

Oct. 11, 1966

H. A. LEFLET, JR., ETAL

3,278,287

METHOD OF PRODUCING PATTERN-CUT BENT GLASS SHEET

Filed May 28, 1963

2 Sheets-Sheet 1

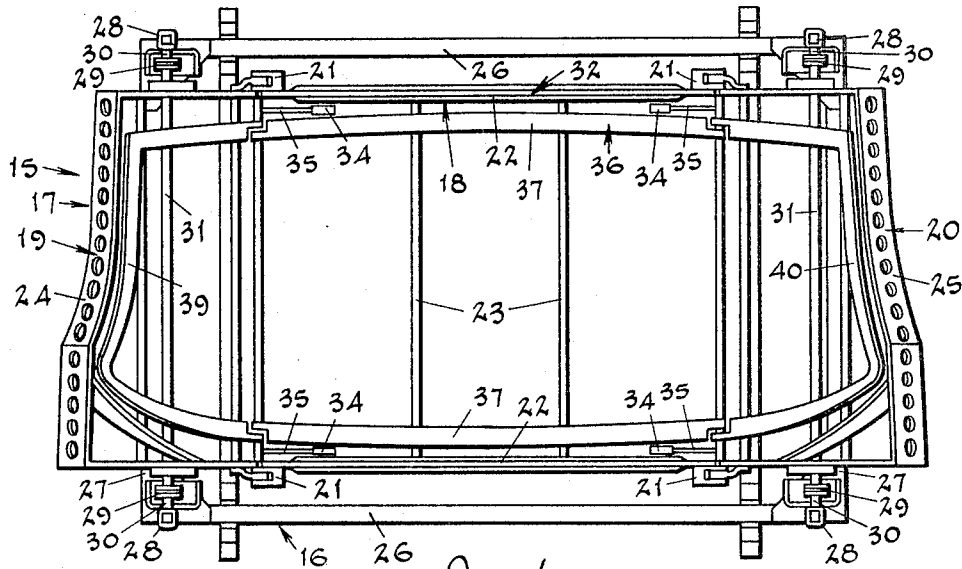


Fig. 1.

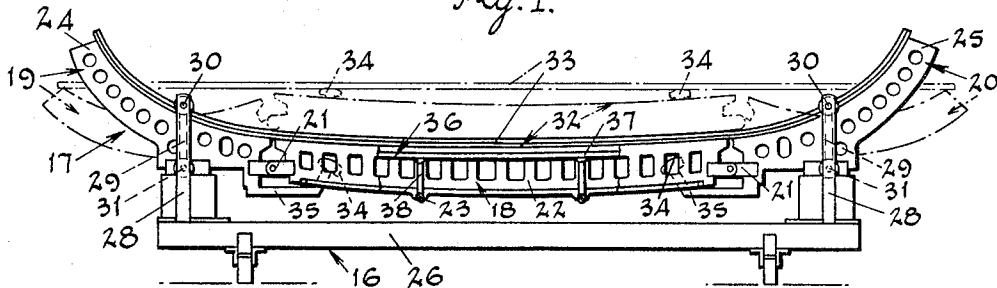


Fig. 2.

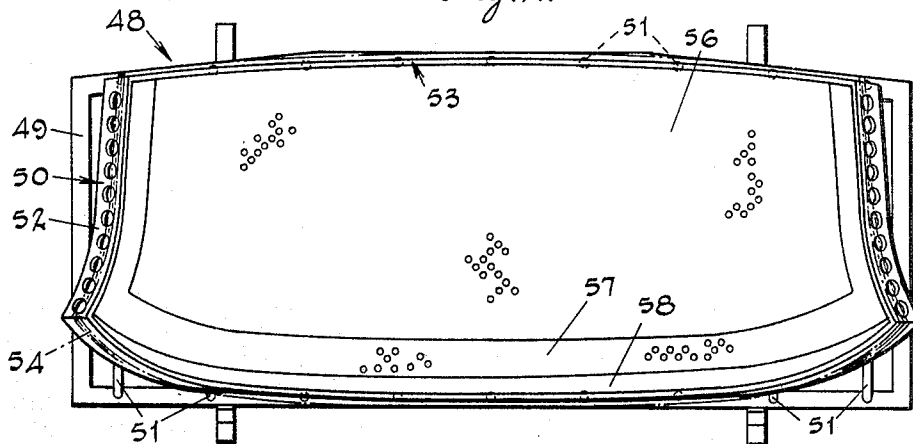


Fig. 4.

INVENTORS  
Herbert A. Leflet, Jr. and  
BY David M. Clamper  
Robb & Swope  
ATTORNEYS

Oct. 11, 1966

H. A. LEFLET, JR., ETAL

3,278,287

METHOD OF PRODUCING PATTERN-CUT BENT GLASS SHEET

Filed May 28, 1963

2 Sheets-Sheet 2

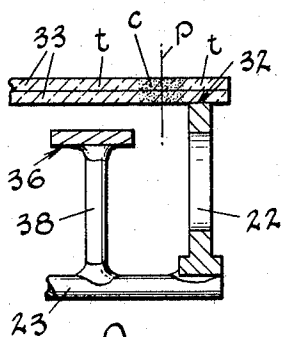


Fig. 3.

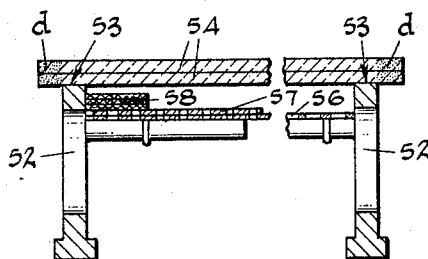


Fig. 5

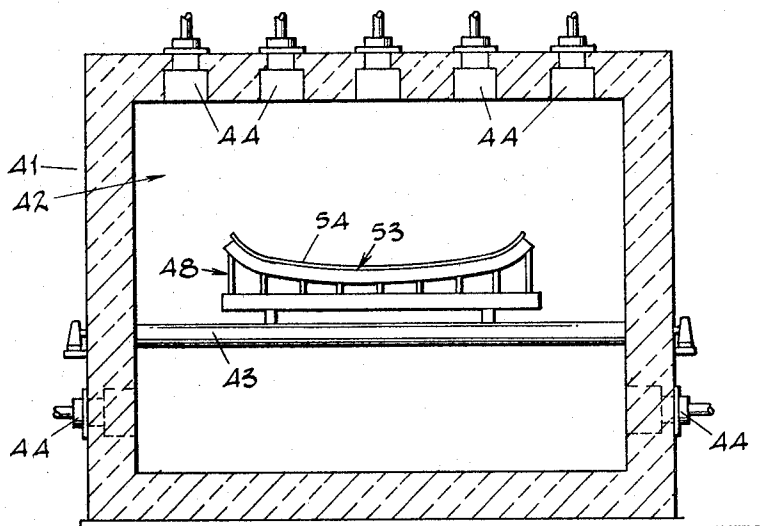


Fig. 6.

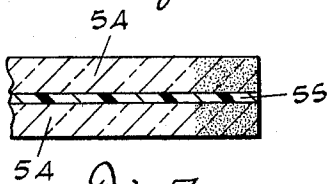


Fig. 7.

INVENTORS  
Herbert A. Leflet, Jr. and  
BY David M. Crampler  
Hobbe & Swope  
ATTORNEYS

1

2

3,278,287

## METHOD OF PRODUCING PATTERN-CUT BENT GLASS SHEET

Herbert A. Leflet, Jr., and David M. Wampler, Toledo, Ohio, assignors to Libbey-Owens-Ford Glass Company, Toledo, Ohio, a corporation of Ohio  
Filed May 28, 1963, Ser. No. 283,737  
2 Claims. (Cl. 65—103)

The present invention relates broadly to the art of bending glass sheets and more particularly to an improved method of producing pattern-cut bent glass sheets.

It is the primary object of this invention to provide an improved method of producing pattern-cut bent glass sheets of increased physical strength and in which the marginal edge portions thereof are more resistant to breakage.

Another object of the invention is to provide an improved method of increasing the edge strength of pattern-cut bent glass sheets by control of the regional strain patterns created in the sheets during the bending and annealing thereof.

Another object of the invention is the provision of a two-step method of bending and strengthening glass sheets in which block size sheets are first bent to a predetermined curvature and annealed, after which the bent sheets are cut to pattern, placed on bending molds having a curvature corresponding to the curvature of the bent sheets and reheated and annealed in a manner to place the marginal edge portions of the sheets in compression without further bending of said sheets.

A further object of the invention is the provision of an improved method in which a continuous regional compression area is created in a block size glass sheet when it is heated, bent and annealed; a pattern of the desired outline is cut from the block size sheet along a line running through the compression area; the pattern-cut bent sheet being then supported upon the shaping surface of a ring-type mold having substantially the same curvature as the bent sheet and the sheet reheated to a temperature sufficient to relieve all stress therefrom but not high enough to bend the glass, after which the sheet is cooled in such a manner as to place the marginal edge portions thereof in compression.

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 plan view of a bending mold for bending the block size glass sheets according to the invention;

FIG. 2 is a side elevation of the bending mold;

FIG. 3 is a fragmentary vertical section of the bending mold;

FIG. 4 is a plan view of a bending mold for the pattern-cut bent glass sheets;

FIG. 5 is a fragmentary vertical section of the bending mold of FIG. 4;

FIG. 6 is a transverse vertical section through a bending furnace; and

FIG. 7 is a fragmentary section of a laminated glass sheet formed of pattern-cut bent glass sheets produced in accordance with the invention.

It is known that glass, when properly heated and then cooled or annealed, reaches a state of stability in which the characteristics of tension and compression are said to be in equilibrium. These characteristics, however, have been found to localize in areas or regions within a glass body or sheet, particularly when it is bent, since a sheet, in planular form or outline, must be adequately supported to produce the desired bent formation. Thus, in the

vicinity of those portions of a glass sheet in contact with a bending mold, regions of tension will inevitably be developed as distinguished from regions of compression in areas of the bent glass sheet which are more readily subject or exposed to the controlled cooling temperatures during annealing. This arises from the fact that the residual heat of the bending mold unbalances the normal tendency of the glass to uniformly cool and anneal and, consequently there will be particularly marginal areas, above the shaping rail of the bending mold, which are held at a higher heat for a longer period of the cooling time. On the other hand, the peripheral edges and central areas of the bent glass sheets are more readily influenced by the controlled cooling or annealing temperatures. The mechanical strength and resistance to edge breakage of bent glass sheets is greatly increased when these regions of tension and compression have been so located as to provide a compression area at the edges thereof. This is particularly important when bent glass sheets in matched pairs are later used in the manufacture of laminated safety glass.

According to the present invention, the development of compression in the marginal edge portions of the pattern-cut bent glass sheets is carried out in two phases of operation during which the glass sheets in block size are first bent to the required curvature, cut to pattern outline and then reheated and cooled in a manner to establish a compression area entirely about the edges of the pattern-cut bent sheets.

Referring now to the drawings and particularly to FIGS. 1, 2 and 3, there is illustrated a bending apparatus, generally designated by the numeral 15 and comprising a support rack 16 and a bending mold 17 carried thereby for the bending of block size sheets. Since the invention is in no way limited to the exact construction of the bending mold, it may be of the solid outline or ring type or, as herein shown of the outline type formed of sections that are relatively movable with respect to one another from an open position to a closed position. The mold 17 is thus of the multiple-section type including a central section 18 and end sections 19 and 20 which are swivable relative to the central section 18 by means of hinges 21. The central section 18 is formed by the substantially parallel shaping rails 22 interconnected by bracing rods 23 while the end sections 19 and 20 are similarly formed by substantially U-shaped shaping rails 24 and 25, the end portions of which form substantial continuations of the side shaping rails 22. The shaping rails have, in plan, an outline corresponding to that of the block size glass sheets and are of a curvature corresponding to the curvature to which the said sheets are to be bent.

The support rack 16 is formed with side rails 26 and end rails 27 and is provided at its respective corners with vertically disposed posts 28 on which the mold 17 is bodily supported by means of pivoted links 29 carried at their upper ends by rods 30 attached to the posts, and receiving in their lower end rods 31 carried by the end mold sections 19 and 20.

Upon reference to FIG. 2, the mold is shown in closed position by the full lines and in open position by the broken lines. The mold sections 18, 19 and 20 are, of course, moved to the open position for reception of the flat glass sheets to be bent. A flat glass sheet 33, shown in broken lines, is supported at its opposite ends upon the end mold sections 19 and 20 and also inwardly of its ends by means of non-abrasive blocks 34 carried by arms 35 attached to and movable with the end mold sections 19 and 20. With the mold 17 in its closed position, as shown in full lines, the supporting blocks 34 are positioned beneath the mold shaping surfaces 32 and out of engagement with the glass sheet.

In plan, the central mold section 18 and end mold sections 19 and 20 provide a substantially continuous shaping surface approximating the area and outline of glass sheets initially cut to a so-called block size which is larger than the area of the pattern size sheets to be subsequently cut therefrom. The bending of a glass sheet, or pair of glass sheets, in block-size, has been found to improve the quality of the finished pattern-cut sheet in that any marring or distortion attributable to contact of the glass with the bending mold at relatively high bending temperatures is confined to the marginal areas of the sheet or sheets. These areas along the sides and at the ends of the block-size sheet in actual contact with the bending mold, are of course spaced outwardly from the central area from which the pattern size sheet is to be subsequently cut. Another reason is to initially provide a sufficiently large central area so that inadvertent movement of one sheet relative to the other during bending will not prevent identical curvatures being obtained in the central areas of the bent sheets.

In bending the block-size sheets it has been found desirable to provide a compression band in the sheets inwardly of the edges thereof and of substantially the same outline as the pattern size sheets to be cut therefrom. For this purpose, the bending mold 17 is equipped with a substantially continuous metallic heat absorbing member 36 located in inwardly spaced relation to the shaping rails 22, 24 and 25 and having an outline conforming to but slightly smaller in area than the pattern size sheet to be cut from the block-size sheet. The heat absorbing member 36 is formed by center rails 37, supported by posts 38 on bracing rods 23, and end rails 39 and 40 opposite the end mold sections 19 and 20. The rails 39 and 40 are carried by the said mold mold sections 19 and 20 to the end that they move therewith during opening and closing of the mold. Positioning of the heat absorbing member 36 in spaced relation to the shaping rails 22, 24 and 25 of the mold establishes a continuous open area therebetween in which the surfaces of the bent glass sheets will, during the annealing cycle, be more subject or exposed to the controlled cooling temperatures of the annealing Lehr. As will be seen upon reference to FIG. 3, this will result in the creation of a continuous area or band of compression, indicated by the letter *c*, between areas of tension, indicated by the letters *t*. Thus, the residual heat in the shaping rails will operate to retard or create a differential in the rate of cooling along the margins of the glass. At the same time, the heat absorbing member will affect the areas of the sheet or sheets thereabove to similarly retard the cooling along a line inwardly of the glass margins. This retarding of the cooling of the glass sheets along spaced longitudinally extending areas coincident with the shaping rails and the heat absorbing member will cause the retarded areas to be placed in tension while the area therebetween will be in compression.

Generally stated, the bending operation can be carried out in a furnace 41 illustrated in FIG. 6, and comprising an enclosed heating chamber 42 in which is arranged a horizontally disposed roll conveyor 43 for carrying the molds and glass sheets to be bent therethrough. The chamber 42 is provided in the side walls and ceiling thereof with heat sources 44 which are controlled to progressively raise the temperature of the glass sheets as they pass through the furnace until they are sufficiently heat softened to be bent by gravity into conformity with the shaping surface of the molds. Generally speaking, the bending temperature of sheet and plate glass ranges from about 1140° F. to about 1250° F.

In the practice of the invention, the glass sheets are gradually raised from room temperature to a temperature of about 940° F. to relieve all stress therefrom, and additionally heated to a temperature sufficient to soften the sheets so that they settle into conformity with the shaping surfaces of the molds in the closed position thereof.

After bending, the glass sheets are annealed during

which the areas *c* and *t* thereof (FIG. 3) will be differentially cooled to establish the compression area or band *c* as described above. The bent block-size sheets are then removed from the molds and pattern cut to the desired outline. This cut is generally made along a line running through the compression band *c*, as indicated by the letter *p* in FIG. 3. This permits a much cleaner breaking of the glass along the line of cut and insures pattern-cut bent sheets relatively free from distortion.

In carrying out the second phase of the invention, the pattern-cut bent glass sheets are supported on bending apparatus of the type shown in FIGS. 4 and 5, and designated generally by the numeral 48. The bending apparatus 48 includes a support rack 49 and a ring-type mold 50 supported on the rack by vertical posts 51. The bending mold 50 is preferably formed with a solid ring-type shaping rail 52 which, in plan, is of the same outline as the bent pattern-cut sheets, but is of a relatively smaller size so that the margins of the glass sheets overhang the shaping rail as shown in FIG. 5.

In elevation, the shaping surface 53 of shaping rail 52 conforms to the curvature of the shaping surface 32 of bending mold 17 and thus also to the curvature of the bent sheets. When pattern-cut sheets 54, shown in broken lines in FIG. 4, in bent and matched pairs, are placed on the shaping surface 53 of mold 50 they will be supported thereby inwardly of their peripheral edges in conformity with the curvature to which they were previously bent on the mold 17 of bending apparatus 15.

The bending mold 50 and glass sheets supported thereon are then passed through a bending furnace to reheat the glass sheets and to re-establish a compression band in the margins thereof. More particularly, the glass sheets are reheated to a predetermined temperature above 940° F., to relieve all stress therein, including the compression area formed in the margins of the glass sheets during the initial bending operation. However, the glass sheets are not reheated to a temperature sufficient to cause any further bending thereof.

After the sheets have been reheated to the desired temperature, they are subjected to a controlled cooling or annealing. As pointed out above, the bending mold is of a relatively smaller outline than the glass sheets, with the result that the marginal areas of the sheets will project beyond the mold and be free from contact therewith. Consequently, when the bent glass sheets are cooled, the projecting marginal edge portions will neither be in contact with the mold nor influenced by the residual heat therein. This will permit the marginal edge portions to cool more rapidly thereby placing the same in compression, as indicated at *d* in FIG. 5, to produce a resultant structurally stronger and breakage resistant continuous edge portion in the sheets.

The two-step method of bending and strengthening glass sheets according to the present invention possesses several distinct advantages. Thus, by bending the glass sheets in block size, the pattern-size sheets subsequently cut therefrom will be free from distortion, marring and other defects which ordinarily result from contact between the glass and mold since these portions of the glass will be removed when pattern cutting the sheets. Also by creating a continuous area or band of compression in the block size sheets corresponding in outline to that of the pattern size sheets, and cutting the sheets along a line extending through the compression area, it has been found that a better, cleaner cut can be obtained. Additionally, any slight slippage that might occur between the two block-size sheets during bending will not adversely affect the proper matching of the two pattern-cut bent sheets and registration of the edges thereof. This is particularly important when, as shown in FIG. 7, two pattern-cut bent glass sheets 54 are laminated together with a plastic interlayer 55 to form a composite safety glass structure. It has been further found that by reheating the pattern-cut sheets the exactness of conformity thereof to the mold

curvature can be more definitely controlled although the sheets are not elevated in temperature to the same degree required to effect bending of the block-size sheets. The compression in the marginal edge portions of the sheets is also more fully established since after the sheets are reheated, the upper, lower and vertical surfaces of the edges of the sheets extending beyond the mold shaping rail are exposed and will be more rapidly cooled than the area of the sheets above the shaping rail.

During annealing the area of the glass sheets above the shaping rail 52 are placed in tension and, if desired, the rate of heat loss from the glass sheets can be controlled to produce a tension pattern in the central area thereof having a predetermined gradient in the degree of strain. Thus, the degree of tension can be progressively reduced inwardly from the area of the glass above the shaping rail by the use of a shielding member in the form of a relatively thin perforated metal sheet 56 located within the confines of the shaping rail 52. Along the trailing side and ends of the mold as it passes through the furnace, the thickness of this shielding member can be increased by the provision of a strip 57 of similarly perforated material. Immediately adjacent the inner surface of the shaping rail also at the trailing side of the mold, layers 58 of glass cloth, asbestos or combinations thereof may also be employed to further increase the thickness of the heat retaining or shielding member and thereby result in a gradual reduction in the tension in the glass inwardly from the area of greatest tension above the shaping rail.

It is to be understood that the form of the invention herein described is to be taken as an illustrative embodiment only of the same, and that various procedural changes may be resorted to without departing from the spirit of the invention.

We claim:

1. A method of bending glass sheets, which comprises bending a block-size sheet while at its bending temperature to a predetermined curvature and cooling said sheet in a manner such that a substantially continuous band-like area of said sheet spaced inwardly of the outer edge thereof is cooled more rapidly than contiguous areas to form an area which is in regional compression through the thickness of the sheet, cutting the bent, block-size sheet to pattern along a line running through said compression area which is spaced inwardly of the area of the sheet which contacts the mold, supporting the pattern-cut bent sheet upon the shaping surface of a ring-type mold of the same curvature as said bent sheet and having substantially the same outline as the sheet but of a relatively smaller size, reheating said sheet and then cooling the sheet while maintaining contact between said shaping surface and said sheet about the entire periphery but inwardly of the outer edge of said sheet to place the marginal edge portions thereof in compression.

2. A method of bending glass sheets as claimed in claim 1, in which the bent, pattern-cut sheet during reheating is raised to a temperature sufficient to relieve all stress therefrom, including the compression area created during bending of the block-size sheet, but not high enough to bend the glass.

#### References Cited by the Examiner

##### UNITED STATES PATENTS

|           |        |               |        |
|-----------|--------|---------------|--------|
| 2,869,287 | 1/1959 | Bamford       | 65—104 |
| 2,897,632 | 8/1959 | Fowler et al. | 65—103 |

DONALL H. SYLVESTER, *Primary Examiner*.

A. D. KELLOGG, *Assistant Examiner*.