

Nov. 17, 1942.

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2,301,960

METHOD AND APPARATUS FOR FORMING METAL SHEETS

Filed Dec. 5, 1940

5 Sheets-Sheet 1

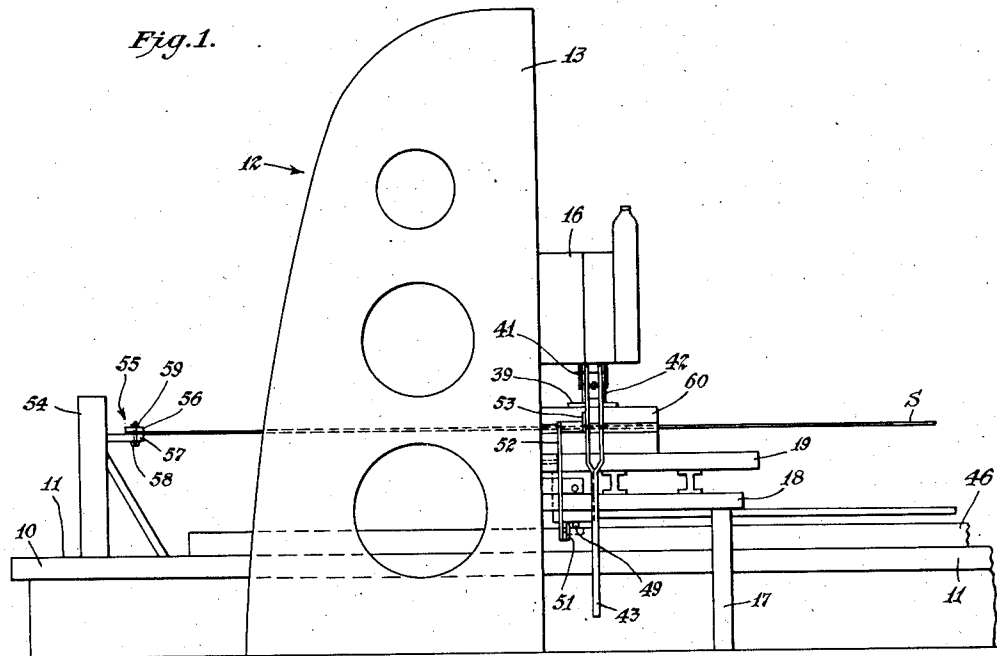
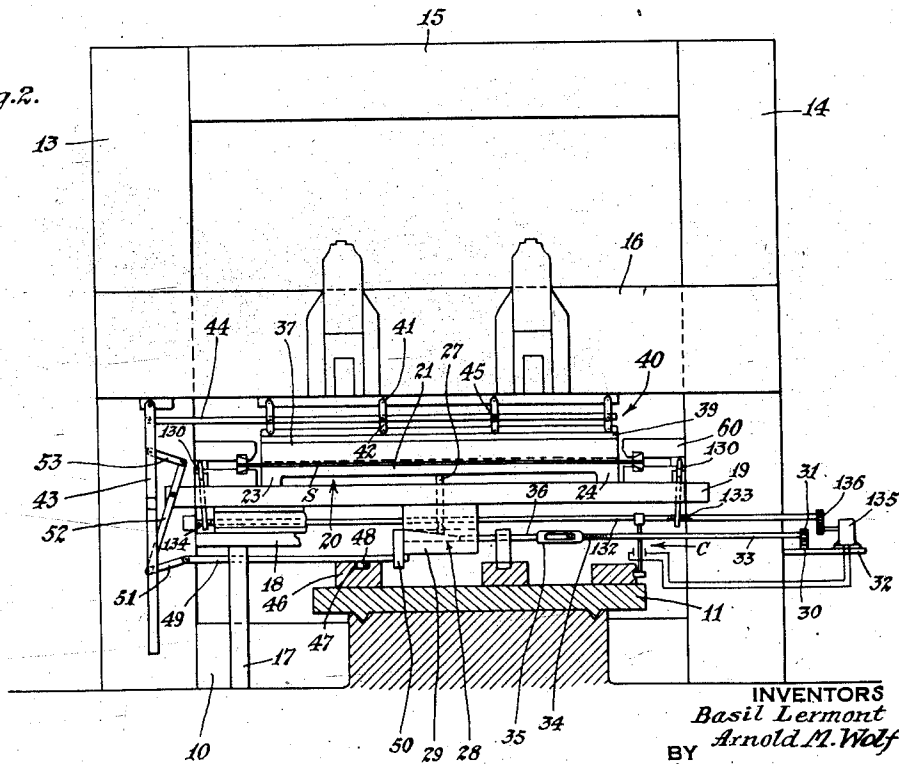


Fig. 2.



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5 Sheets-Sheet 2

Fig. 3.

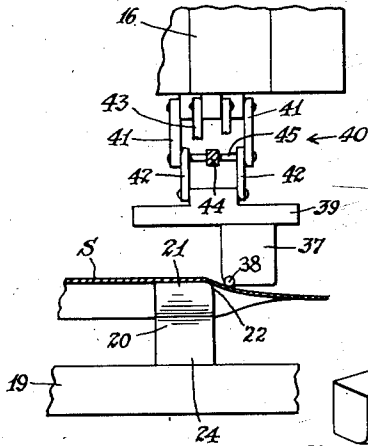


Fig. 4.

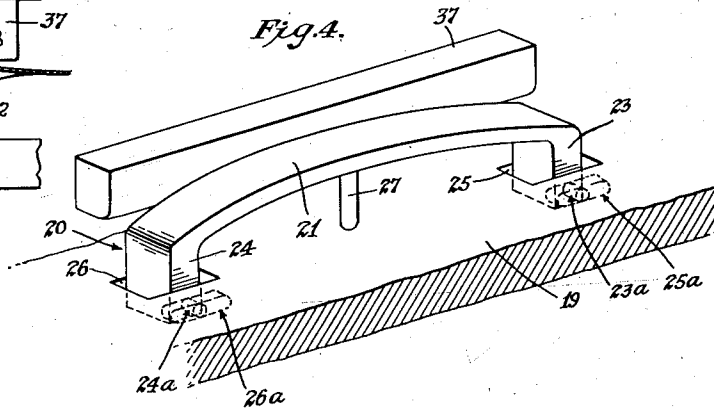
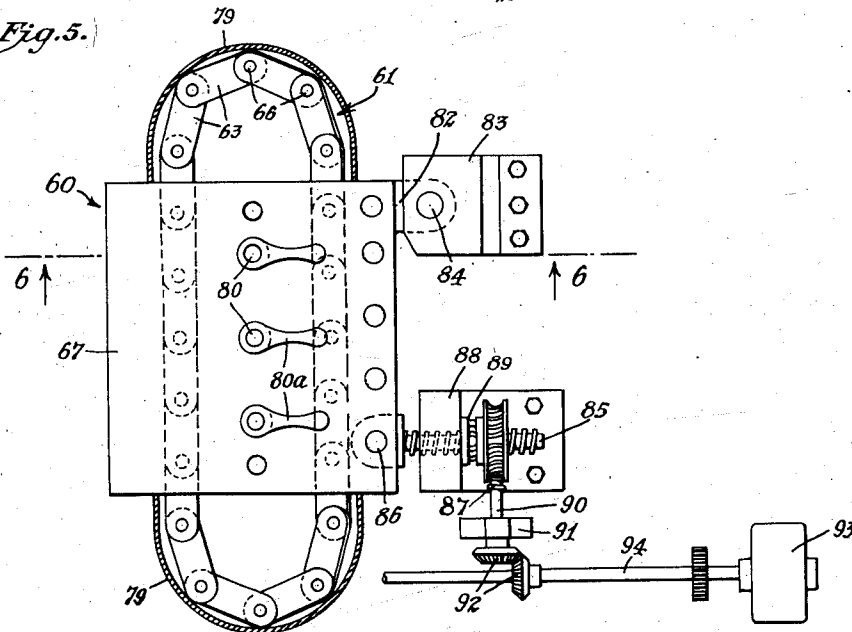


Fig. 5.



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Fig. 6.

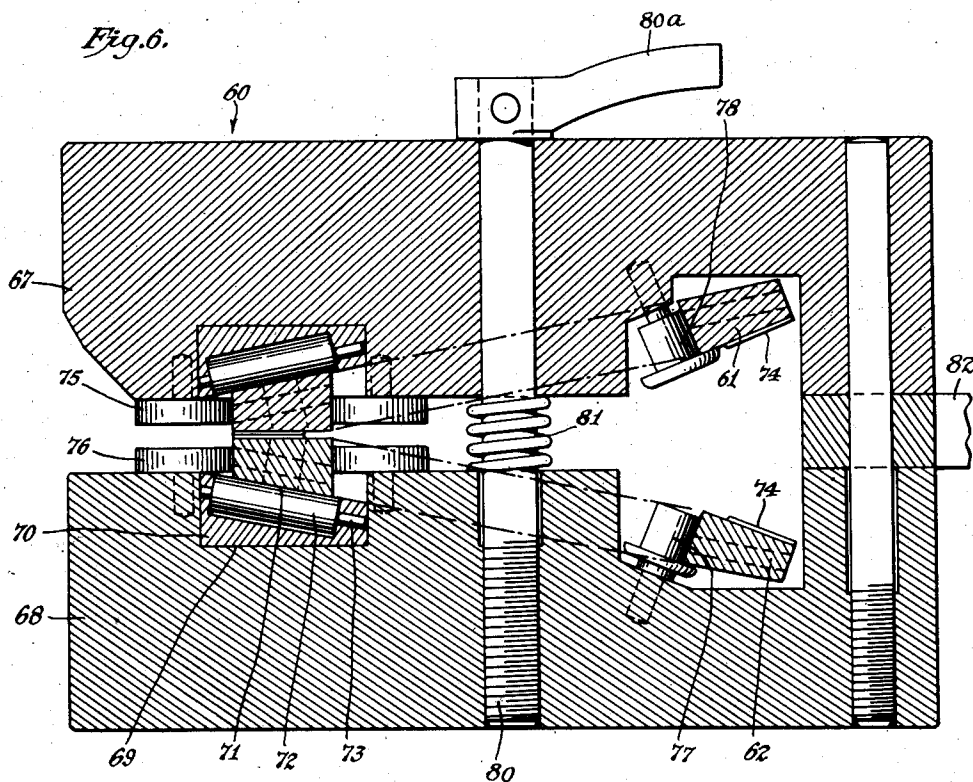


Fig. 7.

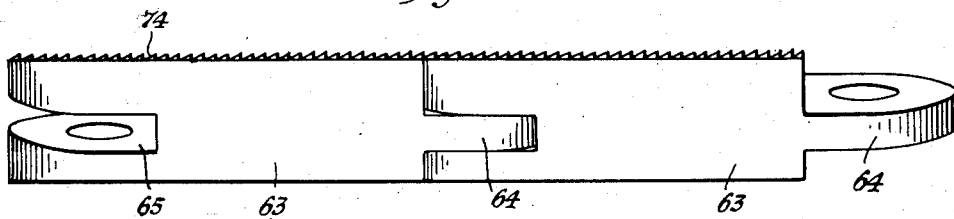
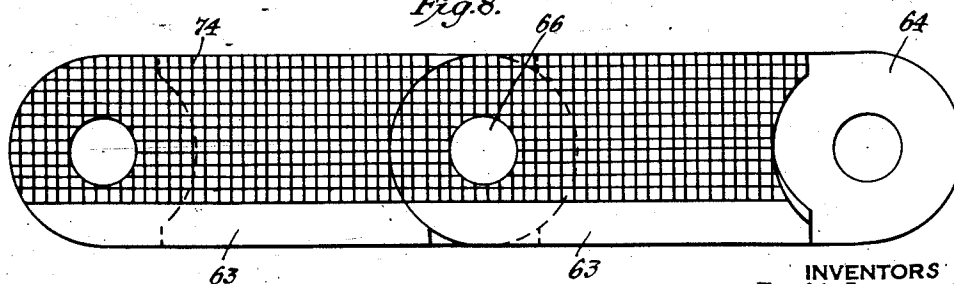


Fig. 8.



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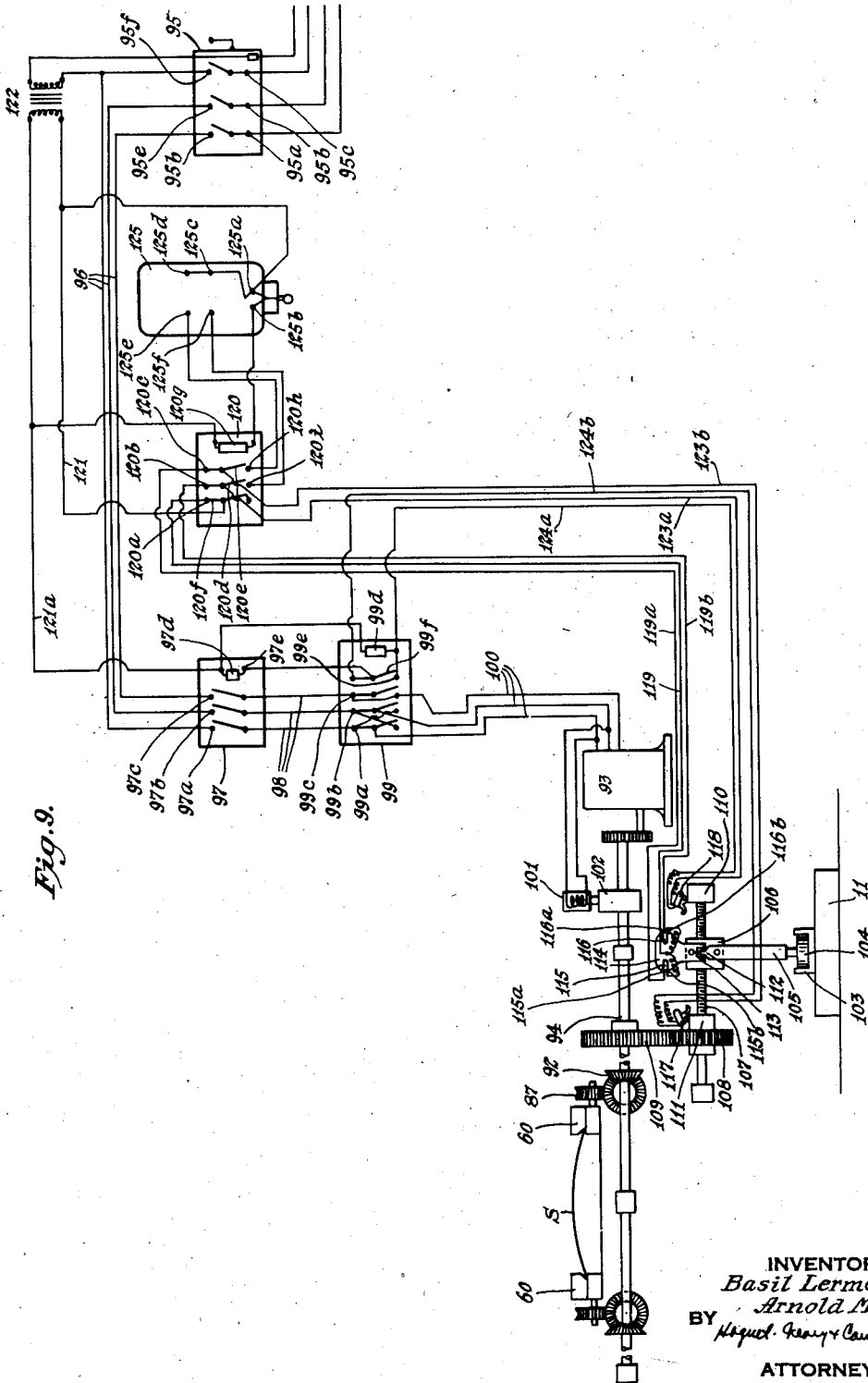
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Filed Dec. 5, 1940

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Fig. 10.

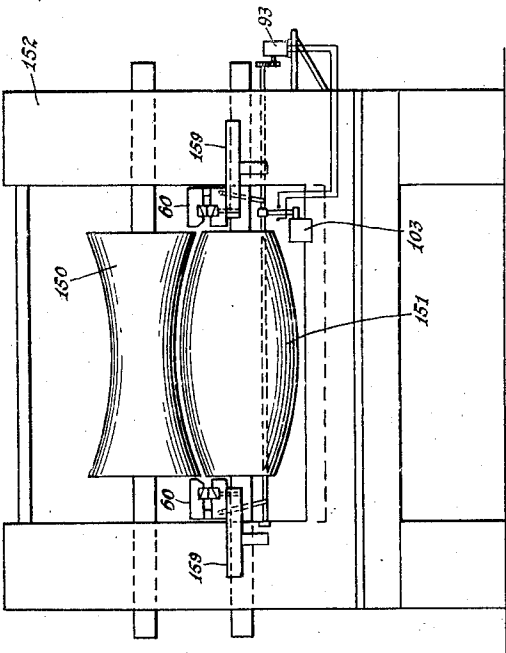
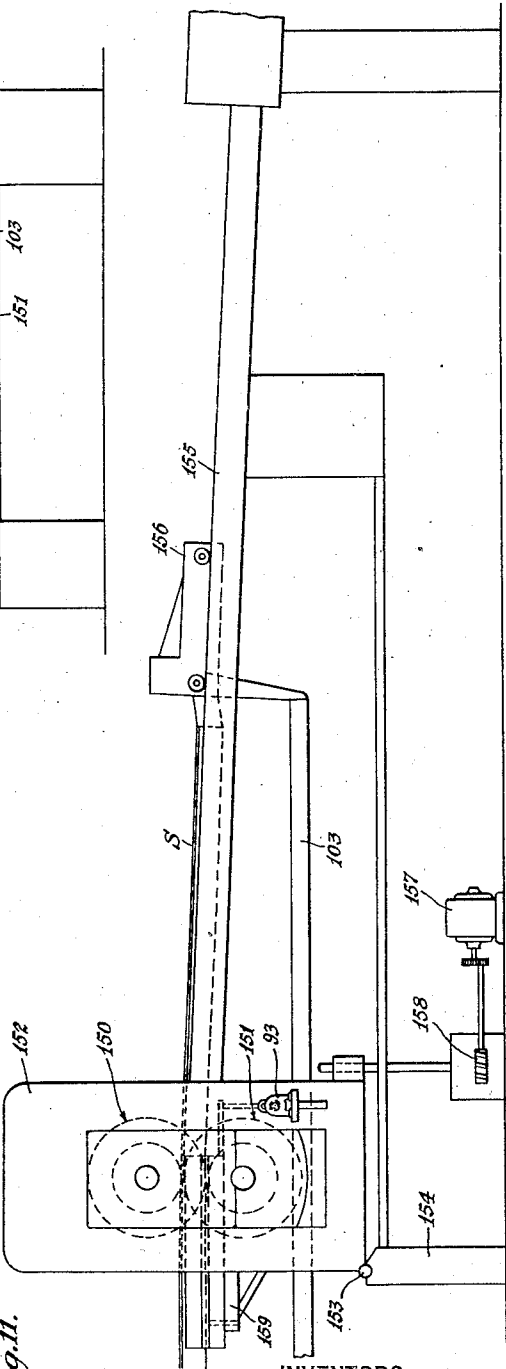


Fig. 11.



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METHOD AND APPARATUS FOR FORMING
METAL SHEETS

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Application December 5, 1940, Serial No. 368,604

22 Claims. (Cl. 153—2)

This invention relates to methods and devices for shaping sheets of metal into compound curved forms and relates more particularly to methods and devices for forming transversely and longitudinally curved sheets by means of a pulling or drawing operation.

Devices of the type embodying the invention are characterized by transversely curved forming elements by means of which sheets may be stretched at their centers and edges to varying degrees to cause the sheets to bulge and thereby assume transverse and longitudinal curvatures by pulling the sheets over said forming elements. The forming elements may be moved relatively to vary the curvature of the sheet. The sheets are stretched principally in the direction of pull but at the same time stresses are set up in the sheet having components extending at angles to the direction of pull. These stresses tend to cause the sheet to spring back or form the sheet into a coil. In addition to the mechanism described above the devices embodying the present invention may also include elements for limiting the shrinkage of or for stretching the sheet transversely to the direction of pull simultaneously with the longitudinal stretching operation in order to overcome the tendency of the sheets to form themselves into coils. The transverse stretching strains the sheet transversely in opposition to the transverse component set up by stressing sheet longitudinally and overcomes the tendency of the sheet to curl or form itself into a coil. This straining of the sheet transversely results in the accurate control and the stabilizing of the transverse curvature directly, as contrasted with the relatively uncontrolled transverse curvature imparted to the sheet as a component of the longitudinal stretch.

Devices of this type may be manually or automatically controlled to produce characteristically shaped sheets or large numbers of identical sheets of many different shapes, such as for example, aero-dynamically curved plates for use in the wings and fuselages of airplanes. Such aerodynamic forms usually are of varying curvature and must be carefully and accurately formed so that they may be joined without setting up undesirable stresses therein. The transverse stretching of the sheets together with the longitudinal stretching assures the formation of smooth sheets of accurately controlled curvature which do not tend to buckle or change shape due to unequally distributed stresses therein.

For the better understanding of the present in-

vention reference may be had to the accompanying drawings, in which

Fig. 1 is a view in side elevation of a typical form of device embodying the present invention;

Fig. 2 is a view in end elevation of the device;

Fig. 3 is a view in side elevation of the forming elements of the device;

Fig. 4 is a perspective view of the cooperating curved and straight edge forming elements of the device;

Fig. 5 is a plan-view of one of the elements for transversely stretching the sheet of metal;

Fig. 6 is a view in section taken on line 6—6 of Fig. 5;

Figs. 7 and 8 are respectively side and top views of portions of the links forming the gripping elements of the transverse stretching device;

Fig. 9 is a wiring diagram of the controls for the transverse stretching mechanism;

Fig. 10 is a view in side elevation of a modified form of device embodying the invention; and

Fig. 11 is an end view of the device disclosed in Fig. 10.

In the form of the invention disclosed in Figs. 1 to 4 the sheet shaping mechanism is applied, for example, to a conventional metal planer. This device includes a supporting framework 10 upon which is slidably mounted a draw bench 11 which is adapted to be moved longitudinally of the supporting frame 10.

The device includes a standard 12 consisting of side elements 13 and 14 connected by a cross member 15 and having a planer crosshead 16 extending between the side elements 13 and 14 about midway of their height.

A secondary framework, which consists of supporting legs 17 and having a platform 18 further supported on the standards 13 and 14, serves as a support for the lower forming element of the device, presently to be described. The platform 18 also supports a second spaced platform 19 upon which the lower forming element 20 is directly supported as best shown in Figs. 3 and 4. The lower forming element 20 consists of a flexible bar 21 of generally rectangular cross-section but having a curved leading edge 22 and downwardly projecting end portions 23 and 24 which are received in recesses 25 and 26, respectively, in the supporting platform 19. The recesses 25 and 26 are of substantially the same width as the end portions 24, but are of greater length in order to permit the end portions to move toward and away from each other. The end portions 23 and 24 may be secured in the slots 25 and 26 by means of pins 23a and 24a which pass through the end

portions and are received in slots 25a and 26a in the sides of the slots 25 and 26.

The bar 21 normally is flat, but can be bowed transversely by means of a plunger 27 which projects upwardly through the platform 19 and is moved in a vertical direction by means of a tapered cam 28.

The cam 28 is slidably supported in a housing 29 which is secured to the under surface of the platform 19, said cam being movable only in a horizontal direction. The movement of the cam 28 is controlled by a rack and pinion construction 30 and 31, the rack 30 being supported for sliding movement on a platform 32 which projects laterally from the standard 14. The rack may be moved endwise in any desired way as, for example, by means of a crank and pinion (not shown).

The pinion 31 is fixed to a horizontal shaft 33 and has an externally threaded inner end 34 which is received in a turn buckle 35 on the end of a rod 36 which is connected to the right-hand end of the cam 28. Upon endwise movement of the rack 31 the shaft 33 is rotated thereby screwing it into or out of the turn buckle 35 and shifting the cam 28 endwise. As the cam 28 moves to the right the plunger 27 is moved upwardly causing the strip 21 of the forming element to bend upwardly. As the inclined cam 28 moves to the left the normal resiliency of the strip 21 of the forming element 20 causes it to straighten and tend to return to its initially flat form.

As best shown in Figs. 2 and 3, a second cooperating forming element is also provided for causing the sheet of material S to be stretched and worked and thereby shaped into transversely and longitudinally curved form. This forming element 37 consists of an elongated block preferably formed of metal to afford strength and having a generally rectangular cross section. The lower left-hand edge of the block 37 as viewed in Fig. 3 is rounded and, if desired, may consist of a circular steel rod 38 which forms a smooth surface under which a sheet of metal S may be drawn. The block 37, as best shown in Fig. 3, is supported by a plate 39 which in turn is connected to the cross-head 16 by means of a toggle construction 40. The toggle construction consists of a plurality of pairs of links 41 joined pivotally to the under edge of the cross-head 16. The lower ends of the links 41 are connected to the upper ends of other pairs of links 42 which in turn are pivotally connected to the upper surface of the plate 39.

The toggle construction 40 is collapsed and expanded by means of a lever 43 which is pivotally connected to the under surface of the crosshead 16 and is provided with a horizontally extending link 44 which is connected to the shafts 45 connecting the adjacent ends of the links 41 and 42 of the toggle. Thus upon movement of the lever 43 to the left as viewed in Fig. 2 the toggle is collapsed lifting the forming element 37 and upon movement of the lever 43 to the right the forming element 37 is moved downwardly to a position below the upper surface of the forming element 20 when the latter is in its uncurved position. The intermediate adjustments of the toggle permits the relationship of the forming elements 37 and 20 to be varied at will to control the amount that the sheet S is bent and stretched in passing between these elements.

The position of the forming element 37 may be controlled by a cam 46 having cam track 47 therein which is supported by the draw bench

11 and movable therewith. The cam track 47 receives a roller 48 which is fixed to a horizontal rod 49 which is adapted to move endwise under the control of the cam track. The right-hand end of the rod 49 as viewed in Fig. 2 is received in a bushing 50 connected to the housing 29 while the opposite end is pivotally connected to a link 51 which is, in turn, pivotally connected to a lever 52 pivotally mounted on the upright 13. The upper end of the lever 52 is connected by means of a link 53 to the lever 43 whereby endwise movement of the rod 49 under the control of the cam track 47 will move the lever 43 to the left or right and thereby raise or lower the forming element 37, as described above.

The relationship between the forming elements 37 and 20 and the curvature of the upper surface of the forming element 20 determine to a large extent the transverse and longitudinal curvature imparted to the sheet S. It will be understood that inasmuch as the sheet S is bent more at its center by passing beneath the forming element 37 and over the curved upper edge of the forming element 22 than it is at its edges, the center of the sheet when drawn between these elements will be stretched to a greater extent than its edges. These added increments of length tend to cause the sheet to curve longitudinally and transversely. By moving the forming element 37 upwardly and downwardly the longitudinal curvature can be varied and by bending the forming element 20 to a greater or lesser extent both the longitudinal and transverse curvatures can be varied. Thus by gradually changing the curvature of the forming element 20 and by gradually moving the forming element 37 relative to the forming element 20 the curvature of the sheet can be varied throughout its length.

Preferably the sheet is drawn between these forming elements by means of the draw bench 11 which, as illustrated in Fig. 1, is provided with a standard 54 having rearwardly projecting gripping jaws 55 thereon. The gripping jaws may consist of a pair of plates 56 and 57 which have roughened insert portions, such as for example, file-like teeth for seizing the end of the sheet S. The plates 56 and 57 may be clamped together by means of bolts 58 and nuts 59.

In accordance with the present invention means are also provided for preventing wrinkling of the sheets, which is sometimes caused by flow of the metal from the edges to the center of the sheet as the center of the sheet is stretched and also for eliminating undesirable stresses at an angle to the direction of pull of the sheet which would tend to cause the sheet to curl up. As shown in Figs. 1 and 2 devices 60 are provided for gripping the edges of the sheet outwardly of the ends of the forming elements 20 and 37. As best shown in Figs. 5 to 9 the elements 60 include pairs of chains 61 and 62 which are mirror images and are inclined with relation to each other so as to be brought into engagement with the edges of the sheet S on the side adjacent the forming element and separated on the side remote from the edge of the sheet in order to facilitate entry of the sheet between the chains. As shown in Figs. 7 and 8 the chains consist of a plurality of links 63, of generally trapezoidal cross-section, each having at one end a tongue 64 and at the other end a groove 65 for receiving the tongue 64 on the next adjacent link. The links are connected by means of pins 66 which pass through the tongue 64 and the portions of the links defining the groove 65. The ends of

the links 63 may be suitably curved and recessed in order to permit relative pivotal movement.

The chains 61 and 62 are supported in a suitable framework which may consist of a housing and guide element, which is generally C-shaped in cross-section, formed of an upper section 67 and a lower section 68. The lower section 68 is provided with a stepped longitudinally extending recess 69 in which is received a generally trapezoidal insert 70 having an inclined upper surface corresponding in inclination to the inclined outer surface 71 of the links 63. The insert 70 has a longitudinally extending recess in which are received a plurality of rollers 72 for supporting the chain 62 for movement with a minimum of friction. The rollers 72 are supported upon shafts 73 having their ends received in bores in the walls of the insert 70. The inclination of the rollers 72 and the outer surfaces 71 of the links 63 is such that the gripping faces 74 of the links are disposed horizontally on the pass adjacent the edge of the sheet S. The upper chain 61 is similarly anti-frictionally supported by an insert and roller construction in the upper section 67 identical with that supporting the lower chain 62.

Outward movement of the links of the chains 61 and 62 is provided by means of rollers 75 and 76 supported by the upper section 67 and the lower section 68, respectively, which engage the outermost edges of the chains. The rearward pass of the chain 61 is supported by rollers 77 in the lower section 68 and the rearward pass of the upper chain 61 is supported by rollers 78 in the upper section 67 so that the proper inclination of the chains without buckling or binding is assured.

The outer curved ends of the chains may be covered by suitable semi-circular housings 79 supported on opposite ends of the blocks 67 and 68.

The sections 67 and 68 may be separated in order to facilitate repair and to permit the edge of the sheet S to be initially inserted therebetween. This is accomplished by means of the threaded pins 80 which pass through both of the sections 67 and 68 and thus upon rotation by means of the handles 80a permit the sections 67 and 68 to be moved together or separated. Springs 81 may be interposed between the sections 67 and 68 to facilitate their separation.

The construction described above, if fixedly connected to the platform 19, would prevent inward shrinkage of the metal while passing between the forming elements. In many instances a mere retention of the initial width of the sheet by means of these gripping elements is sufficient to prevent the coiling of the sheets, but when working with other types of materials and when different degrees of curvature are to be imparted to the sheet it is often desired to support the gripping elements 60 in such a manner that they may stretch the sheet transversely.

A mechanism for so moving the gripping and stretching elements 60 is shown in Fig. 5. This construction consists of a lug member 82 which may be rigidly connected to one of the members 68 or 67 and is connected to a boss 83 by means of a pivot pin 84. The boss 83 is bolted firmly to the platform 19. The gripping and stretching member 60 therefore may be moved about the pivot pin 84 by the preferred mechanism illustrated in Fig. 5, or by the simpler mechanism shown in Fig. 2, in order to control the amount of stretch to be imparted to the sheet. In the

mechanism disclosed in Fig. 5 the stretching element 60 is moved about the pivot pin 84 by means of a shaft 85 having its right-hand end, as viewed in Fig. 5, slidably pivotally connected to the element 60 by means of a pivot pin 86. The opposite end of the shaft 85 is threaded and is received in a threaded bore in a worm gear 87. The shaft 85 is supported in a boss 88 and a thrust bearing 89 is interposed between the boss 88 and the worm gear 87. The worm 87 is mounted on a shaft 90 which is supported in a journal 91 and is driven through bevelled gearing 92 by means of a motor 93. The bevelled gearing is driven by a transverse shaft 94 which in a similar manner to that described above is attached to the gripping and stretching element 60 at the opposite side of the machine. Thus upon operation of the motor 93 in one direction or the other the gripping and transverse stretching elements 60 are swung around the pivot pins 84 inwardly or outwardly. Inasmuch as the sheet will be gripped firmly by the chains 61 and 62, the sheet will be stretched as it moves along while retained by the gripping element, if the chains in opposite gripping and separating elements 60 diverge. Preferably the shaft 85 which controls movement of the forming elements is substantially in axial alignment with the forming elements 20 and 37 and accordingly will impart the greatest amount of stretch to the sheet at the time it is being stretched longitudinally.

The amount of transverse stretch imparted to the sheets is extremely small per inch of width of the sheet under most conditions. However, this stretch is sufficient to interpose stresses transversely of the sheet which tend to neutralize the stresses extending longitudinally of the sheet and thereby produce a stable form of curved sheet having no tendency to curl or coil up. In addition since the sheets are gripped at their edges throughout a zone extending from forwardly of the forming elements 20 and 37 to these forming elements any tendency of the edges to wrinkle is entirely eliminated. As a result a smooth curved sheet which does not require additional working is obtained by means of this device.

The control of the transverse stretch to be imparted to the sheet may be accomplished manually. However, for large scale production and when it is desired to duplicate the curvature of a large number of sheets it is preferable to control the movement of the elements 60 automatically. A circuit for controlling the forming elements is shown diagrammatically in Fig. 9. The mechanism for controlling the forming elements 60, as described above, includes a motor 93 for driving a shaft 94 and by means of the bevelled gearing 92 and the worm and worm gear, controls the movement of the forming elements 60. The power circuit for the motor 93, which may be a conventional three-phase sixty-cycle reversing motor, includes a main control switch 95 having the contacts 95a, 95b and 95c thereof connected to the service lines. The opposite contacts 95b, 95e and 95f are connected by suitable lines 96 to the input contacts 97a, 97b and 97c of a relay switch having solenoid relay actuating coil 97d. The blades of the relay switch 97 are connected by suitable wiring 98 to the input contacts 99a, 99b and 99c of a reversing relay double throw switch including the actuating solenoid 99d. The output contacts of the switch 99 are connected by means of suitable leads 100 to the motor 93. Two of the leads 100 are further connected to a

solenoid coil 101 which controls the operation of conventional solenoid control spring brake 102 which operates to stop the shaft 94 immediately when energization of the motor ceases. When the motor 93 is energized, the solenoid 101 is likewise energized and the brake 102 is released thereby permitting the motor to operate.

The control circuit for actuating the relay switch 97 and the reversing relay double throw switch 99 which is normally biased to cause the motor 93 to rotate in one direction will now be described. The direction and amount of operation of the motor may, as illustrated, be controlled by a suitable cam 103 which is supported by the draw bench 11 and movable therewith. The cam 103 may have an appropriate contour to cause a variation in the transverse stretch to be imparted to the sheet. Engaging in the cam 103 is a roller 104 which is mounted upon a lever 105. The lever 105 is pivotally connected to an internally threaded block 106 which is supported by a threaded shaft 107 that is driven by means of gears 108 and 109, the latter being fixed to the shaft 94 to rotate therewith. Thus upon rotation of the shaft 94 the threaded block 106 will move to the right or left along the threaded shaft 107 which is suitably supported by journal blocks 110 and 111. The ratios of these gears may be such that a relatively large traverse of the block 106 takes place for a small shifting movement of the stretching elements 60. The upper end of the lever 105 is provided with a finger 112 which engages between a pair of fingers 113 on an upwardly projecting plate 114 which is likewise pivotally connected to the block 106. Thus upon rocking of the lever 105 in one direction the plate 114 will rock in the opposite direction. This movement of the plate 114 is utilized to control the operation of a pair of mercury switches 115 and 116 which are provided with suitable contacts 115a and 115b and 116a and 116b.

Movement of the block 106 along the threaded shaft 107 is limited by means of other mercury switches 117 and 118 which are pivotally mounted on the journal blocks 111 and 110, respectively. The mercury switches 117 and 118 are provided with suitable abutments which upon engagement by the block 106 rock the switches into their open position, these switches normally being closed. Movement of the various mercury switches 115, 116, 117 and 118 control the operation of the motor, 93.

The contacts 115b and 116b of the mercury switches 115 and 116 are connected to a common lead 119 which is connected in turn to the contact 120a of a change-over relay double throw switch 120. The contacts 115a and 116a are connected by leads 119a and 119b, respectively, to the contacts 120b and 120c of the switch 120. The contact 120a of the switch is connected through the switch blade 120f, lead 121 to one side of a transformer 122 which is energized from the service lines and placed into operation by the main switch 95. The blades 120d, and 120e are normally connected to the contacts of 120b and 120c respectively, and are connected by means of leads 123a and 123b to one contact of each of the mercury switches 118 and 117, respectively. The other contacts of the switches 118 and 117 are connected by means of leads 124a and 124b to the solenoid control circuit for the switches 97 and 99. The lead 124a is connected to the solenoid coil 99d and

the contact 99e through the solenoid 99d to one end 97e of the solenoid 97d and thence through the conductor 121a to the opposite side of the transformer. The lead 124b is connected to the switch blade 99f of the switch 99 and through the blade 99f to the contact 97e of the solenoid coil 97d of the switch 97.

Assuming that the curvature of the cam 103 is such as to move the roller 104 to the right slightly, the lever 105 will swing counterclockwise and the plate 114 will swing clockwise, thus closing the mercury switch 116 and allowing current to flow from the transformer 122 through the blade 120f of the switch 120 to the contact 120a, through lead 119, through the switch 116, through the lead 119b, the contact 120b to the blade 120d, through the lead 123a, mercury switch 118, through lead 124a, through the solenoid 99d, the blade 99f, energizing the solenoid 97d and thence through the lead 121a, to the transformer 122, thereby causing the motor 93 to be energized by closing of the switch 97 and moving the switch from its normally biased position to reverse the motor and rotate the shaft 107 in such a direction as to move the block 106 to the right. When the block 106 is moved into such a position that the lever 105 is vertical, the solenoid switch 116 will be opened, de-energizing the solenoid coils 99d and 97d and opening the circuit to the motor and thereby deenergizing the motor 93 and causing the solenoid brake to stop rotation of the shaft 94. This movement to the right can continue until the block 106 trips the solenoid switch 118 which opens the circuit and prevents further movement of the block to the right.

If the cam 103 has a curvature such that the lever 105 is rocked clockwise the plate 114 is rocked counterclockwise, thereby closing the mercury switch 115. Closing of this switch permits current flow from transformer through lead 121 to blade 120f to contact 115b of mercury switch, the contact 115a, through lead 119a to contact 120c of the relay switch 120, to blade 120e, through lead 123b, through the solenoid switch 117 through lead 124b to blade 99f of the relay switch 99, to contact 97e of the solenoid 97d and through the lead 121a to the transformer 122 thereby energizing the motor 93 by closing the switch 97 causing the motor 93 to rotate in the opposite direction and moving the block 106 to the left. The switch 99 is normally biased to a position for causing the motor to drive the block to the left. The limit mercury switch 117 in this instance will open if there is a tendency for the block to overrun the left-hand end of the threaded shaft 107.

In order to permit manual control of the devices instead of automatic control a manual switch 125 may be provided which is connected to a solenoid coil 120g of the change-over relay switch 120. The contact 125a of the switch 125 is connected to the lead 121, the contact 125b is connected to one end of the solenoid coil 120g while the opposite end of the coil 120g is connected to the lead 121a. When the contacts 125b and 125a are connected by closing the switch 125 the solenoid 120g is energized and the blades 120d, 120e swing into engagement with the contacts 120i and 120h at the same time moving out of engagement with contacts 120b and 120c. The switch 125 is also provided with contacts 125c and 125d which are connected in parallel with the contact 125a. The contacts 125e and 125f

of the switch may be connected respectively to the contacts 120i and 120j of the switch and by means of the switch blades 120d and 120e thereof to the leads 123a and 123b of the mercury switches 117 and 118, the remainder of the automatic control switches being broken. By connecting contact 125d with contact 125e the motor 93 is driven in one direction and by connecting contact 125c with contact 125f the motor is driven in the opposite direction. In this way movement of the gripping and stretching mechanisms 60 may be controlled manually while at the same time causing movement of the block 106 along the threaded shaft 107 following movement of the motor. If desired, under these circumstances the lever 105 may be provided with a stylus which permits it to trace its path on a suitable surface, thereby providing secondary means for preparing a cam to automatically impart the same movements to the gripping and stretching elements if duplicate sheets are to be made.

The control mechanism described above can be applied readily to the device disclosed in Figs. 1 to 4. However, other forms of control mechanisms can be used if desired. For example, as shown diagrammatically in Fig. 2 the gripping elements 60 may be moved about their pivots by means of levers 130 which are pivotally supported on the platform 19 and have their upper ends engaging between the lugs 131 on the ends of the elements 60. The levers are moved by means of a shaft 132 having oppositely threaded portions 133 and 134 thereon. The shaft 132 is driven by a motor 135, by means of suitable reduction gearing 136. The motor control system may be the same as that disclosed in Fig. 9 and is indicated only diagrammatically as C.

The transverse stretching mechanism may be applied with equal facility to the type of device disclosed for example in the Cairns Patent No. 1,828,489, dated October 20, 1931, as shown in Figs. 10 and 11. In this form of device a pair of complementally curved concave and convex forming rolls 150 and 151 are supported for rotation in a frame 152 which is supported on a suitable pivot 153 for rocking movements relatively to a supporting base 154. Associated with this frame is a draw bench 155 upon which is mounted a carriage 156 adapted to grip the end of a sheet of metal S and draw it between the rolls. During movement of the sheet between the rolls the frame 152 is rocked by means of a motor 157 through suitable shafting and gearing in order to impart the desired longitudinal transverse curvature to the sheet. In this construction the transverse stretching elements 60 may be supported on suitable platforms 159 fixed to the frame 152. The motor 93 for moving the forming elements may be supported likewise on the frame and is controlled by the cam 103 which is connected at one end to the carriage 156 and moves therewith. The operation of this device is similar to that described above.

Devices embodying the present invention, as will be understood from the foregoing description, will impart a controlled smooth and stable longitudinal and transverse curvature to a sheet thereby rendering such sheets usable for many purposes and permitting the production of sheets of such curvatures as would be impractical to produce by the known methods of die stamping.

It will be understood that the above described embodiments of the invention are susceptible to considerable variation, such as for example

in size, shape, proportion and the manner in which the various elements thereof are supported. Therefore the forms of the invention described above should be considered as illustrative of the invention only and not as limiting the scope of the following claims.

We claim:

1. In a device for forming longitudinally and transversely curved sheets, the combination of a substantially straight member engageable with one surface of a sheet, a forming element having a curved portion engageable with the opposite surface of said sheet, means for pulling a sheet between said member and said element at an angle to cause said sheet to bend thereover and cooperative with said forming elements to stretch said sheet longitudinally to varying degrees from its center to its edges, and means for gripping the edges of said sheet at opposite ends of said forming elements to transversely stress said sheet as it passes over said member and said element.

2. In a device for forming longitudinally and transversely curved sheets, the combination of a pair of opposed forming elements, at least one of which has a longitudinally curved surface, means for pulling a sheet between said forming elements over said curved surface to bend and stretch said sheet transversely and longitudinally and thereby impart a longitudinal and transverse curvature to said sheet, and means for gripping the lateral edges of said sheet at opposite ends of the ends of said forming elements to stress said sheet transversely as it passes over said curved surface.

3. In a device for forming longitudinally and transversely curved sheets, the combination of a member engageable with one surface of a metal sheet to retain it in a substantially flat condition, a curved forming element engageable with the opposite surface of a sheet and offset with respect to said member to flex said sheet transversely and bend said sheet on a line extending transversely of said sheet, means to pull said sheet between said forming elements, and means for gripping the longitudinal edges of the sheet throughout a zone extending from at least in alignment with the ends of said forming element to in front of said forming element to stress said sheet transversely during its passage over said forming element.

4. In a device for forming longitudinally and transversely curved sheets, the combination of a member engageable with one surface of a metal sheet to retain at least a portion of the latter substantially in a plane, a forming element offset with respect to said plane engageable with the opposite surface of said sheet, means to pull said sheet between said forming elements and cooperating with said forming elements to bend, flex and stretch said sheet to impart a transverse and longitudinal curvature to said sheet, and means for gripping the longitudinal edges of the sheet and movable therewith throughout a zone extending from in front of said forming element at least into alignment with the ends of said forming element to stress said sheet transversely during its passage over said forming element.

5. In a device for forming longitudinally and transversely curved sheets, the combination of a pair of relatively offset forming elements having sheet engaging surface portions of different curvature for bending a sheet on a line extending transversely of the sheet and simultaneously

flexing said sheet transversely, means for drawing a sheet through said forming elements at an angle thereto to cause said sheet to engage said forming elements and to stretch the sheet longitudinally to different degrees from its center to its edges and impart a longitudinal and transverse curvature to said sheet, and means for gripping the lateral edges of said sheet throughout zones overlapping the ends of said forming elements for stressing the sheet transversely as it passes through said forming elements.

6. In a device for forming longitudinally and transversely curved sheets, the combination of a pair of relatively offset forming elements having sheet engaging surface portions of different curvatures for bending a sheet on a line extending transversely of the sheet and simultaneously flexing said sheet transversely, means for drawing a sheet through said forming elements at an angle thereto to cause said sheet to engage said forming elements and to stretch the sheet longitudinally to different degrees from its center to its edges and impart a longitudinal and transverse curvature to said sheet, and means for gripping the lateral edges of the sheet throughout zones overlapping said forming elements and stretching said sheet transversely as it passes through said forming elements.

7. In a device for forming longitudinally and transversely curved sheets, the combination of a pair of relatively offset forming elements having sheet engaging surface portions of different curvatures for bending a sheet on a line extending transversely of the sheet and simultaneously flexing said sheet transversely, means for drawing a sheet through said forming elements at an angle thereto to cause said sheet to engage said forming elements and to stretch the sheet longitudinally to different degrees from its center to its edges and impart a longitudinal and transverse curvature to said sheet, and elements extending throughout zones overlapping each end of said forming elements for gripping the edges of said sheet and movable with the latter for stressing said sheet transversely during its passage through said forming elements.

8. In a device for forming longitudinally and transversely curved sheets, the combination of a pair of relatively offset forming elements having sheet engaging surface portions of different curvatures for bending a sheet on a line extending transversely of the sheet and simultaneously flexing said sheet transversely, means for drawing a sheet through said forming elements at an angle thereto to cause said sheet to engage said forming elements and to stretch the sheet longitudinally to different degrees from its center to its edges and impart a longitudinal and transverse curvature to said sheet, and elements extending throughout zones overlapping each end of said forming elements for gripping the edges of said sheet, means for restraining said gripping elements against inward movement and means for varying the angular relationship between said gripping elements and the longitudinal axis of said sheet to stretch the sheet transversely during its passage through said forming elements.

9. In a device for forming longitudinally and transversely curved sheets, the combination of an elongated flexible forming element, means for flexing said forming element into a longitudinally bowed form, a second forming element having a straight forming surface adjacent to said flexible forming element, means for moving said second forming element into overlapping relationship

with said flexible forming element and means for drawing a sheet of metal successively over said straight forming surface and said flexible forming element at such an angle as to cause said sheet to engage said surface and said element and be bent and stretched thereby to impart a longitudinal and transverse curvature to said sheet.

10. In a device for forming longitudinally and transversely curved sheets, the combination of an elongated flexible forming element, means for flexing said forming element into a longitudinally bowed form, a second substantially straight elongated forming element adjacent to said flexible forming element, means for moving said forming elements relatively into and out of overlapping relationship and means for drawing a sheet of metal successively over said forming elements at substantially right angles to the longitudinal axes thereof and at such an angle as to cause said sheet to engage said forming elements and be bent and stretched thereby.

11. The device set forth in claim 10 in which the means for flexing the flexible forming element comprises a cam and the means for moving said forming elements relatively comprises a toggle.

12. In a device for forming longitudinally and transversely curved sheets, the combination of an elongated flexible forming element, means for flexing said forming element into a longitudinally bowed form, a second substantially straight elongated forming element adjacent to said flexible forming element, means for moving said forming elements relatively into and out of overlapping relationship, means for drawing a sheet of metal over said second forming element toward and over said flexible forming element at substantially right angles to the longitudinal axes thereof and means for gripping the edges of the sheet and stressing the sheet transversely while it is being drawn between said forming elements.

13. In a device for forming longitudinally and transversely curved sheets, the combination of an elongated flexible forming element, means for flexing said forming element into a longitudinally bowed form, a second elongated substantially straight forming element adjacent to said flexible forming element, means for moving said forming elements relatively into and out of overlapping relationship, means for drawing a sheet of metal over said second forming element toward and over said flexible forming element at substantially right angles to the longitudinal axes thereof, means for gripping the edges and movable with said sheet throughout a zone extending from in alignment with said forming elements to in front of said forming elements, to stress said sheet during passage of the latter between said forming elements, and means for varying the angle between said means for gripping said sheet to vary the amount said sheet is stressed.

14. In a device for forming longitudinally and transversely curved sheets, the combination of an elongated flexible forming element, means for flexing said forming element into a longitudinally bowed form, a second elongated forming element adjacent to said flexible forming element, means for moving said forming elements relatively into and out of overlapping relationship, means for drawing a sheet of metal over said second forming element toward and over said flexible forming element at substantially right angles to the longitudinal axes thereof, a pair of chain members adjacent each end of said forming means

for receiving the edges of said sheets, means for forcing portions of said pairs of chain members together to grip the edges of said sheets and means for varying the angles between said pairs of chain members.

15. In a device for forming longitudinally and transversely curved sheets, the sub-combination of two pairs of traveling chain members for receiving the edges of said sheets, means for forcing portions of said pairs of chain members together to grip the edges of said sheets and means for varying the angular relationship of said pairs of chain members on opposite sides of said sheet with respect to each other to vary the stress imparted transversely to said sheet comprising a reversible motor for moving adjacent ends of said pairs of chain members toward and away from each other, an elongated cam member movable with said sheet, a cam follower movable by said cam, switching means controlled by said cam follower, a circuit including switches for controlling the direction of operation of said motor, and a second circuit for controlling said switches responsive to operation of said switching means for controlling the direction and amount of operation of said motor.

16. In a device for forming longitudinally and transversely curved sheets, the sub-combination of two pairs of traveling chain members for receiving the edges of said sheets, means for forcing portions of said pairs of chain members together to grip the edges of said sheets and means for varying the angular relationship of said pairs of chain members on opposite sides of said sheet with respect to each other to vary the stress imparted transversely to said sheet comprising a reversible motor for moving adjacent ends of said pairs of chain members toward and away from each other, an elongated cam member movable with said sheet, a cam follower movable by said cam switching means controlled by said cam follower, a circuit including switches for controlling the direction of operation of said motor, and a second circuit for controlling said switches responsive to operation of said switching means for controlling the direction and amount of operation of said motor.

17. In a device for forming longitudinally and transversely curved sheets, the sub-combination of means for gripping portions of the edges of a sheet and traveling with said sheet, means pivotally supporting said gripping means, and means for varying the angular relationship of the gripping means on opposite sides of said sheet with respect to each other to vary the stress imparted to said sheet comprising a reversing motor, a circuit including switches for controlling the operation and direction of operation of said motor, a threaded shaft operated by said motor, a threaded member on said shaft and movable in opposite directions therealong by said motor, an elongated cam movable with said sheet, a cam follower pivotally supported on said threaded member and movable by said cam,

switching means actuated by movement of said follower, and a circuit including said switching means for controlling said switches to render the said motor responsive to the contour of said cam.

18. A method of forming transversely and longitudinally curved sheets comprising pulling an initially flat sheet of metal over at least one forming element curved transversely to the direction of movement of said sheet, changing the angle at which said sheet is pulled over said forming element to impart a varying longitudinal and transverse curvature to said sheet, and stressing said sheet transversely during passage of said sheet over said forming element to neutralize the longitudinal stresses therein and prevent the formation of wrinkles in said sheet.

19. A method of forming longitudinally and transversely curved sheets comprising drawing a sheet of metal over a substantially straight element while bending said sheet on a transverse line, drawing and bending said sheet over another forming element having a curvature transversely of said sheet to stretch said sheet longitudinally to varying degrees from its center to its edges and stressing said sheet transversely as it is drawn over said forming elements.

20. A method of forming longitudinally and transversely curved sheets comprising drawing a sheet of metal over a substantially flat member while bending said sheet on a transverse line, drawing and bending said sheet over a forming element offset at least partially out of the plane of said member having a curvature transversely of said sheet to stretch said sheet longitudinally to varying degrees from its center to its edges and stretching said sheet transversely as it is drawn over said forming element.

21. An apparatus for forming curved sheets which comprises means for gripping portions of the opposite edges of a sheet of metal and exerting a tension thereon tending to hold said sheet flat, means for varying the spacing of said gripping means to vary the tension exerted on said sheet, a curved forming member engageable with said sheet between said gripping means to bend said sheet into transversely curved form, means for adjusting said forming member to vary the curvature of said sheet, and means for pulling the sheet over said forming member and through said gripping means.

22. In a device for forming longitudinally and transversely curved sheets, the subcombination of two pairs of endless traveling chain members positioned on opposite sides of a traveling sheet, each pair serving to grip one longitudinal edge of said sheet, means for forcing portions of said pairs of chain members together to grip the edges of said sheet and means for variably positioning said chain members with respect to each other for varying their relative angular relationship and thereby varying the lateral pull of said members on the sheet gripped thereby.

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