CONTROL OF PLUNGERS IN GLASSWARE FORMING MACHINES

A control system is described for controlling the movement of a plunger for use in forming parisons in a glassware manufacturing machine in which the plunger is driven between first and second positions by a pneumatic piston and cylinder device in which pressure sensors sense the pressure on opposite sides of the piston. An electronic signal processing system incorporates a memory in which a motion profile and force limits are stored and which receives through each cycle a feedback signal relating to the transducer position of the plunger and from the pressure sensors the pressure on opposite sides of the piston and which produces control signals for a solenoid driven proportional pneumatic valve in accordance with a repetitive algorithm which takes account of (a) the displacement of the plunger from the motion profile, (b) the velocity of the plunger as derived from the rate of change of its position, and (c) the force exerted on the plunger as derived from the pressure difference across the piston. In this way the valve supplies air to the piston and cylinder device to cause the plunger to move from rest to a first position, for a first period of time in a manner limited by the motion profile. Thereafter a first force limit is applied to the plunger. Movement during a second period of time is controlled in a manner limited by the reduction from the first force limit to a second force limit and during a third period of time is limited by the second force limit.
FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<table>
<thead>
<tr>
<th>Code</th>
<th>Country</th>
<th>Code</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>Austria</td>
<td>GB</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>AU</td>
<td>Australia</td>
<td>GE</td>
<td>Georgia</td>
</tr>
<tr>
<td>BB</td>
<td>Barbados</td>
<td>GN</td>
<td>Guinea</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>GR</td>
<td>Greece</td>
</tr>
<tr>
<td>BF</td>
<td>Burkina Faso</td>
<td>HU</td>
<td>Hungary</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>IE</td>
<td>Ireland</td>
</tr>
<tr>
<td>BJ</td>
<td>Benin</td>
<td>IT</td>
<td>Italy</td>
</tr>
<tr>
<td>BR</td>
<td>Brazil</td>
<td>JP</td>
<td>Japan</td>
</tr>
<tr>
<td>BY</td>
<td>Belarus</td>
<td>KE</td>
<td>Kenya</td>
</tr>
<tr>
<td>CA</td>
<td>Canada</td>
<td>KG</td>
<td>Kyrgyzstan</td>
</tr>
<tr>
<td>CF</td>
<td>Central African Republic</td>
<td>KP</td>
<td>Democratic People's Republic of Korea</td>
</tr>
<tr>
<td>CG</td>
<td>Congo</td>
<td>KR</td>
<td>Republic of Korea</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>KZ</td>
<td>Kazakhstan</td>
</tr>
<tr>
<td>CI</td>
<td>Côte d'Ivoire</td>
<td>LI</td>
<td>Liechtenstein</td>
</tr>
<tr>
<td>CM</td>
<td>Cameroon</td>
<td>LK</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>CN</td>
<td>China</td>
<td>LU</td>
<td>Luxembourg</td>
</tr>
<tr>
<td>CS</td>
<td>Czechoslovakia</td>
<td>LV</td>
<td>Latvia</td>
</tr>
<tr>
<td>CZ</td>
<td>Czech Republic</td>
<td>MC</td>
<td>Monaco</td>
</tr>
<tr>
<td>DE</td>
<td>Germany</td>
<td>MD</td>
<td>Republic of Moldova</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
<td>MG</td>
<td>Madagascar</td>
</tr>
<tr>
<td>ES</td>
<td>Spain</td>
<td>ML</td>
<td>Mali</td>
</tr>
<tr>
<td>FI</td>
<td>Finland</td>
<td>MN</td>
<td>Mongolia</td>
</tr>
<tr>
<td>FR</td>
<td>France</td>
<td>MR</td>
<td>Mauritania</td>
</tr>
<tr>
<td>GA</td>
<td>Gabon</td>
<td>MW</td>
<td>Malawi</td>
</tr>
<tr>
<td>NE</td>
<td>Niger</td>
<td>NL</td>
<td>Netherlands</td>
</tr>
<tr>
<td>NO</td>
<td>Norway</td>
<td>NZ</td>
<td>New Zealand</td>
</tr>
<tr>
<td>PL</td>
<td>Poland</td>
<td>PT</td>
<td>Portugal</td>
</tr>
<tr>
<td>RO</td>
<td>Romania</td>
<td>RU</td>
<td>Russian Federation</td>
</tr>
<tr>
<td>SD</td>
<td>Sudan</td>
<td>SE</td>
<td>Sweden</td>
</tr>
<tr>
<td>SI</td>
<td>Slovenia</td>
<td>SK</td>
<td>Slovakia</td>
</tr>
<tr>
<td>SN</td>
<td>Senegal</td>
<td>TD</td>
<td>Chad</td>
</tr>
<tr>
<td>TG</td>
<td>Togo</td>
<td>TJ</td>
<td>Tajikistan</td>
</tr>
<tr>
<td>TT</td>
<td>Trinidad and Tobago</td>
<td>UA</td>
<td>Ukraine</td>
</tr>
<tr>
<td>US</td>
<td>United States of America</td>
<td>UZ</td>
<td>Uzbekistan</td>
</tr>
<tr>
<td>VN</td>
<td>Viet Nam</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Title: Control of plungers in glassware forming machines.

Field of the invention
This invention is concerned with plunger mechanisms for use in forming a gob of molten glass into a parison in a glassware forming machine.

Background to the invention
In a common type of glassware forming machine, the so-called I.S. machine, molten glass is formed into a parison and the parison is transferred to a mould in which it is blown into the shape of a container. Gobs of molten glass are formed into parisons either by a pressing operation alone (in the so-called press and blow method) or by a pressing and blowing operation (in the so-called blow and blow method), both operations involving the use of a plunger mechanism.

The operation of the plunger mechanism is crucial in the successful operation of the glassware forming machine. The time taken for the operation is often a significant factor in determining the cycle time of the machine, and to obtain consistent containers it is necessary that consistent operation of the plunger mechanism is provided. Small variations in the weight of a gob and in the size of the mould cavity make it difficult to determine when a pressing operation should terminate: it is essential that the pressure is sufficient to ensure that, when using the press and blow method, molten glass is forced down into a neck ring to form the eventual neck of the container, without being sufficient to force a two part blank mould apart and forming seams on the parison.

Prior Art
In EP 165012-A, a plunger mechanism is described which is hydraulically operated, and comprises a piston and cylinder arrangement with the plunger being mounted for movement on the piston. A servo mechanism operates to control the rate at which hydraulic fluid enters and/or leaves the cylinder, and a position feedback device provides signals indicative of the position of the plunger to a control device which is arranged to control the movement of the piston during the first part of its stroke: towards the end of the stroke, when excessive pressure
might cause opening of the parison mould, control is changed over from a position control to a pressure control - that is to say a limited pressure is exerted on the piston and its movement is determined to a large extent by a shrinkage of the glass in the mould which may take place.

From the point of view of the movement achieved by the plunger, the arrangement in EP 165012-A is effective. However, in glass machines hydraulic mechanisms suffer from several disadvantages, and there is therefore a requirement for a pneumatically operated system. Hydraulic systems have an intrinsically higher cost than pneumatic systems, and also require significantly more maintenance - an air bubble or dirt in the hydraulic fluid can cause malfunction of the system. In many cases, of which glass machinery is one, the significant disadvantage of a hydraulic system is the fire risk - a small puncture in the system can lead to a fine spray of oil resulting which, in the context of a machine operating with molten glass gives a substantial risk of fire.

By contrast a pneumatic system has lower cost, is easier to maintain, has minimum fire risk and is much less sensitive than a hydraulic system to variations in ambient temperature which occur in glass forming machines. The disadvantage of a pneumatic system is that control is more difficult, particularly when it is desired to bring a component to rest at a desired position as the compressibility of air can allow moving pneumatically operated components to overrun or to oscillate.

It is one of the objects of the present invention to provide a pneumatically operated plunger mechanism in which the movement of the plunger is controlled and the risk of applying excessive force to the plunger avoided.

The Invention
The invention provides a control system for controlling the movement of a plunger for use in forming parisons in a glassware manufacturing machine which plunger is driven between first and second positions by a pneumatic piston and cylinder device, comprising a solenoid driven proportional pneumatic valve adapted to control the supply of air under pressure to the piston and cylinder device,
a transducer which senses the position of the plunger
pressure sensors which sense the pressure on opposite sides of the piston of the piston and cylinder device
an electronic signal processing system incorporating a memory in which a motion profile and force limits are stored, which processing system throughout each cycle receives as a feedback from the transducer the position of the plunger and from the pressure sensors the pressure on opposite sides of the piston and which produces control signals for the valve in accordance with a repetitive algorithm which takes account of
(a) the displacement of the plunger from the motion profile
(b) the velocity of the plunger as derived from the rate of change of its position, and
(c) the force exerted on the plunger as derived from the pressure difference across the piston, so that the valve supplies air to the piston and cylinder to cause the plunger to move from rest at the first position for a first period of time in a manner limited by the motion profile and a first force limit applied to the plunger, for a second period of time in a manner limited by the reduction from the first force limit to a second force limit and for a third period of time limited by the second force limit.

A plunger mechanism which embodies the invention will now be described with reference to the accompanying drawings in which

Figure 1 shows, diagrammatically, the plunger mechanism embodying the invention;
Figure 2 shows schematically a graph of position of the plunger against time;
Figure 3 shows schematically a graph of the force limits applied to the plunger against the position of the plunger;
Figure 4 shows a block diagram of a signal processing system of the mechanism.
Figure 5 is a functional block diagram of the machine controller.

The plunger mechanism embodying the invention is for use at the blank mould station of an individual section glassware forming machine. Referring to Figure 1, at the blank mould station is positioned the blank mould, comprising two side mould members 2,4, two neck ring members, 6,8 and a baffle 10. In operation of the machine, when the side mould members 2,4.
and the neck ring members 6, 8 are in closed positions to provide a mould cavity, a plunger 12 of the plunger mechanism is in a first retracted position in the mould cavity and the baffle 10 is in an out of the way position. A gob of molten glass is then supplied into the mould cavity and rests on the plunger. The baffle 10 is then moved into position over the mould cavity, and the plunger 12 is moved upwards towards its advanced position, forcing the molten glass into the shape of the mould cavity to form a parison, a neck portion of which is formed in the neck ring members 6, 8. The plunger 12 is then retracted to a fully withdrawn position, the baffle 10 moved to its out of the way position, the mould members 2 and 4 opened away from each other and the formed parison carried away to a blow mould station by the neck ring members 6, 8.

Movement of the plunger 12 is obtained by a piston and cylinder arrangement comprising a piston 14 attached to the plunger and a cylinder 16. An air line 18 communicates with the cylinder 16 above the piston 14 and air line 20 with the cylinder 16 below the piston 14. The air lines 18 and 20 are connected to a servo controlled proportional pneumatic valve 22 which, as desired, can connect one of the air lines 18 and 20 to a source of compressed air 24 and the other exhaust, thus to obtain movement of the piston 14 and of the plunger 12.

Operation of the valve 22 is controlled by a valve controller 26 which is connected to the valve 22 by two lines, a valve spool control line 28 through which a signal may be sent from the controller to the valve to obtain movement of the valve spool, and a valve spool position line 30 which transmits a signal from the valve to the controller to indicate the precise position of the valve spool.

As shown in figure 1, a first pressure transducer 32 is connected to the cylinder 16 to sense the air pressure in the cylinder 16 above the piston 14 and a second pressure transducer 34 is connected to the cylinder 16 to sense the air pressure below the piston 14. A position transducer 36 senses movement of the piston 14, and thus of the plunger 12. The three transducers 32, 34, 36 are connected by the lines 38, 40, 42 to a servo control card 44 which is arranged to pass the necessary instructions to the valve controller 26 along a line 46.
The servo control card 44 provides a signal processing system. It comprises a micro controller 48 which is connected to the valve controller 26 through a digital/analogue converter 50 and the line 46, through which spool position demand signals are provided to the valve controller 26.

The micro controller 48 is connected through an analogue to digital converter 52 to the position transducer 36 and the two pressure sensors 32 and 34, the position transducer 36 providing signals indicating the actual position of the plunger 12 and the sensors 32 and 34 indicating the pressures above and below the piston 14. The micro controller 40 is also connected to an EPROM 54 and a RAM 56 in either of which is stored a profile program for the plunger movement and force limits on the plunger.

A supervisory computer 58 of the glassware manufacturing machine is connected through a network interface 60 to the micro controller 48, and hence through to the RAM 56. Algorithm information is passed to RAM 56 and stored and is accessed at appropriate times by the micro controller 48. A synchronization signal is supplied to the micro controller 48 through a digital interface 62. If desired the micro controller can be arranged to provide the synchronization signal internally.

A UART (Universal Asynchronous Receiver Transmitter) 64 is connected to a Hand Held Terminal (HHT) 66 to allow constant factors of the algorithm program to be adjusted to enable the actual path followed by the plunger 12 to be modified. These factors are provided to the micro controller 48.

Thus the micro controller 48 takes the profile program and the force limits from the EPROM 54 or RAM 56, the algorithm program from the EPROM 54 or RAM 56 and the individual factors from the EPROM 54, ram 56, UART 64 or Supervisory computer 58, and combines them to enable it repetitively to use the algorithm program to enable it to provide the necessary position demand signals to the valve controller 26.
An operator interface is provided. The mechanism described uses the HHT 66 or the
supervisory computer 58, but if desired the HHT 66 can be dispensed with and the necessary
individual factors provided from the computer 58.

The computer 58 comprises display means which can display motion profile and force limit
data. By use of the HHT 66 the motion profile and force limit data can be modified.

It will be understood that the valve controller 26 and the valve 22 form a servo system, the
controller receiving a feedback signal indicating the actual spool position of the valve 22 from
a sensor 64 and developing the actual valve control signals from the valve spool demand
signals supplied by the micro controller 48 and the feedback signals from the sensor 64.

An algorithm which may conveniently be used to cause the plunger mechanism to operate as
desired will be described later. The manner in which movement of the plunger 12 is controlled
will be understood better from a consideration of Figures 2 and 3.

In Figure 2 a graph is shown which sets out the motion profile stored in the control system (in
dotted lines). The actual movement of the plunger 12 is set out in full line. From the first
position of the plunger (O in Figure 2), the plunger is moved upwards for a first period of time
t1, and is attempting to follow the motion profile but a first force limit F1 (see Figure 3) is
applied the movement which has the result that it lags behind the profile. The extent of this
lag is somewhat exaggerated in Figure 2 for clarity.

At t1, the first force limit F1 is reduced, over a second period of time t2 to a lower force
limited F2, and the plunger 12 is constrained in its movement by the force limit reduction over
this period. For the period of time t2 - t3, movement of the plunger is solely constrained by
the second force limit F2. At time +3 the motion profile will operate to obtain a rapid
downward movement of the plunger.

The algorithm which is used in the plunger mechanism is now explained with reference to the
functional block diagram of figure 5.
The various parts and functions of the controller are described below.

**Force, Velocity, Position and Input Filters**

In all cases a simple low pass filter is used to reduce high frequency signal noise. One example is given below, which is the low pass filter for the force signal.

The filtered force, fforce, is given by

\[
fforce = af * fz-1 + bf * FORCE \quad (1)
\]

where
- \(af\) & \(bf\) are constants in the force filter
- \(fz\)-1 is the calculated filtered force from the previous algorithm iteration.
- \(FORCE\) is force value calculated during the present iteration of the algorithm.

\[
af = \frac{\text{iter} \times T_F}{(1.0 + \text{iter} \times T_F)}
\]

\[
bf = \frac{1.0}{(1.0 + \text{iter} \times T_F)}
\]

where
- \(iter\) is the iteration rate of the controller (Hz)
- \(T_F\) is the filter constant which is tuned to give an acceptable level of valve noise.

The filters are all of the same form. The equations for the force filter are shown above. The corresponding variables used in the other filters are listed in the table below. The filtered variable being calculated by an equation (1).

The input, force position and velocity signals are filtered in a similar manner, and can be conditioned when a discontinuity is encountered. This can be done to achieve smooth continuous motion. The values of the filter constants for the input, force, velocity and position are tuned upwards from a very low value until an acceptable level of noise is achieved on each signal whilst still achieving the required performance. The penalty for increasing the value too
high is loss of performance due to the increased time delay which accompanies the increased
smoothing effect of the filter.

The input filter prevents noise from being transmitted through the system, and allows the
demand to be conditioned when a discontinuity (e.g. the force limit) is encountered. The lines
labelled "LOGIC" in the diagram indicate the conditioning. The filter helps to prevent high
frequency resonances within the controlled system from being excited.

The corresponding variables for the four filters are listed below:

<table>
<thead>
<tr>
<th>Force</th>
<th>Velocity</th>
<th>Input</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>fforce</td>
<td>FVELOC</td>
<td>infil</td>
<td>FPOS [filtered values]</td>
</tr>
<tr>
<td>T_F</td>
<td>T_V</td>
<td>T_I</td>
<td>T_P [tuned filter constants]</td>
</tr>
<tr>
<td>af</td>
<td>av</td>
<td>ai</td>
<td>ap</td>
</tr>
<tr>
<td>.bf</td>
<td>bv</td>
<td>bi</td>
<td>bp</td>
</tr>
<tr>
<td>FORCE</td>
<td>veloc</td>
<td>demand</td>
<td>POSIT Values during present iteration</td>
</tr>
<tr>
<td>fz-l</td>
<td>fvz-l</td>
<td>infil-l</td>
<td>fpz-l Filtered values from previous iteration</td>
</tr>
</tbody>
</table>

veloc is the calculated mechanism velocity.
demand is obtained from the demand profile. A value from this profile is
used by the algorithm at each iteration.

POSIT is the position of the mechanism. A new value for POSIT is
obtained from the position sensor at each iteration of the new algorithm.

Error Limiter

This is used to clip the value of the error so that it remains within pre-chosen limits. This is
useful, for example, to prevent overshoot of the mechanism in cases where the mechanism has
been prevented from following the profile because it becomes jammed with another
mechanism and is then suddenly released.
error = infil - FPOS

The error is clipped to be within the range +/- ERRLIM

**Non-Linearity and K_P.**

End point stiffness is improved by multiplying the forward gain factor K-P by a further factor "nlerr". When the error becomes zero the function "nlerr" rises to its maximum value. The rate at which "nlerr" rises, and the range over which it rises can be altered by tuning the parameter "SHARPN" in the equation shown below. The value of "NL_OFF" is tuned to give a suitable value to the peak of "nlerr".

\[
\text{nlerr} = 1.0 + \frac{\text{NL_OFF}}{1.0 + \text{SHARPN} \times \text{error} \times \text{error}}
\]

The error is then multiplied by the forward gain. The variable \( uv \) is defined by the equation

\[
\text{uv} = K_P \times \text{nlerr} \times \text{error}
\]

or may be described as the active error reducing component of the algorithm.

**Differentiation**

The position value is used to calculate the velocity as follows:

\[
\text{veloc} = w2 \times (\text{POSIT} - p2-l) \times \text{iter} + 2.0 \times \text{zx} \times \text{vz-2} \times 2 \times \text{zx} - 2
\]

\[
w2 = \text{vfilt} \times \text{vfilt}
\]

\[
\text{zx} = 1.0 - \text{VFILT}
\]

\[
\text{x2} = \text{zx} \times \text{zx}
\]

\[
\text{vz-1} \text{ is the value of the velocity from the last iteration}
\]

\[
\text{vz-2} \text{ is the value of the velocity from the last but one iteration}
\]

\[
\text{P2-1} \text{ is the value of the position from the last iteration (unfiltered)}
\]
The equation for evaluating veloc is a digital filter, which provides an estimate of velocity based on the position measurement at discrete times. VFILT is the tuned filter constant. It is used to obtain an acceptable compromise between noise and time delay. With VFILT, time delay is reducing, though noise in the velocity estimate due to noise on the position signal is increasing. As VFILT is reduced, noise is reduced at the expense of increased time delay, which may introduce oscillation into the mechanism movement. A compromise has to be made.

\[ uf = uv - [FVELOC + K_D] \]

where \( K_D \) is the velocity gain and \( uf \) is the input to a force control loop.

If the mechanism is in the correct demand position and the velocity is zero, the force required to move the mechanism to the correct position is zero and the value of \( uf \) is also zero.

**Force Limiter**

"uf" is effectively the demand input for a force loop controller, and this force demand is compared with the force limit. If it exceeds the limit it is clipped back to the limit. When this happens it is necessary to condition some of the earlier low pass filters in order to achieve smooth motion at this discontinuity:

\[ \text{infl is reset to } \#\text{infl-1} \]
\[ \text{FVELOC is reset to } (1.0/K_D)*(uv-uf) \]

When the value of "uf" drops below the limit, the plunger continues upwards once more until it press es with the desired limiting force.

**Force Model**

Gravity exerts force on the moving parts of the mechanism. In the plunger this force is constant, and is equal to the weight of the piston, rod and plunger assembly. The force exerted
by the pressures above and below the piston is calculated. The effective force available to move the mechanism is "FORCE":

\[
\begin{align*}
gravity &= G1 \times 9.81 \\
FORCE &= (PRESS\_B \times A\_below - (PRESS\_A \times A\_above)) - gravity \\
gravity &= \text{this is the gravity term. In the plunger mechanism this is simply}
\end{align*}
\]

The weight of the piston, rod and plunger assembly,

- \(G1\): mass of piston, piston rod and plunger assembly
- \(PRESS\_A\): pressure above piston
- \(PRESS\_B\): pressure below piston
- \(A\_above\): effective area of top of piston
- \(A\_below\): effective area below piston

The values "PRESS\_A" and "PRESS\_B" come from the pressure transducers. Values are read at each algorithm iteration.

**Calculation of valve demand output**

The valve demand \(u\) is calculated from

\[
u = uf - (fforce \times K\_F)
\]

where \(K\_F\) is the force gain.

The valve demand "\(u\)" is clipped to the physical limits of the system.

**Force Limit Schedule**

In the movement of the piston in a pressing stroke, at the start of the stroke for a first period of time, high value, limit is applied to the pressing stroke, a smooth reduction from the first force limit to a second force limit is achieved using a trigometric function, and towards the finish of the stroke the second force limit is applied for a third period of time.
Up to the point "CHNGSTRT" the high limit "HILIM" is used. A smooth transition to a lower limit "LOLIM" occurs over a range "DELTA". After this "LOLIM" is used as the limit. Suitable values for these parameters are found by experience and experimentation. Over the transition range ("DELTA") the intermediate values for the limit are given by:

\[
\begin{align*}
\text{angle} & = \frac{3.14}{\text{DELTA}}(\text{FPOS-CHNGSTRT}) \\
\text{force\_limit} & = (\cos(\text{angle})+1)\times0.5\times(\text{HILIM}-\text{LOLIM})+\text{LOLIM}
\end{align*}
\]

Parameters to be tuned by the operator to achieve the desired results from the force limiter are:

- CHNGSTRT
- HILIM
- LOLIM
- DELTA

The important things to be achieved when tuning the parameters are:

Final pressing force must be high enough to press glass into finish, but not so high as to force molds open (seams). Force earlier in stroke must be sufficiently high so as to press glass quickly. Transition range and the position for the start of the transition must be chosen so as to achieve a smooth and continuous plunger action.

**Update History**

After the valve actuation signal is sent, the variables used within the filters and the differentiator are updated e.g:

\[
\begin{align*}
fz-1 & = fforce \\
vz2 & = vzl \\
vz1 & = veloc
\end{align*}
\]

The algorithm then repeats.
Claims

1. A control system for controlling the movement of a plunger for use in forming parisons in a glassware manufacturing machine which plunger is driven between first and second positions by a pneumatic piston and cylinder device comprising:
   a solenoid driven proportional pneumatic valve adapted to control the supply of air under pressure to the piston and cylinder device
   a transducer which senses the position of the plunger member,
   pressure sensors which sense the pressure on opposite sides of the piston of the piston and cylinder device
   an electronic signal processing system incorporating a memory in which a motion profile and force limits are stored, which processing system through each cycle receives as a feedback from the transducer the position of the plunger and from the pressure sensors the pressure on opposite sides of the piston and which produces control signals for the valve in accordance with a repetitive algorithm which takes account of
      (a) the displacement of the plunger from the motion profile
      (b) the velocity of the plunger as derived from the rate of change of its position, and
      (c) the force exerted on the plunger as derived from the pressure difference across the piston,

so that the valve supplies air to the piston and cylinder device to cause the plunger to move from rest at the first position for a first period of time in a manner limited by the motion profile and a first force limit applied to the plunger, for a second period of time in a manner limited by the reduction from the first force limit to a second force limit and for a third period of time limited by the second force limit.

2. A system according to claim 1, wherein operation of the pneumatic valve is controlled by a valve controller connected to the valve by two lines, one of which supplies a drive signal to the valve to drive the valve spool and the other of which returns a spool-position indication signal.
3. A system according to claim 1 or claim 2, wherein the pressure sensing transducers sense the pressures in the cylinder above and below the piston and the position-sensing transducer ceases movement of the piston.

4. A system according to claim 3, wherein the three transducers supply signals through analogue/digital converters to a servo central card incorporating a micro controller which instructs the valve controller through a digital/analogue converter.

5. A system according to claim 4, wherein the micro controller is connected to a memory which stores a profile program for the movement of the plunger and force limits for the plunger.

6. A system according to claim 5, wherein a supervisory computer for the machine is connected through an interface to the servo central card to pass algorithm information to the memory, which information is accessed by the valve controller under the control of a synchronisation signal.

7. A system according to claim 6, wherein means are provided to enable the constant factors of the algorithm information to be adjusted and adjustments stored in the memory.

8. A system according to claim 7, wherein the microcontroller repetitively accesses the memory for the profile program, force limits, algorithm program and any factor adjustments and combines the accessed information to generate position demand signals fed to the valve controller.

9. A system according to any of claims 1 to 8, wherein the algorithm operates repetitively to generate position signal signals, subject to a valve demand limit, on the basis of a filtered force value subject to an error limit.

10. A system according to claim 9, wherein the algorithm operates on the basis of the functional block diagram of Figure 5 hereinbefore described.
11. A control system for controlling the movement of a plunger for use in forming parisons in a glassware manufacturing machine constructed and adapted to operate substantially as herein described and with reference to the accompanying drawings.
**Fig. 2**

- **POSITION vs. TIME**
  - Motion Profile
  - Actual Movement
  - Points: $t_1$, $t_2$, $t_3$

**Fig. 3**

- **FORCE LIMIT vs. POSITION**
  - Force $F_1$
  - Force $F_2$
  - Points: $a$, $b$
A. CLASSIFICATION OF SUBJECT MATTER

IPC: C03B 9/41 // G05D 16/20
According to international Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C03B, G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DIALOG: WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>DE, C2, 3151521 (VEBA-GLAS AG), 26 April 1984 (26.04.84), column 3, line 35 - column 4, line 8, figure 1</td>
<td>1-11</td>
</tr>
<tr>
<td>A</td>
<td>DE, C1, 3401465 (FA. HERMANN HEYE), 31 January 1985 (31.01.85), column 4, line 56 - line 65, figure 1</td>
<td>1-11</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search: 8 June 1994

Date of mailing of the international search report: 30.06.94

European Patent Office, P.B. 5818 Patenten 2
NL-2330 HV Rijswijk
Tel. (+31-70) 340-2040, Fax: 31 451 340-3016

MAY HALLNE

Form PCT/ISA/210 (second sheet) (July 1992)