

July 27, 1948.

E. HOCHREITER

2,446,089

APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

Filed Dec. 16, 1943

10 Sheets-Sheet 1

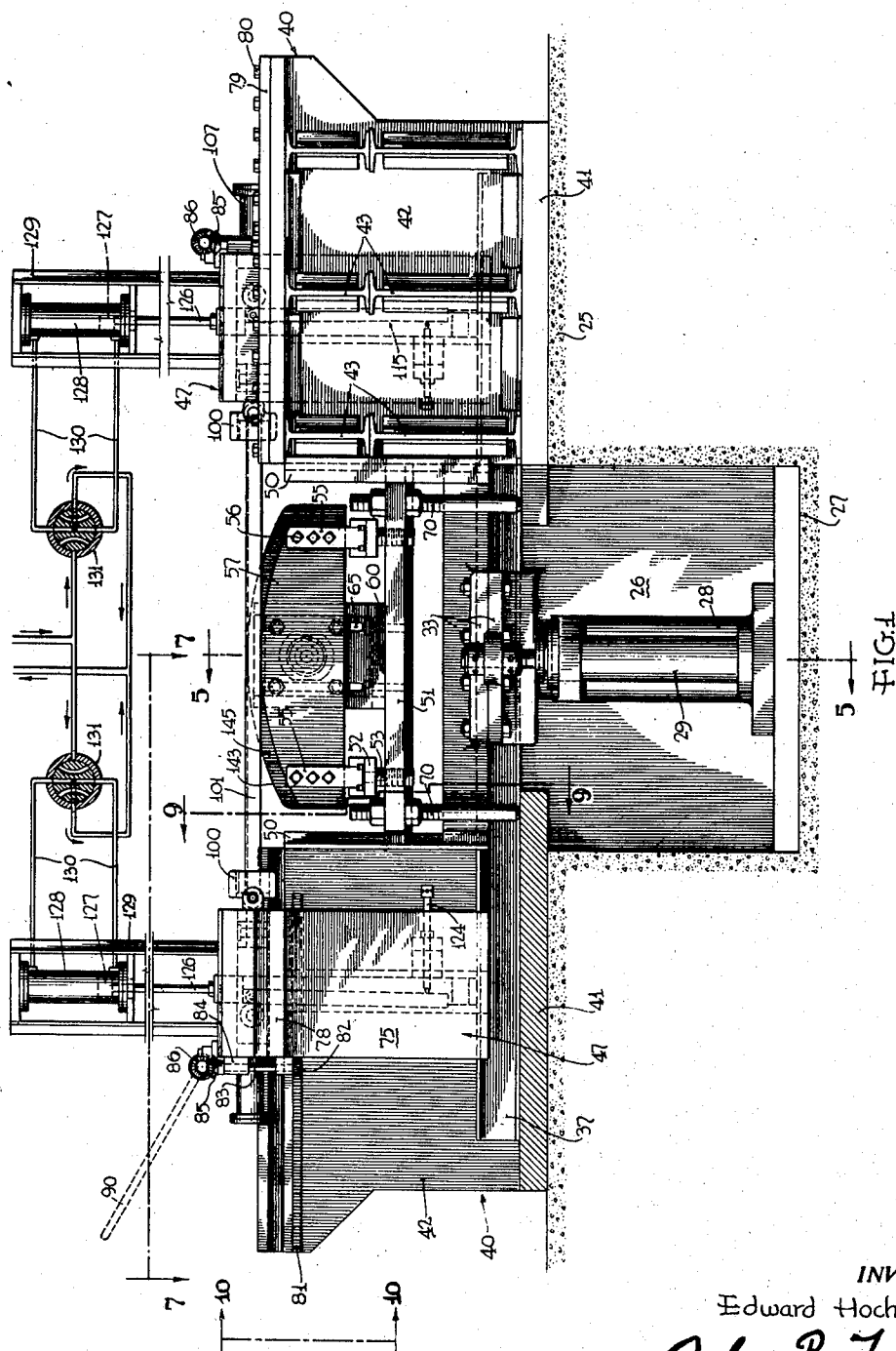


FIG. 1

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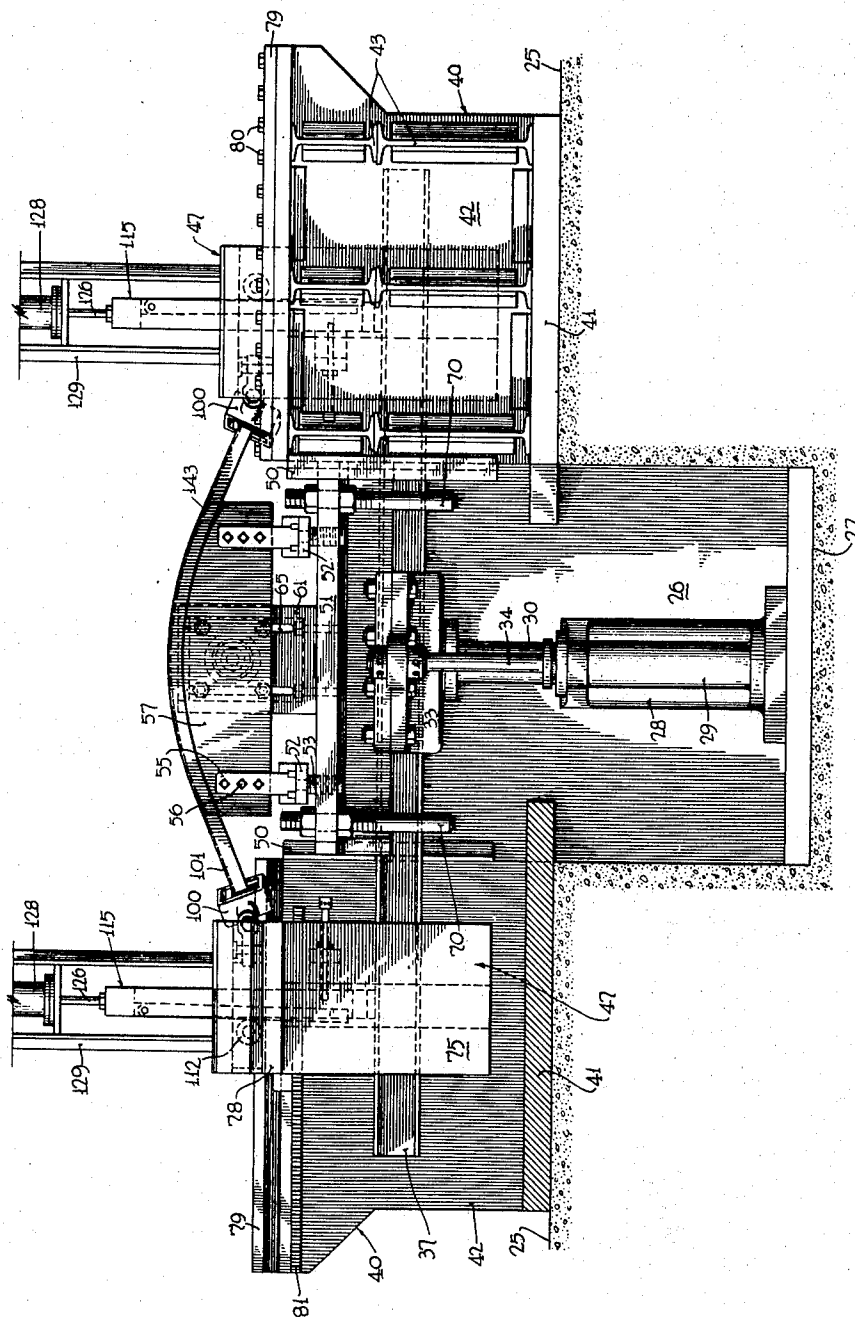
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10 Sheets-Sheet 2



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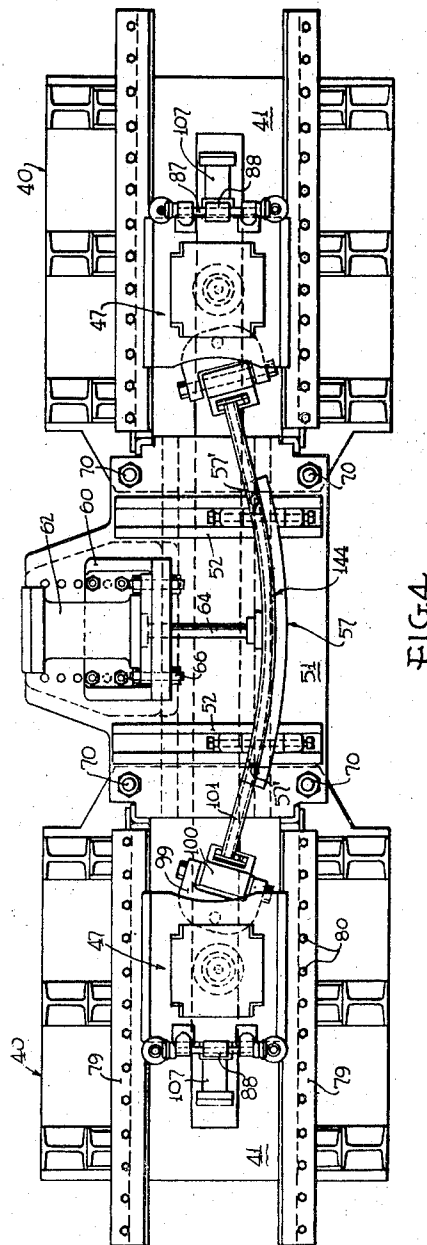
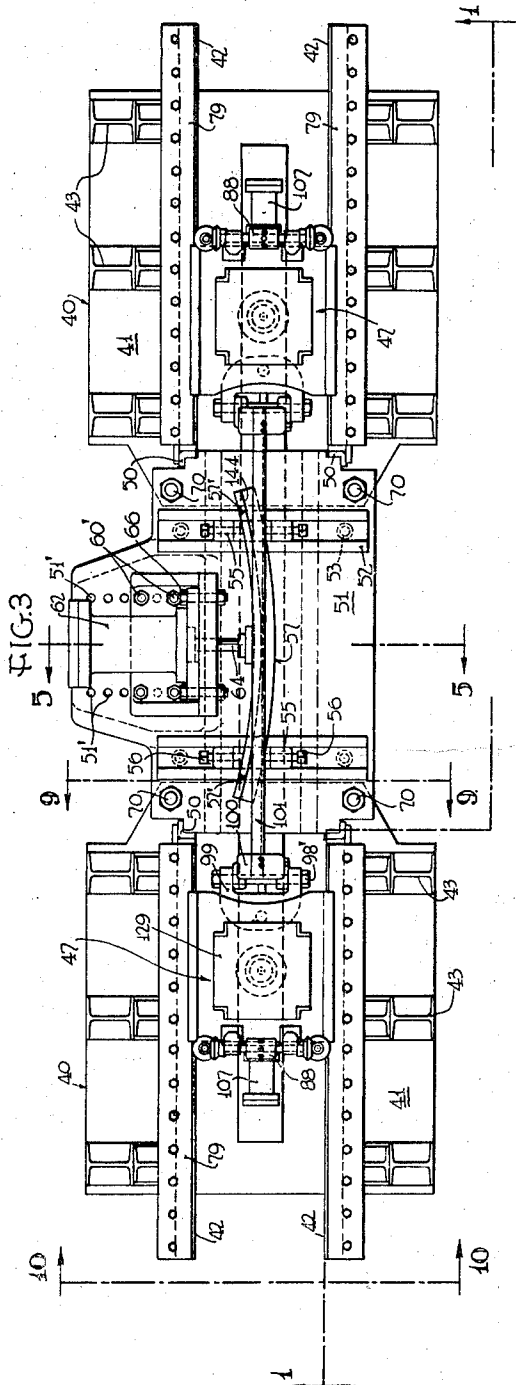
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10 Sheets-Sheet 3



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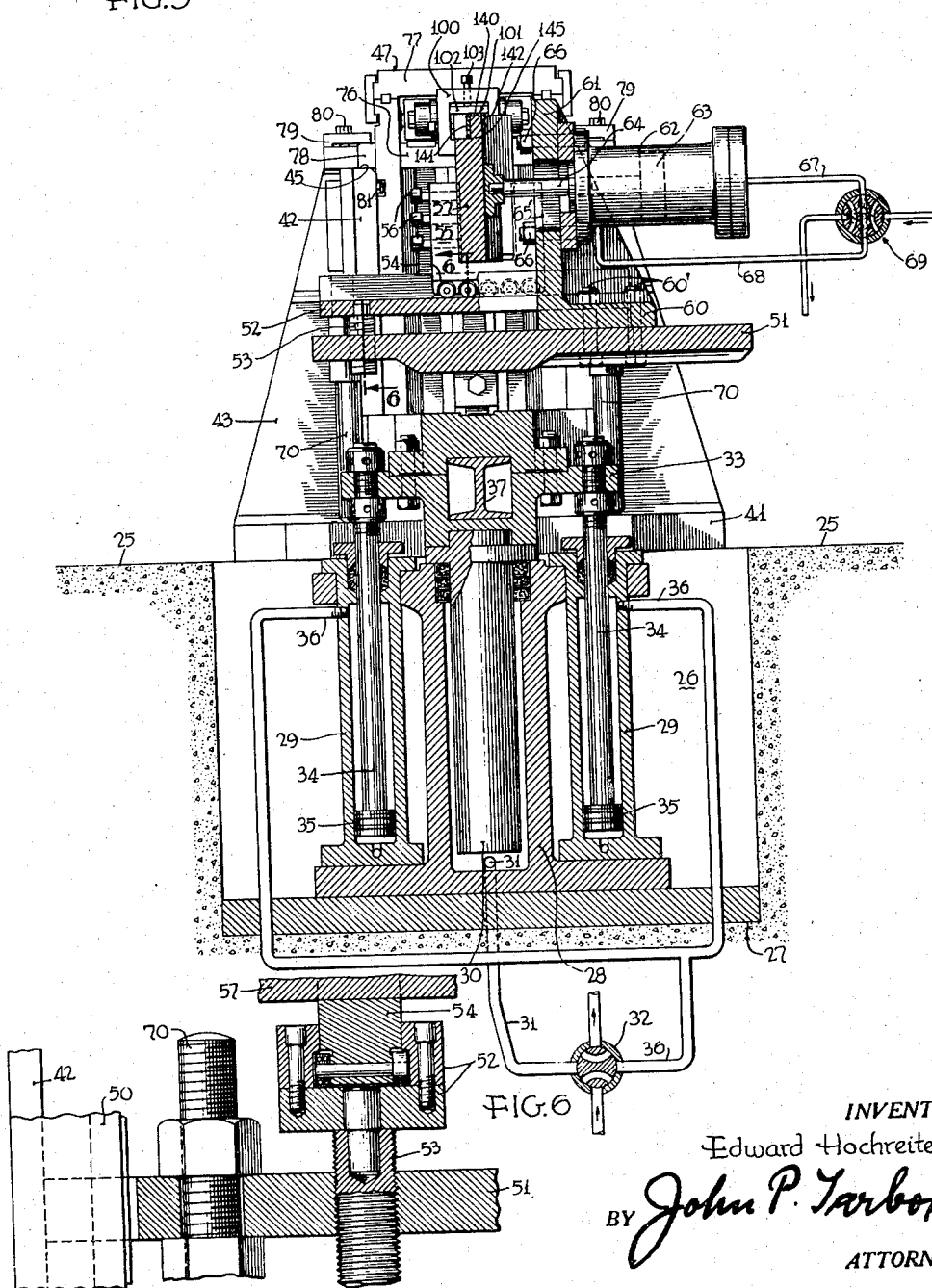
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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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FIG. 5



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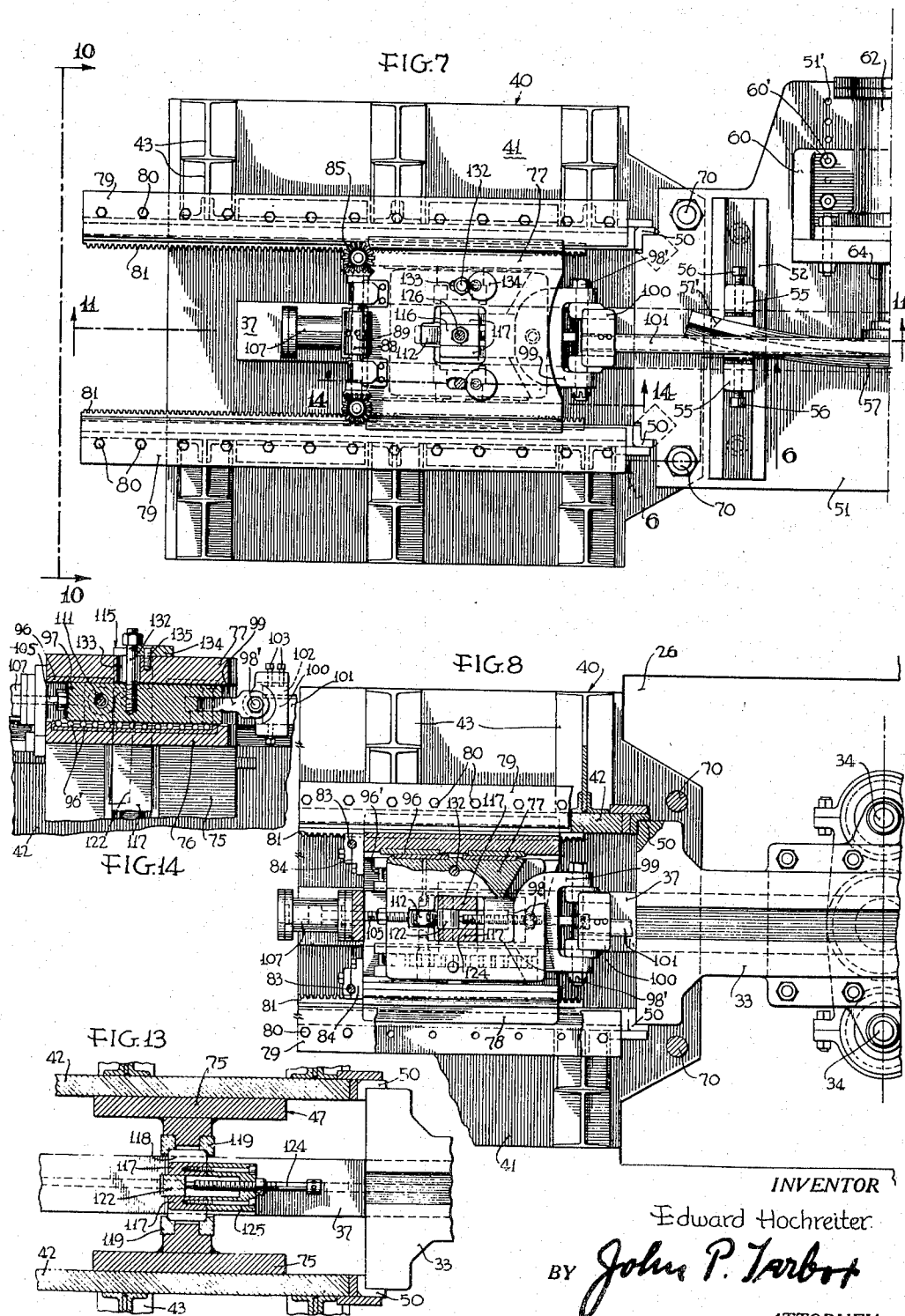
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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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10 Sheets-Sheet 5



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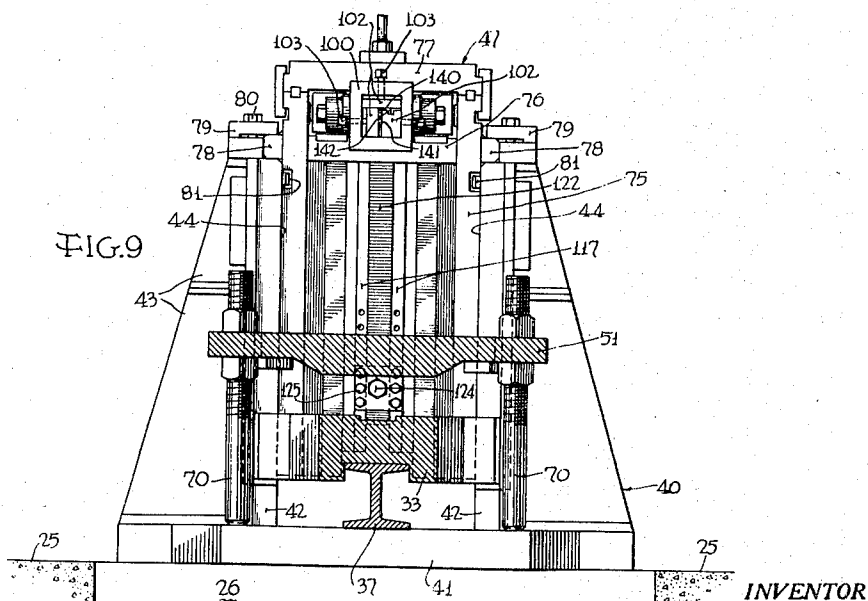
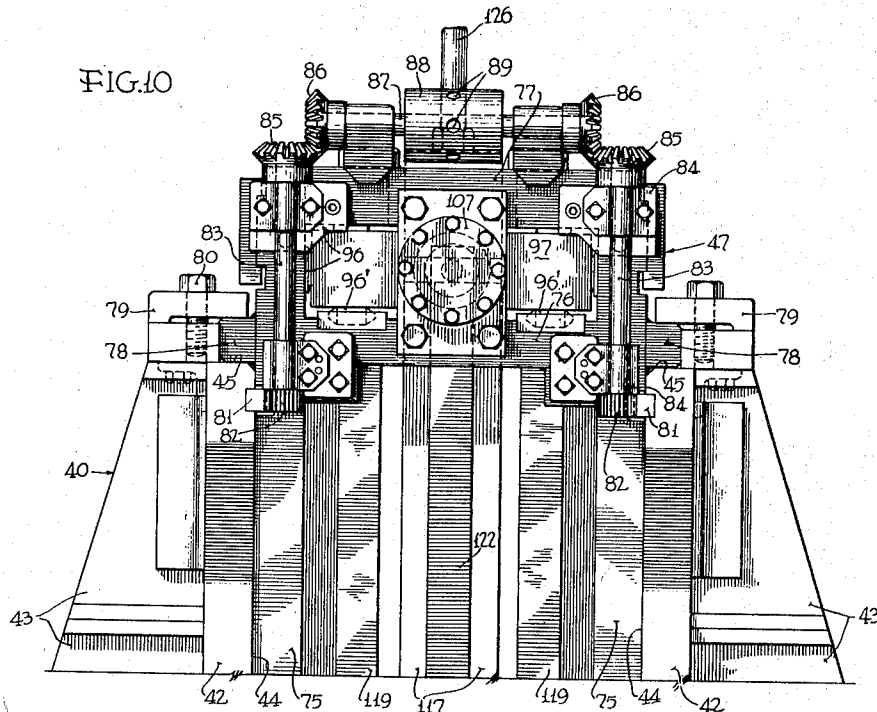
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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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10 Sheets-Sheet 6



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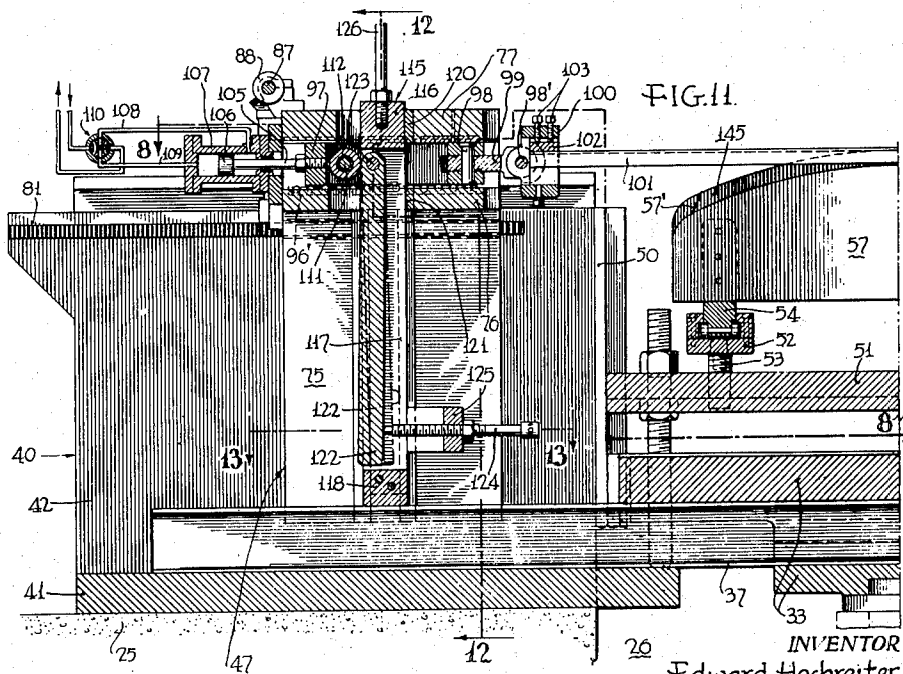
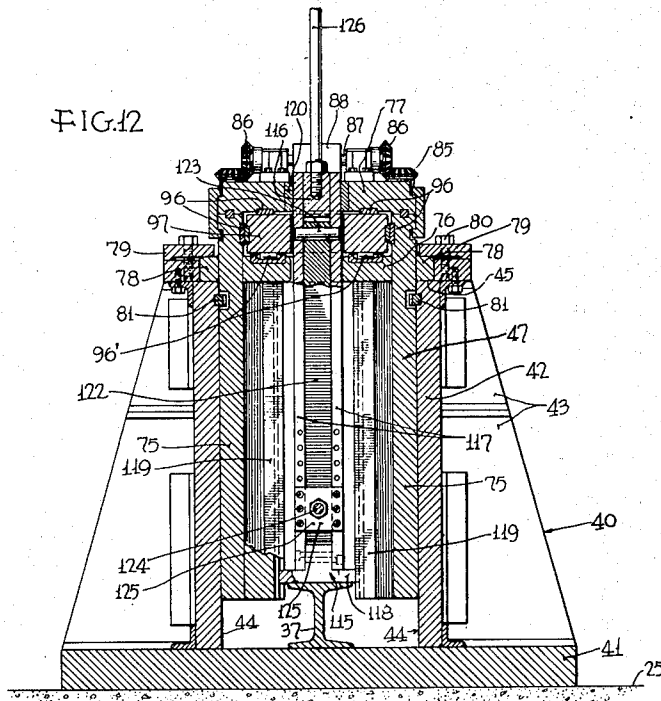
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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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10 Sheets-Sheet 7



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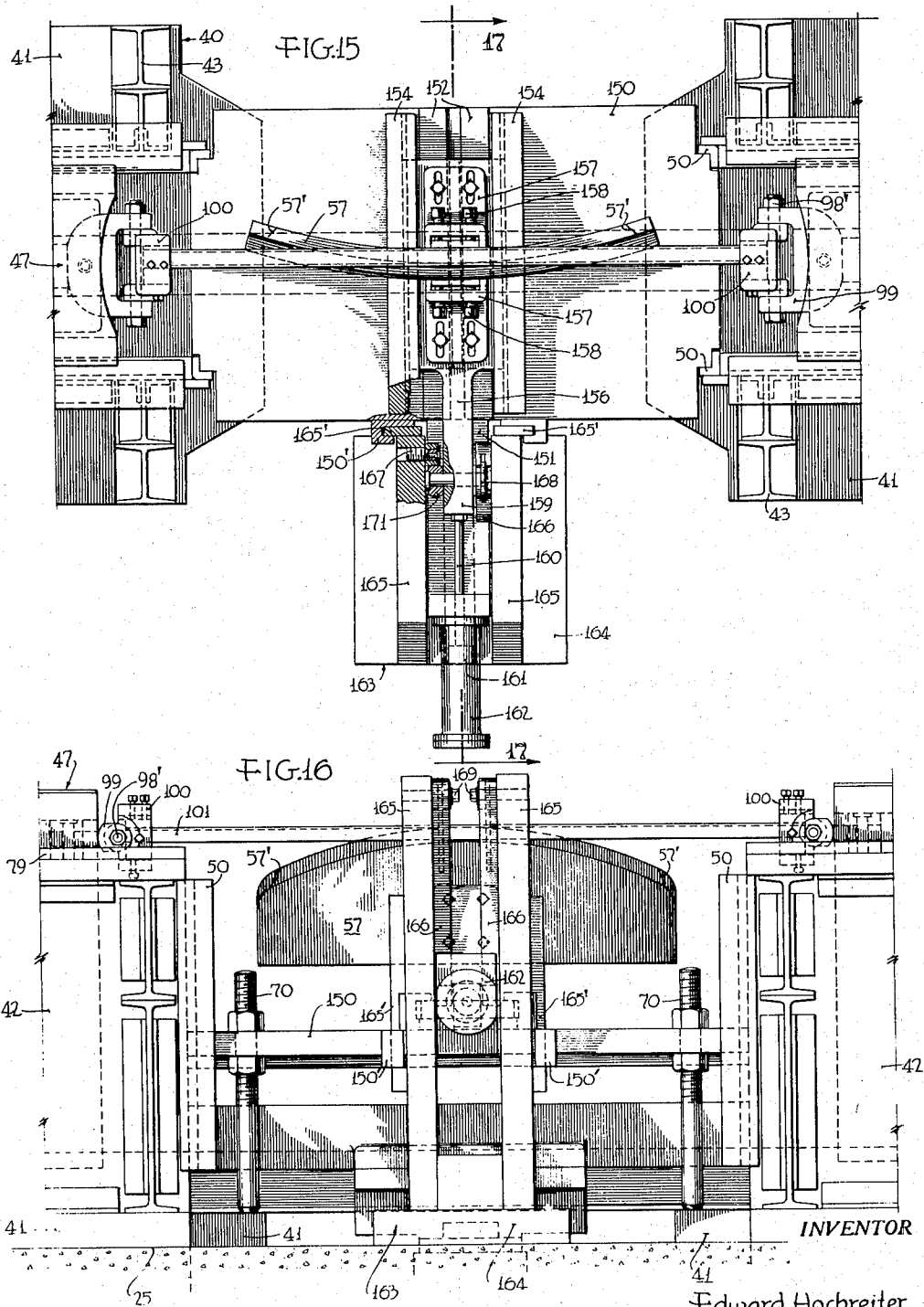
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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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10 Sheets-Sheet 8



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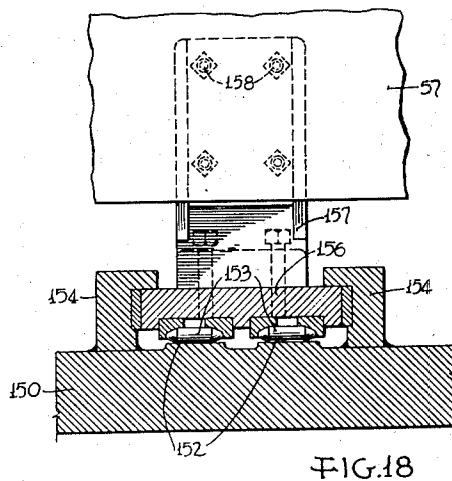
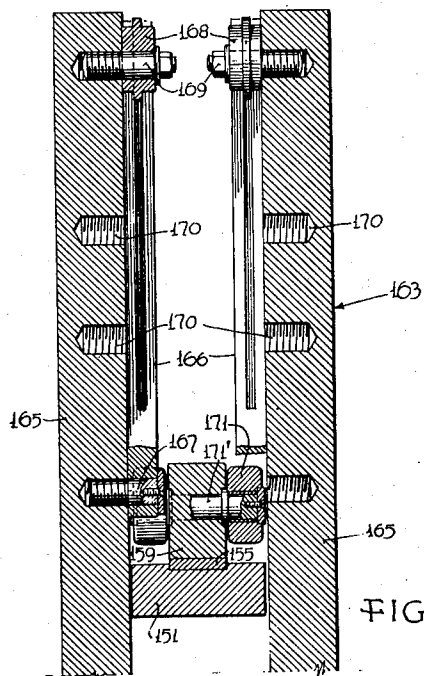
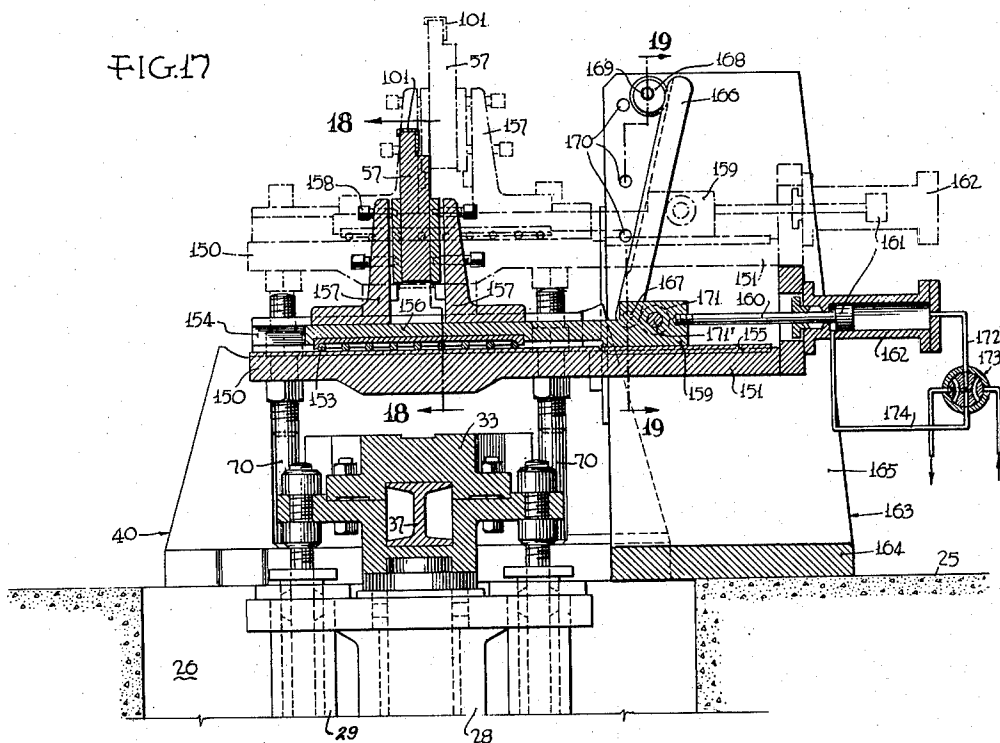
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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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10 Sheets-Sheet 9



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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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10 Sheets-Sheet 10

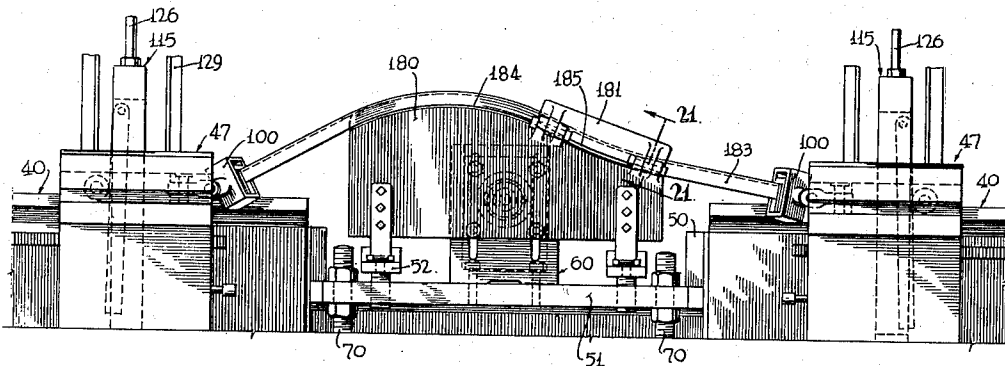


FIG. 20

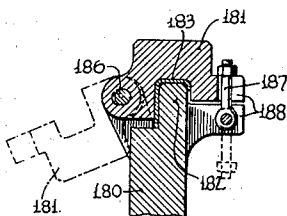


FIG. 21

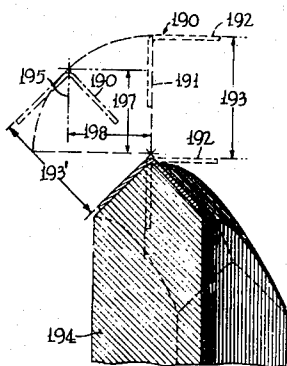


FIG. 26

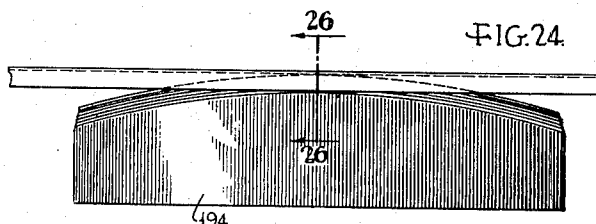


FIG. 24



FIG. 25

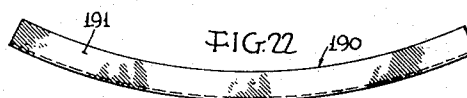


FIG. 22

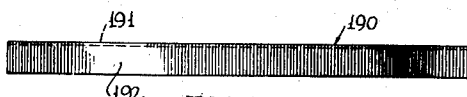


FIG. 23

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UNITED STATES PATENT OFFICE

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APPARATUS FOR STRETCH FORMING ELONGATED ARTICLES

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tion of Pennsylvania

Application December 16, 1943, Serial No. 514,573

14 Claims. (Cl. 153—48)

1

The invention refers to means for forming articles. More particularly, the invention refers to means for forming curved members such as, for instance, the ribs of airplane structures, from web material or extruded sections.

Still more specifically, the invention refers to improvements in the stretch-forming of articles of the indicated type.

Among the objects of the invention is equipment which permits the comparatively cheap, easy and highly accurate forming of curved profiles.

Among the objects of the invention are, furthermore, means which permit accurate forming of curved profiles to the accurate shape of a form or die without the necessity of providing for spring-back and without the danger of subsequent warping or other changes of the desired shape.

Among the objects of the invention are also means which permit the formation of members which are curved in more than one plane.

Among the objects of the invention are in general means and ways for solving the problems briefly outlined in the following.

Great, and sometimes nearly unsurmountable-appearing, difficulties have been encountered in the forming of many profiles needed for airplanes and other structures. Often, recourse had to be had to tedious hand-work so as to attain the required accurate shapes. Indeed, frequently all efforts have been in vain because the formed profiles would not keep the desired shape but would warp a certain time after their forming.

Attempts have been made, sometimes with and sometimes without success, to stamp between a male and a female die profiles which could not be formed by simpler forming methods, such as bending. Die forming in this manner is not only costly but time-consuming for different reasons: the dies are expensive; the material of the blank required for holding the margins of the blank goes to scrap; and an extra set of dies and an extra operation for trimming off the marginal portions are required.

Moreover, it proved impossible to form certain materials and shapes accurately by any known method and means. Outstanding among such materials are high-tensile stainless steel, especially in its hard or half-hard rolled form, and outstanding among such shapes are compound and/or reverse curves and/or complicated sections.

A further problem is presented by the fact that airplane constructions become, in these times, very quickly obsolete, so that the shapes of the members to be formed change frequently and so that the total number of identically shaped members to be produced is ordinarily not large.

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Also for this reason, forming by methods and means requiring long and expensive preparations, such as connected with the above-mentioned stamping between two dies, are often very unsuited and undesirable. If the preparation of the product requires too much time, an airplane construction may even become obsolete before it goes into production.

The aforesaid and other objects of the invention as well as additional advantages are mainly achieved and the outlined problems are solved by the means constituting the invention. These means can be more clearly explained in connection with and will be more easily understood from the embodiments illustrated in the attached drawing and the following description thereof.

In the drawing:

Figure 1 is a front elevation of one embodiment of the new machine partly in section along line 1—1 of Figure 3 showing the parts of the machine at the start of a stretch-forming operation;

Figure 2 is a similar elevation of the machine, showing the parts thereof in the position at the end of a forming operation, certain accessories shown in Figure 1 being omitted;

Figures 3 and 4 are somewhat diagrammatic plan views of the machine corresponding, respectively, to Figures 1 and 2;

Figure 5 is a transverse vertical section taken along line 5—5 of Figures 1 and 3;

Figure 6 is a fragmentary section taken along line 6—6 of Figure 5;

Figure 7 is a plan view partly in section along line 7—7 of Figure 1 showing the left-hand part of Figure 3, yet on a larger scale and with more details;

Figure 8 is a fragmentary plan view, partly in section along line 8—8 of Figure 11 on the same scale as Figure 7;

Figure 9 is a section along lines 9—9 of Figures 1 and 3 on a larger scale;

Figure 10 is a fragmentary end elevation seen in the direction of the arrows along lines 10—10 of Figures 1, 3 and 7;

Figure 11 is a fragmentary section along line 11—11 of Figure 7;

Figures 12 and 13 are fragmentary sections along the correspondingly numbered lines of Figure 11;

Figure 14 is a fragmentary section along line 14—14 of Figure 7;

Figure 15 is a fragmentary plan view of the machine with a modified arrangement for the transverse movement of the forming die;

Figure 16 is a fragmentary front elevation of the machine shown in Figure 15;

Figure 17 is a section along line 17—17 of Figure 15;

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Figures 18 and 19 are fragmentary sections, respectively, along lines 18—18 and 19—19 of Figure 17;

Figure 20 is a fragmentary diagrammatic view corresponding to part of Figure 2, yet showing a different form or die in the machine;

Figure 21 is a fragmentary section along line 21—21 of Figure 20;

Figures 22 and 23 are a plan view and front elevation, respectively, of an angle-section rail;

Figures 24 and 25 are, respectively, a front elevation and a plan view of the die for making the member illustrated in Figures 22 and 23; and

Figure 26 is a vertical fragmentary section along line 26—26 of Figure 24 illustrating in dotted lines and in dot-and-dash lines, respectively, the prior art method of making the member illustrated in Figures 22 and 23 and the new method of making this member by the die shown in this figure and in Figures 24 and 25.

In the embodiment illustrated in Figures 1 to 14, 25 is a floor around a well or pit 26 having a bottom 27. Supported on the bottom 27 of the well or pit 26 are a hydraulic main cylinder 28 and two auxiliary cylinders 29. A plunger 30 in the cylinder 28 is adapted to exert an upward thrust when a pressure medium, such as oil, is admitted to the interior of the cylinder by means of the diagrammatically indicated pipe line 31 and valve 32. The plunger 30 engages a cross head 33 to which are attached the rods 34 of pistons 35 housed in the cylinders 29. The pistons 35 serve for pulling the cross head 33 and the plunger downwardly when a pressure medium is admitted through the pipe line 36 and the valve 32, which latter at the same time relieves the pressure from the cylinder 28. Securely held in the cross head 33 is a horizontal beam 37.

One frame structure 40 each is secured to the floor 25 on opposite sides of the pit 26. The two structures 40 and their accessories are substantially identical, so that only one of them will be described in detail.

Each structure 40 comprises a heavy base 41 to which are secured two vertical plates 42 arranged at a distance from each other and at about equal distances from the plane defined by the axis of piston and plunger 28, 30 and beam 37. The plates 42 are firmly secured, as by welding, to the bottom plate 41 and braced by bracket members 43. The surfaces 44 facing each other and the top faces 45 of the plates 42 are arranged and prepared so as to slidably guide and support the structure 47 to be described later on.

Secured to the vertical margins of the plates 42 which face the pit 26 are gibs 50 (see Figures 1, 2 and 7) which serve together for securely guiding in vertical direction the cross head 33 and a horizontally arranged supporting structure, plate or table 51. The plate 51 carries two guideways 52 by means of adjusting screws 53. Slidable in these guideways are sleds 54 which are provided with means, such as arms 55 and screws 56, for securely holding a stretching die 57. A heavy angle bracket 60—is also adjustably secured in horizontal position to the table 51 by one of its arms and bolts 60' passing through holes 51'. The upstanding arm 61 of the bracket holds a cylinder 62. A piston 63 is movable in cylinder 62 and engages by its rod 64 the form 57 or a member connected therewith, such as the sleds 54. The height of the cylinder is adjustable on account of a vertical slot 65' through which rod 64 projects (see Figure 5) and the elongated slots

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65 provided in the bracket arm 61 through which the securing bolts 66 pass (see Figures 1 and 2). A pressure medium can be admitted to the cylinder 62 on either side of the piston 63 by means of the pipe lines 67, 68 and the valve 69 (see Figure 5).

The downward movement of the table or plate 51 is adjustable by means of the bolts 70 arranged near its four corners. The lower ends of these bolts engage marginal portions of the base plates 41. If the rods 70 are adjusted as shown in Figures 1, 2, 5, 9 and 11, the plate will not be in contact with the cross head 33 when the latter and the plunger 30 are in their lowermost position. This serves for an important purpose to be explained later on.

Without describing the complete operation of the machine, it may be pointed out here that, upon admission of pressure medium to the cylinder 28, the plunger with the cross head 33 and the beam 37 will be forced upwardly and the cross head 33 will, after a certain movement, engage the plate 51 and move the same upwardly together with form 57 and other members connected therewith. At the same time, the form 57 may be moved in horizontal direction by admitting pressure medium to the cylinder 62 on one side of the piston 63. The piston 63 may push the form 57 in one direction or may pull it in the other direction, depending upon the special conditions to be met. Upon relieving the pressure from the cylinders 62 and 28 and upon admitting pressure medium to the cylinders 29 and the other side of the cylinder 62, the members will be brought back to their initial position either by said pistons or, as in the case of table 51, by gravity. The form 57 and the sleds 54 may be pushed back by hand if the rod 64 is not secured to one of them.

Each of the structures 47 has two vertical plates 75 (see Figures 1, 2 and 9 to 14) which slidably engage the surfaces 44 of the plates 42 and are connected near the top by a pair of transverse vertically spaced plates 76, 77 (see Figures 11 and 14). A horizontal rib 78 (see Figures 8, 9 and 12) on each plate 75 extends laterally outwardly and rests on the top surface 45 of the plates 42. Clamping rails 79 and screws 80 serve for securely holding the structure 47 at any desired location along the length of the plates 42. Upon loosening the screws 80, the structure 47 may be moved between the plates 42 by means of racks 81 secured to the plates 42 and pinions 82 secured to shafts 83 rotatably supported in brackets 84 on the structure 47. The upper ends of the shafts 83 carry bevel pinions 85 (see Figures 7, 8 and 10) which mesh with bevel pinions 86 on a common horizontal shaft 87 rotatably supported by the structure 47. A member 88 is secured to the central portion of the shaft 87 and is provided with holes 89 for the insertion of a removable handle bar 90, shown in dotted lines in Figure 1.

Slidably guided between the walls 76, 77 (see Figures 8, 11, 12 and 13) and the upper ends of the walls 75 by means of gibs 96 and rollers 96', is a sled 97 which, in plan view, presents the general form of a rectangular frame. Universally movably journaled to sled 97 by means of pins 98, 98' and an intermediate member 99, is a vise 100 adapted to clampingly grip one end of a work-piece 101 by means of jaws 102 and bolts 103. The opposite side of the frame 97 has secured thereto the rod 105 of a piston 106 movable in a cylinder 107. A pressure medium is admissible to the cylinder 107 on either side of the piston

106 by means of the pipe lines 108, 109 and valve 110. In the interior of the frame 97 and near its wall connected to the piston rod 105 is a transverse horizontal shaft 111 carrying rotatably thereon a roller or cam follower 112.

Through the opening in the frame 97 and through similar openings in the walls 76, 77 extends an elongated vertically arranged frame 115 having a top member 116, vertical side members 117 and a transverse bottom member 118. The member 118 extends beyond the side walls 117 and is guided in gibs 119 secured to the walls 76 of the structure 47 (Figure 13). The upper end of the structure 115 glides on gibs 120, 121 (see Figures 11 and 12) secured, respectively, to the walls 77 and 76 of the structure 47. By the described arrangement, the structure 115 is securely guided for reciprocating vertical movement in the structure 47 (see Figures 11 and 12).

A cam member 122 is journaled by a pin 123 near its upper end to structure 115 so that it can be swung back and forth between the side walls 117 of the structure 115. The position of the cam member 122 is adjustable by bolt 124 screw-threaded in the bridge structure 125 connecting the side walls 117. One surface of the cam member 122 rides against the previously described roller or cam follower 112 (see Figure 11). The dot-and-dash line marked 122 indicates another adjustment of the member 122.

Secured to the top member 116 of the structure 115 is the rod 126 of a piston 127 movable in cylinder 128 (see Figures 1, 2, 11 and 12). The cylinder 128 is supported by a structure 129, which latter is secured to the top of the structure 47. A pressure medium can be admitted to the cylinder 128 above or below the piston 127 through pipes 130 and valve 131.

The frame or sled 97 carries on each side a pin 132 (see Figures 7, 8 and 14) which extends through an elongated slot 133 in the top wall 77 of the structure 47. This pin engages at one end of the stroke of the sled 97 a disc 134 eccentrically secured at 135 to the wall 77. By rotating the disc 134, it is possible to adjust the stroke of the frame or sled 97 for a purpose which will be more fully described later on.

Before describing the operation of the entire machine, it appears appropriate to describe briefly the operation of the members guided in the structure 47.

At first, the structure 47 is moved by means of the racks 81 and the device 82 to 90 to the desired position within the structure 40 and is secured in this position by means of the plates 79 and bolts 80. This position depends upon the length of the work 101. If, thereupon, the beam 37 is raised by means of plunger 30, the beam pushes the structure 115 upwardly with the effect that the cam member 122 presses against the cam follower 112 and pushes the frame or sled 97, together with the vise 100, away from the center of the machine. Upon return of the beam 37 to its lower position, the sled 97 and the structure 115 can be moved back to their initial position by admission of pressure medium to the cylinders 107 and 128. The amount of movement of the sled 97 depends upon the adjustment of the cam member 122 by means of the bolt 124. The adjustment can even be such that the cam member 122 allows the sled 97 to move toward the center of the machine; such position is indicated by dot-and-dash lines in Figure 11.

In certain cases, it is desirable that the sled 97 does not start its movement at once upon the

movement of the beam 37 and the structure 115. In such an event, the discs 134 (see Figures 7 and 14) are turned about their securement bolts 135 so that they push the pins 132, together with the sled 97, in the direction of the cylinder 107 and thereby keep the cam follower 112 at a distance from the cam member 122 in the latter's lowermost position. The cam follower 112 will then engage the cam member 122 only after the latter, with the structure 115 and the beam 37, have been moved upwardly a certain distance.

The entire machine illustrated in Figures 1 to 14 is operated as follows:

The article to be formed is a channel-section profile having a bottom wall 140 (see Figure 5), a wide side wall 141 and a narrow side wall 142. The finished article has a compound curvature, the curvature in one elevation being shown at 143 in Figures 1 and 2, and the curvature in another elevation at 144 in Figures 3 and 4. The workpiece 101 has received its general cross-sectional form preferably, but not necessarily, before being placed in the described machine. Such pre-forming of the section may be carried out, for instance, on a draw or roller bench, or on a power brake. Moreover, the workpiece 101 may, in certain cases, be partly curved beforehand, for instance, on a bending machine, so as to reduce the amount of forming to be done on the new machine.

The form 57 may consist of any proper metal, even zinc alloys, aluminum, Wood's metal or of compressed board. The upper marginal portion 145 of the form 57 has its surfaces accurately shaped to the inside form of the section 140, 141, 142. The surface for the wide side wall 141 is located on the convex side of the form.

After adjusting the table 51 by means of the bolts 70, the form 57 is secured in the slidable supports 54 (see Figures 1, 5 and 11) at such height that its apex is on the same level with the vises 100. The jaws 102 of the vise 100 are shaped corresponding to the cross-section of the workpiece 101. The ends of the workpiece are secured in the vises 100 so that the middle portions of the workpiece and of the form 57 engage each other.

The cam member 122 is adjusted by the bolt 124 (see Figures 7 and 13) so as to impart the desired stretch to the workpiece 101 during the forming operation. Often, the necessary stretch has to be determined by trial and error.

After these preparations, pressure medium is admitted to the cylinder 28 so that the plunger 30, with its head 33 and beam 37, is forced upwardly. With the adjustment as shown in Figures 1 to 14, the beam 37 engages first the structures 115 only with the effect that the cam members 122 push the frame or sleds 97 with the vises 100 outwardly away from the center of the machine and impart an initial stretch to the workpiece 101. Later on, the head 33 engages the table 51 and thereby moves the form 57 against the workpiece 101. During this upward movement of the form 57, pressure medium is admitted to the cylinder 62 (see Figures 3 to 5 and 7) so that simultaneously a transverse movement is imparted to the form 57. The upward movement and the transverse movement of the form 57 have to be coordinated so that at all times the free ends of the workpiece 101 extend about tangentially to those parts of the form where contact is made. The final stage of the operation is shown in Figures 2 and 4. The importance of the universal connection (see Fig-

ures 3, 7, 11 and 14) between the vises and the sleds 97 will now be self-evident.

The proper coordination between upward and transverse movement of the form 57, of the initial stretch imparted to the workpiece before the upward movement of the form begins, and the total amount of stretch imparted to the workpiece 101 by the adjustment of the cam members 122 have to be determined for each single form and will often require a number of experimental runs by the crew operating the machine. So as to obtain a permanent setting of the workpiece at the desired shape without spring-back, twisting or the like, it is necessary that the workpiece be stretched beyond its elastic limit before leaving the form or die. This is especially important for such difficult materials as semi-hard rolled or completely hard rolled stainless steel, but it is also important for other material such as, for instance, aluminum alloys.

After having finished the forming operation, the beam 37 is moved slightly downwardly by admitting pressure medium to the cylinders 29, the structures 115 are moved downwardly by admitting pressure medium to the cylinders 128, and the sleds 97 with vises 100 are moved slightly inwardly by admitting pressure medium to the cylinders 107, whereupon the jaws 102 of the vises 100 are loosened and the vises are withdrawn by admitting pressure medium to the opposite side of the cylinders 107. Now the article can be taken from the form.

Tension on the workpiece through the vises may also be applied by admitting pressure medium to the cylinders 107 and/or 128 on the inner sides of the pistons 106 or 127.

The possibility of delaying the beginning of the stretching by means of the cam member 122 by appropriate adjustment of the stops 134 (see Figures 7 and 14) has been outlined hereinbefore.

It will be understood that many of the movements of the machine are relative movements between workpiece and form, and that these relative movements can be achieved also by means different from those illustrated in the drawing.

If properly operated, the forming is so accurate that the form 57 can be made exactly to the contours of the finished article without any allowance whatever for spring-back or the like, so that the same form may be used for transcribing on the workpieces the trim lines marked at 57' (see Figures 3, 4, 7 and 11) on the form or die, for instance, by the device disclosed in the inventor's application Serial No. 517,509, filed January 8, 1944, for Scribing fixture, now Patent No. 2,402,890, of June 25, 1946, and so that the form may even be used as a checking fixture for the trimmed pieces prior to their assembly with other members.

The machine illustrated in Figures 15 to 19 is identical with the previously described machine except for the construction of the die supporting table and of the members associated therewith. For this reason, the machine as such will not be described again but the main parts thereof, as far as they are shown in Figures 15 and 19, are identified by the same reference numerals as in Figures 1 to 14.

The table 51 of the first embodiment is supplanted in the second embodiment by a slightly different table 150 which is provided with adjusting bolts 70 determining the lowermost position by engagement with the bottom plates 41.

The table 150 is laterally extended at 151 (see Figures 15, 17 and 19). The table's main portion carries races 152 for rollers 153 and guiding members 154, the latter extending parallel to and arranged on both sides of the former. The extension 151 carries a gib 155 (see Figures 17 and 19) arranged in the same direction as the races 152. A structure 156 supported by the rollers 153 and guided by the members 154 has upwardly projecting brackets 157 between which the form 57 is secured by means of the bolts 158. The structure 156 has a head 159 slidably supported on said gib 155 and connected to the rod 160 of a piston 161 movable in a cylinder 162.

Supported on the floor 25 is a pedestal structure 163 having a base plate 164 and two spaced vertical walls 165 extending on both sides of the extension 151 and the head 159. The table 150 slidably engages by members 166' (see Figures 15 and 16) gibs 165' secured to the walls 165. Cam members 166 are arranged on the opposite surfaces of the walls 165. These members have their lower ends swingably attached by bolts or pins 167 (see Figures 15, 17 and 19) to said walls, whereas their upper ends rest against discs 168 eccentrically secured by bolts 169. The inclination of the cam members 166 can be adjusted by securing the discs 168 in different angular positions with respect to these members and/or by holding them in one of the different holes 170 provided for this purpose in the walls 165. The side opposite the discs 168 of the members 166 is engaged by cam follower rollers 171 carried rotatably about pin 171' by the head 159 of the structure 156.

The operation of the device is indicated in Figure 17 by dot-and-dash lines. When the head 33 is moved upwardly and takes the table 150 along, the rollers 171 are pushed by the cam members 166 to the right in Figure 17, and pull, of course, the structure 156 attached to them with brackets 157 and form 57 in the same direction so that in the uppermost position, indicated by the dot-and-dash lines in Figure 17, the form 57 is considerably moved to the right as compared with its initial position shown in the same figure in full lines.

The lateral return of the structure 156 with its form 57 is achieved by admitting pressure medium through the pipe 172 and the valve 173 to the cylinder 162. Here again, the cylinder 162 with its piston 161 may be used for effecting the transverse shaping movement or for assisting in such movement by admitting pressure medium to the other side of the cylinder through the pipe 174.

The operation of the machine is substantially the same as that of the first embodiment except for the fact that the transverse movement is positively controlled. The amount of the transverse movement is determined by the transverse curvature of the form or die. It is obvious that certain forms may necessitate irregular transverse movement, in which event a correspondingly shaped cam device would be required.

Both described machines can, of course, be used for forming members which are curved in one plane only. In such event, no transverse movement would be imparted to the supporting structure for the form, or the form might be directly secured to the table 51 or 150, respectively.

It should be understood also that in both machines, the movements of the vises on both sides may be controlled independently and differently from each other. In this way, specific conditions,

such as differences of the shape of the die on both sides of its middle region, may be met.

Figures 20 and 21 illustrate the formation of reversely bent members with a form and on a machine built in accordance with the invention.

The illustrated machine, as such, is the same as illustrated in Figures 1 to 14 and, therefore, its most important parts only are provided with the same reference numerals as in Figures 1 to 14 but will not be described again. The differences over the preceding embodiments consist exclusively in the form or die and in its use.

The form or die illustrated in Figures 20 and 21 consists of two members 180, 181. In the illustrated case, the part 180 may be called the main form or die and the part 181 may be called an auxiliary form or die.

The main die 180 has the surface of its upper marginal portion 182 shaped corresponding to the complete one surface of the workpiece 183 in its finished state, that is, including the convex portion 184 and the concave or reversely bent portion 185. The shading in Figure 20 indicates that the die and the finished workpiece are compoundly curved, that is, also curved in plan view. The auxiliary die 181 is shaped complementary to the concave section 185 of the main die. The main die 180 is supported by the table 51 and is transversely movable in the same manner by the same means as the die 57 of Figures 1 to 14. The auxiliary die is hinged on one side at 186 to the main die and removably secured on the other side of the workpiece 183 to the main die by a hinged screw bolt 187 connecting two projections 188 on the two dies.

After having secured the workpiece 183 in the vises 100 and after having stretched the workpiece over the convex portion 184 of the main die 182, while the auxiliary die is kept in the position shown in Figure 21 in dot-and-dash lines, the auxiliary die is brought into the position shown in full lines in Figure 21 and forced down on the workpiece and the main die so as to bring the workpiece into contact with the reversely bent section 185 of the form. While the auxiliary die 181 is forced down on the workpiece, the tension exerted on the workpiece through the vises 100 may be relieved to a certain extent. After the auxiliary die has been brought in working position, the stretching tension is again applied to the workpiece so that it obtains its final setting by being stretched beyond its elastic limit over its entire length, including the reversely bent portion. Of course, the auxiliary die should not be clamped down so hard on the main die that it would impede considerably or even prevent the sliding of the workpiece between the two dies. Indeed, there may be considerable play between the two dies because the forming in the reversely bent section 185 is confined to the auxiliary die 181. Consequently, for certain cross-sections, the lower die might be altogether out of contact with the workpiece in the region of the reverse bend.

It will be understood that the device shown in Figures 20 and 21 is liable to many modifications in regard to the making of reversely bent articles and is by no means restricted to the specific form of the two-part die or to the machine in which it is used. Outstandingly important is the fact that the workpiece is stretched between two dies, one of which shows the curvature in the one direction and the other the curvature in the other direction, and that the two dies engage the workpiece from different sides. This concept allows for the forming of reversely bent members on

stretcher presses, a procedure which had generally been considered unfeasible up to this time. It will be understood also that the means for bringing or holding the two dies in proper relative position to each other can be varied within very wide limits; it is especially obvious that this need not be restricted to hand operation.

Figures 22 to 26 illustrate diagrammatically the use of the new machine for making members which could be made on prior art stretcher presses with movements in one plane. Nevertheless, the procedure and the form or die illustrated in Figures 22 to 26 has advantages which will become apparent from the following description.

Figures 22 and 23 illustrate two projections of a member 190 which is angle-shaped in cross-section and has two arms 191 and 192. This member has no double curvature because the arm 191 is arranged in one plane. Consequently, this member could be made by bending and stretching it vertically to its arm 192 in one plane only over a correspondingly shaped die, as diagrammatically illustrated by dotted lines in Figure 26. Line 193 indicates the length of the stroke of the die required for such one-plane stretching.

Figures 24 to 26 show in full lines and in dot-and-dash lines the formation of the same member 190 on a machine according to the invention. The form or die 194 has its upper surface formed in accordance with the form of the inside of the angle of the piece 190 when the line 195 bisecting the angle is arranged vertically. The top surfaces of the form are now double-curved in regard to a horizontal plane and a vertical plane.

The workpiece 190 is stretched over the form by means of the vises 100 (not shown), and by moving the form or die 194 upwardly and horizontally. These movements may be imparted by such means as illustrated in Figures 1 to 19. The starting positions of the die and workpiece in the plane of the section are shown in Figure 26 in full lines and the end position of the workpiece is indicated by the dot-and-dash line. It is apparent that each of the strokes, the vertical stroke 197 and the horizontal stroke 198, is smaller than the vertical stroke 193 required with the old machines, even though the resultant stroke 193' is, of course, the same.

Before concluding this description, a few further modifications and details of the invention will be explained.

While Figure 1 of the drawing shows independent valves for each of the cylinders for the vises and for the cams acting on the vises, the valves of each pair may be coupled so as to operate them in unison if desired, or the two valves controlling corresponding cylinders may be merged into one valve. However, the independent controllability of movements of the vises is desirable for certain types of work.

Certain forms require several passages of the workpiece through the machine. More than one passage are, for instance, required if the stroke of the machine is not sufficient for forming the article in one stroke or if the cam arrangement does not permit the movement of the vises in such a way as the particular article requires. Some articles require outward pull of the vises and later on inward movement of the vises or any other combination of different movements of the vises.

Regarding the stretching of the workpiece, it will be understood that the stretching beyond the elastic limit should extend over the entire cross-section of the workpiece because otherwise spring-

back or warping would occur after the workpiece leaves the machine.

The trim lines 57' marked on several figures on the dies indicate, as mentioned before, the locations where the workpiece after the forming operation has to be cut. The cutting of the workpieces along the trim lines is performed after the forming operation. The portions of the workpieces between the trim lines and the vises go in most cases to scrap. Sometimes several articles may be formed by stretching one workpiece over a form and cutting it later on along several lines. In such case, the amount of waste is considerably reduced.

The invention is not restricted to the illustrated and described embodiments. Partly in repetition of what has been said before, it is pointed out that any of the means described and illustrated may be substituted by other means, and that outstandingly only the relative movement of the different parts, such as the vises, the die, and the workpiece, count. For instance, the term "vise" is intended to mean any means adapted to engage and hold the ends of the workpiece. It should be understood also that out of the countless number of cross-sections and curvatures which can be made by using the features of the invention, a very few only have been illustrated. Each form different from those illustrated in the drawing requires proper adaptations of the invention and sometimes changes in the set-up.

The claims are intended to cover all such broad aspects of the invention unless specifically restricted to features of the illustrated and described embodiments.

What is claimed is:

1. Stretch-forming machine comprising a frame structure, a support for a form and a pair of vises adapted for immovably engaging an elongated member to be formed at longitudinally spaced points thereof; means for reciprocatingly guiding and moving during the operation of the machine said support in said structure along a generally straight path; means for reciprocatingly guiding and moving during the operation of the machine both said vises on said structure along paths extending transversely to and on opposite sides of the path of said support, and further means for guiding one of said support and said pair of vises relative to the other along a path transversely to the aforesaid paths during the operation of the machine.

2. Stretch-forming machine comprising a frame structure, a support for a form and a pair of vises adapted for engaging immovably spaced points of an elongated member to be formed; means for reciprocatingly guiding and moving during the operation of the machine said support in said structure along a generally straight path; means for reciprocatingly guiding and moving during the operation of the machine at least one of said vises in said structure along a path extending transversely to said support so as to stretch the member, and further means for guiding during the operation of the machine one of said supports and said vises relative to the other along a path transversely to the aforesaid paths.

3. Stretch-forming machine comprising a frame structure, a support for a form and a pair of vises adapted for engaging immovably spaced points of an elongated member to be formed; means for reciprocatingly guiding and moving during the operation of the machine said support in said structure along a generally straight path; means for reciprocatingly guiding and

moving during the operation of the machine said vises in said structure along paths extending transversely to and on opposite sides of the path of said support, and further means for guiding and moving said support also along a second path transversely to the two aforesaid paths and relative to said structure.

4. Stretch-forming machine comprising a pair of spaced vises adapted for gripping spaced points of a workpiece, a support for a form arranged between the vises, means for relatively moving said support and said vises in one plane on a path transversely to a connecting line between the two vises, and further means for relatively moving said support and said vises in a second plane intersecting said first plane and likewise on a path transversely to a connecting line between the two vises.

5. Stretch-forming machine comprising a support for a form and a pair of vises flanking said support and adapted for engaging spaced points of a workpiece, means for imparting to said support and said vises movements relative to each other in two directions which are generally perpendicular to each other and which intersect a line connecting the two vises.

6. In a stretch-forming machine, a pair of vises arranged for holding a member to be formed between them, a supporting structure, said vises and said supporting structure being reciprocatingly movable relative to each other in one direction transversely to a line connecting said vises, a member adapted for holding a form and reciprocatingly movable on said support in a direction transversely to the aforesaid direction and connecting line between the two vises.

7. In a stretch-forming machine, a pair of vises arranged for holding a member to be formed between them, a supporting structure, said vises and said supporting structure being reciprocatingly movable relative to each other in one direction transversely to a line connecting said vises, a member adapted for holding a form and reciprocatingly movable on said support in a direction transversely to the aforesaid direction and connecting line between the two vises, and driving means adapted to impart movement to said holding member.

8. In a stretch-forming machine; a foundation structure; a beam; driving means adapted to reciprocatingly move said beam relative to said structure and in a direction transversely to the longitudinal extent of the beam; a member for supporting a form; means on said structure and said member for guiding the latter in the former in the direction of the movement of said beam and generally in line therewith so that the beam may engage said member; a pair of vises, one on each of two opposite sides of the path of said member; guiding means for holding at least one of said vises in said structure reciprocatingly movable in a direction transversely to the direction of movement of said beam member and parallel to the former; and means for transmitting movement from said beam to said reciprocatingly movable vise.

9. In a stretch-forming machine; a foundation structure; a beam; driving means adapted to reciprocatingly move said beam relative to said structure and in a direction transversely to the longitudinal extent of the beam; a member for supporting a form; means on said structure and said member for guiding the latter in the former in the direction of the movement of said beam and generally in line therewith so that

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the beam may engage said member; a pair of vises one on each of two opposite sides of the path of said member; guiding means for holding at least one of said vises reciprocatingly movable in a direction transversely to the direction of movement of said beam member and parallel to the former; the guiding means for said movable vise comprising a member guided in said structure in the same direction as the vise; means for securing said guided member to said structure in different positions; and means at least partly supported by and movable with said guided member for transmitting the movement of said beam to said movable vise.

10. In a stretch-forming machine; a foundation structure; a beam; driving means adapted to reciprocatingly move said beam relative to said structure and in a direction transversely to the longitudinal extent of the beam; a member for supporting a form; means on said structure and said member for guiding the latter in the former in the direction of the movement of said beam and generally in line therewith so that the beam may engage said member; a pair of vises one on each of two opposite sides of the path of said member; guiding means for holding said vises reciprocatingly movable in a direction transversely to the direction of movement of said beam member and parallel to the former; the guiding means for said vises comprising for each vise a member slidably guided in said structure in the same direction as the vises; means for securing said slidable member to said structure in different positions; and means at least partly supported by and movable with said slidable member for transmitting the movement of said beam to said vises.

11. In a stretch-forming machine; a foundation structure; a beam; driving means adapted to reciprocatingly move said beam relative to said structure and in a direction transversely to the longitudinal extent of the beam; a member for supporting a form; means on said structure and said member for guiding the latter in the former in the direction of the movement of said beam and generally in line therewith so that the beam may engage said member; a pair of vises one on each of two opposite sides of the path of said member; guiding means for holding at least one of said vises in said structure reciprocatingly movable in a direction transversely to the direction of movement of said beam member and parallel to the former; means for transmitting movement from said beam to said movable vise; and an adjustment for said movement transmitting means permitting to change the amount and to reverse the direction of the movement of the vise relative to the movement of the beam.

12. In a stretch-forming machine; a motor; a frame structure; a support for a forming die guided in said structure along a substantially straight path and reciprocatingly driven by said motor; a pair of vises one on each of two opposite sides of said path and adapted to hold a member to be formed between them and across the path of said support; means for reciprocatingly guiding at least one of said vises in a direction intersecting the direction of said path; means for driving said reciprocatingly guided vise by said motor; lost-motion transmission means between said motor and said support and between said motor and said guided vise, and

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means for adjusting the lost motion so as to regulate the sequence of the start and the duration of the movement of said support and said vises.

13. In a stretch-forming machine; a foundation structure; a motor in said structure equipped with a reciprocating driving member; a forming die support guided in said structure along a substantially straight path and adapted to be drivingly engaged by said driving member; a pair of vises one on each of two opposite sides of said path and adapted to hold a member to be formed between them and across the path of a die on said support; means for reciprocatingly guiding at least one of said vises in a direction intersecting the direction of said path; means for transmitting movement from said driving member to said reciprocatingly guided vise; adjustable means for holding said support on said structure at a distance from said driving member so as to regulate the sequence of the start and the duration of the movement of said support relative to the movement of said vise.

14. In a stretch-forming machine; a base structure; a support; means on two sides of said support for holding and stretching a workpiece between them; means for guiding said support on said structure on a substantially straight path transversely to a line connecting said holding means; means acting between said structure and said support for reciprocatingly moving the latter along said path; a member for holding a forming die; means for guiding said member on said support along a path transversely to said first-named path and said connecting line between the holding means; means between said member and said structure imparting movement to said member along said second path upon movement of said support along said first path.

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