United States Patent

[11] 3,630,056

[72] Inventor Pierre Cuq
6 Rue Limouzin, Firminy, France

[21] Appl. No. 838,152
[22] Filed July 1, 1969
[45] Patented Dec. 28, 1971
[32] Priorities July 4, 1968
[33] France
[31] 146;
Dec. 17, 1968, France, No. 257; Apr. 9, 1969, France, No. 6909551

[54] **METHOD AND ASSEMBLY FOR THE PRODUCTION BY HYDROFORMING OF PARTS OF LARGE SIZE, ESPECIALLY IN LENGTH**
9 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** **72/28,** 72/58
[51] **Int. Cl.** **B21d 26/04**
[50] **Field of Search** 72/57, 58, 60, 61, 62, 28, 29, 31, 34; 29/421

[56] **References Cited**

UNITED STATES PATENTS

2,713,314	7/1955	Leuthesser, Jr. et al.	72/58
2,743,691	5/1956	Cuq	72/58
3,072,085	1/1963	Landis	72/58
3,160,130	12/1964	Pesak	72/61
3,335,590	8/1967	Early	72/58
3,358,488	12/1967	Fochs, Jr.	72/62
3,358,489	12/1967	Hutchins	72/62

FOREIGN PATENTS

1,083,354	9/1967	Great Britain	72/57

Primary Examiner—Richard J. Herbst
Attorney—Waters, Roditi, Schwartz & Nissen

ABSTRACT: A method of forming blanks of stamped metal sheets, into a finished part by a combination of mechanical and hydraulic actions. The hydraulic action is strictly connected in synchronism and magnitude, according to a univocal relationship, with the mechanical action. This univocal relationship is defined by the variation of the internal volume of the part as a function of its shortening, enabling the surface of the part to be maintained constant from the blank up to the finished part. An assembly for performing this method with any press of normal power is actuated by the press by a double-acting oleohydraulic transmission having a master cylinder and regulator. The assembly includes a frame of parallel plate and U-shaped binders for clamping the opening parts of the mold. Actuation of the assembly can be electrical, hydraulic or mechanical. The regulator is a rotary cam upon which the univocal relationship is registered and which is calibrated. The cam is phase-locked by levers, cogs or a hydraulic multiplier to the shortening jack, Several concentric jacks interconnected by cushions of oil constitute the bending ram for multidiameter shapes.

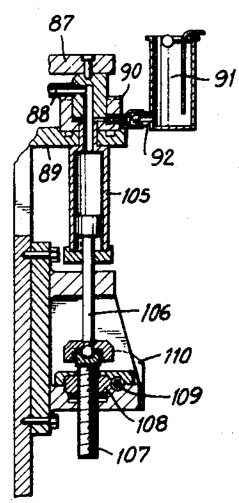


FIG. 1

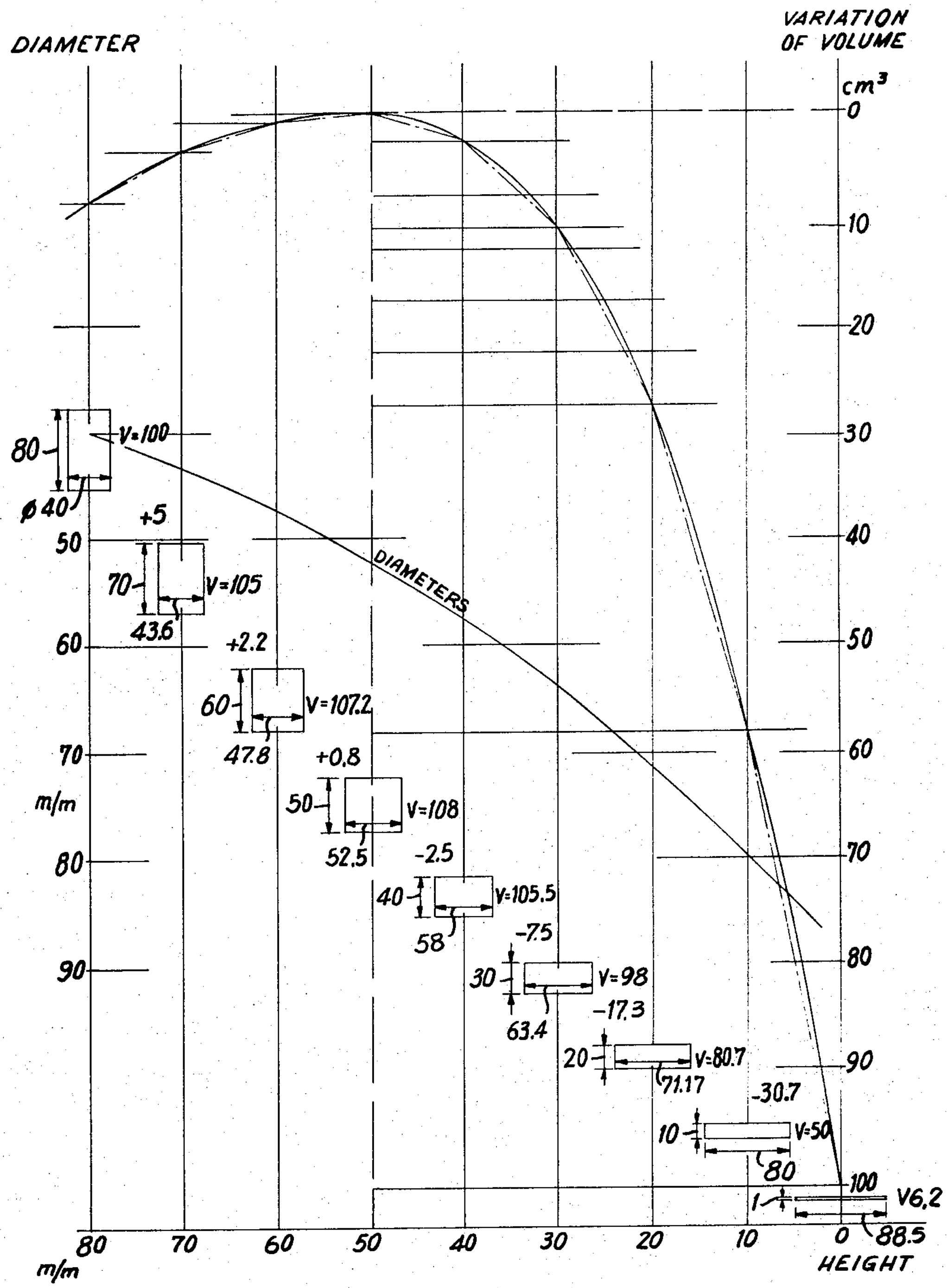

DIAMETER
VARIATION OF VOLUME
cm³
0
10
20
30
40
50
60
70
80
90
100
80
ø40
V=100
+5
50
70
V=105
43.6
60
+2.2
60
V=107.2
47.8
70
+0.8
50
V=108
52.5
m/m
80
-2.5
40
V=105.5
58
90
-7.5
30
V=98
63.4
-17.3
20
V=80.7
71.17
-30.7
10
V=50
80
1
V6.2
88.5
DIAMETERS
80
70
60
50
40
30
20
10
0
m/m
HEIGHT

FIG. 2

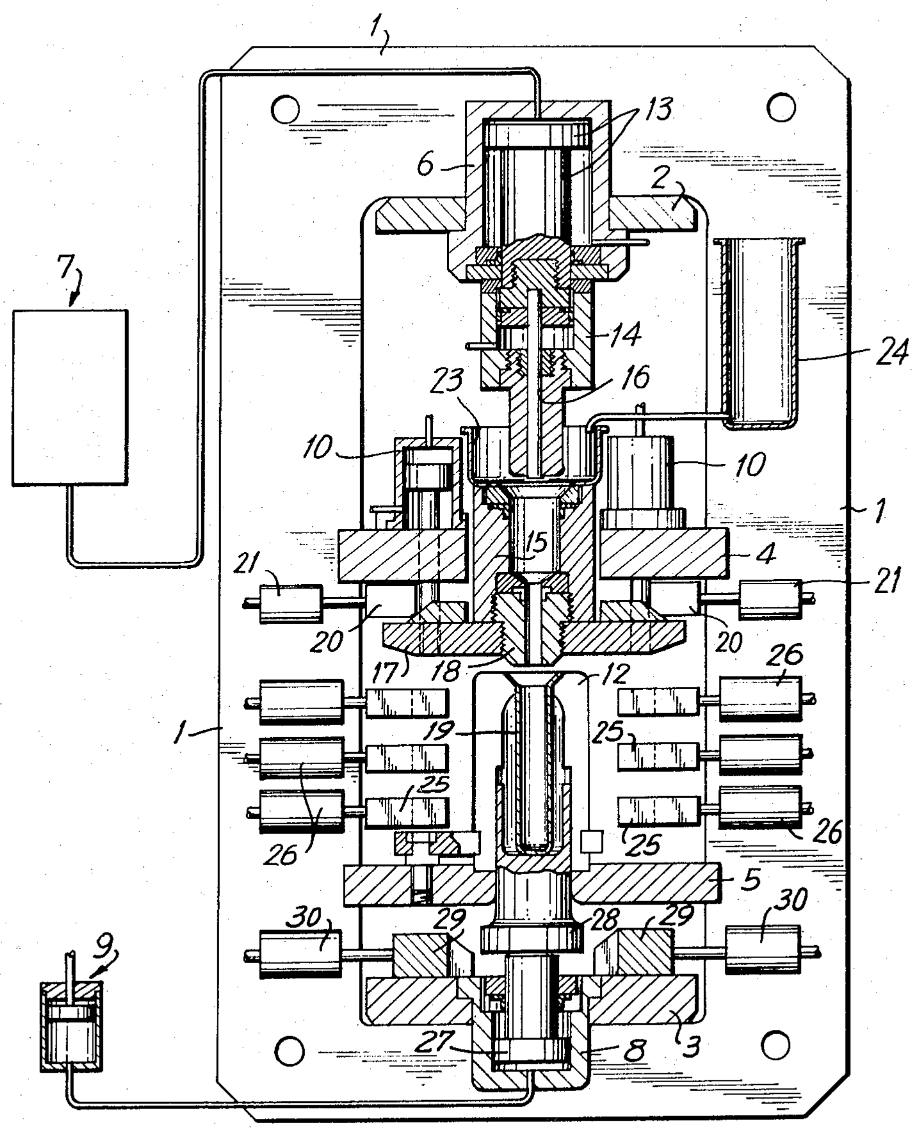

1
13
6
2
7
14
24
23
16
10
10
15
1
21
4
21
20
20
17
18
12
26
19
1
25
25
26
25
26
5
30
29
28
29
30
9
27
8
3

FIG. 3

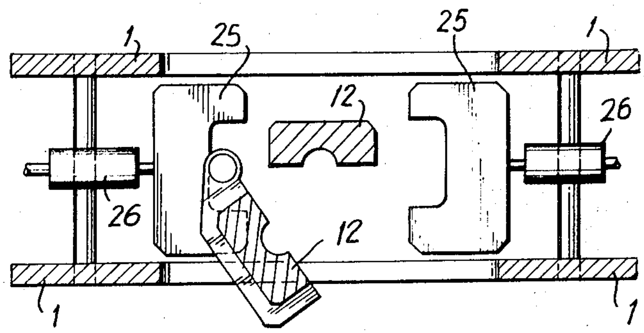

1
25
25
1
12
26
26
12
1
1

FIG. 4

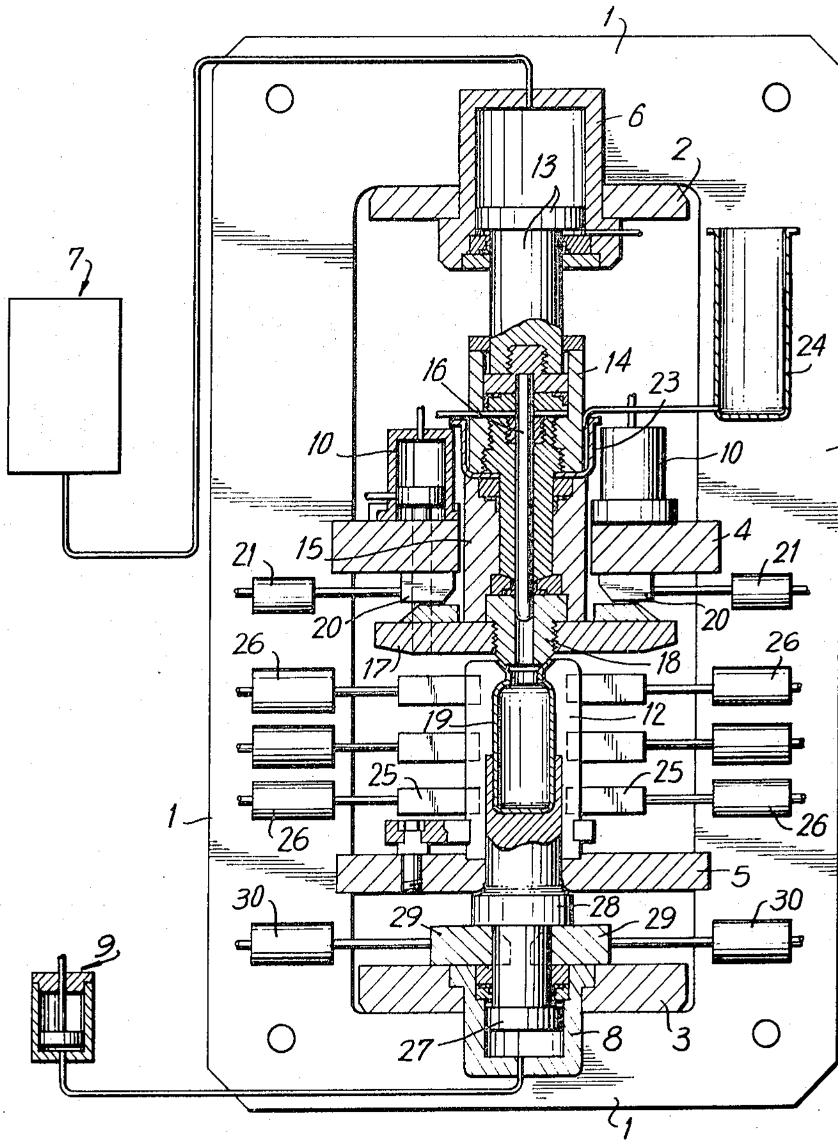

1
6
13
2
7
24
14
16
23
10
10
1
15
4
21
21
20
20
17
18
26
26
19
12
25
25
26
1
26
5
30
28
29
29
30
9
27
8
3
1

FIG. 5

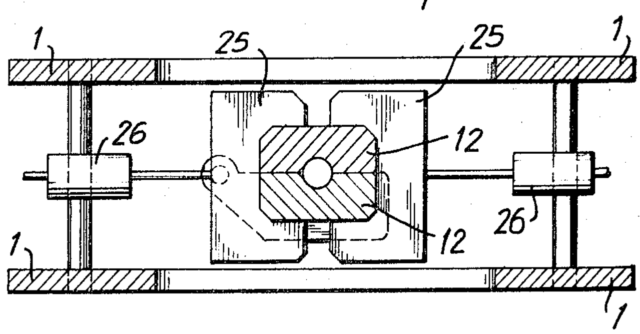

1
25
25
1
26
12
26
12
1
1

FIG. 6

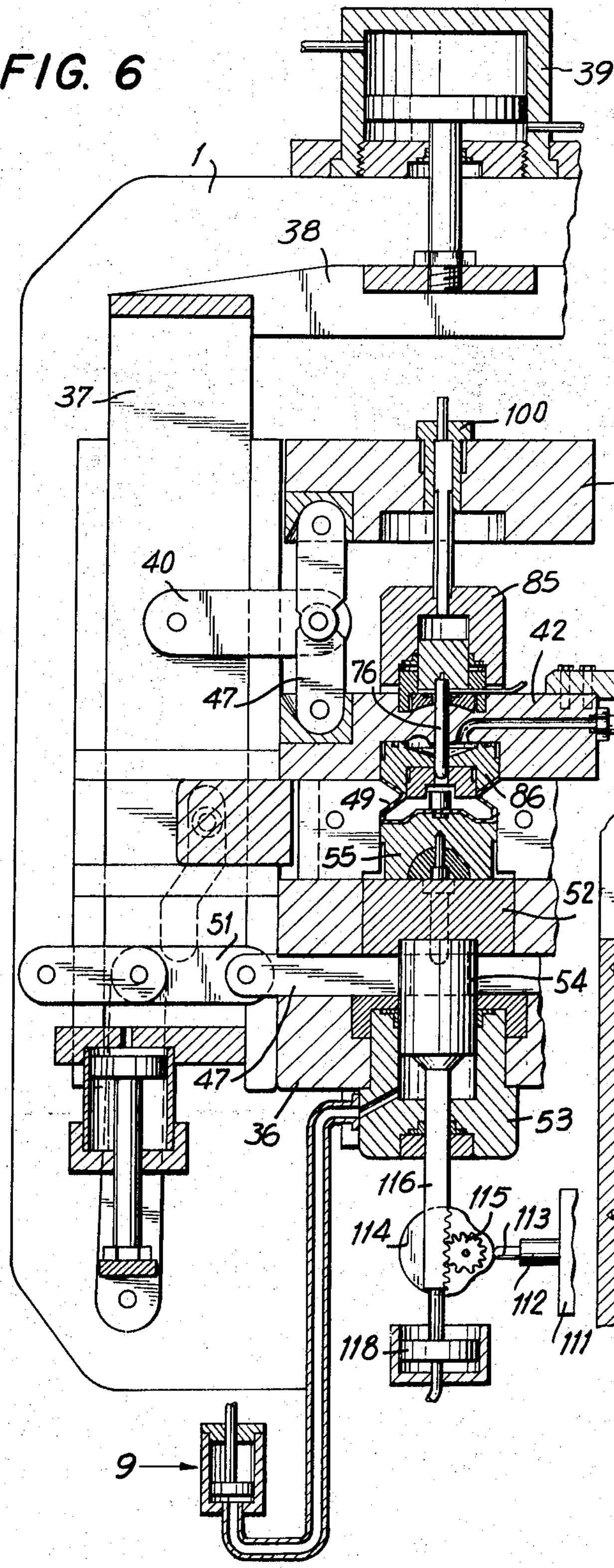

39
1
38
37
100
35
40
85
42
76
47
49
86
55
52
51
54
47
36
53
116
115
114
113
112
111
118
9

FIG. 7

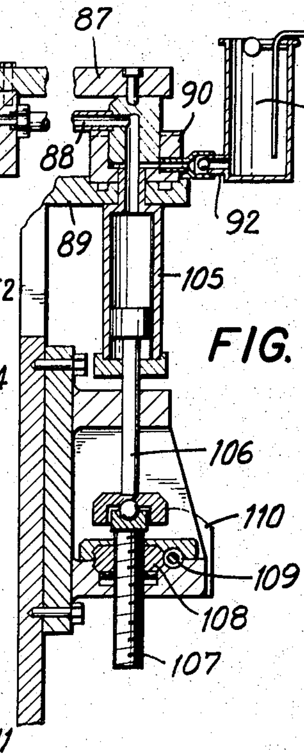

87
90
91
88
92
89
105
106
110
109
108
107

FIG. 9

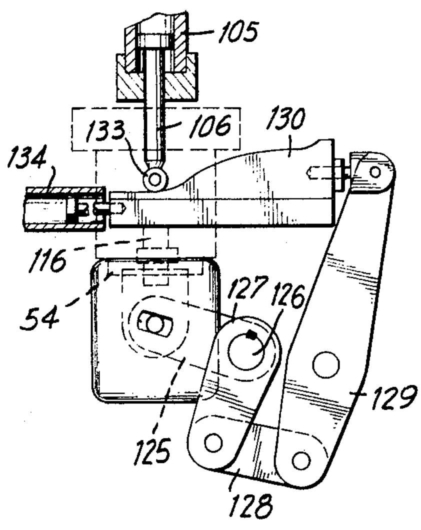


FIG. 11

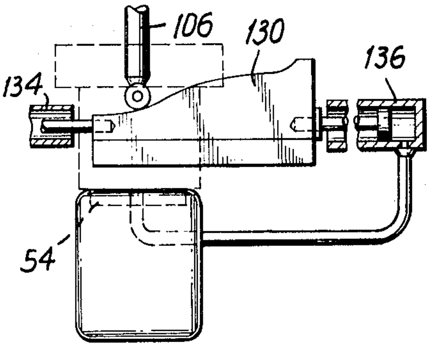


FIG. 10

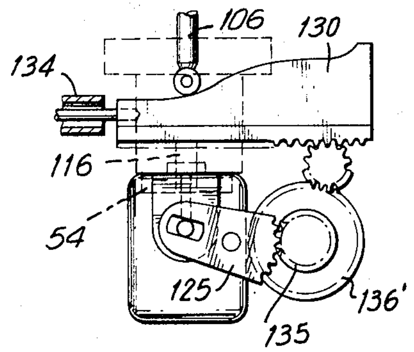


FIG. 8

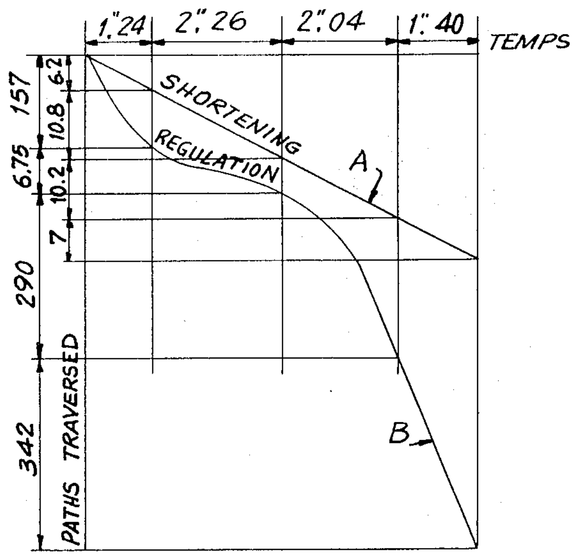
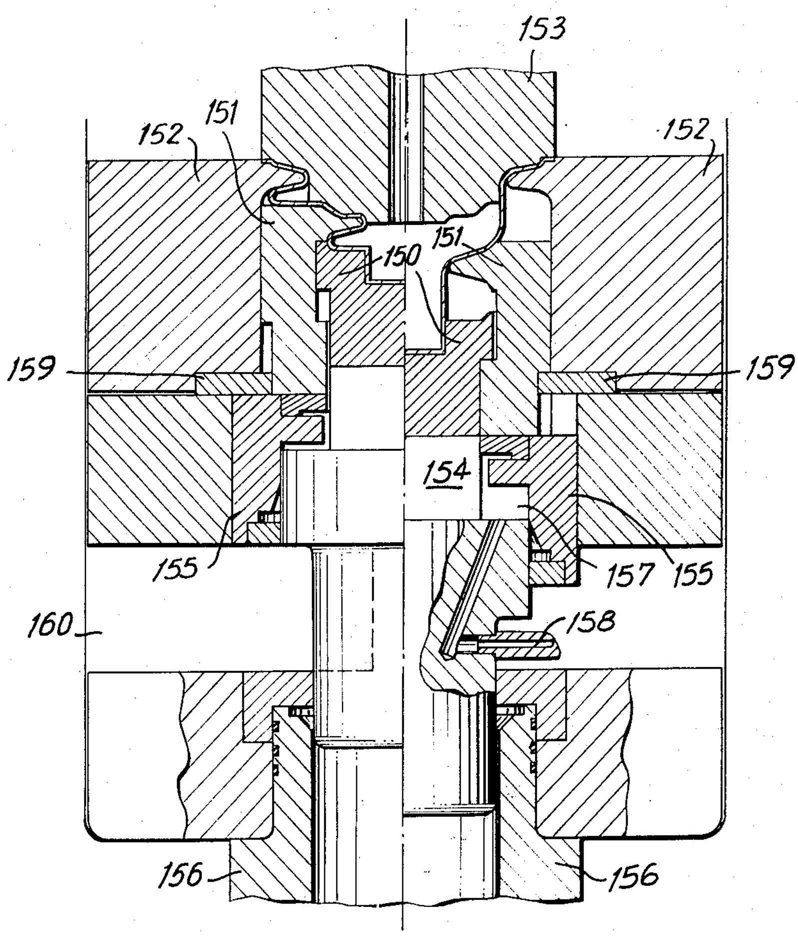


FIG. 12



METHOD AND ASSEMBLY FOR THE PRODUCTION BY HYDROFORMING OF PARTS OF LARGE SIZE, ESPECIALLY IN LENGTH

The present invention relates to a method and assembly for the production by hydroforming of parts of large size, especially in length.

For a very long time, it has been known to transform, by hydraulic action in a suitable mold, a blank of a dished sheet metal into a swollen hollow body or various shapes which it is not possible to obtain by conventional pressing. But the deformation resulting from this hydraulic action, considered alone, is accompanied by an often inacceptable thinning of the wall of the blank.

To avoid this drawback, it is sought, by the concomitant application of an axial mechanical thrust, to bring back metal into the zone having to undergo expansion, so as to compensate the tendency of the material to stretching. The proportioning of mechanical and hydraulic actions therefore takes on very great importance. In fact, the axial mechanical thrust exerted on each of the fibers of the blank causes buckling; successive deformations which characterize buckling of the whole of the fabric obviously must not be translated by a reduction in diameter of the blank, the latter having on the contrary to be applied progressively against the inner wall of the mold without forming folds. For this, it is indispensable that the liquid contained in the blank be constantly subjected to a sufficient overpressure, all the greater as the free length of the fabric of the blank is less but with an upward limit to avoid any excessive and premature inflation, and thereby eliminating troublesome consequences, namely the bursting of the blank or the formation of folds at the end of the operation. To this end, there are currently used more or less complex pump or accumulator devices; but the determination of the optimal pressure for each of the successive phases of the transformation of the blank remains in all cases very empirical; the calculation of the bursting pressure itself, approximately equal to the expression : $2K\mathit{e}Ke/\Phi$ is revealed to be impracticable by reason of the continual variation of the thickness e, of the rupture strength K, and of the diameter Φ as a result of elongation, of strain-hardening and of expansion of the metal in the course of forming. Each new application of this method of hydroforming therefore necessitates a delicate adjustment, and any irregularity in the blanks is manifested by manufacturing rejects.

To overcome these difficulties, it has recently been conceived to replace the regulation of the internal pressure in the blank by a volume control based on the following observation: if one considers, for example, a blank 40 mm. in diameter and 80 mm. in height, this height having to be reduced to zero by hydroforming, it is known how to calculate step by step the increases in diameter and the variations in volume corresponding to successive shortenings of 10 mm. and ensuring the maintenance at a constant value of the total surface of the blank, and consequently, of its thickness; FIG. 1 shown thus as ordinate the diameter and the internal volume as a function of the shortening plotted as abscissa; the first phase, in the course of which the height remains greater than the diameter, corresponds to a transformation with increase in volume; the second phase, in the course of which the height becomes and remains less than the diameter corresponds on the contrary to a transformation with reduction in volume. Whatever may be, in practice, the form of the part to be obtained, and conditional upon having selected a blank of the same total surface of this latter, it is always possible to break down its forming according to the method set forth above, and to determine the curve describing the variation of the internal volume of the blank as a function of its shortening. The liquid enclosed in the blank being a very slightly compressible fluid, it suffices, in principle, to impose on it the variations in volume thus calculated, is synchronism with the shortening of the blank; under these conditions, at each moment in the course of the transformation, the pressure of the liquid contained in the blank assumes exactly the value necessary for the obtaining of the desired deformation. When the final height is reached, the operation must be, preferably, completed by a calibration effected by means of a considerable increase in the pressure of the liquid contained in the blank. The parts thus formed have a constant thickness, are free of folds, and mate perfectly with the shape which is assigned to them.

However, the industrial application of this method of hydroforming with volume control can only be applicable to the extent that various technological production difficulties, especially as regards the device for synchronization of shortening and of variation in volume can be overcome in simple and effective manner.

It is an object of the present invention to provide an improved method of hydroforming large parts which overcomes the aforementioned difficulties.

It is another object of the invention to provide an assembly for performing the aforesaid improved method.

It is a further object to provide for the application of said method, an assembly of reduced bulk, not necessitating the employment of a powerful and expensive press, and ensuring the total automation of the process, comprising here the filling of the blank.

According to the invention there is provided a method of forming into a finished part by a combination of mechanical and hydraulic actions, blanks of stamped metal sheets, the hydraulic action being strictly connected, as much in value as in synchronism, and according to a univocal relationship, with the mechanical action, said univocal relationship being defined by the variation of the internal volume of the part as a function of its shortening, enabling the maintenance of the surface of the part at a constant value, from the blank up to the finished part.

The assembly having recourse to a combination of mechanical and hydraulic actions, is characterized by the univocal relationship connecting both actions, this univocal relationship being defined by the variation of the internal volume of the part as a function of its shortening enabling the maintenance of its total surface at a constant value.

The mechanical action, or bending, is ensured by a jack receiving the flux of a master cylinder actuated by the ram of a suitable press; in practice the connection between the bending jack and the ram is direct; the press may be of conventional type, or consist, preferably, of an assembly specially dimensioned for this use.

The hydraulic action is obtained by means of a regulator constituted by a jack of fairly large stroke but of small section, so as to facilitate the obtaining precisely of the variations of volumes sought and to avoid, for corresponding maneuvers of the regulator, any considerable force associated with the balanced forming pressure. Taking into account the short stroke of the bending ram with respect to the stroke of the regulator, the energy necessary for the operation of the latter must be necessarily furnished to it directly, and not at all through the bending ram. Thus, the connection between the regulator and the bending ram can be ensured by various mechanical, electrical or hydraulic devices such as:

Rotary cam displaying the variations in volume to be obtained and driven directly by the bending ram considered as pilot, this cam acting on a potentiometer and thyristors proportioning the supply from a DC motor driving the hydraulic acting jack by wheel and worm gear forming an irreversible assembly on the loaded side;

Rotary cam as above acting on the feeler of an oleohydraulic assembly of known "copying" type proportioning the supply of a hydraulic motor driven as above a wheel with worm gear;

Rotary cam and oleohydraulic assembly as above proportioning the supply of a hydraulic jack, driving the jack directly by hydraulic action;

Travelling cam causing directly the displacement of the hydraulic action jack, the displacement of the bending ram being positively monitored by a mechanical device, or preferably hydraulic, on the translation of the cam.

According to these various methods, the relation between the internal volume of the part and the position of the bending ram is interposed in univocal manner by means of a cam adapted to follow the particular curve of the manufactured part.

In addition, a supply reservoir is associated with the regulator, preferably by means of a pump of known "aspirating-recirculating" type actuated by the opening and closing of the mold, so as to ensure the filling of the regulator and of the blank at the beginning of the operation.

According to another feature of the invention, the matrix or mold of two opening elements of which the unity is ensured by bound elements displaced horizontally in a frame is placed on said frame formed of two parallel plates connected by tables. This frame, fixed outside the path of the slide of the press used, is not therefore limited in size; it enables the passage of long or voluminous parts. In the case of parts of small size, and according to the power available, it is possible to group several assemblies controlled by a single operator.

In order that the invention may be more fully understood, various embodiments thereof are described below purely by way of illustrative but nonlimiting example, with reference to the accompanying diagrammatic drawings in which:

FIG. 1 is a diagram showing the variations of the internal volume and the increase in the diameter as a function of the reduction in height of a cylindrical blank in the course of transformation with constant total surface;

FIG. 2 is a general view of the whole of the assembly in elevation before actuation of the press in the case of a part characterized by its increase in volume in the course of forming;

FIG. 3 is a horizontal section of this assembly showing the binding elements in the open position;

FIGS. 4 and 5 are views analogous respectively to the preceding ones, but in the position of the end of the operation;

FIG. 6 is a section of an assembly intended for the forming of a grooved pulley, and shown at the end of the operation;

FIG. 7 is a section of a regulator, in the case of an electrical or hydraulic solution;

FIG. 8 is a diagram giving the curves of shortening and of regulation of volume;

FIGS. 9, 10 and 11 show, respectively, three variations of the embodiment of FIGS. 6 and 7; and

FIG. 12 shows the assembly used for obtaining a pulley with two grooves of different diameters, the left-half portion of this figure showing the mold at the end of the operation, whilst the right-half portion shows the blank in position before processing.

According to the embodiment of FIGS. 2 to 5, between two elements 1 of sheet steel constituting a frame, there are placed tables 2, 3, 4 and 5.

On the table 2, is supported a cylinder 6, connected to a regulator 7.

On the table 3, is supported a cylinder 8 constituting a double-acting jack controlled by a second master cylinder 9.

The table 4 supports pneumatic jacks 10.

As for table 5, it supports the opening elements 12 of the mold.

The piston 13 of the cylinder 6 which receives the impulse from the regulator 7 ensures the downstroke of a piston 14 which, forming a cylinder in the upper first part, causes, on its arrest by abutment in a part 15, the emergence and the downstroke of a small calibration piston 16.

The pneumatic jacks 10 are rigidly fixed to a plate 17 on which is supported a plug 18 intended to ensure the closing of the blank 19, this closing being rendered irreversible by the positioning of wedges 20, actuated by hydraulic jacks 21. The aforesaid plug 18 serves, in its upper part 15, as variator cylinder. It is surmounted by a funnel 23 serving to channelize water which arrives there from the reservoir 24 at the moment of filling of the blank 19. Elements 25 in the form of a slightly opened U are pneumatically controlled by jacks 26 to ensure the reassembly and closing of opening elements 12. These binding elements 25 are superposed in a suitable number (three in the case in the drawing) as a function of the height of the blank 19, hence of the elements 12 to be held.

In the double-acting cylinder 8 moves a piston 27 actuating a ram 28 held locked at the end of its stroke by wedges 29 actuated pneumatically by jacks 30.

The operation of this assembly is as follows:

After positioning the blank 19, the operator ensures successively: the closing of the mold 12 by binding elements 25, then the closing of the said blank by the plug 18 with, by contact at the end of the stroke, release of the filling of the blank by water contained in necessary and sufficient quantity in the reservoir 24.

The starting of the press by acting on the master cylinder 9 as well as on the regulator 7, which may be controlled directly by the piston 27, sends a well-measured flow of oil to each of the cylinders 6 and 8 of which the action is thus perfectly synchronized. The cylinder 6 ensures the hydraulic action in the blank 19 with preponderance on the mechanical action of bending ensured by the piston 27 and the ram 28 of the cylinder 8, the essential characteristic resulting therefrom being a geometric deformation with increase in volume.

The first phase of the deformation being ended (ram 28 at the end of its stroke and piston 14 in abutment against 18), the wedges 29 are placed in position by the action of the jacks 30 and ensure positive support for the finishing of the part under a progressively heavy pressure ensured by the downstroke of the small piston 16.

As regards the embodiment of FIGS. 6 and 7, the plate 42 is rigidly fixed to a support 87 bearing the piston of a water pump 90, to which is fixed a support 89, itself rigidly fixed to the frame 1. This pump 90 is connected by a channel 88 to the passage arranged in the plate 42 for the filling of the part 49 with water with an excess and a slight overpressure to avoid the presence of air in the said part.

This water, led by a conduit into a reservoir 91, is aspirated by the pump 90. At the outlet of the reservoir is placed a valve 92. The jack 85 ensuring the high pressure is fixed on the plate 42; it is connected to the oil conduit by a telescopic element 100. The plunger 76 is fixed on the piston of this jack; it traverses a plug 86 to act on the liquid contained in the part 49.

The operation of this embodiment of FIGS. 6 and 7 is as follows:

The operator having caused the starting of the assembly by the simple fact of having closed on the empty blank the front part of the mold which, by contact, releases the pressurizing of the jack 39, the plate 42 descends to close the blank. This descent causes that of the piston of the pump 90 and the liquid, such as water, which is contained in this pump is expelled through the channel 88 into the blank 49.

At the end of its stroke, the plate 42 and the pump 90 are immobilized and processing commences.

The liquid contained in the blank is thus in direct contact with the regulator through the pump 90.

The lower part 55 of the mold being in its final position, the wedges 47 are inserted under the support 52.

By making contact with the seal of the plug 86, the plunger 76 isolates, first of all, the regulating circuit, then causes localized high pressure in the part, thus ensuring the insertion of the detail of this part.

A monocontact arranged on the high-pressure circuit having caused, on the one hand, the arrest of this pressure and, on the other hand, the reversal of the movement of the jack 39, the plate 42 reascends by driving the piston of the pump 90. The plunger 76 continuing to obstruct the orifice of the channel 88, there is produced a depression in the pump 90 which aspirates water from the reservoir 91 through the valve 92.

When the plate arrives at the end of its stroke, a contact admits compressed air into the lower part of the jack 85 and the wedges 47 are withdrawn by the action of the elbows 51.

In reascending, the plunger 76 uncovers the opening of the channel 90, which enables water contained in the regulator to escape. This latter movement, with the return of the piston 54 in the jack 53 closes the cycle which will be ended without the presence of the operator which would thus proceed to a progressive production by feeding a battery of several assemblies.

This embodiment of FIGS. 6 and 7 relates to phase-locking the nonconstant speed of the regulator according to a definite curve at the constant speed of shortening.

The speed curves are determined in the following manner:

Starting from a predetermined and adjudged satisfactory diameter of the regulator, and the volume curve of the part to be produced, this volume curve is analyzed into several slices.

By fixing the operational speed of shortening, there is then determined, for the strokes of each slice, the necessary time which is borne as abscissa (FIG. 8). There is borne, on the other hand, as ordinate, the travel in millimeters of each slice and there is obtained the shortening curve A which is a straight line.

The reference volumes of the slices selected in the curve give, by division by the surface of the regulator, a quotient which represents the displacement, for each of these slices, of the piston of the regulator. These quotients are also plotted as ordinates.

One has thus the speed curve of this regulator, that is to say the volume regulation curve B.

Then, by fixing on the shortening jack considered as pilot, a rack rod actuating a cam representing the curve thus defined, one can, by the intermediary of a potentiometer and of thyristors, cause the voltage in a DC-current motor arranged to drive the regulator, to vary according to this criterion.

This action can be exerted either mechanically by a wheel and screw, or hydraulically.

The possibility of reversing the direction of rotation of the motor enables the respect of a curve of volume composed of a part of "increase" and of a part of "reduction" in volume to be ensured.

The regulator 105, composed of a single cylinder, is rigidly fixed, by its piston 106, to a screw 107.

This latter is moved by a nut 108 cut on its periphery to compose, with a worm gear 109, an assembly with a high and irreversible reduction ratio in the case where the load would risk becoming driving (case of reduction in volume).

A DC-current motor 110 receives the current from the sector transformed by thyristors and proportioned by a linear potentiometer 112 of which the movable element 113, in contact with a cam 114, copies the variations registered on this latter. This cam 114 is driven in rotation by a gear 115 in engagement with a rack cut or fixed on the rod 116 of the piston 54.

A pneumatic jack 118 ensures the return of the assembly.

The operation of the regulator is as follows:

The displacement of the jack 54 causes, through the rack of its rod 116 and the pinion 115, the rotation of the cam 114. On its contact, the linear potentiometer 112, through the thyristors located in an enclosure 11, makes the voltage vary of the current sent into the motor 110, the nonuniform speed of which motor, is regulated according to each variation registered on the different sectors of the cam. An electronic control assembly contained in the casing III follows and corrects the development of the operation.

The regulating jack 106 thus driven by the screw 107 is displaced therefore in positive manner.

In the case of a variation in volume, in addition to in diminution, a microcontact actuated by the rod 116 controls a reverser to ensure the necessary change in direction.

The solution by hydraulic drive corresponds with that of the aforesaid electrical drive. In fact, by starting always from the volume curve with a regulator of constant diameter and, consequently, from the speed variation curve of the latter, one can use the so-called "copying" method, well known in machining mechanics.

By reason of the character of the disclosure of this method of working per se, it has not been shown in the drawing of the particular embodiment.

The cam 114 established, as indicated above, according to the speed curve, controls a feeler which regulates, by a pilot valve, the variation of the flow supplying a hydraulic motor.

As for solutions with mechanical drive, they are as follows:

According to the embodiment of FIG. 9 resorting to a mechanical multiplication by means of levers, the regulator 105, of which the piston rod 106 bears a roller 133, is actuated directly by a cam 130, which is rigidly fixed by levers 129, 127 and 125 coupled by a link 128 and a keyed shaft 126, with the rod 116 of the shortening jack 54.

An auxiliary jack 134, fed at the same time as the jack 54, compensates the inertias and the frictions of the transmission. By reason of the reduction factor, the jack 54 can even be dispensed with without change in the operation.

Finally, the final calibration is ensured by the increase of the pressure in the blank resulting from the displacement of a downstroke piston controlled hydraulically by the aforesaid master cylinder; at the beginning of its displacement, the said downstroke piston closing the communication between the inner cavity of the blank and the regulator, which is therefore not subjected to the calibration pressure.

According to the embodiment of FIG. 10, the same result is obtained by replacing the aforesaid levers by cog wheels 135–136′ and 137 making the rod 116 rigidly attached to the cam 130, the lever 125 bearing a part forming a toothed sector to ensure connection with the toothed wheel 135.

Finally, according to the embodiment of FIG. 11 resorting to a hydraulic multiplication, the cam 130 is rigidly attached to the rod of the jack 134, which actuates it and to the rod of a jack 136 which directly supplies the jack 54. The stroke of the jacks 134 and 136 being identical with that of the cam 130 and defined by the latter, it suffices therefore to define the diameter of the jack 136 by equality of volume with the jack 54 by taking advantage of the reduction ratio effect.

According to the embodiment of FIG. 11, the jack 54 is phase-locked directly to the cam 130 which, in being displaced, causes the movement of the regulator.

For the solutions of FIGS. 9, 10 and 11, after having separated the volume curve into four or five sectors, and after having defined the stroke of the regulator for each of them, as a function of the height of shortening, the design of the cam 130 is established taken care to fix the values as abscissae (in the most unfavorable cases) greater than the ordinate values. There is obtained, due to this fact, the ratio between the stroke of this cam and the shortening stroke which enables the control jacks to be defined.

An important parameter resides in the univocal connection existing between the displacement of the bending ram and of the ram of the press. To conform to this rule, whilst preserving the hydraulic flexibility of the type shown in FIG. 11, it is indispensable to compensate any possible leak from the circuit by a replenishment supplement at low pressure at the starting position by means of a small auxiliary accumulator, not shown in the drawing, since it is of the type of those currently used in numerous hydraulic circuits. On the other hand, all hydraulic circuits are obviously provided with suitably placed drain plugs.

This method obviously lends itself to the production of any complex shape, whether of revolution or not. Thus, for example, there can be formed on the same part several profiles, such as several grooves of the same diameter according to the conventional method of sliding rings. There can also be formed several profiles of different diameters, but the solution is more complex.

In the case, for example of a pulley which must comprise two grooves of different diameters, it is necessary to first cause the bending of large diameter, then that of small diameter. In fact, the combination bending-hydraulic action on the small diameter is only possible if the skirt of the latter is supported on the mold. Now, this support would only appear after the formation of the large diameter groove as is seen in FIG. 12 of which the left half shows the mold at the end of the operation with the finished part, whilst the right portion shows the blank in position before processing.

The bending ram must hence be composed of several elements acting successively in the desired order: the ram **150** proper and two movable half-elements **151**; in the course of operation, the latter slide in the two half-molds **152** to become supported against the plug **153**. The ram **150** and the movable elements **151** are driven vertically by the central piston **154** and by the crown **155** respectively, the central piston being itself actuated by the hydraulic jack **156**. Between the central piston **154** and the crown **155** is arranged an annular cavity **157** filled with oil which can escape through a throttle arranged on the channel **158**.

A washer **159** is included in the fixed elements **152** and wedges **160** are arranged for insertion under the piston **154** and the crown **155**.

The arrival of oil in the jack **156** causes the reascent of the central piston **154**. The overpressure created then in the annular cavity **157** by flattening effect causes the simultaneous reascent of the crown **155** of the blank, thus ensuring the bending of the upper part until the half-elements **151** come into abutment against the plug **153**, whilst the crown **155** is supported on the washer **159**.

Then, the central piston **154** continues its path by expelling oil from the annular cavity and then causes the bending of the lower part of the blank to bring the ram **150** finally into abutment on elements **151**. The wedges **160** are then positioned to immobilise the central piston **154** and the crown **155** before the application of the high pressure of calibration.

The oil expelled by flattening of the cavity **157** is stored under slight overpressure of air in a small reservoir; it is recycled into this cavity **157** through an antireturn valve in the course of the restoration of the piston **154** into its initial position.

Whilst it is concerned with the obtaining of multiple shapes of the same or different diameters, the rigorous volumetric control of the deformation (shortening and inflation of the blank) enables any excessive radial expansion and the nipping which results therefrom to be avoided.

It will be apparent that various changes and modifications may be made in the embodiments described without departing from the essential concept of the invention as defined in scope by the appended claims.

I claim:

1. In an apparatus for forming a hollow metal article from a liquid-filled dished metal blank, the combination comprising; means imparting an axial mechanical deformation to said blank effecting a reduction of its height; means concurrently hydraulically imparting a radial deformation to said blank so as to effect an increase of its diameter while providing hydraulic calibration at the end of the combined forming operation; and means for controlling the dimensional thickness of said blank during the forming thereof into said article; said controlling means comprising a cam having a profile dimensionally determined in response to the fundamental correlation between the volume of the formed article and the height of the blank prior to its transformation into said article, said mechanical deformation means including a pushrod, which actuates said cam, and said hydraulic means including a jack having a piston operatively connected to said cam for concurrently varying the internal volume of the formed article, whereby said cam effectively controls the combined mechanical and hydraulic forming of said article.

2. An apparatus as claimed in claim **1**, including an oil-hydraulic transmission responsive to said cam for actuation of said pushrod.

3. An apparatus as claimed in claim **1**, including a mechanical transmission responsive to said cam for actuation of said pushrod.

4. An apparatus as claimed in claim **1**, including an openable mold for said blank, a frame formed of two parallel plates having a pair of U-shaped binders; and a pneumatic control operatively connected to said frame so as to effect the blank closing-in and phase-locking sequence of the openable portions of the mold.

5. An apparatus as claimed in claim **4**, including a pump for filling said blank with said liquid, said control, said cam, and said pump comprise a unit detachably mounted apart from the mold-receiving frame.

6. An apparatus as claimed in claim **1**, including a pressure regulator, and a conduit connecting said blank interior with said jack piston, said piston at the start of its hydraulic calibration stroke sealing the conduit connecting the hollow interior of the blank with the regulator so as to prevent the latter from being subjected to high calibrating pressures.

7. An apparatus as claimed in claim **1**, including an electrical direct-current motor having a worm and wheel gear drive unit, said cam comprising a rotating cam adapted to be driven by said drive unit; a potentiometer having thyristors for measuring electrical currents from said motor, said cam being rotatably responsive to said potentiometer; a further jack for controlling the interior volume of the finished article actuated by the piston of said first-mentioned jack, said piston having a displacement controlled by the rotation of said cam.

8. An apparatus as claimed in claim **1**, including hydraulic motive means, a further jack for controlling the interior volume of the finished article adapted to be actuated by the displacement of the piston of said first-mentioned jack; said cam comprising a rotating cam actuating said piston; an oil-hydraulically operated copying unit having a template feeler, rotation of said cam being responsive to said feeler so as to displace said jack piston.

9. An apparatus as claimed in claim **1**, wherein in the formation of an article comprising several profiles of various diameters, said jack comprises a plurality of concentrically spaced auxiliary jacks, said jacks being interconnected by oil pads provided with reduced diameter orifices, said first-mentioned jack being actuated so as to have each auxiliary jack effected the flexure of the blank diameter to which it pertains until formation of the finished formed article, and the oil at that time being expelled through said orifices.

* * * * *