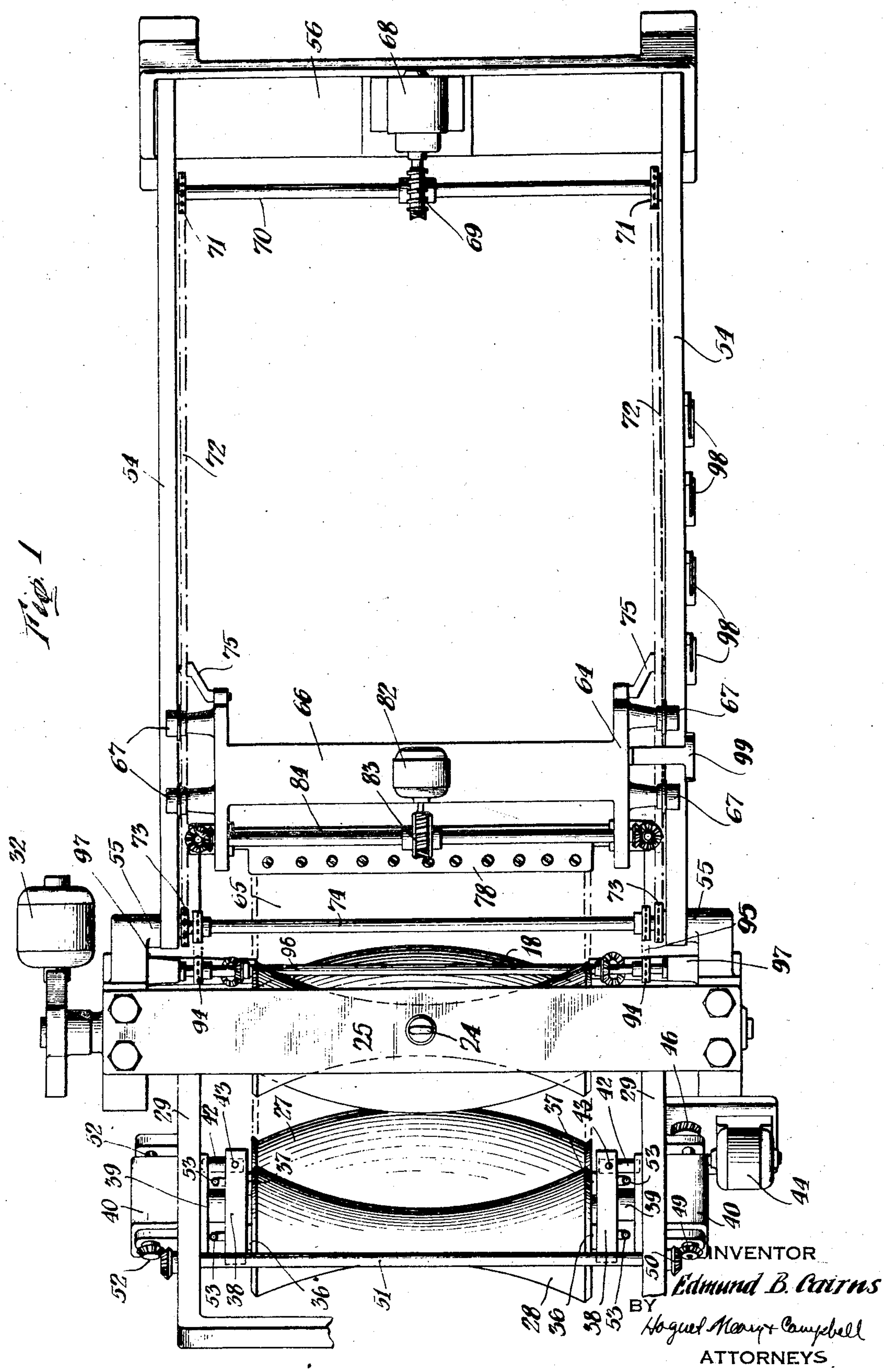
Aug. 5, 1941. E. B. CAIRNS 2,251,901

METHOD AND APPARATUS FOR ROLLING CURVED SHEETS

Filed July 27, 1938 4 Sheets-Sheet 1



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METHOD AND APPARATUS FOR ROLLING CURVED SHEETS

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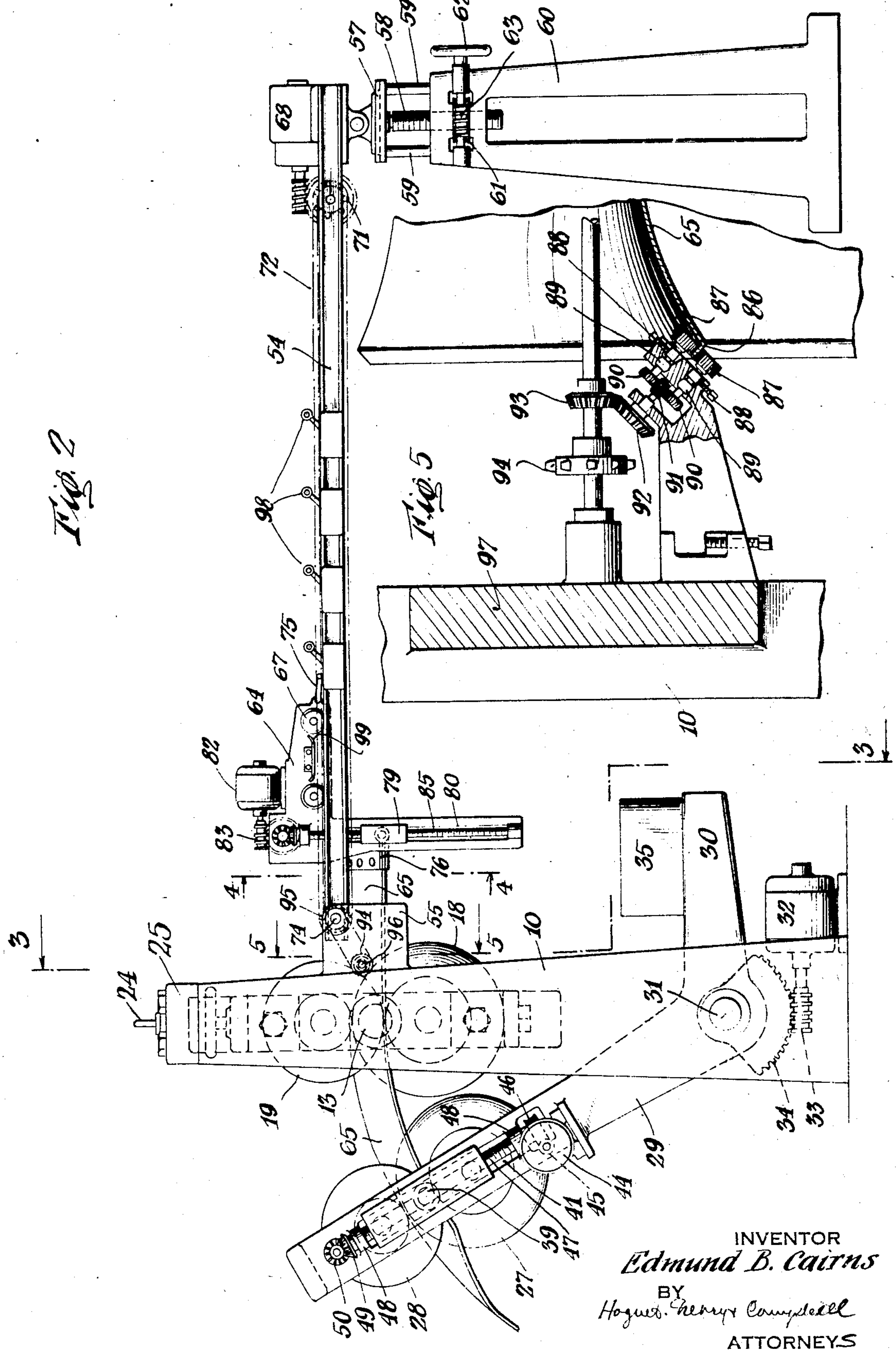

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METHOD AND APPARATUS FOR ROLLING CURVED SHEETS

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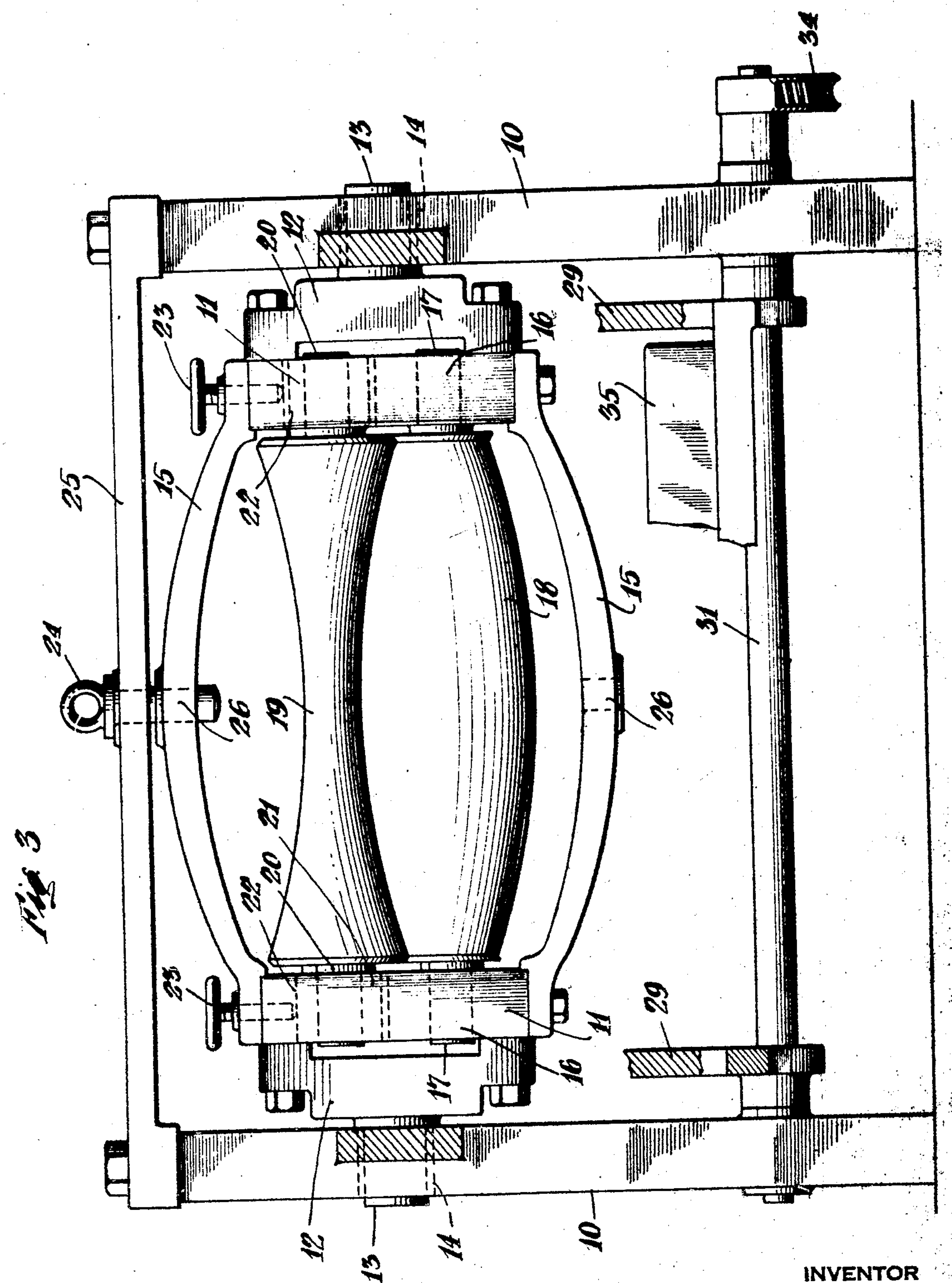

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METHOD AND APPARATUS FOR ROLLING CURVED SHEETS

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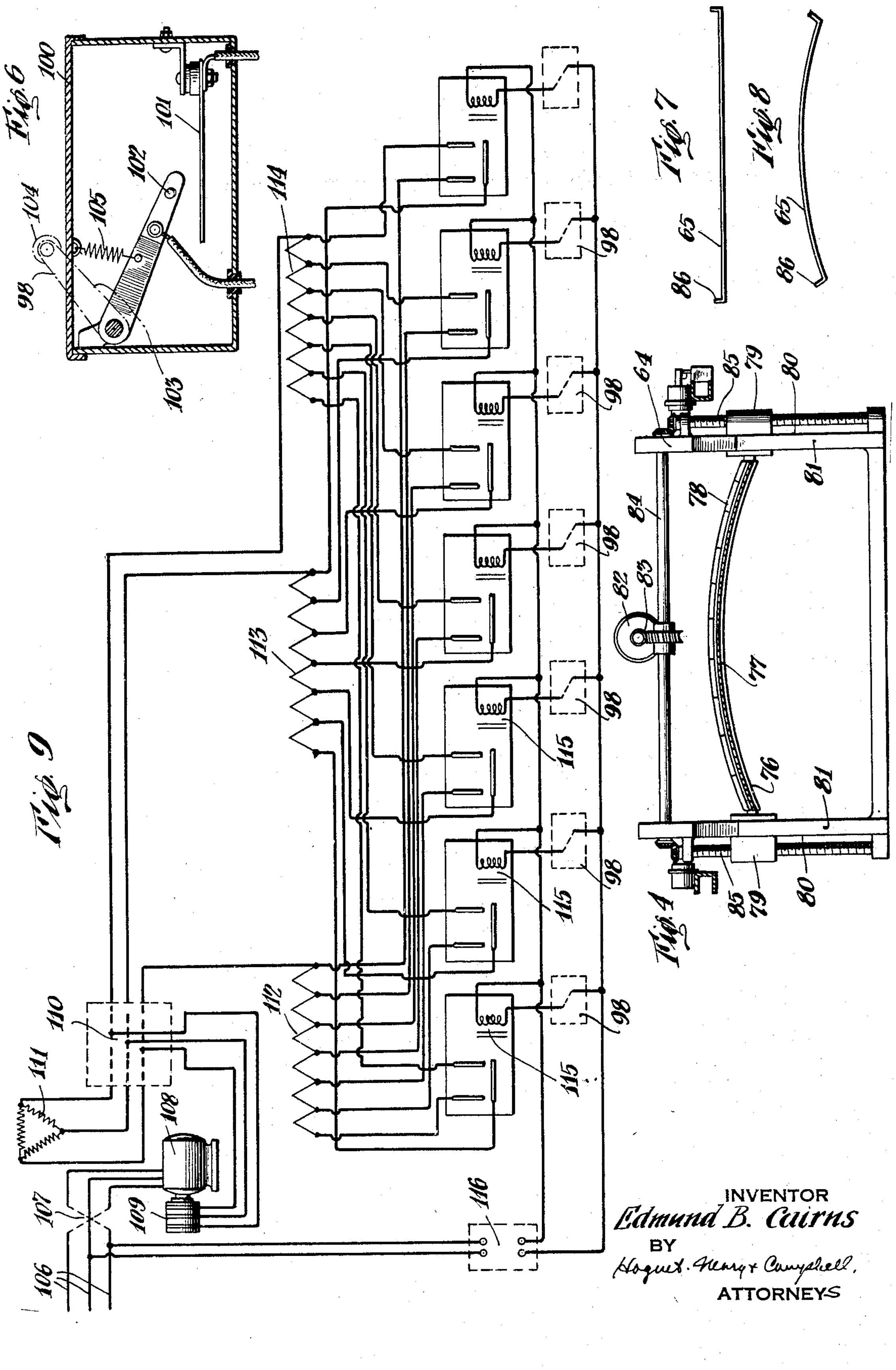

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Patented Aug. 5, 1941

2,251,901

UNITED STATES PATENT OFFICE

2,251,901

METHOD AND APPARATUS FOR ROLLING CURVED SHEETS

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Application July 27, 1938, Serial No. 221,474
In Great Britain August 5, 1937

13 Claims. (Cl. 153—58)

This invention relates to process and apparatus for imparting longitudinal and transverse compound curvatures to sheets of metal. The curved metallic sheets have many uses, such as, for example, in the fabrication of airplane wings and fuselages, boat hulls, and numerous other mechanical structures in which thin, rigid coverings for structural elements are required.

Devices for rolling sheet material with compound curvatures are already known. For example, my United States Patent No. 1,828,489, dated October 20, 1931, discloses a metal rolling device consisting generally of a pair of complementary concave and convex rolls between which a sheet of metal may be drawn to impart a transverse curvature to the sheet. The rolls are mounted so that the angle at which the sheet leaves the roll may be varied and a longitudinal curvature is imparted to the sheet. This device, while successful in operation, has certain disadvantages.

My United States Patent No. 1,820,936, patented September 1, 1931, discloses another form of sheet metal rolling device which consists of a platform for holding a sheet of material and curved racks along which are adapted to move a pair of complementary convex and concave rollers disposed on opposite sides of the sheet of material. This construction is extremely satisfactory for rolling duplicate sheets of material. However, since the longitudinal curvature of the sheet is controlled by the curvature of the racks, many different types of racks must be provided in order to produce different curvatures in the sheets. The racks are expensive to manufacture, and it is desirable to avoid their use.

The present invention has as its principal object the provision of a process and an apparatus which is suitable to form sheets with any desired type of longitudinal and transverse curvature and which through automatically controlled means can duplicate the curvature in successive rolling operations.

The invention may be carried out by means of a device for imparting to a sheet both transverse and longitudinal curvature by pulling the sheet through a forming or crowning element such as a set of curved rolls while passing a similar forming element in a direction opposed to the direction of pull and at a changing angle with relation to the forming elements dependent upon the longitudinal curvature desired. The forming element acting generally opposed to the direction of pull but with a wide range of movement works the sheet causing a flowing, drawing or upsetting of the metal and forms a sheet of desired curvature and improved characteristics as to strength. The sheet passes through a second forming element which acts to preserve the curve of the sheet by supporting the sheet during the drawing. Also this element acts to remove any evidence of the working of the sheet such as unevenness of surface or wrinkles. The means for drawing the sheet is so arranged that in combination with the movement of the opposed forming element the drawing effect is exerted along a line tangent to the longitudinal curvature imparted to the sheet, minimizing the tendency to straighten or buckle the sheet. The sheets may be made to a predetermined curvature by control means which adjust the several movements of the forming means and those means controlling the direction of pull of the sheet.

For better understanding of the invention, reference may be had to the accompanying drawings in which:

Figure 1 is a plan view of a typical form of device embodying the invention;

Figure 2 is a side elevation of the device;

Figure 3 is a view in section of a portion of the device taken along line **3—3** of Figure 2;

Figure 4 is an enlarged sectional view taken on line **4—4** of Figure 2;

Figure 5 is an enlarged sectional view partly broken of a portion of the device taken on line **5—5** of Figure 2;

Figure 6 is a sectional view of a switch used in the electrical circuit;

Figure 7 is a cross-section of a sheet ready to be processed;

Figure 8 is a cross-section of a sheet after a crown has been imposed; and

Figure 9 is a wiring diagram of the electrical control means for the device.

The form of invention illustrated in the drawings consists of a heavy pair of standards **10** in which is journaled a frame **11**. The frame **11** is provided with end plates **12** which carry the pivoting shafts **13**. The shafts **13** are rotatably mounted in bearings **14** in the standard **10**.

The end plates **12** are bolted to the frames **11**. The frames are joined by transverse bars **15**. The frames **11** are provided with journals **16** which rotatably receive the shafts which project from the end of a convex roller **18**.

A complementary concave roller **19** is also provided with end shafts **20** which are journaled in slide blocks **21**. The blocks **21** are slideably mounted in rectangular openings **22** in the frames **11**. Suitable hand wheels **23** are threaded through the transverse bar 15 to regulate the spacing between rolls 18 and 19.

The entire crowning roll assembly is therefore adjustable for varying thicknesses of sheets and also is rotatable to dispose the roll 18 either above or below the roll 19. The roll assembly may be latched in either position by means of a latch pin 24 which is slideably mounted in a cross bar 25 connecting the upper ends of the standards 10. The lower end of the latch pin 24 is selectively received in apertures 26 in the cross members 15.

The rolls 27 and 28 are concave and convex in shape similar to the rolls 18 and 19. They are positioned adjacent but forward of rolls 18 and 19 and are arranged to be moved with relation thereto. It is this movement as opposed to the movement of the sheet through the forming means such as the sets of rolls that causes the desired working and forming of the sheet.

The rolls 27 and 28 are supported in a frame having the sides 29 which have lower extensions 30 acting to form bell crank levers. The sides 29 are fixed to a shaft 31 rotatably mounted in the standards 10. The angular position of the sides or bell crank arms 29 relative to the center line of the standards 10 is controlled by means of an electric motor 32 which drives a worm meshing with a worm gear 33 splined to the end of the shaft 31 whereby upon rotation of the worm 33 the levers 29 and the rolls 27 and 28 will be moved toward or from the rolls 18 and 19. Any other means such as a threaded shaft, a worm, and a worm gear drive may be used for rocking the bell crank levers 29, as desired. The extension 30 may be provided with a counter weight 35 for facilitating the change of position of the rolls and operation of the motor 32.

The shafts 36 and 37 of the rolls 27 and 28 respectively are rotatably mounted in the journal blocks 38. These journal blocks 38 are in turn supported through pivoted connections 39 by the slides 40 moving in the slots 41 in the supporting side frames 29. The pivot connections 39 permit the position of the rolls 27 and 28 to be reversed in the same way that the rolls 18 and 19 may be reversed. The rolls 27 and 28 may be maintained in the selected position by means of the bolts 42 which are fitted to move in holes in the journal blocks 38. When the journal blocks 38 are in alignment with the supporting slides 40, with the concave roll either at the top or bottom position, the bolts 42 may be moved into recesses in the adjacent face of the slides 40 and fixed in locking position by the set screws 43. The slides 40 are moved along the slots 41 by an electric motor 44 which is provided with a worm 45 for driving a worm gear 46 fixed to the end of a threaded shaft 47. The shaft 47 is rotatably mounted in bearings 48 on the arm 29 and is connected by means of threads to the slide 40. The threaded shaft 47 carries at its upper end a bevel gear 49 which meshes with a similar bevel gear 50 fixed to a cross shaft 51 for driving through suitable gears a threaded element 52 similar to shaft 47. When driven by the motor 44 the shafts 47 and 52 act to move the slides 40 and thus the rolls 27 and 28 along the arms or frames 29.

In connection with the working of certain types of metals, it may be of advantage to operate under relatively high temperature conditions. This condition might arise, for example, in working with certain light metals or alloys such as magnesium or aluminum. In such case the rolls may be conveniently heated internally by hot oil or steam which may be circulated by means of flexible conduits attached to suitable connections at the ends of hollow shafts supporting the rolls, as indicated by reference character 53. The rolls may be provided with hollow ducts or chambers through which the heating medium may circulate.

If additional heating is necessary, the frame 29 or 10 may carry a series of gas jets, fed from a manifold and to which gas or other combustion medium may be supplied. Flexible connections may be used if necessary and may be carried overhead to permit movement. The several jets can be adjusted to heat the sheet uniformly across its face. Hoods or muffles may be provided to obtain more effective heating action. Another effective device is the use of electric resistance coils similarly placed across the face of the sheets. The amount of heating can then be closely controlled.

A sheet of metal is drawn between the crowning rolls 18—19 and the forming rolls 27—28 by means of a suitable draw bench arrangement. This draw bench may consist of a substantially U-shaped frame having parallel side members 54 which are pivotally connected to brackets 55 on the standards 10. The opposite ends of the side members 54 are connected by a cross bar 56 which in turn is pivotally and slidably connected to a supporting adjustable member 57. This member 57 is provided with a downwardly projecting threaded stud 58 adjacent its center and a plurality of guide studs 59 at opposite ends, as shown in Figure 2. The threaded stud 58 and the guide studs 59 are received in suitable vertical bores in an end standard 60 which may be fixed to the floor. A worm gear 61 operates on the threaded stud 58 and is retained in an aperture in the standard 60. The worm gear 61 may be rotated to elevate or lower the stud 58 and through the draw bench frame 54, by means of a hand wheel 62 which carries a worm 63 meshing with the worm gear 61.

A drawing carriage 64 which is adapted to grip and hold the end of the sheet of metal 65 is mounted on and for movement along the draw bench. The drawing carriage may consist of a transversely extending frame 66 having a plurality of rollers 67 at its opposite ends which roll along the side rails 54. Movement of the carriage 66 along the side rails is produced by means of an electric motor 68 supported on the cross bar 56. The motor, through a worm gear drive 69, rotates a shaft 70 provided with sprockets 71 at its opposite ends. A chain 72 is carried by each of the sprockets 71 and by sprockets 73 on the shaft 74. This shaft 74 is rotatably mounted in the brackets 55 on the standards 10. The carriage 64 is provided with similar outwardly projecting arms 75 which are fixed to the chains 72 whereby upon operation of motor 68 the carriage 64 is caused to move along the side rails 54.

In order that the drawing stress may be applied in such a manner that straightening of the curved sheet is minimized, I have mounted on the carriage 64 an adjustable jaw member 76 which grips an end of the sheet of metal 65. This jaw member may be caused to move continuously through an arcuate path during the drawing operation. The jaw member 76 may consist of a transversely curved plate 77 and a complementarily curved plate 78 which may be bolted together with the end of the sheet of metal 65 therebetween. The jaw member 76 is pivotally connected at each end to slide members 79 which are disposed in slots 80 in depending arms 81 fixed to the carriage 64. The slides 79 are moved upwardly and downwardly by means of a motor 82 mounted on the carriage 64. The upward or downward movement of the jaw member 76 may take place during movement of the carriage 64 to maintain the proper drawing relationship of the sheet 65 to the rolls 27—28 and 18—19. The motor 82 through suitable worm and worm gearing 83 drives a transverse shaft which is geared to screw threaded elements 85 rotatably mounted on the depending arms 81. The threaded shafts 85 are threaded through the slides 79 and cause upward or downward movement of the jaw member 76 upon rotation.

It has been found in practice that in drawing sheets to impose a material curvature upon them or in drawing relatively long curved sheets that there is a tendency for the edges of the sheet to straighten out, and for the sheet to buckle. This condition in the drawing of the sheets has been remedied in many cases by so adjusting the movement of the carriage 64 and the jaws 76 as well as the track 54 by means of the handwheel 62, that the pull follows the curvature being imposed upon the sheet and is applied tangentially to the curvature.

The rolls 27 and 28 act in a direction generally opposed to the direction of the pull of the sheet and are caused by the movement of the supporting arms 29 about the pivoting shaft 31 to move in the direction of an arc. These rolls also can be moved simultaneously either upwardly or downwardly along the line of the arms 29 depending upon the desired curvature. The speed of movement in each direction with relation to the speed of movement of the sheet also affects the curvature obtained.

The major portion of the working action upon the sheet is accomplished by means of these rolls 27 and 28, or their equivalent in a forming element such as dies, in working generally against the direction of pull. This working action causes a flowing, drawing and upsetting action in forming the compound curvature in the sheets. A sheet is produced not only of usual form but also of unusual stiffness, rigidity and strength.

The rolls 18 and 19 or their equivalent act primarily to support the curved sheet during the drawing action and to relieve the tendency to straighten the chord of the sheet as a result of the pulling action. In this connection, they remove wrinkles or other unevenness which may be present in the sheet as a result of the intensive working imposed by the rolls 27 and 28 and preserve the curvature. The pull upon the curved sheet in working against the rolls 27 and 28 must not exceed the strength of the sheet to retain its form. This strain during the drawing action is imposed particularly upon the edges of the sheet. In order to strengthen the edges and facilitate working a flashing 86 is formed on the sheet edges prior to its insertion in the rolls as illustrated at Figure 7. Figure 8 also illustrates a cross-sectional view of the sheet after the transverse curvature has been imposed, and illustrates the position which the flashing may assume.

It is for this reason that it is desirable to have a means for supplementing the pulling action of the carriage 64. An example of such a device which is particularly adapted to operate on the flashing of the sheet at the edges is illustrated in Figure 5. The edge pulling device preferably should be operated as close to the nip of the rolls 18 and 19 as is possible in order to minimize the effect of a change in direction of pull of the sheet. If necessary, of course, the edge pulling device may be adjusted manually or continuously to compensate for any such change in direction as would tend to make it ineffective in its action.

The pulling effect is accomplished as illustrated by means of knurled wheels 87 which are adjusted to grip between them the flashing 85 of the sheet 65. The gripping effect of these wheels 87 can be adjusted by means of the set screws 88 which bear upon each of them. The necessary amount of the movement of the knurled wheels 87 is available for such an adjustment as the result of the use of pivoting bearings 89 supporting the shafts of each wheel. The shafts are turned by the small gears 90 which preferably have curved faces so as to permit a slight amount of movement of their supporting shafts in and out of line of the shaft of the driving gear 91. This shaft and gear 91 are driven by a beveled gear 92 which in turn is driven by a beveled gear 93 on a shaft 96. A similar pulling mechanism is arranged to operate on the opposite flashing of the sheet and may be actuated from the drive shaft 96. Movement is imparted to the driving shaft 96 for the edge pulling mechanisms by means of sprocket wheels 94 at each side which are connected by driving chains 95 with shaft 74, which supports the chains driving the carriage 64. Thus the motor 68 acting to pull the sheet through the rolls by means of the carriage 64 also acts by means of suitable gear arrangement to simultaneously impose a pull at each edge of the sheet. The shaft 94 as well as the edge pulling mechanism may be supported by arms 97 which in turn may be bolted to or project from arms 55 carried by frame 10.

Each of the motors 32, 44, 68 and 82 may, if desired, be provided with manual controls to regulate their speed and direction and initiate and terminate their operation. The motor 68 is preferably arranged to operate at constant speed, this speed being determined by the characteristics of the metal sheet which is being formed. The motor 32 and the motor 44 may be operated to move the rolls 27 and 28 to predetermined fixed positions when it is desired to impart a constant smooth curvature to the sheet of metal being formed. The motor 82 when used with the rolls 27 and 28 in fixed positions, may be arranged to operate at substantially constant speed to lower the jaw member 76 while the sheet is being drawn to compensate for displacement of the drawn portion of the sheet in an arcuate path.

The outer end of the frame 54 may be adjusted up or down by the hand wheel 62, usually within an angle of less than 15° to compensate for other factors in the drawing of the sheet which tend to affect the obtaining of a sheet of certain desired specifications. In many cases it is desirable to vary the radius of curvature of the sheet from end to end and to do this it is necessary to vary the angle at which the metal passes through the forming elements 27—28 and 18—19. This may be readily done manually when the curvature need only be approximate. However, it is extremely difficult to duplicate the curvatures of sheets by manual control. There is provided therefore an automatic control system which may be adjusted to produce and reproduce any desired sheet curvature or any variations in curvature of the sheet.

This construction may suitably consist of a plurality of switches 98 arranged along the side rail 54 in the determined relationship and adjustable relative to each other along the side rail. The switches 98 may be actuated by a shoe 99 carried at the end of the carriage 64. The switches 98, as best shown in Figure 6, may consist of a housing 100, preferably made of insulating material, which carries a fixed contact member 101 and a movable contact member 102. The movable contact member 102 is carried on a bell crank lever 103 having one arm projecting outside the casing and provided with a roller 104 which is engaged by the shoe 99. Upon contact of the shoe 99 with the roller 104, the contact element 102 is rocked clockwise to engage the contact 101, thereby closing a circuit. The contacts 101 and 102 are normally separated by means of a spring 105 connected to the bell crank arm 103 and the casing 100.

The switches 98 may act successively to increase the speed of the motors 32, 44 and 82 as desired. These motors may be connected in separate circuits of the type best shown in Figure 9, and are arranged to be selectively connected into this circuit or connected to manual controls as desired. If desired, however, a plurality of the motors 32, 44 and 82 may be connected in a single circuit and controlled by one set of switches 98. As shown in Figure 9, these motors may be of the three-phase, slip-ring or induction type. Lead in wires 106 are connected through a reversing switch 107 to the stator 108 of the motor. The rotor 109 of the motor is connected through a double-throw switch 110 either to a manual control 111 having a variable resistance therein, or to an automatically controlled resistance circuit.

The automatically controlled circuit consists of three grids 112, 113 and 114, formed of a plurality of equal resistances connected in series. The resistances are of such value that upon shunting them successively out of the circuit, the speed of the motor can be varied gradually in equal steps between a predetermined minimum and a predetermined maximum speed. The switches 98 are arranged to actuate magnetic switches 115 to shunt the current around the individual resistances in each of the grids 112, 113 and 114. As illustrated, I have provided a series of seven switches 98 and an equal number of magnetic switches 115 for successively cutting out the resistances from left to right as illustrated in Figure 9. As illustrated, all of the switches 115 are in their open position. At the beginning of a forming or shaping operation all of the switches 115 will be closed and will be successively opened by movement of the carriage 64 until they assume the position shown in Figure 7. Therefore, as the carriage 64 moves along the guide rails 54, the switches 98 are successively closed to actuate the magnetic switches to successively shunt out the resistances, thereby decreasing the resistance of the grids 112, 113 and 114 and causing the speed of operation of the motor to increase.

The switches 98 may be arranged in any desired order such as, for example, to cause continuous, even, slow movement throughout the first half of the drawing operation and thereafter to rapidly speed up the movement of any or all of motors 32, 44 and 82. If desired, the reversing switch, or plurality of reversing switches 107 may be positioned in the path of the carriage to impart sinuous or wavey curvatures to the sheets. In fact, the switches can be so arranged that substantially any desired longitudinal curvature can be imparted to the sheet. It may also be found desirable to provide control members for increasing the resistance of the grid, as by example reconnecting a resistance in the circuit which has previously been shunted out of the circuit. This arrangement allows the speed of the motor or motors to be decreased. Any suitable switching arrangement may be used, such as additional magnetic switches which act in reverse of the operation of switches 115. A main switch is indicated by reference character 116.

The sheet or plate of material which is to be worked and formed to a compound curved sheet is preferably preliminarily treated to turn up the edges forming flashings as indicated in Figure 7. Certain materials of the sheet type come in 50-inch widths and are preferably formed with an inch and a half flashing on each side.

The sheet or plate 65 is fed through rolls 27 and 28, if necessary bending it manually to the transverse curvature required to conform with the curvature of the rolls. The rolls 27 and 28 at the beginning of the operation are positioned adjacent to rolls 18 and 19. The sheet is then fed through the rolls 18 and 19 and fastened to the jaw member 76, which has a curvature conforming with that of the rolls. The carriage 64 supporting the jaw member is at the beginning of the operation adjacent the rolls 18 and 19, and the slides 79 supporting the jaw member 76 are in a raised position usually on a level with the nip of the rolls 18 and 19. The rolls 27 and 28 in the supporting arms 29 are also placed at the uppermost position at the beginning of the working operation.

Both sets of rolls are adjusted by means of hand screws or otherwise to bear tightly against the sheet. With ordinary sheet material, the rolls may have a setting to give an opening of three to four-thousandths of an inch. The adjustment at the outer end of the frame 54 by means of the manually controlled screw 58 can be made, if necessary, after a test operation, to give a level of the frame with relation to the other factors which results in a true curvature of the desired characteristics.

When the machine is adjusted and ready for operation, the motors are started. Motor 68, drawing the carriage 64, usually operates at a constant speed to pull the sheet forward along the frame 54. This motor, as already pointed out, also drives the edge gripping mechanisms illustrated in Figure 5, which, as illustrated, grip the flashing as it comes through the nip of rolls 18 and 19 and pulls it forward. This pulling action supplements the pull upon the sheet by means of the moving carriage 64 and the jaw 76 and may impose upon the sheet as high as 50% or more of the total pulling action. As the sheet moves forward through the forming elements, the rolls 27 and 28 are caused to move backward against the pulling direction of the sheet. This acts to deform the metal plate or sheet into a compound curved shape. As the result of the action of these rolls, the sheet enters the crowning rolls 18 and 19 under a tension and the wrinkles or uneven portions of the sheet resulting from the intense working action are removed by the action of these rolls.

As soon as the curved portion of the sheet passes through the rolls 18 and 19, it is desirable to change the position of the pulling jaw 76 to which the end of the sheet is attached to compensate for the resulting curvature. This can be done by the operation of the motor 82 which acts through a suitable means to lower the slides 79 carrying the jaw 76.

The rolls 27 and 28 may be raised and lowered within the arms 27 as already described to impose additional controlled curvature upon the sheet when related to the other movement described.

The operations of the motors and the movements of the sheet and rolls may be controlled manually but they are preferably controlled automatically by a proper and suitable adjustment of switches which are actuated by movement of the carriage 64 as already described. It can be appreciated therefore that the speeds of the various motors may be increased or decreased or reversed and thus the types of curved forms which may be made are almost limitless. It should also be noted, as already described, that the relative positions of the concave and convex rollers may be reversed in each set, which again expands the flexibilities and possibilities of the machine in making desired compound curved forms.

The movement of the rolls 27 and 28 against the direction of the pull and in the direction of an arc with relation to rolls 18 and 19 acts to draw and flow the metal in such a manner as to obtain a crystalline rearrangement which results in sheets of unusual rigidity and strength, even though they have been made from relatively thin material. The movement of the rolls 27 and 28 downwardly along the arms 29 acts to form a curve of decreasing radius longitudinally of the sheet. The effective working action is also dependent upon the rate of forward movement of the sheet being pulled by the carriage 64 in relationship to the backward movement and possible downward movement of the rolls 27 and 28.

In addition to the working action of the rolls 18 and 19, they also act to support the sheet and minimize buckling during the operation, particularly when a considerable longitudinal curvature has been imposed. The control of the position of the edges 76 with relation to the curvature of the sheet also tends to minimize injury of the sheet during the working operation. The working action imposed upon the sheet must not be greater than can be resisted by the sheet, for although the characteristics of the metal and the form of the sheet tend to give it unusual strength and rigidity, yet it has been found in practice that too great a pull during the working operation tends to flatten out the edges and cause wrinkling or buckling. Edge pulling mechanisms which may be of the type illustrated in Figure 5 have been found very helpful in overcoming the possibility of edge flattening or buckling. By applying the edge pull directly at the nip of the second set of rolls 18 and 19, the change in direction of the sheet as it comes through these rolls is minimized and a gripping action can be obtained without material adjustment. However, such an adjustment can easily be made either manually or automatically.

It can be appreciated, of course, by those skilled in the art that various modifications may be made in this apparatus without departing from the invention. The rolls may be varied in shape and curvature. In fact, it is not essential that they have a continuous transverse curvature but may be formed to impose irregular shapes upon the sheet being processed. The automatic control device may be suitably adjusted to roll in duplicate a variety of shapes. Also the arrangement of the various elements of the device may be varied considerably without departing from the invention. Therefore, the form of the invention described should be considered as illustrative only and not as limiting the scope of the claims.

I claim:

1. In a device for imparting transverse and longitudinal curvatures to sheets of metal, the combination of a pair of forming elements having complementary curved adjacent surfaces, means for moving a sheet of metal between said forming elements, means including a motor for swinging the forming elements bodily about an axis spaced therefrom to vary the angle between the means for moving the sheet of metal and a tangent to the sheet at the zone of contact thereof with the forming elements, and a plurality of control elements actuated successively in response to movement of said sheet moving means for controlling the speed and direction of operation of the means for swinging the forming elements to impart accurately controlled longitudinal and transverse curvatures to the sheet.

2. A device for imparting transverse and longitudinal curvatures to sheets of metal comprising a main frame, crowning rolls having complementary curved surfaces mounted in the main frame, a second frame pivotally connected to the main frame, complementary curved forming elements movable axially of the secondary frame, means for moving a sheet of metal through and in engagement with said crowning rolls and forming elements and means for shifting the forming elements axially of the secondary frame and moving the latter about its pivot.

3. The rolling device set forth in claim 2, wherein the means for moving the sheet of metal comprises a draw bench, means movable along the draw bench for gripping the sheet metal, and means for moving the gripping means through an arcuate path longitudinally of the draw bench.

4. The rolling device set forth in claim 2, wherein the means for moving the sheet of metal comprises driven rollers engaging and gripping the opposite longitudinal edges of the sheet of metal.

5. A rolling device comprising a pair of forming rolls, a draw bench, a carriage movable along the draw bench, means on said carriage for gripping a sheet of metal and drawing it between the forming rolls, a plurality of switches adjustably mounted on the draw bench, means on said carriage for operating said switches, an electric motor for bodily moving the forming rolls through an arcuate path and an electrical circuit having variable resistances therein controlled by the switches for varying the speed of operation of the motor.

6. The device set forth in claim 5, in which the electrical circuit includes a plurality of grids, a plurality of resistances in each grid, and a plurality of switches for successively shunting out resistances in each of the grids to increase the speed of the motor.

7. A metal rolling device comprising a pair of standards, forming rolls rotatably mounted in said standards, a draw bench pivotally connected to the standards, a carriage movable along the draw bench, a pair of depending arms on said carriage, means for gripping sheet metal movable longitudinally of and pivotally connected to said arms, and means for moving said gripping means longitudinally of the arms as the carriage moves along the draw bench.

8. The metal rolling device set forth in claim 7, comprising an electric motor for moving the gripping means and a control circuit for varying

the speed of operation of the motor in accordance with the variation in curvature of the sheet of metal.

9. In a device for imparting transverse and longitudinal curvatures to sheets of metal, the combination of a pair of complementary concave and convex crowning elements, a pair of complementary concave and convex forming elements, means for drawing a sheet of metal between the forming elements and the crowning elements and means for bodily shifting the forming elements in a direction opposite to the direction of movement of the sheet and varying the angle between the tangents to the sheet at the forming and crowning elements.

10. The process of imparting compound longitudinal and transverse curvatures to a sheet of metal comprising drawing the sheet between curved crowning elements and moving curved forming elements along and in engagement with opposite sides of said sheet in a direction opposite to the direction of movement of the sheet while changing the angle between tangents to the sheet at the crowning elements and the forming elements.

11. The process of imparting longitudinal and transverse curvatures to sheets of metal comprising drawing a sheet between curved forming elements, moving the forming elements angularly and oppositely to the direction of movement of the sheet and supporting the sheet between its leading end and the forming elements whereby the curvature imparted to the sheet is retained.

12. The process set forth in claim 11 comprising the step of applying drawing stresses to the longitudinal edges of the sheet.

13. A process of preparing sheets of metal having a varying longitudinal curvature and a transverse curvature comprising pulling a sheet of metal through two forming elements, moving one of said forming elements relatively to the other forming element in a direction opposed to the direction of pull, changing the angle at which the sheet is pulled from said moving forming element and changing the angle at which said sheet is pulled from said other forming element during pulling of said sheet through said forming elements to cause a varying working and drawing of the metal to form a sheet of the desired longitudinal and transverse curvatures.

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