United States Patent [19]

Nedelec et al.

[11] **3,778,244**

[45] **Dec. 11, 1973**

[54] **BENDING OF FLAT GLASS ON A MOLD WITH VACUUM**

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[22] Filed: **Apr. 22, 1971**

[21] Appl. No.: **136,501**

[30] **Foreign Application Priority Data**

Apr. 23, 1970 France 7014794

[52] **U.S. Cl.**..... **65/106,** 65/275, 65/287

[51] **Int. Cl.**..... **C03b 23/02**

[58] **Field of Search**..... 65/102, 106, 286, 65/287, 275

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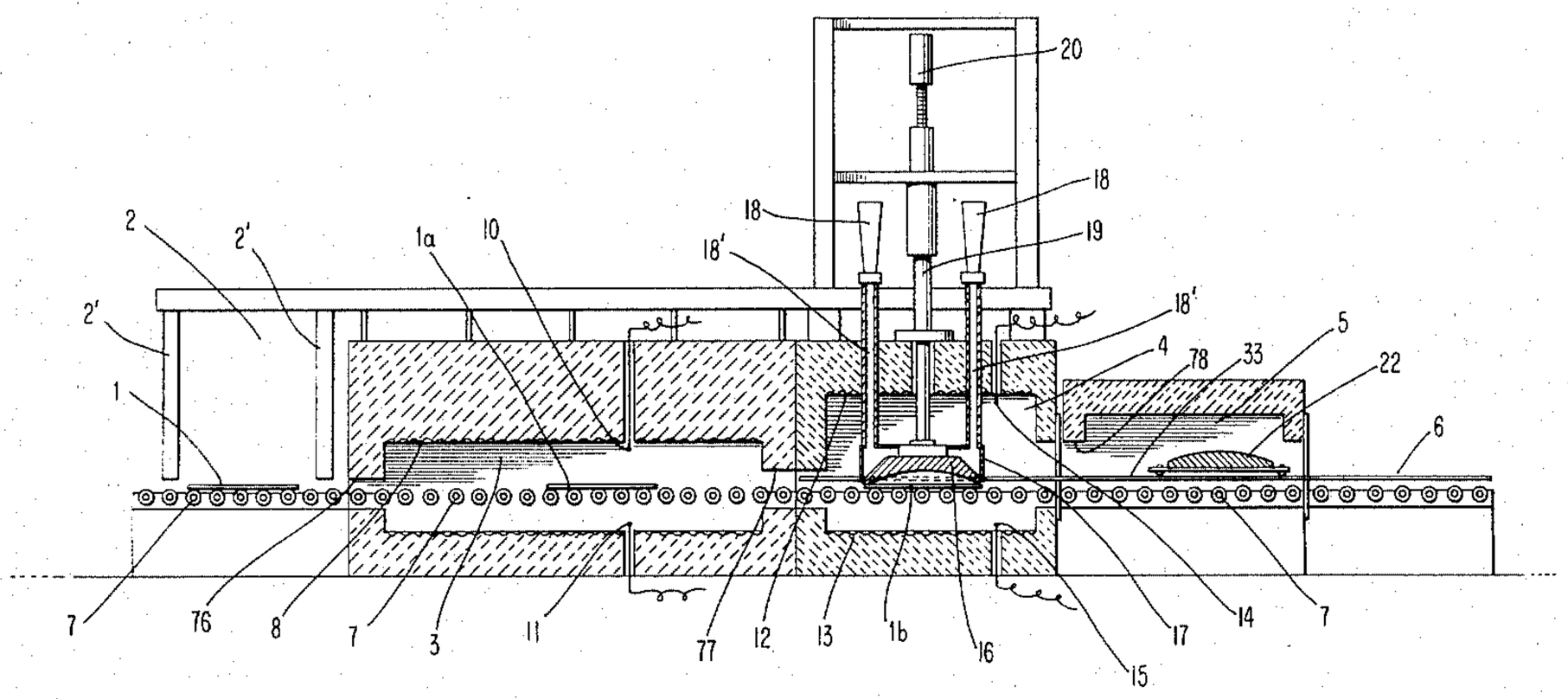
[57] **ABSTRACT**

The invention involves a method of bending a sheet of thermoplastic material which comprises heating the sheet to bending temperature, placing it adjacent a shaping form, pneumatically forcing the sheet toward and bending it against the form, and cooling the bent sheet; and apparatus for the bending of thermoplastic sheets which comprises a bending form, means to transport a hot thermoplastic sheet into proximity to the bending form, pneumatic means to bend the sheet against the form, and means to cool the bent sheet.

29 Claims, 14 Drawing Figures



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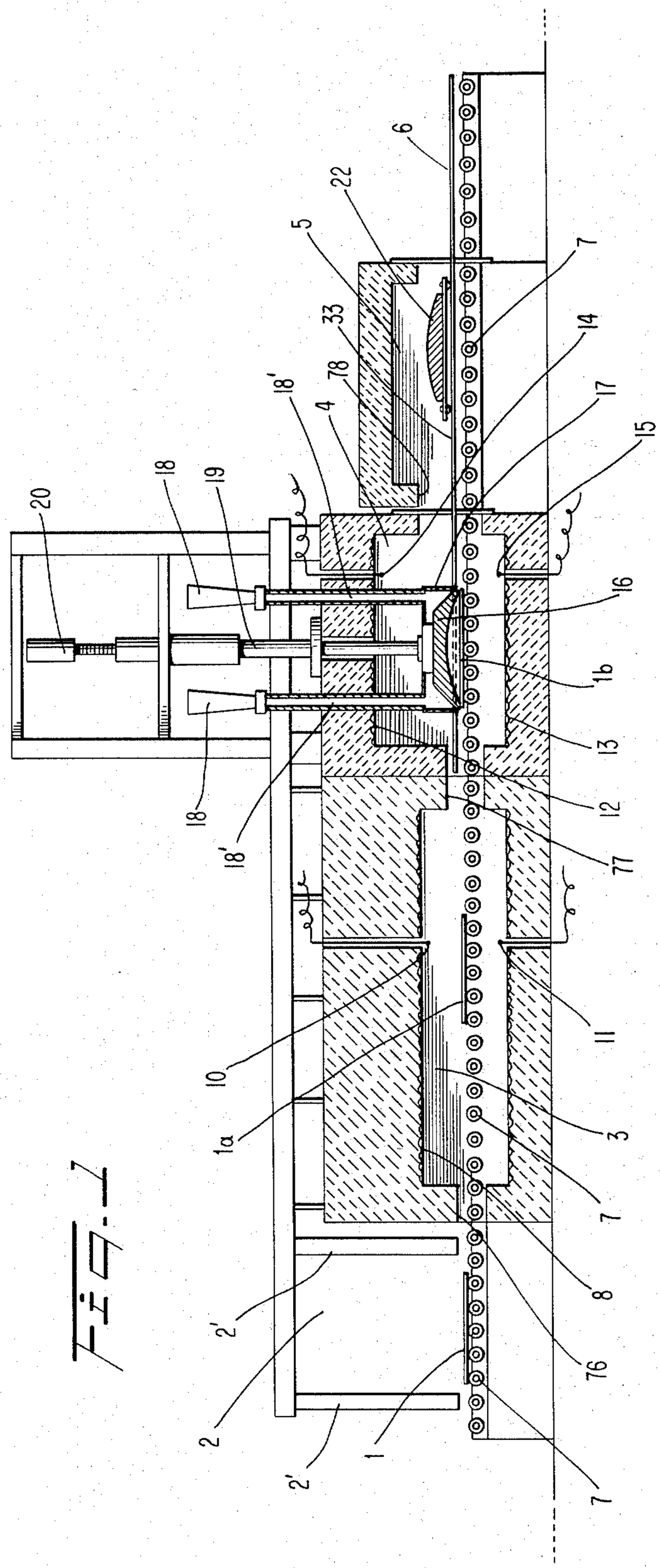

FIG. 1

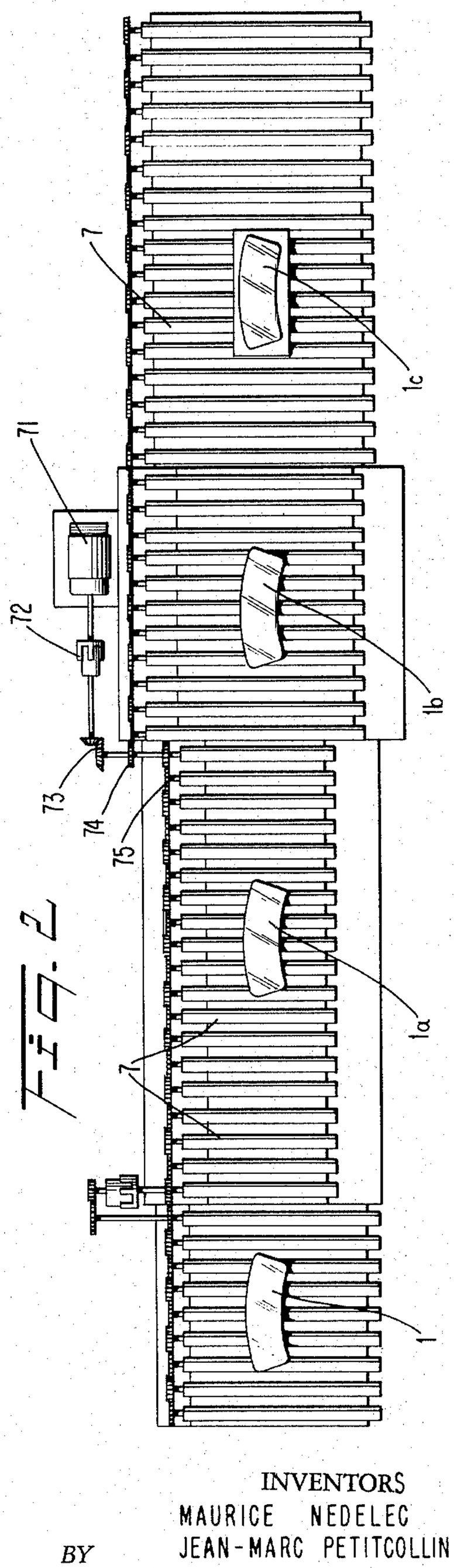

FIG. 2

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Fig. 3

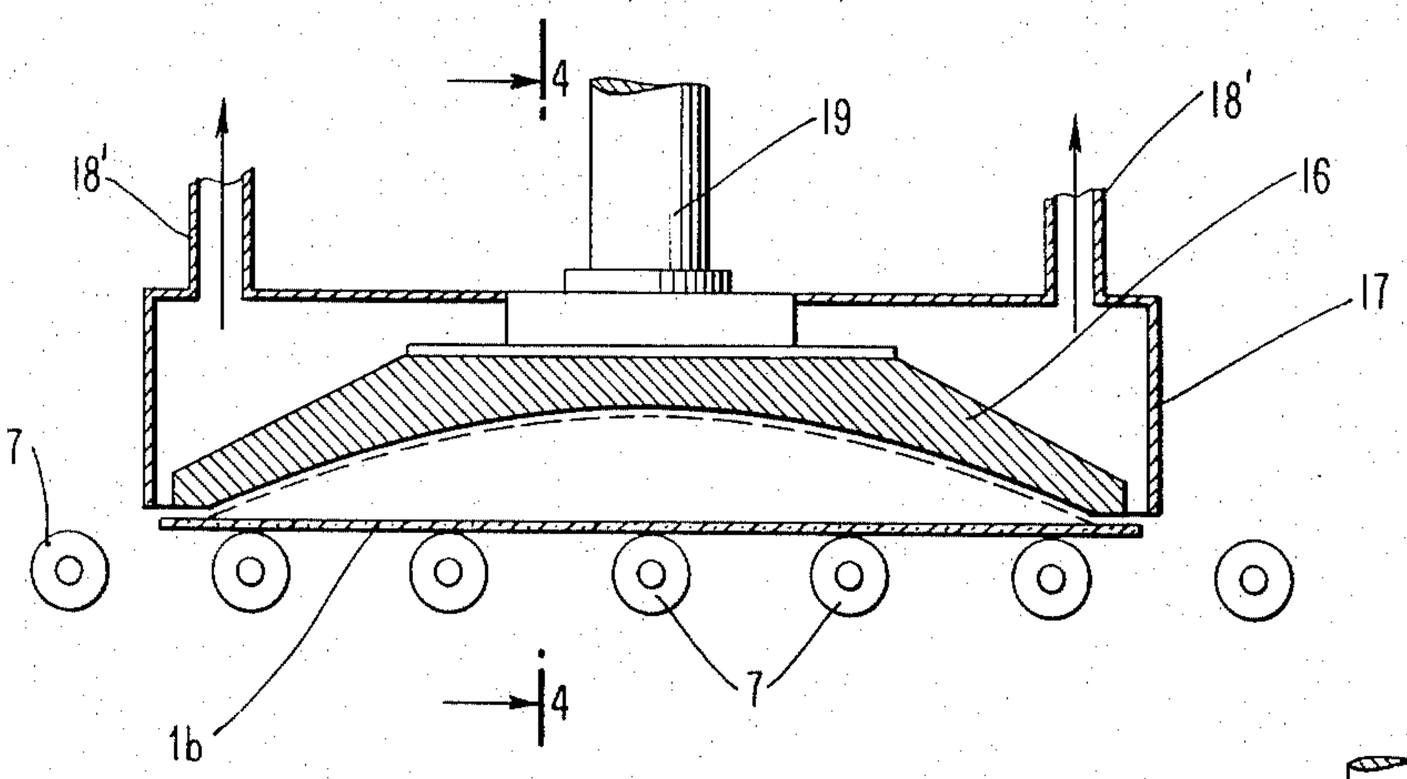

Fig. 4

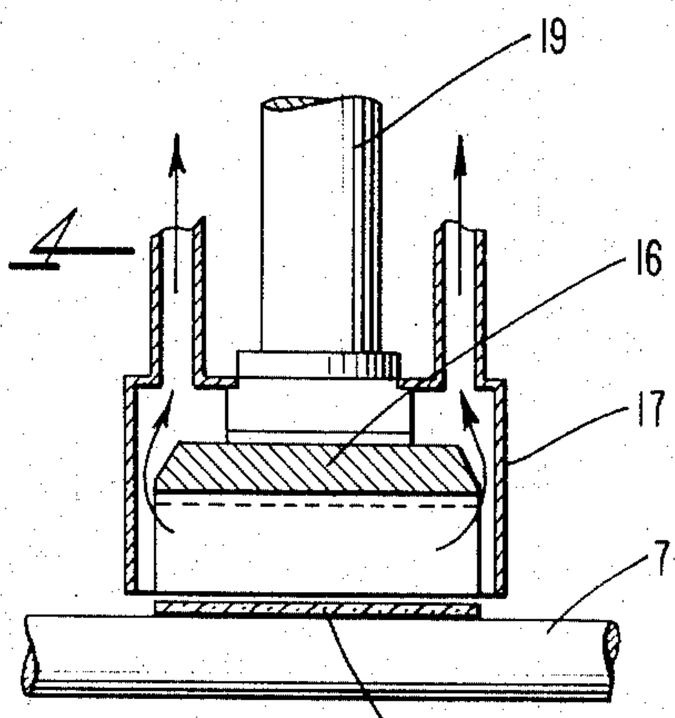

Fig. 5

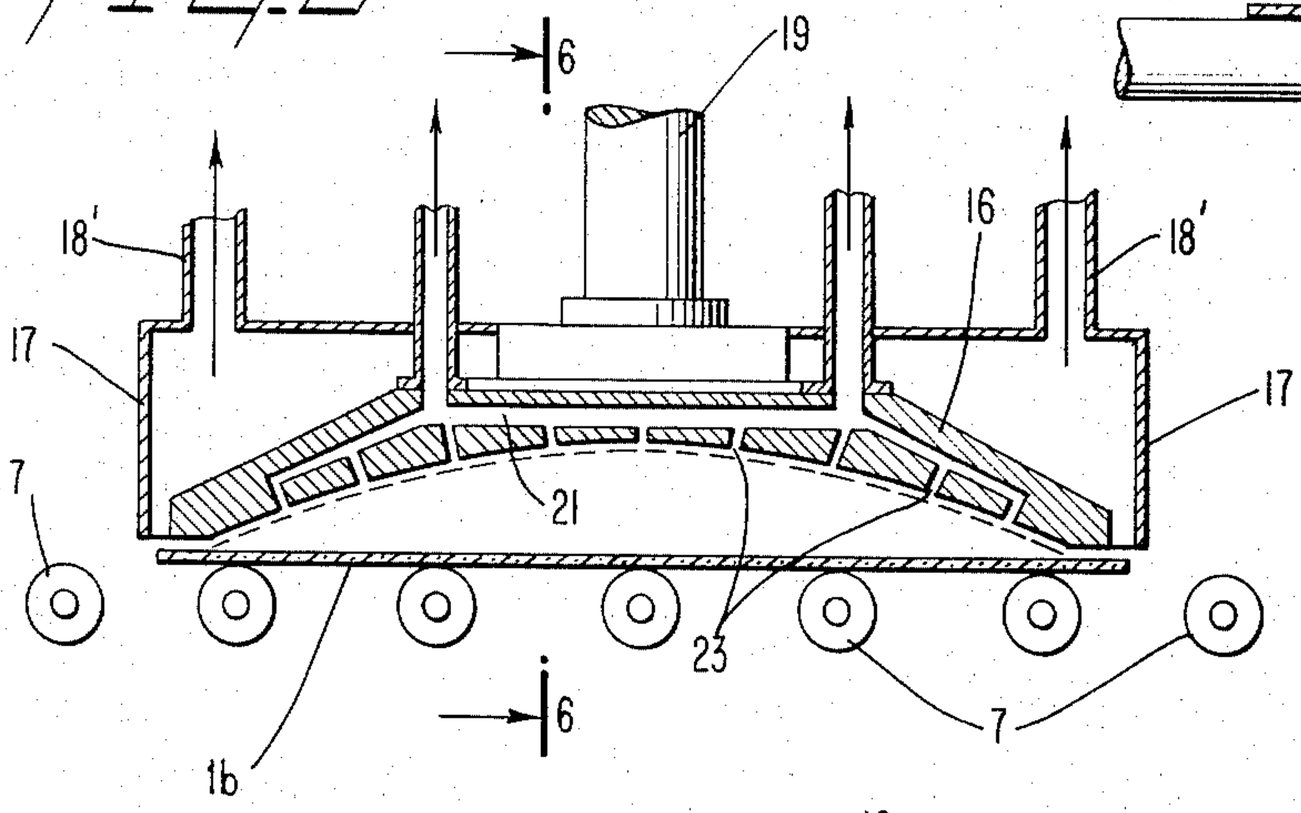

Fig. 6

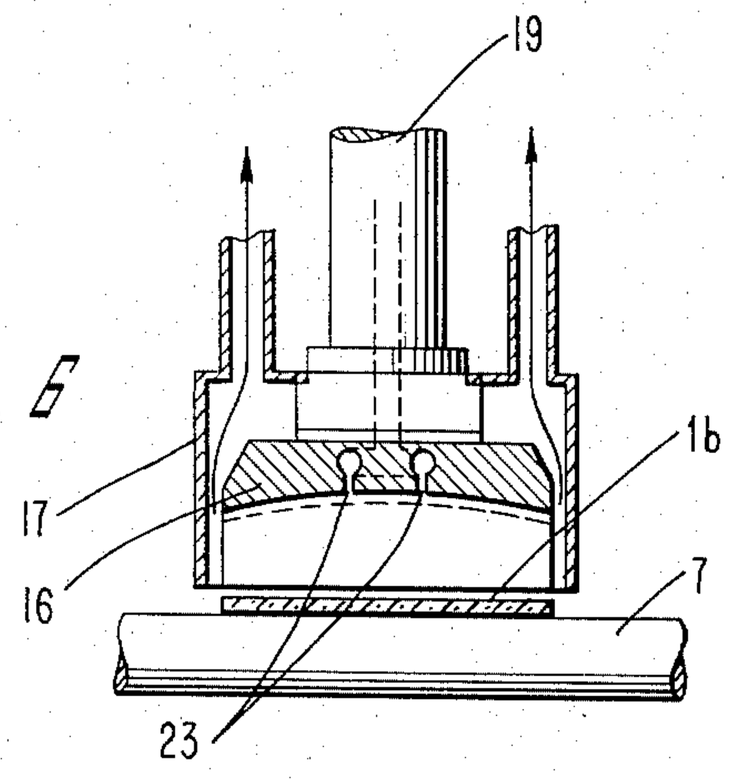

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FIG. 7

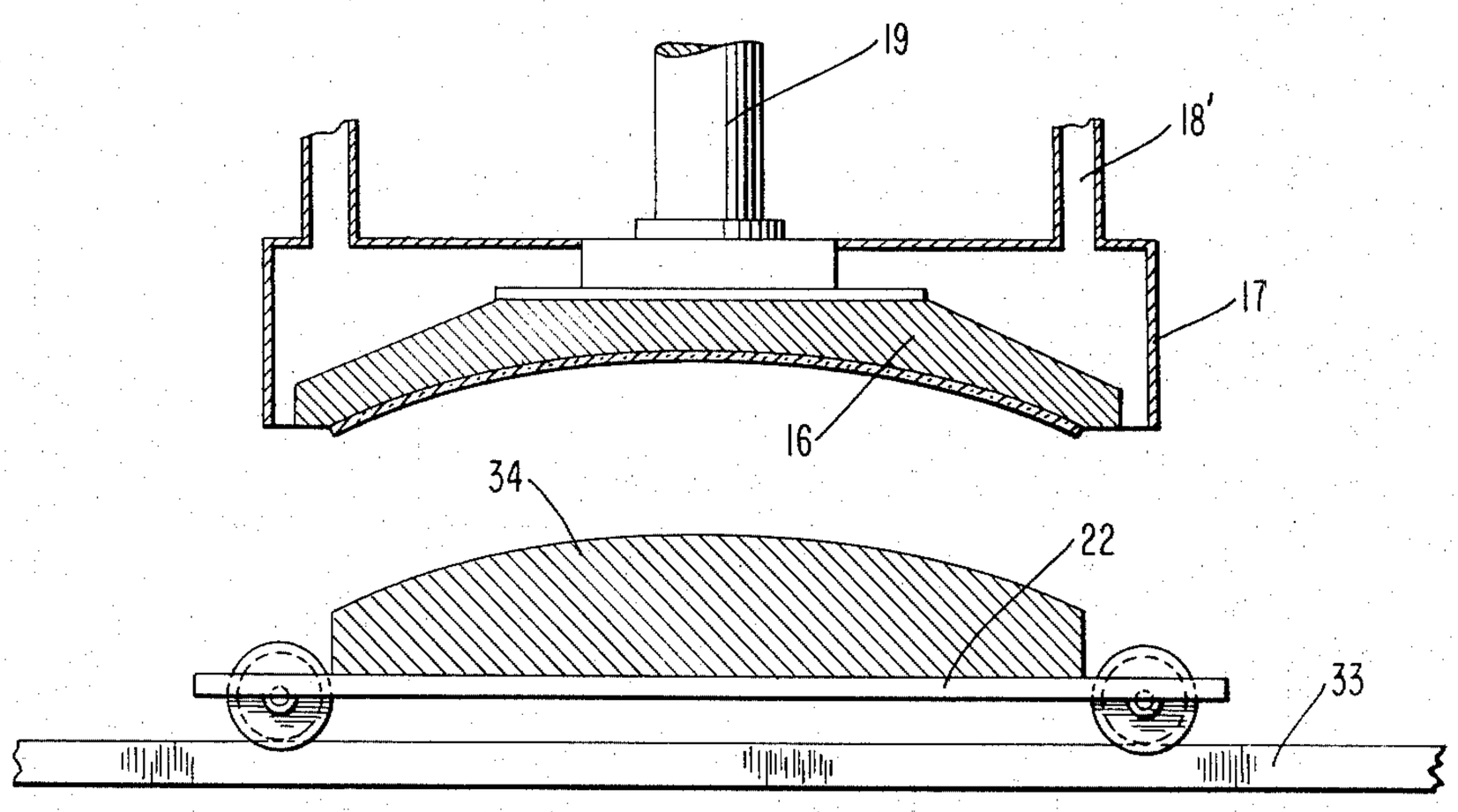

FIG. 8

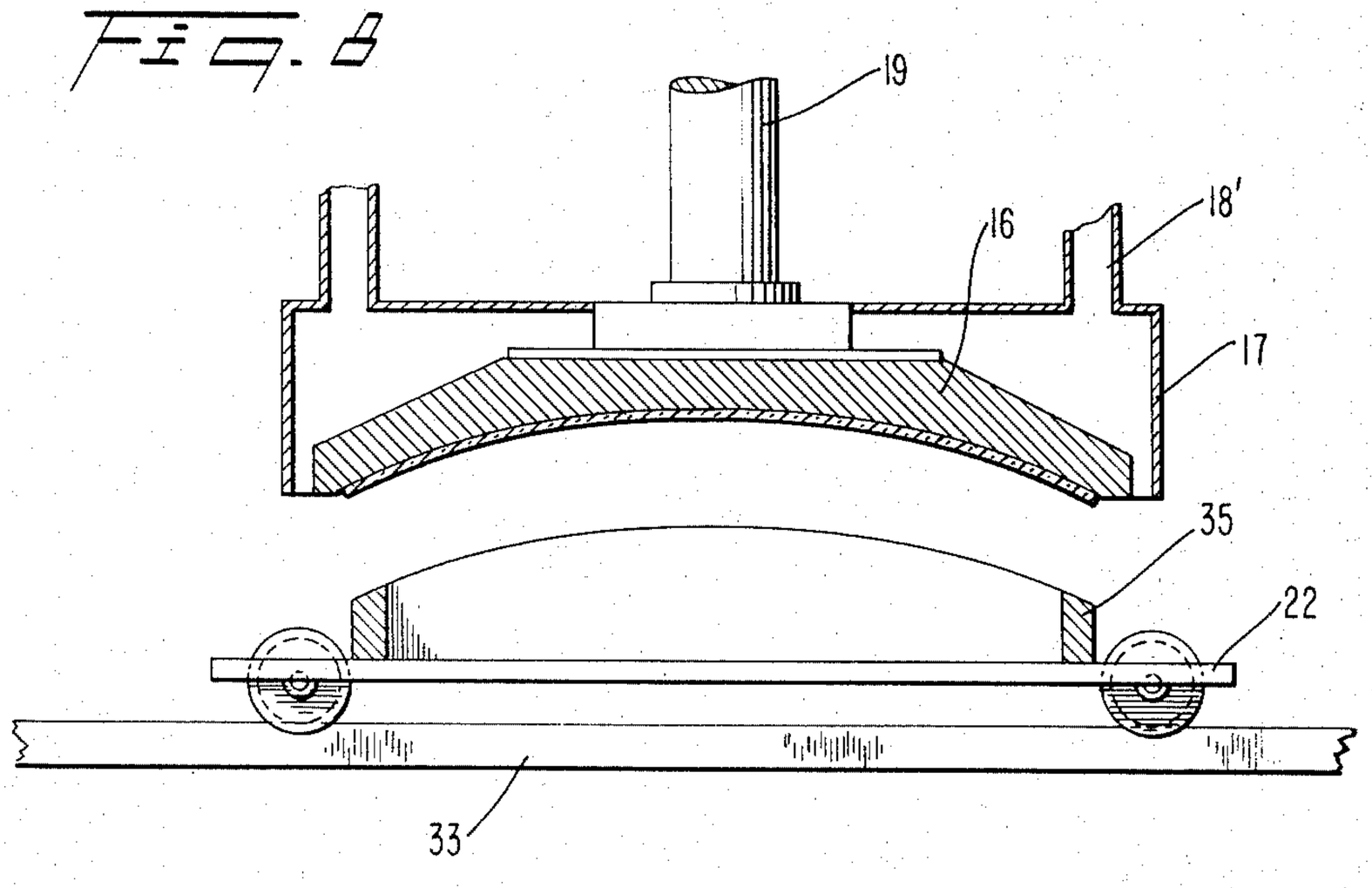

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FIG. 9

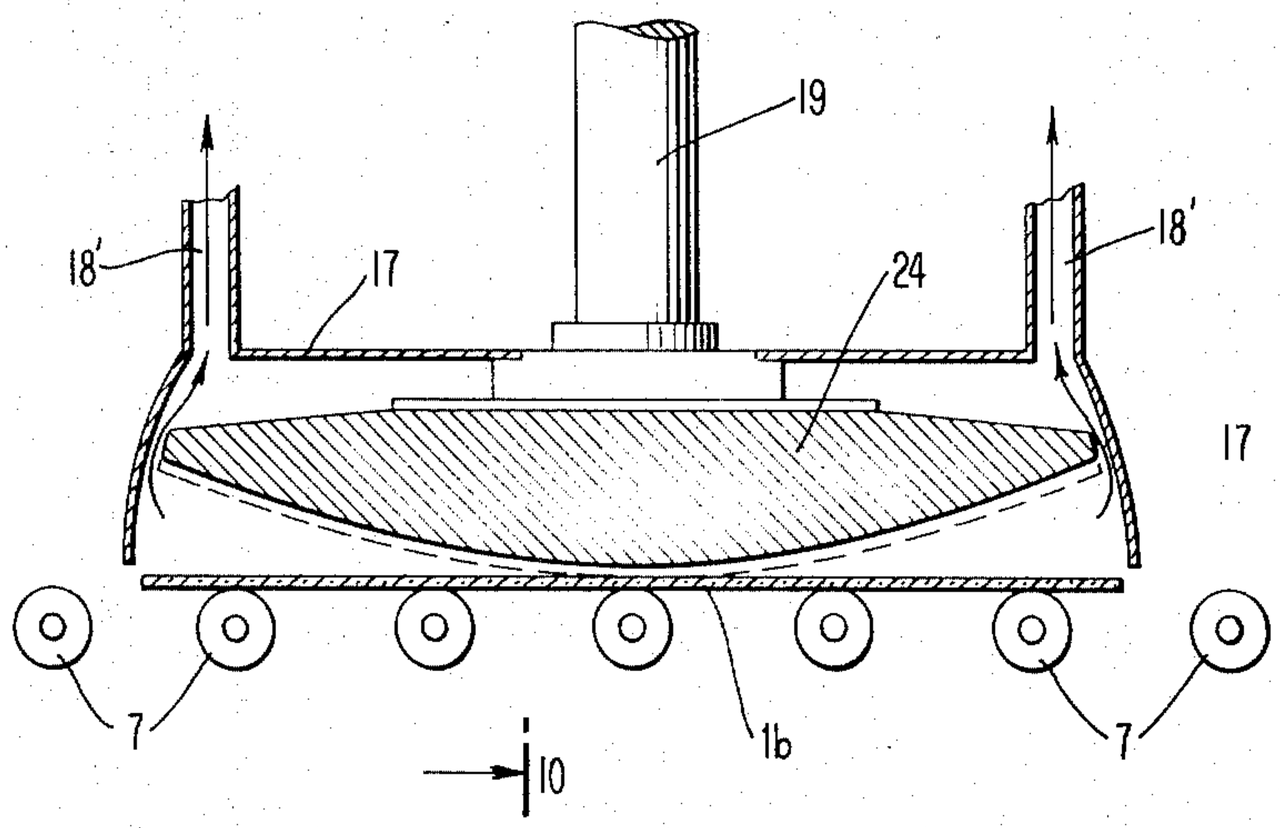

FIG. 10

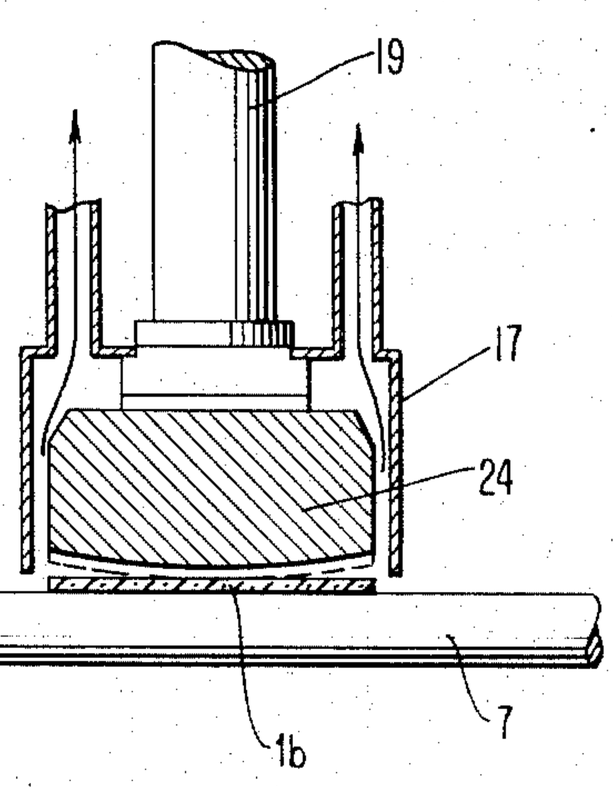

FIG. 11

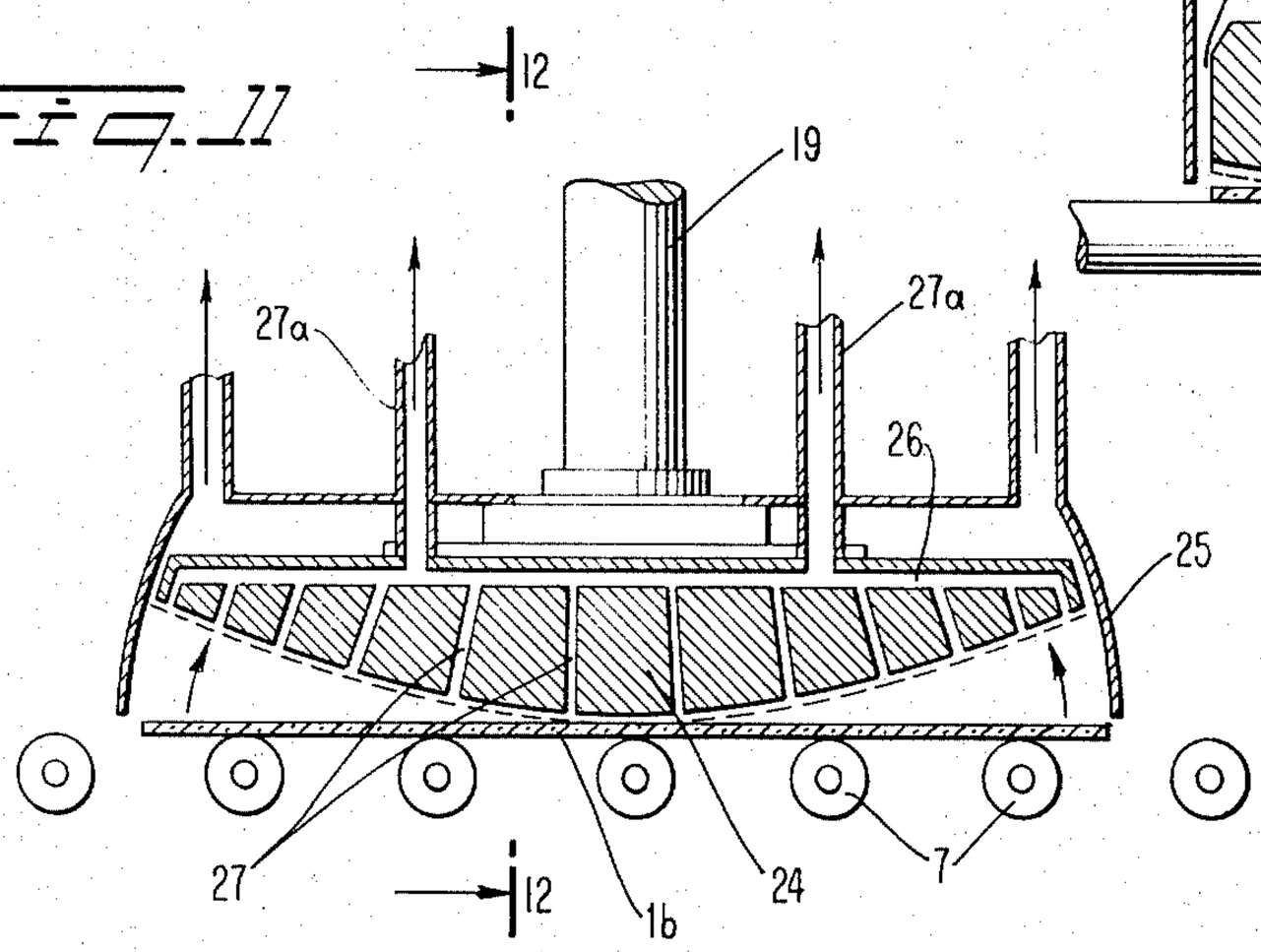

FIG. 12

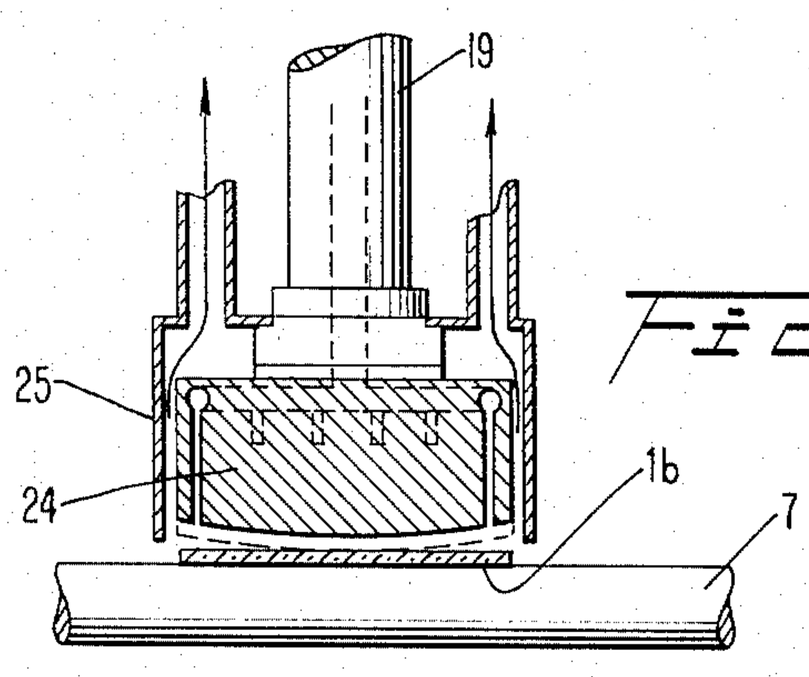

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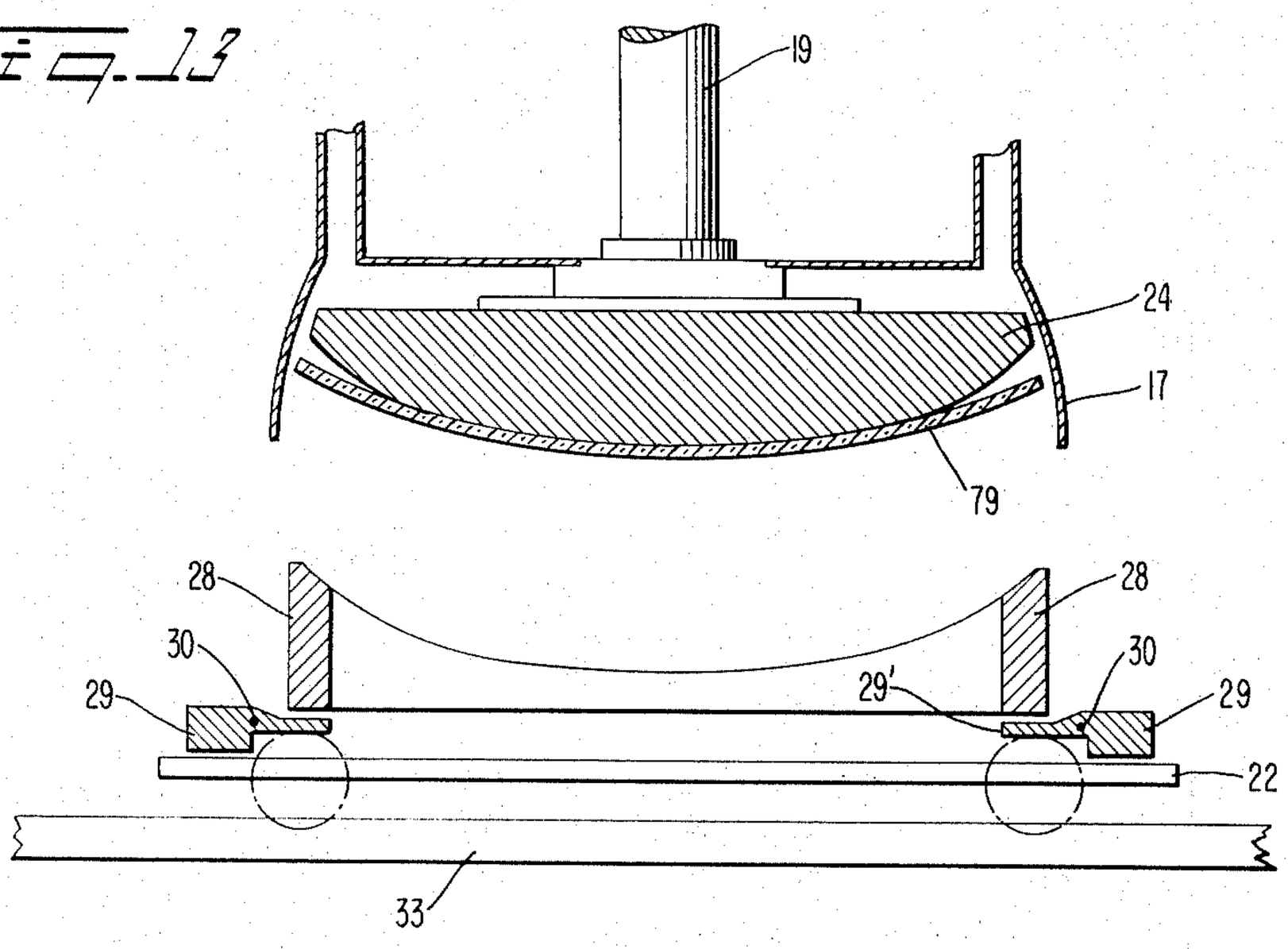
Fig. 13



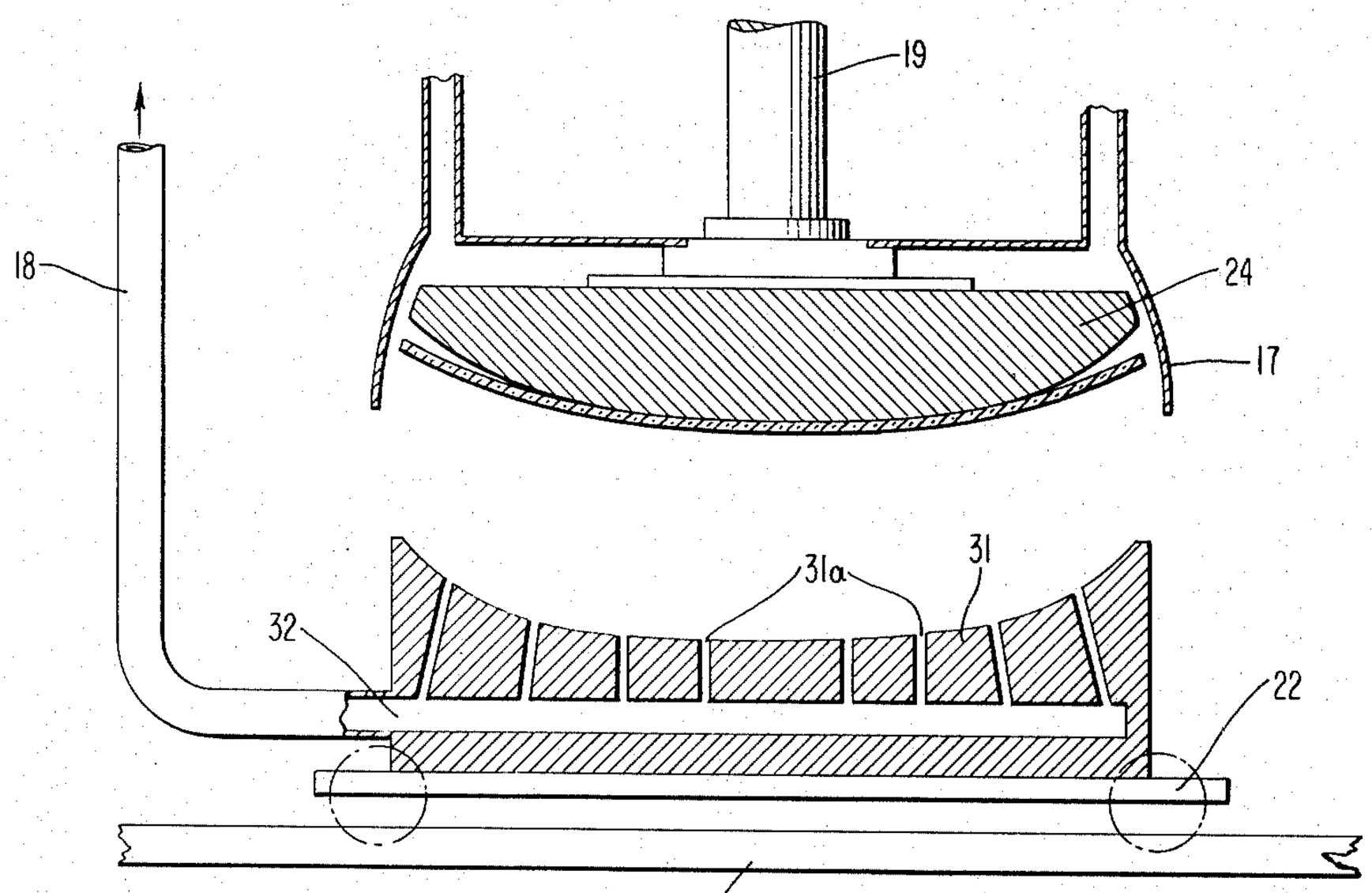


Fig. 14

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BENDING OF FLAT GLASS ON A MOLD WITH VACUUM

This invention relates to the bending of flat thermoplastic materials in sheet form of which an outstanding example is an automobile light, e.g., a windshield blank composed of glass, to which is to be imparted a shape suited to its use, frequently involving a double curvature. In view of its importance the invention will be described in that use without limiting the generality of its application or the nature of the thermoplastic sheet material, organic or inorganic, to which it is applied. Many such windshields are composed of two thin sheets of glass bonded together by polyvinyl butrayl. To assemble them properly is difficult.

To achieve perfect conformation of two sheets of bent glass being assembled with an interlayer of polyvinyl butyral it is customary to mount the glass sheets on a frame. These sheets of glass are placed one on the other, matched by a peripheral form and heated to the softening point of the glass. The action of gravity, acting on the softened sheets causes them to sag on the peripheral form but the shaping of the central part is imperfect because it is not in contact with anything solid, the central portions bending as viscosity and time allow.

The shaping of thin sheets of glass of large size requires the use of a third, thicker piece of glass to support the other two during shaping; it serves to retard the deformation of the thin sheets and produces a better final form. The third sheet serves only once, which materially increases the costs of production. In particular, for an installation which is to have high productivity the number of frames rotating through the furnace is large, which multiplies the difficulties of timing and control.

It is an object of this invention to overcome these obstacles, to produce bent sheets of high quality, perfectly shaped, rapidly, in large numbers with minimal controls and without the use of third sheets. Another object is to separate the heating and shaping steps of the process and thus to limit the heat used to that which is actually required at each stage of the process. Another object is to shape the sheet against a rigid shaping form by pneumatic forces, transferring the glass pneumatically from the conveyor to the form without solid contact. Another object is to maintain equal temperature in the bending form and the sheet which is being pneumatically transferred and bent.

The objects of the invention as to method are accomplished by a method of bending a sheet of flat glass which comprises heating it to bending temperature, placing it adjacent the shaping face of a bending form which is at bending temperature, applying vacuum to the circumference of the form and the sheet and thereby reducing the pressure between the form and the sheet, maintaining the vacuum until the sheet is pneumatically bent against the form, removing the bent sheet from the form, and cooling it; and the objects as to apparatus are accomplished by apparatus for the bending of hot thermoplastic sheets which comprises a horizontally disposed bending form having a shape approximating the shape of the sheet to be bent, means to move a hot sheet horizontally into proximity to and alignment with the bending form, hood means encompassing the bending form, means to evacuate the hood means, and means to cool the bent sheet.

In the method a vacuum is established, at the circumference of the bending form, near the periphery of the softened glass sheet and outside of it, which acts by aspiration to raise the softened sheet and bend it against the face of the form. It is another part of the invention to move the sheet horizontally into a preheating furnace, then to a shaping chamber in which it is pneumatically pressed against a bending form by establishing a vacuum about the periphery of the sheet which transfers the sheet vertically and presses it against the shaping face of the form.

The above and further objects and novel features of the present invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and are not intended as a definition of the limits of the invention.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

FIG. **1** is a diagrammatic vertical section through a preferred form of apparatus embodying the invention;

FIG. **2** is a diagrammatic plan view taken on a plane just above the rollers **7** of FIG. **1**;

FIG. **3** is a vertical, longitudinal, sectional view of the hood and bending form;

FIG. **4** is a cross section on line **4—4** of FIG. **3**;

FIG. **5** is a vertical, longitudinal, sectional view of a first modification of the hood and bending form;

FIG. **6** is a cross section on line **6—6** of FIG. **5**;

FIG. **7** is a longitudinal, vertical section through a second modification of apparatus involving two forms;

FIG. **8** is a section similar to that of FIG. **7**, showing a yet further modification;

FIG. **9** is a vertical longitudinal section through another modification of hood and bending form;

FIG. **10** is a cross section on line **10—10** of FIG. **9**;

FIG. **11** is a vertical, longitudinal section through a yet further modification of hood and bending form;

FIG. **12** is a section on line **12—12** of FIG. **11**;

FIG. **13** is a vertical, longitudinal section through another modification of apparatus involving a truck-mounted pressure balance; and

FIG. **14** is a section similar to that of FIG. **13** through a further modification.

As shown in FIG. **1** and FIG. **2** an apparatus according to the invention includes a receiving chamber **2** having walls **2′—2′** which approach a roller conveyor **7** but leave space for the passage of glass sheets **1**, which are shown as windshield blanks of appropriate shape. A heating furnace **3** is equipped with electrical heating resistances **8, 9** in roof and sole. Thermocouples **10, 11** maintain the temperature of the chamber **3** at peak efficiency by controlling the resistances. Such mechanism of control being known is not shown. The driving means for the roller conveyor **7** is illustrated diagrammatically at **71-72-73-74-75** in FIG. **2.** By appropriately restricting the openings **76, 77** through which the glass enters and leaves the heating chamber **3** that chamber is maintained at its own proper temperature with small heat loss. A glass sheet **1***a* is shown in the chamber.

From chamber **3** the rollers **7** transfer the sheets to the bending chamber **4,** through narrow opening **77** and beneath a hood **17** which contains a rigid bending form **16,** shown in FIG. **1** as having a concave bending face. Pane of glass **1***b* is shown in vertical alignment

with the form. The sides of the hood closely approach the circumference of the form and its rim in lowered position (FIG. 3) allows just enough room for the passage of the glass without contact. Two aspirators **18—18** are connected to the hood and evacuate it, upon operation, through appropriate pipes **18'—18'**. The hood and bending form are mounted for vertical movement upon a vertically movable shaft **19** controlled by a motor operated, reversible screw **20.** The temperature in the shaping chamber **4** is maintained at its own proper value by resistor **12, 13** mounted in roof and sole and controlled by thermocouples **14–15.**

Inside the chamber **4,** slightly above the level of rollers **7,** and outside the hood are two rails **33** which support a truck **22** (FIG. **7**) which can be rolled into and out of the shaping chamber when desired. The carriage may support a form **34** having a shape complementary to that of the form **16** which will either support the bent glass in its new shape or serve as the lower part of a two part mold when desired. The opening **78** between the chamber **4** and cooling-conditioning chamber **5** is large enough to permit the passage of the truck with its burden when the truck is to be used. Beyond the chamber **5** is unloading station **6** where the glass, cooled to hardness is removed for packing or storage.

The rollers **7** are made of refractory material, for instance silica which has a small coefficient of expansion. The rollers and all surfaces that touch the glass, for instance the faces of the shaping forms, are covered with a refractory, resilient covering, for example woven or braided silica fiber cloth which prevents the marring of the softened surface of the glass by contact with solid parts of the apparatus. The rollers are conveniently small, for instance 30 mm. in diameter.

The glass issuing from heating chamber **3** is, with ordinary windshield glass, at a temperature about 500°–600° C. and the controls in chamber **4** may be set to maintain that temperature during shaping.

The bending form **16** is made of any satisfactory material which can be molded to the desired shape and will harden to a rigid, undeformable shape, for instance refractory cement, of which several types are well known. This form is preferably provided with a circumference slightly less extensive than that of the glass blank **1b**, e.g., 15 mm. less. The hood follows the contour of the glass and may conveniently be spaced about 10 mm. from it. The aspirators **18** may be any satisfactory type of air pump, which by establishing a pressure difference between the interior of the hood and outside of its raises the glass vertically against the form. The bending face of the form may be concave (FIG. **7**) or convex (FIG. **9**). The soft, refractory facing on rollers and forms has not been illustrated in most figures.

The concave forms (FIGS. **3–8**) are used to make simple forms of large radius of curvature. The forces required to force the glass against the form are small and compatible with the different requirements which produce correct quality. These forms may be aspirated only at the periphery or they may be provided with centrally located aspiration also, as shown in FIGS. **5** and **6** at **21, 23** the conduits of which may be as fine as desired, and may be connected to the same or different aspirators. The double aspiration is particularly useful when a double curvature is to be imparted to the central part of the sheet. The size of the canals **23** is small, so as to prevent any disturbance of the surface of the glass. These canals permit the application of vacuum to the center of the sheet in addition to that provided at its rim by the hood and permits the imposition of greater curvature to the sheet. After shaping is completed the shaft **19** is raised, the truck is run under the shaping form, the vacuum is released and the bent sheet is received by gravity fall on the soft-covered surface of the support **34** of conforming shape, upon which it is transported into cooling chamber **5** and to unloading station **6.**

The shaping of a sheet against a bending form of concave face is the more difficult as the radius of curvature becomes the shorter and the bends the sharper and eventually results in the degradation of the glass surface, but this problem is overcome by using an upper form of convex face, elminating surface marks derived from sharp bends, rub marks on the ends of the sheet, and local deformations. Such forms are shown in FIGS. **9** and **10,** wherein the face has the same shape and dimensions as would a convex form but the results are superior with different bending operations. The mounting of convex and concave forms within the hood is usually the same, but there is a material point of difference: complete contact of the whole face of the sheet against the form can be made against a concave form of small curvature but against an upper convex form the contact is not usually complete. In effect, the force of application of the glass against the form being constant the surface of contact increases and the motor couple derived from force times distance decreases and even in the more favorable cases there remains a zone of the glass near the periphery which is not fully in contact with the form. The secondary apparatus of aspiration **26** (FIGS. **11** and **12**) reduces this zone, the ranks of canals **27,** of small diameter, covered by porous silica cloth, do not mar the surface or permit minor surface displacement. These canals placed near the edge of the form and only a short distance inside the edge of the sheet are connected by conduits **27*a*** to vacuum apparatus of appropriate type. It will be understood that in difficult cases the first bending operation may be followed, according to this form of the invention, by a second which may be either mechanical or pneumatic.

In the mechanical second bending step the incompletely bent sheet (FIG. **13**), having been partially shaped on the upper convex form **24** is lowered by the shaft **19** until it makes contact at its insufficiently bent edge **79** with an annular form **28** which shapes it to its final form by mechanical pressure. The pressure permitted in this shaping step is limited to a degree which will not mar the glass by mounting the frame **28** upon balances **29–30,** of which weights **29,** pivoted to the truck frame **22** by pivots **30,** project tongues **29'** into supporting position beneath the frame. As soon as the weights lift the pressing is complete and the shaft is raised. This can be done manually or automatically. The form **28** may be made of the same material as form **24** and with the same contour and it is shaped with an exterior circumference equal to that of form **24** and an interior circumference a few centimeters less. By changing the weights of the balances different degrees of pressure are automatically achieved. During mechanical pressing, or afterward, the aspirators are turned off, leaving the sheet on the form **28** when the shaft **19** is raised.

In the pneumatic second bending step (FIG. **14**) the truck **22** carries a form **31** penetrated by holes **31a** which are aspirated through conduit **32** and aspirator

means 18. The lower, convex form is rigid and undeformable and covered by the usual woven or braided silica cloth. When the upper aspirators are turned off the partially bent sheet falls into the lower form and is drawn pneumatically into perfect conformity to its shape, the force of gravity assisting. The truck is then run out of the bending chamber and the glass is unloaded.

The conditioning chamber 5 (FIG. 1) is equipped with rollers as are the other chambers. The roof and the sole of this cell are provided with resistances which deliver the energy necessary for the establishment of a temperature somewhat lower than that in the shaping chamber. Thermocouples maintain the temperature. The rollers serve to handle the glass when the truck is not needed. The truck (FIG. 7) receives a convex form 34, or a concave form (FIG. 14) according to whether the upper form is concave or convex.

The following example illustrates the invention by operations on a windshield blank 2 mm. thick, of ordinary silica-soda-lime glass, using an upper convex form 24. The hood encloses the upper form, aspiration being applied at the circumference only. A concave form is mounted on the truck (FIG. 13). The dimensions of the windshield, 1 m. × 0.5 m. × 2 mm., is to be bent on a radius of curvature of 200 mm., which permits the use of an upper convex form. The heating chamber 3 is 5.4 m. long and is kept at a temperature of 800° C. at roof and sole. The shaping chamber is 2 m. long and is kept at 530° C. at roof and sole. The conditioning chamber 5 is 2 m. long and kept at 500° C. at roof and sole. The silica rollers 7 are 30 mm. in diameter, 40 mm. apart between axes and covered with braided silica sleeves. All of rollers 7, except those in the loading chamber 2, are driven at 8 linear cm./sec. which suffices to maintain their surfaces in good condition. In shaping chamber 4 the convex for 24 within the hood 7 is in lowered position, 5 mm. from the upper surface of the rollers. The vacuum in the hood 7 is in lowered position, 5 mm. from the upper surface of the rollers. The vacuum in the hood is kept at 5–6 g./cm.^{2} by two aspirator pumps, e.g., VT 55 of Bertin.

In the conditioning chamber 5 is the truck 22 carrying the annular frame 28 which is to be used to finish bending mechanically and to run the bent sheet out of the apparatus. The blank is placed carefully on the rollers of the chamber 2 so that when it reaches 1*b* it will be correctly centered under the hood. The blank being in place the following steps may be followed:

The rollers 7 of the chamber 2 are started by a clutch at high speed and inject the blank 1 into the furnace 3. Inside the furnace the blank is slowed down on rollers 7 run at slower speed, the time in the furnace being about 3 seconds. As soon as the blank is inside the furnace the loading rollers are stopped. At the end of deceleration the linear speed of the rollers is about 8 cm./sec. inside the furnace. The heating ends in about 45 sec. as the blank reaches the aperture 77, with the blank at 640°–650° C. The speed of the rollers is related to the viscosity of the glass and its thickness to achieve a perfectly heated piece. The blank is now injected at high speed into the chamber 4 by acceleration and retard, taking about 3 sec. to position it below the hood, the acceleration having the effect of equalizing the temperatures of the ends of the blank. The rollers which position the blank beneath the hood travel at about 8 cm./sec. As the blank is positioned under the hood detecting mechanism of a known type stops the rollers and starts the vacuum pumps, establishing a vacuum of 5–6 g./cm.^{2} which is enough to lift the blank off the rollers against the shaping form. After about one-half second the shaft 19–20 raises the form, hood, and glass away from the rollers and the truck with the concave form 28 is rolled under them, taking about 3 seconds to accelerate it and bring it to rest in a position to receive the blank. The shaft is now lowered until the glass is pressed against the frame 28 which is allowed 5–10 mm. vertical movement by the balance weights, which achieves the final peripheral pressing without damage to the glass surface. After a few seconds (e.g., 5) the aspirators are stopped, the upper form rises, and the lower form on the truck removes the bent windshield, taking not more than 5 seconds for transfer to the conditioning chamber, and the apparatus is ready for a new cycle.

The advantages of the invention are a method and apparatus of great versatility capable of working with all types, weights, shapes and thicknesses of glass, rapidly and without surface damage. The apparatus operates pneumatically in a single step, in a plurality of pneumatic steps, or in a pneumatic followed by a mechanical pressing step.

As many apparently widely different embodiments of the present invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments.

More particularly the method allows to bend two sheets together instead of one on the same apparatus without having to change any step of the process even when these sheets have to be sharply bent.

What is claimed is:

1. A method of bending a sheet of thermoplastic material which comprises heating the sheet to bending temperature, placing it in alignment with a shaping form, and lifting the sheet against the form by aspiration applied through a restricted passage around the periphery of the form and between the form and the skirt of an evacuated hood closely surrounding said periphery, the rate of aspiration being such that the sheet is lifted and bent into contact with the shaping surface of the form.

2. The method of claim 1 which includes simultaneously applying aspiration through perforations in the bending form.

3. The method of bending a sheet of thermoplastic material which includes the steps of heating the sheet to bending temperature, placing it in alignment with a shaping form, lifting the sheet against the form by aspiration applied to the periphery of the sheet, and pneumatically bending the sheet against the said shaping form and perfecting the contours of the sheet by pressing the sheet mechanically between said form and a complementary form.

4. The method of claim 3 in which the complementary form yields when a certain pressure is applied by the said shaping form to the sheet.

5. A method of bending a sheet of flat glass which comprises heating it to bending temperature, placing it adjacent the shaping face of a bending form while it is at bending temperature and adjacent the open end of a hood containing said form, applying vacuum to the space within the hood between the shaping face of the form and the sheet through a passage between the cir-

cumference of the form and the adjacent inner surface of the hood and thereby reducing the pressure in said space, the application of the vacuum being at a rate such that the sheet is pneumatically lifted and bent against the shaping surface of the form, removing the bent sheet from the form, and cooling it.

6. A method of bending a sheet of glass according to claim **5** which comprises simultaneously applying vacuum to said space through passages in the bending form.

7. A method of bending a sheet of glass according to claim **5** which comprises the step of mechanically bending a part of the vacuum-bent sheet between conforming pressing surfaces.

8. Apparatus for the bending of hot thermoplastic sheets which comprises a horizontally disposed bending form having a peripheral shape approximating the peripheral shape of the sheet to be bent, hood means encompassing the bending form and having an open end approximating the peripheral shape of the sheet to be bent, there being a clearance space between the periphery of the form and the adjacent inner wall of the hood means, means to move a hot sheet into proximity to and alignment with the bending form and said open end of the hood means, and means to evacuate the space in the hood means between the bending form and the sheet through said clearance space.

9. Apparatus according to claim **8** including means to move the hood means and bending form vertically.

10. Apparatus according to claim **8** including supplemental means to evacuate said space through the bending form.

11. Apparatus according to claim **8** including means to move bending means of conforming shape into alignment with the bending form, and means to move the bending form and bending means relatively whereby to press the sheet therebetween.

12. Apparatus according to claim **11** in which the bending means is mounted on balances.

13. Apparatus according to claim **8** in which the circumference of the unbent sheet is slightly greater than the circumference of the bending form and less than the circumference of the open end of the hood means.

14. A method of bending flat glass which comprises pneumatically lifting a piece of flat glass at bending temperature against a shaping form at bending temperature and pneumatically bending it against the form, releasing the bent glass from the form upon a second form having a complementary shape, and completing the bending pneumatically upon the second form.

15. In apparatus for the bending of flat glass panes which comprises a tunnel having a plurality of interconnected chambers of which a first chamber is provided with means to heat flat glass panes to bending temperature, a second chamber is provided with bending apparatus, and a third chamber comprises cooling means, conveyor means movable between the second and third chambers, vertically movable bending means in the second chamber comprising an aspirated hood having an internal periphery complementary to and slightly longer than the periphery of the flat glass panes being bent and means within the hood to bend the panes having a periphery complementary to said periphery of the hood and spaced therefrom to form a peripheral passage, means to aspirate the hood and to thereby aspirate the space between said last-named means and a pane therebelow through said peripheral passage to lift the pane into the hood against said means to bend the panes when a pane is in alignment therewith, means to raise and lower said bending means, and means to release the vacuum and release the bent pane to the conveyor means.

16. Apparatus according to claim **15** in which said means to bend has a perforated, curved, bending surface, and aspirator means operatively connected thereto.

17. Apparatus according to claim **15** in which the conveyor means includes a carriage having a surface which conforms to the shape of the rim of the bent pane and the bending means has a surface adapted to press the pane against the said carriage surface, thereby providing the pane with accurate circumferential shape, and comprising means to move the carriage beneath the hood to receive the bent pane when it is released by the bending means and thence into the cooling chamber.

18. Apparatus according to claim **17** in which means for receiving the bent pane is mounted on the carriage upon balances which yield when a certain pressure is exerted upon the pane by the bending means.

19. Apparatus according to claim **15** in which the conveyor means includes a carriage which has a shape corresponding to the bending face of the bending means and to the conformation desired in the bent pane and a perforated surface, and comprising aspirator means operatively connected to the perforations, and means to move the carriage beneath the hood to receive the bent pane when it is released by the bending means and thence into the cooling chamber.

20. A method of bending flat glass panes which comprises aspirating the flat plane against a vertically positioned bending form and partially bending it, depositing the partially bent pane upon a bending form therebeneath, and completing the bending thereon.

21. A method according to claim **20** in which the bending on the lower form is completed by aspiration.

22. A method of bending glass panes which comprises heating the pane to bending temperature, moving the pane into alignment with and beneath a bending form in spaced relation thereto, surrounding the space between the form and pane by a hood containing the form, pneumatically lifting the pane against the form and bending it upon the form by withdrawing the air from said space radially through the circumferential passage between the peripheral edges of the form and pane, and releasing the bent pane from the form.

23. A method according to claim **22** in which the bending form is perforated and air is simultaneously withdrawn from said space through the perforations in the bending form.

24. A method of bending a sheet of flat glass which comprises heating it to bending temperature, placing it adjacent the shaping face of a bending form which is at bending temperature, applying vacuum to the circumference of the form and the sheet and thereby reducing the pressure between the form and the sheet, maintaining the vacuum until the sheet is pneumatically bent against the form, mechanically bending a part of the vacuum-bent sheet between conforming pressing surfaces, weighing the pressure applied between conforming pressing surfaces, removing the bent sheet from the form, and cooling it.

25. Apparatus for the bending of hot thermoplastic sheets which comprises a horizontally disposed bending

form having a shape approximating the shape of the sheet to be bent, means to move a hot sheet horizontally into proximity to and alignment with the bending form, hood means encompassing the bending form and having an arcuate shape conforming to the bending path of the rim of the sheet, means to evacuate the hood means, and means to cool the bent sheet.

26. A method of bending a sheet of thermoplastic material, such as glass, which comprises heating the sheet to bending temperature, confining a shaping form within an enclosure having an open lower end, placing the sheet below the form and enclosure in alignment therewith and in spaced relation thereto, and evacuating the space between the sheet and the adjacent face of the form by applying suction thereto through a narrow peripheral clearance between the entire periphery of the shaping face of the form and the wall of the enclosure adjacent thereto, whereby the sheet is lifted by ambient pressure into engagement with the form within the enclosure and bent by such pressure into general conformity with the shaping face of the form.

27. The method of claim **26** wherein the peripheral margin of the unbent sheet extends outwardly slightly beyond the periphery of the form.

28. The method of claim **27** wherein the unbent sheet fits within the open end of the enclosure.

29. The method of claim **26** which includes simultaneously applying suction to said space through passages terminating in the face of the form.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,778,244 Dated December 11, 1973

Inventor(s) Maurice Nedelec et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 45, for "15" substitute --5--;
line 50, for "its" substitute --it--.

Signed and sealed this 7th day of May 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents.