

[54] SELF-ADVANCING PROGRAMMER AND PRESSURE ACTUATED DEVICES CONTROL ARRANGEMENT

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Related U.S. Application Data

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[52] U.S. Cl. 62/233, 62/353

[51] Int. Cl. F25c 1/00

[58] Field of Search. 62/233, 353

[56] References Cited

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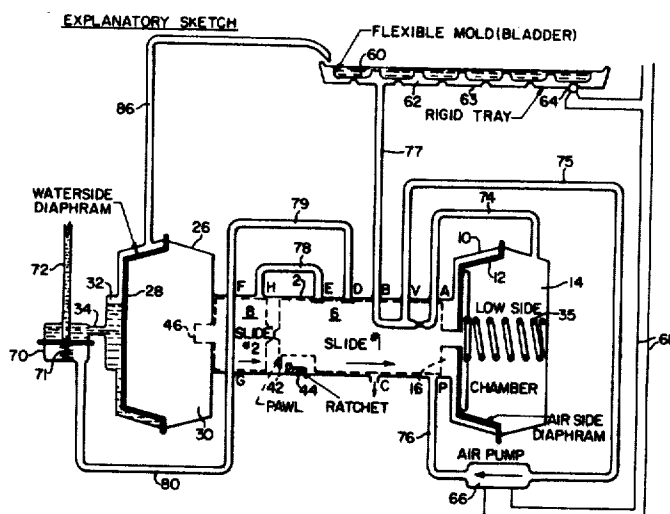
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Primary Examiner—William F. O'Dea
Assistant Examiner—P. O. Ferguson
Attorney—F. H. Henson et al.

[57] ABSTRACT

A control arrangement in which pressure actuated devices are selectively actuated from a self-advancing programmer provided with higher pressure areas (typically pressure) and lower pressure areas (typically suction) selectively placed in registry with ports in communication with the pressure actuated devices. The pressure and suction areas are positionable in accordance with the position of a displaceable member separating a low pressure side space and a high pressure side space which are in normal communication with the suction areas and pressure areas, respectively. Provision is made for selectively venting, and preventing venting, of the pressure areas and suction areas in accordance with the character of the pressure condition (e.g., pressure or alternatively vacuum) to be applied to a particular device. With this arrangement shifting of the character of the pressure condition on the displaceable member takes place to correspond to the pressure condition to be applied to the particular device and the advance of the programmer occurs in accordance with the attainment of the pressure condition applied to the device. The arrangement of the invention is particularly adapted in one embodiment to control a flexible mold or bladder type ice maker and the supply of water thereto.

4 Claims, 26 Drawing Figures



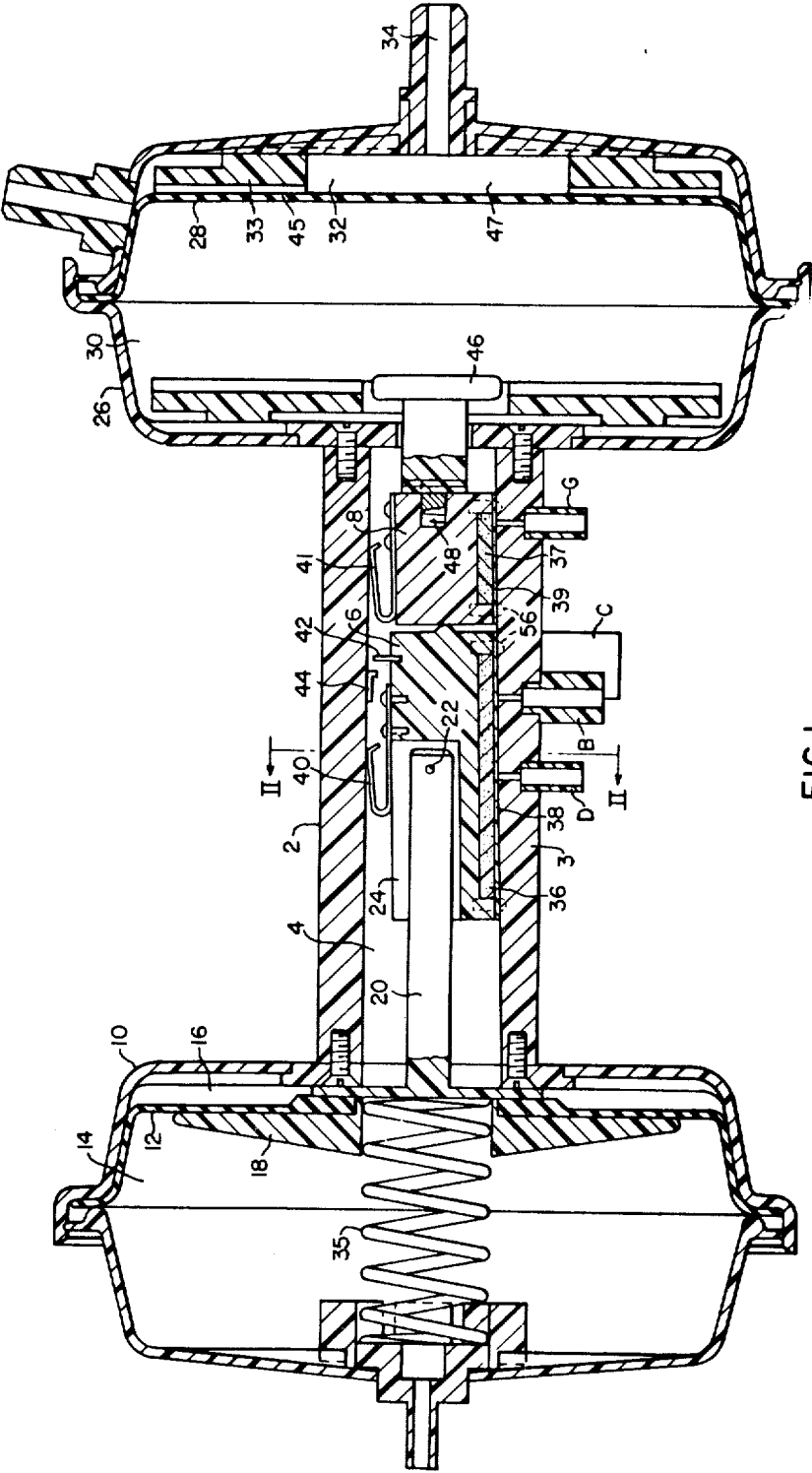


FIG. 1.

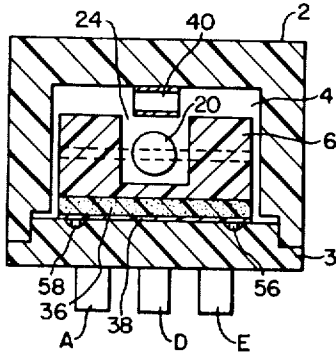


FIG. 2.

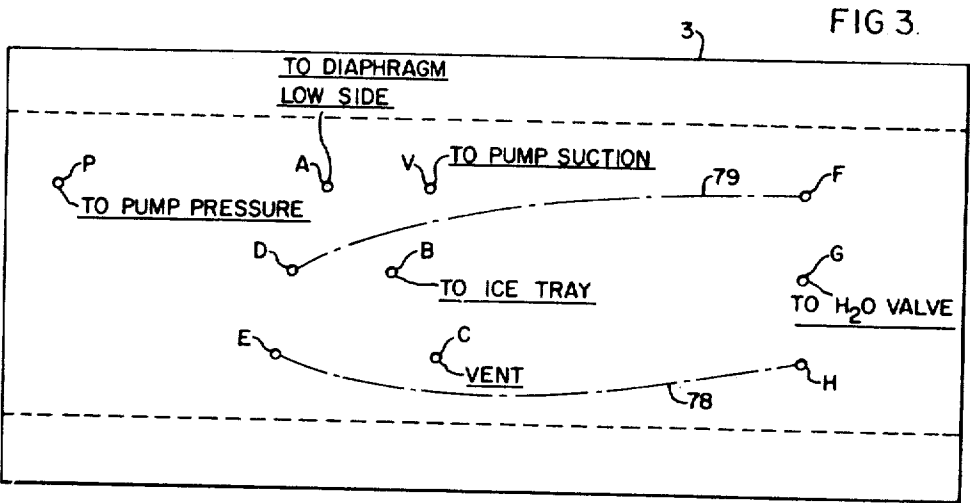


FIG. 3.

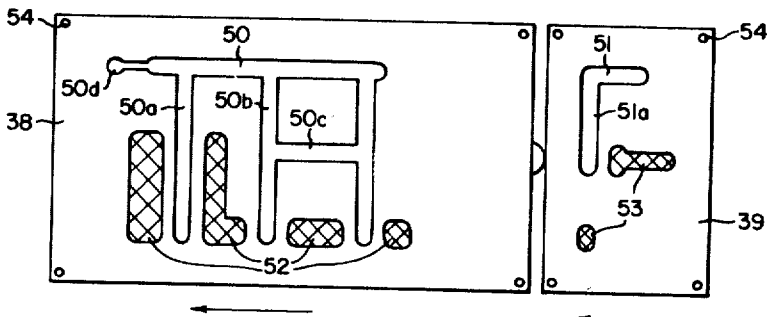


FIG. 4.

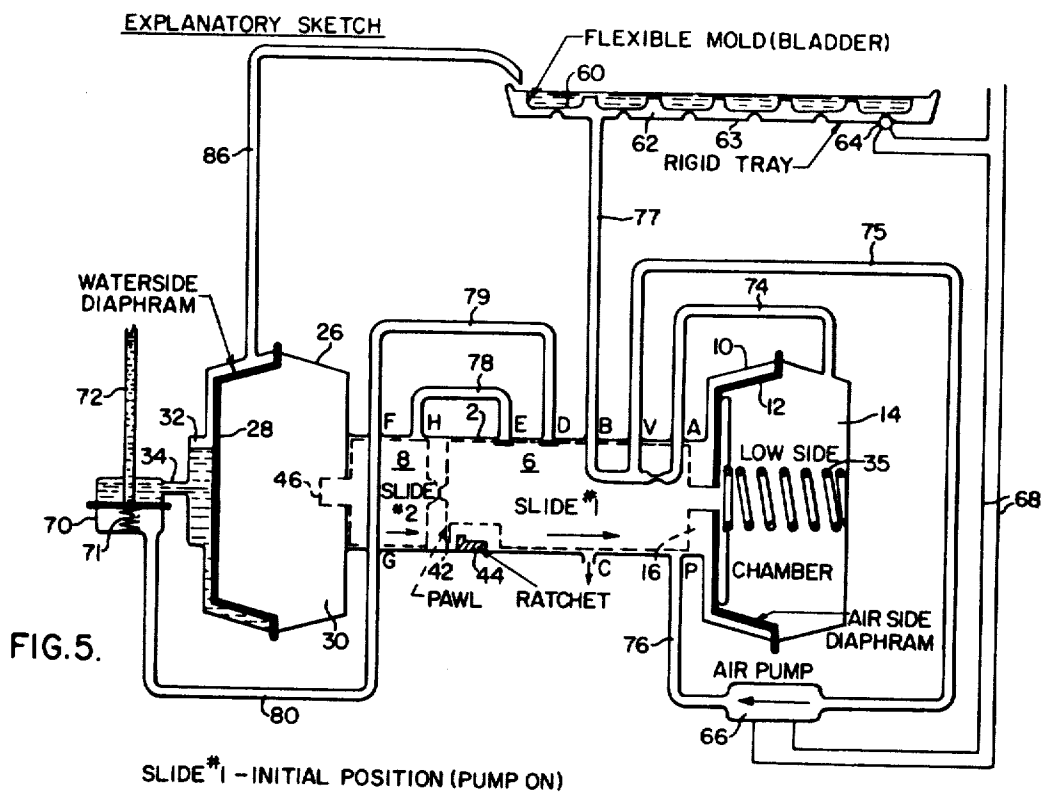
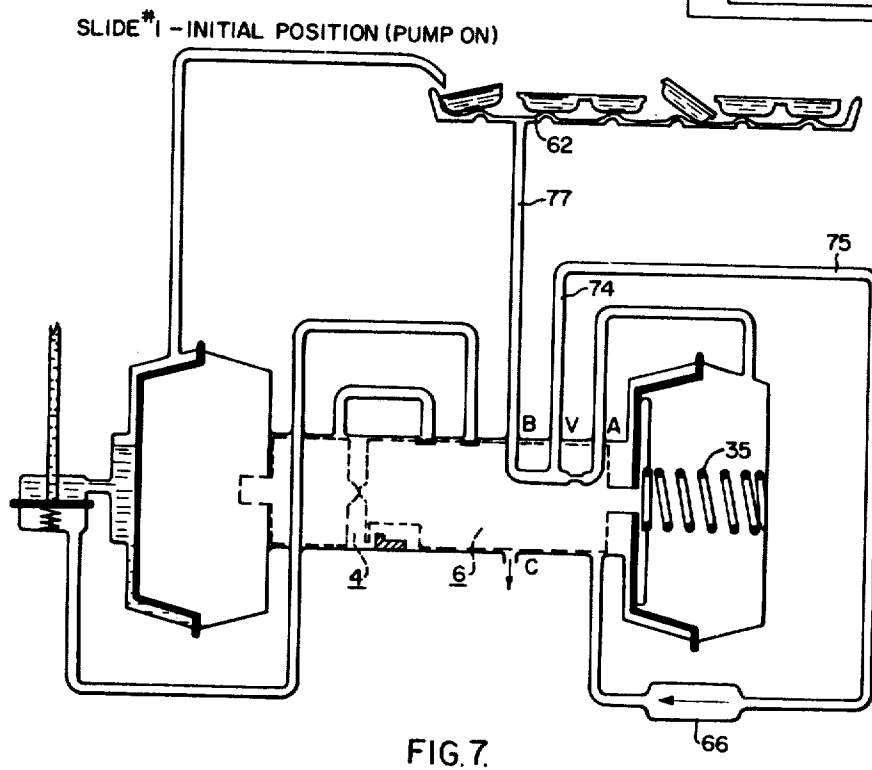
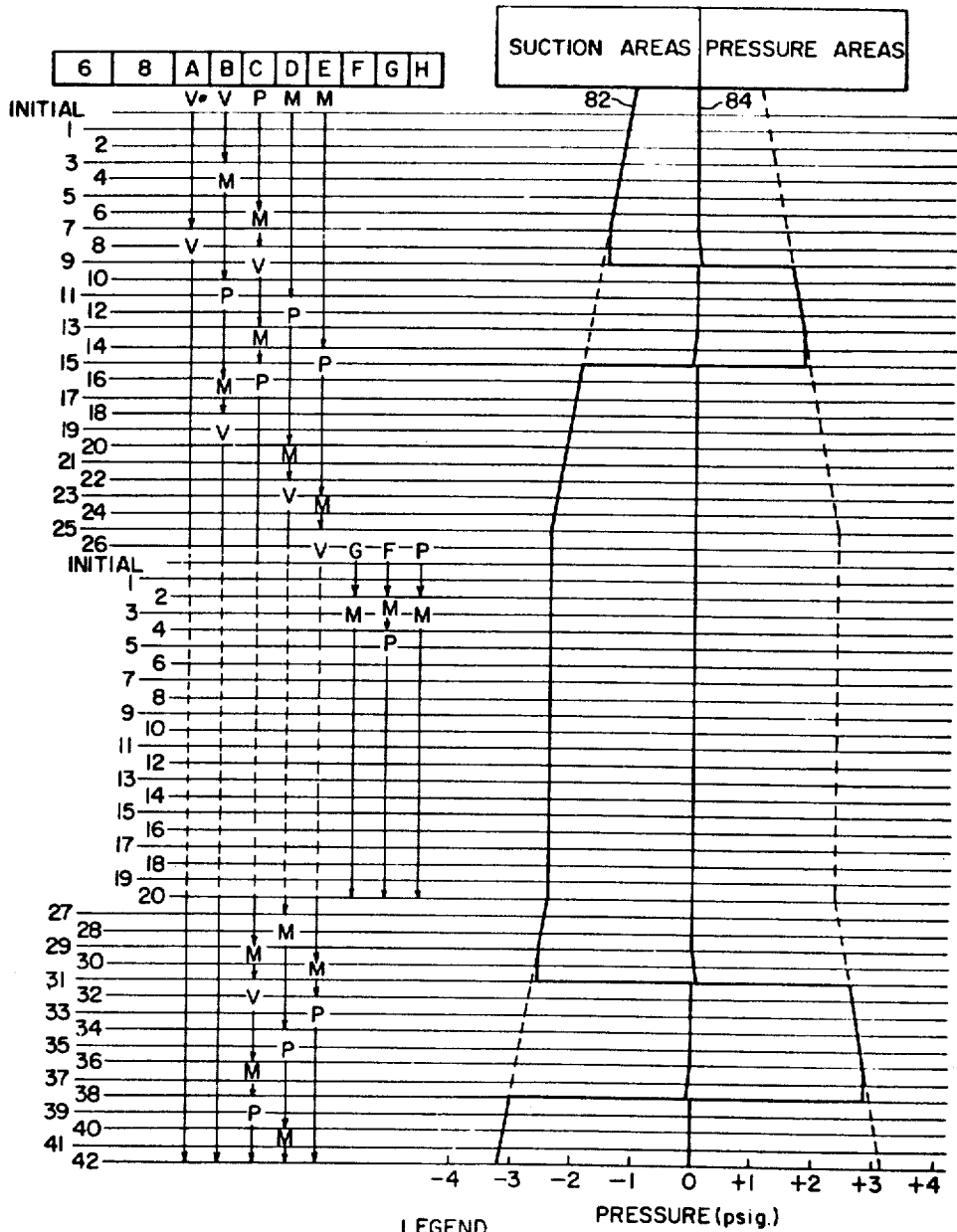


FIG. 6.



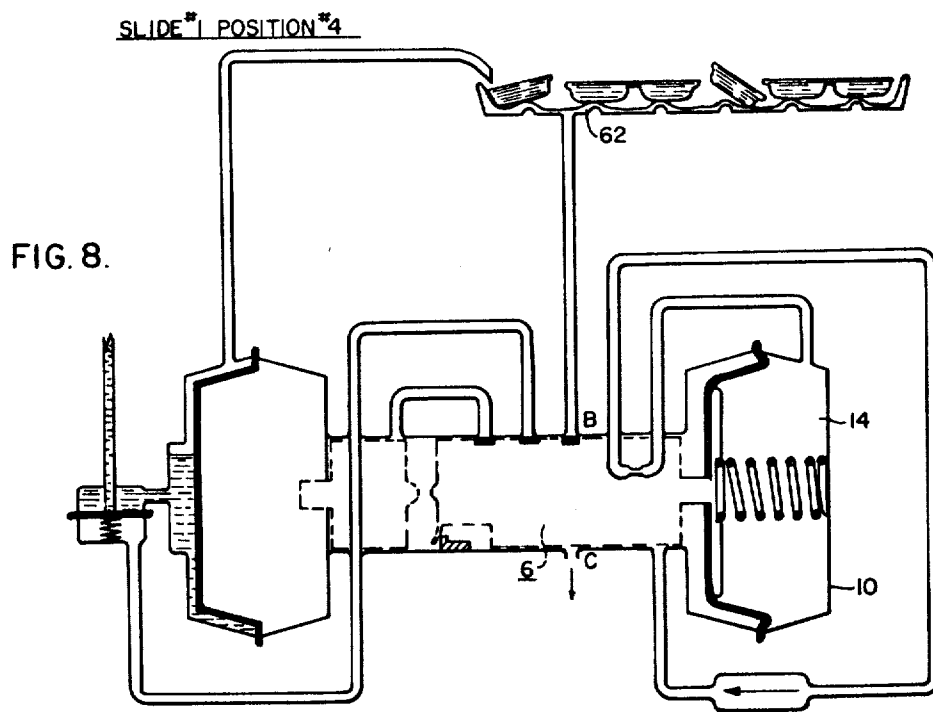
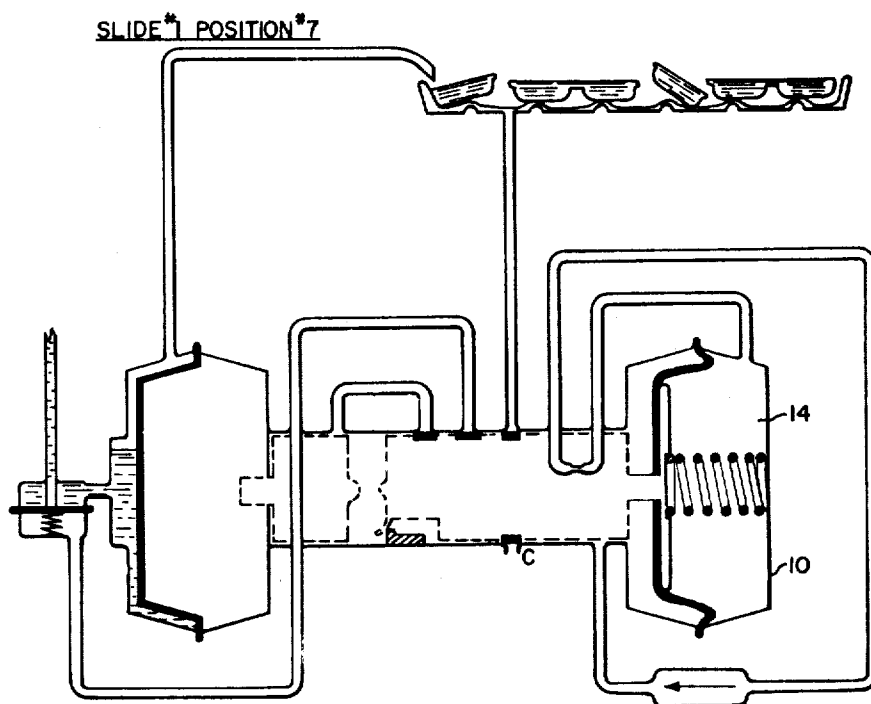


FIG. 9.

FIG. 10.

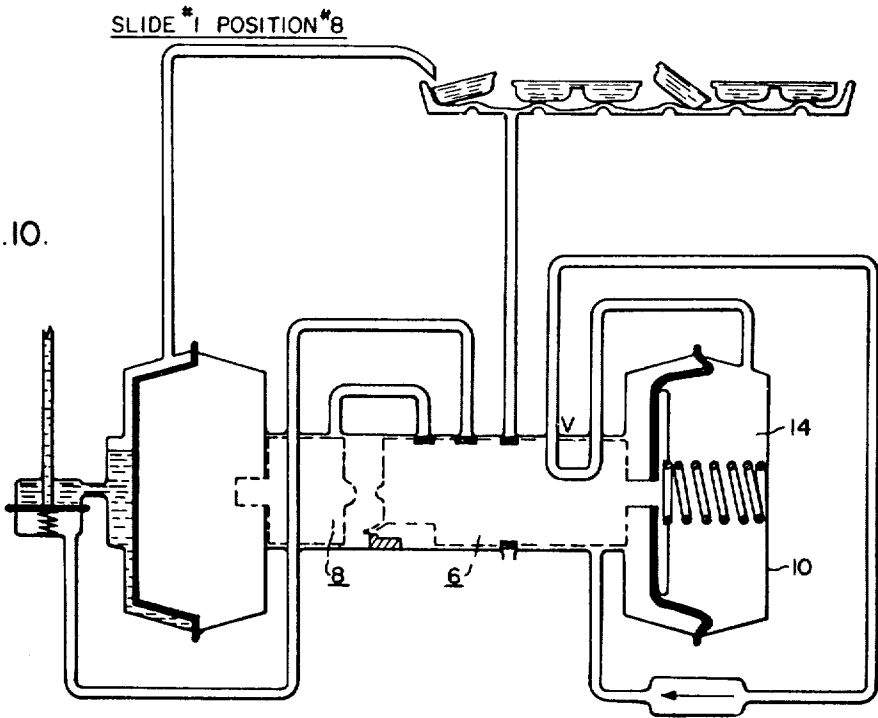
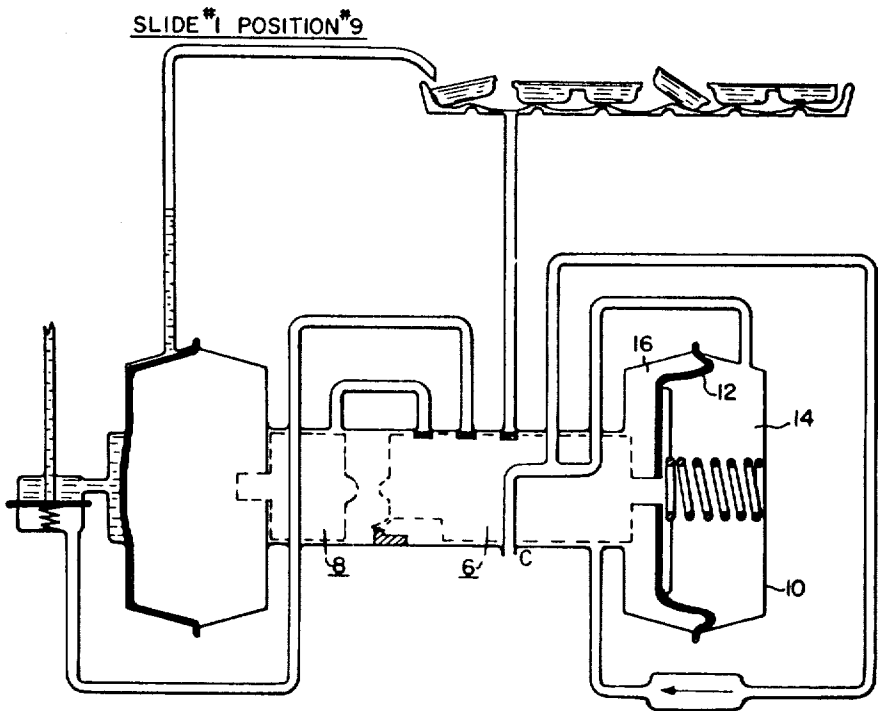


FIG. 11.



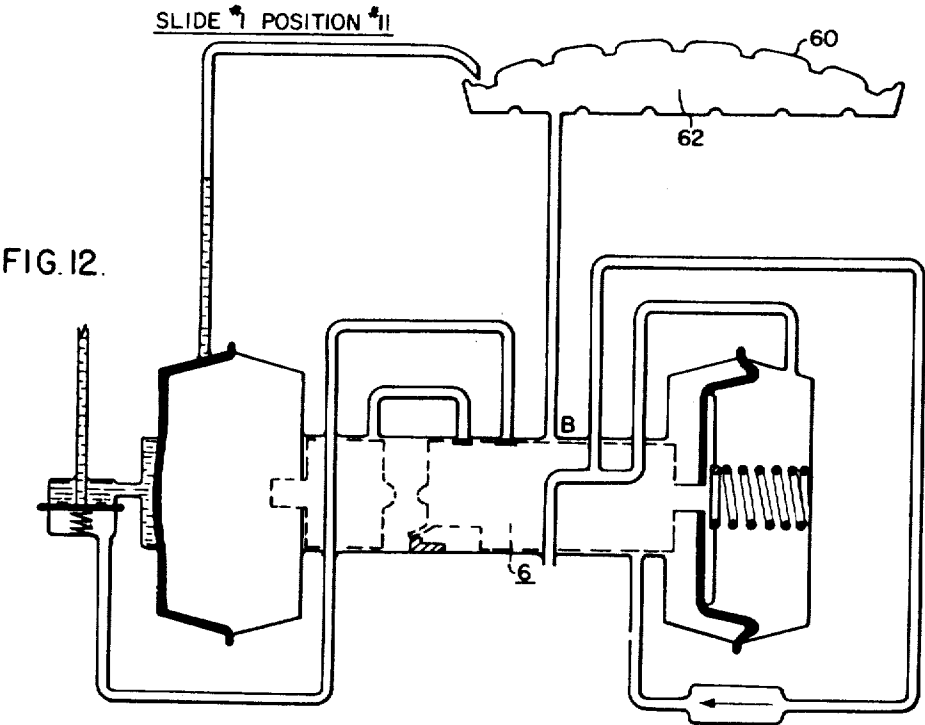
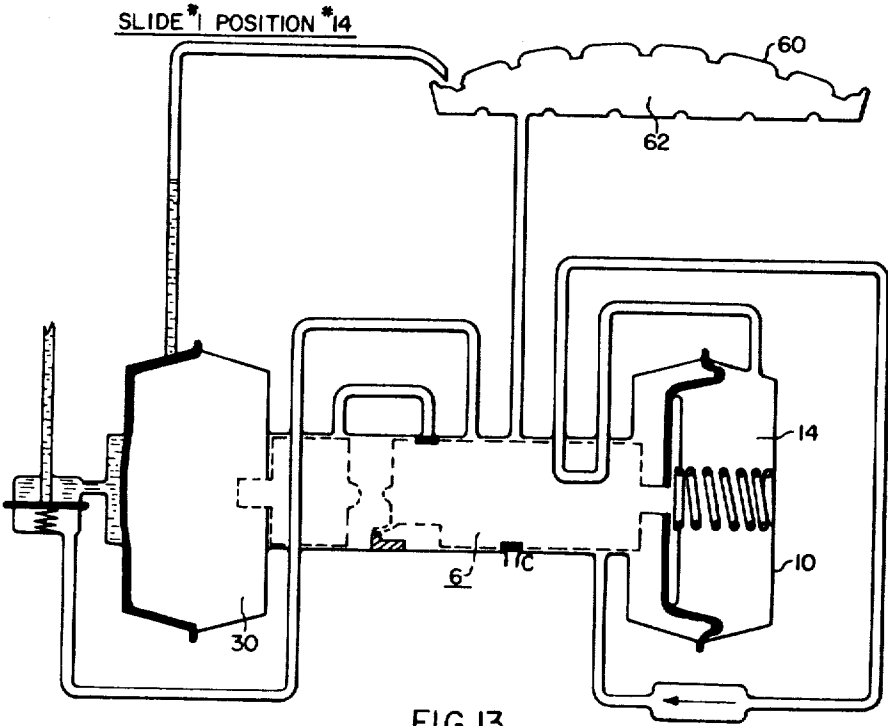


FIG. 14.

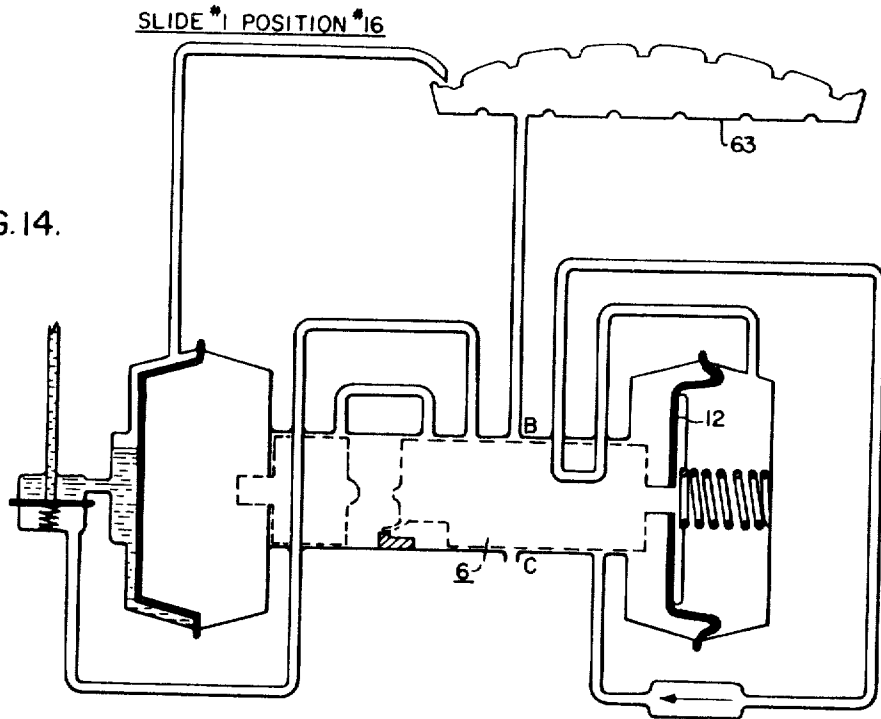
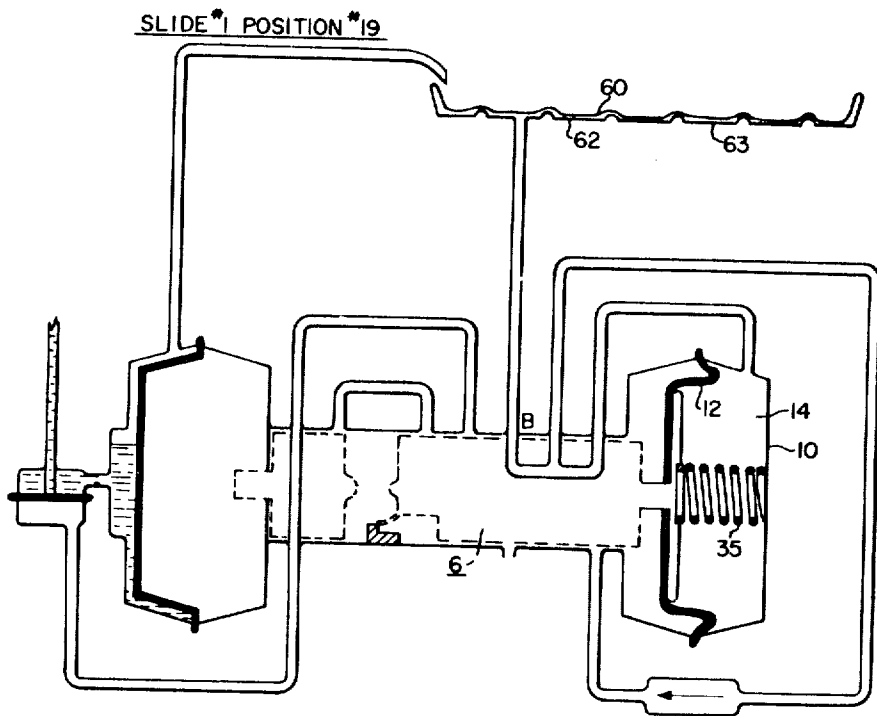
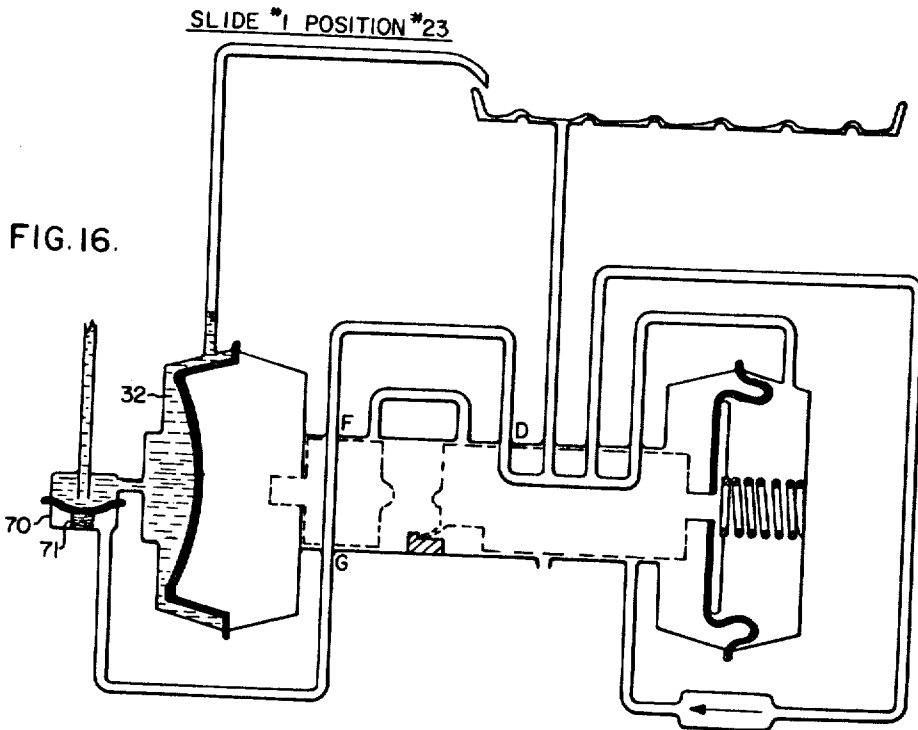
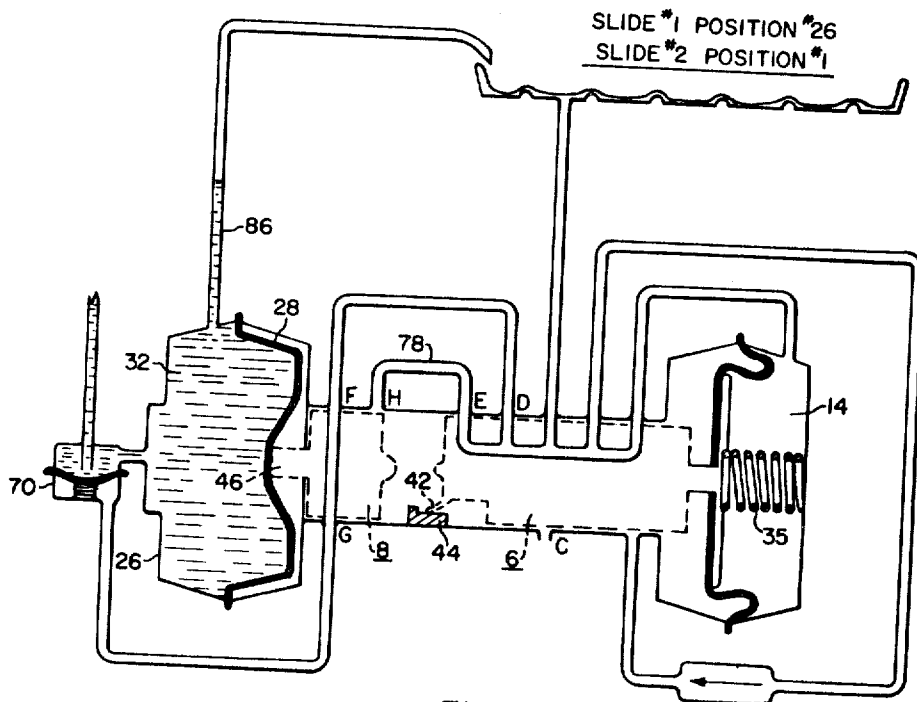


FIG. 15.



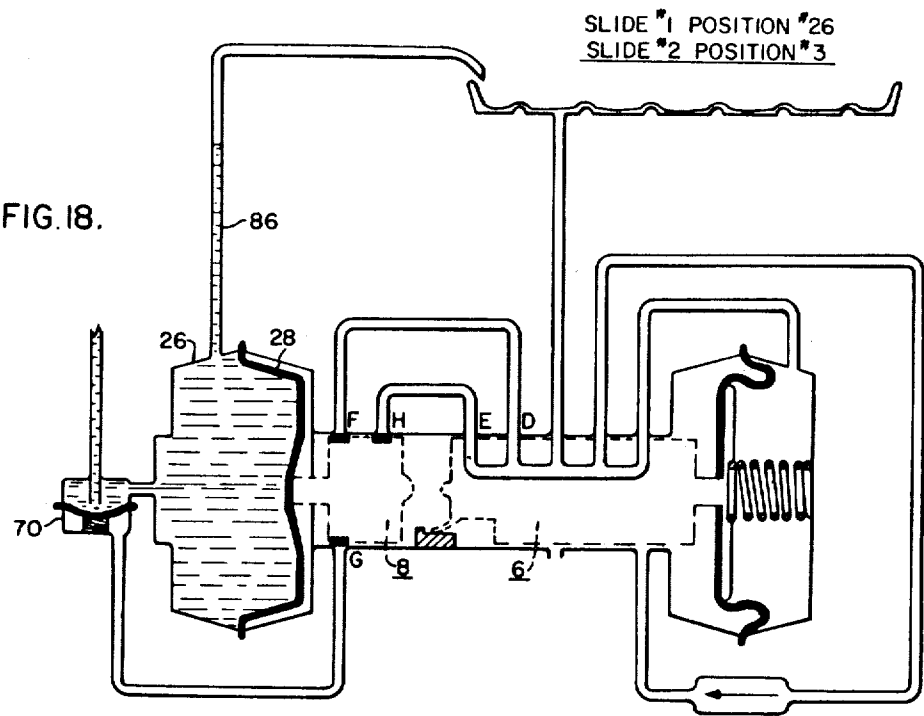
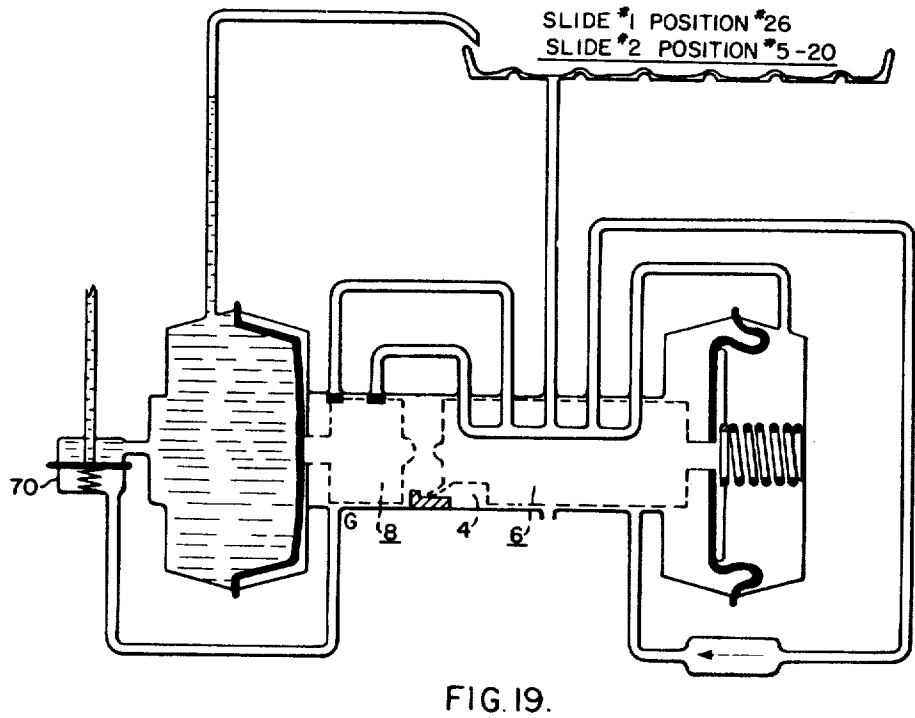


FIG.20.

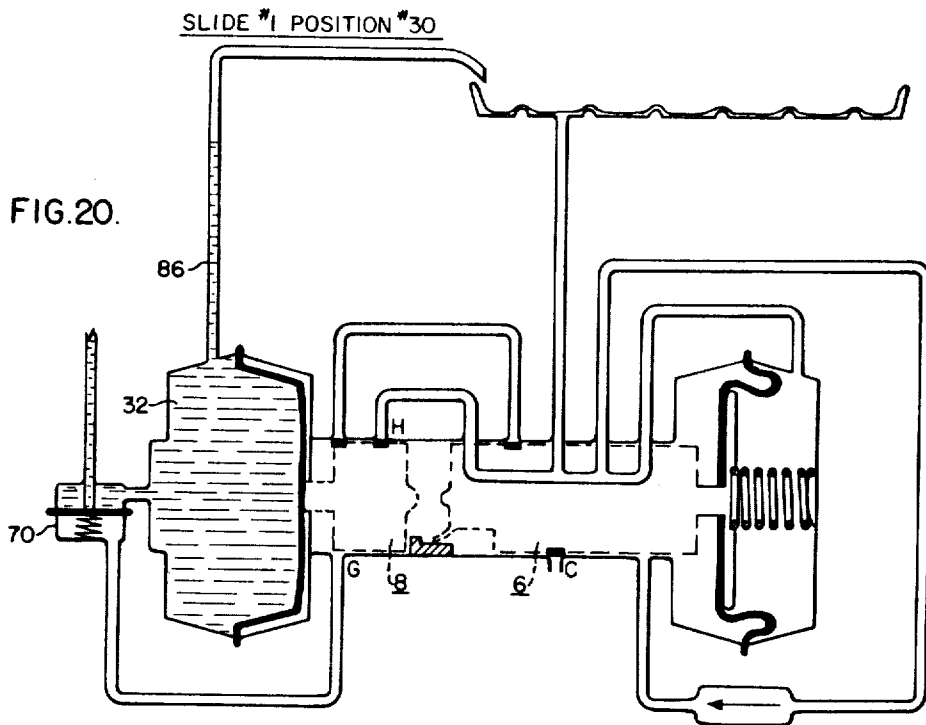
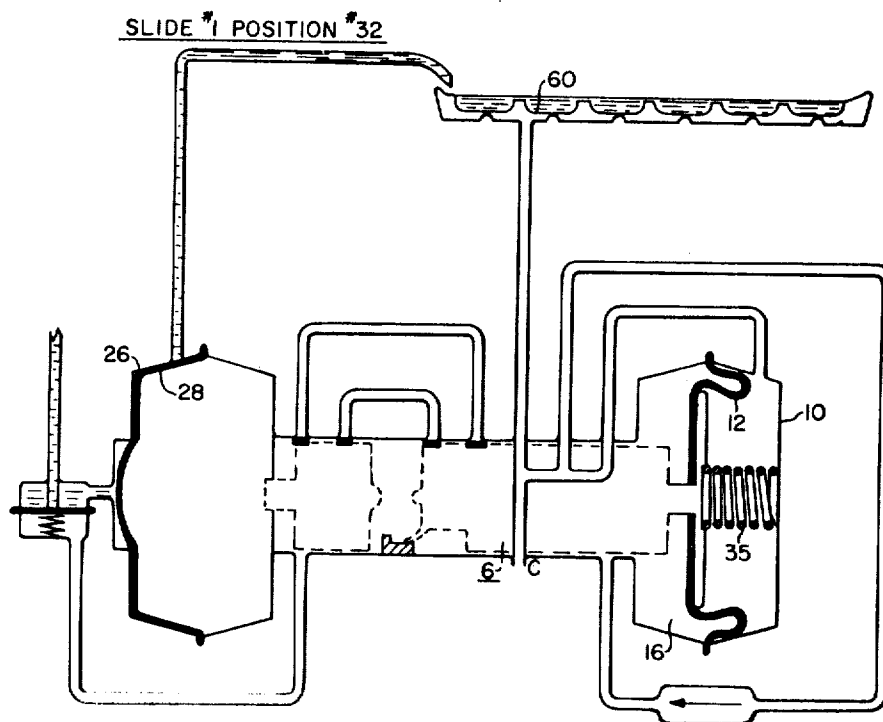


FIG. 21.



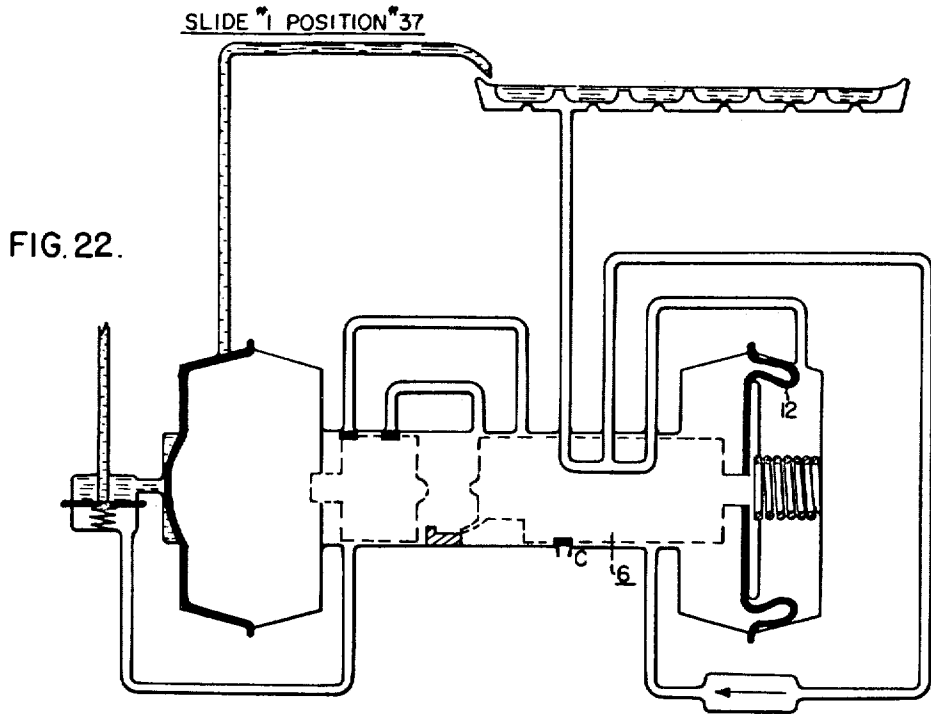
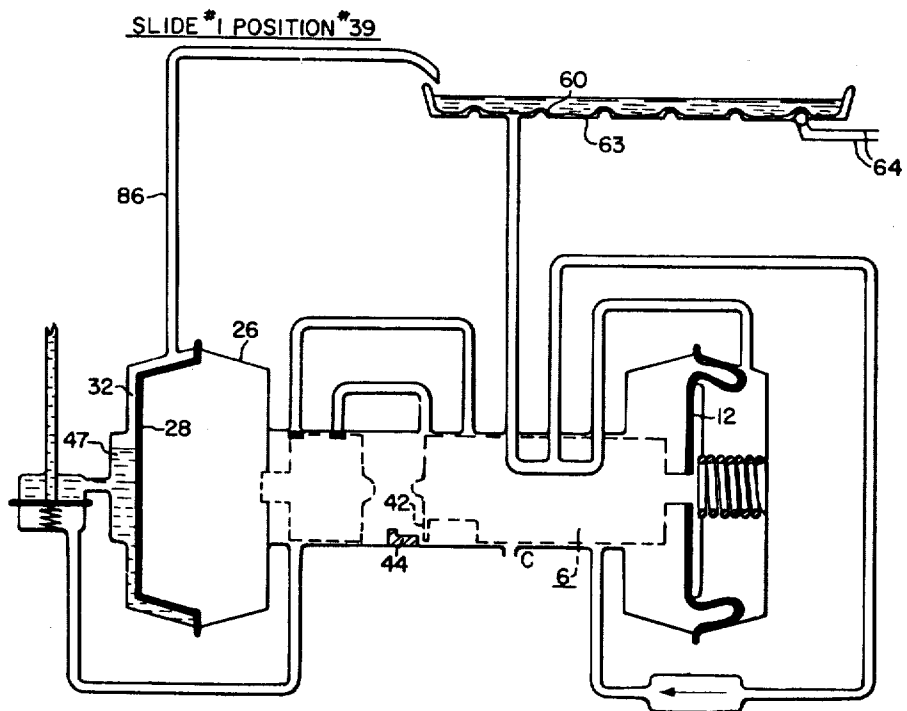
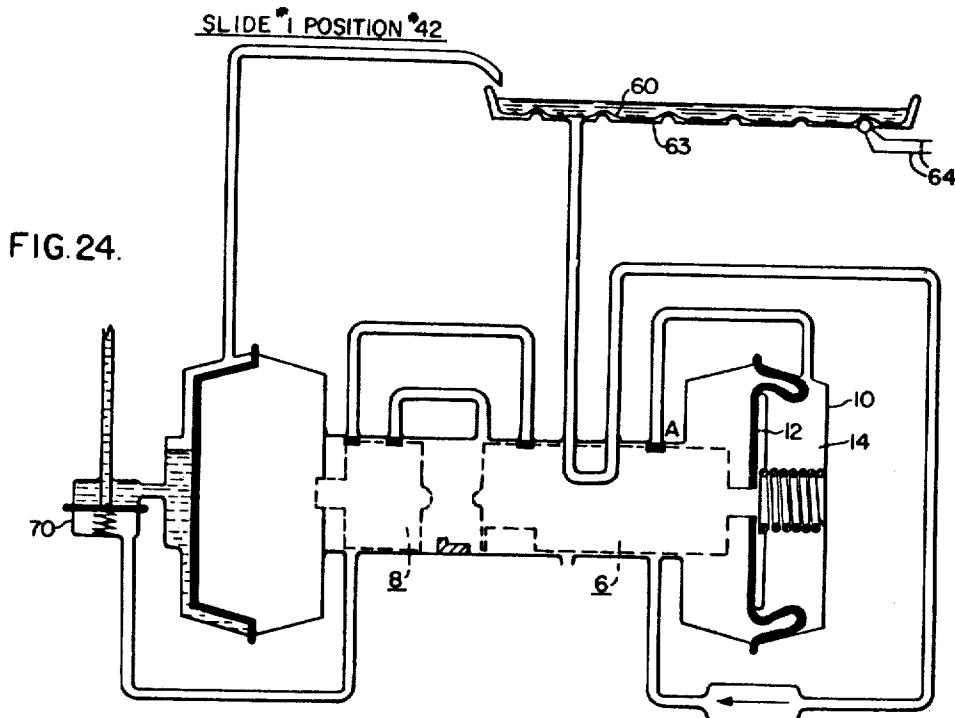
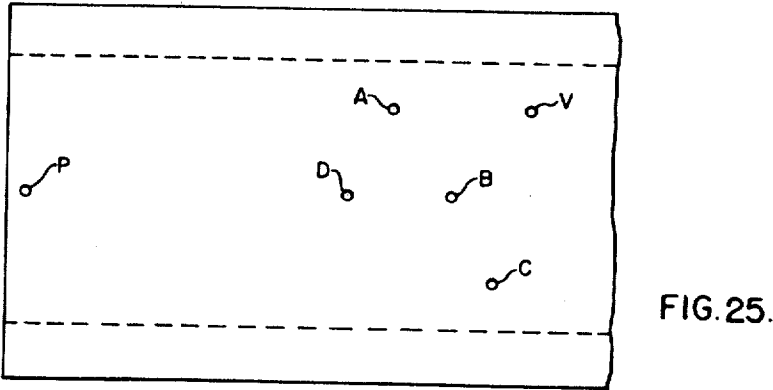
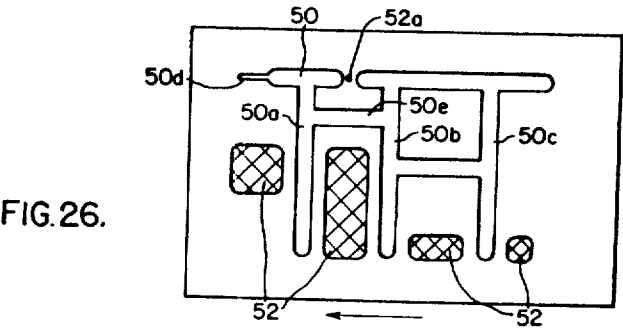


FIG. 23.



SELF-ADVANCING PROGRAMMER AND PRESSURE ACTUATED DEVICES CONTROL ARRANGEMENT

CROSS REFERENCE TO RELATED APPLICATION

This is a division of application Ser. No. 874,598 filed Nov. 6, 1969 and now U.S. Pat. No. 3,648,732.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to the art of control and programming systems.

2. Description of the Prior Art

Pneumatic control systems with programming mechanisms for automatically controlling the sequence of operation of pressure actuated devices, and in which pressure areas and suction areas are selectively placed in communication with such devices, are known as evidenced by U.S. Pat. No. 3,286,730, for example. In the arrangement there disclosed, however, a timer motor is used to control the advance of the member carrying the reading surface provided with the pressure and suction areas. Thus, the advance of the programmer is independent of the attainment of the pressure condition for actuating a given device.

As noted before, this invention is particularly adapted in one of its embodiments for controlling an automatic ice maker of the flexible mold type. Such flexible mold ice makers are also known as evidenced by U.S. Pat. Nos. 3,388,560 and 3,390,543 for example. However, in the taught arrangements for controlling such ice makers, a timer motor is typically used to control the sequence of operations through a fairly complex arrangement.

SUMMARY OF THE INVENTION

In contrast with the prior art time-controlled programmers, the programmer is self-advancing in accordance with the attainment of the desired pressure condition at any pressure actuated device controlled by the programmer. A pressure actuated device means a device actuated by either pressure or a vacuum as the term is used herein. In accordance with the invention in its broader sense of an arrangement including a pneumatic programmer which advances in accordance with the attainment of a given pressure condition effecting the actuation of a pressure actuated component, the arrangement includes means defining a chamber containing displaceable means therein separating the chamber into a higher pressure side space and a lower pressure side space, the displaceable means being biased toward the high side, means for selectively supplying and for selectively exhausting a fluid to and from the high and low pressure side spaces, respectively, to effect the displacement of the displaceable means in a direction toward the low pressure side in accordance with the pressure differential across the displaceable means, and means for selectively placing the pressure actuated devices in communication with either the high side or the low side space of the chamber in accordance with the character of the pressure condition required to actuate the device, and venting the opposite side space.

In the currently preferred form of the arrangement according to the invention, the programmer includes a body portion with one wall thereof provided with selec-

tively arrayed apertures to serve as a reading head along which interior slide means is movable to place suction areas and pressure areas arrayed on the slide means in registry with the apertures of the reading head. The slide means, or at least a portion thereof, is movable in accordance with movement of a displaceable member (diaphragm) located in a chamber at the end of the slide means. The diaphragm separates the chamber into a high pressure side space and a low pressure side space, and is biased toward the high pressure side space. The low pressure side space of the chamber is in normal communication with the suction areas of the slide means, while the high pressure side of the chamber is in open communication with the pressure areas of the slide means. Pump means is connected to the programmer and has a suction side in normal communication with the suction areas of the slide means and a pressure side in normal communication with the pressure areas of the slide means. The body portion also includes a venting aperture in the reading head which is disposed so as to be selectively placed in registry with either the pressure areas or the suction areas, or neither, to selectively vent or prevent venting of these areas as the slide is advanced. Accordingly, a vacuum may be built up in the low side space of the chamber, or pressure may be built up in the high side space of the chamber, or both vacuum and pressure may be built up. Conversely either the low side space or high side space may be vented. The positioning of the slide means is in accordance with the pressure differential across the diaphragm. This pressure differential, with the arrangement according to the invention, may exist as a result of pressure only, vacuum only, or both, all in accordance with the selective venting, or preventing of venting, through the venting aperture.

One or more pressure actuated devices are connected to one or more ports of the reading head. These devices may be of the character which require either pressure or a vacuum to actuate them to accomplish their intended function, or which require pressure at one time, and vacuum at another time, to accomplish their intended function. In the case of the application of the invention in an automatic ice making operation in which a flexible mold ice tray is used, it is desirable to first pull the flexible mold down away from the ice cubes to break them loose, thus requiring a vacuum first, and then inflating the mold to invert it and eject the ice cubes (thus requiring pressure), and finally to draw the flexible mold back into the tray to form water receiving pockets (thus again requiring a vacuum). The arrangement of the invention as applied to an automatic ice maker also includes provision for controlling the supply of water to the ice tray in which a water valve is controlled by the application of a vacuum and in which the pressure of the programmer is utilized to force water from a batch fill chamber to the ice tray.

The way in which the advance of the programmer is accomplished, while at the same time effecting the required pressure condition at the device to be actuated, is considered particularly interesting. The gist of the arrangement for accomplishing this is by selectively venting, and preventing venting, of the pressure and suction areas in accordance with the pressure condition to be applied to the devices, and also shifting to the

character of the pressure condition on the diaphragm which corresponds to the pressure condition to be applied to the devices.

Thus, when a vacuum is to be applied to a device, the programmer is arranged so that the pressure areas are vented (to prevent the existence of a pressurized space exerting a force upon the diaphragm), and movement of the diaphragm will be controlled solely by the attainment of an adequate vacuum to accomplish the desired purpose, and then a further increase in vacuum to make the diaphragm move further.

Then, assuming a pressure condition is to be applied thereafter to a device, venting of the pressure areas is prevented so that an increasing pressure is applied to the high side of the diaphragm, while a lower vacuum is pulled on the low side of the diaphragm, so that the diaphragm will advance in response to the increasing pressure differential thereacross to a position in which the suction areas are vented through the corresponding advance of the slide upon which the pressure areas and suction areas are presented. Now the further advance of the diaphragm and slide is under the control of the pressure areas so that an increasing pressure moves the diaphragm and slide to a position in which the device to be actuated by pressure is placed in communication with the pressure areas. The slide will not advance further until the device attains a pressure value exceeding the pressure at which communication is first established. Then as the pressure at the device and in the pressure areas continues to increase (because of the continued pumping action of the pumping means), the device will accomplish its intended function and the slide will advance farther to a position in which a shift may again be made to effect control through a vacuum condition on the low side of the diaphragm.

In summary then, the shifting of control between vacuum and pressure is made in accordance with the type of pressure condition required to actuate a particular device. During the shifting, a stall condition (including possible hunting) obtains while a pressure or vacuum condition is being built up in whichever of the areas (pressure or suction) which will achieve control from the other. For example, in shifting from a vacuum control to a pressure control, both the pressure and suction areas are first prevented from venting, which causes a fast rise in the differential across the diaphragm and a slight movement of the slide to a position in which the suction area starts to vent. This partial release of vacuum will correspondingly permit a decrease in the differential pressure across the diaphragm and, if sufficient to overcome the slide friction, will permit the slide to back-up slightly to a position again blocking or partly blocking the suction area from the vent. This permits a further fast increase in differential pressure and another advance of the slide to a suction area vent position. However, during this possible hunting condition, the pressure on the high side of the diaphragm is constantly increasing, while the vacuum on the low side is being relieved so that finally the differential pressure across the diaphragm, achieved wholly by pressure on the high side, exceeds the pressure differential existing when the pressure area was first prevented from venting. In this way the shifting of control is achieved, it being understood that in shifting from pressure control to vacuum control the

converse occurs. In any case, the advance through the steps of a cycle is in accordance with the attainment of a pressure condition for the particular device to be actuated, instead of an arrangement in which pressure or vacuum is applied to a device for a time period determined by the operation of an independent timer means and in which latter case there is no direct control of the pressure or vacuum level reached.

DRAWING DESCRIPTION

FIG. 1 is a vertical section of one form of a pneumatic programming valve for carrying out the invention;

FIG. 2 is a vertical section corresponding to one taken along the line II—II of FIG. 1;

FIG. 3 is a face view of the face of the valve body portion containing the array of apertures or ports and serving as the reading head of the programmer;

FIG. 4 is a face view of the array of pressure and suction areas provided in the reading sheet means movable along the reading head of FIG. 3;

FIG. 5 is a schematic view of an automatic ice maker system embodying the invention;

FIG. 6 is a chart which includes a tabular presentation on the left identifying the particular pressure condition at each of the ports of the readinghead of FIG. 3 at the various positions of first and second slides and includes a graphical presentation on the right showing the changes in the pressure conditions on both the high and low sides of the diaphragm;

FIGS. 7 through 24 are schematic views corresponding to the schematic view of FIG. 5 and illustrating the steps which occur during a complete cycle of the automatic ice maker; and

FIGS. 25 and 26 are views similar to FIGS. 3 and 4, but showing an array of ports and pressure and suction areas adapted to a single slide arrangement.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates one form of a programmer valve for carrying out the invention. The valve includes a center body portion 2 of hollow, generally rectangular cross section providing a rectangular bore 4 which accommodates a first slide 6 and a second slide 8.

An air pressure control chamber 10 is secured in sealed relation to the left end of the body portion 2 and contains a displaceable member in the form of a diaphragm 12 which separates the space to the left of the diaphragm in FIG. 1, characterized as the low pressure side space 14, from the space on the right of the diaphragm in FIG. 1 characterized as the high pressure side space 16. A backup plate 18 secured to the diaphragm for movement therewith seals the central opening of the diaphragm, and includes a rod extension 20 projecting into the bore 4 of the body portion 2. The right-hand end of the rod is pivotally connected at 22 to the first slide 6. FIG. 2 best shows the channel 24 provided in the block-shaped form of the first slide 6 to accommodate the rod 20.

At the right-hand end of the programmer as shown in FIG. 1, another bell-shaped chamber 26 is provided in sealed relation to the body portion 2. This chamber 26, which may aptly be termed the waterside chamber, includes a diaphragm 28 which separates the space 30 on

its left which is in open communication with the bore 4 and the high side space 16, from the space 32 on the right side of the diaphragm 28 and which is adapted to receive a batch of supply water for the ice maker through port 34 on the end of the chamber 26.

The first slide 6 (FIGS. 1 and 2) is of generally right rectangular block shape except for the channel 24 provided to accommodate the rod 20, and a recess extending for the width and most of the length of the bottom face of the block as viewed in FIG. 1. The recess accommodates a porous resilient material 36 such as an open cell urethane foam over which a thin reading sheet 38, which may be of Mylar material, is disposed. A leaf spring 40 carried by the opposite face of the block 6 presses the reading sheet side surface of the block tightly against the reading surface formed by the inner face of the lower wall 3 of the body portion 2.

The second slide 8 is of similar construction in that it also includes a recess in its one face which accommodates a urethane foam piece 37 over which lies a separate reading sheet 39, the second slide 8 being biased toward the reading head wall 3 by another leaf spring 41.

The first slide 6 is provided with a pawl element 42 in the form of a thin, semi-rigid strip seated in a slot extending across the width of the block 6, the free edge of the pawl element being adapted to engage ratchet means 44 secured to the inner face of the upper wall (as viewed in FIG. 1) of the body portion 2.

The slides 6 and 8 are shown in their at-rest position in FIG. 1 corresponding to a lack of differential pressure across the diaphragm 12. The movement of the slide 6 is toward the left as viewed in FIG. 1 in accordance with displacement of the diaphragm 12 toward the left corresponding to a differential pressure thereacross working against the bias of compression spring 35 in the airside chamber. The slides 6 and 8 are not attached, the second slide 8 being moved from its position in FIG. 1 to the left in accordance with displacement of the diaphragm 28 to the left as the space 32 is filled with water, to a position in which the diaphragm central portion abuts the head of an adjustable screw 46 which is turned into a bore 48 of the second slide 8. The return of the second slide 8 to its at rest position as shown in FIG. 1 is effected by the return of the first slide 6 at the end of the cycle. This will be understood better in connection with the explanation of the cycle as a whole in connection with FIGS. 7-24.

FIG. 3 is a view of the arrangement of ports or taps provided on the exterior face of wall 3 forming the reading head of the programmer. These taps are connected through small diameter bores (FIG. 1) to the inner face of the wall 3, the inner ends of the bores being arrayed to form the reading surface. The legends associated with FIG. 3 indicate the connections from each of the taps, while the dash lines extending between taps D and F, and between E and H, indicate an external tubing connection between these taps.

FIG. 4 illustrates the array of the suction areas 50 and 51 on the two sheets, as well as the array of the pressure areas 52 and 53 (cross hatched areas) on the two sheets. The form of the suction areas 50 and 51 is simply that of channels molded or embossed in the face of the reading sheets, while the areas characterized as pressure areas are simply apertures in the sheets. While

the areas 50 are characterized as suction areas since they normally function as conduits for placing one or another element in communication with a suction space, at those times during the cycle when the suction areas are in communication with the vent C the suction areas will be essentially at atmospheric pressure. The same holds true for the pressure areas which at times will be essentially at atmosphere when one or another of them is in registry with the vent C. Since the pressure areas are simply apertures in the reading sheet means, and because of the porous nature of the underlying foam pieces 36 and 37, the pressure area spaces are in open communication with the bore space 4 within the central body portion 2, as well as in open communication with the space 16 and the space 30 on the inner sides of the diaphragm 12 and 28, respectively.

The array of the suction and pressure areas of FIG. 4 is especially selected in accordance with the array of the taps on the reading head 3 of FIG. 3, with the exception of the tap P which is connected to the pressure side of a pump, and which may be placed in any position in which it is in open communication with the interior bore 4 of the body portion 2. The reading sheets 38 and 39 are secured relative to the slide blocks 6 and 8 against displacement by being provided with holes 54 in each corner which receive small bumps 56 (FIGS. 1 and 2) at the corners of the blocks. These bumps 56 also are received in channels 58 extending through the length of the body portion 2 to serve as tracks for the blocks. It is noted that the provision of an arrangement of reading head having a reading surface against which a thin sheet reading means is pressed by porous urethane foam arrangement is disclosed in U.S. Pat. No. 3,286,730 noted heretofore. The invention is not dependent on such an arrangement however, since the reading means may also take the form of a graphite block with a machined surface provided with grooved areas forming the suction areas, and in which the pressure areas are simply holes drilled through the block to place them in open communication with the interior high side space of the valve body.

Reference should now be had to FIG. 5 for a schematic showing of an overall arrangement of an automatic ice maker system in which the invention is utilized to carry out the operating cycle. Parts shown in addition to those described heretofore include a flexible mold ice tray of known character in which the flexible bladder 60 forms the ice cube pockets in its normally unstressed position, and which may be inverted by pressurizing the space 62 between the rigid tray section 63 and the bladder. The tray is also shown as being provided with a thermostat 64 having a switch which controls the power to pump means 66 through the electrical conductors 68. The pump 66 may be a simple diaphragm pump of relatively limited capacity and power since a system as described will operate quite satisfactorily with the pump being capable of producing as little as three and a half pounds per square inch pressure. The system also includes a pneumatically operated water valve 70 which is biased closed by a spring 71 and is openable to permit the introduction of water from water supply pipe 72 into the space 32 in the water side chamber 26. The other parts of the system as shown in FIG. 5 include the connecting tubes which are as follows. Tube 74 connects the low pres-

7

8

sure side of air side chamber 10 with tap A; tube 75 connects the suction side of the pump 66 with tap V, tube 76 connects the pressure side of the pump 66 with tap P, tube 77 connects the space 62 between the rigid portion and the flexible portion of the ice tray with tap B, tube 78 connects tap E with tap H, tube 79 connects tap D with tap F, and tube 80 connects tap G with the water valve.

The showings in FIG. 5 and 7-25 are schematics in which the tap positions do not correspond with the actual tap positions but are rearranged for a better understanding of the operation of the system. Further, the orientation of the programmer valve is reversed relative to FIG. 1.

Before proceeding with a detailed description of the steps of an operating cycle of an arrangement according to the invention, reference is had to FIG. 6 which shows in tabular and graphic form essentials of the operation of the arrangement in a full cycle. In that connection, the positions which the first slide 6 assumes in a total cycle are numbered from 1 to 42, while the positions that slide 8 assumes are indicated as 1 through 20. The pressure condition for each of the ports at any position of either slide is indicated by the letters P indicating pressure, V indicating vacuum, and M indicating the particular tap or port is masked or blocked off. An asterisk in connection with the vacuum indication denotes a throttled vacuum condition. The graphical presentation shows the change in pressure in the low side space 14 of the chamber 10 as the slides progress, and also the changes in pressure throughout the bore space of the valve body portion and the communicating spaces on the inner sides of both diaphragms. Curve 82 indicates the low side pressure while curve 84 indicates the high side pressure. While the numerical values of the pressure condition are shown in connection with the graph, it will be appreciated that other values would obtain for a different arrangement depending upon the service to be performed and the values required to actuate whatever pressure actuated devices were involved.

FIG. 7 - MAIN SLIDE INITIAL
POSITION - PUMP ON

The pump 66 has been energized in response to sensing that the ice cubes are frozen and that a harvesting cycle is in order. In this position the vent C is in communication with one of the pressure areas so that the interior bore 4 and communicating spaces will be at atmospheric pressure. The suction side of the pump is connected by tube 75 and the V tap to the lengthwise extending portion 50 (FIG. 4) of the suction area and thence through the first cross leg 50A, which is in registry with the B tap and through tube 77 to the space 62 between the bladder and rigid part of the tray. Since direct suction is applied to the bladder, the air is evacuated from the space 62 and a high partial vacuum is obtained. The atmospheric air forces the bladder down against the interior of the tray and the cubes are prestripped from the bladder. At the same time the throttled portion 50D (FIG. 4) of the suction area, which throttle portion is formed by providing a narrower groove in the lengthwise portion of the suction channel 50, is in registry with the tap A which leads

through tube 74 to the low side of the diaphragm 12. This arrangement initially restricts the rate at which air is drawn from the chamber and the rate at which a partial vacuum is obtained in the space on the low side of the diaphragm. When the differential pressure across the diaphragm increases to the point where the force on the diaphragm overcomes the initial compression force of the spring 35, the first or main valve slide 6 starts to move. Thus, a time delay of approximately 15 to 20 seconds is provided for the prestripping operation of the ice cubes in the arrangement as shown.

While it is not considered necessary to refer to FIG. 6 in connection with each of the positions of the programmer, perhaps a better understanding of the information provided in FIG. 6 will be afforded if an example is given of the meaning of some of that information in connection with the early slide positions. The V asterisk in the A port column indicates the throttled vacuum at the port which exists until position 8 of the first slide is attained. The V designation in the column under the B port indicates a vacuum condition at the port which exists until the main slide has reached its number 4 position. The value of this vacuum may be determined by referring to the suction area line at the right of FIG. 6, which indicates the vacuum is increasing on the average in the first slide positions from 1 through 6. The designation P under the port identified as C indicates that the vent port C is in communication with a pressure area of the reading means. The value of this pressure area is seen to be atmospheric pressure by referring to the heavy line 84 of the graphical portion of FIG. 6. This atmospheric pressure exists until the main slide has passed through its position number 7. Port D is indicated to be masked, which means that it is in registry with an area of the reading sheet which is neither suction area nor pressure area. The same situation exists for port E.

FIG. 8 - MAIN SLIDE POSITION 4

The port B which leads to the ice tray is masked from the suction of the pump in preparation for inflation of the bladder. The main slide 6 will continue to move to the right. It is noted at this point that since the pump suction is directly connected to exhaust the air from the tray space 62 while the low side space 14 of the airside chamber 10 is in throttled communication with the pump suction, the attainment of the substantial vacuum in the prestripping operation is not only more rapidly achieved but is also required to be achieved before it is possible to obtain a significant vacuum in the low side space. As a result, the attainment of the desired vacuum condition for prestripping is a pre-requisite to subsequent substantial movement of the main slide 6 to a next position.

It will be noted in FIG. 8 that the pressure areas of the reading means remain in communication with atmosphere through vent C.

FIG. 9 - MAIN SLIDE POSITION 7

In this position the venting of the pressure areas is terminated because the vent port C is in registry with a portion of the reading means which is neither suction nor pressure area. Accordingly, the pressure in the pressure areas and all communicating spaces begins to rise above atmospheric pressure while suction con-

tinues to be applied to the low side space 14 of the air chamber 10. However, the throttling effect is still present until the main slide moves to position 8. Accordingly, the rise in differential pressure is not substantially different from the rate of rise in the previous positions.

FIG. 10 — MAIN SLIDE POSITION 8

In this position it will be noted that the throttling effect between the pump suction portion V and the low side 14 of the air chamber 10 has been removed because of the distance of shift to the right of the main slide 6 at this position 8. It will also be noticed that the auxiliary slide 8 has remained in its initial position and that the main slide has drawn some distance therefrom.

FIG. 11 — MAIN SLIDE POSITION 9

When the main slide 6 reaches this position the suction areas and the communicating low side space 14 of the air chamber 10 are vented through port C to atmosphere. A stall and possible hunting condition of the main slide may obtain at this point since the release of suction from the low side of the air chamber may reduce the differential pressure across the diaphragm at a faster rate than the pressure build up on the pressure side space 16 of the diaphragm can increase. However, to the extent that the slide shifts backwardly (if at all) to its position 8, the venting of the low side is terminated. This permits a further fast increase in differential pressure and another advance of the main slide to the right to a suction area vent position. As this hunting continues however the pressure on the high side of the air diaphragm is constantly increasing while the suction on the low side is decreasing so that finally the differential pressure across the member, achieved wholly by pressure on the high side, equals and then exceeds that pressure differential existing when the suction areas were first vented. This change from a suction condition maintaining the position of the slide, to a pressure condition maintaining the position of the slide is graphically illustrated in FIG. 6 in which the horizontal line at position 9 represents the change. At this time it is well to appreciate that the horizontal character of the line does not indicate an immediate change, but rather indicates the final result. In that connection it is also noted that the position indications are not indicative of the expiration of equal increments of time. Thus, the horizontal line portions of the curves 82 and 84 of FIG. 6 occupy a period of time which may well be in excess of the period of time for the main slide to move through several successive numerical positions during a period when a stall or hunting is not occurring. With the pressure control finally attained in position 9, continued pressurization in the pressure areas in communicating spaces will displace the diaphragm 12 farther to the right and accordingly pull the main slide 6 farther to the right.

FIG. 12 — MAIN SLIDE POSITION 11

At this position the B port is in registry with a pressure area so that pressurized air flows into the tray cavity 62 to begin inflation of the bladder 60. This flow of air for inflating the bladder restricts the rate at which pressure can be built up and results in stalling of the

main slide 6. Since the pump continues to force air to the pressurized areas and communicating spaces in an attempt to maintain the necessary pressure differential to hold position 11, the bladder continues to inflate. It finally becomes inverted causing the cubes to fall off into the cube receiving receptacle (not shown). Continued inflation forces the bladder into a taut inverted position. Further pumping causes an increase in pressure in the pressure areas and a resultant farther advance of the main slide.

In connection with the operation of pressurizing the bladder, the shifting from a vacuum control condition to a pressure control condition upon the air diaphragm precedes the step of inflating the bladder. This permits the type of operation in which the advance of the slide beyond a certain position requires the attainment of the necessary pressure condition of the pressure actuated device, which in this case is the ice tray with the invertible bladder. In other words, with a pressure control condition upon the diaphragm, the slide cannot advance to a position beyond position 11 of the main slide until it is assured that the bladder has been inverted. In this connection of course, it will be appreciated that the bladder material must be selected so that the inversion can be effected with a pressure corresponding to that existing upon the high side of the diaphragm at the number 11 position and that the bladder be sufficiently stiff in its inverted position that it will not stretch easily with a further increase in pressure of the order necessary for the continued advance of the main slide.

FIG. 13 — MAIN SLIDE POSITION 14

In this position the suction area of main slide 6 has moved out of registry with the vent port C so that suction will be again applied to the low side space 14 of the airside chamber 10. The high side of the diaphragm and pressure areas are also prevented from venting so that continued operation of the pump effects an increasing pressure differential and a corresponding advance of the main slide. The communication between the tray cavity 62 and the pressure areas is maintained in this position.

FIG. 14 — MAIN SLIDE POSITION 16

In this position a pressure area is in registry with the vent port C so that the pressure areas and communicating spaces are vented to atmosphere. This occurs for the purpose of again shifting control from a pressure condition upon the airside diaphragm 12 to a vacuum condition. As has been explained previously in connection with the shift from a vacuum to a pressure control condition, a stall and possible hunting condition obtains while the shifting of control is occurring. The bladder remains inflated because the B port is in registry with an area of the reading sheet means which is neither suction area nor pressure area.

After sufficient air flow has occurred, to exhaust the high side spaces and the requisite vacuum has been built up in the space 14 on the low side of the diaphragm, the diaphragm 12 and main slide 6 will continue to advance.

Masking of the B port connected to the tray 63 occurs as the slide advances beyond position 16 and through positions 17 and 18.

FIG. 15 — MAIN SLIDE POSITION 19

The B port connected to the tray cavity 62 is now in registry with the suction area which tends to destroy the partial vacuum and reduce the pressure differential across the diaphragm 12. This results in the valve stalling and possible hunting. Continued pumping however removes the air from the tray cavity and deflates the bladder 60 as shown. When the bladder is pulled down tightly against the tray 63 the partial vacuum in the low side space 14 of the air chamber 10 and the tray increases to the point where the pressure differential across the diaphragm can again cause the main slide 6 to advance against the force of spring 35.

FIG. 16 — MAIN SLIDE POSITION 23

In this position the D port, which is externally connected to the F port in the portion of the reading head associated with the reading means carried by the second or auxiliary slide 8, is partly in registry with a suction area of the reading means of the main slide 6. The suction area 51 (FIG. 4) of the reading sheet 39 of the auxiliary slide is of L-shaped configuration, and the crosswise portion 51A of the suction area conveys a vacuum to the G port which leads to the water supply valve 70. Accordingly, this vacuum opens the valve against the bias of the spring 71 and admits water to the water batch space 32 of the water side chamber 26.

FIG. 17 — MAIN SLIDE POSITION 26 —

AUXILIARY SLIDE POSITION 1

In this position port E is in registry with a suction area of the main slide 6 reading means. Port E is externally connected by tube 78 to port H of the reading head part associated with the auxiliary slide means 8. Since port H is in registry with a pressure area on the second reading means, in this position of the second slide, and since the C port is open to atmosphere, a partial venting condition obtains with respect to the suction areas of the main slide and the low side space 14. The result is a stall condition of the main slide. That is, if the main slide attempts to advance, the increased venting will prevent it by decreasing the pressure differential. However, if the main slide 10 slides back very far, the port E loses registry with the suction area and halts the venting. This throttling condition will hold the main slide in position 26 until the partial venting is broken by movement of the second slide causing the H port to lose registry with a pressure area.

It will also be noted in FIG. 17 that the position of the main slide is now such that the pawl 42 has passed over the first notch of the ratchet 44 to provide insurance against a return of the main slide beyond the position in which the pawl engages the first stop of the ratchet.

The water valve 70 is maintained in an open position due to the suction applied thereto through the previously noted connections. This level of vacuum then obtaining is sufficient, because it is equal to the pressure differential required to hold the main slide 6 against the biasing spring 35, to open and hold open the water valve. Water then slowly flows into the water batch space 32 of the water side chamber 26 and fills the space. This forces the water side diaphragm 28 against the protruding head 46 (FIG. 1) of the auxiliary slide.

The water then starts to go up the delivery tube 86 so that the pressure in the water side of the chamber increases in accordance with the increase of the head of water in the delivery tube. Thus the force of the water side diaphragm pushing against the auxiliary slide increases. A head pressure of one-half to one and a half feet of water is sufficient to overcome the static friction holding the second slide so that thereafter the water side diaphragm pushes the auxiliary slide toward the main slide.

FIG. 18 — MAIN SLIDE POSITION 26 —

AUXILIARY SLIDE POSITION 3

In this position the auxiliary slide 8 has advanced sufficiently that all of the ports F, G, H associated therewith are masked. This closes off the vacuum connection from the ports D and E in registry with the suction areas of the main slide 6. Thus the partial venting condition through port H is eliminated so that the main slide is again in a position for advance. Since the vacuum which has obtained on the water valve 70 is maintained with the G port masked off, the water valve remains open and water continues to flow into the water side chamber 26 and rise in delivery tube 86. This of course increases the pressure on the water side diaphragm 28 and results in the auxiliary slide advancing farther.

FIG. 19 — MAIN SLIDE POSITION 26 —

AUXILIARY SLIDE POSITIONS 5-20

The auxiliary slide 8 in advancing to position 5 results in the registry of the G port with a pressure area of the auxiliary slide reading means. Since the pressure area is in open communication with the bore 4 of the valve body, which in turn is vented because of the position of the main slide 6, the vacuum to the water supply valve 70 is also vented and results in closure of the valve. It is also here noted that the subsequent pressurization of the pressure areas during expelling of the water will result in the same pressure being applied to the water valve to assure a positive shut off of the water valve.

FIG. 20 — MAIN SLIDE POSITION 30

The main slide 6 has advanced to this position as a result of the disconnection of the partial venting through the movement of the auxiliary slide 8 by masking the H port associated with the auxiliary slide. When the main slide reaches position 30 the vent from the pressure areas is closed in preparation for forcing water up the delivery tube 86 from the batch space 32. The closing of the vent C also results in the pressurizing of the water supply valve 70 because the port G is in registry with a pressure area of the reading means associated with the auxiliary slide.

FIG. 21 — MAIN SLIDE POSITION 32

The suction areas of the main slide 6 are now vented through port C while a pressure control condition is being built up on the high side 16 of the air diaphragm 12 in airside chamber 10. Since this is another occurrence of shifting of control from a vacuum condition to a pressure condition, the small stall and possible hunting condition described previously in connection with

position No. 7 of the main slide occurs. The same pressure condition being built up on the high side of the air diaphragm is also applied against the airside of the water diaphragm 28. As this pressure condition builds up the water is forced from the batch space 32 on the water side of the diaphragm 28.

The biasing spring 35 which works against the pressure differential in the airside chamber is selected so that the spring force at this position 32 of the main slide is such that a head pressure of greater than 6 feet of water is required to hold the main slide in this position. That is, since one pound per square inch is equivalent to about 2.77 inches of water, the approximately 3 psig of pressure differential available at position 32 of the main slide is adequate to elevate the water more than the height of a normal domestic refrigerator. This permits the programmer and valve portions of the ice maker system to be in the machine compartment at the base of the refrigerator cabinet while permitting elevating of the liquid to an ice maker disposed in an upper freezer section of the refrigerator cabinet.

With nearly all the water squeezed out of the water side chamber by forcing the water diaphragm 28 against the exterior walls of the chamber, the pressure can continue to increase in the pressurized areas and communicating spaces of the programmer. It is also noted that the ice tray bladder 60 has been permitted to revert to an atmospheric condition as it receives the water through the delivery tube 86.

The interior configuration of the water batch space 32 includes a disc-like plate 33 (FIG. 1) with a series of radial grooves 45 and a central recess 47 in the particular form of programmer illustrated. When the diaphragm 28 is stretched at the high pressures during water expulsion, it is forced into the recess to a greater degree than at the lower pressures of FIGS. 11-13. Also when the pressure is released (in position 39 of the main slide) from the airside space 30 of the diaphragm so that the diaphragm can assume a normal at rest position, the recess 47 provides a storage space for the water in the delivery tube 86 and drawn back down into the space 32 on the water side of the diaphragm. This avoids the possibility of water being left in tube 86 near the tray and then freezing.

FIG. 22 — MAIN SLIDE POSITION 37

In this position both the suction areas and pressure areas are prevented from venting through port C so that the full pump output is used to increase the pressure differential across the air side diaphragm and advance the slide 6 farther. This is preparatory to again shifting from a pressure control to a vacuum control condition. Accordingly, the same stall and possible hunting condition as previously described when control is shifted will occur.

FIG. 23 — MAIN SLIDE POSITION 39

In this position control has been shifted to vacuum control of the air side diaphragm 12. The pressure areas are vented to atmosphere through port C and accordingly the water side diaphragm 28 has assumed its normal at rest position which permits the water in the delivery tube 86 which has not flowed into the ice tray to return into the storage space 32 and recess 47 in the water side chamber 26 as noted before.

In the position 39 the pawl 42 of the main slide 6 has slipped over the second and largest step of the ratchet 44 so that upon the subsequent return of the main slide to its initial position the pawl 42 can flex in a direction permitting the pawl to ride over the successive steps.

Further, a vacuum is again pulled in the tray cavity causing the bladder 60 to be pulled down tightly against the tray 63 so that thermostat 64 can sense the temperature condition of the tray. Continued pumping results in the farther advance of the main slide to position 42.

FIG. 24 — MAIN SLIDE POSITION 42

The suction side of the pump is now blocked from the low side space 14 in the airside chamber 10 because the main slide 6 has advanced to a position in which the end of the suction area 50 (FIG. 3) which extends longitudinally along the reading sheet means has passed beyond registry with the port A. A limited hunting condition will occur at this stage due to leakage. However, as a practical matter the main slide holds the position 42 while the vacuum is continued to be applied to the tray cavity to hold the bladder 60 down tightly against the tray 63. The pump of course continues to run.

When the thermostat 64 senses an increased temperature due to the warmth of the water, it opens its switch to deenergize the pump. The release of suction from the pump and the slight leakage condition between the interface of the reading head 3 and the reading sheet means 38 gradually permits a reduction in the differential pressure across the air diaphragm 12 so that the force of the spring starts to return the main slide 6 to its initial position. Since the auxiliary slide 8 has remained in its position 20, no vacuum can be applied to the water valve 70 through the auxiliary slide when the main slide passes through position 26. Upon the farther return of the main slide, it starts pushing the auxiliary slide back toward its original position until it is restrained by a mechanical stop at its original position. Both slides are then in their initial positions (FIG. 7) and are ready for another cycle when sufficient cooling of the thermostat 64 is sensed to indicate a frozen condition of the ice cubes.

FIGS. 25 AND 26

The invention is also adapted to be employed in an ice maker where a single slide is used, rather than two slides as previously described. Only the array of ports and the suction and pressure areas on the reading means are shown in FIGS. 25 and 26, since the slide length is sufficient that its water side chamber end projects into the water side chamber enough that the water diaphragm will abut that end during the water batch fill operation. The ports of FIG. 25 are identified as in FIG. 4. However since no auxiliary slide is involved, the ports E-H are omitted and port D is connected directly to the water valve. The suction and pressure areas of FIG. 26 correspond in identification with those of FIG. 4, except that the longitudinally extending suction area 50 is interrupted and is bypassed by channel 50E, and in the interrupted portion a pressure area aperture 52a is provided.

The general operation of the system is much the same as the two slide arrangement. However, since throttling and stalling of the slide cannot take place

through venting of the suction areas through a second slide pressure area when the water batch fill is to occur, the throttling takes place when pressure area 52a (at atmosphere) registers with the A port connected to the low side space of the airside chamber. At this position, the D port is in registry with suction area 50a so that the water valve is opened. The water pressure will subsequently nudge the slide past its registry of pressure area 52a with port A so that further advance can take place under the normal control of the airside diaphragm. There as the slide moves through positions in which the vent C is out of registry with the second to last pressure area, the pressure builds up and forces the water to the ice tray in the same fashion as with a two slide arrangement. The shut off of the system is also the same as with the two slide system and the slide moves back to its starting position.

The factors which make the two slide system preferable to the one slide system are the following. The size of the throttling hole 52a is somewhat critical. It functions of course to stall the slide as water enters the batch fill chamber. If the hole is too small, the slide may pass over it without stopping. If the hole is made overly large to insure that this does not happen, the water side diaphragm is required to be larger than is now considered to be desirable to insure that sufficient force is available to restart the slide, since the vacuum in the stall position may be less than desired at that point. Also, as the slide returns from its final position to its initial position during a leakage condition after the pump has stopped, the D port leading to the water valve again is in registry with the suction area 50a for a short period, which suction area is of course at essentially the same vacuum level as when the water valve was opened. If the slide tends to stick at that location, unwanted water will be introduced to the batch fill chamber.

MISCELLANEOUS

While the terms "suction area" and "pressure areas" in connection with the reading sheet means have been used in the description, they are so used to indicate that these areas are subject to either pressure or to suction, respectively, even though at times they are vented to atmosphere. In that same connection, while atmosphere has been used as the reference pressure about which shifting of the control occurs, the control can be shifted about a reference pressure other than atmosphere, provided that the actuated devices of the system are in an environment having that particular reference pressure, and the vent is in communication with that environment or an equivalent pressure environment.

What is claimed is:

1. A control system for an automatic ice maker of the inflatable bladder type, including
 - pneumatic programmer means including a central hollow body portion containing slide valve means having reading means presenting pressure areas and separate suction areas thereon, said body portion including a reading surface provided with an array of apertures therein and along which said reading means is movable to selectively place said pressure areas and said suction areas in registry with selected ones of said reading surface apertures,

- a first chamber at one end of said body portion, said first chamber containing a first displaceable member therein biased toward said body portion and separating said first chamber into an outer low pressure side space and an inner high pressure side space in open communication with said pressure areas;
- a second chamber at the other end of said body portion, said second chamber containing a second displaceable member separating said second chamber into an outer side space adapted to receive water for supplying said ice maker, and an inner side space in open communication with said pressure areas;
- means connecting at least a portion of said slide valve means to said first displaceable member for movement therewith;
- pump means connected to said programmer and having a suction side in normal communication with said suction areas and a pressure side in normal communication with said pressure areas;
- means placing said suction areas in communication with said low pressure side space;
- one of said reading surface apertures comprising a vent opening for selectively venting either said pressure areas or said suction areas in accordance with the registry of either therewith, and for preventing venting of both when said areas are out of registry;
- means connecting a second aperture of said reading surface to said ice maker for controlling the inflation and deflation of said bladder in accordance with registry of said second aperture with said pressure and suction areas;
- a pneumatically operated water supply valve for controlling the supply of water to said second chamber outer side space;
- means for conducting water from said second chamber to said ice maker;
- means connecting a third aperture of said reading surface to said water supply valve for controlling the admission of water to said second chamber outer space;
- said aperture of said reading surface being arrayed, relative to the array of said pressure and said suction areas;
- to effect inflation and deflation of said bladder through registry of said second aperture with a pressure area and then a suction area, respectively, to subsequently effect opening and then closing of said water supply valve through registry of said third aperture with a suction area and a pressure area,
- and to pressurize said pressure areas in response to an indication that said outer side water space of said second chamber has received the supply of water, to force said water through said water conducting means to said ice maker;
- said vent aperture being disposed to selectively vent, and prevent venting, of said pressure areas and said suction areas in accordance with the pressure condition to be applied to said ice maker bladder, and said water supply valve, and said water chamber displaceable member, so that the differential pressure imposed across said first displaceable member is achieved by a pressure condi-

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tion of the same character as that applied to said ice maker bladder, and to said water supply valve, and to said water chamber displaceable member.

2. A control system according to claim 1 wherein:

said slide valve means comprises a first portion and a second separate portion;

said connecting means connects said first portion of said slide valve means to said first displaceable member; and

said second portion of said slide valve means is independently movable in accordance with a supply of water received by said second chamber outer side space.

3. A control system according to claim 1 wherein;

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said suction areas of said reading means includes a throttling portion thereon for restricting communication, during the initial operation of said pump means, between said suction side of said pump and said low pressure side of said first chamber so that the rate of increase of the pressure differential developed across said first displaceable member is initially restricted while said second aperture of said reading surface is in registry with said suction areas to permit an initial deflation of said bladder.

4. A control system according to claim 1 wherein;

said first and said second displaceable members comprise flexible diaphragms.

* * * * *