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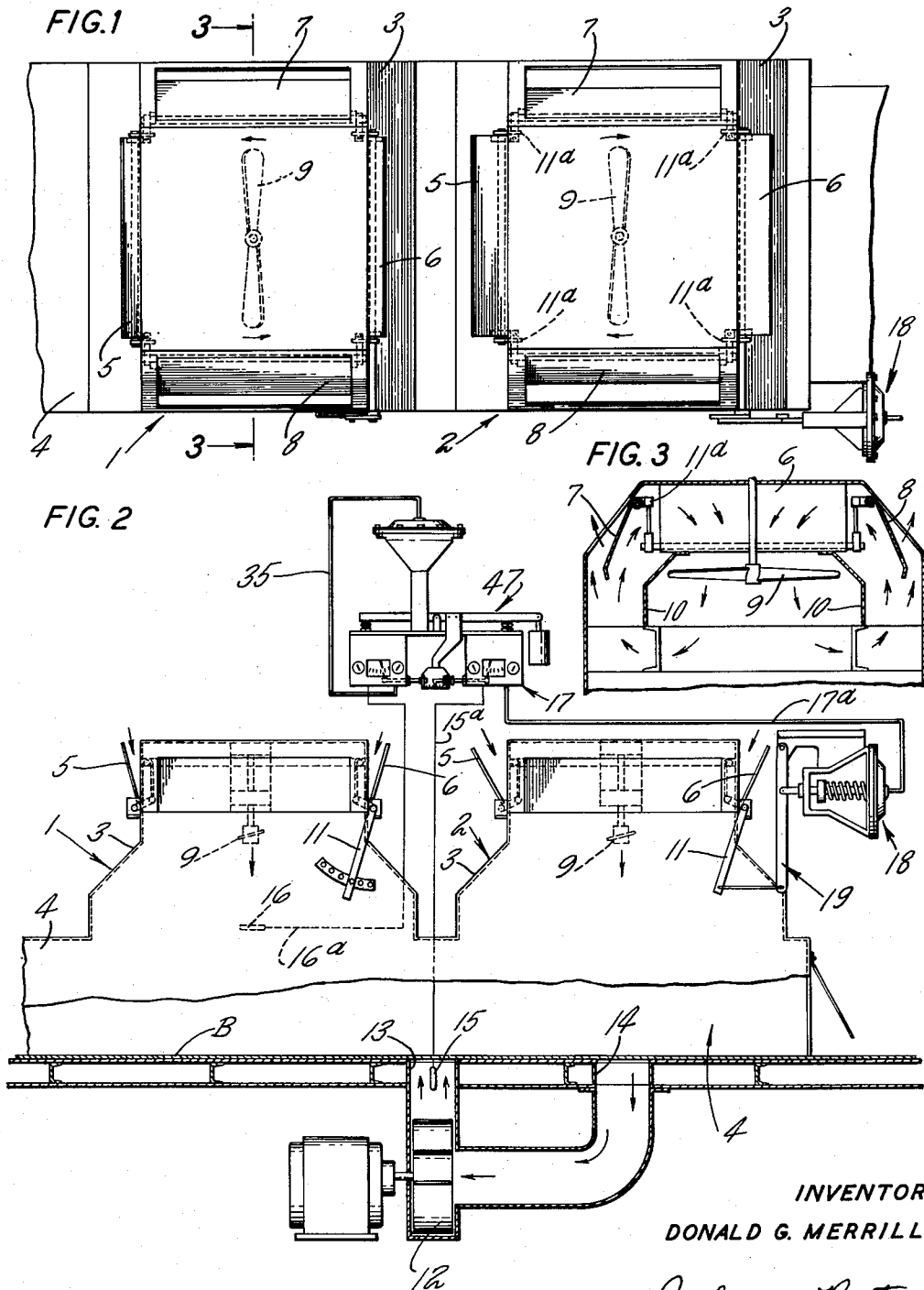
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2,669,069

GLASSWARE ANNEALING METHOD AND APPARATUS

Filed Nov. 24, 1950

3 Sheets-Sheet 1



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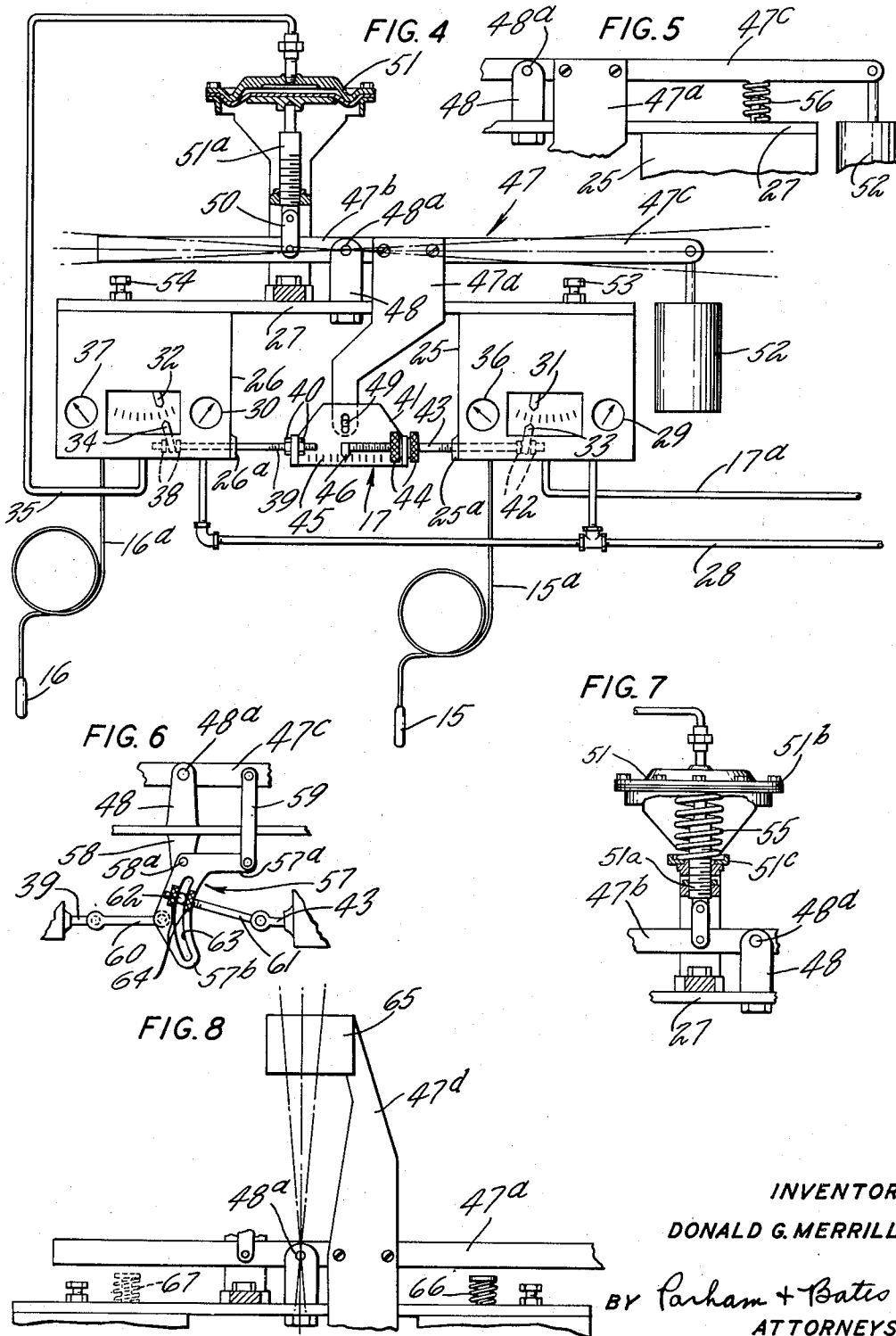
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3 Sheets-Sheet 3

FIG. 9

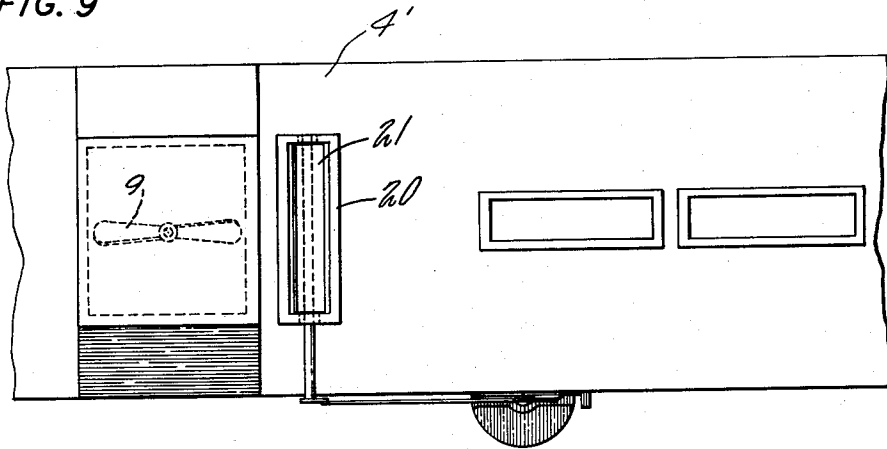
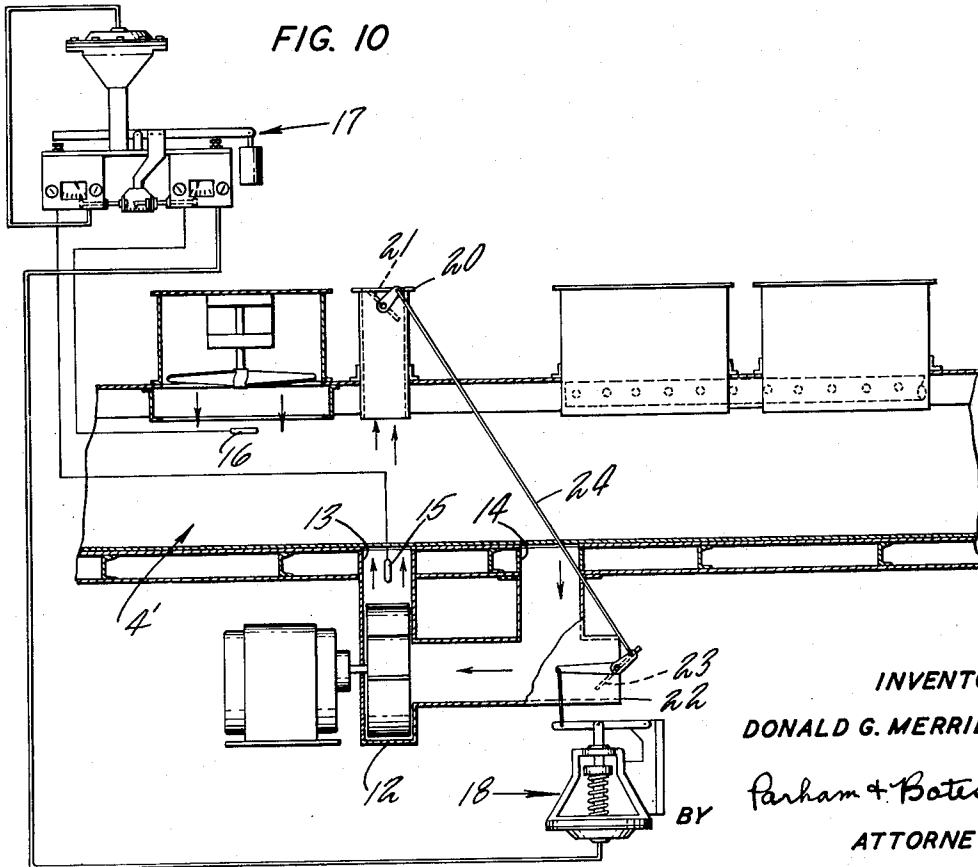


FIG. 10



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## UNITED STATES PATENT OFFICE

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## GLASSWARE ANNEALING METHOD AND APPARATUS

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Application November 24, 1950, Serial No. 197,255

12 Claims. (Cl. 49—47)

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The present invention relates to the manufacture of glassware and, more particularly, to the detection of ware which has poor resistance to heat shock.

Experience indicates that glass which is extremely cordy or otherwise lacking in homogeneity frequently breaks as it reaches the forced cooling section of a lehr. This breakage may sometimes reach a high percent merely as the result of normal cooling. Moreover, ware which is not broken by the heat shock of normal cooling subsequently may be broken by mild heat shock which the ware should withstand.

Heretofore, lehr design and operation has been directed toward obtaining gradual cooling and avoidance of heat shock.

The present invention is an abrupt departure from former practice and has as its principal object the subjecting of ware in a lehr to a preselected heat shock corresponding to an acceptable minimum standard for the ware so that the only unbroken ware which leaves the lehr is that which meets a preselected minimum heat shock standard.

Introduction of heat shock requires careful control to produce neither more nor less than the desired and intended effect. The factors determining heat shock for any given type of ware include the speed of translation from one environment to another in the lehr; the difference in temperature between the glass and its new environment; and the rate of heat transfer from the ware to the environment or ambient atmosphere.

The speed of translation or belt speed of a lehr is determined by production requirements and therefore it is not practical to vary it to regulate heat shock. However, temperature difference may be adjusted to compensate for different belt speeds. It has been found that in order to make the transition as prompt as possible a cooling blast should be introduced transversely of the lehr and preferably beneath, and directed against, the bottom of the ware so that the blast does not move longitudinally through the lehr and entrain other air which might effect a gradual rather than the desired abrupt change. Moreover, by introducing the chilling blast through the belt directly against the bottom of the ware, that portion of the ware which normally is most vulnerable to heat shock is most effectively exposed to it.

It also is preferable that the shock be applied when the glass temperature is below the temperature at which permanent strain can be introduced and, at the same time, sufficiently high

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to permit latitude to the shock and while the temperature is fairly uniform throughout the ware.

It has been found that these conditions are best met in the lehr at the point at which forced cooling is initiated. Preferably, strong recirculation is effected in the preceding slow cooling or annealing zone so as to establish the ware at a substantially uniform temperature and approximately the same temperature as the ambient air in the zone so that the temperature of the air as determined by a suitable indicating device is truly indicative of the temperature of the ware.

Various arrangements which will produce the desired effect on the ware within the lehr may be employed without disturbing other lehr functions.

It therefore is a principal object of the invention to provide a process and suitable means for automatically effecting the desired heat shock.

A more specific object is to provide heat shocking means which may be adjusted to effect any selected amount of shock between two points and which automatically maintains the selected shock between the two points regardless of variations in absolute values at the two points and without controlling the absolute value at the points.

In addition to providing means for automatically maintaining temperature difference which is constant in amount, it is an object to provide means with which the temperature difference may be made to automatically increase or decrease as the temperature at one point increases or decreases.

A slight decrease in temperature difference or shock frequently may be desirable as the temperature at one point increases so as to compensate an increase in the heat transfer coefficient with absolute temperature.

An increasing temperature difference also may be desirable as the temperature at one point departs from some absolute value such as 400° F. which is the approximate point at which glass strength is a minimum.

It also is desirable under certain conditions for the temperature differences to automatically be decreased as the temperature at a control point departs from some chosen value.

It therefore is a further object of the invention to provide automatic shock control means with which these conditions and combinations thereof may be maintained.

These and other objects are more fully pointed out or apparent in the following description of

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the illustrative embodiments of the invention shown in the accompanying drawings in which:

Figure 1 is a plan view of a portion of a lehr in which the present invention is incorporated;

Fig. 2 is a side elevation partly in cross-section of the portion of the lehr shown in Fig. 1 together with temperature responsive pneumatic controls embodying the present invention;

Fig. 3 is a cross-sectional view taken on line 3—3 of Fig. 1;

Fig. 4 is an enlarged view of the control mechanism of Fig. 2;

Figs. 5-8 are views of modified portions of the controls shown in Fig. 4;

Figs. 9 and 10 are views similar to Figs. 1 and 2, respectively of a different lehr showing control mechanism embodying the present invention incorporated therein.

While a variety of lehrs and temperature control devices may be employed to practice the present invention, Figs. 1-3 show a preferred temperature control mechanism incorporated in the so-called Hartford 92 lehr which is disclosed in copending application Serial No. 219,685, filed April 6, 1951, by the present inventor. Figs. 1 and 2 generally show at 1 and 2 two cooling sections of such a lehr, each of which comprises a generally rectangular dome or housing 3, mounted on the lehr tunnel 4, through which glassware is transported as by means of an endless belt conveyor B.

The dome or housing 3 of each of the cooling sections 1 and 2 is provided with a pair of inlet air dampers 5 and 6 which extend transversely of the tunnel 4 and a similar pair of spaced dampers 7 and 8 for controlling outlet of air from each cooling section extending longitudinally of the tunnel 4 between the inlet dampers 5 and 6 and at the opposite sides of the housings 3.

As is readily apparent from inspection of Fig. 3, a fan 9, which rotates about a centrally disposed vertical axis within the housing 3, draws cooling air past the dampers 5 and 6 into the cooling section and directs it downwardly onto glassware passing beneath it. Depending upon the size of the air intake openings, established by the setting of the dampers 5 and 6, a greater or lesser amount of outside cold air may be discharged against the ware. The cold air thereafter is circulated upward and, either in whole or in part, escapes out of the section past the exhaust dampers 7 and 8, or any part not escaping, is drawn back to the fan 9, where it mixes with new intake air and is recirculated. As shown in Fig. 3, partitions 10 preferably are provided in the cooling section which separates the air directed downwardly on the ware from that drawn upwardly by the fan 9 and either exhausted from the section through dampers 7 and 8 or recirculated.

The inlet dampers 5 and 6 may be, and preferably are, linked together and to the outlet dampers 7 and 8, as at 11a, so that they may be adjusted in unison by means of a lever 11 which is provided for each section. It also is preferable that the connections between the intake dampers 5 and 6 and the exhaust dampers 7 and 8 be such that like amounts of intake and exhaust air are involved for any position of adjustment so that tunnel pressure changes are minimized when the damper settings are changed.

In accordance with the present invention, an auxiliary blower 12 discharges air through a slot 13 which extends transversely of the tunnel 4. In

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the embodiment illustrated in Figs. 1-3, the slot 13 is located between the two cooling sections 1 and 2. The intake from the blower 12 is through a slot or opening 14 which extends transversely of the tunnel directly beneath the fan of the second cooling section 2.

As shown in Fig. 2, a temperature sensitive element 15 is located in the lehr tunnel 4 in the slot 13 and a similar temperature sensitive element 16 is located beneath the fan 9 in the housing 1. The two elements 15 and 16 are operatively connected by lines 15a and 16a, respectively, to control mechanism 17 which is generally designated 17 and which maintains a preselected difference between the temperature of elements 15 and 16 by suitable means including a damper motor, generally designated 18, which operates the damper lever 11 for the cooling section 2 to regulate admission of cold air to the section 2 and indirectly, to the intake 14 of the secondary blower 12.

In the embodiments illustrated in the drawings, the control apparatus 17 and the damper motor 18 are pneumatically actuated responsively to the difference in the pressures within the lines 15a and 16a. However, it will be understood that electric, mechanical or other hydraulic controls may be substituted.

In the pneumatic system illustrated, the pressure in each of the lines 15a and 16a varies responsively to variations in the temperature of their respective temperature sensitive elements 15 and 16. The control apparatus 17 regulates the pressure in a connecting line 17a to the damper motor 18 responsively to variations in the pressure differential established in the control apparatus 17 by the lines 15a and 16a. If the difference in temperature of elements 15 and 16 increases so as to exceed a selected differential, the controlling apparatus 17 automatically operates to lower the pressure supplied through line 17a to the motor 18 whereupon the motor, through a suitable mechanical linkage, generally designated 19, adjusts the damper lever 11 and the interconnected dampers 5, 6, 7 and 8 of the second cooling section 2 so as to reduce the cold air intake through dampers 5 and 6 and the air exhausted through the outlet dampers 7 and 8. This adjustment raises the temperature of the air in the section 2 from which the secondary blower 12 draws air through the supply opening 14. As a result, warmer air is discharged through the secondary blower outlet 13 which raises the temperature of the element 15 and re-establishes the selected temperature differential between elements 15 and 16 and between the two sections of the lehr in which the elements are located.

It will be understood that if the difference in the temperatures at 15 and 16 in the lehr falls below the preselected differential, the controlling mechanism 17 raises the pressure of the air supplied through line 17a to the motor 18 thereby further opening the intake dampers 5 and 6 and the exhaust dampers 7 and 8 of the second section 2. As a result, the temperature of the air in the second cooling section 2 and of the air directed against the element 15 by the secondary blower 12 is lowered until the preselected temperature differential is re-established between elements 15 and 16.

Figs. 9 and 10 illustrate the invention embodied in a somewhat different lehr 4' which is generally referred to by those familiar with the glass art, as the Hartford standard 51 lehr. The portion of the lehr 4', shown in Figs. 9 and 10, differs from the portion of the lehr 4 shown in Figs. 1-3, in so

far as is material to the present invention, in that an outlet or exhaust stack 20 having an adjustable damper 21 replaces the second cooling section 2 heretofore described. The stack 20 is located directly above the secondary blower outlet 13. In addition to the blower intake 14 shown in the embodiment of Fig. 2, the blower assembly 12 shown in Fig. 10 is provided with a cold air intake 22 having a damper 23, the adjustment of which is by the pneumatic motor 18 responsively to variations from the preselected temperature differential between the elements 15 and 16 in the same manner as in the embodiment shown in Figs. 1-3. Preferably, as shown in Figs. 9 and 10, the dampers 21 and 23 are connected for simultaneous adjustment through a rod 24 so that substantially no change in the atmospheric pressure within the lehr is effected by adjustment of the dampers.

Glass container annealing practice at the present time involves cooling ware from its upper to its lower annealing point at a relatively low cooling rate. The annealing range for the common container glasses is approximately 1000° F. to 800° F., the limits varying somewhat for different glass compositions. The rate of cooling within annealing range normally is approximately 5°-10° F. per minute. In accordance with standard annealing practice, the cooling rate is stepped up at the lower annealing limit to a rate which will not produce shock failure of the ware. This rate normally does not exceed 50° F. per minute for the customary glass compositions employed for container ware and the like.

The present invention involves an abrupt departure from the prior art and proceeds in a direction exactly opposite to that taught by the art. In accordance with the invention, after strong recirculation of air in the lehr at the location where the lower annealing, or a lesser temperature is established, the ware is thereafter shock cooled at a rapid rate such that all ware which is inherently weak to heat shock, including cordy, non-homogeneous, checked and mold marked, is destroyed and only homogeneous ware survives. The rapid shock cooling of this invention involves an abrupt temperature drop in the lehr of approximately 150°-300° F., the higher limits applying to thin ware. The ware leaving the strong recirculation point preferably is carried immediately into a stream of air at the shock temperature which is maintained at the preselected value below the recirculation temperature to destroy all glassware not having the requisite homogeneity. While the recirculation temperature is preferably at or close to the lower annealing point for the glass it, as previously pointed out, may be somewhat lower but above 400° F.

It also is preferable, following the described shock cooling, to reduce the forced cooling rate below that employed for the shock.

As previously pointed out, the application of heat shock in a lehr in accordance with the present invention requires control means which maintain a preselected temperature difference between the two points in the lehr at which the temperature sensitive elements 15 and 16 are located without controlling the absolute temperatures at the two points. While such control can be had as, for example, with an electric pyrometer actuated by opposed thermocouples, such a device is relatively complicated and has the disadvantage of being non-linearly responsive to changes in couple millivoltage.

A preferred control is provided by the pneu-

matic control apparatus 17 which has been described heretofore in a general way, and which hereinafter is described in greater detail with reference to Fig. 4.

The control apparatus 17 includes a pair of like pneumatically operated thermometer controllers 25 and 26 which are made commercially available by a number of manufacturers. The housing of the two controllers are both secured to a common fixed frame member 27 in spaced side-by-side relation to each other. Air is supplied at a constant pressure, for example, 15 p. s. i. by a line 28 to each of the controllers and the pressure indicated by their like gages 29 and 30. The lines 15a and 16a of the temperature sensitive elements 15 and 16 are respectively connected to the two controllers 25 and 26 and their temperatures indicated by gauge pointers 31 and 32, respectively. Set pointers 33 and 34 are connected to the internal mechanism (not shown) of their respective controllers 25 and 26 so as to control the air pressure in their respective lines 17a and 35.

The pressure in line 17a is indicated by a gage 36 of the controller 25 and varies with the position of the pointer 31 relative to pointer 33. Similarly, the pressure in line 35 is indicated by a gauge 37 of the controller 26 and varies with the position of pointer 32 relative to pointer 34. If, for example, the pointer 32 indicates a temperature of 500° F. for the element 16 and the pointer 34 also is set at 500° F., gauge 37 will register a pressure for the line 35 of approximately one-half the pressure in the supply line 28, or such other proportion as may be selected. Thus, if the latter is maintained at 15 p. s. i. the pressure in line 35 will be 7½ p. s. i. If, while the pointer 34 remains stationary the temperature of the element 16 increases above 500° F., an increase in the pressure in line 16a to the controller 26 is effected and the controller in turn effects a proportionate increase in the pressure in line 35 up to the limit of the pressure in the supply line 28 as, for example, 15 p. s. i. Similarly, adjustment of the pointer 34 downwardly (i. e. to the right as seen in Fig. 4) relative to the pointer 32 causes the pressure in line 35 to rise.

Conversely, the pressure in line 35 is reduced whenever the temperature of element 16 falls or the pointer 32 indicates a lower temperature than the pointer 34. It will be apparent that it is the movement of the two points relative to each other rather than their individual absolute movement as indicated by reference to the scale which determines the rise or fall of pressure in line 35.

The described controller 26 provides for an increase in the pressure of line 35 whenever there is an increase in the amount which the temperature indicated by pointer 32 exceeds that indicated by pointer 34 or a decrease in the amount which pointer 34 exceeds the pointer 32. A decrease in the pressure of line 35 occurs whenever the change is the reverse of that just described. However, it should be understood that controllers such as 25 and 26 customarily are provided with adjustment by means of which the operation, if desired, may be reversed, and it will be appreciated that the adoption of the reverse adjustment and operation to the maintenance of a selected temperature differential is contemplated by the present invention.

The operation of the controller 25 is identical with that heretofore described for the controller 26. The pressure in line 17a rises whenever the temperature of element 15 causes the pointer 31 to further exceed, or to reduce the amount

by which it is less than the temperature indicated by pointer 33, or whenever adjustment of the position of pointer 33 effects a like change in the relationship of the two pointers. The pressure in line 17a of course falls whenever the opposite change in the relationship of the two pointers 31 and 33 is effected.

As best seen in Fig. 4, adjustment of the pointer 34 is effected automatically by a shipper fork 38 secured to one end of a rod 39, which is slidably supported in a bearing portion 26a of the controller housing 26, and the other end of which is secured by nuts 40 to a crosshead 41 located between the two controllers 25 and 26 and automatically moved by mechanism hereinafter described. The positions of the nuts 40 may be adjusted if desired so as to locate the pointer 34 at a specific temperature indicating position for a particular position of the crosshead 41.

A simultaneous like adjustment of the pointer 33 is effected by a shipper fork 42 secured to the outer end of a second rod 43, which is slidably supported by a portion 25a of the controller 25, and the other end of which is adjustably secured to the crosshead 41 by knurled thumb nuts 44. Any desired temperature differential may be maintained between the pointers 33 and 34 by adjustment of the nuts 44. This difference may be indicated on a scale 45 on the crosshead 41 by a pointer 46 secured to the rod 43.

In accordance with the invention, the crosshead 41, which together with the rods 39 and 43 are slidably carried as a unit by the bearings 25a and 26a, is automatically slidably adjusted by a shipper arm 47a of a three-arm lever generally designated 47. Arm 47b of the lever is pivoted at fulcrum point 48a on a fixed fulcrum member 48 preferably at a point directly above the point 49 at which the shipper arm 47a operably engaged the crosshead 41. Arm 47b is connected by a link 50 to the armature 51a of a diaphragm motor 51 which is secured to the frame member 27 and actuated by the controlled air pressure in line 35. A counterweight 52 is carried by arm 47c of the three-arm lever and is of the proper weight to counter the pressure exerted on lever arm 47b by the motor 51 when the pressure in line 35 is one-half the pressure in the constant pressure supply line 28, or in other words, is the  $7\frac{1}{2}$  p. s. i. pressure which is established when pointers 32 and 34 are in registry and the line 28 maintains the constant 15 p. s. i. supply pressure heretofore mentioned as illustrative.

Referring to Figs. 1-4, the operation of the control apparatus 47 in the lehr 4 is substantially as follows: The thumb nuts 44 (Fig. 4) are adjusted and tightened so that the pointer 46 indicates the selected temperature differential to be maintained between the points in the lehr at which the thermometer elements 15 and 16 are located. As long as the differential is maintained the pairs of pointers 31, 33 and 32, 34 remain in registry and the lever 47 is balanced. However, if for example the temperature at 16 drops, pointer 32 moves to the left of pointer 34 and the pressure in line 35 drops so that the diaphragm motor 51 does not sustain the counterweight 52 and maintain the lever 47 in balance. As the weight 52 falls the lever 47 turns clockwise on its pivot 48a and the shipper arm 47a moves the crosshead 41 to the left (Fig. 4) so that the shipper fork 38 moves the pointer 34 to the left until it registers with the new posi-

tion of pointer 32, at which time the counterbalancing  $7\frac{1}{2}$  p. s. i. pressure is restored in the line 35 so that the motor 51 again sustains the weight 52, but in a slightly lower position. When the temperature at 16 rises, the reverse action takes place so that the pointer 34 follows the pointer 32 automatically and moves into registry therewith. In order to prevent momentary overtravel of the crosshead 41 and over-correction of the pointer 34, stop screws 53 and 54 may be provided in the paths of the lever arms 47b and 47c.

Adjustment of the pointer 34 by crosshead 41 is simultaneously accompanied by a corresponding adjustment of the pointer 33. When the movement of the pointer 33 is to the left of the pointer 31, the pressure in line 17a will automatically be increased and the motor 18 operates to open the dampers 5 and 6 of the cooling section so that additional cold air is drawn into the section 2 by the fan 9. Consequently, the temperature of the lehr is lowered at the point at which the thermometer element 15 is located by the colder air discharged at that location from the secondary blower 12. Thereupon, the temperature of the element 15 is lowered and the pointer 31 moves into registry with the new position of pointer 33.

A similar result, of course, is effected by the control apparatus 17 in the lehr arrangement heretofore described with reference to Figs. 9 and 10. The opening damper 23 admits additional cold air to cool the element 15 to the temperature registered by pointer 33.

In both the arrangement illustrated in Figs. 1-3 and the arrangement illustrated in Figs. 9 and 10, the controlling apparatus 17 shown in Fig. 4 acts to automatically correct the temperature at element 15 so that it always follows temperature changes of element 16 and at all times maintains the selected constant temperature differential.

In addition to maintaining a temperature differential which is constant in amount, the present invention provides a number of modified control patterns for the temperature differential to meet special conditions. Instead of maintaining a temperature difference which is constant, the difference may be automatically varied in a number of ways including the following:

(a) Temperature difference increasing as temperature at 16 increases.  
(b) Temperature difference decreasing as temperature at 16 increases.  
(c) Temperature difference increasing as temperature at 16 departs from some preselected value.

(d) Temperature difference decreasing as temperature at 16 departs from a preselected value.

Fig. 7 illustrates a modification of the control apparatus heretofore described with reference to Fig. 4 which provides for increasing the amount of temperature differential as the temperature at 16 increases. More particularly, a spring 55 is compressed between diaphragm 51b and housing 51c of the motor 51 so as to assist the weight 52 (Fig. 4) in counteracting the force exerted by the motor armature 51a on the lever 47, weight 52 being somewhat lighter to allow for the force exerted by the spring 55. When the spring 55 is used, the pressure supplied to the motor 51 through the line 35 is different for different positions of the lever 47. Thus when element 16 is at a relatively low temperature, the spring 55 is less compressed so that higher

pressures are required in the line 35 to counterbalance the spring and weight 52. The higher pressure in line 35 required to balance the lever 47 is attained when pointer 32 registers a somewhat higher temperature than the pointer 34. However, when the element 16 is in a higher temperature range, such that the pointer 32 is swung to the right (Fig. 4), the bias of the pointers is reversed, pointer 34 being somewhat above pointer 32 when the lever 47 is balanced. Thus, when operating in the higher temperature range, the pointers 33 and 34 travel more degrees on their scales than the actual degrees of temperature change effected at 16 and indicated by pointer 32. Use of the spring 55 in the manner described is particularly adapted to increase the amount of heat shock when the ware in the Lehr is delivered in an upper temperature range and to automatically reduce the shock where ware is delivered into a lower temperature range wherein glassware normally has a lower heat shock strength.

Thus, the modification illustrated in Fig. 7 compensates for physical changes in the heat shock relative to changes in absolute temperatures of one of the limits. Furthermore, it compensates for differences and provides for "proportional control" at different parts of the temperature range.

Fig. 5 illustrates the use of a spring 56 counteracting the weight 52 and assisting the diaphragm motor 51. This arrangement provides for a greater temperature differential and heat shock when the temperature of element 16 is in a low range and for a lesser heat shock when the element is in the upper temperature range. Instead of progressively increasing or decreasing the temperature differential with an increase or decrease in the absolute temperature of one of the limits, it may be desirable as in some drying processes to make a temperature at element 15 vary more rapidly in a linear relation to the temperature 16 when the latter temperature varies. As shown in Fig. 6, the crosshead 41 of Fig. 4 is replaced by a bell crank lever 57 which is pivoted at 58a on a fixed fulcrum member 58 directly beneath the pivot point of the lever 57. The bell crank 57 is oscillated about its pivot point by movement of the lever arm 47 to which its arm 57a is connected by a link 59. A link 60 connects bell crank arm 57b with the rod 39 which reciprocates to adjust the position of pointer 34, as in the embodiment described with reference to Fig. 4. The rod 43 simultaneously is moved to adjust the position of pointer 33 in an amount differing from but in proportion to the movement of the rod 39 and the pointer 34, through a link 61 which connects the rod 43 with a stud 62 adjustably carried by arm 57b of the bell crank 57. More particularly, the stud 62 may be adjusted in slot 63 of the bell crank arm 57b to any selected distance from the bell crank pivot 58a. Knurled thumb nuts 64 provide for adjustment in the effective length of the connecting link 61 between the crank arm pivot 62 and the connection with the rod 43, so as to fix the distance between the pointer shipping forks 38 and 42 to correspond to a selected temperature difference for the elements 15 and 16, as indicated by the pointer 33 and 34.

Fig. 8 illustrates the further modification of the control apparatus, wherein a large weight 65 is secured to a projection 47d of the lever arm 47a, with the center of gravity of the weight located directly above the pivot point 48a of the lever 47 when the pointer 34 (Fig. 4) indicates a pre-

selected temperature for element 16. Therefore, if the pointer 34 shifts to indicate temperatures higher than that selected, the weight 65 moves to the left (Fig. 8) so that it augments the motor 51 in counterbalancing the weight 52. As a result, the temperature difference between elements 15 and 16 is progressively increased as the temperature of the element 16 increases above its aforesaid preselected temperature. On the other hand, when the pointer 34 shifts to indicate that element 16 is below the preselected temperature, the weight 65 moves to the right and augments the weight 52 on the lever 47. However, lever arm 47c thereafter engages a compression spring 66 which has more than enough stiffness to counteract the effect of the weight 65 on the balance of the lever 47. Consequently, the moment of weight 52 is lightened as the temperature at 16 is decreased from the initial point and the temperature difference between the elements 15 and 16 is again increased.

The temperature difference may be decreased as the temperature at 16 departs from a preselected value by omitting spring 66 and locating a like compression spring 67 (shown in dotted line in Fig. 8) between the lever arm 47 and the spring member 27 to the left of the pivot point of the lever 47.

In addition to the specific modifications heretofore described with reference to Figs. 5-8, inclusive, it will be apparent that a number of these alternative arrangements may be combined to modify their individual effects on the operation of the control apparatus 17. Thus, for example, the arrangement of Fig. 6 may be combined with either of the two arrangements described with reference to Fig. 8.

While the described embodiments of the present invention all illustrate the control of the temperature at one point in a Lehr relative to the temperature at a second point which is upstream of the first point in the Lehr, it will be apparent that, if desired, the apparatus embodying the invention readily can be adapted to control temperature at an upstream point relative to a downstream point merely by reversing the positions of the apparatus components relative to one another.

While the temperature of only one of the two control points is regulated and the temperature of the other point is unaffected by the operation of apparatus embodying the invention, it will be apparent that the invention may be incorporated in equipment in which the temperature at the second point is regulated by other independent controls. Thus the temperature of element 16 in the Lehr may be regulated by suitable drift control equipment and apparatus embodying the present invention will continue to regulate the temperature difference between elements 15 and 16 in the intended manner.

Having thus described my invention, I claim:

1. The method which comprises subjecting glassware to heat treatment appropriate for conventional annealing thereof until said glassware has a temperature approximately that of its lower annealing limit, and then subjecting the glassware at about said temperature to heat shock by applying thereto a cooling medium at a temperature approximately 150-300° F. lower than said lower annealing limit and of sufficient cooling intensity to cause breakage of glassware having less than a predetermined minimum resistance to heat shock.

2. The method of annealing glassware which

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includes gradually cooling the ware in a heated lehr the gaseous internal atmosphere of which gradually varies in temperature from the upper to the lower annealing temperature for the glass, thereafter cooling at a more rapid rate while above 400° F. by abrupt exposure to 150-300° F. cooler atmosphere within the lehr so as to effect an abrupt temperature drop such that all ware rejectionably weak in heat shock is broken and only acceptable heat shock-proof glassware remains.

3. The method recited in claim 2 and wherein said remaining ware is further cooled at a lesser cooling rate than that effected by said abrupt temperature drop.

4. The method recited in claim 2 and wherein said abrupt temperature drop is effected from a temperature adjacent the lower annealing point for the glass.

5. The method recited in claim 2 which includes the step of strongly recirculating the atmosphere at the upper limit point of said drop immediately preceding the abrupt temperature drop in the atmosphere of the lehr.

6. The method of annealing glass container ware which includes gradually cooling the ware in a heated lehr, the internal gaseous atmosphere of which gradually varies in temperature from the upper to the lower annealing point for the glass in a portion of the lehr through which the ware travels, strongly recirculating lehr atmosphere which is at approximately the lower annealing temperature point and thereby establishing throughout the ware in the recirculating atmosphere a substantially uniform temperature near and not greater than said lower annealing temperature, thereafter immediately directing at the uniform temperature ware a stream of air at a temperature 150-300° F. below said uniform temperature to shock and break all objectionably cordy and non-homogeneous shocked ware without breaking ware of acceptable homogeneity, and thereafter further cooling said ware at a lesser cooling rate than that effected by the shock cooling air stream.

7. In a glassware annealing tunnel lehr, a first section of the tunnel having means for recirculating and maintaining the atmosphere of said section at a first temperature, a second tunnel section having damper means for controlling the flow of outside cold air into said second section, damper means for controlling exhaust of air directly from said second section, means for circulating air transversely of said second section, means for drawing air from one point in the tunnel and discharging it in a transversely directed stream back into said tunnel directly adjacent said first section, a first temperature responsive element located in said first section, a second temperature responsive element located in the lehr adjacent the said discharge point and in said air stream, and control means responsive to said two elements for automatically and simultaneously opening and closing said dampers of the second section to maintain a preselected temperature differential between said two elements.

8. The apparatus recited in claim 7 and wherein

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said dampers are automatically opened to increase the intake of cold air when the temperature of said second element varies from the temperature of said first element by less than said preselected temperature differential and the dampers are moved toward their closed positions when the temperature difference of the two elements exceeds said preselected differential.

9. Apparatus as recited in claim 7 and wherein the control means includes adjustment means for varying the preselected temperature differential.

10. Apparatus as recited in claim 7 and wherein said control means includes means for automatically varying the amount of said temperature differential responsive to changes in absolute temperature of one of said elements.

11. Apparatus for maintaining a preselected temperature differential between first and second spaced points within a heated lehr including means for controlling intake of cold air into and the exhaust of heated air from a section of the lehr, a temperature responsive element at each of said spaced points, the temperature at the second being influenced more than the temperature of the first point by said intake and exhaust, a pair of pressure controllers one of which is responsive to changes in temperature of the element at the first point and the other of which is responsive to the element at the second point, a separate adjustable temperature selecting pointer associated with each controller, common shipper means for maintaining the two pointers a distance apart corresponding to a preselected temperature difference between the responsive elements, said common means including an adjustment for preselecting the difference between the temperatures indicated by said pointers, means operated by the controller which is responsive to the temperature of the element at the first point for actuating said shipper means so that the selecting pointer of said controller follows temperature changes of the element at said first point, and means controlled by the other controller for adjusting said intake and exhaust dampers so as to automatically regulate the temperature of the element at said second point to correspond to the temperature indicated by the pointer of said other controller.

12. Apparatus as recited in claim 11 wherein said means operated by the controller which is responsive to the temperature of the element at the first point includes a line the pressure of which varies with changes in temperature of said first element, a motor actuated by the pressure in said line and operably engaging a pivoted lever one portion of which ships the said shipper when the lever is pivoted, and a weight acting on said lever with a moment counter to the moment exerted by the motor on said lever.

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