

March 17, 1953

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2,631,410

APPARATUS FOR FORMING FLAT GLASS

Filed Aug. 20, 1945

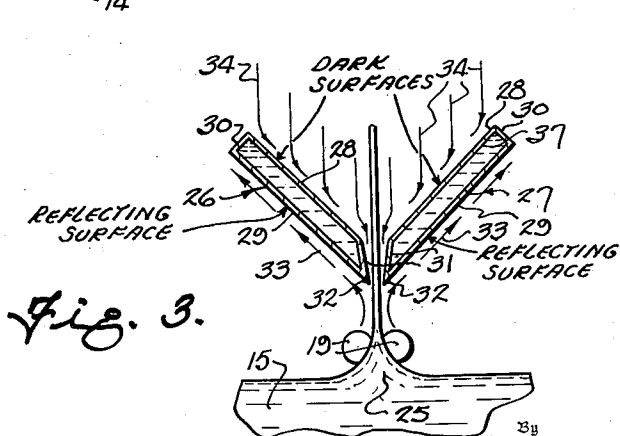
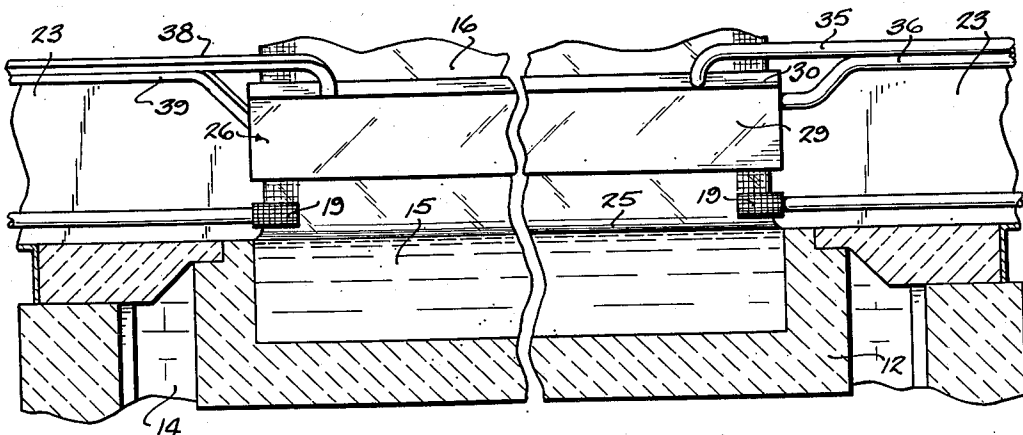
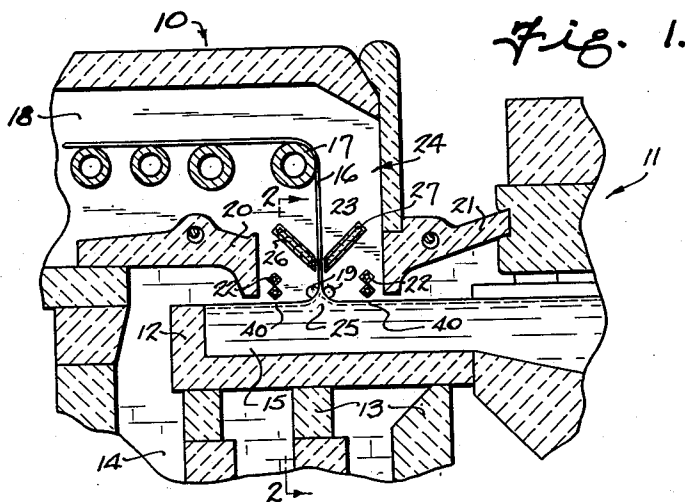


Fig. 2.

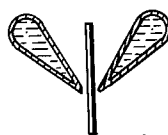


Fig. 4.

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2,631,410

APPARATUS FOR FORMING FLAT GLASS

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Application August 20, 1945, Serial No. 611,505

5 Claims. (Cl. 49—17)

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The present invention relates to the production of flat glass, and more particularly to the drawing of a sheet or ribbon of glass from a molten bath.

Briefly stated, the invention has to do with the treatment of the sheet being drawn, and of the atmosphere surrounding it, in a manner to materially improve the quality of the finished product and to increase the speed at which it can be produced.

So-called flat drawn sheet or window glass is considerably simpler and cheaper to produce than is mechanically ground and polished plate glass, but it also exhibits characteristic defects such as waves, distortion and lack of uniform thickness that have heretofore made it a less desirable product.

It is believed that these defects are due almost entirely to the non-uniform temperatures and atmospheric turbulence inherently present in the forming zones of conventional sheet glass drawing machines. There are a number of different types of these machines in commercial use today, but in all of them a ribbon or sheet is drawn upwardly from a bath of molten glass, so that the problems of temperature control in the zone of sheet formation are quite similar in each case.

In drawing a sheet from a mass of molten glass, a thickened portion, known as the meniscus, is created at the base and this meniscus is pulled progressively thinner and thinner by the drawing action until the sheet reaches its final thickness dimension. Consequently the average thickness of the finished product, its uniformity of thickness and its general surface contour are dependent on the amount of drawing force exerted and the viscosity of the sheet being drawn.

Since the drawing force is constant and substantially equal across the entire sheet, the flatness and uniformity of thickness of the sheet is really dependent on its viscosity, which is just another way of saying that it is dependent on temperature. Thus, any lack of uniformity of temperature will make itself felt in a non-uniform thickness of sheet, and the pattern of the one determines the pattern of the other.

Among the contributing factors to air turbulence and temperature differentials in the well known glass drawing machines is the stack effect that is always present, and which draws hot air upwardly along the center lines of the sheet, while at the same time drawing relatively cold air inwardly from beyond the sheet edges. Another factor is the convection currents that are

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naturally set up in the vicinity of the hot sheet as it is formed, and which move upwardly along the surface of the sheet and downwardly at a distance therefrom.

Attempts have been made to cut down on the uncontrolled air movements with the drawing chambers of these machines by enclosing the chambers as completely as possible from the outside air. This has proved to be good practice, but its action is to reduce, rather than to completely correct the difficulty, and there is always a certain amount of infiltration through the enclosures.

It is an aim of this invention to counteract, and so to more completely overcome, the effects of the undesirable temperature and atmospheric conditions in regular sheet glass drawing machines, by protecting the sheet therefrom, and by setting up new and controlled temperature conditions and air movements designed to offset the uncontrolled ones that are naturally present.

A more specific object is the provision of means for reversing the natural flow of convection currents adjacent the newly formed sheet.

Still another object is to provide a special type of heat exchanger for accomplishing the above results, and which is of unusual shape and provided with a novel surface finish.

Other objects and advantages of the invention will become more apparent during the course of the following description, when taken in connection with the accompanying drawings.

In the drawings, wherein like numerals are employed to designate like parts throughout the same:

Fig. 1 is a longitudinal, vertical section through a Colburn type of sheet glass drawing machine and associated parts;

Fig. 2 is a section on an enlarged scale taken substantially on the line 2—2 of Fig. 1;

Fig. 3 is an enlarged fragmentary view of the molten bath, the sheet rising therefrom, and the special sheet coolers of Fig. 1; and

Fig. 4 is a fragmentary view showing a modified form of sheet cooler.

My invention can be employed in connection with any of the well known sheet glass forming machines, and it has been illustrated, and will be described, here as applied to the familiar Colburn type, which is considered to be representative.

Thus, in Fig. 1 the actual drawing machine is designated in its entirety by the numeral 10, and is associated with the working end 11 of a continuous glass tank furnace which supplies proper-

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ly conditioned molten glass to a working receptacle, or draw pot, 12. The receptacle 12 is mounted upon stools 13 in a pot chamber 14, heated by suitable gas burners (not shown) to maintain the bath of molten glass 15 at working temperature.

In operation, a ribbon or sheet of glass 16 is drawn upwardly from the bath 15 and then bent into the horizontal plane over a bending roll 17, before being passed through a flattening chamber 18 and an annealing leir not shown. Knurled edge rolls 19 are provided to hold the sheet to width, and in this type of apparatus the ribbon is not cut into individual sections until after it leaves the leir. Lip-tiles 20 and 21 and lip-tile coolers 22 are provided to protect the rising sheet from blasts of hot air from the pot chamber 14, and from the furnace, and the coolers 22 also act to reduce the temperature of the surface of the glass in the bath 15 just before it is drawn into the sheet.

Although not absolutely essential, I prefer to use a standard machine enclosure, indicated at 23, at either end of the drawing chamber 24; and the area of the drawing chamber lying below the bending roll 17, and bounded by these enclosures 23 and the lip-tiles 20 and 21 with their coolers 22, is the area referred to herein as the zone of sheet formation. Within this zone is the surface of the molten bath 15, the glass ribbon 16 rising therefrom, and its meniscus or thickened base portion 25. The bending roll 17 is positioned at a height sufficient to allow the sheet to set to a point where it will not be marred as it is bent thereover, providing of course, that the contacting surfaces are clean.

It is during its passage through this forming zone or forming area that the sheet being drawn is in its most critical state, and most susceptible to conditions around it. For this reason I carry out my special treating or conditioning technique within this area, and subject the sheet as it moves therethrough to a positive and uniform cooling transversely thereof, and to a controlled flow of air thereover, in a manner to counteract the irregular atmospheric and temperature conditions that are naturally present.

The actual apparatus that I employ is relatively simple and comprises primarily, a pair of heat exchangers or sheet coolers 26 and 27 of somewhat unusual conformation, positioned one on either side of the rising sheet and in horizontal alignment with one another. In construction these heat exchangers are somewhat like an ordinary rectangular cooler in that they are made of sheet metal and formed with two long sides 28 and 29 and two short sides 30 and 31. However, the four sides form a trapezoid in cross section in which one of the short non-parallel sides 30 extends between and at right angles to the two parallel long sides, while the second short side 31 slants sharply between the two long sides forming an obtuse angle with one and an acute angle with the other.

In positioning these coolers, their pointed corners 32, formed at the juncture of the sides 29 and 31 of each, are positioned as close to the surface of the sheet 16 as possible, while their angled sides 31 are arranged to slant upwardly and slightly away from the sheet. With this arrangement the trapezoidal body portion of the coolers will also angle upwardly and away from both the sheet surface and from the surface of the molten bath 15.

In addition to the particular shape of these

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coolers, and their arrangement relative to the sheet being drawn, they also have special finishes on certain of their surfaces. That is, the outer surface of the upper long side 28 of each cooler is black while the surface of the lower long side 29 is made shiny or reflecting.

These blackened and shiny surfaces on the coolers may be produced in any desired manner. For example, by the application of special paint or metal coatings, or by treatments of their original surfaces, i. e., polishing, tarnishing, sand-blasting, etc. Or, by the use of a casing material having a surface that is naturally either bright or dark.

The coolers of this invention when arranged in the manner shown and described perform a threefold function. In the first place they are close enough to the glass sheet to baffle or interrupt the convection currents that would be naturally set up along its heated surface. Secondly, the coolers will set up a controlled air flow in a direction counter to the natural convection currents in this area, and finally they will exert a positive and uniform radiant cooling action on the sheet across its entire width at the critical point in its formation.

Natural convection currents that are set up in the vicinity of a hot vertical surface normally follow a short of elliptically shaped path, with the hottest air rising along the heated surface while the cooler air in the current moves downwardly through the portion of the path that is away from the sheet surface. Also there is a practically stagnant area or film of air or gas in contact with any flat surface along which convection currents are set up.

This thin layer or film has no motion at the solid surface and, although its velocity increases as the distance from the surface increases, in the film proper the rate of air flow is below the "critical velocity" and convection currents scarcely exist. The thickness of a stagnant air layer of this kind depends upon the temperature of the surface. For example, it is estimated at $\frac{3}{4}$ of an inch on surfaces at about 400 degrees Fahrenheit but on hotter glass surfaces it would probably be thinner.

The coolers 26 and 27 are therefore intended to be placed sufficiently close to the surfaces of the glass sheet 16 so that their corners 32 will lie within the limit of the stagnant air layer or film in contact with the sheet surface. In this way the coolers will prevent or break up the formation of natural convection currents adjacent the surfaces of the sheet.

In addition, the angled side 31 of the coolers will side track the hottest air, which in the natural convection currents tends to rise along the sheet, and cause it to move away from the sheet as shown by the arrows 33. This action is augmented by the shiny or reflecting surface 29 on this side of the coolers, which tends to reflect the heat away.

At the same time the blackened surfaces 28 on the opposite sides of the coolers act to absorb heat and thus create a relatively cooler area thereabove. The cooler air in this area will tend to fall, and will be guided in its downward movement along the sides 28 and 31 toward, and finally along and against, the glass surface as shown by the arrows 34.

In other words, the particular shape, positioning and type of surface on the coolers 26 and 27 will set up a controlled flow of air adjacent the sheet within the zone of sheet formation that is

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directly contrary to the flow of the natural convection currents there. That is to say, while the hottest air in natural convection currents moves upwardly along the heated surface and the cooler air downwardly at a distance away from the sheet, with my novel cooler arrangement the rising streams of hot air are directed away from the sheet and the falling streams of cooler air are caused to flow past and in contact with the heated surface.

The movement of cool air over the sheet surface exerts a uniform cooling action transversely thereof which serves to further equalize, modify and distribute the radiant cooling action exerted on the sheet surface by the direct action of the coolers themselves. Moreover, the direct or radiant cooling is also effected in a manner calculated to give unusually uniform results from edge to edge of the glass ribbon.

Thus the greatest radiant cooling action is exerted, or, differently expressed, the most heat is absorbed from the sheet, along a line opposite the corners 32 of the coolers. Due to the inherent waviness and unevenness in sheet metal of sufficient thinness to be used for coolers, it is possible to achieve much more uniform cooling along such a line than where a wider surface area of the cooler is exposed. The next most intense cooling is exerted along the relatively narrow faces 31, and these faces are angled gradually away from the sheet to lessen the possibility of temperature variations transversely of the sheet through this area, and to accommodate a thicker body of cooling air for the same reason. Similarly, the largest surface area 28 is angled even more sharply away from the sheet 16 and provides a much larger air space between it and the sheet surface.

The coolers 26 and 27 are supported at one end by means of the pipes 35 and 36 which are also used to circulate the cooling medium 37, preferably water, therethrough. Bars 38 and 39 are secured in a similar manner to the opposite ends of the coolers to support them there. Although I prefer to locate the coolers about as shown in the drawings, it may be desirable to shift their positions slightly in one direction or another to compensate for unusual conditions, particular temperatures encountered, thickness of sheet desired, etc. For this reason, it is advisable to provide the cooler supporting means with universally adjustable mountings (not shown). In some cases a single cooler on one side of the sheet, rather than a pair, may be employed advantageously. And for more complete control through a larger zone, a plurality of pairs of coolers arranged one above the other may also be used.

It will be noted that the controlled circulation of air within the sheet forming zone according to this invention utilizes only the air already within the machine. This is important in that it does not disturb the balance of atmospheric pressure within the area of sheet formation, and does not introduce or encourage the infiltration of outside air.

Another feature of the invention lies in the fact that the lip-tile coolers 22 are of a shape to pre-condition the surface of the molten bath 15 in a manner similar to that in which the surface of the sheet is subsequently conditioned by the coolers 26 and 27. That is, lip-tile coolers having the sort of sharply angled bottom shown will give an accelerated cooling action along a line 40 running transversely of the pot 12, with a lesser

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cooling action at the side of this line, which acts to equalize the temperature across the surface of the molten glass before it moves into the sheet.

The temperature and speed of movement of the air flowing in the directions of the arrows in Fig. 3 can be regulated by controlling the temperature of the heat exchange medium within the heat exchangers 26 and 27. Likewise, the speed of movement of this controlled flow of air will effect the degree of radiant cooling exerted by the coolers themselves.

When properly handled, sheet drawing machines in which this invention is incorporated will produce sheets that are noticeably higher in quality and of much more uniform thickness. Moreover, because the cooling action is so uniform, the sheet being formed can be cooled faster, and consequently can be drawn at a higher rate of speed for any given thickness.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred embodiment of the same, and that various changes in the shape, size and arrangement of parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

For example, coolers that are pear-shaped in cross section, and arranged with the sharp longitudinal edge adjacent the glass sheet and the rounded and enlarged horizontal edge away from the sheet, as shown in Fig. 4, may be substituted for the trapezoidal shape shown, with very good results.

I claim:

1. In apparatus for producing sheet glass, a working receptacle containing a bath of molten glass, means for drawing a sheet from said molten bath, a heat exchanger at one side of the sheet comprising, a casing trapezoidal in cross section and having two short non-parallel sides and two long parallel sides with one of its short non-parallel sides at right angles to the two long parallel sides, said casing being positioned with its other short side in close proximity to but angling slightly away from said sheet and with the body of the casing slanting upwardly from its second-mentioned short side away from the molten bath and away from the surface of the sheet, and means for circulating a heat control medium through said casing.

2. In apparatus for producing sheet glass, a working receptacle containing a bath of molten glass, means for drawing a sheet from said molten bath, heat exchangers positioned at opposite sides of said sheet and each comprising, a body portion and means for controlling the temperature thereof, said body portion being arranged with one of its ends closely adjacent the sheet being drawn and in angular relation thereto so that the said body portion slants from its end adjacent the sheet upwardly away from the molten bath and away from the surface of the sheet, with the surfaces on the upper side of said body portions away from the surface of the molten bath and toward the surface of the sheet having their entire surfaces darkened to render them more heat absorbing.

3. In apparatus for producing sheet glass, a working receptacle containing a bath of molten glass, means for drawing a sheet from said molten bath, heat exchangers positioned at opposite sides of said sheet and each comprising, a body portion and means for controlling the temperature thereof, said body portion being arranged with one of its ends closely adjacent the sheet

being drawn and in angular relation thereto so that the said body portion slants from its end adjacent the sheet upwardly away from the molten bath and away from the surface of the sheet, with the surfaces on the upper side of said body portions away from the surface of the molten bath and toward the surface of the sheet being darkened over their entire areas for greater heat absorption, and the surfaces on the lower sides of said bodies lying toward said molten bath and away from the surface of said sheet being heat reflecting.

4. In apparatus for producing sheet glass, a working receptacle containing a bath of molten glass, means for drawing a sheet from said molten bath, a heat exchanger at one side of the sheet comprising, a casing trapezoidal in cross section and having two short non-parallel sides and two long parallel sides with one of its short non-parallel sides at right angles to the two long parallel sides, said casing being positioned with its other short side in close proximity to but angling slightly away from said sheet and with the body of the casing slanting upwardly from its second-mentioned short side away from the molten bath and away from the surface of the sheet, a darkened outer surface on the upper of said long parallel sides, and means for circulating a heat control medium through said casing.

5. In apparatus for producing sheet glass, a working receptacle containing a bath of molten glass, means for drawing a sheet from said molten bath, heat exchangers at opposite sides of the sheet, each of said heat exchangers comprising

a casing trapezoidal in cross section and having two short non-parallel sides and two long parallel sides with one of its short non-parallel sides at right angles to the two long parallel sides, said casing being positioned with its other short side in close proximity to but angling slightly away from said sheet and with the body of the casing slanting upwardly from its second-mentioned short side away from the molten bath and away from the surface of the sheet, means for circulating a heat control medium through said casing, a darkened surface on the upper of the long parallel sides and a reflecting surface on the lower of the long parallel sides.

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