# United States Patent

**Davis**

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## [54] CURVING METHOD AND APPARATUS FOR RIDGED SHEET MATERIAL


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[52] **U.S. Cl.** ..... **72/307,** 72/385, 72/379

[51] **Int. Cl.** ..... **B21d 11/04**

[58] **Field of Search** ..... 72/307, 385, 166, 169, 196, 72/379; 113/116 R



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[57] **ABSTRACT**

Method and apparatus for forming ridged sheet material into arcuate shape. Sheet material having an elongated major ridge or corrugation extending along a line is curved along said line by progressive formation therealong of a series of corrugations or pleats directed substantially normal to said line.


**7 Claims, 18 Drawing Figures**

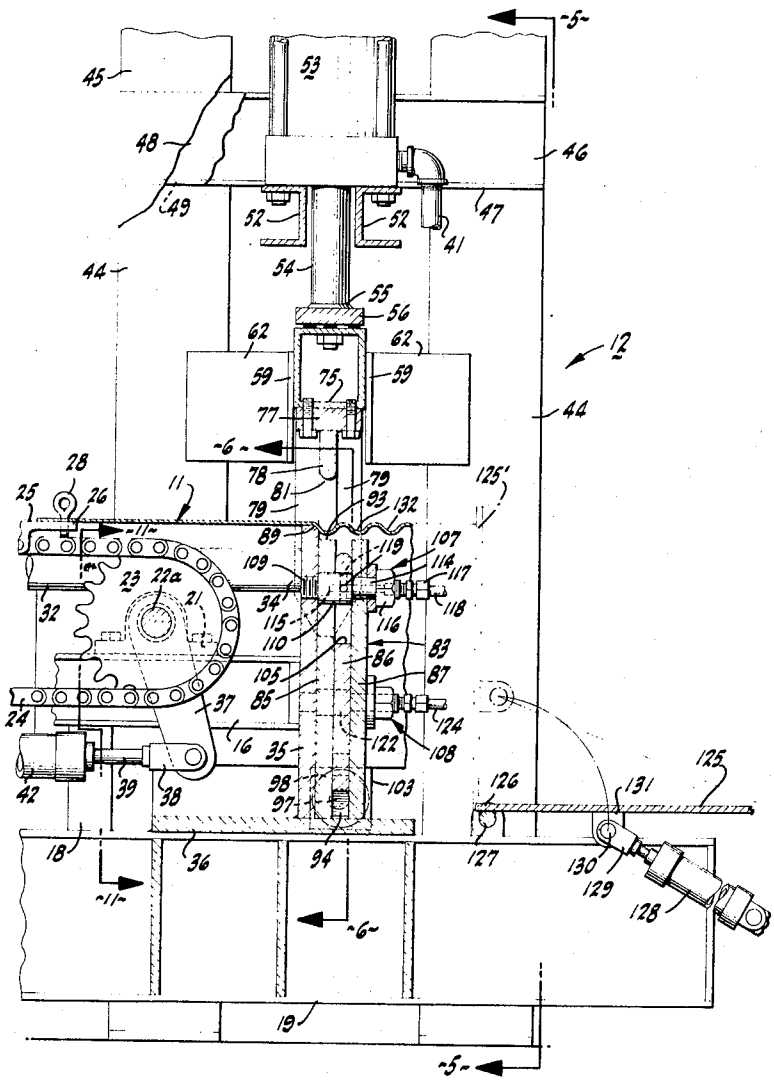
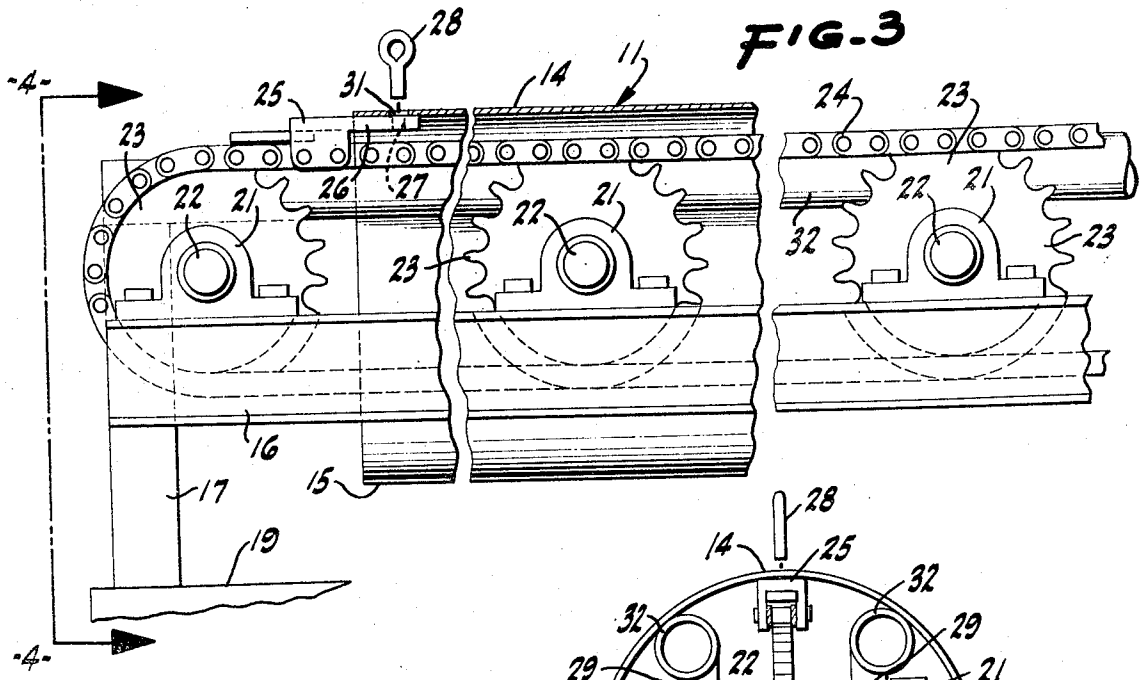


FIG-3



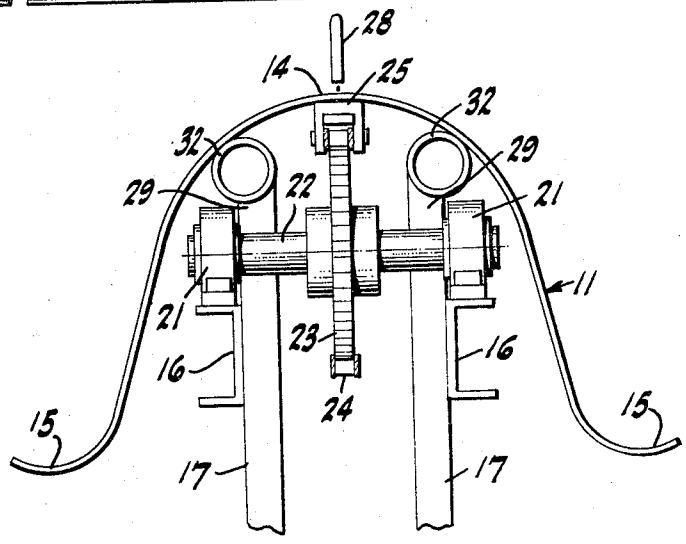




FIG-8

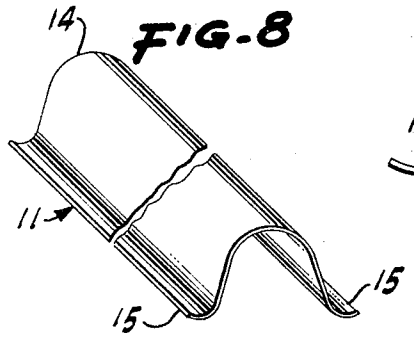
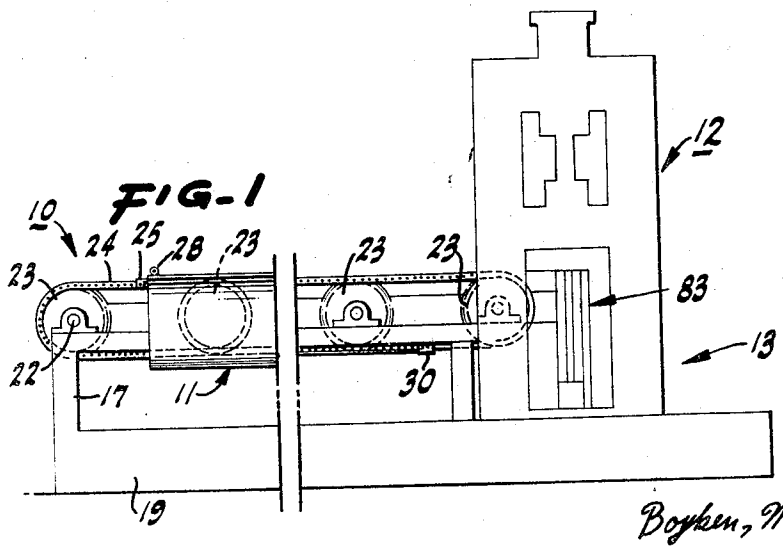



FIG-4

FIG-1




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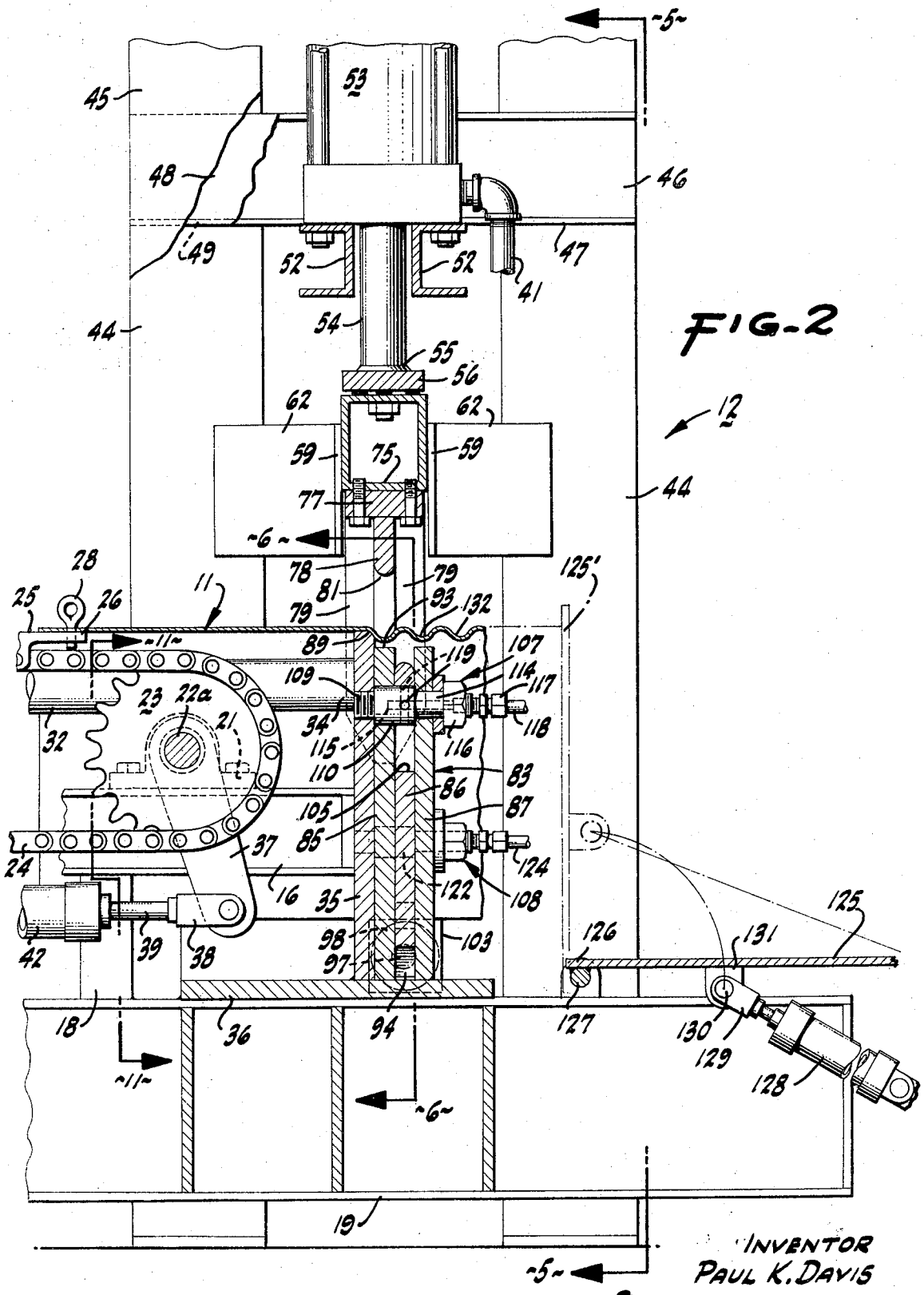



FIG-2

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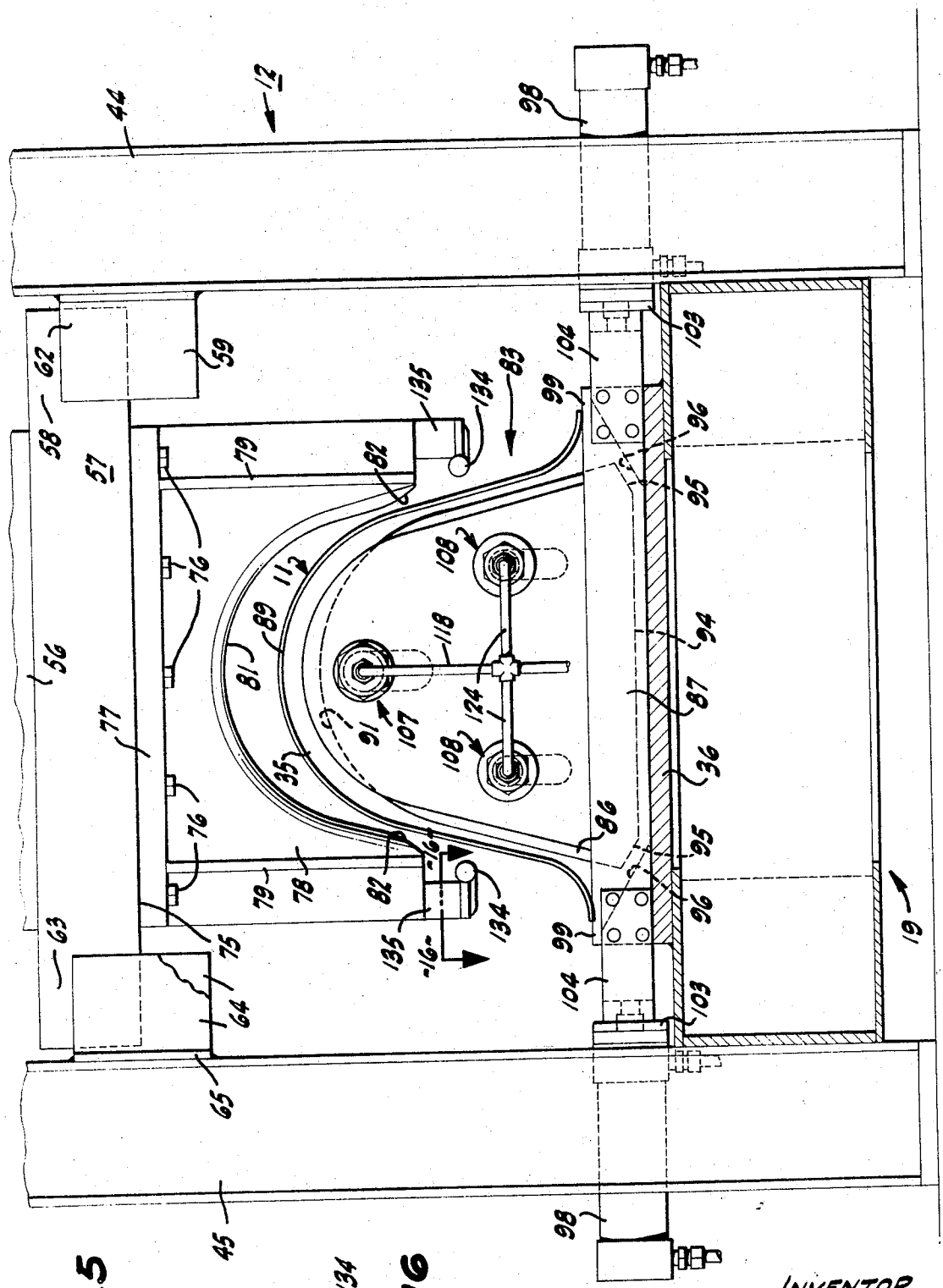



FIG-5

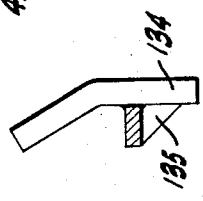
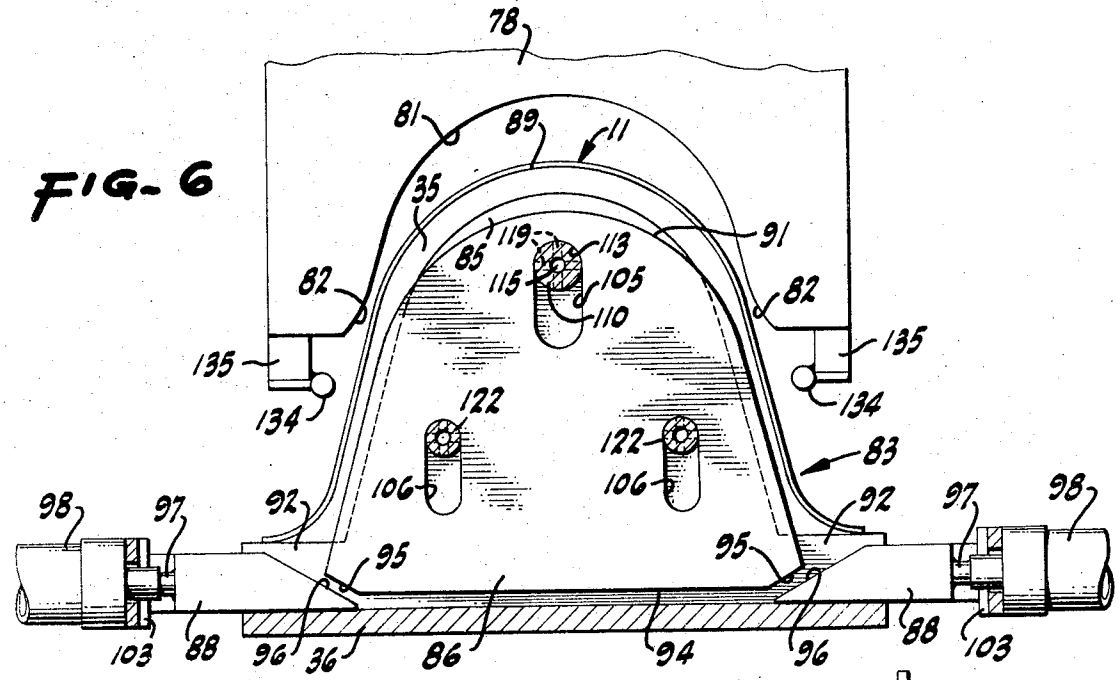



FIG-16

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FIG-6



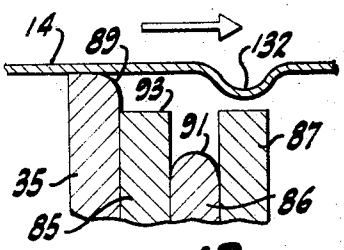
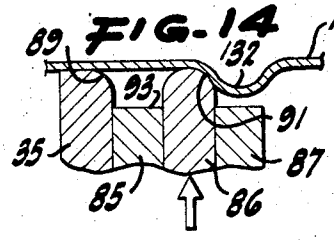




FIG-13

FIG-14



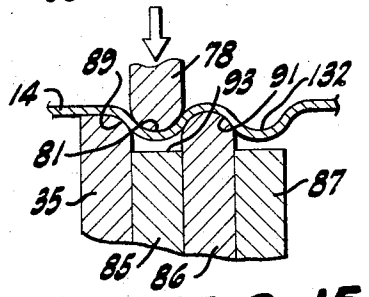




FIG-15

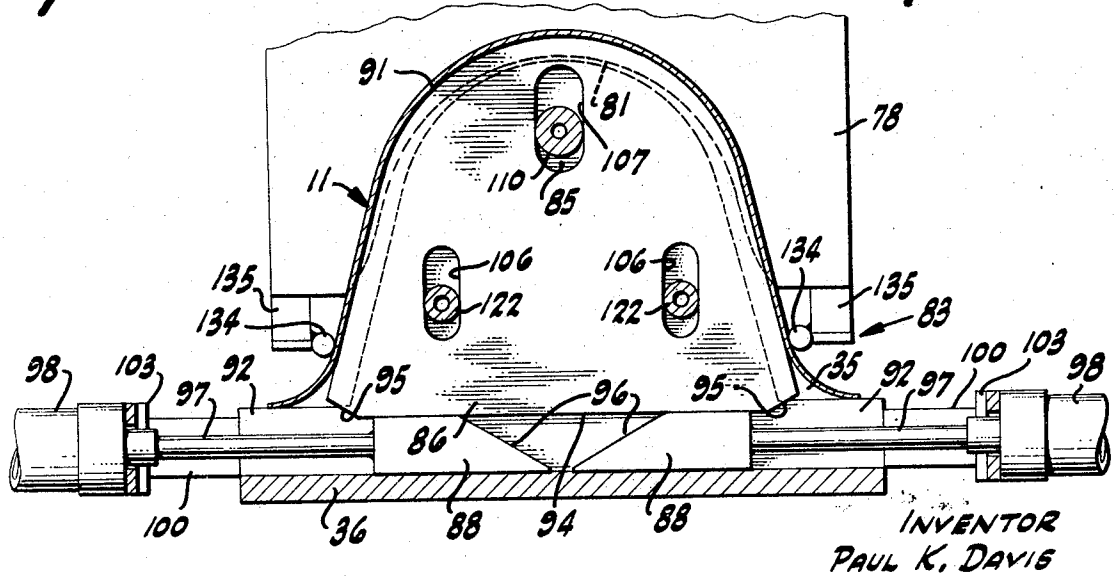
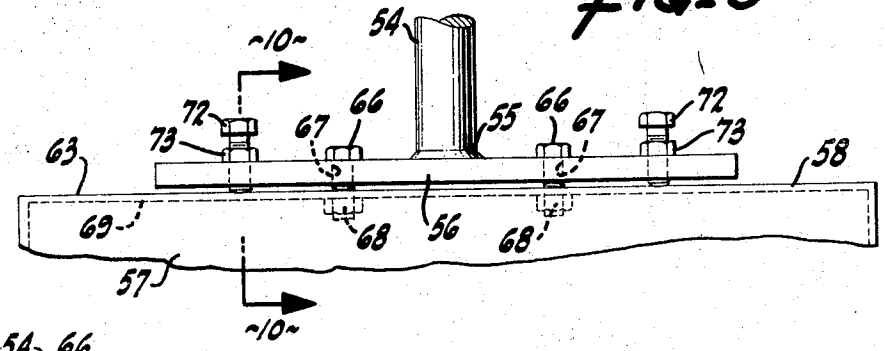



FIG-7

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FIG-9



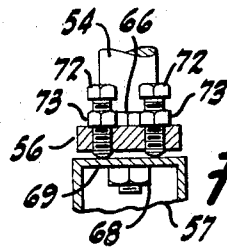




FIG-10

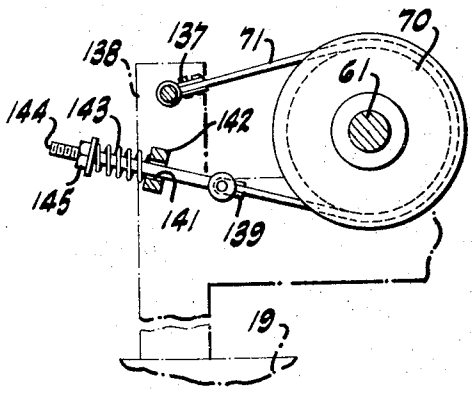



FIG-12

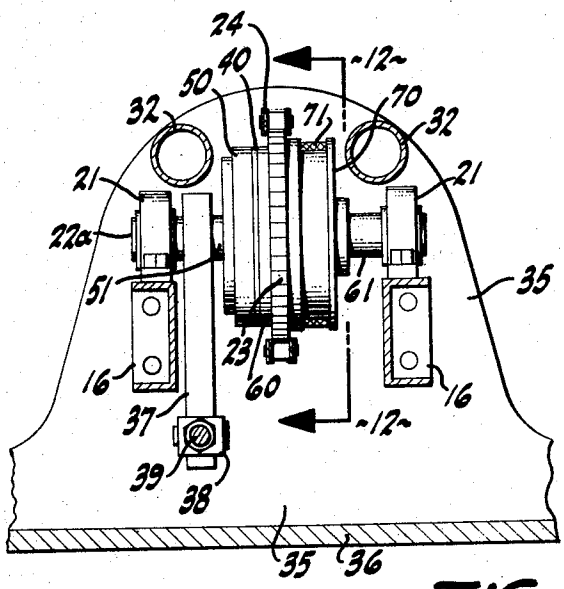



FIG-11

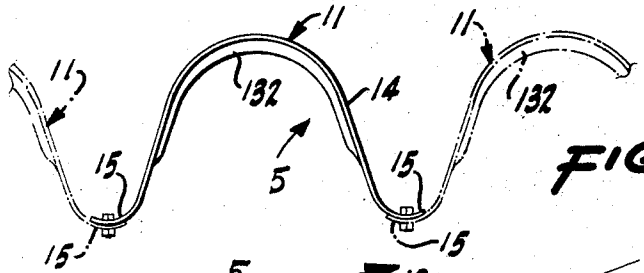



FIG-18

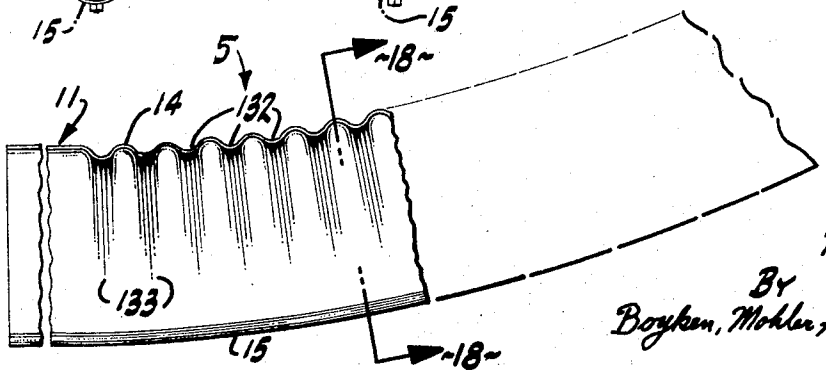



FIG-17

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# CURVING METHOD AND APPARATUS FOR RIDGED SHEET MATERIAL

## BACKGROUND OF THE INVENTION

This invention relates to forming of metal sheet material or other plastically deformable materials, and more particularly to the curving of an elongated longitudinally ridged sheet metal workpiece into arcuate shape suitable for use as a high strength structural member.

The curving method and apparatus of this invention are advantageously utilized in formation of arcuate sheet metal panels for construction of arched structures such as corrugated waterway conduit or quonset building structures. Commonly, individual panels employed in such structures have one or a series of elongated ridges or corrugations, hereinafter termed the "major corrugation(s)", and are curved in the direction of extent of the corrugations about a radius corresponding to the desired radius of curvature of the completed structure. Known curving methods and apparatus are severely limited as to maximum thickness of sheet material, cross-sectional profile of the major ridge or corrugation, or degree of curvature obtainable. For example, objectionable buckling or other spurious deformation occurs if it is attempted to employ conventional methods and apparatus to curve a corrugated metal sheet along the direction of corrugation when the corrugation depth is of the order of 1 foot. The inherent limitations in prior art methods and apparatus preclude formation of curved structural panel of exceedingly high strength, since increased strength results from increased sheet thickness and greater depth of the major corrugation.

## SUMMARY OF THE INVENTION

In this invention for curving ridged sheet material, which may take the form of a sheet metal workpiece formed with one or a series of major corrugations or ridges extending in a longitudinal direction, a series of secondary corrugations or pleats is progressively formed along the direction of extent of the longitudinally extending ridge or ridges. The secondary corrugations are directed transversely, i.e., substantially normal to the direction of extent of the major corrugation and function as gathers or pleats enabling the material to be curved along the line of extent of the major corrugation without objectionable buckling or other undesired deformation. The curvature which occurs during progressive formation of the secondary corrugations is most significantly affected by the spacing and configuration of the secondary corrugations, and may accurately be controlled by adjustment of such spacing and configuration. The method and apparatus of this invention obviates the problem of buckling or interference between adjacent deformed sheet portions, and thus renders it feasible to obtain curved structural panels of higher strength then heretofore obtainable, from sheet material of greater thickness and with major corrugations having more pronounced cross-sectional profiles. A steel sheet workpiece approximately one-eighth inch thick and having a major corrugation 1 foot in depth and 2 feet in pitch is representative, but thicker materials with more pronounced major corrugations may be accommodated.

It is therefore, an object of this invention to provide a novel method of and apparatus for curving ridged sheet material in the direction of extent of the ridge.

Another object of the invention is to provide a method of and apparatus for curving ridged sheet material along the length of the ridge, which material is more resistant to such curving than materials heretofore curved, because of greater thickness or a more pronounced ridge therein.

A further object of the invention is the provision of a method of and apparatus for curving ridged sheet material along the length of the ridge accurately to different desired degrees of curvature.

Additional objects of the invention are to provide, a method of and apparatus for curving a ridged sheet workpiece along the length of the ridge so as to avoid buckling of material, a



method and apparatus that will accommodate a workpiece that is unlimited as to length, a method and apparatus that will not weaken the material, and an exceedingly rapid and efficient curving method and apparatus.

Other objects and advantages of the invention will become apparent from the following description of a preferred embodiment of the invention.

## DESCRIPTION OF THE FIGURES

FIG. 1 is an overall, partially schematic, side view of a preferred form of apparatus embodying the invention, with parts broken away for purposes of clarity;

FIG. 2 is a side, partly sectional view of the press assembly portion of the apparatus of FIG. 1;

FIG. 3 is a fragmentary, side view of the input end of the apparatus of FIG. 1;

FIG. 4 is an end view of the input end illustrated in FIG. 3, as viewed from line 4—4 thereof;

FIG. 5 is an end view of the press assembly portion of FIG. 2, as viewed from line 5—5 thereof with parts removed for purposes of clarity;

FIG. 6 is a fragmentary, sectional view of a portion of the apparatus of FIG. 2 substantially as viewed along line 6—6 thereof;

FIG. 7 is a view similar to FIG. 6, but with parts differently positioned as at termination of a pressing operation;

FIG. 8 illustrates one form of workpiece on which may be performed the method of this invention;

FIG. 9 is a fragmentary view of adjustable punch plate mounting means in the assembly of FIG. 2;

FIG. 10 is a fragmentary, sectional view taken along line 10—10 of FIG. 9;

FIG. 11 is a cross-sectional view of a portion of the feed means of the apparatus illustrated in FIG. 2, as viewed substantially from line 11—11 thereof;

FIG. 12 is a fragmentary view of a braking wheel assembly as seen from line 12—12 of FIG. 11;

FIG. 13 is a fragmentary sectional view of the upper portion of die members of the assembly of FIG. 2, showing their initial position as seen in FIG. 2, but on an enlarged scale relative thereto;

FIG. 14 illustrates the parts of FIG. 13 in position during an intermediate point in a pressing operation;

FIG. 15 illustrates the parts of FIGS. 13 and 14 at completion of a pressing operation;

FIG. 16 is a fragmentary view of a material hold-down assembly taken along line 16—16 of FIG. 5;

FIG. 17 is a side view of a portion of a curved structural panel formed by performing the invention; and

FIG. 18 is a cross-sectional view of the structural panel of FIG. 17, taken along line 18—18 thereof.

## DESCRIPTION OF A PREFERRED EMBODIMENT

In detail, with reference to FIG. 1, a preferred embodiment of the apparatus of this invention comprises a feed means 10 for advancing a sheet material workpiece 11 along a path of travel, toward the right in FIG. 1, through a press assembly 12 wherein curving is accomplished. After passage through press assembly 12 the curved structural panel formed from workpiece 11 is removed from the curving apparatus past the output end 13 for further handling.

Workpiece 11 may take the form of an elongated sheet metal strip (FIG. 8) having a central longitudinally extending upwardly directed major ridge or corrugation 14, between curved outwardly flared side edge portions 15. It is supported for travel along a horizontal path on feed means 10 comprising a pair of horizontally spaced parallel channel members 16 (FIGS. 3, 4) extending in the direction of the feed path and each supported at one end by a vertical member 17 (FIG. 3) and proximate the opposite end nearest press assembly 12 by a vertical member 18 (FIG. 2), members 17, 18, in turn, being supported on a base 19 (FIGS. 2, 3). At regular intervals along

channel members 16 are mounted opposed pairs of bearing blocks 21 (FIGS. 3, 4 and 11) between which extend shafts 22 (FIGS. 3, 4) for rotation in said bearing blocks. A shaft 22*a* in bearing blocks 21 nearest press assembly 12 is of different broken construction, as will be described. Midway along each shaft 22 is fixed a sprocket wheel 23, so that there is provided a plurality of aligned sprocket wheels 23 around which extends a continuous feed chain 24.

A bracket member 25 (FIGS. 2, 3, 4) is attached to a link of chain 24 and includes an elongated bracket portion 26 spaced outwardly of chain 24 and provided with an aperture 27 (FIG. 3) for receiving a removable pin 28 (FIGS. 2, 3, 4). A bracket member 30 (FIG. 1) similar to bracket member 25 is similarly attached to a link of chain 24 at a point remote from bracket member 25 whereby one such bracket member will be on the upper run of chains 24 proximate one end of feed means 10 when the other bracket member is on the lower run proximate the opposite end of feed means 10 (FIG. 1). The upper portion 29 of each vertical member 17 (FIG. 4) extends above channel member 16 and has fixed to its upper end the end of a tubular member 32 that extends in the direction of the material feed path to a point of attachment at the opposite end 34 (FIG. 2) to a vertical plate 35 (FIGS. 2, 5) which, as will hereinafter be described, serves as a die plate. Vertical plate 35 is mounted on a horizontal plate 36 which is on the upper surface of base 19 so that the uppermost surface of plate 35 is at the same level as the upper surface of bracket members 25, 30 when they are on the upper run of chain 24. When workpiece 11 is disposed with the peak of major corrugation 14 supported on the upper one of bracket members 25, 30 and on the uppermost surface of vertical plate 35, the pair of tubular members 32 provide additional guide support symmetrically at each side of the corrugation peak.

One end of a crank arm 37 (FIGS. 2, 11) is keyed on the shaft 22*a* nearest die plate 35 at a point on the shaft adjacent one bearing block 21 (left-hand bearing block 21 in FIG. 11), and the opposite end of crank arm 37 is connected to a yoke 38 at the outer end of a piston rod 39 associated with a hydraulic cylinder 42 (FIG. 2). Also on shaft 22*a* between arm 37 and sprocket wheel 23 is a ratchet wheel assembly 40 (FIG. 11) of conventional construction. Arm 37 and an adjacent ratchet wheel portion 50 are on a common shaft portion 51, of shaft 22*a* having an end terminating within ratchet wheel portion 50. Ratchet wheel portion 60 and sprocket wheel 23 are on a common shaft portion 61 having an end terminating within ratchet wheel portion 60. When piston rod 39 is retracted arm 37 is rotated (clock-wise in FIG. 2) causing corresponding rotation of shaft portion 51 and ratchet wheel portion 50 (FIG. 11) and through said ratchet wheel portion the ratchet wheel portion 60, shaft portion 61 and sprocket wheel 23. When piston rod 39 is extended to cause reverse rotation of crank arm 37 the portions of ratchet wheel assembly 40 are not interengaged and sprocket wheel 23 is not rotated in the reverse direction. Thus, sprocket wheel 23 is adapted to be driven only in the direction for advancing chain 24. To prevent override of chain 24 beyond the desired distance of advancement a braking wheel 70 (FIGS. 11, 12) on shaft portion 61 carries a strap 71 (FIG. 12) that is attached at one end 137 to vertical member 138 on base 19. The opposite end 139 of strap 71 is connected to a rod 140 slidingly received through an aperture 141 in bracket 142 on member 138, and a helical spring 143 is carried on the threaded free end 144 of rod 140 between bracket 141 and an adjusting nut 145. When nut 145 is threaded toward bracket 141 drag on braking wheel 70 by frictional contact with strap 71 is increased, and with nut 145 the drag is adjusted so as to permit shaft portion 61 to be rotated by crank arm 37 and associated parts without undersired override.

Press assembly 12 (FIGS. 1, 2 and 5) provides a corrugating means or station and includes a vertical frame comprising a pair of vertical frame members 44 (FIGS. 2, 5) spaced in the direction of the feed path and each extending upwardly from a point of support on the ground at the side of base 19. A pair of similar frame members 45 (only one of which is shown in FIGS. 2, 5) are opposite frame members 44 at the opposite side of base 19. Horizontal cross-members 46, 48 extend between frame members 44, 45, respectively, at an elevated portion thereof, and respectively include a lower inwardly directed horizontal flange 47, 49 (FIG. 2). A pair of opposed, horizontally extending channel members 52 are connected between flanges 47, 49 respectively of cross-members 46, 48 and have bolted thereon the lower end of a heavy-duty hydraulic cylinder 53 having a piston rod 54 depending between channel members 52. The upper end of the frame includes suitable additional frame members of conventional construction to assure necessary strength. Cylinder 53 is supplied with fluid through pipe 41.

Fixed to the lower end 55 of piston rod 54 (FIG. 2) and extending parallel to channel members 52 is a horizontally disposed mounting bar 56, to the underside of which is connected a box member 57 (FIGS. 2, 5 and 9). Box member 57 extends substantially fully the distance between the pairs of frame members 44 and 45, and at one end 58 (FIG. 5) is slidingly received between the inwardly directed plates 59 (FIGS. 2 and 5) of a pair of guide brackets 62 on frame members 44, and at the other end 63 (FIGS. 5 and 9) is similarly received between the plates 64 (FIG. 5) of guide brackets 65. Box member 57 is adjustably connected to bar 56 for varying the spacing therebetween, by means comprising a pair of connecting bolts 66 (FIGS. 9 and 10), one on each side of piston rod 54. Bolt 66 is slidingly received in an aperture 67 (FIG. 9) in bar 56 and is threadedly received through a nut 68 fixed to the interior surface of the upper wall 69 of box member 57. At each end portion of bar 56 a pair of adjusting bolts 72 (FIGS. 9 and 10), are threaded through a nut 73 and through bar 56. To adjust spacing between bar 56 and box member 57 bolts 66 and nuts 73 are backed from the upper surface of bar 56, bolts 72 are then threaded to project below bar 56 the distance of desired spacing between the bar and box member 57, and nuts 73 and bolts 56 then are tightened to lock parts in place.

Bolted to the undersurface of the lower wall of box member 57 (FIGS. 2 and 5) by bolts 76 is the horizontally disposed mounting plate 77 of a vertical punch plate 78 (FIGS. 2, 5, 6 and 7) having pairs of vertical reinforcing ribs 79 (FIGS. 2 and 5). The downwardly facing working surface or punch surface 81 of punch plate 78 is concavely curved substantially fully between reinforcing ribs 79, but adjacent said ribs includes reversely curved portions 82 (FIGS. 5, 6 and 7). In cross section through plate 78 punch surface 81 is rounded (FIG. 2) as more fully described below.

On horizontal plate 36 (FIGS. 2, 5, 6, and 7) directly below punch plate 78 is a vertical die spacer plate 85 of a die assembly 83 positioned between die plate 35, and a vertically slidable die plate 86, against the opposite face of which is an end plate 87 (FIG. 2). The die surface 89 of die plate 35 (FIGS. 2, 5 and 6) is shaped to conform to the contour of workpiece 11 (FIGS. 5, 6, 7) and is rounded at the corner facing toward punch plate 78 (FIGS. 2, 13, 14 and 15). Spacer plate 85 having a flat edge surface 93 is shaped generally similarly to plate 35, but has smaller dimensions so that said edge surface is located inwardly of the edge surface 89 of plate 35, and it includes a pair of lower outwardly directed tab portions 92 (FIGS. 6, 7). Plate 85 is of substantially the same thickness as punch plate 78. The convex die surface 91 of slidable die plate 86 corresponds to the shape of die surface 89 of plate 35. At each corner of the bottom edge 94 of plate 86 (FIGS. 5, 6, and 7) is a bevel portion 95 which is adapted to be engaged by the leading wedge surface 96 of a lifting wedge 88 provided for elevating plate 86. When fully elevated by wedges 88 die surface 95 (FIGS. 6, 7, 13, 14 and 15) is at the same level as die surface 89 of plate 35. In cross section through plate 86 die surface 91 is fully rounded (FIGS. 2, 13, 14 and 15). End plate 87 (FIGS. 2, 5) is similar to spacer plate 85 and includes corresponding tab portions 99 (FIG. 5).

Lifting wedges 88 are mounted in opposed relation for sliding on the upper surface of horizontal plate 36 (FIGS. 5, 6 and

7) and along lower edge 94 of plate 86. Each wedge 88 is fixed at the end of a piston rod 97 (FIGS. 6 and 7) associated with a horizontally mounted double acting hydraulic cylinder 98 of conventional construction, and is slidably received between tab portions 92 and 99 of plates 85 and 87 respectively. To the outer end of each tab portion 92 on spacer plate 85 is bolted a connecting bar 100 (FIG. 7) which extends to connect with the end plate 103 of hydraulic cylinder 98 (FIGS. 2, 5, 6 and 7). Similar connecting bars 104 on tab portions 99 (FIG. 5) also are connected to end plate 103 for mounting hydraulic cylinder 98.

Lubricating means are provided to facilitate sliding of slidable die plate 86 between spacer plate 85 and end plate 87, for which purpose plate 86 is provided with an upper vertically extending slot 105 (FIGS. 6 and 7) and a pair of narrower but equally long lower slots 106. Apertures in the other plates 35, 85 are located to be aligned with the upper end of slots 105, 106 when plate 86 is in its lowermost position, and all plates of die assembly 83 are connected by an upper connector assembly 107 and a pair of lower connector assemblies (FIG. 2). Connector assembly 107 includes a threaded end portion 109 threadedly received in die plate 35, a cylindrical body portion 110 extending through spacer plate 85 and slidable die plate 86 and of the same diameter as the rounded ends 113 of slot 105, and a shank portion 114 extending through end plate 87. A central bore 115 extends through shank portion 114 and partially through body portion 110 and communicates with the interior of a hollow nut 116 threaded against the outer face of end plate 87 and mounting a fitting 117 within which is the end of hydraulic tubing 118. Within bore 115 at a point midway through slot 105 in slidable die plate 86 are transversely extending ports 119, two horizontal and two vertical, communicating between bore 115 and the interior of slot 105 for introduction of lubricating fluid into said slot 105. The construction of each connector assembly 108 (FIG. 2) is similar to connector assembly 107, except the various portions are smaller in diameter. Connector assemblies 108 includes a body portion 122 extending through slot 106, corresponding to body portion 115 through slot 105. The interiors of connector assembly 108 and slot 106 communicate with hydraulic tubing 124 for introduction of lubricating fluid into said slot. Slidable die plate 86 is retained in its lowermost position with bottom edge 94 spaced slightly from plate 36 (FIG. 6) by connector assemblies 107, 108 engaging the upper rounded slot end 113 of slot 105 and the upper rounded ends 123 of slots 106, respectively. Slots 105, 106 are of sufficient length to permit plate 86 to be fully elevated by wedges 88 without interference between the lower ends of said slots and connector assemblies 107, 108.

On base 19 at the output side of press assembly 12 a stop plate 125 (FIG. 2) is connected at an end 126 for pivoting about a horizontal pin 127 between a horizontal position and a vertical position parallel to the plates of die assembly 83 and across the feed path of workpiece 11, under the action of a conventional hydraulic cylinder 128 pivotally connected to plate 125 through yoke 129, pin 130 and bracket 131. When stop plate 125 is in the vertical position 125 (FIG. 2) workpiece 11 may be abutted against the plate to set initial positioning of the workpiece. The plate is withdrawn during the curving operation. During the pressing step of the curving operation the lower portion of workpiece 11 is held against die plates 35, 86 by a pair of hold-down bars 134 (FIGS. 5, 7 and 16) each depending from a mounting bracket 135 on the lower corner of punch plate 78 and including a cylindrical bar 134 adapted to engage workpiece 11 immediately above edge portion 15.

In operation, one of the pair of bracket members 25, 30 on chain 24 is located at the end of the upper run of said chain remote from press assembly 12 (FIG. 1), and workpiece 11 is placed on tubular members 32 with its trailing edge (relative to the direction of feed) extending across elongated bracket portion 26. An aperture 31 in the trailing edge portion of workpiece 11 (FIG. 3) is aligned with aperture 27 in bracket member 25 and pin 28 is inserted therethrough. Stop plate 12 is in the vertical position, and chain 24 with workpiece 11 is advanced by hydraulic cylinder 42 until the leading edge of workpiece 11 is against said plate 125 and workpiece 11 is correctly positioned within press assembly 12 for initiating the first pressing operation. Thereafter stop plate 125 is retracted from the feed path by hydraulic cylinder 128. The terminal points of travel of punch plate 78 are set through adjustment of spacing between bar 56 on piston rod 54 and box member 57 (FIG. 9).

Press assembly 12 is then actuated for causing hydraulic cylinder 54 to descend with punch plate 78 to form the first corrugation or pleat 132 (FIGS. 2, 18, 19) in workpiece 11 in conjunction with die assembly 83. In FIG. 7 punch plate 78 is illustrated in the pressing position. Thereafter, piston rod 54 with punch plate 78 ascend, and simultaneously workpiece 11 is advanced into position for a succeeding pressing operation by retraction of piston rod 39 of hydraulic cylinder 42 (FIG. 2). Because of ratchet wheel assembly 40 on shaft 221, extension of piston rod 39 causes no reverse rotation of sprocket wheel 23 thereon. Braking wheel 70 assures workpiece 11 will advance the predetermined desired distance without override, and such distance may be adjusted by adjusting the distance of travel of piston rod 39. During the pressing of workpiece 11 it is additionally held against die assembly 83 in place by hold-down bars 134 (FIG. 5).

When punch plate 78 is in the initial elevated position, the plates of die assembly 83 are positioned as shown in FIGS. 2, 5, 6 and 13. Lifting wedges 88 are withdrawn from engagement with slidable die plate 86 and said plate is supported by connector members 107, 108 with the upper die surface 95 thereof below the upper surfaces of spacer plate 85 and end plate 87 (FIGS. 13). As punch plate 78 descends hydraulic cylinders 98 are actuated, and lifting wedges 88 are extended initially to contact beveled corner portion 95 to elevate plate 86 and then to slide along lower edge 94 (FIG. 7). Die surface 91 of die plate 86 is level with die surface 89 of die plate 35 (FIG. 14). When punch plate 78 has descended to the pressing position (FIG. 15) die surface 81 thereof is received between rounded die surfaces 89 and 95 respectively of plates 35 and 86. All such die surfaces are rounded to correspond to the desired contour of corrugation 132.

Following the pressing operation punch plate 78 is elevated by hydraulic cylinder 53, and simultaneously lifting wedges 88 are withdrawn whereby plate 86 descends to permit advancement of workpiece 11 for a succeeding pressing operation. Lubricating fluid continuously is introduced under pressure into the interior of slots 105 and 106 in plate 86 through lines 118 and 124 (FIG. 5). When die plate 86 is moving upwardly the volume of the interior of the lower portion of slots 105 and 106 below the connector assemblies 107, 108 decreases and the fluid therein is forced between the die plates under high pressure to provide effective lubrication. On descent of plate 86 a similar pumping effect is obtained with fluid confined within the portion of slots 105 and 106 above the connector assemblies. The cycle is repeated until all desired corrugations 132 are formed.

Referring to FIG. 8, one form of workpiece 11 which advantageously has been utilized is formed of a strip of galvanized steel sheet having a major corrugation approximately 14 inches in depth, and with an overall width of approximately 24 inches including the two side edge portions 15 of approximately 2 inches width from the lower terminal point of the straight sloping side of major corrugation 14 to the edge of said workpiece. It is a desirable feature of this invention that the workpiece may be unlimited as to length. To obtain an arcuate structural panel 5 (FIGS. 17, 18) suitable for construction of arched structures of approximately 25 feet radius it has been found highly satisfactory to form corrugations or pleats 132 having a pitch of approximately 2 inches and a depth of approximately one-half inch, at the peak of major corrugation 14. Utilizing punch plate 78 and die assembly 83 as herein described, the corrugation 132 extends approximately two-

thirds the distance of the sloping side of major corrugation **14**, and is progressively shallower from the peak of major corrugation **14** to its lowest point **133** (FIGS. **17** and **18**). With the corrugations **132** so formed, workpiece **11** will accurately be curved in a longitudinal direction about a radius of 25 feet. Different degrees of curvature may be obtained by changing the pitch or depth or both of corrugations **132** formed. Curved panel **5** is utilized by bolting or otherwise fastening with similar panels 5 feet (FIGS. **18**) in side by side fashion at edge portion **15** and end to end.

It is to be understood that the claims appended hereto are intended to cover all changes and modifications of the example herein chosen for purposes of disclosure which do not depart from the spirit and scope of the invention, including method and apparatus in which a series of corrugations is progressively formed in a stationary workpiece by traveling forming means. No restriction is to be implied as to the initial configuration of the ridged workpiece. Alternative means for forming the corrugations or pleats may include roller devices, and when it is necessary to feed a workpiece it may be supported and advanced by a traveling die member, or alternatively, an intermittently rotated pressure roller may frictionally engage said workpiece for advancing it.

I claim:

**1**. A method of curving sheet material having at least one elongated ridge, to form an arc therein in the direction of extent of said ridge, comprising:

a. providing a corrugating station;

b. relatively moving said sheet material and said corrugating station along the longitudinal axis of said ridge;

c. progressively forming along said ridge a series of corrugations of predetermined depth, said corrugations each being directed transversely of said ridge;

d. at said corrugating station said corrugations each being formed by:

1. supporting said material at the surface thereof external to said arc to be formed therein against a first die surface,

2. supporting said material at said surface thereof against a second die surface spaced from said first die surface along said axis,

3. intercepting the opposite surface of said material and deforming said material against the said surfaces with a punch surface located therebetween, and

e. thereafter releasing said material by moving said punch surface and at least one of said die surfaces from said material in opposite directions normal to said axis for a distance at least as great as said predetermined depth.

**2**. The method of claim **1**, including:

f. forming said corrugations regularly spaced along said ridge, for curving said sheet material about a single point.

**3**. A method of curving an elongated strip having at least one rounded ridge extending longitudinally of said strip between opposite ends of said strip, to form an arc therein in the direction of extent of said ridge, comprising:

a. supporting said strip for movement along a longitudinal path of travel;

b. providing a corrugating station at a location along said path;

c. intermittently longitudinally advancing said strip to position successive portions of said strip at said corrugating station; and

d. at said corrugating station forming corrugations in each of said successive portions of said ridge, extending transversely thereof by;

1. at spaced points along said portions, supporting same at the surface thereof external to said arc to be formed in said strip against the surface of a first die element,

2. supporting same at said surface thereof against the surface of a second die element reciprocable in directions normal to said path, and

3. intermittently intercepting said path at a point between said spaced points from the side thereof internal of said arc to be formed in said strip with a surface of a corrugating element reciprocable in directions normal to said path; and

e. thereafter releasing said portions by retracting at least said first die element and said corrugating element in opposite directions normal to said path for a distance at least as great as said predetermined depth for permitting advancement of succeeding portions along said path.

**4**. Apparatus for curving an elongated strip having a rounded ridge extending longitudinally of said strip, to form an arc therein in the direction of extent of said ridge, comprising:

a. support means for supporting said strip for movement in a path along the longitudinal axis of said strip;

b. corrugating means positioned at a point along said path adapted for forming a corrugation of predetermined depth in said ridge transversely thereof;

c. Feed means for intermittently advancing said strip along said path and positioning said portions of said ridge at said point;

d. actuating means for actuating said corrugating means for forming a corrugation in each of said successive portions of said ridge;

e. said corrugating means including,

1. a punch member at the side of said strip internal to the arc to be formed therein and reciprocable in directions normal to said path,

2. a die assembly at the opposite side of said strip in opposed relationship to said punch member,

3. said punch member having a punch surface arcuately shaped transversely of said path for forming said corrugation transversely in said ridge, and

4. said die assembly including a portion retractable in a direction normal to said path a distance at least as great as said depth.

**5**. The apparatus of claim **4**, wherein:

f. said die assembly includes a die member reciprocable in directions normal to said path for positioning against the surface of said ridge at said opposite side of said strip during said forming and retraction therefrom for a distance at least as great as said depth prior to said advancing.

**6**. The apparatus of claim **5**, including:

g. at least one reciprocable wedge member engageable with sad die member for alternately positively moving said die member into position against said surface of said ridge and permitting retraction therefrom; and

h. means for imparting reciprocating motion to said wedge member.

**7**. The apparatus of claim **5**, including:

g. means for imparting reciprocating motion to said die member in said directions normal to said path;

h. a stationary member at each of two opposite sides of said die member in slidable contact therewith;

i. a source of lubricating fluid;

j. at least one aperture defined in said die member having a fixed dimension normal to the directions of movement thereof;

k. a conduit for conducting said fluid to within said aperture including a stationary conduit portion within said aperture substantially coextensive with said fixed dimension;

l. said fluid being positively urged between opposed surfaces of said stationary members and said die member by said reciprocating motion of said die member for lubricating said surfaces.

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