

[54] **APPARATUS FOR FORMING URETHANE FOAM STOCK**

[75] Inventor: **Lawrence C. Porter**, Palos Verdes Peninsula, Calif.

[73] Assignee: **The Upjohn Company**, Kalamazoo, Mich.

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[52] U.S. Cl.**425/330, 264/51, 425/4, 425/224, 425/115, 425/371, 425/471**

[51] Int. Cl.**B29d 27/04**

[58] Field of Search**18/5 A, 5 P, 4 B; 264/51; 425/4, 330, 471, 371, 450, 4, 224, 363**

[56]

References Cited

UNITED STATES PATENTS

3,152,361	10/1964	Edwards	18/4 B
3,249,486	5/1966	Voisinet et al.	18/4 B X
3,325,823	6/1967	Boon	18/4 B X
3,528,126	9/1970	Ernst et al.	18/4 B
3,560,599	2/1971	Ferstenberg	18/4 B X

Primary Examiner—Robert L. Spicer, Jr.

Attorney—Fidler & Bard

[57]

ABSTRACT

Apparatus and methods are disclosed by which the wall surfaces of a form for expanding urethane stock are provided with horizontal, vertical and longitudinal pitch to enhance the character and shape of the foam product. Embodiments include means for selectively altering the pitch and curvature of a wall surface.

15 Claims, 22 Drawing Figures

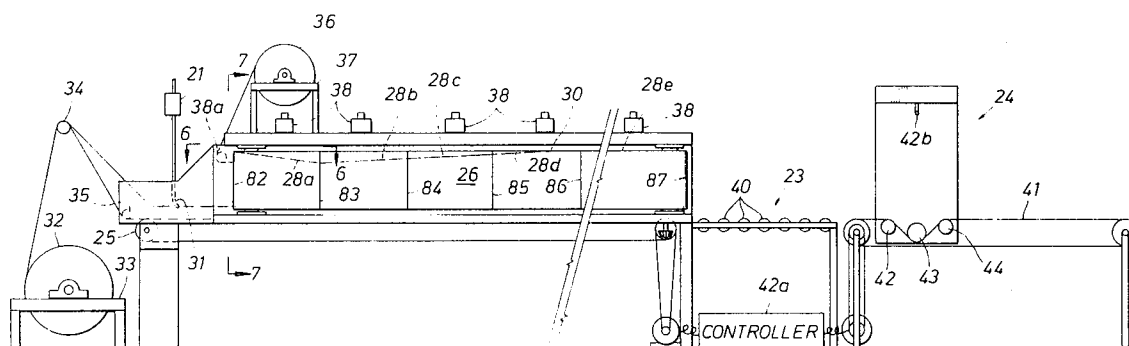


FIG. 1

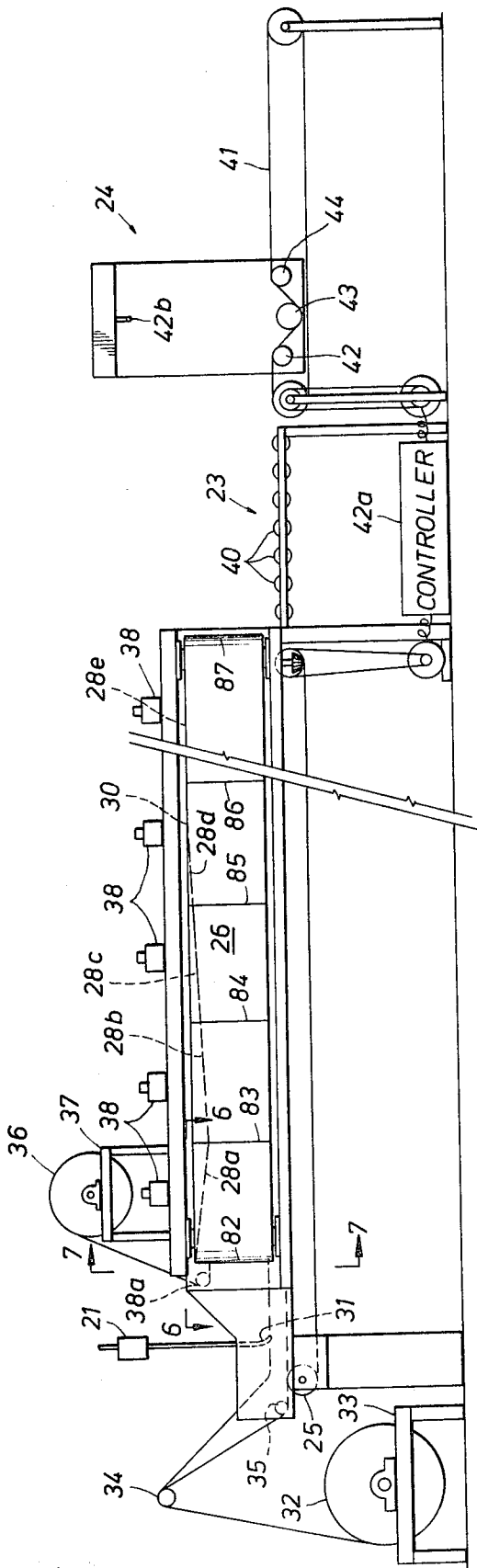
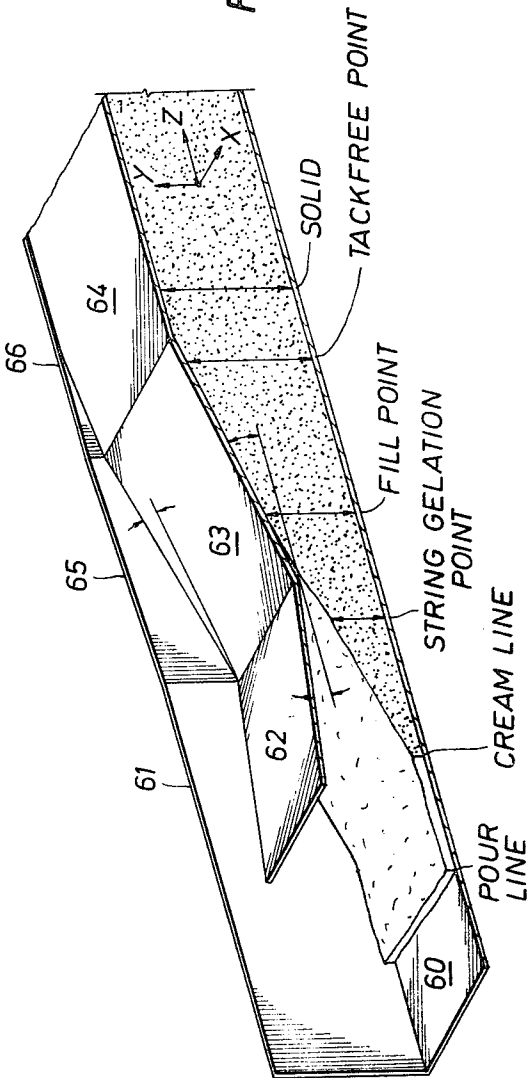


FIG. 5



Lawrence C. Porter
INVENTOR

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FIG. 2

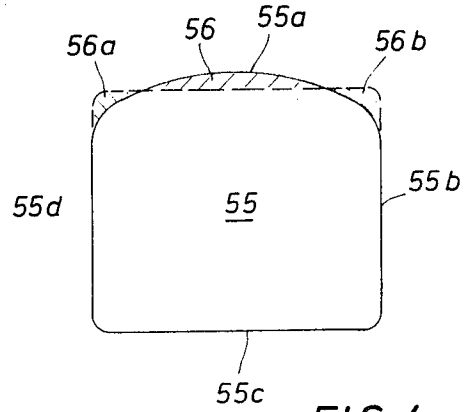
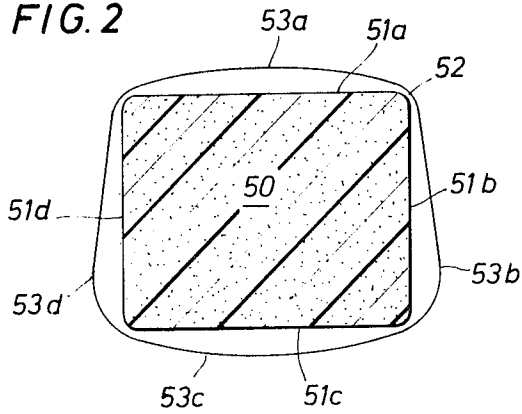


FIG. 4

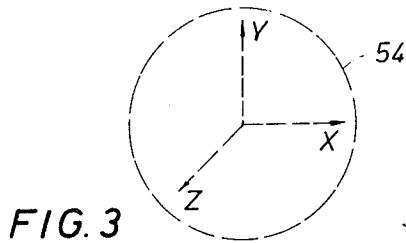


FIG. 3

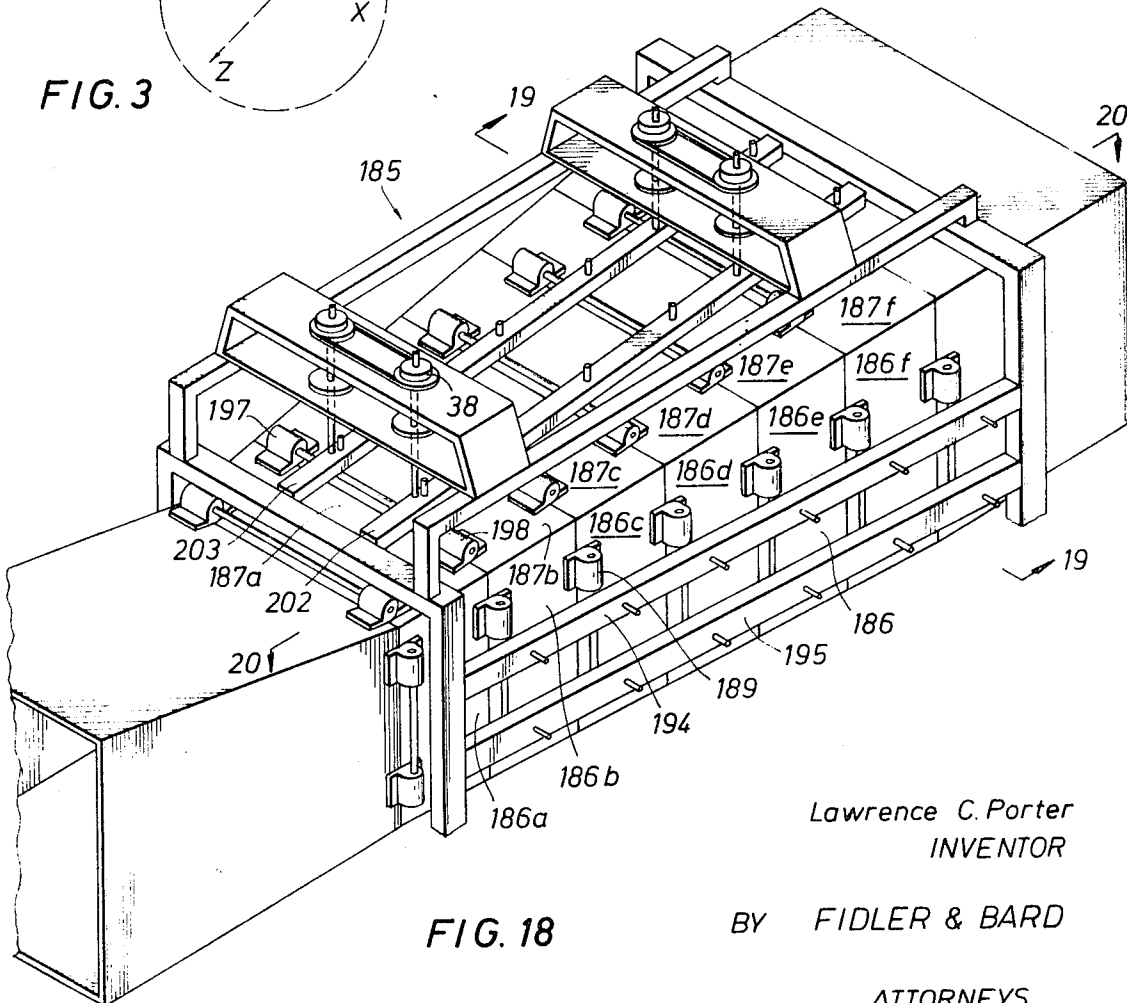


FIG. 18

Lawrence C. Porter
INVENTOR

BY FIDLER & BARD

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FIG. 6

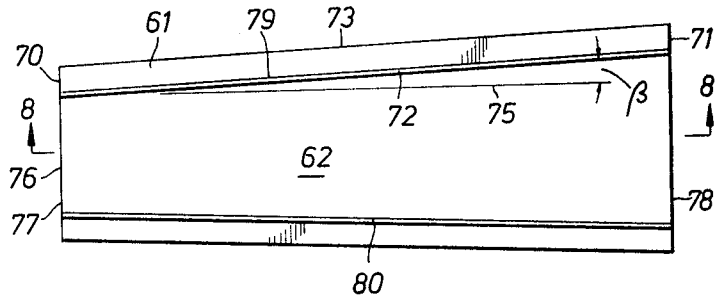


FIG. 7

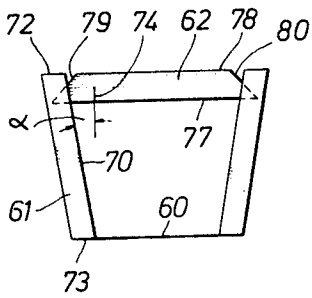


FIG. 8

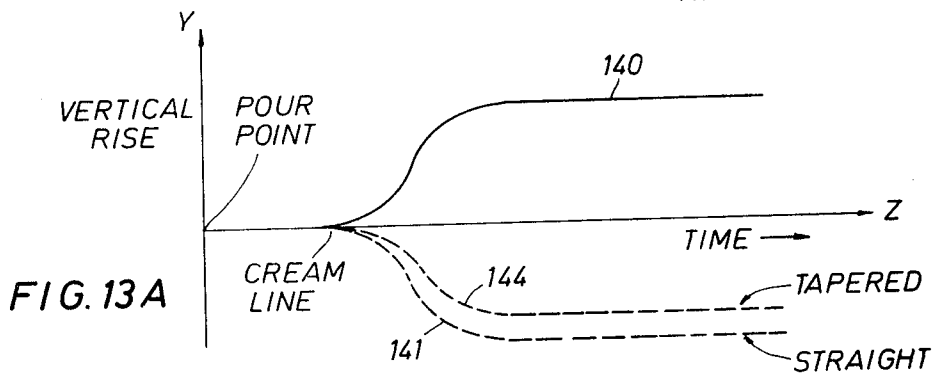
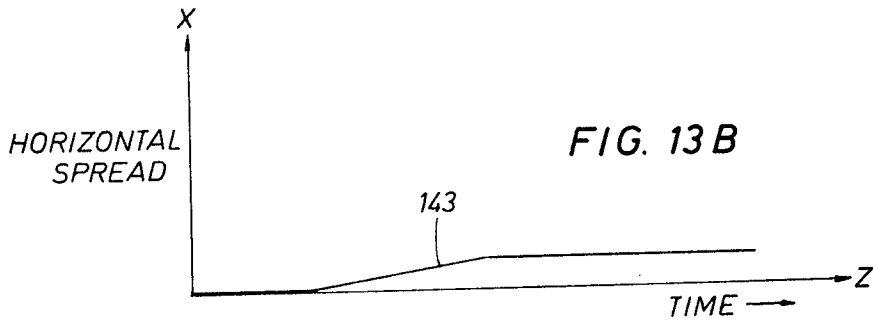
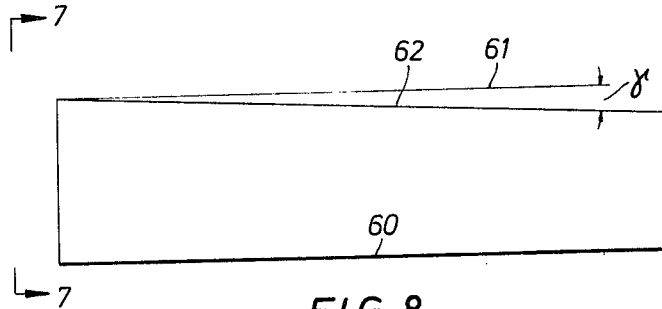
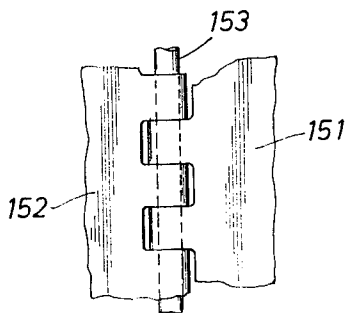


FIG. 16



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INVENTOR

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FIG. 9

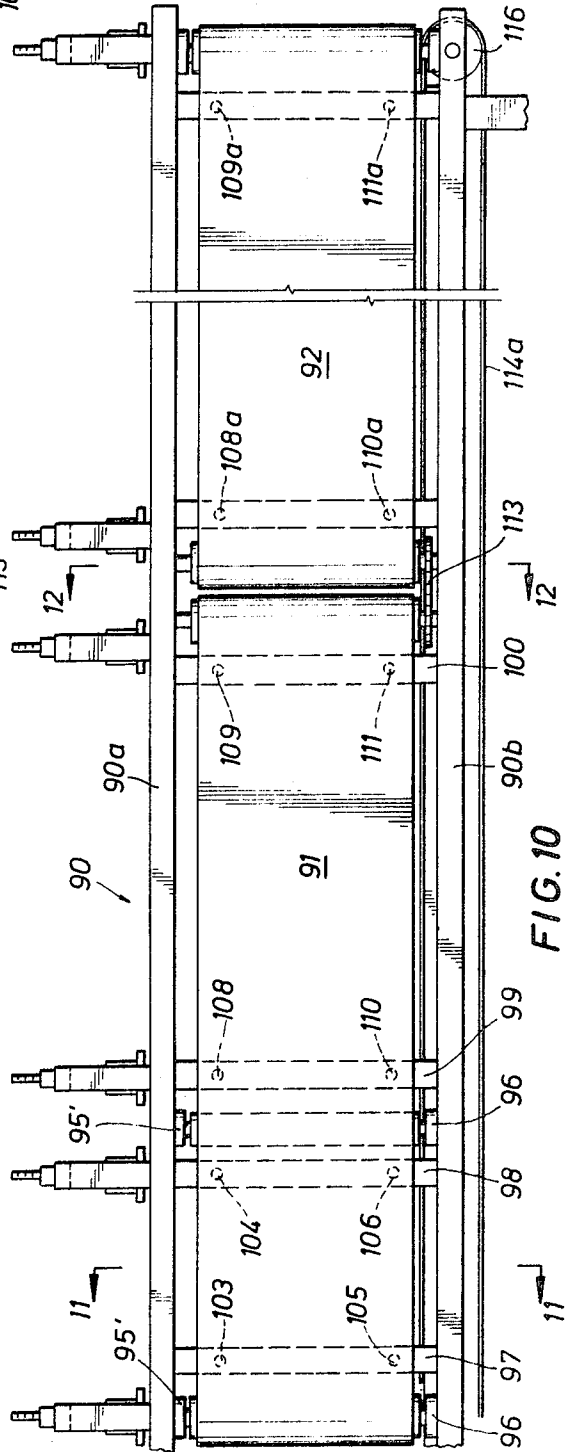
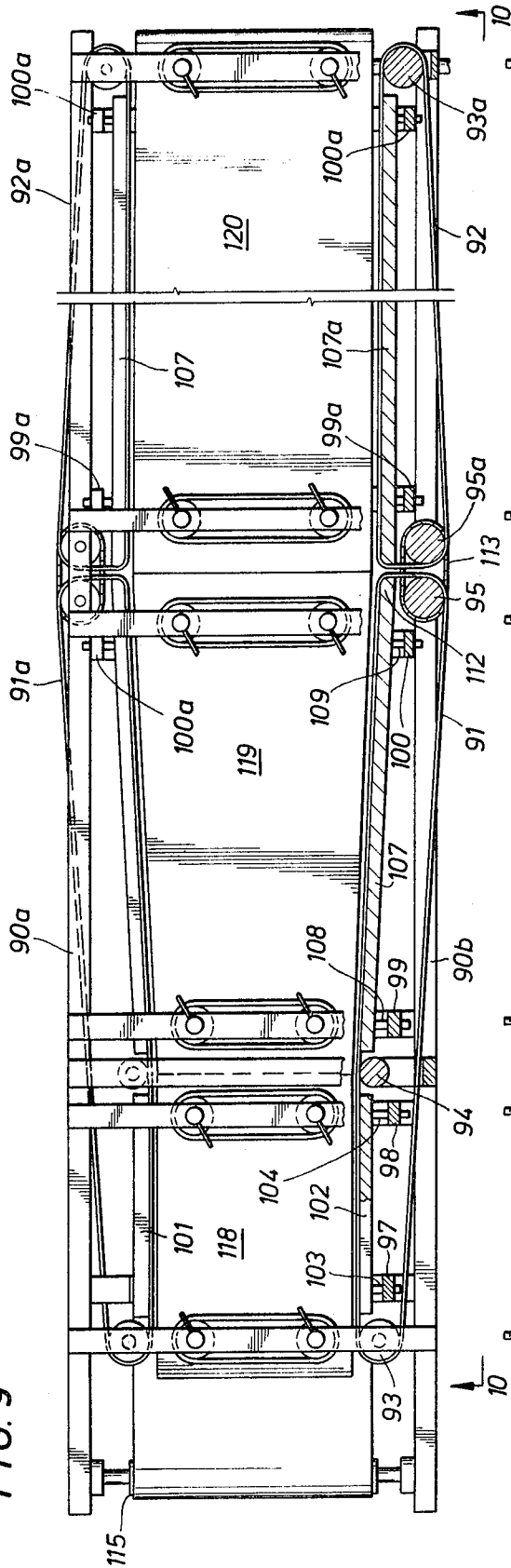


FIG. 10

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INVENTOR

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FIG. 11

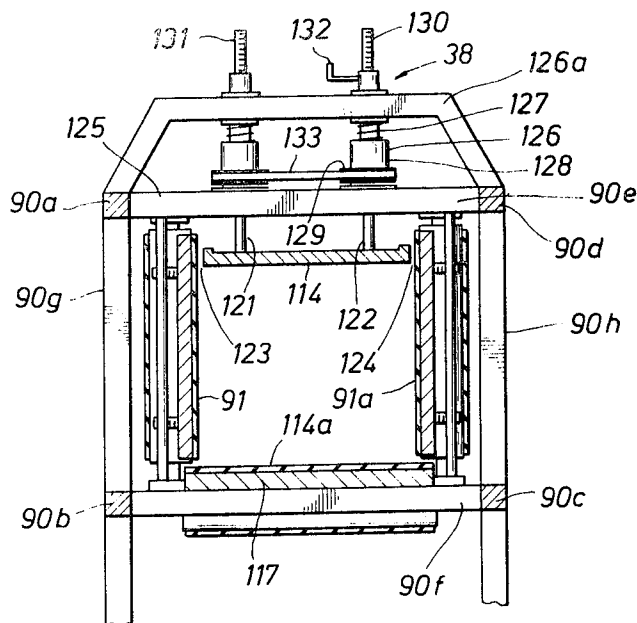
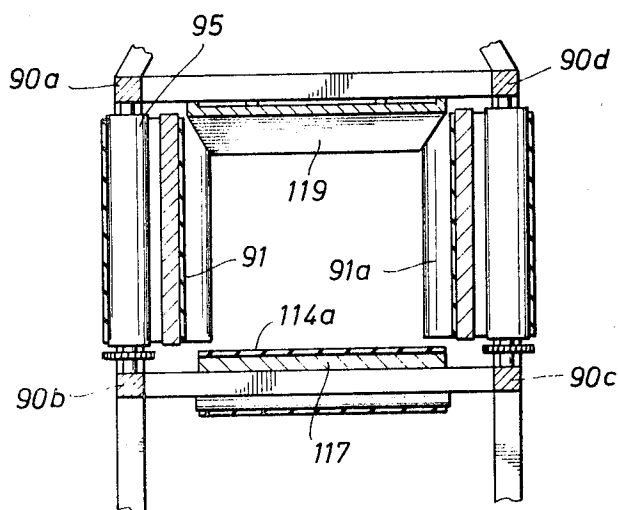


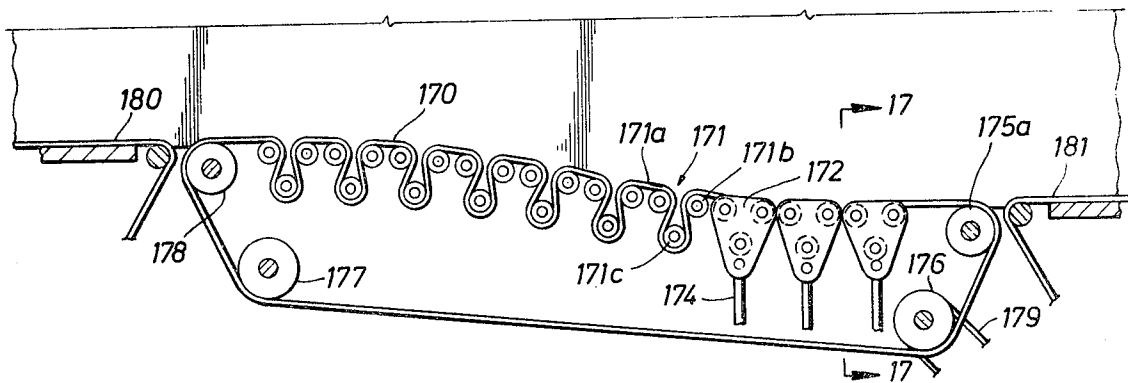
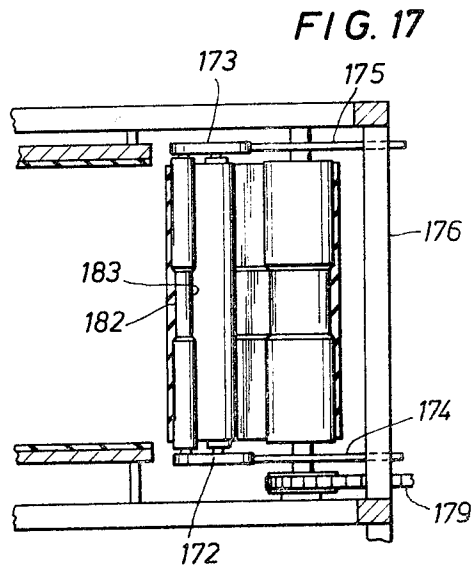
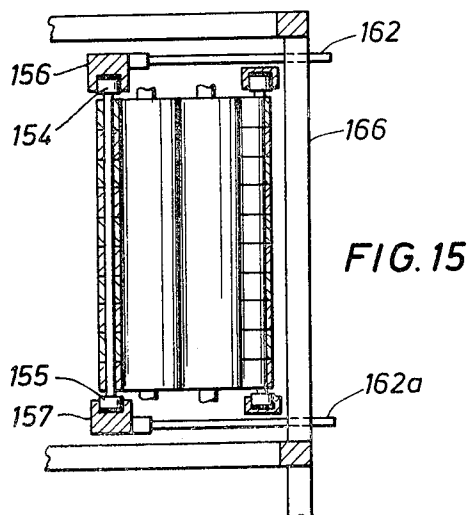
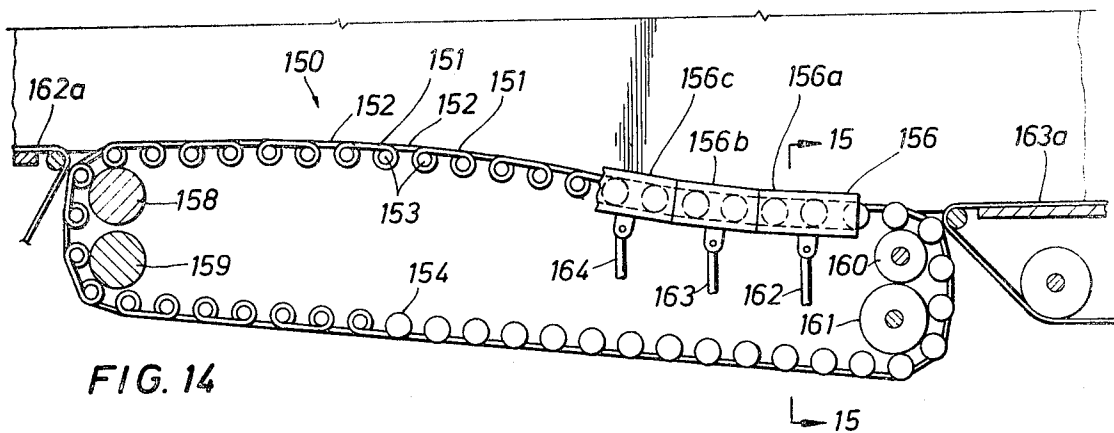
FIG. 12



Lawrence C. Porter
INVENTOR

BY FIDLER & BARD

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Lawrence C. Porter
INVENTOR

BY FIDLER & BARD

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FIG. 19

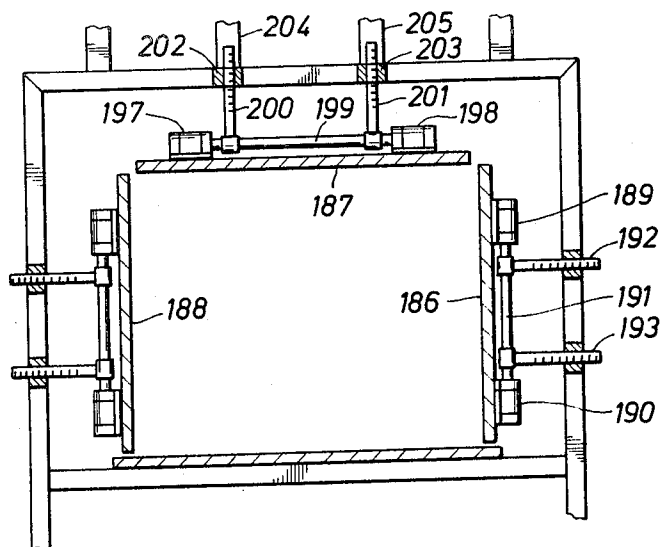


FIG. 20

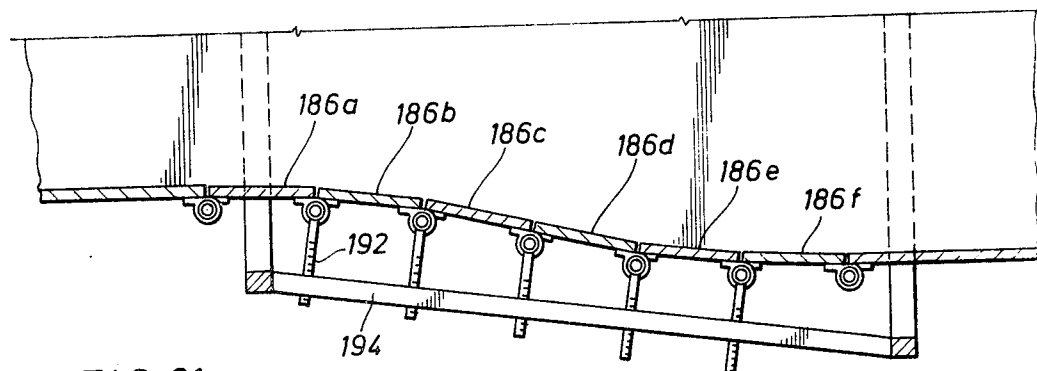
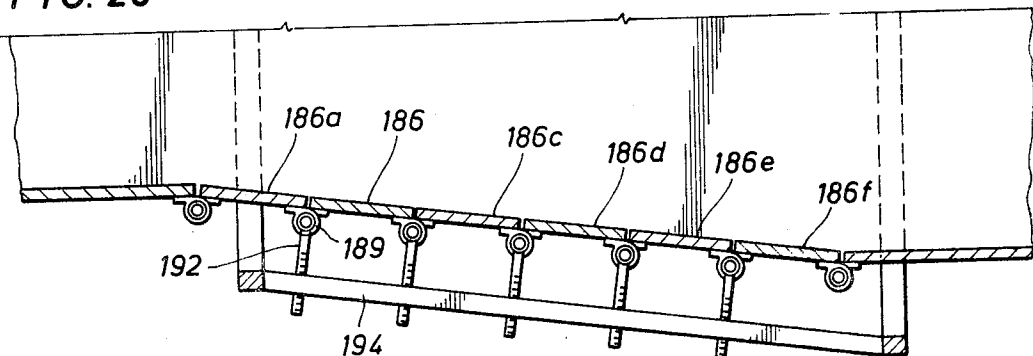


FIG. 21

Lawrence C. Porter
INVENTOR

BY FIDLER & BARD

ATTORNEYS

APPARATUS FOR FORMING URETHANE FOAM STOCK

This invention relates to the production of cellular synthetic resins and, more particularly, to methods and apparatus for producing polyurethane foam with isotropic characteristics and a substantially rectangular cross-section.

Polyurethane foams are expanded cellular products produced by combining essential ingredients including a suitable polyfunction hydroxyl compound, a blowing agent, a suitable polyfunctional isocyanate, a catalyst and a cell size regulator. Sometimes filler or additives are used to obtain special properties. In a "one-shot" system these ingredients are combined in liquid form at one time and, through a chemical reaction, expand and solidify into a cellular material. It is highly desirable for a rigid isotropic foam that the cell structure be uniform and symmetrical in order to provide adequate strength and compressive yield strength characteristics along X, Y and Z direction axes.

As mentioned heretofore, the polyurethane foam is produced by a reaction of a selected hydroxyl and a selected polyisocyanate. The blowing agent which is added in liquid form vaporizes or gasifies to produce a leavening effect while the resulting polyurethane mass "rises" and creates the cellular character of the foam. It is typical in foam manufacturing techniques to deposit a mixed hydroxyl, isocyanate and blowing agent mixture in a restricted or partially restricted enclosure to form a product having a generally preselected configuration in accordance with the shape of the mold. In a "continuous" process it is desirable to deposit the mixture on a conveyor which carries the mixture through a mold and, while the mixture is expanding and solidifying, the mold shapes the cross-sectional configuration of the product. This process is typically performed by pouring the liquid mixture of hydroxyl, isocyanate and blowing agent onto a moving conveyor which carries the mixture into and through a tunnel-like enclosure or mold as the mixture rises and solidifies. In other words, the mixture rises within the tunnel, and the cross-sectional configuration of the tunnel forms the product to the cross-sectional configuration of the tunnel. As the completed product exits from the tunnel, it may be cut into preselected lengths or billets which are subsequently cut into such shapes as may be desired.

The cell structure of the product, inter alia, is dependent upon the blowing agents and surfactants and is formed during the forming process which occurs prior to gelling of the foam. It is the vaporizable liquid which gasifies to form bubbles, and the cell structure results from the formation of bubbles. As will be readily appreciated, in the expansion process it is desirable to control, if possible, the shape of the cells formed by the vaporized liquid and, theoretically, it is desirable to have spherical gas-formed cells which would give the product equal strength characteristics along the X, Y and Z axes. There are a number of factors that affect the cell shape and character, and one of the controllable factors which affects the cell size and structure is the shape of the tunnel or mold which forms or shapes the expanding liquid during the transition period where the mixture converts from a true liquid to a solid. By controlling the shape of the tunnel along its length where the transition from foaming of the mixture to gelling of

the mixture occurs, the final cell configuration can be controlled and made more uniform with respect to the various directional axes.

Prior art techniques have attempted to control cell configuration by use of a somewhat V-shaped cross-section where the side walls are resiliently supported, and the object is to displace the foaming material toward the top of the product in an effort to control its cell structure. However, this technique has not been particularly successful.

In the present invention, the disadvantages of the prior art are overcome by novel methods and apparatus in which the configuration of the side and upper walls of the tunnel are selectively shaped to correlate with the expansion characteristics of the foam during the transition period where it converts from a foaming liquid towards a solid gelled material. This is accomplished by forming the tunnel with expanding vertical and horizontal dimensions along the zone where the transition period occurs. In its basic form, the expansion dimensions can be in the form of inclined walls, and, in the more refined aspects of the present invention, the walls may be selectively curvilinear to match expansion characteristics of the foam.

These and other advantages and features of the present invention will be more apparent from the following detailed description when taken in connection with the drawings wherein the accompanying drawings illustrate the present invention.

In the drawings:

FIG. 1 is a side plan view of one form of the present invention;

FIG. 2 is a view in cross-section of a foam product;

FIG. 3 is a schematic illustration of forces involved in a cell;

FIG. 4 is a view in cross-section of a foam product to illustrate volume redistribution;

FIG. 5 is a perspective view in cross-section of a foam reaction utilizing the principles of the present invention;

FIG. 6 is a top view of a part of a tunnel form embodying the present invention;

FIG. 7 is an end view of FIG. 6;

FIG. 8 is a side view of FIG. 6;

FIG. 9 is a top view of another form of the present invention;

FIG. 10 is a side view taken along line 10—10 of FIG. 9;

FIG. 11 is a view in cross-section taken along line 11—11 of FIG. 10;

FIG. 12 is a view in cross-section taken along line 12—12 of FIG. 10;

FIGS. 13A and 13B are respectively a plot of rise time and wall configuration and an illustration of a side wall configuration;

FIG. 14 is a partial view in cross-section of another form of the present invention;

FIG. 15 is a view taken along line 15—15 of FIG. 14;

FIG. 16 is a partial view in cross-section of another form of the present invention;

FIG. 17 is a view in cross-section taken along line 17—17 of FIG. 16;

FIG. 18 is another form of the present invention illustrated in perspective;

FIG. 19 is a view in cross-section taken along line 19—19 of FIG. 18;

FIG. 20 is a view in cross-section taken along line 20—20 of FIG. 18; and

FIG. 21 is a view similar to FIG. 20 but illustrating another position of the apparatus.

Referring now to FIG. 1, there is illustrated a functional, and partially pictorial, representation of an apparatus for receiving a mixture from a mixing device 21 and for forming polyurethane foam to a rectangular shape and gelled product. In particular, the system may be generally defined as being comprised of three main components, i.e., the tunnel mold section 22, a transitional conveyor section 23 and a saw assembly 24. It is a function of the tunnel mold section 22 to receive the reaction mixture from a mixer 21 which deposits the mixture on a conveyor and, upon expansion of the mixture, to provide a mold wherein the mixture will foam up into a polyurethane product having preselected dimensions and properties. It is the function of the transitional conveyor section 23 to conduct the "finished" product between the tunnel mold section 22 and the saw assembly 24, and it is the function of the saw assembly 24 to cut the finished product into billets of a preselected length.

The details of the tunnel mold section 22 hereinafter will be more completely illustrated and described but, generally, the mold section 22 has a lower, endless conveyor 25 and side belt conveyors 26 (only one side illustrated in FIG. 1). Resiliently mounted top sections 28 a-c of the tunnel define the fourth side of the cross-section of the tunnel. The mixing device 21 receives the various components for the reaction mixture and, after mixing, deposits them via a spout 31 onto the lower conveyor belt 25. It is a great convenience in the operation to utilize a layer of paper to wrap the finished product as well as provide a barrier between the mold and the reaction mixture. To this end, a roll of paper 32 mounted on a suitable stand 33 is carried over a roller 34 and, by means of suitable creasing rollers 35, is formed into a U-shaped trough to separate a part of the sides and the bottom of the tunnel from the reaction mixture. Separate strips of paper for the sides (not shown) having overlapping portions with respect to the bottom paper are also used. A second roll of paper 36 is shown on a frame 37 and is supplied via a roller 38a to provide a separating sheet for the top part of the product. A number of adjusting units 38 are illustrated on the tunnel mold section which are used to adjust the position of the top panels 28 a-c of the mold as well as resiliently bias the top panels with respect to the main frame 39 of the mold. The transition conveyor, which includes driven rollers 40, the endless belt 41 of the saw conveyor and the belts of the tunnel mold, are driven by a suitable driving means operated in synchronism by a master controller 42a. While not illustrated, it is desirable to incline the tunnel so that its entrance end is above the exit end and to adjustably mount the tunnel to vary this amount of inclination. The inclination of the tunnel, of course, provides a control over the flowing liquid to prevent the reaction front or rising foam of the liquid from falling back onto the freshly foaming mixture.

While not illustrated, there are means provided to move the mixing nozzle and its spout laterally across the paper at the entrance end of the tunnel to distribute the mixture evenly upon the bottom paper. The speed and traverse of the mixing nozzle and spout are, of

course, regulated relative to the speed of the conveyor belts, and these features are conventional.

A saw 42b is mounted on a saw carriage 24, and the saw carriage is traversed by the belt 41 by means of rollers 42-44 from the front to the back. During this traverse, the saw blade 42b moves downwardly through the product as it is moved by the conveyor belt 41 and cuts through the product. Subsequently, the saw 42b is returned to its initial cutting position before reaching the far end of the conveyor section, and the rollers of the saw carriage 24 are disengaged so that the carriage can be returned automatically to the front end of the saw section to repeat the operation. This apparatus and its function are well known and need not be further elaborated upon in this specification.

Referring to FIG. 2, a typical cross-section of a finished product 50 is illustrated in somewhat exaggerated form for purposes of discussion. The rectangular portion of the cross-section of material defined by the sides 51 a-d is what typically would be desired from a process of the type under consideration here. However, as a practical matter, while the relatively flat sides 51 a-d can be obtained on the product as it exits from the tunnel, the corners 52 are sometimes rounded; and, in addition, after a period of time following the exit of the product from the tunnel, the curing process completes so that, in fact, the sides of the product bulge outwardly somewhat as illustrated by the sides 53 a-d to form a somewhat trapezoidal cross-section. Thereafter, in the trimming of the product these bulged edge portions are cut off, leaving the square-shaped finished product. Therefore, the fact that the product is confined inherently produces a certain amount of physical as well as cell distortion along the sides, top and bottom and along the length of the product. However, since the billet must be trimmed to provide the rectangular configuration, such physical distortion is not entirely dissatisfactory, but it does entail a considerable amount of waste. The real problem is an inherent strength weakness due to cell elongation in the direction of the conveyor travel.

FIG. 3 is a simple diagram of a spherical cell 54 illustrating X, Y and Z axes. For orientation purposes, consider the X axis as parallel to the width of a tunnel, the Y axis as parallel to the height of vertical dimension of a tunnel, and the Z axis as parallel to the length of the tunnel. With reference to FIG. 3, it is desirable to provide spherical cells in the product so that forces along the X, Y and Z axes would have equal effect on the product. Such a state theoretically can be obtained where there is no confinement of the foam. However, as a practical matter, confinement is necessary to obtain a desired form, and therefore certain compromises must be accepted. For example, if it were desired to have a thirty psi strength along each of the X, Y and Z axes, a suitable compromise would be 24 psi strength along the Y axis, 20 psi along the X axis and 18 psi in the Z axis. With a tunnel having rigid walls, during the transition period of the material in a tunnel between foaming and gelling, the cells will tend to elongate along the Y axis because of the rise effect and will elongate along the horizontal axis Z because of the lack of confinement, while the cell will be narrowed along the X axis because of the confinement by the side walls. Simply stated, therefore, the system of the present invention is intended to control the shape of the cells by selectively controlling the degree of restriction during

the transition period. The degree of restriction is controlled in such a manner that the foam expands relatively freely in the vertical and horizontal directions, yet it does so in a controlled degree of confinement.

As shown in FIG. 4, the concept of forming foam to a rectangular configuration 55 necessarily involves redistribution of foam volume. In the case of a rectangular shape, the sides 55b, 55c, 55d are confined so that expansion predominantly occurs in the vertical direction, and a crown 55a would ordinarily occur. By providing any upper confinement surface, the crown volume 56 is redistributed to volumes 56a and 56b. This strict confinement has the disadvantage of affecting the lateral characteristics of the cells. As will hereinafter become more apparent, the present invention alleviates the effect of the side and top walls on the final shape of the product.

In FIG. 5, the basic concepts of the present invention are illustrated in diagrammatic form. In FIG. 5, a base conveyor 60 is illustrated which generally defines a base plane (which may be tilted, as noted heretofore). At the forward end of the conveyor are vertically arranged side panels 61 (only one being shown). Three top panels 62-64 are illustrated which are disposed at angles relative to the base plane. A reactive mixture, as heretofore defined, is deposited continuously across the moving conveyor 60 at the pour line. As an example, with a typical multistage reaction mixture, a tunnel inclination of 2° to 2½°, a belt speed of 8 to 8½ fpm and a throughput of 160 pounds per minute, a cut billet can be produced with dimensions of 26 × 51 × 106 inches and will weight 20 pounds per linear foot. The billet will subsequently be trimmed to a 24 × 48 inch dimension. With the foregoing parameters, the cream line will occur about 7½ to 8 feet from the pour line. The cream line is defined as the point where the mixture takes on a "creamy" appearance and a substantial foaming reaction begins with incident rapid expansion. In general, while the reaction begins immediately, the transition period begins when the foaming rise starts in about 25 seconds after mixing and is completed within 2 to 3½ minutes. From the pour point to the cream line, there is rapid gas generation and, at the cream line, self-nucleation will occur. During the rise of the foam, cells are formed by the vaporizing liquid. Once a cell is formed, its shape can be changed until the mixture gels.

By way of background, the rise of the foam involves a sequence where the blowing agent, whatever it may be, generates gas in solution in the liquid phase, with the gas reaching its saturation limit in solution, then becoming supersaturated and finally coming out of solution in the form of a bubble. This formation of a bubble is called "nucleation" and is assisted by the presence of a second, finely divided phase such as a finely divided solid or an irregular solid surface. When the bubble is first formed, it is a sphere surrounded by a relatively thick liquid phase. As more gas is generated by the blowing agent, the new gas may form new bubbles, and it may also diffuse from the liquid phase into existing bubbles, causing them to become larger. As more bubbles form and as the bubbles grow, the foam volume increases, with the result that the polymerizing liquid phase becomes ever thinner. As soon as nucleation relieves the gas concentration sufficiently, no more bubbles are formed, but the concentration of gas in solution is further reduced by diffusion into the bubbles

that already exist. The bubbles tend to lose their spherical shape as the liquid phase becomes thinner, with the bubbles finally assuming a structure bounded by several flat planes or membranes of polymerizing liquid. When the membranes join each other, a rib or stalk is seen that is thick as compared to the membranes.

The point of the process where membranes are formed is defined as the "string gellation" point which is about 13 to 15 feet from the cream line. "String gellation" is defined as the condition where the mixture includes "strings," i.e., if a straightened coat hanger is submerged into the mixture, when retrieved it will carry stringy materials. The "fill point" is about 2 feet from the string gellation point and is the location where the expanding mixture "fills" the cross-section of the tunnel. Beyond the fill point, about 2 to 5 feet, is the "tack" point where the conversion of the liquid to solid nears completion and the material is "tacky" to the touch. Between the fill point and the tack point, the foam rise is substantially completed. A short distance beyond the tack point is the solid line where the material is substantially solid and where very little effect can be produced on the cell. The time of "rise" is about 3 to 3½ minutes from the time of deposit to the time the material solidifies. When the mixture "gels," the cell structure is finally defined.

The object of the tunnel configuration which is about to be described is to fill the tunnel cross-section while the mixture is fairly liquid but then expand the cross-section at a rate related to the rate of expansion so that the forces applied to the expanding mixture are only sufficient to provide the configuration and are insufficient to provide confinement or packing of the mixture. By "packing" it is meant that the expanding material produces cell deformation along the Z axis and a compression along the X axis.

In summary, cell structure is defined by expanding the tunnel along the Y and X axes during the transition period while the cell formation is taking place. By expanding in both directions simultaneously, the foam is manipulated to the final cross-section while rigid confinement is avoided, thereby enhancing the character of the formed cell.

As shown in FIG. 5, expansion along the X and Y axes is obtained by inclination of the side and top panels. The top panel 62 is inclined downwardly and is at an angle with respect to the plane of the belt. The last top panel 64 is inclined at a different angle with respect to the plane of the belt 60. As noted from the diagram, the top panel 62 does not perform any function if the process is properly operating and serves as a containment factor only when the expansion occurs prematurely.

Referring now to FIGS. 6 and 7, the angulation of the first section is illustrated as typical. In FIGS. 6 and 7, the left side wall 61 has a front generally vertical edge 70, a rear generally vertical edge 71, a top longitudinal edge 72, and a bottom longitudinal edge 73. The angle that the generally vertical edges 70 and 71 make with respect to a true vertical 74 or perpendicular to bottom surface 60 is identified as α . The angle that the longitudinal edges 72 and 73 make with respect to a line 75 perpendicular to a horizontal line 76 is defined as β . Angle α , the vertical pitch, in a preferred embodiment is 2.2°. Preferably angle α should be between 1° and 3°. Angle β , the longitudinal pitch, is 31.5°. The left and right sides have similar or opposite pitches. The top

side 62 has a front edge surface 77 and a rear edge surface 78 which are parallel to the horizontal line 76. Side edge surfaces 79 and 80 are at an angle β and spaced slightly inward of the side walls. Thus, the top side 62 is trapezoidally shaped. The top side 62 has a horizontal pitch with respect to the plane parallel to the plane of bottom side 60 defined by an angle γ as shown in FIG. 8. The angle γ is, for example, 47° . The horizontal and longitudinal pitches should be less than 2° .

Referring back to FIG. 1, an example of apparatus embodying the present invention will be given. In FIG. 1, a tunnel as defined by the side panels may be 44 feet long and have five longitudinal sections respectively defined between vertical lines 82-83, 83-84, 84-85, 85-86 and 86-87. The lengthwise dimension of each section is approximately 106 inches. The horizontal dimensions at the top and bottom of each section and the height from the bottom conveyor to the top plate as taken along lines 82-87 is as follows:

Section Line	82	83	84	85	86	87
Top Horizontal Width (inches)	46	48	50	50	50	50.5
Bottom Horizontal Width (inches)	44	46	49	49	49	49.5
Height of Top Plate to Bottom Surface (inches)	25	23.5	23	25	26	26

As will be appreciated from the foregoing example, there is a vertical pitch, a horizontal pitch and a longitudinal pitch for each section. The general cross-section along the length of the tunnel from entrance to exit is trapezoidal. The trapezoidal cross-section at line 82 is that of an isosceles trapezoid, and the cross-sections toward line 83 have decreasing altitudes and increasing horizontal bases. From line 83 toward line 84 toward line 86, the altitude of successive trapezoidal cross-sections increases while the bases increase between lines 83 and 84 and remain constant from line 84 to line 86. From line 86 to line 87, the altitude remains constant while the horizontal bases increase slightly.

The foregoing example was utilized to provide a substantially rectangularly shaped cross-section in foam products after curing and has measurably improved the strength characteristics in X, Y and Z directions.

Referring now to FIGS. 9-12, a different form of apparatus in accordance with the present invention is illustrated. In the drawings, a frame 90 includes a number of transverse and longitudinal support members which are interconnected and provide a supporting frame. As will be noted from FIG. 9, the side walls are identical, mirror-image arrangements, so that the description will be confined to one side for simplicity of description. The frame 90 generally includes four longitudinally extending sidebars 90a-d. Upper and lower transverse bars 90e and 90f and vertical side bars 90g and 90h complete the frame structure and are disposed periodically along the length of the frame.

As illustrated, two or more endless belts 91 and 92 are included in the side walls. Belt 91 is supported by longitudinally spaced rollers 93-95. Rollers 93 and 94 are respectively journaled for rotation in upper and lower adjustment blocks 95' and 96. The blocks 95' and 96 journal the roller shafts for pivoting so that the blades can be transversely moved relative to the frame to incline the rollers. Conventional means are provided to permit a limited transverse positioning of the blocks, the journals being slidably and rotatably received in the

blocks to accommodate different vertical angles for the shafts. Roller 95 is journaled for rotation between the frame parts 90a and 90b.

Intermediate of the loop of belt 91 are vertical bars 97-100 which are attached to the frame. The vertical bars 97 and 98 are longitudinally spaced between rollers 93 and 94, while the bars 99 and 100 are longitudinally spaced between rollers 94 and 95. Between the vertical bars 97 and 98 and the inner loop of the belt is a back-up plate 101 which is coextensive with or slightly greater in its vertical dimension than the belt. Back-up plate 102 has four pivotally and rotatably coupled screws 103-106 which are received in threaded openings in bars 97 and 98. Adjustment of screws 103-106 can provide a vertical pitch for the plate 102.

Between the vertical bars 99 and 100 and the inner loop of the belt is a back-up plate 107 which is coextensive with or slightly greater in its vertical dimension than the belt. Back-up plate 107 has four pivotally and rotatably coupled screws 108-111 which are received in threaded openings in bars 99 and 100. Adjustment of screws 108-111 can provide a vertical pitch for plate 107. Plate 107 in addition has a round cornered edge 112 for guiding the belt to roller 95. With respect to belt 92, belt 91a and belt 92a, a similar belt and back-up plate system is employed as described above. It will be appreciated from this embodiment that separate belts which can be individually pitched can be employed. Rollers 95 and 95a are interconnected by a chain drive 113 for synchronous operation.

With respect to the top and bottom of the mold, the bottom is formed by an endless belt 114a carried by rollers 115 and 116. A bottom back-up plate 117 provides a support under the belt. The top of the mold includes top plates 118-120. Each of the plates is carried by a four-point suspension system which includes pivotally coupled screw members 121 and 122 (for example as shown in FIG. 11), the screw members being received by adjusting units 38. Insofar as the top plate mounting is connected, it is substantially the same as the mounting for the top plates of FIG. 1. Each top plate has a space between it and an adjacent side belt as shown at 123 and 124 in FIG. 11.

The top plates are supported by the adjustable supporting means 38 which are attached to transverse frame members 125. Typically, there are two horizontally spaced support means 38 for each frame, and two frames, one at each end of a plate, are adequate for supporting a top plate. Adjoining edges of adjacent top plates may have overlapping portions if so desired to provide a continuous surface.

The supporting means 38 include a housing 126 which has an upper cylindrically shaped part 127 rotatably mounted in the brace 126a and a lower, larger diameter, cylindrically shaped part 128 rotatively mounted in a transverse frame member 90e. A compression spring 129 is received on the part 127 and is contained between the brace 126a and a stepped shoulder on the cylindrical part 127. Thus, the spring 129 normally urges the part 127 downward with respect to the frame 126. The adjustment shafts 121 and 122 have threaded portions 130 and 131 threadably received in the housing 126. The housing 126 has a hand crank 132 so that rotation of the housing 126 moves the adjustment shaft 122 and changes the position of a top panel 114. The adjacent supporting means 38 are coupled to one another by sprockets on the housing 126 and an

endless chain 133. As will be appreciated, the top panels are thus spring-loaded and, of course, the degree of loading can be adjusted as desired.

As noted heretofore in connection with FIG. 5, from the cream line to the tack-free point the foam rises and expands. Dependent upon the rise characteristic, it may be desirable to make one or more of the walls curvilinear. As shown in FIG. 13A, a rise curve 140 may be plotted in terms of rise versus time. To determine the rate of use for any specific formulation, a large cylindrical tub is used where a light-weight disc lies on the top of the formulation. A chart recorder obtains the rise displacement as a function of time. This data can be correlated to a given foam system process where the parameters are defined. If the bottom wall is dropped off as shown by the line 141 in relation to the rise curve, the reaction mixture is moved away from the formed foam and a more uniform product can be produced. Where it is desired to simultaneously alter the horizontal dimension, a taper or curve can be introduced as shown by line 143 of FIG. 13B, in which case the curvature of the bottom pan is decreased as shown by line 144 of FIG. 13A. In actual practice, the precise predetermination of the wall configuration is left to actual production where the walls are adjusted to match the characteristics of the formulation.

Turning now to FIGS. 14-15, a curvilinear bottom wall section is illustrated. An endless articulated belt 150 is comprised of pivotally interconnected, outwardly facing plate members 151 and 152. Pivot pins 153 interconnect the plate members 151 and 152 to one another. At the end of each pin are guide rollers 154 and 155 which are respectively received in side guide tracks 156 and 157. The guide tracks provide a support for the belt. At each end of the belt are rollers 158-161 which are journaled for rotation with respect to a frame. One of the rollers carries a sprocket gear (not shown) for driving the belt. At either end of belt 150 are conveyor belts 162a and 163a which provide a continuation for the conveyor system. The guide tracks 156 and 157 between belts 162a and 163a are segmented as illustrated by segments 156 a-c. The segments 156 a-c are arranged to be displaced relative to one another by means of tie rods 162-164 which are threadedly received in the frame 166. Thus, by adjustment of the tie rod positions, the locations of the segments and the curvature of the belt 150 can be regulated.

In FIGS. 16 and 17, another form of articulated belt is illustrated which can also define a curvilinear wall surface. In FIG. 16, an endless belt 170 has one portion of its loop which is controlled by triangularly spaced roller groups 171. Each roller group includes two adjacent but spaced apart rollers 171a and 171b and an inwardly situated roller 171c. The rollers of each group are journaled for rotation in end plates 172 and 173. The end plates 172 and 173 are, in turn, connected to support and adjustment tie rods 174 and 175 which are threadedly received in a frame 176. The belt 170 loops over a roller 171a, under a roller 171c and over a roller 171b, with the rollers 171a and 171b being positioned fairly close to one another. Larger rollers 175a-178 provide an end support for the belt and are suitably journaled in a frame. Roller 176 is provided with a chain drive 179. At either end of belt 170 are conveyors 180 and 181 to complete the system. To maintain alignment of the belt 170, it has an internal projection

182 which is received in a grooved recess 183 of the rollers. It will be appreciated that the position of the plates 172 and 173 will affect the curvature of the wall, and the curvature can be selectively adjusted.

With respect to the foregoing description of curvilinear wall surfaces for a tunnel mold, it will be appreciated that a curvilinear wall can be used on any or all of the walls, and it is adaptable to varying conditions. While not illustrated, it is readily apparent that the walls can be provided with a pitch by providing universal mountings where necessary.

Turning now to FIGS. 18-21, still another form of the present invention is illustrated. For simplicity of illustration, the side and bottom belt means are not specifically shown. In this embodiment also, a single tunnel section is disclosed, it being contemplated that as many sections as necessary may be employed. The tunnel section 185 consists of articulated side and top walls 186, 187 and 188. Side wall 186, for example, consists of a number of side-by-side plates 186 a-f which are interconnected by means of spaced apart hinges 189 and 190. A part of each pivot hinge is respectively coupled to adjacent plates so that adjacent plates are articulately mounted with respect to one another. Hinges 189 and 190 are coupled to an adjustment shaft 191 which, in turn, is coupled to spaced apart adjustment shafts 192 and 193. The shafts 192 and 193 are rotatively coupled to shaft 191 and threadedly received in cross-bars 194 and 195. Thus, by rotation of the shafts 192 and 193, the pivot location of adjacent panels can be adjusted.

The top wall 187 consists of a number of side-by-side plates 187 a-f which are interconnected by means of spaced-apart hinges 197 and 198. A part of each hinge is respectively coupled to adjacent plates so that adjacent plates are articulately mounted with respect to one another. Hinges 197 and 198 are coupled to an adjustment shaft 199 which, in turn, is coupled to spaced apart adjustments shafts 200 and 201. The shafts 200 and 201 are rotatively coupled to shaft 199 and threadedly received in cross-bars 202 and 203. The cross-bars 202 and 203 are, in turn, coupled to shafts 204 and 205 of spring-loaded adjustment means 38 which have heretofore been described. Thus, by rotation of shafts 200 and 201, the form of the wall can be altered and by adjustment of shafts 204 and 205 the position of the assembly can be altered. The top wall 187 is arranged to fit between the side walls 186 and 188 and have a slight spacing therebetween. As shown in FIGS. 20 and 21, the side walls can be adjusted to provide a straight as well as a curvilinear form, and, in either case, a matched form top panel is employed.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. Apparatus for forming polyurethane foam material having improved isotropicity and a substantially rectangular cross sectional configuration, comprising a four-sided molding tunnel having a transition section with fixedly mounted sidewall members outwardly and angularly positioned relative to the longitudinal axis of said tunnel for permitting substan-

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tially free and lateral expansion of said polyurethane foam within preselected limits functionally related to the foaming and gellation thereof, said transition section of said tunnel also having a top member upwardly and angularly positioned relative to said longitudinal axis of said tunnel for further permitting substantially free and vertical expansion of said polyurethane foam within preselected limits functionally related to the foaming and gellation thereof, said side and top members cooperating with the bottom members of said tunnel to provide said transition section thereof with a progressively outwardly flaring configuration with preselected internal cross sectional dimensions along said longitudinal axis functionally related to the characteristics of the polyurethane foam formulation along said axis of said tunnel, and conveyor means for transporting said polyurethane foam into and longitudinally through said transition section in functional cooperation with said foaming and gellation of said polyurethane foam and the internal dimensions and configuration of said transition section for achieving substantially uniform polyurethane foam cell configuration throughout said foam material.

2. The apparatus according to claim 1 wherein the angle of the sidewall members is equal and opposed.

3. The apparatus according to claim 2 wherein the angle of the top member and sidewall members is each less than 2°.

4. The apparatus according to claim 3 wherein there

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is a vertical pitch of the side wall members of from 1° to 3°.

5. The apparatus according to claim 2 wherein the longitudinal cross section is trapezoidal.

6. The apparatus according to claim 2 wherein at least one side includes means for selectively altering said one side.

7. The apparatus according to claim 6 wherein said one side is curvilinear.

8. The apparatus according to claim 7 wherein the sidewall members are curvilinear.

9. The apparatus according to claim 6 wherein said bottom member is angularly and downwardly positioned.

10. The apparatus according to claim 9 wherein said bottom member is curvilinear.

11. The apparatus according to claim 2 wherein said top member is yieldably mounted.

12. The apparatus of claim 6 wherein said conveyor means is an endless belt, and means for adjusting the position of the belt along at least a part of said belt.

13. The apparatus of claim 6 wherein said one side comprises articulated, pivotally interconnected plate members.

14. The apparatus of claim 6 wherein said transporting means is comprised of articulated, pivotally interconnected plate members.

15. The apparatus of claim 6 wherein said transporting means is comprised of endless belt means supported by roller means, and means for selectively positioning said roller means.

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