

May 8, 1951

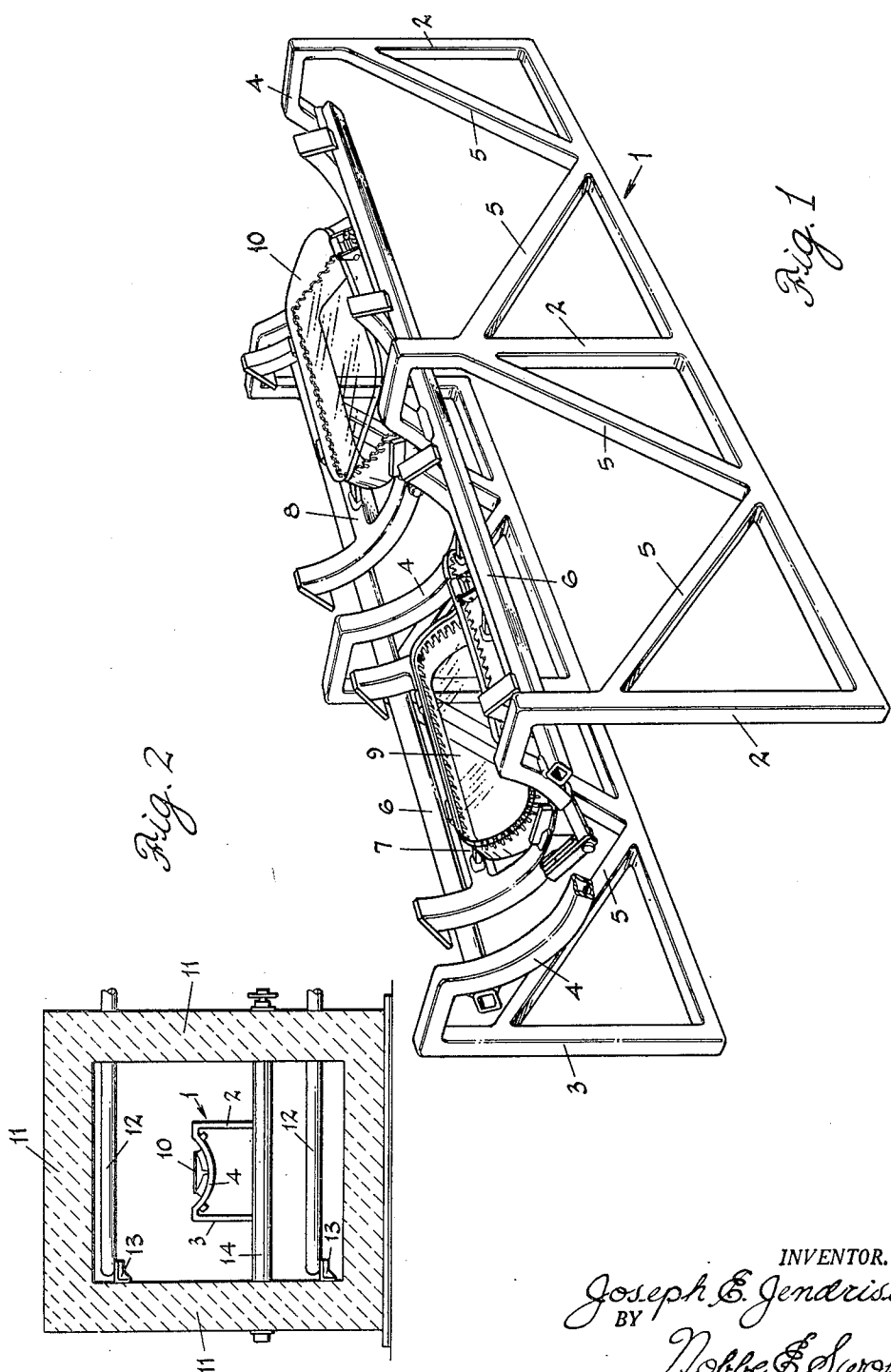
J. E. JENDRISAK

2,551,606

GLASS BENDING APPARATUS AND METHOD

Filed May 28, 1948

5 Sheets-Sheet 1



INVENTOR.
Joseph E. Jendrisak
BY
Noble E. Swope
ATTORNEYS

May 8, 1951

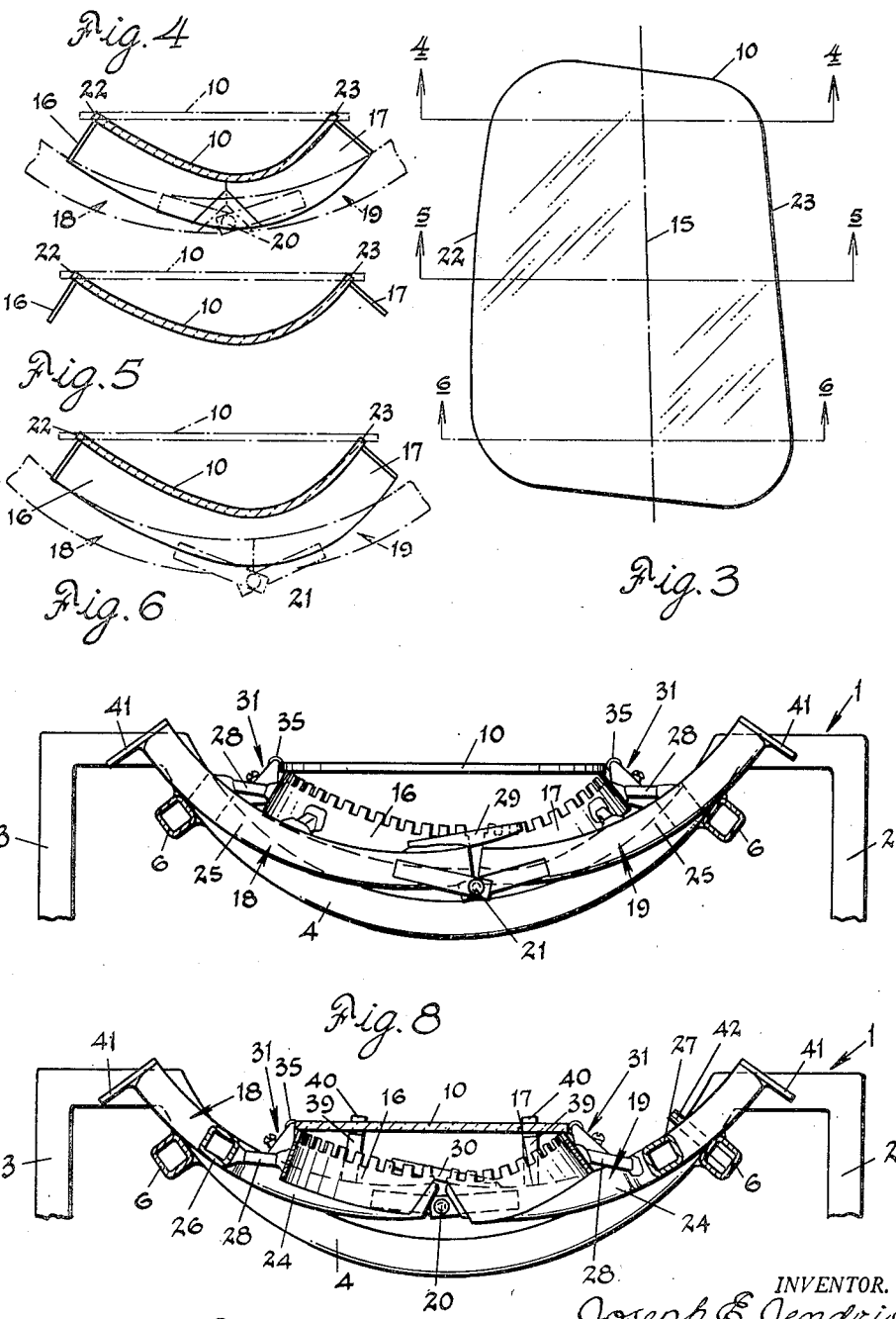
J. E. JENDRISAK

2,551,606

GLASS BENDING APPARATUS AND METHOD

Filed May 28, 1948

5 Sheets-Sheet 2



INVENTOR.
Joseph E. Jendrisak
BY Noble E. Swope
ATTORNEYS

May 8, 1951

J. E. JENDRISAK

2,551,606

GLASS BENDING APPARATUS AND METHOD

Filed May 28, 1948

5 Sheets-Sheet 3

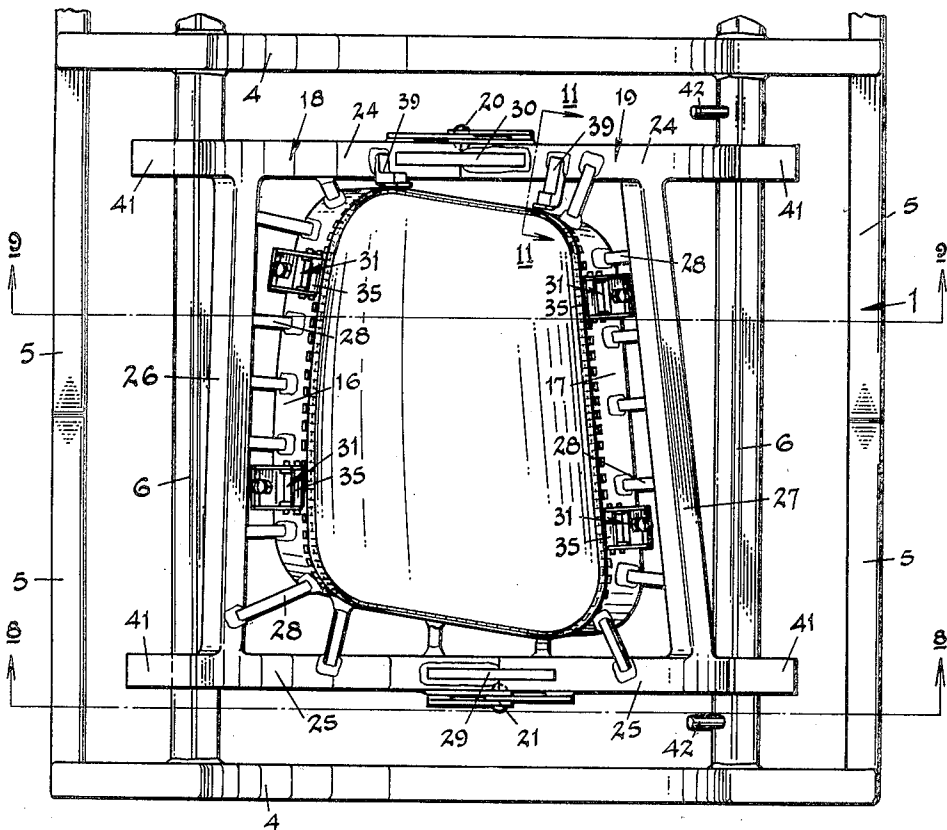


Fig. 7

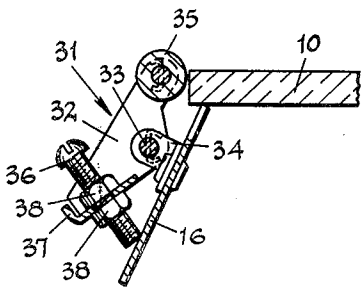


Fig. 10

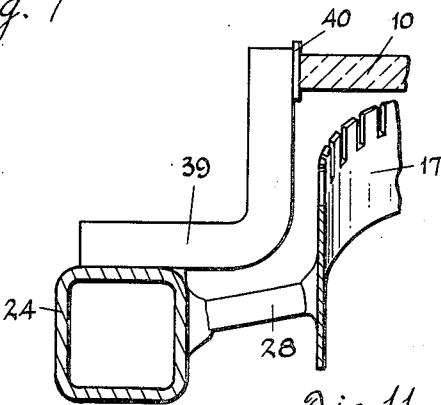


Fig. 11

INVENTOR.
Joseph E. Jendrisak
BY
Hobbs & Swope
ATTORNEYS

May 8, 1951

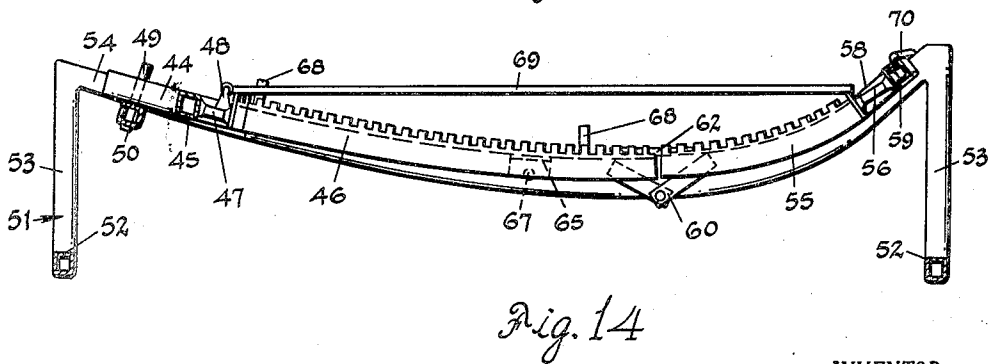
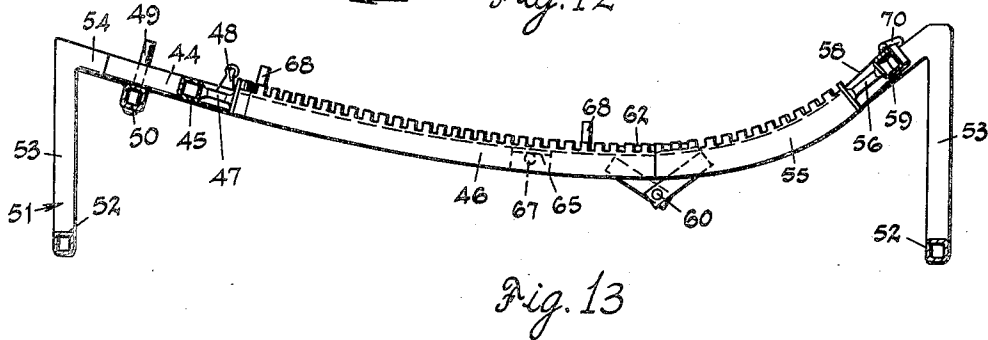
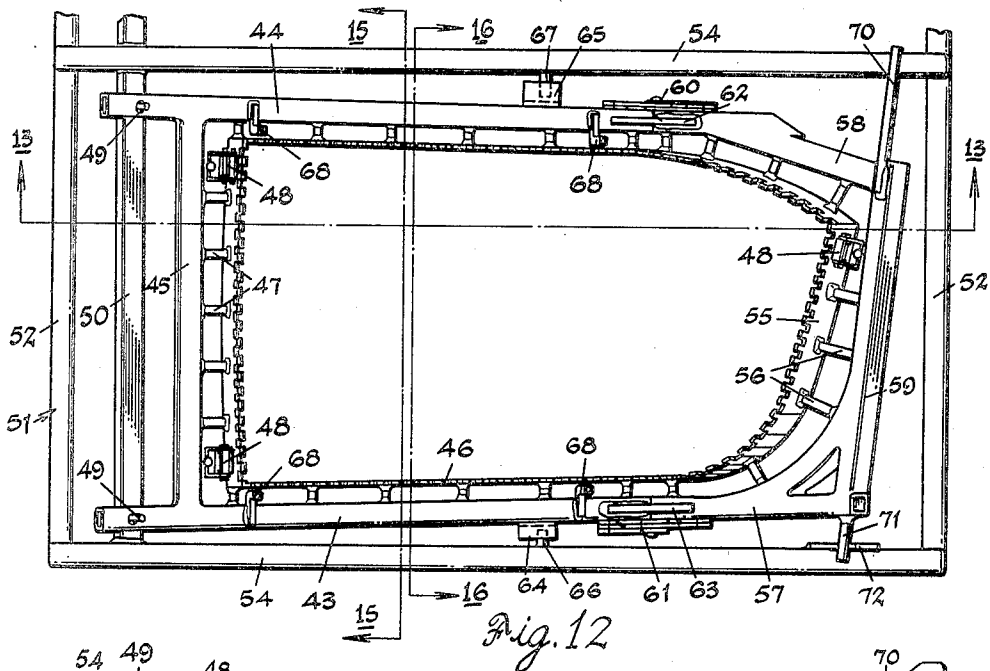
J. E. JENDRISAK

2,551,606

GLASS BENDING APPARATUS AND METHOD

Filed May 28, 1948

5 Sheets-Sheet 4



INVENTOR.
Joseph E. Jendrisak
BY
Noble E. Swope
ATTORNEYS

May 8, 1951

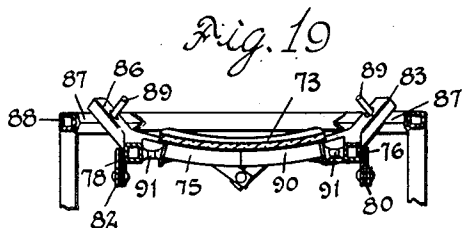
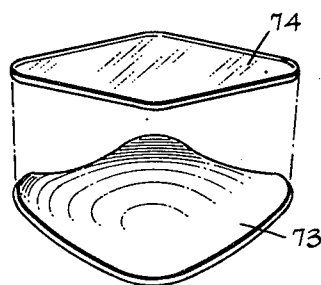
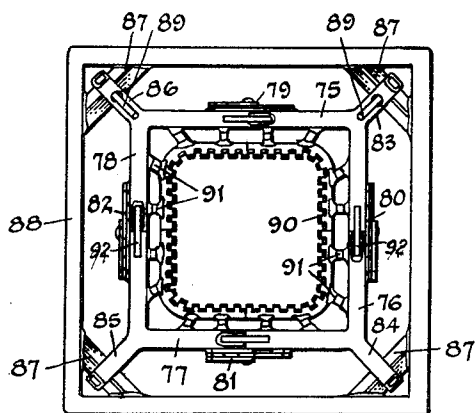
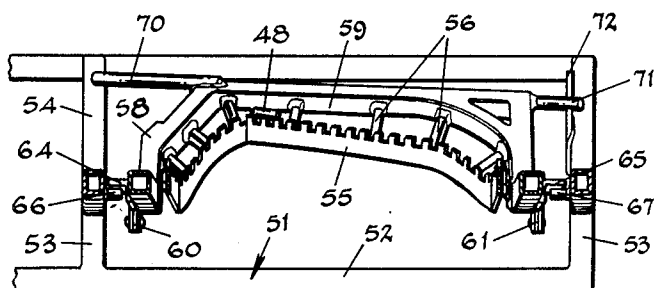
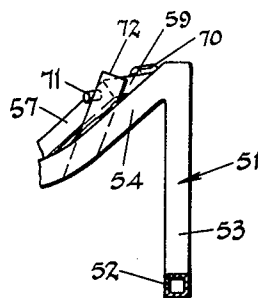
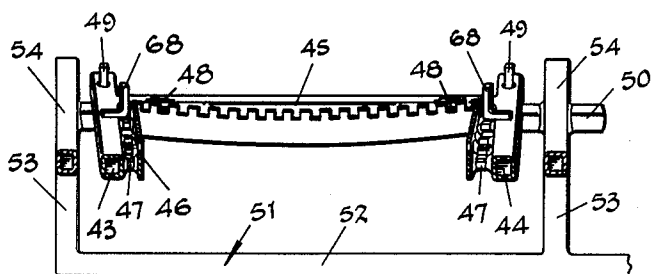
J. E. JENDRISAK

2,551,606

GLASS BENDING APPARATUS AND METHOD

Filed May 28, 1948

5 Sheets-Sheet 5



INVENTOR.
Joseph E. Jendrisak
BY
Nobbe & Swope
ATTORNEYS

UNITED STATES PATENT OFFICE

2,551,606

GLASS BENDING APPARATUS AND METHOD

Joseph E. Jendrisak, Rossford, Ohio, assignor to
Libbey-Owens-Ford Glass Company, Toledo,
Ohio, a corporation of Ohio

Application May 28, 1948, Serial No. 29,701

14 Claims. (Cl. 49—67)

1

This invention relates to a glass bending apparatus and method and in particular to an improved mold that moves with the glass during a bending operation so that there is no relative movement between the glass and those portions of the mold that are in contact with the glass.

When glass sheets that are to be employed as windows are bent to curved form it is important that the optical qualities of the glass are not impaired. It is, therefore, necessary to support the glass sheet during the bending operation in its marginal area only. It is also necessary that the movement of the glass with respect to those portions of the mold that are in contact with the glass shall be reduced to a minimum or entirely eliminated because the uncertainty of the frictional force exerted between the mold and the glass produces variations in the final shape of bent glass which variations exceed the permissible tolerances for the finished product.

Gravity bending—bending in which the glass is allowed to sag against the shaping surface of a mold—while satisfactory for relatively simple shallow bends is not generally suitable for producing relatively deep bends or bends that are confined to a relatively small portion of the entire glass sheet. These relatively sharper or localized bends require the application of force in addition to that of gravity acting alone to insure that the glass is forced to the proper shape during the bending operation.

The principal object of this invention is to provide a mold for use in the bending of sheets of glass which mold holds the glass sheet in compression as a substantially horizontal column or strut.

Another object of the invention is to provide a mold that holds a glass sheet along two of its edges and that applies pressure urging such edges toward each other until the bending operation is substantially completed at which time the glass sheet is allowed to settle against the shaping surface of the mold.

A still further object of the invention is to provide a mold that is divided into a plurality of parts which are hinged together and which are adapted to be carried on a frame in a manner such that the sheet of glass in its unbent condition holds the mold in its open condition and which, as the glass softens and sags, moves toward its closed position as the glass approaches the shaping surface of the mold.

A still further object of the invention is to provide a glass bending mold that comprises a plurality of hinged connected sections and that

2

is adapted to move from an open to a closed condition as a sheet of glass is being bent, which mold is supported on a frame the surfaces of which are oriented so as to vary the bending forces transmitted to the glass during various portions of the bending operation.

An ancillary object is to provide a mold for bending sheets of glass in which mold a plurality of hinged connected portions carry portions of the mold shaping surface which shaping surface is divided near its points of maximum curvature and in which the hinged connections between the portions are spaced from the shaping surface a distance that is generally proportional to the curvature of the shaping surface.

More specific objects and advantages are apparent from the following description of embodiments of the invention.

According to the invention, the improved mold comprises a plurality of hinged connected portions each carrying a section of the shaping surface of the mold. The portions are movable between two positions in one of which the shaping surfaces are substantially continuous around the marginal area of the sheet of glass and in the other of which portions of the shaping surface are spread apart so as to register with parts of the marginal area of an unbent sheet of glass. During the bending operation the mold sections move from one position to the other as the sheet of glass softens and sags, the movement of the hinged connected mold sections serving to maintain those portions of the shaping surface in contact with the glass in continuous substantially unvarying registry with the marginal area of the glass.

The invention further contemplates that the mold shall be divided at those points where the curvature of the shaping surface is the greatest and that the hinged connection between the portions of the mold shall be located a distance from the shaping surface that varies according to the curvature of the shaping surface at the point of division. In the improved mold in which the portions are hinged connected together the glass is held in compression by forces exerted against its edges during substantially the entire bending operation and it is accordingly a part of the invention to orient the mold supporting surfaces in a manner such that the resulting compression forces applied to the glass sheet vary in a predetermined manner throughout the bending operation.

Minor improvements afforded by the inven-

tion include adjustable devices located adjacent the shaping surface of the mold in position to engage the edge of the glass sheet during substantially all of the bending operation. The devices are made adjustable so that the forces may be accurately distributed and so that the glass may be relieved of the pressure just prior to the time when it settles into full contact with the shaping surface of the mold.

The improved mold is supported at points located remote from the hinged connection between the portions of the mold so that in the absence of a sheet of glass the mold tends to assume its closed position. In moving from its open to its closed position portions of the mold slide on the frame on which it is loosely supported. When a glass sheet is to be placed on the mold the mold is opened by lifting the hinged portions until a flat glass sheet may be located with portions of its marginal area in registry with portions of the shaping surface. The mold is held in its open condition by the sheet of glass which acts as a strut and which being located above the hinged connection prevents the mold from assuming its closed position. As the glass softens and bends it can no longer act as a strut and consequently the mold settles toward its closed position and during the settling it continues to maintain pressure on the edges of the glass thus hastening the bending process and, furthermore, because of the control that may be exercised over the magnitude of the pressure a substantial degree of control over the uniformity of the finished bent glass product may be exercised.

Various embodiments of the invention are illustrated in the accompanying drawings.

In the drawings:

Figure 1 is an isometric view of a frame and a pair of the improved molds, one shown in its closed position and the other shown in its open position.

Figure 2 is a vertical cross section of a tunnel-type furnace suitable for supplying the heat for bending glass sheets.

Figure 3 is a schematic plan view of a sheet of glass prior to a bending operation.

Figures 4, 5 and 6 are cross sections illustrating the relationship between the degree of curvature of the shaping surface of the mold and the corresponding position of the hinged connection between the sections of the mold.

Figure 7 is a plan view of one of the molds of the type shown in Figure 1.

Figures 8 and 9 are transverse sections taken along the lines 8—8 and 9—9 respectively of Figure 7.

Figure 10 is a fragmentary section showing one of the adjustable locating members that are mounted on the mold adjacent the shaping surface.

Figure 11 is a fragmentary section taken along the line 11—11 of Figure 7 to show the locating members that are positioned adjacent the shaping surface at the hinged ends of the mold.

Figure 12 is a plan view of another hinged mold to show the modification in the mold to adapt it to another shape of bend to be produced in a sheet of glass.

Figures 13 and 14 are vertical sections taken along the line 13—13 of Figure 12 showing the mold in closed and opened positions respectively.

Figures 15 and 16 are vertical sections taken parallel to the hinge line of the mold as indicated by the lines 15—15 and 16—16 of Figure 12.

Figure 17 is a fragmentary detail showing a

portion of the frame that supports the mold.

Figure 18 is a perspective sketch showing a bend from a flat to a generally spherical surface as illustrating a type of bend that may be produced by a modification of the molds previously illustrated.

Figure 19 is a plan view of a mold suitable for producing the bend indicated in Figure 18.

Figure 20 is a vertical section taken along the line 20—20 of Figure 19.

These specific figures and the accompanying description are intended merely to illustrate the invention but not to impose limitations on the claims.

Referring to Figure 1, a frame 1 constructed of rectangular cross-section stainless steel tubing comprises vertical side members 2 and 3 which at their upper ends are connected by cross members 4 the center portions of which are curved downwardly so as to conform, in end elevation, to the curvature of the bent glass sheets. The vertical side members 2 and 3 are rigidly held in spaced upright position by diagonal braces 5 and the upper cross members 4 are connected by longitudinally extending rails 6 that carry a pair of similar hinged molds 7 and 8. The mold 7, carrying a glass sheet 9, is shown in its closed position which it occupies after the bending operation has been completed. The mold 8, carrying a flat glass sheet 10, is shown in its open position in which the flat glass sheet 10 is held in edgewise compression prior to the bending operation.

Referring to Figure 2, a furnace suitable for supplying the heat required to soften the glass is constructed with insulating walls 11 and is heated by upper and lower burner tubes 12 that, extending through one wall of the furnace, are carried on supports 13 attached to the opposite wall. A conveyor 14 consisting of a great plurality of parallel transversely oriented rollers is located between the upper and lower burner tubes 12 in position to carry the mold frames 1 through the furnace. From Figures 1 and 2 it may be seen that the frame 1 in end elevation consists merely of the vertical side members 2 and 3 and the transverse partially arcuate cross members 4. The frame is entirely lacking in transverse bracing because such bracing would interfere with certain parts of glass processing equipment which must of necessity be located close to the upper and lower surfaces of a sheet of glass carried on the molds. The lack of transverse bracing permits the frames 1 to straddle that portion of the apparatus employed to treat the lower surface of the glass while the lip in the cross members 4 permits close positioning of the apparatus that is used to treat the upper surface of the glass sheets. Since this processing apparatus is employed subsequently to the bending operation and affects only the shape of the frame 1 and does not cooperate otherwise with the molds 7 and 8, it is not shown in the drawings.

Figure 3 is a plan view of the sheet of glass 10 after it has been cut to pattern and before it has been bent to shape. In this particular embodiment the bend to be produced in the glass is such that the resulting bent glass conforms approximately to a small portion of the surface of an oblique cone. In other words, the bent glass is bent to a generally cylindrical surface the radius of which varies from one end of the glass sheet 10 to the other end and the axis of which is not parallel to the center line of the glass sheet. This means that the radius of curvature

varies from point to point. In this particular embodiment the points of maximum curvature in the glass are located generally along a line 15 that is generally parallel to one edge of the flat glass sheet 10.

Figures 4, 5 and 6 are schematic sections taken along the lines 4—4, 5—5 and 6—6 of Figure 3 to show the nature of the curve produced in the glass along these various section lines. Thus the curve at the upper end of the glass sheet as seen in Figures 3 and 4 is relatively deep and sharp as compared to the width of the glass sheet in this region. At the other end of the glass sheet, along the line 6—6, the sheet is wider, the depth of the curve is about the same, and the degree of curvature is less. The curve at the middle of the glass sheet, i. e., along the line 5—5, is intermediate in shape between the curves produced at the ends of the glass sheet. Figures 4, 5 and 6 show in full lines the glass sheet 10 after it has settled to conform to shaping surfaces 16 and 17 of the mold 8 while the broken lines show the sheet before it has been bent. From these figures the difference in length between a straight line—a chord—drawn between the edges of the glass along the sections 4, 5 and 6 and a line following the arc of the bent glass surface is readily apparent.

If one were to attempt to use a solid mold having shaping surfaces corresponding to the shaping surfaces 16 and 17 and to allow the glass to soften and settle from the dotted line position of the glass sheet 10 to the solid line position he would find that the marginal areas of the glass that were originally in contact with the shaping surfaces would be seriously marred as they slid over the edges of the shaping surface. Furthermore, the glass contacting portions of the shaping surfaces 16 and 17 are crenelated to reduce the area in contact with the glass as well as to permit the free flow of air around the glass during the heating and annealing operations. It has been found that with a crenelated edge the glass tends to soften enough to allow the tooth-like portions of the shaping surface to slightly indent the glass and thus resist any relative motion between the glass and the shaping surfaces 16 and 17. As a result tensile forces are set up in the glass as it sags and these tensile forces may be sufficient at times to prevent the glass from conforming accurately to the entire periphery of the shaping surface.

These difficulties are overcome according to the invention by dividing the molds 7 or 8 into parts 18 and 19 which at their ends are connected by hinges 20 and 21. The mold sections 18 and 19 carry the shaping surfaces 16 and 17 and the hinges 20 and 21 are located on the mold sections 18 and 19 in relation to the shaping surfaces 16 and 17 so that when the mold is closed as shown in Figures 4, 5 and 6 the shaping surfaces 16 and 17 conform to the entire periphery of the marginal area of the bent glass sheet. When the mold is opened or swung to a second position by hinged movement between the mold sections, portions of the shaping surfaces 16 and 17 that carry the permanently straight edges 22 and 23 of the glass sheet are spread apart far enough to accommodate the flat sheet of glass. Thus the hinged movement of the mold sections increases the length of the chord of the shaping surface until the chord is equal in length to the width of the glass sheet at that particular section. The hinged movement, of course, produces a break in the con-

tinuity of the shaping surface but this break is of no consequence because it is closed before the glass settles into contact with the portions of the shaping surface immediately adjacent the break.

The mold sections 18 and 19 are each relatively rigid members and because they are subjected to high temperatures during the glass bending operation they must not be subjected to twisting forces or in fact high stresses of any type. This lack of strength in the mold and frame results because even with stainless steel the parts tend to deform when under heat until the stress is relieved. Since the mold sections are each rigid and since the edges of the shaping surfaces 16 and 17 that conform to the edges 22 and 23 of the glass sheet must register with those edges both before and during the bending operation it follows that to avoid stress and accurately follow the glass the location of the hinges 20 and 21 must be carefully selected. The precise positioning or average distance from the line through the hinges 20 and 21 to the shaping surface is not in itself important except as it affects the angular movement of one mold section with respect to the other. However, once the angular movement of one mold section with respect to the other has been determined by the arbitrary location of one hinge and the required relative movement between the edges of the shaping surface at that end of the mold then the other hinge must be located so that the given angular movement produces the required variation in length of the chord of the shaping surface at the second end of the mold. In general, the hinges are located from the shaping surface a distance that is roughly proportional to the curvature of the shaping surface adjacent the hinge.

This arrangement with the hinge connection below the shaping surface of the mold eliminates any sliding of the glass on the crenelated edges of the shaping surface and confines the contact between the shaping surface and the glass to the extreme marginal area of the sheet of glass. This is one important advantage attained by hinging the mold sections together. Another important advantage resides in the fact that locating means may be attached to the shaping surfaces 16 and 17 so as to bear against the edges of the glass sheet and, by placing the sheet under compression as a strut, to force it into its bent condition at a much more rapid rate than it would bend or sag under the influence of gravity alone.

Referring now to Figure 7, which is a plan view of the mold 7 and the cooperating parts of the frame 1, the mold includes the mold sections 18 and 19 each of which includes end pieces 24 and 25 that are arcuate in end elevation and that are joined by side members 26 and 27. The arcuate end sections 24 and 25 are curved to conform generally to the curvature of a bent sheet of glass, and, when the glass is bent, are in alignment with the frame crosspieces 4. The shaping surfaces 16 and 17 are attached to the mold sections 18 and 19 by a plurality of struts 28 that are spaced at intervals around the periphery of the shaping surface.

The end pieces 24 of the mold sections 18 and 19 carry the hinge 20 while the end pieces 25 are connected by the hinge 21. Each of the hinges is made up of a number of strips of steel that are welded some to one of the members and some to the other in overlapping relation and that are connected by a loosely fitting bolt or pin.

7

Furthermore, the mold section 18 at the end of its arcuate end piece 25 is provided with a stop bar 29 which when the mold is closed strikes the upper surface of the end piece 25 of the other mold section 19. Likewise, a stop bar 30 is welded to the end of the arcuate end piece 24 of the mold section 19 in position to engage the upper end surface of the end piece 24 of the mold section 18 as the mold is closed. The stop bars 29 and 30 in cooperation with the hinges 20 and 21 accurately lock the mold in its closed position with the shaping surfaces 16 and 17 accurately registering at each side of the break between the mold sections as well as conforming to the marginal area of a sheet of bent glass.

Locating devices 31 mounted from the sides of the shaping surfaces 16 and 17 are employed to position the sheets of glass accurately on the mold by engaging the edges of the glass sheet.

Referring to Figure 10 each of the locating devices 31 comprises a frame 32 that is pivotally carried on a pin 33 of a bracket 34 secured to the shaping surface 16. The pivoted frame 32 at its upper end journals a small ceramic roller 35 which roller is the only portion of the locating device to contact a glass sheet such as the sheet 10 positioned on the mold. The position of the roller 35 with respect to the shaping surface 16 may be varied by an adjusting screw 36 that is held in a lower portion 37 of the pivoted frame 32 by a pair of lock nuts 38. The adjusting screw 36 bears against the side of the shaping surface 16 at a point below the bracket 34.

Referring to Figures 7 and 11, additional locating means consisting of L-shaped bars 39 welded to the mold end pieces 24 project upwardly and carry pads 40 that contact the ends of the glass sheet 10 when the glass is placed on the mold. The pads 40 are optional and if desired may be eliminated and the L-shaped bars 39 bent so that the upper ends project toward the glass. The L-shaped bars 39 including the pads 40 contact the edge of the glass sheets during only the initial portion of the bending operation with the glass moving completely free of the bars 39 before it settles against the shaping surfaces 16 and 17.

Referring now to Figures 8 and 9, the mold is shown in its open position with the glass sheet 10 held in compression as a strut between the locating devices 31. The mold rests on the side rails 6 of the frame 1 and the side rails are spaced apart far enough so that the center of gravity of each of the mold sections 18 and 19 lies between the hinged connection and the side rails 6. If the glass sheet 10 were not present the mold would immediately close. The glass sheet 10 acts as a strut between the mold sections and being located at some distance above the hinged connection prevents the mold from closing. As the glass softens during the bending operation it loses its strength as a strut and as soon as it starts to sag it is immediately forced to its bent condition as the mold drops to its closed position. During this operation the arcuate end members 24 and 25 of the mold slide over the rails 6 but there is no sliding action between any portion of the glass and cooperating portion of the shaping surfaces 16 or 17.

As the glass sheets sag during the bending operation and the mold approaches its closed condition, the end sections 24 and 25 slide on the rails 6. Ordinarily, this sliding action is uniformly divided between each of the mold sections but to guard against any excessive sliding of one of the mold sections which would permit it to slide past

8

the rail and drop through the frame each of the mold sections 18 and 19 at the outer ends of the arcuate end pieces 24 and 25 is provided with downwardly directed ears 41 serving as hooks to prevent the side members from falling free of the rails 6. Longitudinal motion of the mold with respect to the frame 1 is also prevented by a pair of pins 42 set into one of the side rails 6 at some clearance from the end pieces 24 and 25. In normal operation these safety locating devices, the depending ears 41 and the pins 42, are not called into use but they are nevertheless always available to prevent any serious misalignment of the molds with respect to the frame 1.

The amount of force applied to the sheet of glass may be varied by design through extremely wide ranges. The principal factors in determining the magnitude of this force are the weight of the mold sections, the spacing of the rails 6 with respect to the centers of gravity of the mold sections, and the distance between the shaping surface and the hinge line. The further apart the side rails 6 are located or the nearer the center of gravity of the mold sections is to the hinge line the greater will be the turning moment applied to each of the mold sections. This turning moment is resisted by a counter moment the force of which is the compression stress in the glass sheet and the moment arm of which is the distance of the sheet from the hinge line. The lower the hinge line, i. e., the further it is from the shaping surface, the less will be the force applied to the glass for a given counter-balancing moment. As the hinge line is dropped with respect to the shaping surface the angular movement between the mold sections is also reduced.

By properly coordinating all of these factors it is possible to accurately and positively bend sheets of glass to complex curved form. Since most of the bending is done under forces that are much greater than the force of gravity acting alone on the glass and since the greater forces are obtained through structure that is relatively constant in its effect it follows that quite precise control of the bending conditions may be maintained.

Figures 12 to 17 inclusive show another type of hinged mold that is designed for producing a different type of bend in the glass sheets. Whereas in the first embodiment the bend to be produced resembled a section of an oblique cone, the bend to be produced in the glass sheet by the mold illustrated in Figures 12 to 17 is relatively much shallower but is confined largely to one end of the glass sheet. In this example the mold includes a first section comprising side portions 43 and 44 that are connected by a crossbar 45. The side portions 43 and 44 and the crossbar 45 together support a shaping surface 46 that conforms to the marginal area of the relatively flat end of the sheet of glass as it is bent on this mold. The shaping surface 46 is carried from the side members 44 and crossbar 45 by a series of struts 47 arranged at intervals along the surface. Furthermore, the end portions of the shaping surface 46 are provided with locating devices 48 that are similar in all respects to the locating devices 31 illustrated in the previous example. The side members 43 and 44 project beyond the crossbar 45 and near their ends are drilled to receive pins 49 set into a rail 50 of a supporting frame 51. The supporting frame 51 includes base members 52 having uprights 53 which at their upper ends carry cross frame members 54 which in end elevation have substantially the same curvature as that of the bent glass sheet.

The other end of the mold includes a shaping surface 55 that is carried on struts 56 from a mold portion having side pieces 57 and 58 that are connected together by a crossbar 59. The side member 44 is connected by a hinge 60 to the side member 58 of the other portion of the mold while a similar hinge 61 (Figure 16) connects the side members 43 and 57. Stop bars 62 and 63 welded or otherwise secured to the side members 58 and 43 respectively engage the adjacent corresponding portions of the side members 44 and 57 respectively to provide precise alignment of the abutting portions of the shaping surfaces 46 and 55 when the mold is closed. As a further safeguard and to partially relieve the stress on the hinges 60 and 61 and the stop bars 62 and 63 the side members 43 and 44 are provided with shelf-like flanges 64 and 65 which when the mold is closed rest on pins 66 and 67 set in the cross members 54 of the frame 61.

In this example rigid guides 68 are mounted on the side members 43 and 44 in position to guide a sheet of glass 69 placed on the mold during an initial portion of the bending operation. Corresponding to the L-shaped guides 39 of the preceding example, the guides 68 do not contact the glass during the final stages of the bending operation.

In the first example the hinge line of the mold is more or less symmetrically located with respect to the side rails 6 of the supporting frame. It is not always possible to secure such a relationship and Figures 12, 13, 14 and 17 illustrate an alternative construction that may be employed when there is a substantial misalignment between the hinge line and the frame rails. In the second example, the crossbar 59 of one of the mold sections carries an extension bar 70 which during a bending operation is supported on and slides along an inclined face of the cross member 54 of the frame. Since the position of the hinge line in space is uniquely determined by the frame rail 50 supporting the ends of the side members 43 and 44 and the contact of the extension bar 70 with the inclined face of the cross frame member 54 it becomes necessary to supply an accurately located support for the remaining corner of the mold. In this example this support is provided by an extension bar 71 that is attached to the mold and that slides down the edge of an inclined track 72 as the mold approaches its closed condition. The angle and shape of the track 72 is such that the corner of the mold frame is supported throughout the bending operation as the mold moves from its open to its closed position.

In this example, as in the previous example, the mold is held in its open position by the glass to be bent which glass acts as a strut between the locating devices. Since the glass is located a substantial distance above the hinge connection, it effectively prevents the mold from moving to its closed condition until the glass has softened and sagged. As the glass sags the force applied to its ends accelerates the bending operation at the same time that the mold drops to its closed position. In this example the glass is subjected to substantially greater force that is a glass being processed on a mold constructed according to the first example. This follows because the mold illustrated in Figures 12 to 17 is supported at its ends and is relatively longer than the mold of the first example.

Another factor tending to increase the force applied to the glass is the slope of the portion of the side rail 54 and the track 72 on which the

extension bars 70 and 71 rest. If these surfaces are substantially vertical the force applied to the glass is very great while if these surfaces are substantially horizontal the force applied to the glass depends almost entirely upon the weight of the mold and the distance between the glass and the hinge. If the track 72 and the inclined surface of the cross member 54 is intermediate these two extremes, a horizontal component of force is applied to the end of the mold frame which component of force tends to augment the force supplied by the weight of the mold sections. By properly selecting the slope of the supporting surfaces and the position of the hinges 60 and 61 with respect to the shaping surfaces 46 and 55 it is possible to vary the force applied to the glass through a very wide range as may be necessary to accommodate various types of glass or as may be required to localize the bending in particular areas of the glass sheet.

Figures 18 to 20 inclusive illustrate a hinged mold in which the mold is divided into more than two sections. Such a mold is desirable if a spherically curved sheet 73 of glass is to be formed from a flat blank 74. In the preceding examples the bend was either conical or cylindrical or substantially so and in such a bend the hinge line may extend along those elements of the glass sheet that tend to remain straight throughout the bending operation. However, a spherical surface has no permanently straight elements and it is, therefore, necessary to apply force along both axes to produce sufficient compression in the peripheral portions of the glass sheet to allow its central portion to sag to the desired curvature.

Figure 19 is a plan and Figure 20 an elevation of a substantially square mold that is hinged along axes at right angles to each other. Thus the mold is divided into quarter sections 75, 76, 77 and 78 which are joined together by hinges 79, 80, 81 and 82. Extensions 83, 84, 85 and 86 project from the corners of the quarter section and rest on diagonal crosspieces 87 of a frame 88. The corner extensions 83 and 86 are drilled to loosely receive locking pins 89 which serve to position the mold on the frame 88. The corner extensions 84 and 85 are not drilled but rather slide over the supporting diagonal frame pieces 87 as the mold settles to its closed condition. The mold quarter sections 75, 76, 77 and 78 each carry a portion of a shaping surface 90 which when the mold is in its closed position conforms to the marginal area of the bent glass sheet 73. The shaping surface 90 is carried from the mold sections on struts 91 in the same manner as the shaping surfaces of the other molds were carried from the mold sections.

As in the preceding examples, stop bars 92 are provided at each of the hinged joints to securely lock and align the mold sections when the mold reaches its closed position.

These examples of improved molds are useful in carrying out the improved method of bending glass sheets. This method includes the steps of supporting a glass sheet to be bent in bending relation over separated portions of the shaping surface of a mold, applying force to the edges of the glass tending to stress the glass as a column or strut, maintaining the force on the glass as the glass bends and approaches the shaping surface of the mold and bringing the separated portions of the shaping surface together as the glass settles to the shaping surface. The bending is produced as the glass is heated to its softening temperature at which time it yields to the force

being applied and settles to the shaping surface of the mold before any portion of the glass becomes sufficiently soft to sag beyond the intended shape. By stressing the glass as a column or as a strut, important advantages are obtained in that the glass is strong until it starts to yield and then it becomes increasingly weaker because of its change of shape to resisting the applied force. This results in a relatively rapid movement from its flat to its bent condition. Bringing the separated portions of the shaping surface together as the glass settles prevents any overbending as a substantially complete marginal support for the bent glass is thus provided at the finish of the bending operation. The application of edgewise compression causes the bending to take place at a slightly lower temperature than would be required to accomplish the same bending were the force of gravity alone employed to change the shape of the softened glass.

Various modifications and improvements in the mold may be made without departing from the spirit and scope of the invention.

Having described the invention, I claim:

1. In an apparatus for bending glass sheets, in combination, at least two movable members that are hinged together, curved shaping surfaces on the members, both of said members being movable to a position at which said curved shaping surfaces conform to the margin of a bent glass sheet, means for locating a glass sheet on the shaping surfaces, said members being movable to a second position such that an unbent glass sheet may be positioned between the locating means, and a frame that supports said members at points such that said members are urged from the second to the first position.

2. In an apparatus for bending glass sheets, in combination, at least two movable members that are hinged together, curved shaping surfaces on the members, both of said members being movable to a first position at which the curved shaping surfaces conform to the margin of a bent sheet of glass, means for locating a sheet of glass on the shaping surfaces, said members being movable to a second position at which an unbent glass sheet may be positioned between the locating means, and a frame that supports the members at spaced points such that the center of gravity of each member lies between the hinge connection and the points of contact with the frame.

3. In an apparatus for bending glass sheets, in combination, at least two movable members that are hinged together, curved shaping surfaces on the members, stop means for limiting the relative movement between the hinged members at a first position at which the curved shaping surfaces conform to the margin of a bent sheet of glass, locating means adjacent the shaping surfaces, said members being movable to a second position such that a flat sheet of glass may be positioned and held in compression between the locating means, and a frame that supports said members and that permits sagging of the members to their first position as the glass sheet softens.

4. In an apparatus for bending glass sheets, in combination, at least two movable members that are hinged together, curved shaping surfaces on the members, stop means on the members for limiting the relative movement between the members at a first position at which the curved shaping surfaces conform to the margin of a bent sheet of glass, locating means adjacent the shaping surfaces, said locating means being adjacent

but not touching the edge of a bent sheet of glass, said members being movable to a second position at which a flat sheet of glass may be positioned and held in compression between the locating means, and a frame for supporting said members at points remote from their hinge connection.

5. In an apparatus for bending glass sheets, in combination, at least two movable members, a curved shaping surface having a portion on each member, hinge means connecting adjacent ends of said members together, said curved shaping surface in a first position of said members conforming to the margin of a bent sheet of glass with the hinge means located outside the convex side of the bent sheet of glass positioned on the shaping surface, means for locating a sheet of glass on the shaping surfaces, said members being movable about said hinge means to a second position at which a flat sheet of glass may be located between said locating means, and a support that urges the member toward said first position.

6. In an apparatus for bending glass sheets, in combination, at least two movable members, a curved shaping surface on each member, said curved shaping surfaces in combination conforming to the margin of a sheet of bent glass, and hinge means joining adjacent ends of the members together, said hinge means being separated from the shaping surfaces a distance that varies generally inversely as the radius of curvature of the adjacent portion of the shaping surface.

7. In an apparatus for bending glass sheets, in combination, a pair of movable mold members, curved shaping surfaces on the members, said shaping surfaces together conforming to the margin of a sheet of bent glass, and hinge means connecting adjacent ends of the members together, said shaping surfaces having their regions of greatest curvature near the junctions between the members, and said hinge means being located from the shaping surfaces a distance that is generally proportional to the curvature of the adjacent portions of the shaping surfaces.

8. In an apparatus for bending glass sheets, in combination, a pair of movable mold members, curved shaping surfaces on the members, hinge means joining adjacent ends of the members together, a frame upon which the members are loosely carried such that the members are urged toward a position at which the shaping surfaces conform to the margin of a bent sheet of glass, locating means on the members adjacent the shaping surfaces, and means for adjusting the position of the locating means to loosely engage a bent sheet of glass.

9. In an apparatus for bending glass sheets, in combination, a pair of movable mold members, curved shaping surfaces on the members, hinge means joining adjacent ends of the members together, a frame upon which the members are loosely carried such that the members are urged toward a position at which the shaping surfaces conform to the margin of a bent sheet of glass, locating means on the members adjacent the shaping surfaces, said members being movable to a second position at which a flat sheet of glass may be placed between the locating means, and means for adjusting the position of the locating means to provide release of the glass from the locating means as the bending operation nears completion.

13

14

10. In an apparatus for bending glass sheets, in combination, a pair of mold members, shaping surfaces on the members, hinge means joining adjacent ends of the members together, a frame having spaced apart side rails upon which said mold members may rest, said members being movable between two positions at one of which the shaping surfaces conform to the margin of a bent sheet of glass and at the other of which the shaping surfaces are separated to receive a flat sheet of glass, said members being adapted to slide on the side rails during movement from one of said positions to the other of the positions.

11. In an apparatus for bending glass sheets, in combination, a plurality of mold members, a shaping surface having a portion carried on each of the mold members, hinge means for joining the mold members, a frame, means for locating one of said members on the frame, and inclined surfaces on said frame for supporting another of said members for sliding movement thereon and for urging the mold members toward a position at which the shaping surface conforms to the margin of a sheet of bent glass.

12. A method of bending glass sheets comprising the steps of separating portions of the shaping surface of a mold, placing a sheet of glass in bending relation to the mold, applying force to edges of the glass, subjecting the glass to bending temperature while maintaining the force against the edges of the sheet of glass, and moving the portions of the shaping surface into mutual contact as the glass settles to the shaping surface.

13. A method of bending glass sheets comprising the steps of separating portions of the shaping

ing surface of a mold, placing a sheet of glass in bending relation to the mold, applying force to the edges of the glass, subjecting the glass to bending temperature, varying the magnitude of the force applied to the glass as it softens and bends, and simultaneously moving the portions of the shaping surface into mutual contact as the glass settles to the shaping surface.

14. In apparatus for bending glass sheets, a plurality of mold sections having shaping surfaces thereon, means for hinging said sections together to form a complete mold of which the shaping surfaces of the different sections will conform to the margin of a glass sheet bent thereon when said sections are in one position relative to one another, means for locating a glass sheet on said sections, a frame for supporting said sections for swinging movement at points remote from said hinging means, whereby said sections can be swung to a second position relative to one another to receive an unbent sheet between said locating means but will tend to fall by gravity into said first-mentioned position.

JOSEPH E. JENDRISAK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,999,558	Black	Apr. 30, 1935
2,330,349	Galey	Sept. 28, 1943
2,348,279	Boyles et al.	May 9, 1944