

Oct. 18, 1938.

D. G. MERRILL

2,133,783

METHOD OF AND APPARATUS FOR ANNEALING GLASSWARE

Filed Dec. 14, 1935

3 Sheets-Sheet 1

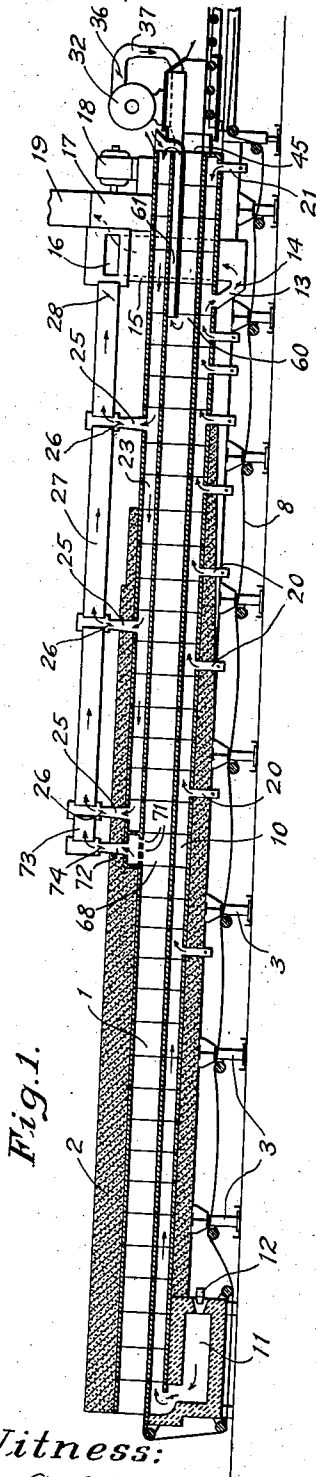


Fig. 1.

Witness:
A. A. Horn.

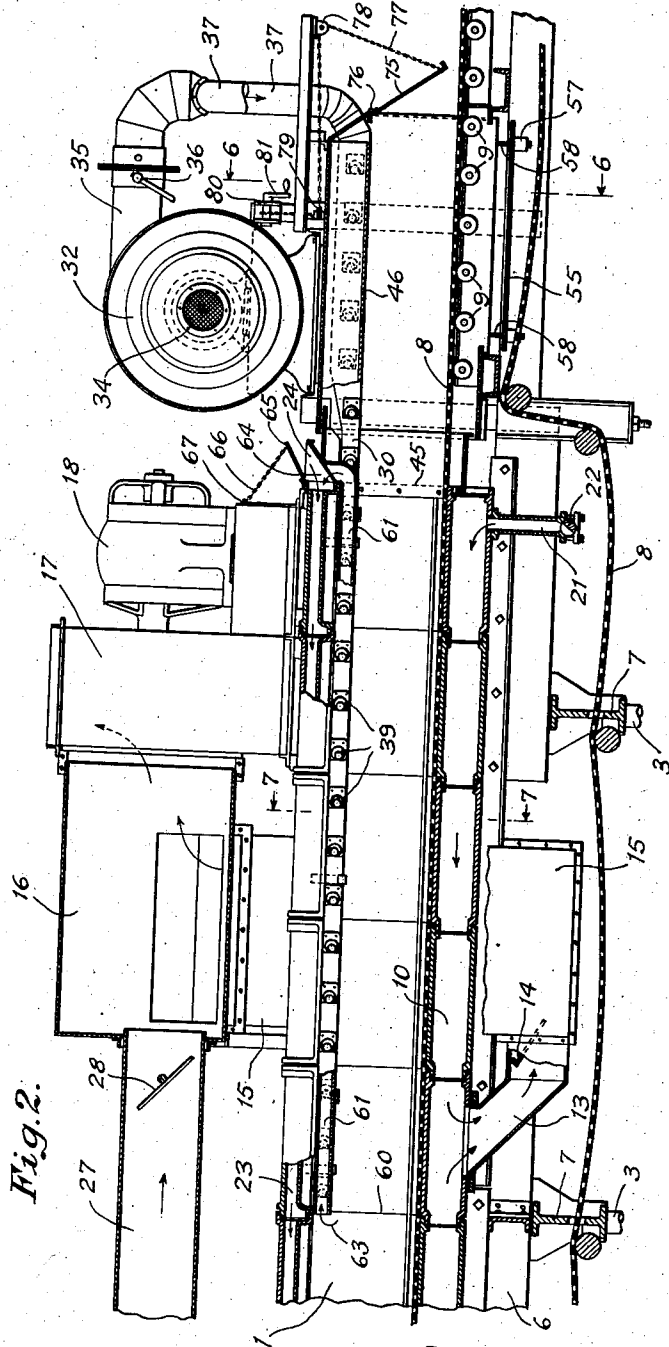


Fig. 2.

Inventor:
Donald G. Merrill
by Brown & Carlaw
Attorneys.

Oct. 18, 1938.

D. G. MERRILL

2,133,783

METHOD OF AND APPARATUS FOR ANNEALING GLASSWARE

Filed Dec. 14, 1935

3 Sheets-Sheet 2

Fig.3.

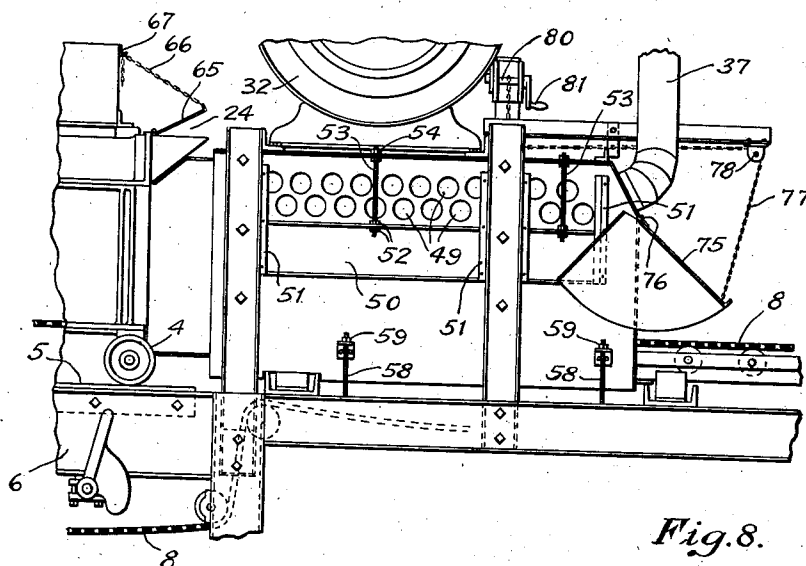


Fig.4.

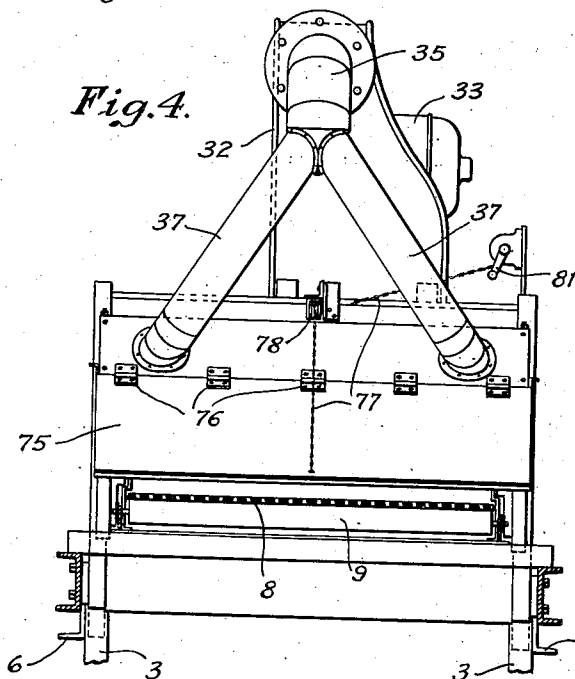
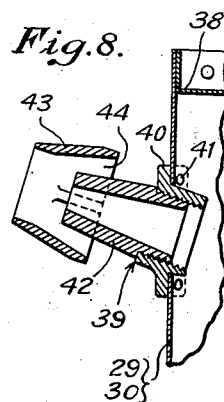


Fig.8.



Witness:
A. A. Horn

Inventor:
Donald G. Merrill
by Brown & Parkman
Attorneys.

Oct. 18, 1938.

D. G. MERRILL

2,133,783

METHOD OF AND APPARATUS FOR ANNEALING GLASSWARE

Filed Dec. 14, 1935

3 Sheets-Sheet 3

Fig. 5.

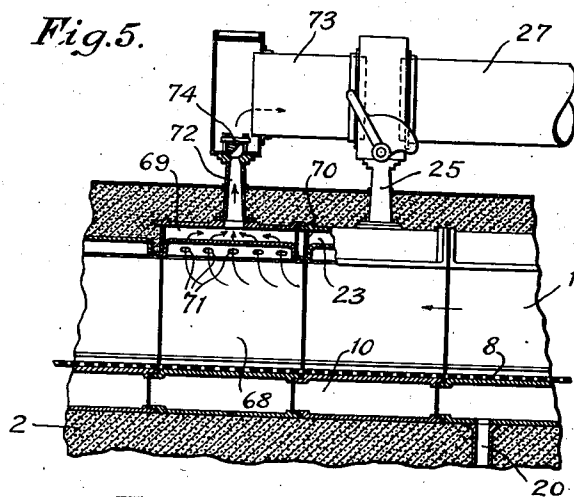


Fig. 6.

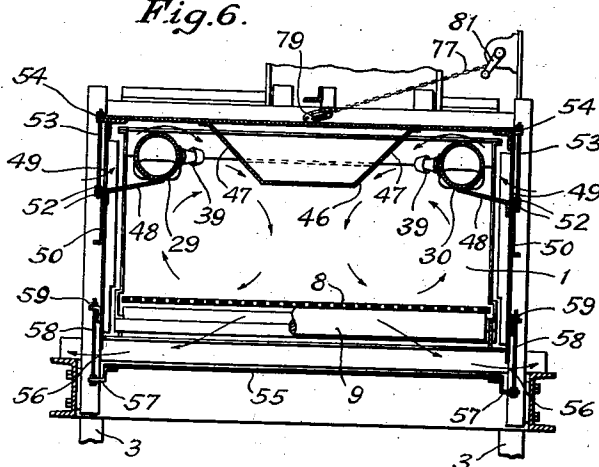
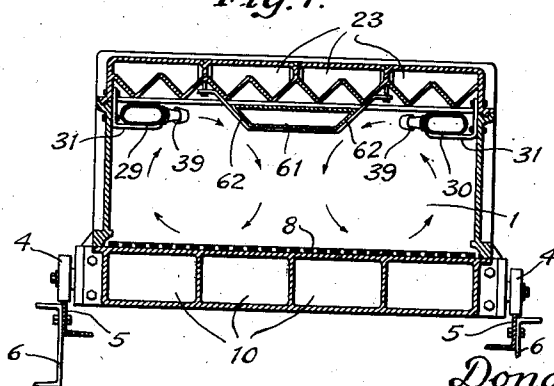


Fig. 7.



Witness:

A. A. Horn

Inventor:
Donald G. Merrill
by Brown & Parkman
Attorneys.

UNITED STATES PATENT OFFICE

2,133,783

METHOD OF AND APPARATUS FOR ANNEALING GLASSWARE

Donald G. Merrill, West Hartford, Conn., assignor
to Hartford Empire Company, Hartford, Conn.,
a corporation of Delaware

Application December 14, 1935, Serial No. 54,448

21 Claims. (Cl. 49—47)

This invention relates to a method of and apparatus for the annealing of glassware and more particularly to such a method and apparatus including the cooling of the ware in the cooler portion of a lehr tunnel by means of air circulation within the tunnel in a path which will pass repeatedly through the path of the ware and having a major component of velocity transversely of such ware path and a minor component of this velocity longitudinally of the tunnel opposite the direction of movement of the ware therethrough.

Among the objects of the present invention are to provide for the cooling of the glassware in the cooler exit end portion of a tunnel lehr by means of air circulation within the tunnel as aforesaid, the emphasis being placed upon circulation transversely of the path of the ware to increase the heat transfer between the ware and air while at the same time the air moves gradually through the tunnel countercurrent to the ware, so that at any given point along the tunnel in the zone in which the air is circulated as aforesaid, the air will have been heated to some extent by heat derived from the ware at cooler portions of the tunnel and thus the temperature difference between the ware and the air will not be so great as to cause damage to the ware.

A further object of the invention is to create a circulation as aforesaid by the use of a plurality of jet nozzles through which air or other gaseous medium is injected into the tunnel at relatively high pressure and thereby the air in the tunnel is caused to circulate along with the air or other gaseous medium thus injected, the amount of air thus circulated being many times greater than that of the gaseous medium injected into the tunnel through the nozzles.

A further object of the invention is to provide for the arrangement in the tunnel of jet nozzles and deflectors in such arrangement as to create a desired character of circulation in the tunnel, specifically one in which the air is circulated in two substantially helical paths, the axes of which lie longitudinally of the lehr and side by side in the tunnel, the air flowing downwardly adjacent to the longitudinal center line of the tunnel, so that the ware at the center of the conveying means of the lehr will be cooled to a greater extent than that nearer the sides of such means during its passage through the last zone of the tunnel. This in practice tends to balance the cooling influence of the atmosphere on the ware after it has emerged from the tunnel, which is effective to a major extent on the ware at the

sides of the conveyor, so that all the ware is brought down to a fairly uniform temperature.

A further object of the invention is to establish a zone in which air is circulated as aforesaid adjacent to the exit end of the tunnel and in which provision is made for the introduction of air from the atmosphere into the circulation at one portion thereof and in a controllable amount, and preferably also for the discharge of a controllable amount of air from the circulation to the atmosphere.

A further object of the invention is to provide for the cooling of the ware in several zones in which the effectiveness of the cooling is progressively increased. Specifically the cooling is preferably effected in three zones, the cooling in the first zone from the exit end of the lehr including the general circulation as aforesaid, and also including the introduction into and exhaust from the circulation of air at each cycle of flow of the air transversely of the tunnel. In the second zone, air is circulated as aforesaid, but without the introduction or exhaust of air to and from the circulation intermediate the ends of the zone, and in the third zone, a controllable amount of air is caused to flow countercurrent with respect to the ware, but without positive transverse circulation.

A further object of the invention is to provide for the controlled withdrawal of the cooling air from the tunnel intermediate the ends thereof at one or more points, the withdrawal preferably being so controlled that there will be a desired flow of air, including zero flow, in the hotter portions of the tunnel between the withdrawal point for air nearest the hotter end of the tunnel and the entrance end thereof, so that in effect the apparatus provided may function as a drift control means for the lehr.

Other and more detailed objects of the present invention will become apparent from the following specification and appended claims when taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view substantially in longitudinal vertical section of a glass annealing lehr embodying my invention;

Fig. 2 is a detailed view similar to Fig. 1, but on a larger scale and showing the exit end portion of the lehr including certain of my novel provisions for cooling the ware passing there-through;

Fig. 3 is a fragmentary view substantially in side elevation of a portion of the lehr shown in Fig. 2;

Fig. 4 is an end elevation of the lehr tunnel as would be seen from the right of the portion shown in Fig. 2;

Fig. 5 is a fragmentary view substantially in vertical longitudinal section showing the withdrawal means for tunnel atmosphere toward the hotter end of the lehr, this means being diagrammatically shown substantially at the middle in Fig. 1;

Fig. 6 is a view in transverse vertical section taken on the line 6—6 of Fig. 2;

Fig. 7 is a view in transverse vertical section taken on the line 7—7 of Fig. 2; and

Fig. 8 is a fragmentary view substantially in horizontal section showing in detail one of the injector nozzles and its relation to the duct through which compressed air is supplied thereto.

While I contemplate that my invention may be applied to various types of lehrs, including both direct fired and muffle types, and lehrs in which there is provision for muffle cooling or where such provisions are omitted, I have chosen to illustrate my invention as applied to a lehr of a type now in general commercial use, which lehr is substantially the same as that disclosed in Mulholland Patent No. 1,560,481, granted Nov. 3, 1925. This lehr will be described but briefly in the present application except as it is varied according to my present invention. Reference may be had to the aforesaid Mulholland patent for a specific description of any details of construction not included herein.

As shown, the lehr comprises an elongate tunnel 1 which may be made up of a plurality of metallic sections as shown and which is surrounded for the major portion of its length by suitable insulation generally indicated at 2. The lehr is suitably supported upon a plurality of spaced legs or pedestals 3. Provision may be made for permitting the expansion of the tunnel when it is heated, such provision preferably including the mounting of the major portion of the tunnel upon wheels as shown at 4, Figs. 3 and 7, these wheels running upon suitable rails 5, which are in turn secured to longitudinally extending channels 6, the channels being secured together in a suitable manner, as by transverse structural members 7 and being supported upon the pedestals 3.

Means are provided for conveying the ware through the tunnel, comprising a conveyor belt 8, which is preferably of suitable woven wire construction and which has its ware-bearing or active strand passing through the tunnel and slidably supported upon the floor thereof throughout the major portion of the tunnel and upon a plurality of rollers 9 in the exit end portion of the tunnel, as shown best in Fig. 2. The return strand of the belt 8 passes to the forward end of the lehr beneath the same, as diagrammatically illustrated in Fig. 1. The means for drawing the belt 8 through the tunnel are not shown in the accompanying drawings as they are located to the right of the portions shown in Figs. 1 and 2, but may be assumed to be the same as or equivalent to the corresponding means of the Mulholland patent above referred to.

Means are provided for supplying heat to the lehr and for controlling the temperature of the ware in its passage through the tunnel 1, such means including one or more flues 10 extending longitudinally beneath the tunnel substantially as in the Mulholland patent. Products of com-

bustion are supplied to the flues 10 from a fire box diagrammatically illustrated at 11 in Fig. 1, wherein these products are generated by combustion of fuel supplied thereto through a burner 12. The gases are withdrawn from the flue or flues 10 through a tap-off passage 13, Figs. 1 and 2, under control of a damper 14 and thence pass through a pair of saddle pipes 15, one on each side of the lehr, to a wind box 16 above the tunnel, which communicates with a suitable exhaust fan 17. The fan 17 may be driven by any suitable prime mover, as for example an electric motor 18. The gases from the fan 17 are discharged through a suitable stack, as indicated at 19, Fig. 1.

At desired intervals along the flues 10 and immediate the fire box 11 and the tap off 13, there are provided air inlet openings 20 which are each controlled by a suitable damper. In this way, controllable amounts of air may be admitted at intervals to the flues 10 for diluting and cooling the gases passing therethrough and consequently for controlling the temperature in corresponding portions of the tunnel.

At the end of the flue or flues 10 adjacent to the exit end of the tunnel, there is provided an inlet opening 21 (Figs. 1 and 2), which is controlled by a damper 22. Thus air may pass into the exit end portions of the flues 10 through the opening 21 under control of the damper 22 and flow in a path countercurrent of the movement of the ware to the outlet passage 13 for effecting a muffled cooling of the ware in this zone.

Above the tunnel and extending from the exit end thereof part way toward the entrance end, there are provided one or more flues 23 (Figs. 1, 2 and 7), these flues being open to the atmosphere at the exit end of the tunnel as generally indicated at 24 as hereinafter set forth, and being provided with a plurality of tap-off passages 25, each of which is controlled by a damper 26 and all of which communicate with a takeoff conduit 27, which in turn communicates with the wind box 16, and there being a damper as indicated at 28, Fig. 2, for controlling the flow through the takeoff conduit 27. In this way, the cooling air may be drawn a desired distance from the exit end of the lehr toward the entrance end through the muffle flues 23 and portions of such cooling air may be withdrawn from this flue as desired through each of the several tap-off passages 25 under the respective control of the dampers 26.

The construction thus far described is substantially the same as that of the Mulholland patent above referred to.

Means are provided according to my invention for creating a circulation of air in the cooler portions of the tunnel, this circulation having a major effective component of velocity transversely of the tunnel and a minor effective component of velocity longitudinal of the tunnel and countercurrent to the direction of movement of the ware therethrough. More specifically, the circulation is created in two substantially helical paths which traverse the path of the glassware, have their axes extending side by side and substantially longitudinally of the tunnel and are so arranged that the air circulated therein will be moved downwardly adjacent to the longitudinal center line of the tunnel. Such circulation is preferably created by the injection into the tunnel of air or other cooling medium under a desired relatively high pressure as compared to the pressure of the air in the tunnel, the air being injected through a plurality of nozzles disposed at spaced inter-

vals along a pair of longitudinally extending ducts.

As shown, there are provided a pair of ducts 29 and 30 which are disposed in the upper corners of the tunnel as best shown in Figs. 6 and 7. The form of the ducts varies intermediate their ends, the endmost portions being substantially round as shown in Fig. 6, while the portions nearer the hotter end of the lehr are flattened as shown in Fig. 7. This also makes for a control of the air distribution as the cross sections of the portions of the ducts shown in Fig. 7 are less than those of the upstream portions of the ducts shown in Fig. 6. The ducts are suitably supported as by brackets shown at 31, Fig. 7, from the side walls of the lehr.

Means are provided for supplying air under pressure to the ducts 29 and 30, such means in the present instance comprising a blower 32, Figs. 1, 2 and 4, which is suitably driven as by a prime mover shown as an electric motor 33. The blower 32 has an intake centrally thereof at 34 and an outlet passage 35, which is provided with a suitable damper control 36 and which branches as shown into two passages 37 communicating respectively with the ducts 29 and 30.

The ends of the ducts 29 and 30 toward the hotter end of the lehr are closed as indicated at 38, Fig. 8, in which a portion of one of the ducts is shown, the duct in this figure being given both reference numbers to indicate that it is representative of both ducts. Each of the ducts 29 and 30 is provided with a plurality of jet nozzles 39, these nozzles being directed generally transversely of the lehr in a substantially horizontal plane but being inclined at a small angle, perhaps 15°, with respect to a line exactly transverse of the lehr and in a direction toward the hotter end of the lehr. The specific arrangement of one of these nozzles is illustrated in Fig. 8. As shown in this figure, the ducts 29 and 30 may be formed of sheet metal and are provided at the point where a nozzle is to be arranged with a fitting 40 suitably secured thereto as by rivets 41. In this fitting is threaded a nozzle member 42 through which the air or other cooling fluid may pass from the inside of the duct to the inside of the tunnel. Around the end of each of the nozzle members 42 there may be arranged a member 43 to assist in inducing a flow of air under the action of the pressure jet supplied through the nozzle member 42, the air being induced to flow through the annular space 44 intermediate the nozzle member 42 and the member 43 and thus being caused to circulate with the air injected into the tunnel through the nozzle. In this way, I am enabled to cause a somewhat larger amount of air to be circulated than would be possible with the use of the nozzles 42 without the members 43 associated therewith. It will be understood, however, that the jet action of the nozzles without the use therewith of the members 43 will be effective to circulate a relatively large amount of air in the tunnel as compared to the amount of air injected thereinto through the nozzle members.

In the extreme exit end zone of the tunnel, or the first zone from the exit end, which may be said to include that portion of the tunnel from the exit end substantially to the point 45 (Figs. 1 and 2), I provide means for deflecting the air circulated by the injector nozzles as aforesaid and also for the introduction and exhaust of air into and from the circulation in the tunnel. As shown in Figs. 2 and 6, there is provided a deflector 46 which may be formed of sheet metal

or other suitable material and suitably secured to the top of the tunnel. This deflector has sloping sides 47 against which the air supplied by the nozzles 39 in this zone of the lehr will impinge, so as to cause the air to be circulated substantially as shown by the arrows in Fig. 6. It will be understood, of course, that when the lehr is filled with glassware in its normal operation, the path of the air will not be in a truly helical path as generally indicated by the arrows, but will take some substantially helical path traversing the path of the ware and passing down through the perforate conveyor belt 8 intermediate the supporting rollers 9 near the center of the lehr and thence upwardly again adjacent to the sides of the lehr tunnel to be recirculated by the jet action of the nozzles. This recirculation is assisted by deflector members 48, which are provided in this zone intermediate the sides of the tunnel and the under portions of the ducts 29 and 30.

Means are provided for the introduction of atmospheric air into the tunnel through the lateral sides thereof to join in the circulation in the first zone as aforesaid. For this purpose, the tunnel walls are provided with a plurality of apertures as indicated at 49, Figs. 3 and 6, the air passing thereinto as indicated by the arrows in Fig. 6 to join in the circulation in the tunnel. The inflow of air through the apertures 49 is controlled by vertically sliding damper members 50 arranged one at each side of the lehr in guide members 51, which are secured to the side walls of the lehr. Vertical adjustment of the damper members 50 may be effected by suitably threading up or down nuts 52, which clamp an upper flange of each of the damper members to spaced depending bolts 53, the upper ends of which are secured in flange portions of the top and sides of the lehr at 54. Thus, the damper members 50 may be suitably vertically adjusted and secured in adjustable position to control the inflow of air through the apertures 49.

In a somewhat similar way means are provided for controlling the exhaust of air from this first zone at the bottom thereof. For this purpose a portion 55 (Figs. 2 and 6) of the bottom of the tunnel in this zone is arranged to be vertically adjustable or, if desired, wholly removable to provide for the controlled exhaust of air between this vertically adjustable bottom portion and the edges of the side and bottom walls of the tunnel through openings indicated at 56. As shown, the adjustable bottom portion 55 is provided with suitable brackets 57 in which are secured threaded bolts 58, the upper ends of which pass through suitable fixed brackets secured to the side walls of the lehr, there being nuts as indicated at 59 threaded on the bolts 58 above the fixed brackets by which the bolts and therefore the bottom member 55 may be vertically adjusted in a manner which will be obvious from the drawings and from the above description.

Thus in this first or coolest zone of the lehr, I have provided not only for the circulation of tunnel atmosphere in a path as aforesaid, but have also provided for the controlled introduction of air into the circulation as created and the controlled exhaust of air therefrom intermediate the ends of this zone. This will effect a maximum cooling of the ware passing through this zone, which is desired at this point in order that the ware be brought down to a temperature approximating that at which it may be handled by the workers whose duty is to select and pack

it upon the packing table of the lehr, which extends to the right as seen in Figs. 1 and 2 of the lehr construction there shown.

In the second coolest zone of the lehr, which may be considered as extending approximately from point 45, Figs. 1 and 2, to the point 60, I provide for the circulation of air as in the first zone with the exception that no means are provided for introducing atmospheric air into this circulation or for discharging circulated air therefrom intermediate the ends of such zone. The ducts 29 and 30 extend through this second zone as best illustrated in Fig. 7, but are flattened as shown so as to accommodate them to the reduced vertical space available in view of the presence of the flues 23 above referred to, these flues ending substantially at the point 45 as shown in Fig. 2.

For directing the circulation in this second zone, there is provided a duct 61, which is formed in approximately the same general shape as the baffle 46, that is, with beveled sides as shown at 62 (Fig. 7) against which the air from the nozzles 39 in this zone will impinge, so as to direct the circulated air substantially in the paths shown by the arrows in Fig. 7. Thus, intermediate the end of this second zone, the air will be circulated as aforesaid to flow on and between the articles of glassware passing through the tunnel and with such a component of velocity transversely of the lehr as to insure a fairly high coefficient of heat transfer between the ware and the air, so that the cooling of the ware will be quite efficient. Due to the fact that there is no additional air supplied to the circulation intermediate the ends of the zone, the air gradually moving in repeated circulations from the cooler toward the hotter end of the lehr will gradually be heated up by heat received from the ware and not dissipated to the side and bottom walls of the lehr. Thus the temperature difference between the ware and the air will be kept within the desired limits and breakage of the ware by too sudden cooling prevented.

At the hotter end of this second zone, there is provided means for withdrawing from the tunnel a desired portion of the air which has been circulated throughout this zone as aforesaid. For this purpose, there is an opening into the tunnel from the interior of the duct 61, which as shown at the extreme end of this duct, the air entering the duct as indicated by the arrow 63, Fig. 2. This air thus withdrawn from the tunnel passes through the duct toward the exit end of the lehr and then passes into a chamber 64, which communicates with this duct, with the end of the flues 23 and with the atmosphere at 24 as shown. The communication between this chamber and the atmosphere is controlled by a damper member 65, which may be secured in adjusted position as by providing it with a chain 66, any link of which may be secured to a suitable hook or detent as shown at 67. Thus there is provided suitable means for controlling the communication between the chamber 64 and the atmosphere. Inasmuch as the flues 23 are under sub-atmospheric pressure, due to the influence of the exhaust fan 17 by which all the air is withdrawn from the flues 23 as above described, the closing of the damper member 65 will increase the amount of air drawn through the duct 61 and thence through flues 23; and conversely, the opening of this damper member will reduce the amount of air drawn through the duct 61 and increase the proportion of air pass-

ing through the flues 23 which is drawn directly through the opening 24. In this way, the fan 17 is caused to be effective on the duct 61 to withdraw from the tunnel at the hotter end of the second zone a selected amount of air which has been circulated as aforesaid.

The next cooler zone of the lehr may be considered as that portion extending approximately between the point 60 or the hotter end of the second zone and substantially the point indicated at 68, Fig. 1. Substantially at or adjacent to the point 68, there is provided in the roof of the tunnel a hollow section 69 (Figs. 1 and 5), which is independent of the flues 23, but may be formed in a similar manner, it being separated from the remainder of the flues 23 by a suitable stopper member 70. This section communicates with the interior of the tunnel through a plurality of apertures 71, as shown in Fig. 5, and communicates through a take-off passage 72 and an extension 73 of the take-off conduit 27, with that conduit and therethrough with the wind box 16 and exhaust fan 17. Flow of air through the takeoff passage 72 is controlled by a damper 74 as shown.

In this third cooling zone of the tunnel, there will be a substantially straight countercurrent flow of air which is derived from the air circulated in the second zone and which is withdrawn through the openings 71 and the passages above described by the exhaust fan 17. This will produce a relatively less cooling effect upon the glass than the substantially transverse circulation set up in the second zone, and that circulation will in turn have a less cooling effect than the circulation including the introduction and exhaust of air in the first cooling zone. The glass passing through the tunnel will then be subjected to progressively increasing cooling influences in passing from the third, to the second, to the first of the above mentioned zones.

An advantageous function of the arrangement provided and hereinabove described is that of controlling the drift in the hotter portions of the tunnel specifically from the point 68 to the hotter end of the tunnel. It is desired usually that there be little or no drift through this hotter zone or in some instances that there be a slight drift out the hotter end of the tunnel, so as to prevent the inflow of air at such end, which might damage the ware. Any of these drift conditions may be effected by a suitable control of the amount of air withdrawn from the tunnel at the two points, first through the duct 61 as indicated by the arrow 63 under control of the damper 65, and, second, through the apertures 71 under control of the damper 74, in coordination with the amount of air admitted through the nozzles 39, controlled by damper 36 and the air admitted and exhausted in the first zone controlled by dampers 50 and the setting of the bottom member 55. It will be understood that any suitable means, such as those disclosed in the prior art, some of which are now in commercial use, may be employed for providing an automatic control or drift if such control is preferred to a manual control, but as these means are now in use in the art and are described in the patented art, no further description will be given herein at this time and they have not been shown in the accompanying drawings.

The flow of air into the exit end of the tunnel may be controlled by the provision of the usual door 75, which is usually kept at the lowest

height at which it will clear the ware passing through the tunnel. This door is shown as hinged to the end portion of the lehr at 76 and is provided with an adjusting means including a chain 77 passing over sheaves at 78 and 79 and arranged to be wound upon a drum 80 under the control of a crank 81 as shown.

Also, the several adjustable means may be completely shut to maintain the lehr hot or to heat it up when no ware is for the time being passing therethrough.

I contemplate that certain of the individual cooling arrangements described herein may be used independently of others and that they may be employed in conjunction not only with the muffle type annealing lehr as shown in the accompanying drawings, but also with direct fired types of lehns and that many variations may be made to the specific constructions herein described and shown in the drawings. I do not wish to be limited, therefore, except by the scope of the appended claims, which are to be construed as broadly as the state of the prior art permits.

I claim:

1. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, and accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by circulating a gaseous cooling medium in said zone in a path passing repeatedly through the path of the ware and in such manner that the current thus circulated will have a relatively high effective velocity transversely of the path of the ware and a relatively low effective velocity in the direction opposite the direction of movement of the ware through the tunnel to establish a relatively high heat transfer from the ware to the circulated gaseous medium.

2. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by circulating a gaseous cooling medium in said zone in a path passing repeatedly through the path of the ware and in such manner that the current thus circulated will have a relatively high effective velocity transversely of the path of the ware and a relatively low effective velocity in the direction opposite the direction of movement of the ware through the tunnel to establish a relatively high heat transfer from the ware to the circulated gaseous medium, and withdrawing a part of the gaseous medium thus circulated from the tunnel adjacent to the hotter end of said zone.

3. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, and accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by creating a circulation of air in said zone in a substantially helical path passing repeatedly transversely of the path of the ware and having a relatively high effective velocity transversely of the path of the ware and a relatively low effective velocity in the direction opposite the direction of movement of the ware through the tunnel by introducing into the tunnel a plurality of jets of air at relatively high pressure as compared with the pressure of the air within the tunnel and substantially tangent to the helical path of the circulation.

4. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, and accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by introducing a plurality of jets of air under relatively high pressure and directed in paths, the principal component of which is transversely of the lehr and a minor component longitudinal thereof in the direction opposite that of the movement of the ware therethrough, and admitting air from the atmosphere in such manner that the air thus admitted is caused to circulate in the tunnel due to the action of the jets aforesaid, thereby circulating air in the tunnel in a zone adjacent to the exit end thereof in a path passing repeatedly transversely of the path of the ware through the tunnel.

5. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, and accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by introducing a plurality of jets of air under relatively high pressure and in paths, the major component of which is transverse of the lehr and a minor component is longitudinal thereof in the direction opposite that of the movement of the ware therethrough, controllably admitting air from the atmosphere into the tunnel in such manner that the air admitted is caused to circulate in the tunnel by action of the air jets aforesaid, and controllably exhausting a part of the air thus circulated, and thereby circulating air in the tunnel in a zone adjacent to the exit end thereof in a path passing repeatedly transversely of the path of the ware through the tunnel.

6. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by setting up in said zone two substantially parallel laterally disposed helical circulations of air by the provision in said zone of a plurality of longitudinally spaced air jets which are respectively substantially tangent to the circulations thus set up and which cause the circulations to flow in paths, the major component of which is transverse of the tunnel and a minor component of which is longitudinal thereof in the direction opposite that of the movement of the glassware therethrough, and withdrawing at least a portion of the air thus circulated from the tunnel adjacent to the hotter end of said zone.

7. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, and accelerating the cooling of the ware during its passage through a zone adjacent to the exit end of the tunnel by circulating air in said zone by the introduction of a plurality of jets of air under a relatively high pressure as related to the pressure of the air in the tunnel, which jets are so disposed and directed as to cause the circulation of air in two substantially helical paths, the axes of which are parallel and extend side by side longitudinally of the lehr and so that the air will move in paths each having a major effective component of velocity transversely of the lehr to increase the rate of heat transfer from the ware to the air while having a minor component of velocity in a direction longitudinal of the lehr and opposite the direction of movement of the ware there-

through, the air moving above the path of the ware toward the center of the tunnel and thence downwardly so that the ware nearer the center of the lehr is cooled to a greater extent than the ware at the sides by the circulation as aforesaid.

8. The method of annealing glassware, which comprises the steps of passing the ware to be annealed through a tunnel lehr, accelerating the cooling of the ware during its passage through the cooler portion of the tunnel in a plurality of zones, the effectiveness of the cooling of which is progressively increased toward the cooler end of the tunnel, including the circulation of air in the first zone considered from the exit end of the tunnel by the use of a plurality of jets of air under relatively high pressure to induce air from the atmosphere entering laterally of the tunnel and to cause it to flow in two substantially helical paths traversing the path of the ware and having their major components of velocity transverse of the path of the ware while having their minor components of velocity longitudinal of the path of the ware and opposite its direction of movement, removing a controllable portion of the air thus circulated in the first zone from the circulation on each turn thereof to cause cooling of the ware at a relatively high rate, causing a similar circulation in the second zone from the cooler end but without the introduction or exhausting of air to and from the circulation as in the first zone as aforesaid and thus circulating in said second zone an amount of air which is drawn only from the air circulated in said first zone except for the air supplied by the jets in the second zone, withdrawing a portion of the air thus circulated in the second zone from the tunnel substantially at the hotter end of said second zone, cooling the ware in a third zone of the tunnel from the cooler end by countercurrent flow of air through this zone of the tunnel without positively induced transverse circulation of the air in this zone, and withdrawing the air moving through this third zone from the tunnel at the hotter end of the third zone at such a rate as to establish a condition of substantially zero flow longitudinally of the tunnel in the portion thereof intermediate the hotter end of the third zone and the entrance end of the tunnel.

9. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a duct extending longitudinally of the lehr in a zone thereof adjacent to the exit end of the tunnel, means for supplying a cooling medium to said duct under a relatively high pressure, and means disposed at spaced intervals along said duct and constructed and arranged to discharge such medium from said duct into the tunnel in such manner as to create in the tunnel a substantially helical circulation, the major component of velocity of which will be transverse of the tunnel and of the path of the ware therethrough, while a minor component of said velocity of which will be longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough.

10. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, means for conducting air under pressure longitudinally of said tunnel in the cooler portion thereof adjacent to the exit end of the tunnel, means for supplying air under pressure to the last named means, means constructed and arranged to discharge the air from said air conducting means into the tunnel in such manner as to set up two substantially parallel

helical circulations in the tunnel with the axes of said circulations extending longitudinally of the tunnel, the air so circulated having a major component of its velocity transverse of the tunnel so as to cause a relatively high rate of heat transfer between the ware and the air and a minor component of said velocity longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough, and means disposed intermediate the ends of said tunnel for conducting therefrom at least a part of the air circulated as aforesaid.

11. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a pair of similar ducts extending longitudinally of the lehr in the upper portion of the tunnel adjacent to the lateral sides thereof and in a zone of the tunnel adjacent to the exit end thereof, means for supplying air under pressure to said ducts, means including spaced nozzles constructed and arranged to discharge the air from said ducts into the tunnel in such manner as to create two substantially helical circulations, the axes of which extend longitudinally of the tunnel and are so arranged that the major component of the velocity of the air thus circulated in the tunnel extends transversely thereof while a minor component of said velocity is longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough, and means intermediate the ends of the tunnel for conducting therefrom at least a part of the air circulated as aforesaid.

12. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a duct extending longitudinally of said tunnel in a zone thereof adjacent to the exit end and at each side of the tunnel in the upper portion thereof above the path of the glassware, nozzles disposed at spaced intervals along each of said ducts and directed laterally toward the center of the lehr and inclined in a direction longitudinally of the lehr and opposite the direction of the movement of the glassware therethrough, a deflector extending longitudinally of the lehr arranged to be impinged by the jets from all of said nozzles for directing the air circulated thereby downwardly along the central zone longitudinally of the lehr, the aforesaid parts being so constructed and arranged that there will be created in the tunnel two substantially helical circulations of air, the axes of which extend longitudinally of the lehr and with the air in both circulations moving downward adjacent to the center of the tunnel to cool the glassware at the central portion of the conveying means to a greater extent than that nearer the edges thereof, and means intermediate the ends of the tunnel for conducting therefrom at least a part of the air circulated as aforesaid.

13. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a longitudinally extending duct arranged in a zone adjacent to the exit end of the lehr at each side thereof above the path of the ware through the tunnel, a plurality of nozzles at spaced intervals along each of said ducts and directed to a major extent transversely of the lehr and to a minor extent longitudinally thereof in the direction opposite that of the movement of the ware therethrough, a centrally located and longitudinally disposed conduit formed as a deflecting means and arranged to be impinged by the air circulated by said nozzles and to deflect the air thus circulated downwardly ad-

5 jacent to the center line of the lehr in said zone, said conduit opening into the tunnel adjacent to the end thereof toward the hotter end of the lehr, and means communicating with said conduit for withdrawing therethrough at least a part of the air circulated as aforesaid.

14. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a longitudinally extending duct disposed in a zone of the tunnel adjacent to the exit end thereof, means for supplying air under pressure to said duct, means for discharging the air from said duct into said tunnel along the length of said duct, means for admitting air from the atmosphere into the tunnel adjacent to said duct to be induced and circulated by the air discharged from said duct, a deflector associated with said duct to assist in directing the circulation as aforesaid and to assist in the induction of air into the tunnel, whereby a relatively large amount of air will be circulated in the tunnel by the introduction of a relatively small amount of air under pressure through said duct, and means associated with said duct for causing the air circulated as aforesaid to flow in a path the major component of the direction of which is transverse of the tunnel while a minor component of such direction is longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough, and means for conducting at least a portion of the air thus circulated from the tunnel intermediate the ends thereof.

15. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a longitudinally extending duct disposed in a zone of the tunnel adjacent to the exit end thereof, means for supplying air under pressure to said duct, means for discharging the air from said duct into said tunnel along the length of said duct, means for admitting an adjustably controllable amount of air from the atmosphere into the tunnel in said zone, the above named means for discharging the air from said duct into the tunnel being so constructed and arranged as to cause circulation of air in the tunnel in a path, the major component of which is transverse of the tunnel while a minor component of which is longitudinal thereof in the direction opposite that of the movement of the ware therethrough, means disposed in said zone for discharging therefrom a portion of the air thus circulated, and means for adjustably controlling the amount of air so discharged from the circulation within the tunnel.

16. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a duct extending longitudinally of the lehr in a zone thereof adjacent to the exit end of the tunnel, means for supplying air under pressure to said duct, means constructed and arranged to discharge air from said duct into the tunnel in such manner that the major component of velocity of the air circulated in the tunnel by the inductive action of the discharged air will be transverse of the tunnel and of the path of the ware therethrough and a minor component of said velocity will be longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough, means for controlling the volume and velocity of the air discharged from said duct as aforesaid to control the rate of circulation of the air in the tunnel and also the volume of air moving through the tunnel countercurrent to the ware, means

intermediate the ends of the tunnel for conducting therefrom air circulated as aforesaid, and means for independently controlling the amount of air withdrawn from the tunnel through the last named means and for thereby controlling the flow of air longitudinally of the tunnel in the zone intermediate said last named means and the entrance end of the tunnel.

17. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying glassware therethrough, means in a cooler zone of the tunnel adjacent to the exit end thereof constructed and arranged to circulate air in said zone in the tunnel in a helical path, the major component of the velocity of which extends transversely of the tunnel and of the path of the ware therethrough while a minor component of said velocity extends longitudinally of the tunnel in the direction opposite that of the movement of the ware therethrough, other means for admitting air into the circulation as aforesaid adjacent to the extreme cooler end of the tunnel, means for conducting a part of the air thus circulated from the tunnel adjacent to the extreme cooler end of the tunnel, means intermediate the ends of the tunnel for withdrawing therefrom air circulated as aforesaid, and means for controlling the amount of air withdrawn from the tunnel by the last named means to the end that between such means and the hotter end of the tunnel there will be a desired flow of air longitudinally of the tunnel.

18. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, means in a first zone adjacent to the exit end of the tunnel for creating a circulation of air within such zone in a path the major component of which extends transversely of the tunnel and of the path of the ware therethrough while a minor component of which extends longitudinally of the tunnel in the direction opposite that of the movement of the ware therethrough, means at the hotter end of said first zone for withdrawing a portion of the air thus circulated in the tunnel, and means intermediate the ware-entering end of the tunnel and the point of withdrawal of air as aforesaid for withdrawing an independently controllable amount of air from the tunnel to cause a countercurrent flow of another portion of the air circulated in said first zone aforesaid through a second zone of the tunnel for cooling the ware at a slower rate in such second zone, whereby the ware is subjected to progressively greater cooling as it travels through the tunnel to the exit end thereof.

19. Apparatus for annealing glassware, comprising a tunnel lehr, means for conveying the glassware therethrough, a duct extending longitudinally of the lehr in a zone thereof adjacent to the exit end of the tunnel, means for supplying air under pressure to said duct, means for discharging air from said duct into the tunnel in such manner that the major component of velocity of the air circulated in the tunnel by the inductive action of the discharged air will be transverse of the tunnel and of the path of the ware therethrough while a minor component of said velocity will be longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough, means for withdrawing a part of the air thus circulated from said tunnel adjacent to the hotter end of said zone, other means for withdrawing air from the tunnel intermediate the last named withdrawal means and the ware-entering end of said tunnel, and means

for independently controlling the amount of air withdrawn from the tunnel through each of said withdrawal means, whereby independently to control the rate of cooling in the two zones intermediate the first named withdrawal means and the exit end of the tunnel and intermediate the two named means and to control the rate of flow of air through the remaining zone of said tunnel intermediate the second named withdrawal means and the ware-entering end of said tunnel.

20. Apparatus for annealing glassware, comprising a tunnel Lehr, means for conveying glassware therethrough, means in a first zone starting from the cooler end of the Lehr constructed and arranged to circulate air therein in such manner that the major component of the velocity of the air thus circulated will be transverse of the tunnel and of the path of the ware therethrough while a minor component of said velocity will be longitudinal of the tunnel in the direction opposite that of the movement of the ware therethrough, means in said first zone for admitting air to the circulation from the atmosphere through ports opening laterally of the tunnel, means in said first zone for discharging a portion of the air thus circulated in said zone subsequent to its passage at least once through the path of the ware, means in a second zone from the exit end of the tunnel constructed and arranged to circulate the air as in the first of said zones as aforesaid but without the introduction and discharge of air from and to the atmosphere intermediate the ends of such second zone, means at the hotter end of said second zone for withdrawing from the tunnel a controllable portion of the air circulated in said second zone, and means at the hotter end of a third zone from the cooler end of the tunnel for withdrawing a controllable portion of air which has passed to the last named withdrawal means from the exit end of the tunnel through the first, second and third zones successively, whereby the glassware passing through the tunnel will be sub-

jected to progressively increasing cooling effects as it passes from the third to the second to the first of said zones.

21. Apparatus for annealing glassware, comprising a tunnel Lehr, means for conveying the glassware therethrough, ducts extending longitudinally of the tunnel in the upper corners thereof above the path of the ware, a plurality of nozzles disposed along each of said ducts in a cool portion of the Lehr and having the major component of their directions extending transversely of the Lehr while a minor component thereof extends longitudinally of the Lehr, means for supplying air under pressure to said ducts, means for adjustably controlling the supply of air to said ducts as aforesaid, baffle means disposed longitudinally of the tunnel and centrally of the roof thereof for deflecting the air supplied through said nozzles downwardly adjacent to the longitudinal center line of the Lehr to cause increased cooling of the ware adjacent to the center of the conveying means in respect to the rate of cooling of ware adjacent to the sides thereof, means for admitting an adjustably controllable amount of air from the atmosphere laterally of the tunnel adjacent to said nozzles to be induced thereby in the first or exit end zone of the Lehr, means in such exit end zone for the discharge of an adjustably controllable amount of the air circulated in such zone, means including the portion of said baffle means in the next or second zone of the Lehr toward the hotter end thereof for withdrawing a controllable portion of the air circulated in said second zone from the tunnel, and means at the hotter end of a third zone toward the hotter end of the tunnel from the first two named zones for withdrawing a selected adjustable amount of air from the tunnel and for thereby controlling at will the drift or flow of air through the hottest zone of the tunnel from the last named withdrawal means to the ware-entering end thereof.

DONALD G. MERRILL.