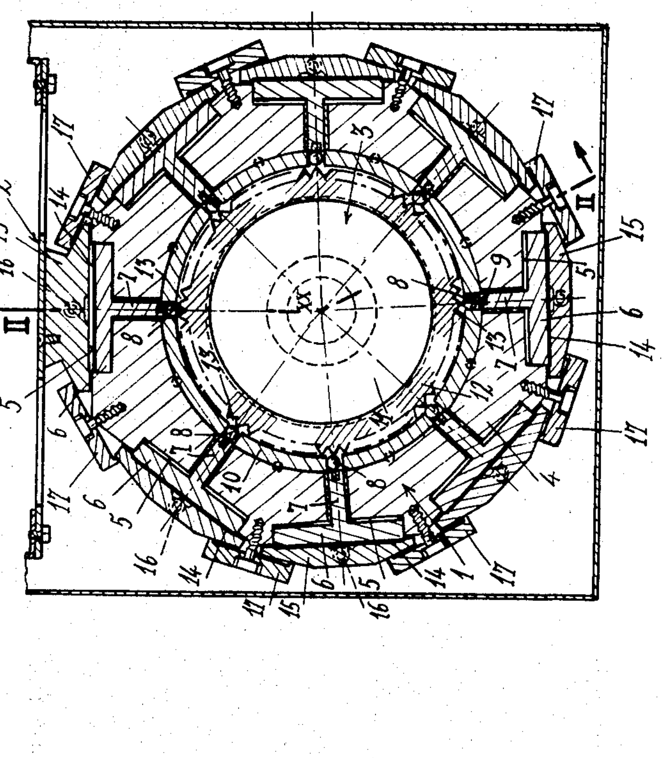


Fig. 1

Fig. 3

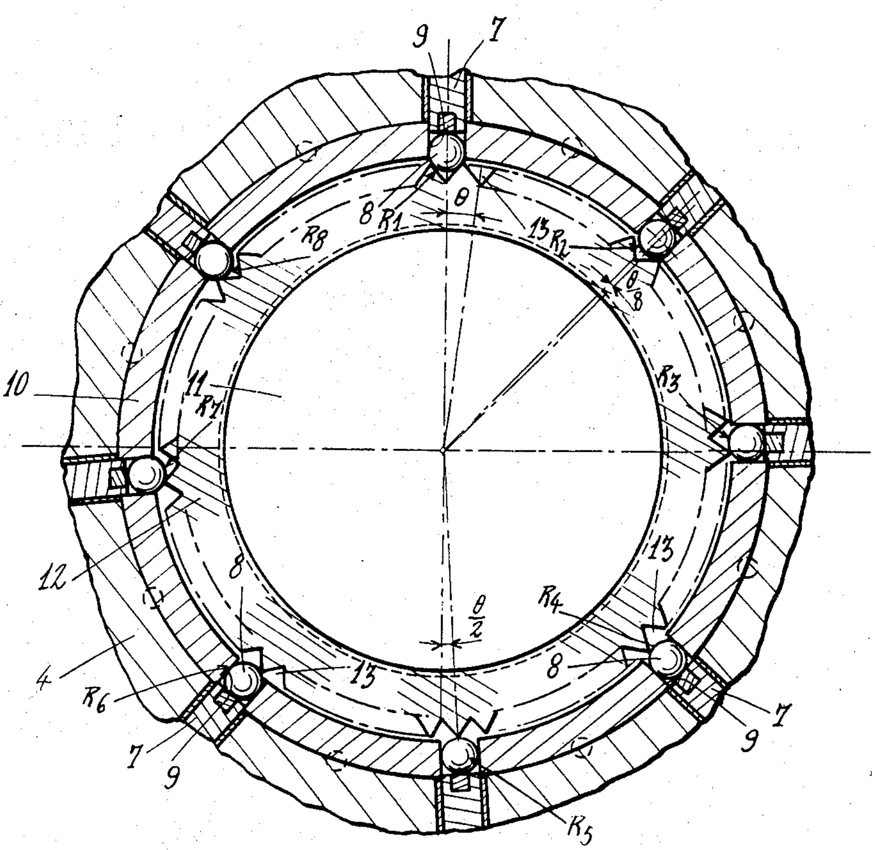
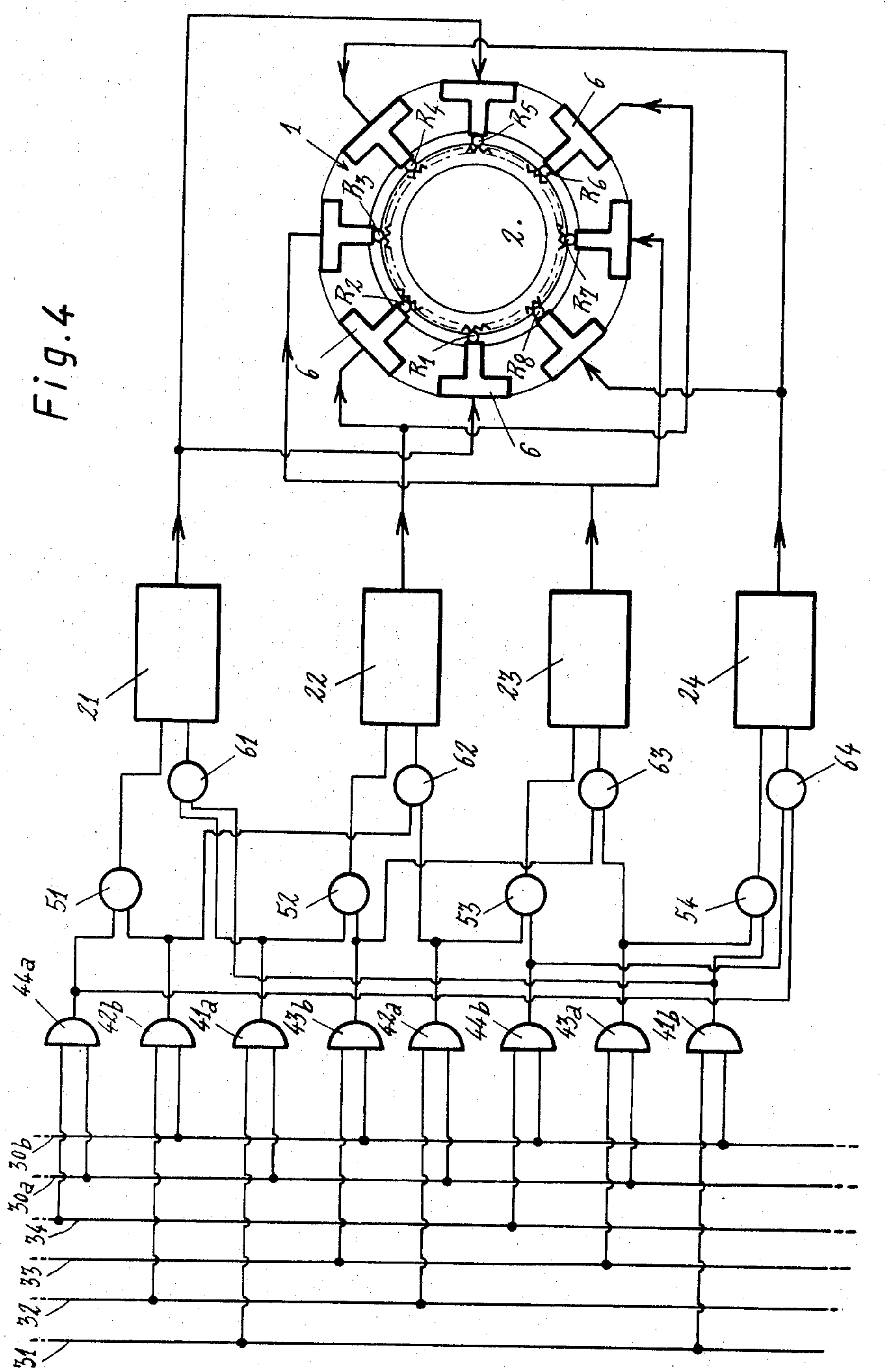


Fig. 4


1
2
6
R1
R2
R3
R4
R5
R6
R7
R8
21
22
23
24
51
52
53
54
61
62
63
64
44a
42b
41a
43b
42a
44b
43a
41b
30b
30a
34
33
32
31

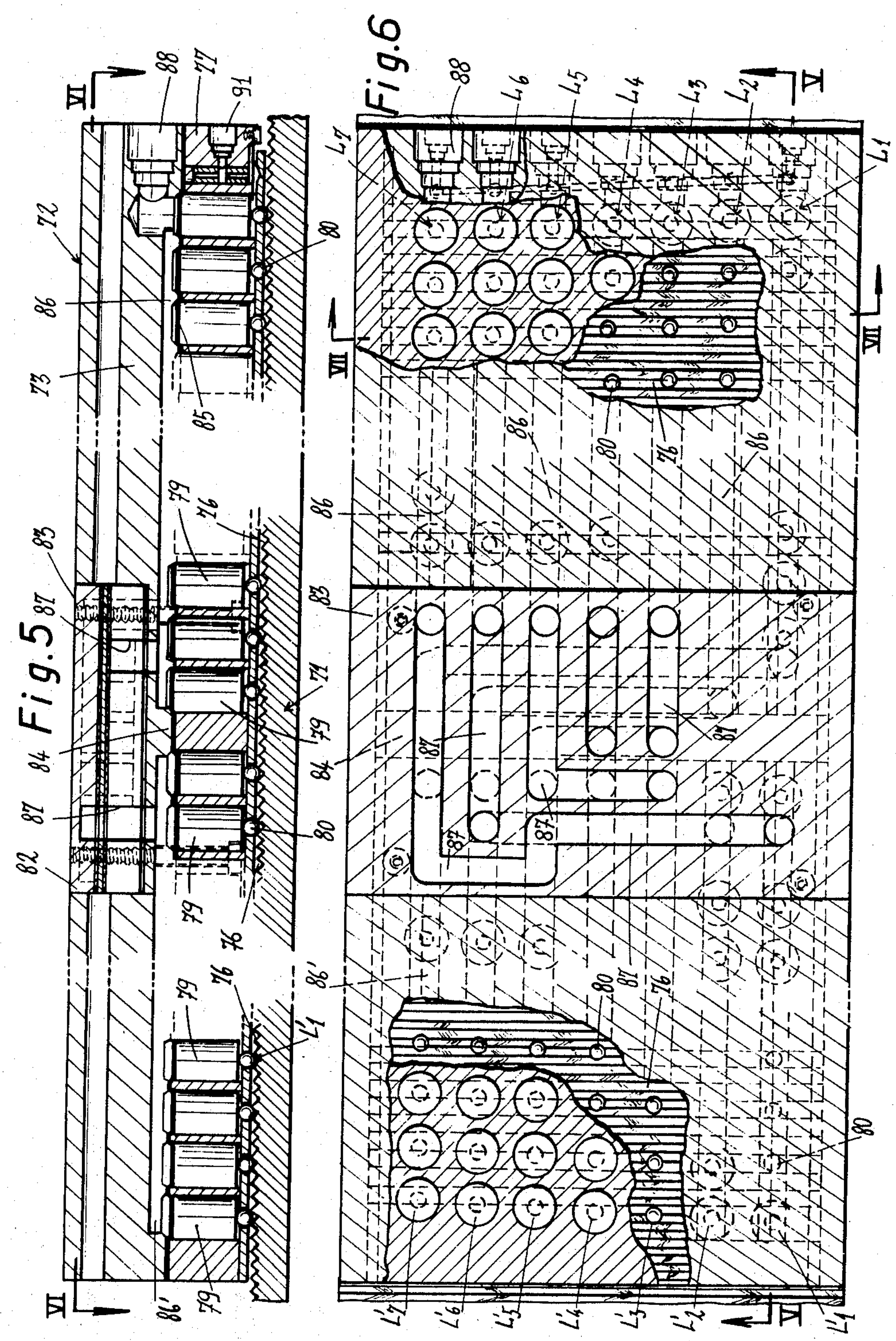


Fig. 5

Fig. 6

Fig.7

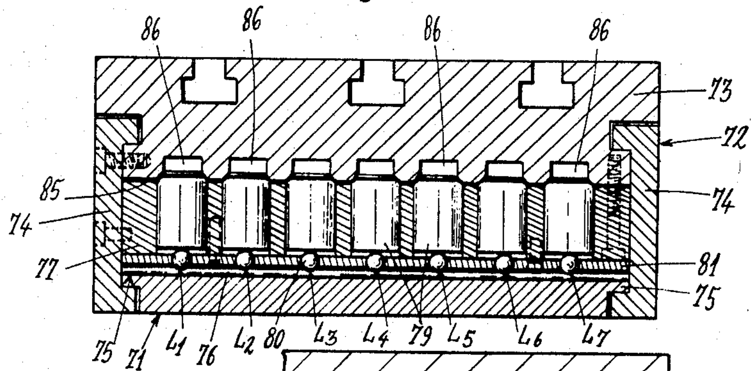


Fig.8

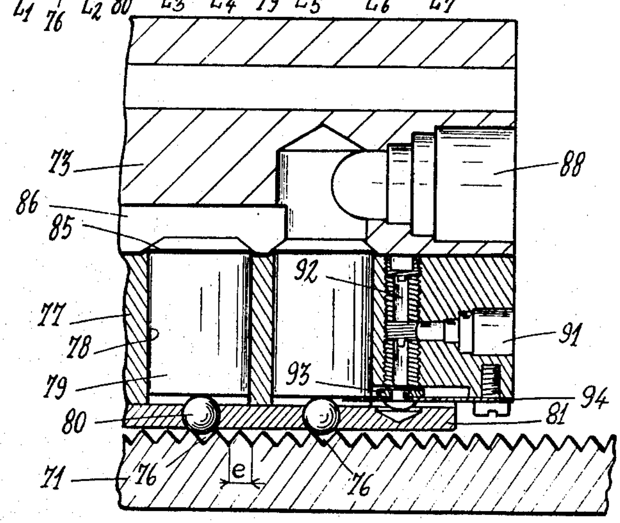
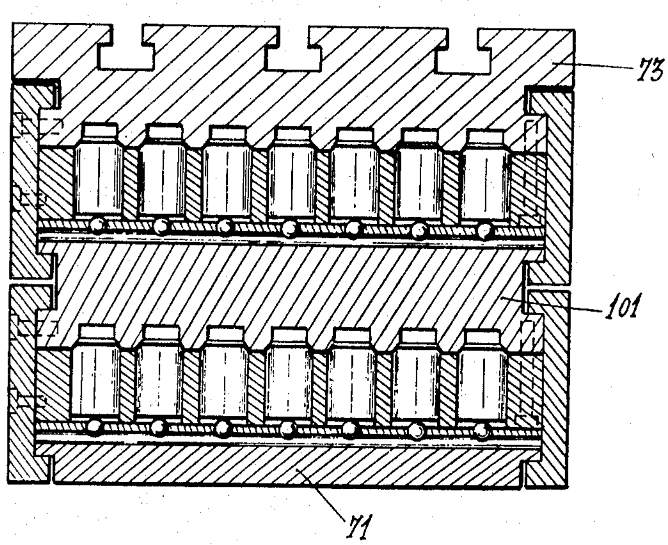


Fig.9



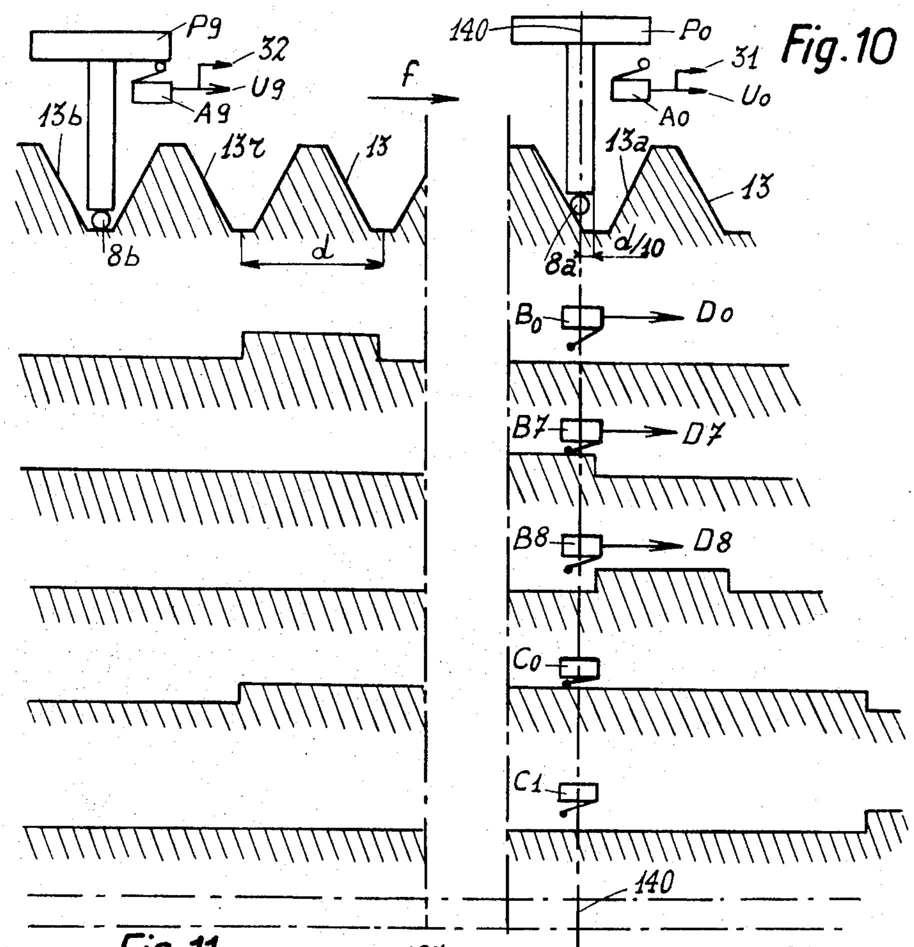
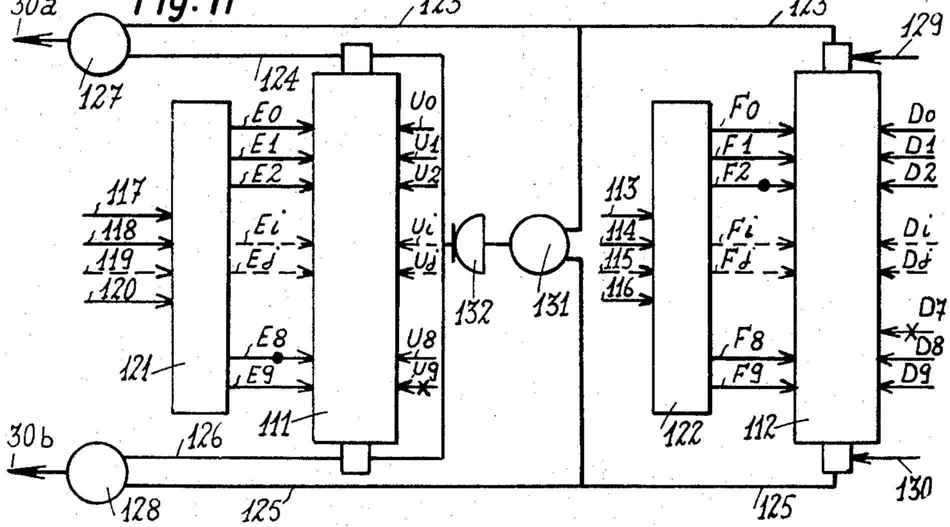

P9
32
U9
A9
13b
13r
13
8b
d
f
140
Po
31
Uo
Ao
13a
8a
d/10
B0
Do
B7
D7
B8
D8
Co
C1
140

Fig.10

Fig.11


30a
123
127
124
Eo
E1
E2
Ei
Ej
E8
E9
117
118
119
120
121
111
Uo
U1
U2
Ui
Uj
U8
U9
132
131
30b
126
128
125
129
Fo
F1
F2
Fi
Fj
F8
F9
113
114
115
116
122
112
Do
D1
D2
Di
Dj
D7
D8
D9
130

STEPPING MOTOR OF THE FLUID PRESSURE TYPE

This invention relates to a stepping motor which operates by fluid pressure.

The stepping motors which are in widest use are often subdivided into three main groups, namely electric motors, hydraulic motors and pneumatic motors.

The motors of the first group have a very fast action and produce low values of torque. The motors of the second type are usually associated with electric motors and perform the function of amplifiers with respect to these latter since they are not capable of operating in an independent manner. So far as the pneumatic motors are concerned, they comprise in most cases a piston and ratchetwheel mechanism which is unreliable and makes it possible to obtain only a low torque.

Moreover, these different types of motors do not provide any information relating to the ends of stepping intervals; in consequence, any errors in step displacements which may arise, especially steps which have not been performed, cannot be located.

The aim of the invention is to overcome the different disadvantages mentioned in the foregoing and to provide a stepping motor which has an extremely high degree of reliability.

In accordance with the invention, the stepping motor which operates by fluid pressure and comprises two members capable of moving with respect to each other is characterized in that one of the members is fitted with a plurality of rows of rolling elements adapted to cooperate with depressions formed in the other member, and means for actuating each row of elements, the elements of successive rows being displaced with respect to the bottom of the depressions at an angular distance which varies by a value corresponding to one step.

The sequential actuation of the rows of rolling elements makes it possible to impart to the moving member displacements which are equal in value to one step. The cooperation of rolling elements with complementary depressions ensures reliable operation with the maximum degree of accuracy.,

The depressions preferably consist of identical successive grooves arranged in parallel relation. The actuating means are pistons controlled by the fluid pressure. In the case of a rotating motor, the two members being movable in relative rotation, the grooves and the rows of rolling elements are oriented parallel to the axis of rotation, the step being equal to the ratio of the angle made between two consecutive grooves to the number of rows.

The actuation of a single row of rolling elements or of two opposite rows serves to initiate a displacement of the rotary member by one step.

In the case of a linear motor, the two members being movable in relative translational motion, the rows of rolling elements are oriented in the direction of translational motion and the grooves are oriented at right angles to this direction, the step being equal to the ratio of the distance between two consecutive grooves to the number of rows. Preferably, the rows of rolling elements are arranged in two symmetrically disposed series in which the rolling elements are inclined at a predetermined angle with respect to the grooves and transversely to the direction of translational motion.

In order that the sequential control should be performed without any omission or error in step, the actuating means are combined with means for generating end-of-travel signals which are connected to a control logic circuit.

In an advantageous embodiment of the invention, provision is made for means whereby the two members are brought both accurately and automatically into a predetermined relative position by means of data which are coded in accordance with a predetermined law.

To this end, the motor comprises a system for detecting the instantaneous relative position of two moving members adapted to deliver position signals which are coded in accordance with a decimal law, a positioning-order generator adapted to deliver primary reference signals which are coded in accordance with a predetermined law and represent the desired relative position of the two moving members, a transcoding system adapted to produce from said primary reference signals secondary reference signals which are coded in accordance with a decimal law, and a comparison system adapted to receive on the one hand the position signals and on the other hand the secondary reference signals and to deliver actuating signals as a function of the relative value of the two series of signals aforesaid to the logic circuit which controls the motor.

Further particular features of the invention will become apparent from the description which is given hereinafter.

In the accompanying drawings, which are given by way of example and not in any sense by way of limitation:

FIG. **1** is a transverse sectional view taken along line I-I of FIG. **2** and showing a stepping motor of the rotary type;

FIG. **2** is a sectional view of said motor, taken along line II—II of FIG. **1**;

FIG. **3** is a detail view to a larger scale and illustrating the relative angular displacement of the rows of balls with respect to the grooves of the rotary member;

FIG. **4** is a diagram representing the motor together with its control logic circuit;

FIG. **5** is a partial longitudinal sectional view taken along line V—V of FIG. **6** and showing a stepping motor of the linear type;

FIG. **6** is a partial sectional view with portions broken away and taken along line VI—VI of FIG. **5**;

FIG. **7** is a sectional view taken along line VII—VII of FIG. **6**;

FIG. **8** is a view to a larger scale showing a detail of FIG. **5**;

FIG. **9** is a sectional view which is similar to FIG. **7** and shows a stepping motor of the linear type having two stages;

FIG. **10** is a diagrammatic view showing the arrangement of the position detectors;

FIG. **11** is a diagram of the transcoding and comparison system.

FIGS. **1** and **2** illustrate a stepping motor of the rotary type comprising a stationary member **1** which is rigidly fixed to a frame **2** and a moving member **3** which is rotatably mounted in said frame inside the stationary member.

The stationary member **1** comprises a substantially cylindrical body **4**, the axis of which coincides with the axis of rotation X—X of the moving member **3** and in which are formed longitudinal chambers **5** having a Tshaped cross-section and each containing a piston **6** provided with an actuating rod **7.** Said chambers **5** and pistons **6,** which are eight in number in the example under consideration, are disposed radially with respect to the axis X—X and in uniformly spaced relation. The piston rods are in contact with rows R_1 to R_8 of balls **8** which are housed respectively in slots **9** formed in a sleeve **10** which is secured to the body **4.**

The rotary member **3** is made up of two rotating end-bosses **11** which are mounted in the frame **2** and of a sleeve **12** of hard metal which is fixed on said end-bosses. Identical V-section grooves **13** which are formed over the entire periphery of the sleeve **12** and oriented parallel to the axis of rotation X—X permit the engagement of the rows of balls R_1 to R_8 to a variable depth, as will be explained hereinafter.

Each piston **6** is rigidly fixed to a diaphragm **14** which is mounted in the corresponding chamber **5** and clamped between the body **4** and a cover **15** in which is formed a passageway **16** having its opening in the volume defined by the diaphragm and the cover. The piston **6** is capable of displacement within the chamber **5** over a short distance determined by the depth of penetration of the rolling element within the groove **13,** thus defining the maximum travel. The covers **15** are held in position by means of intermediate longitudinal components **17** which are attached to the body **4.**

The arrangement is such that the axes of the balls of the successive rows are displaced with respect to the bottom of the respective grooves **13** at an angular distance which varies from one row to another by a value corresponding to the single-step forward displacement of the motor. This single-step displacement is equal to the ratio of the angle θ between the roots of two consecutive grooves (angular pitch of the grooves) to the number N of rows of balls (as shown in FIG. 3).

In the example considered, one of the rows of balls, namely the row R_1 taken as a reference, is in the position of maximum engagement within the corresponding groove whilst the row R_5 which is located directly opposite is displaced by $\theta/2$ inasmuch as $N = 8$. The balls of the last-mentioned row are therefore in a position of withdrawal on a summit or tooth between two grooves **13.** In order to initiate a one-step rotary displacement of the moving member **3,** compressed air is delivered through the passageways **16** into the chambers **5** of the pistons **6** corresponding to the rows of balls R_2 and R_6, for example. The balls of the rows are angularly displaced through an angle $\theta/8$ so that the second row of balls R_2 should then take up the position of maximum engagement which was previously occupied by the row having the reference R_1.

FIG. 4 illustrates the sequential control of the actuating pistons **6** by means of a storage-type logic circuit.

The chambers of the pistons are connected in opposite pairs to two-state storage devices **21–24** of conventional type having two inputs, namely a control and storage input and a cancelling or erasing input, and one output. The pneumatic control signals are delivered from one of two lines **30***a*, **30***b*, depending on the direction of rotation which is selected for the moving member **3.** These lines are combined in pairs with four lines **31–34** of end-of-travel signals corresponding respectively to the pairs of pistons and therefore to the rows $R_1 - R_5$, $R_2 - R_6$, and so forth. Each pair formed by the line **30***a* or **30***b* and a line **31, 32, 33** or **34** is thus connected to an AND-gate **41***a*—**44***a*, **41***b*—**44***b*. The output of each AND-gate is connected on the one hand to an OR-gate **51–54** corresponding to the pair of pistons to be actuated and, on the other hand, to an OR-gate **61–64** corresponding to the preceding pair of pistons (depending on the direction of rotation) which has been actuated; the association of the AND-gates and OR-gates **51–54** is effected in the following order: AND-gate **44***a* and **42***b* – OR-gate **51,** AND-gate **41***a*, **43***b* – OR-gate **52,** and so forth.

A signal derived from one of the pairs of lines **30***a*–**34** and **30***b*–**32, 30***a*–**31** and **30***b*–**33** and so forth is accordingly applied to the OR-gates **51–54** respectively whilst a signal dervied from a pair of lines **30***a*–**31** or **30***b*–**31, 30***a*–**32** or **30***b*–**32** and so forth is applied to the OR-gates **61–64** respectively.

Each OR-gate **51** to **54** (for example, the gate **51**) corresponding to one pair of rows (R_1 and R_5, for example) is connected to the control and storage input of the storage device **21–24** (device **21,** for example). The OR-gate **61** to **64** (namely the gate **64** or **62,** for example) corresponding to the preceding pair of rows (R_8 and R_4 or R_2 and R_6, for example) is connected to the erasing input of the storage device **21–24** (either **24** or **22,** for example).

The end-of-travel signals in the lines **31–34** are delivered under the action of the pistons **6** by means of conventional means for generating end-of-travel signals (which are described hereinafter) with which the pistons are combined.

When an end-of-travel signal and a rotational direction signal appear at an AND-gate, this gate delivers a signal to the OR-gate **51–54** and to the corresponding OR-gate **61–64.** The signal is transmitted from the OR-gate **51–54** to the respective storage device **21–24,** then to the chambers of the pistons corresponding to the pairs of rows $R_1 - R_5$, $R_2 - R_6$, and so forth. The signal derived from the OR-gate **61–64** has the effect of erasing the information contained in the storage device corresponding to the pair of rows which has previously been actuated.

The control of the motor is ensured without any risk of error and with a remarkable degree of regularity since each end of travel constitutes an item of information which is necessary in order to permit of sequential actuation.

FIGS. **5** to **8** illustrate a stepping motor of the linear type comprising a stationary member **71** constituted by a plate and a member **72** which is capable of translational motion and essentially composed of a table **73** such as a machine-tool table, for example, which is fitted with two lateral components **74** guided by means of slideways **75** formed by the plate **71.**

The plate **71** is provided on its top face with a series of identical grooves **76** having a V-shaped cross-section and oriented at right angles to the direction of translational motion.

There is mounted between the plate **71** and the table **73** a support-block **77** which is rigidly fixed to the table **73** and to the lateral components **74,** there being formed in said block individual cylindrical chambers **78** for the pistons **79** which are disposed at right angles to the plate **71.** Each piston **79** is in contact with a ball **80** which is housed in a bore formed in a thin plate **81** which is rigidly fixed to the support-block **77** and located above the grooved plate **71.** The balls **80** can thus engage to a greater or lesser depth within the grooves 76.

The table 73 is provided in its central portion with a recess 82 in which is mounted an added component 83, and with a transverse rib 84 which divides the table into two halves. The chambers 78, the pistons 79 and the corresponding balls 80 are disposed symmetrically in columns on each side of said rib in such manner as to be inclined in the transverse direction at a predetermined angle with respect to the grooves 76. In this example, there are thus formed two series of seven rows of pistons and of balls as designated by the references L_1 to L_7 and L'_1 to L'_7. The pistons 79 are secured to a diaphragm 85 which is clamped between the table 73 and the supportblock 77 and each row $L_1 - L_7$ or $L'_1 - L'_7$ is supplied by a passageway 86 or 86' which is formed in the table 73 and interrupted by the transverse rib 84. Passageways 87 are formed in the added component 83 so as to establish a communication between the passageway 86 of the row L_1 and the passageway 86' of the row L'_7, between the passageway 86 of the row L_2 and the passageway 86' of the row L'_6 and so on up to the passageways 86 and 86' of the rows L_7 and L'_1.

The arrangement is such that, in each series, the balls 80 of the successive rows $L_1 - L_7$ or $L'_1 - L'_7$ are displaced with respect to the bottom of the respective grooves 76 at a distance which varies by a value corresponding to one step. This value is equal to the ratio of the distance e between two consecutive grooves 76 to the number of rows (seven in the case under consideration); this determines the angle of inclination of the columns of balls 80 with respect to the grooves 76 in the transverse direction.

Each passageway 86 which supplies the rows of balls L_1 to L_7 has an extension in the form of a stepped bore 88 constituting a passage which serves to supply fluid under pressure to the passageway 86 aforesaid as well as to the corresponding passageway 86', and consequently to actuate the two corresponding rows of balls.

There are also formed in the support-block 77 ducts 91 which are equal in number to the rows and open into respective bores 92 which are oriented at right angles to the grooved plate 71, and said bores being normally closed-off by a valve 93 mounted on a blade-spring 94 which is secured to the support-block 77.

The free end of the blade-spring is in contact with the underface of the first piston 79 of the row, in such manner that the displacement of said piston under the action of the fluid pressure causes the valve 93 to open and connects the bore 92 and the duct 91 to the exhaust. The ducts 88 and 91 are connected to a fluid-control logic circuit (not shown in the drawings) which produces action in response to the absence of pressure within a duct 91 as a result of connection of this latter to the exhaust, in order to deliver an end-of-travel signal which permits the actuation of a subsequent pair of rows. The control can be of the same type as that shown in FIG. 4.

The pneumatic control signals are transmitted to the pairs of rows in the sequence $L_1 - L'_7$, $L_2 - L'_6$, ... $L_4 - L'_4$, ... $L_7 - L'_1$, followed by a return to the row $L_1 - L'_7$ and this latter accordingly takes up a position which is displaced by the distance *e* with respect to the previous position.

FIG. 9 illustrates a linear stepping motor having two stages, in which the grooved plate 101 of the top assembly performs the function of table for the bottom assembly. The structure of both assemblies is in any case identical.

The bottom stage is intended to carry out a one-step displacement over a relatively long distance such as 1 mm, for example, whereas the top stage must permit a one-step displacement over a very short distance such as 0.05 mm, for example.

The relative spacing of the grooves of the plate 101 is equal to the distance between two columns of balls in the bottom stage. In the example considered, it is therefore possible to initiate a displacement of the table 73 over a predetermined number of millimeters by virtue of the top stage, and over multiple of 0.05 mm by virtue of the top stage.

The two stages are supplied separately with fluid under pressure by means of a control logic circuit. If necessary, the two stages can operate simultaneously, especially in a numerical positioning.

It is apparent that the number of stages can increase according to the degree of precision which is required in the displacement of the moving member, this being essentially dependent on the type of industrial application which is contemplated.

It is also apparent that the structure and operation of the linear motor embodiments of the present invention are substantially the same as those of the rotary motor embodiments, except that the linear motor is in effect a flat form of the rotary motor. In other words, the linear motor is in effect one section of a rotary motor of infinite radius. Accordingly, it is not necessary to repeat, in connection with the linear embodiments, what has already been said in connection with the rotary embodiments.

The use of the stepping motor of the rotary type is particularly advantageous for the control of valves and other devices which can entail the need for limited angular displacements of rotating components.

By way of alternative, the depressions can consist of conical recesses instead of grooves.

There will now be described with reference to FIGS. 10 and 11 a system which permits accurate positioning of the two members of the motor with respct to each other by means of data which are coded in accordance with a predetermined law.

In this system, the selected number N of pistons and rows of balls is equal to ten. Under these conditions, the single-step forward displacement is equal to one-tenth of the angular or linear distance (depending on whether a rotary or linear motor is employed) between two consecutive grooves 13, said distance being such as to correspond to the pitch of the depressions.

There is shown diagrammatically in FIG. 10 a device for detecting the instantaneous position of the moving member 11. The grooves 13 are shown in the developed position with the first piston P_0 and the last piston P_9 and the corresponding rows of balls 8*a* and 8*b*.

In order to define the position of the moving member, there has been chosen a reference position of the grooves which, in this particular case, is the axis 140 of the piston P_0 and of the row of balls 8*a*. In addition, a particular groove 13_r is chosen as origin. Under these conditions, the position of the moving member is defined by the distance, expressed in step displacements, between the axis of the origin groove 13_r and the reference position **140** of the grooves.

In the position shown in FIG. **10**, the axis **140** of the row of balls **8***a* is displaced by one step, that is to say by $d/10$ wherein d designates the grooves pitch, with respect to the axis of the corresponding groove **13***a* whilst the axis of the row of balls **8***b* corresponding to the piston P_9 coincides with the axis of the groove **13***b*. Assuming by way of example that the groove **13***a* is the eighth as counted in the direction of the arrow f from the origin groove 13_r, it is apparent that the position shown is defined by **79** forward-displacement steps.

The system of detection comprises a first series of ten fluid-pressure detectors A_o, A_1, ... A_9 which are actuated by the pistons P when they are located in a reference position. This reference position preferably coincides with the end-of-travel position of the piston.

Thus, in the example illustrated in FIG. **10**, it is the detector A_9 which is actuated and emits a position signal. For the sake of convenience of terminology, these first detectors will be designated hereinafter as "unit detectors" and the signals delivered by these latter will be referred-to as "unit" position signals. The intervals between these unit signals correspond to one single-step displacement of the motor.

The position-detection system further comprises a second series of ten detectors B_0, B_1 ... B_9 which will be designated hereinafter as "tens" detectors. The detectors just mentioned are actuated either by the teeth themselves which are formed between the grooves **13** or by a cam or any equivalent member so as to emit a signal referred-to as a "tens" position signal when the groove **13** which corresponds thereto is in the selected reference position. It is clearly an advantage to choose as reference position for the grooves a position corresponding to the axis **140** of a piston P_0. The detector B_O corresponds to the groove 13_r which is chosen as origin. The intervals between the "tens" signals correspond to 10 single-step displacements of the motor, that is to say to one pitch of the grooves **13**.

If the number of depressions or grooves **13** is greater than ten, the system of detection comprises a third series of ten detectors C_O, C_1 ... C_9 or so-called "hundreds" detectors. Each detector C is actuated by a cam or like component having a boss, the position of which corresponds to that of a set of 10 consecutive grooves **13**. The detectors C emit a signal when the set of 10 grooves corresponding thereto reaches the reference position of the grooves. In consequence, the interval between said "hundreds" signals corresponds to one hundred single-step displacements of the motor or to 10 depression-pitch intervals.

The detection system can also comprise decimal series of detectors having a higher order if the number of grooves **13** so requires, the interval between the signals of one series being such as to correspond to a forward displacement ten times greater in value than that which corresponds to the interval between the signals of the series immediately below.

The outputs of the unit detectors A are connected to lines U_0 to U_9 which terminate in a first comparator **111** (FIG. **11**) of a type which is known per se.

Similarly, the outputs of the "tens" detectors B are connected to lines D_O to D_9 which terminate in a second comparator **112** which is similar to the first comparator.

For convenience of terminology, the comparators **111** and **112** will be designated respectively in the following discussion as "unit" comparator and "tens" comparator.

Although the number of comparators is limited to two for the sake of clarity of the drawings and of the description, it is wholly apparent that these comparators are equal in number to the decimal series of position detectors.

An order generator which is not illustrated and known per se is designed to emit primary reference signals representing the desired position for the moving member expressed in forward-displacement steps as stated earlier.

This number of forward-displacement steps which defines the desired position is represented in accordance with a predetermined code by the primary reference signals which appear on lines such as **113** to **120**, the number of which depends on the code adopted. Said lines terminate in a transcoder of a type which is known per se and which, for the sake of enhanced clarity of the drawings, is illustrated in FIG. **11** in two separate sections **121** and **122**. In a manner which is already known, the transcoder decodes the information represented by the primary reference signals and recodes said information in accordance with a decimal law so as to emit secondary reference signals. These secondary signals comprise a unit signal which appears on one of the lines E_O to E_9 which are connected to the "unit" comparator **111** and a "tens" signal which appears on one of the lines F_O to F_9 which are connected to the "tens" comparator **112**.

It is readily apparent that, as a general rule, the transcoder comprises a number of sections corresponding to the number of comparators.

Each comparator **111** and **112** has two outputs and is arranged in a manner known per se so as to produce an actuating signal which appears either on a line **123** or **124** respectively if the position signal which appears on one of the lines D or U is of lower strength than the reference signal delivered by one of the lines E or F, or on a line **125** or **126** in the contrary case. If the position signal is equal to the reference signal, the comparators do not emit any actuating signal.

The lines **123** and **124** are each connected to one input of an OR-gate **127** whilst the lines **125** and **126** are connected to the inputs of a second OR-gate **128**. The outputs of these OR-gates are connected to the lines **30***a* and **30***b* of the motor-control logic circuit which was described in detail earlier.

This logic circuit is illustrated in FIG. **4** for a number of pistons **6** equal to eight. Within the framework of the present embodiment, it is wholly evident that, if the number of pistons is equal to ten, the circuit must accordingly be extended in a manner which is well known to any one versed in the art in order to adapt that circuit to this number of pistons.

It will be noted in addition that the unit detectors A are connected not only to the lines U of the "units" comparator **111** but also to the lines **31** to **34** of FIG. **4** in order to deliver to the motor-control logic circuit the end-of-travel signals which were mentioned in the foregoing.

The "tens" comparator **112** of FIG. **11** is supplied directly from two lines **129** and **130**. The supply of the "units" comparator **111** is controlled by the actuating signals emitted by the "tens" comparator **112** through an inhibition circuit. This circuit comprises an OR-gate **131** and an inverter or NOT-gate **132** which constitutes in combination a NOR-gate. The OR-gate **131** having two inputs connected respectively to the output lines **123** and **125** of the "tens" comparator and the output of the NOT-gate **132** is connected to the inputs for the supply of the "units" comparator **111.** It is understood that, under these conditions, the "units" comparator can emit a signal only if no signal is present either on the line **123** or on the line **125.**

It is readily apparent that, as a general rule, each comparator is controlled by the comparator having the order immediately above through an inhibition circuit which is similar to that described in the foregoing.

The device which has just been described operates as follows:

In order to simplify the explanation, it will be assumed hereinafter that the position-detecting system comprises only unit detectors A and "tens" detectors B whilst the comparison system similarly comprises only one "units" comparator **111** and one "tens" comparator **112,** as shown in FIG. **11.** The extension to the general case is evident to any one versed in the art.

If it is assumed that the desired position of the moving member of the motor corresponds to a distance of twenty-eight single-step displacements between the groove 13_r which is chosen as origin and the axis **140** which is chosen as reference position of the grooves, the order generator (not shown) emits on the lines **113** to **120** a reference signal which represents this number in a selected code. After decoding and recoding of said signal by the transcoder **121, 122,** there appears on the line E_8 a signal which represents the number eight and on the line F_2 a singal corresponding to the second multiple of ten, that is to say to the number twenty. These two signals are indicated schematically by points on the corresponding lines.

When the motor is in the position shown in FIG. **10,** the "tens" detector B_7 corresponding to the groove preceding the groove **13***a* is actuated and delivers a signal on the line D_7. In addition, the unit detector A_9 emits a signal on the line U_9 since it is the piston P_9 which is located at the end of travel. These two signals represent the number **79** which defines in forward-displacement steps the actual instantaneous position of the moving member as has been stated earlier. These signals are presented by the letters X on the corresponding lines.

The "tens" comparator **112** records the fact that the position signal which it receives on its line D_7 is of higher strength than the reference signal which appears on the line F_2. In consequence, the comparator produces an actuating signal on its output line **125.** This signal is transmitted to the OR-gate **128** and thence to the line **30***b* of the control logic circuit which causes the motor to advance in the appropriate direction.

At the same time, said actuating signal is brought to the inhibition circuit **131, 132** which cuts-off the supply of the "units" comparator **111** and this latter can therefore not deliver any signal.

As the motor advances, so its position is detected by "tens" signals which appear successively on the lines D_6, D_5 ... and so forth. When the "tens" signal appears on the line D_2, the "tens" comparator **112** no longer emits an actuating signal. The position of the motor is defined at this moment by the number **29.**

Since the inhibition circuit no longer receives any singal, it permits the supply of the "units" comparator **111.** This comparator records the fact that the position signal which it receives on the line U_9 is of higher strength than the reference signal which is displayed on the line E_8. In consequence, said comparator produces an actuating signal on its output line **126** which, through the OR-gate **128,** causes the motor to advance in the same direction as before up to the desired position which is defined by the number **28.** When this desired position is reached, the "units" comparator **111** no longer emits its actuating signal and the motor stops.

It is understood that the device which has just been described permits accurate control of the motor by very simple means. In particular, the choice of the number of pistons and the distribution of the position detectors make it possible to obtain instantaneous-position signals which are coded directly in accordance with a decimal base and avoid the need to make use of a special transcoder.

What we claim is:

1. A stepping motor comprising two members capable of moving with respect with each other, one of said members having cage means retaining a plurality of successive rows of rolling elements that engage in successive depressions in the other member, and fluid pressure actuating means for each said row to selectively press only one row of said successive rolling elements to the bottom of one of said depressions at one time, one row (**R1**) being at the bottom of one said depression (**13**) at one time, and each of the other successive rows (**R2–R8**) of rolling elements (**8**) being offset with respect to each of the corresponding successive depressions (**13**) by a distance which is equal to the pitch of the depressions (**13**) divided by the total number of said rows (**R1–R8**) of rolling elements (**8**), whereby only one said actuating means moves said members relative to each other through a said distance at one time.

2. A motor according to claim **1** wherein, the two members being movable in relative translational motion, the rows of rolling elements are oriented in the direction of translational motion and the depressions are oriented at right angles to this direction, the step being equal to the ratio of the distance between two consecutive depressions to the number of rows.

3. A motor according to claim **2,** wherein the rolling elements form columns disposed transversely to the direction of translational motion.

4. A motor according to claim **2,** wherein the rows of rolling elements are distributed in two symmetrically arranged series in which the rolling elements considered transversely to the direction of translational motion are inclined at a predetermined angle with respect to the depressions.

5. A motor according to claim **4,** wherein the rows of the two series are supplied with fluid under pressure through passageways which are put symmetrically into communication with each other in pairs.

6. A motor according to claim **2,** wherein said motor comprises at least one second member fitted with rolling elements in cooperating relation with depressions formed in the first member so as to constitute a motor having at least two stages.

* * * * *