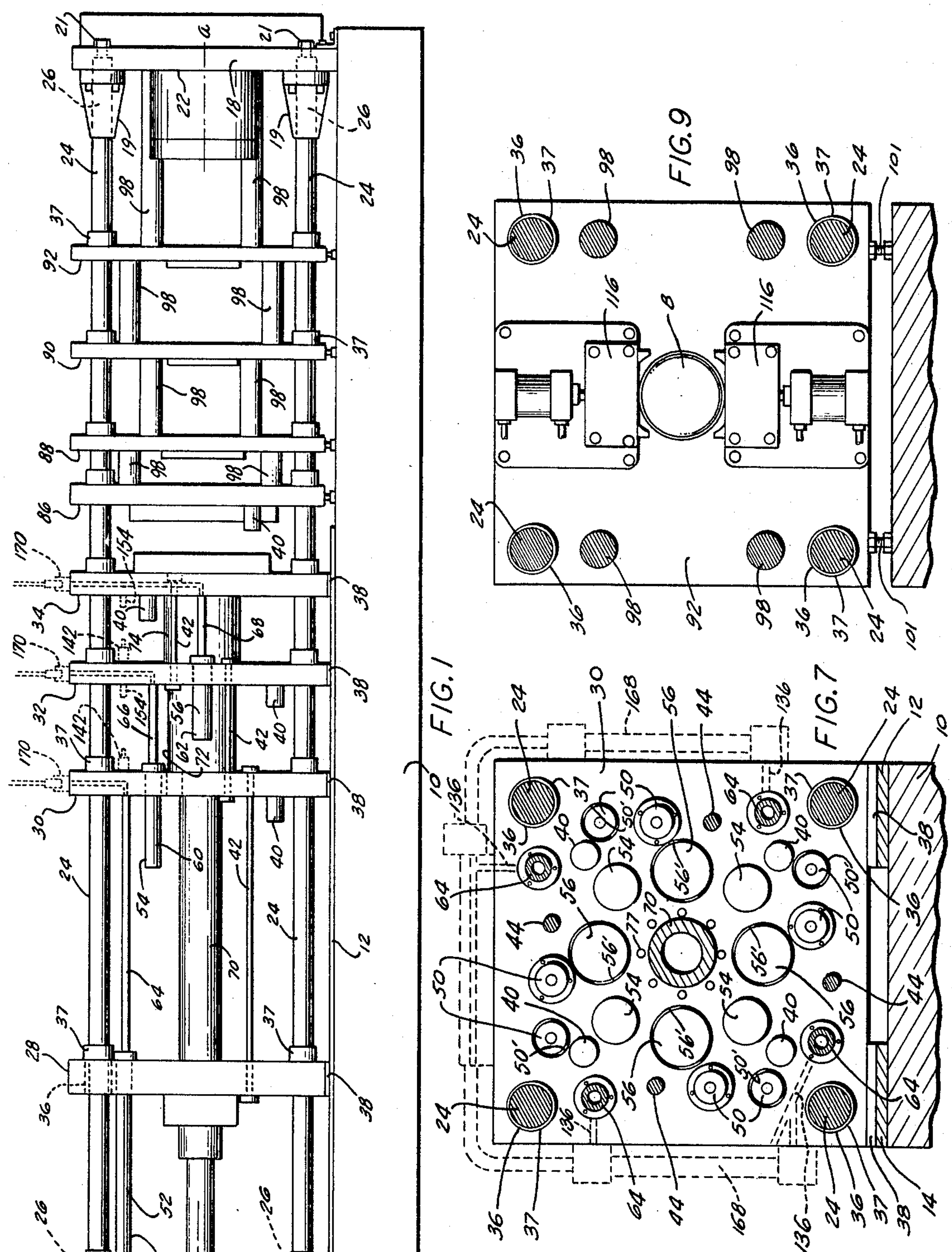
May 5, 1970 J. L. MASSINGILL ET AL 3,509,754

METHOD AND APPARATUS FOR DEEP DRAWING METAL

Original Filed April 23, 1964 8 Sheets-Sheet 1



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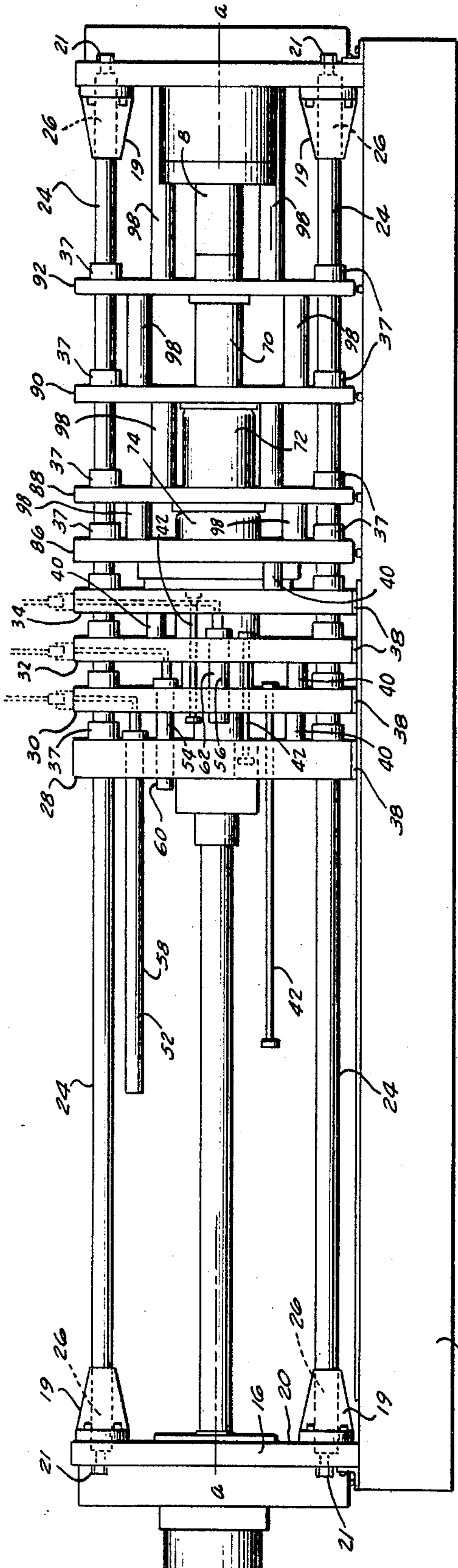

FIG. 2

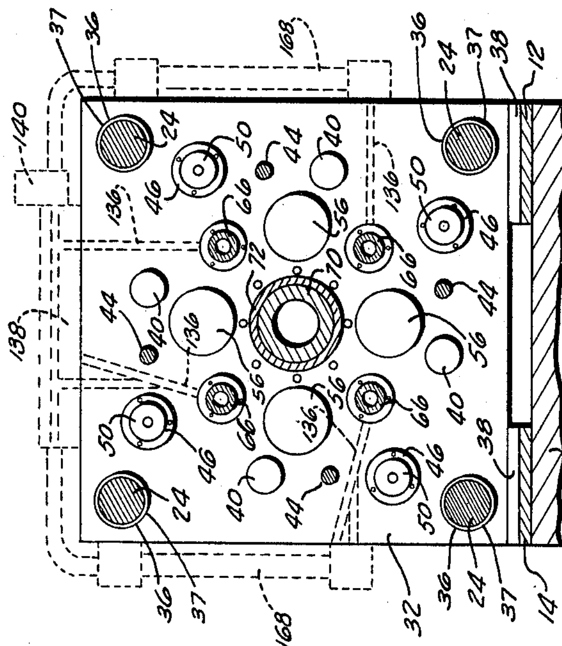

FIG. 6

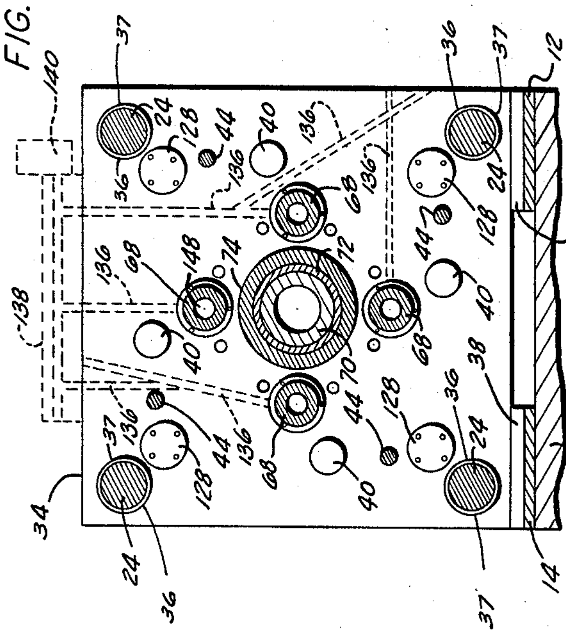

FIG. 5

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Original Filed April 23, 1964 8 Sheets-Sheet 3

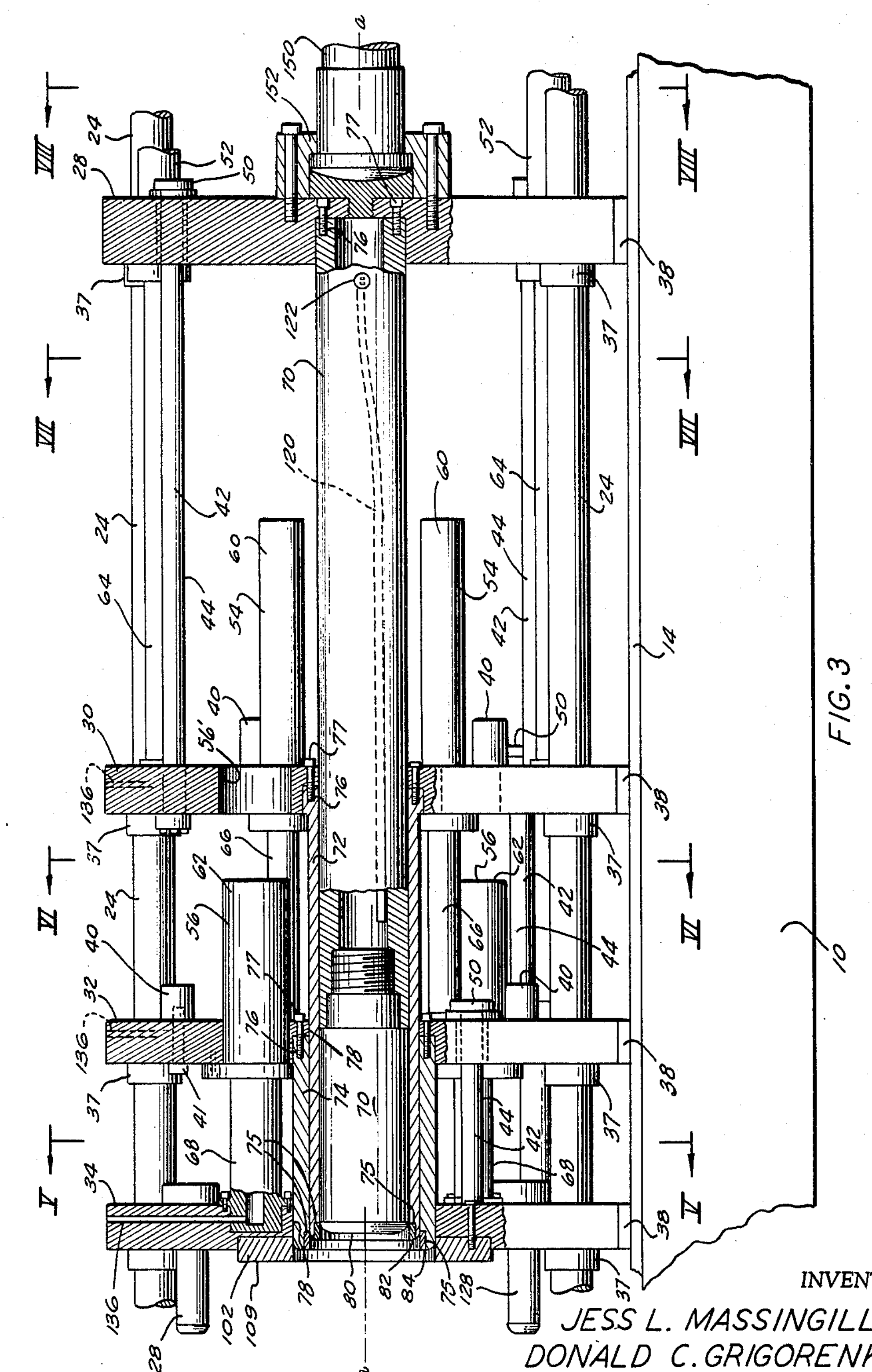

FIG. 3

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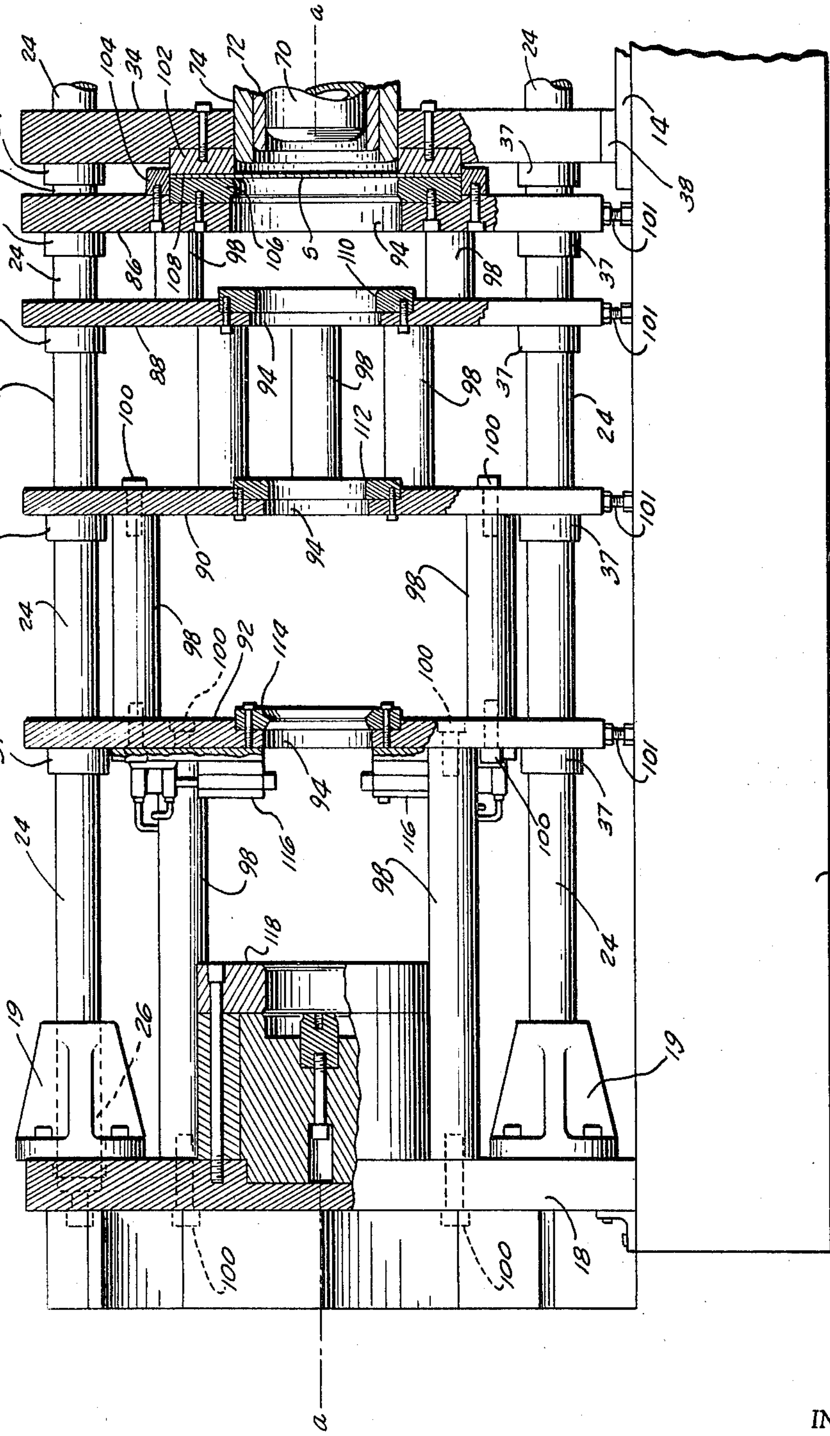

FIG. 4

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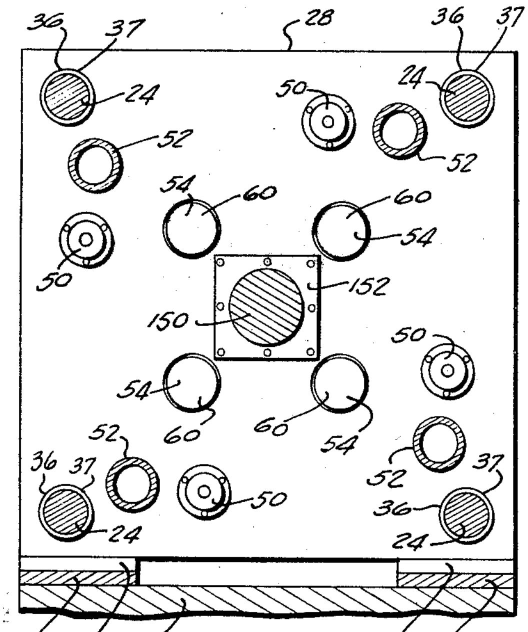

FIG. 8

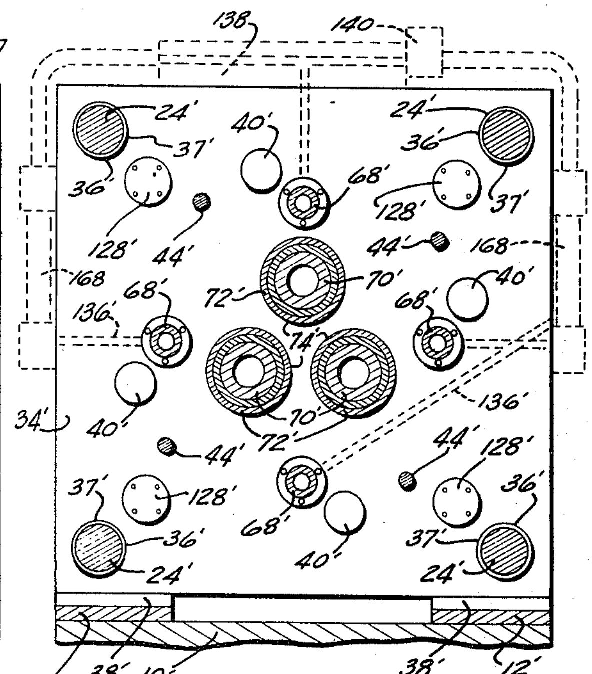

FIG. 24

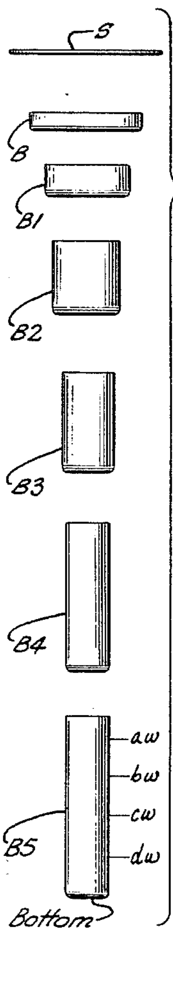

FIG. 21

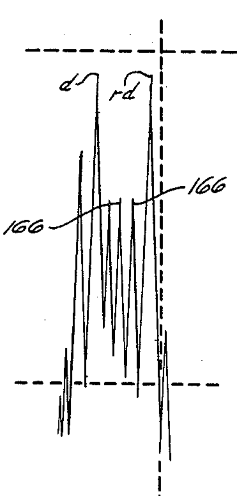

FIG. 23

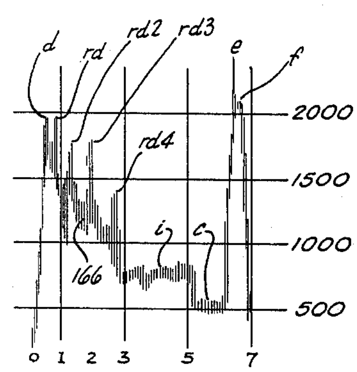

FIG. 22

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METHOD AND APPARATUS FOR DEEP DRAWING METAL

Original Filed April 23, 1964 8 Sheets-Sheet 6

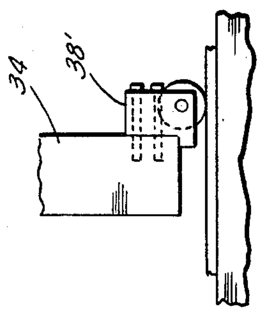

FIG. 25

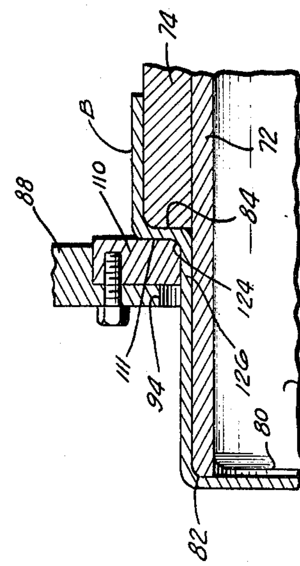

FIG. 15

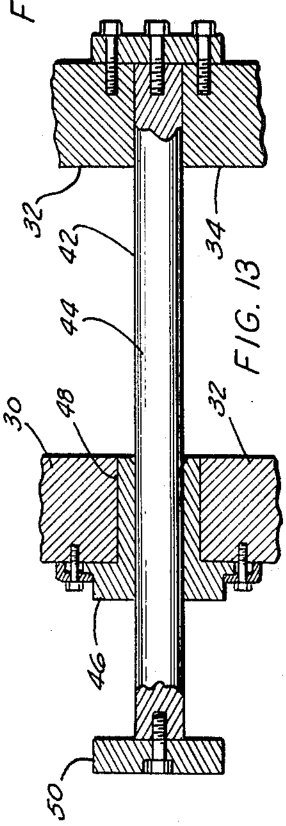

FIG. 13

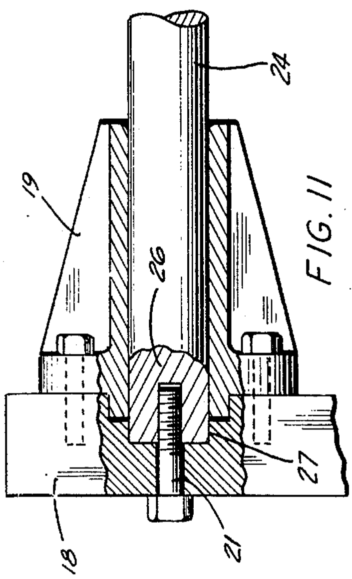

FIG. 11

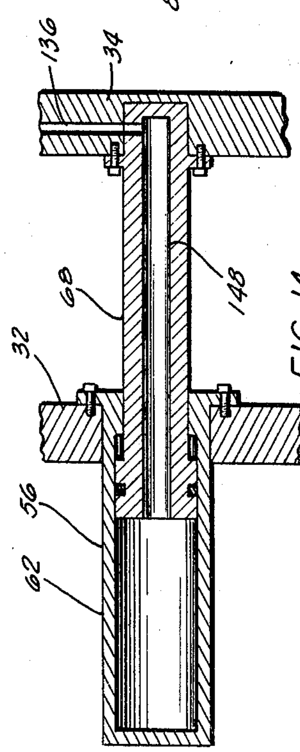

FIG. 14

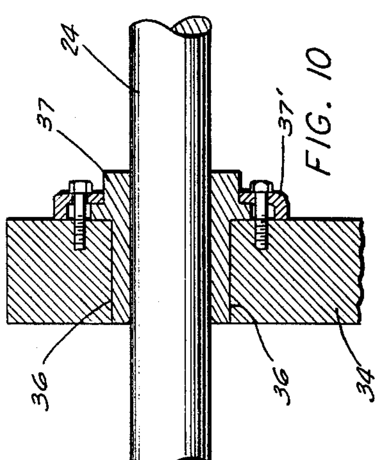

FIG. 10

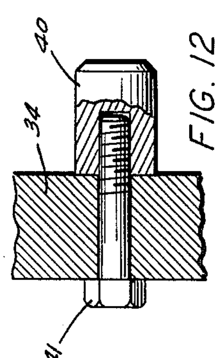

FIG. 12

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METHOD AND APPARATUS FOR DEEP DRAWING METAL

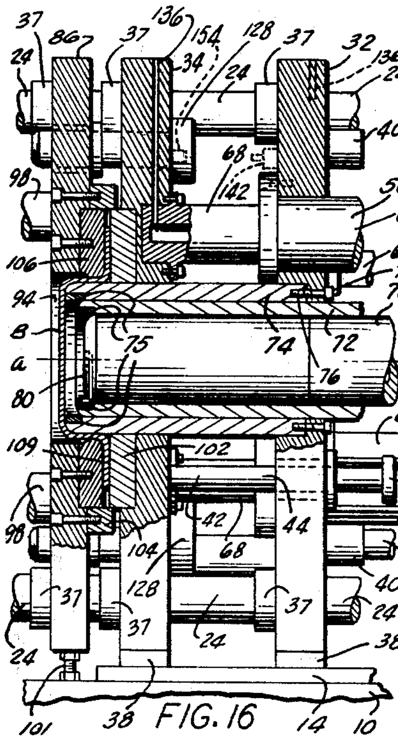

FIG. 16

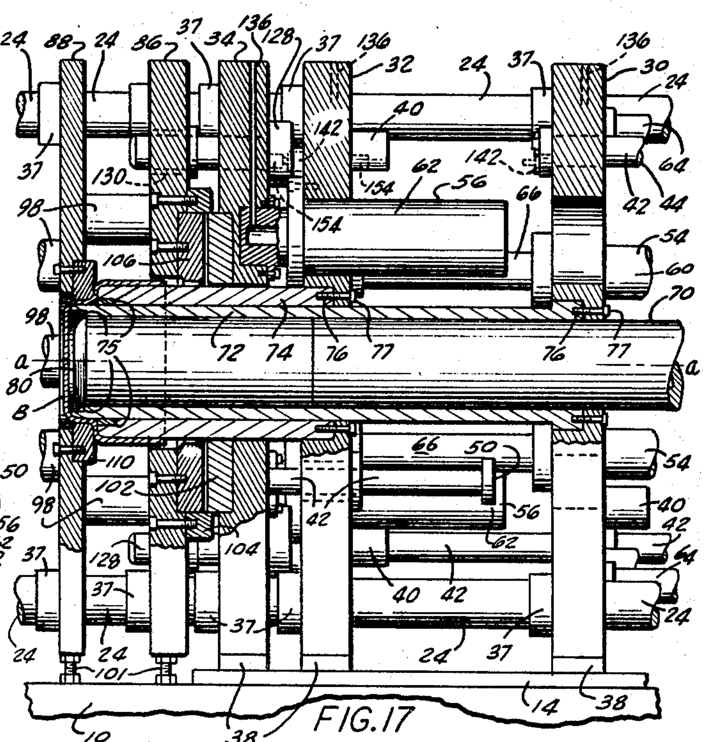

FIG. 17

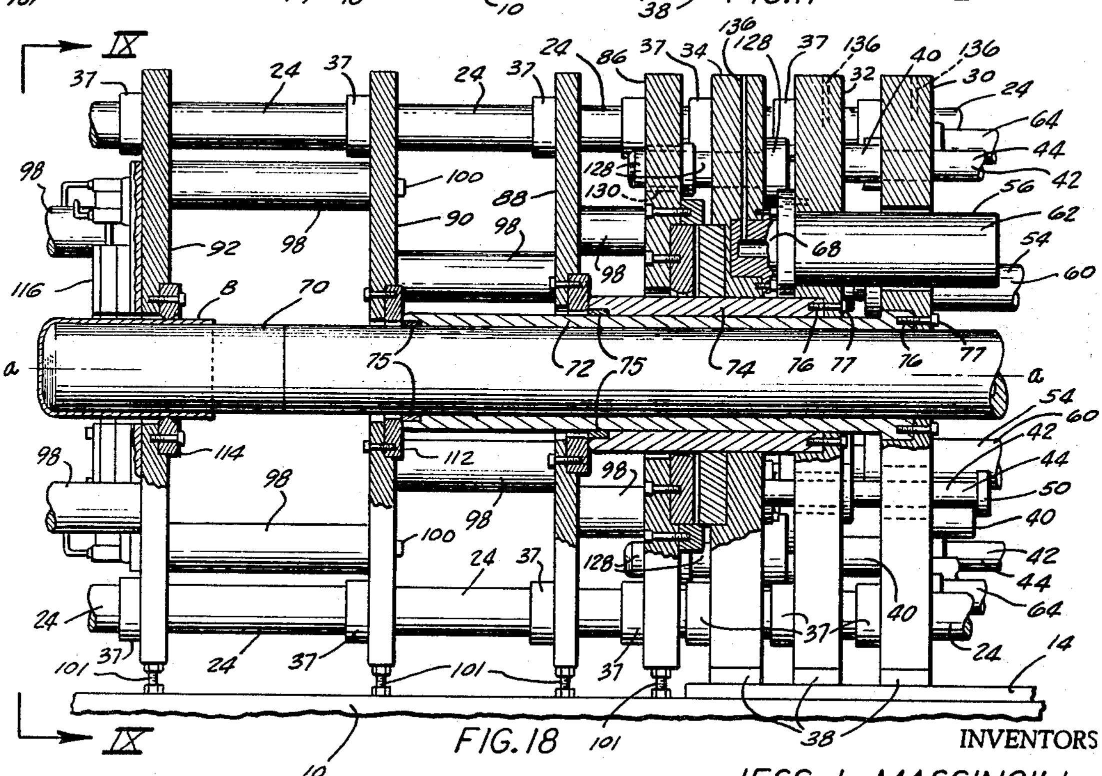

FIG. 18

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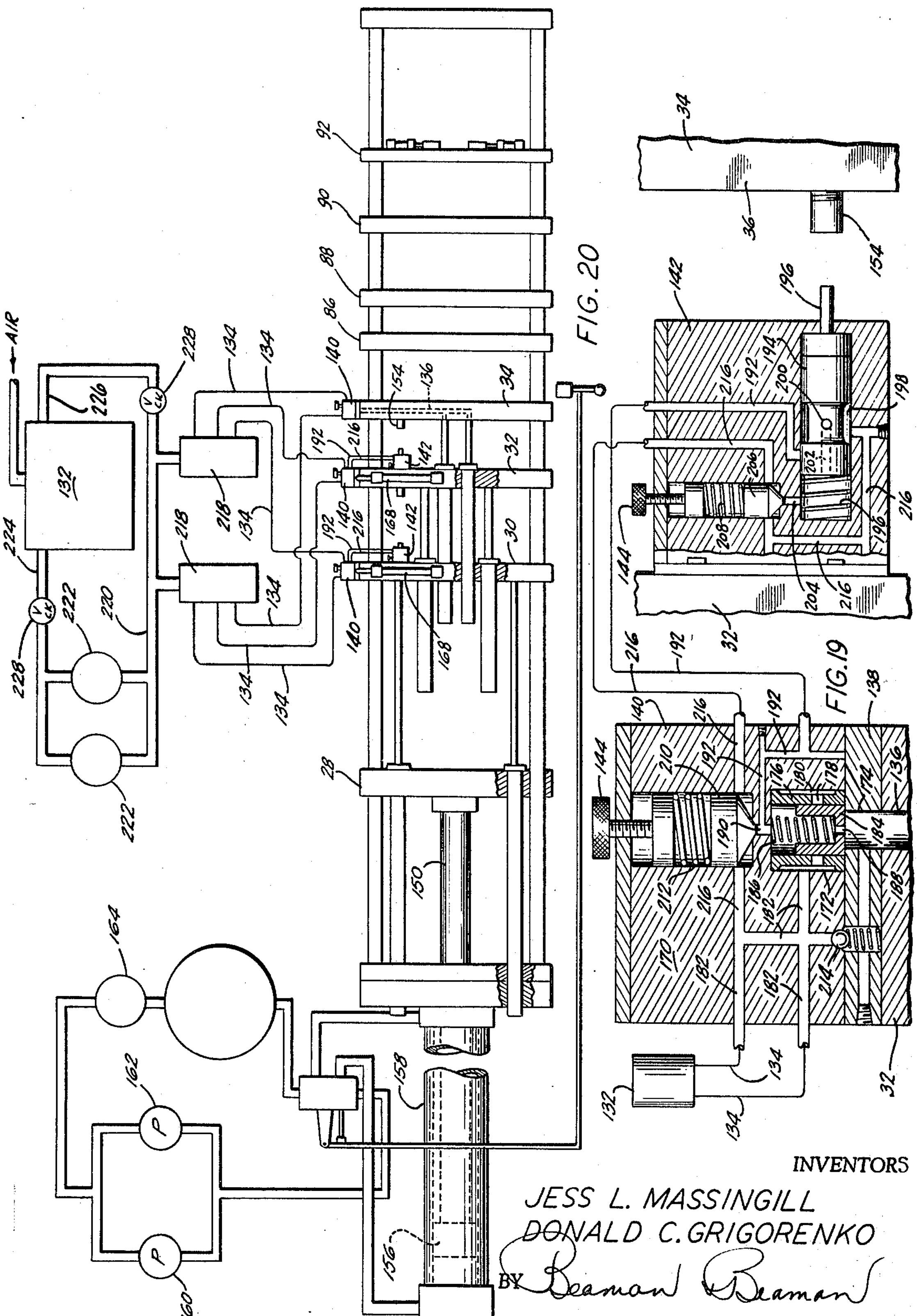

FIG. 20

FIG. 19

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United States Patent Office

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METHOD AND APPARATUS FOR DEEP DRAWING METAL

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Continuation of application Ser. No. 362,004, Apr. 23, 1964. This application May 28, 1969, Ser. No. 843,882
Int. Cl. B21d 22/28
U.S. Cl. 72—349 32 Claims

ABSTRACT OF THE DISCLOSURE

The disclosure relates to a multiple drawing press with pressure actuated telescoping punches and axially aligned dies in which a first punch, after performing a first draw, functions as a hold down during a second draw, the first punch being stop-arrested in its hold down position with a resulting control of gap and pressure with respect to the work blank, there being means for holding the punches in their nested position during the sequential operation thereof, with means moving with said punches for initiating their sequential operation.

CROSS REFERENCE

This application is a continuation of our application Ser. No. 362,004, filed Apr. 23, 1964, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to the art of drawing metal and provides ways and means for the economical production of ultra deep drawn metal cans, shells, tubes, and the like, from first operation cup shells, flat blanks, flat sheet metal strips, and the like.

In the patented art is found many proposals for effecting the deep drawing of metal wherein the metal being drawn is subjected to a sequence of drawing operations during a single and continuous stroke of the drawing apparatus. U.S. Pat. Nos. 783,390; 961,131 and 1,720,375, granted in 1905, 1910 and 1929, respectively, are typical of such proposals.

Notwithstanding the numerous patented proposals for the deep drawing of metal by a sequence of operations performed during a single stroke of both mechanical and hydraulic drawing apparatus, such proposals have not experienced any general acceptance in this art. No present commercial use of the many proposals of the above-mentioned type, which appear in the patented art, is known, nor do such proposals appear in engineering handbooks dealing extensively with the art of metal drawing.

A practical commercial process and apparatus for carrying out the process according to the present invention has been provided by performing the drawing operation in a horizontally disposed press in which all the major structural and functional components are supported, adjusted and operated on a rigid, horizontally disposed support structure on which the weight of such components is distributed, as well as shifted, during the cycle of operation of the press.

The rigidity of the press of the present invention is augmented by the telescoping association of the punches which, in addition to forming the metal in the dies, have the further function of serving as pressure pads and pilots during the sequence of the drawing operations. Each punch of each operation of the press is rigidly associated with a vertical plate which is rigidly supported and guided for horizontal movement. As the drawing operations progress, these plates are moved longitudinally in the press and sequentially approach one another to effect a substantial shifting of the structural and functional mass of the press adjacent the area in which the metal shaping is taking place.

To maintain a high degree of rigid parallelism between the punch carrying plates, each plate is carried on a common guide rod system, and the plates are spaced from each other by several systems of spacer elements which are disposed about each punch. The ram pressure of the press is transferred from one punch plate to the next through the spacer elements, whereby the operating pressure of the ram and the reaction of the metal to shaping both tend to effect parallelism between the punch plates.

The draw dies of the press of the present invention are supported and maintained in rigid parallelism and concentricity with the telescoping punches. In each die of each drawing operation, with the exception of the first, the metal being formed is transferred from the previous drawing operation on the punch that performed the previous draw with that particular punch thereafter functioning as a combination pressure pad and pilot for the drawing operation performed by the following punch. Piloting of the work blank from one punch to the next in each redrawing die tends to promote and maintain a state of concentric association between the dies and punches which contributes to the general rigidity, horizontal alignment and parallelism of the punch and die carrying components of the press.

To prevent as well as to control relative movement between adjacent punch carrying plates, hydraulic means are provided which have a locked state to prevent relative movement, as well as a regulated state for initiating the sequential drawing movement of the punches. The hydraulic means also provides holding pressure for the metal being shaped as well as holding the plates of the moving plate system together.

Through the horizontal arrangement of the press, the ram of the press is substantially relieved of the dead weight of the punch carrying plates, punches and spacer elements, as well as the components of the hydraulic systems associated therewith. At the same time the horizontal arrangement of the press facilitates set-up operations, inspections of the various operating stages, lubrication of the punches and dies, and cooling of the metal-forming components. It also facilitates the feeding of the stock to the machine and removing of fabricated articles. Any tendency for the horizontal disposition of the punches to cause objectionable "drooping" with a resulting lack of concentricity of the punches in the draw dies has been avoided by the rigid and telescoping association of the punches, coupled with a departure in accepted practice in metal drawing which provides a high degree of "punch hugging" by the metal being shaped by a reduction in standard punch and die clearances to a point approaching an "interference fit" with the gauge of metal being drawn.

One possible explanation for the unexpected percentage of reduction that may be performed by the present invention in a single stroke of the press, without metal rupture or intermediate anneals, may be contributed to the combination of "punch hugging," "interference fit" and the piloting action of the punches during the transfer of formed metal from one punch to the next in the draw dies. These functions appear to so uniformly distribute, form and control the metal that stresses on the metal are uniformly distributed with the substantial elimination of localized areas that are less prepared for redrawing than the remaining portions of the formed metal.

When the principles of design discussed in the preceding paragraph are employed in combination with the sequence of drawing operations rigidly performed during a single cycle of operation of the drawing press, the generation of heat and the substantial continuous flowing of the metal throughout the cycle obviously contributes to a substantial extent to the obtaining of greater reductions in blank diameter. However, in order to obtain the repetitive results of the present invention more is required than merely sequential drawing operations performed during a single and continuous stroke of the press.

Thus, an object of the invention is to provide an improved drawing press for the deep drawing of metal articles wherein a sequence of drawing operations is performed without intermediate annealing through novel and coordinated control of punch movement, through the regulation of the restraining pressures on the metal blank at each drawing operation, and the character of the association of the metal blank with the punch and die structure of each drawing operation.

Another object of the invention is to provide an improved press for the deep drawing of metal articles without annealing wherein rupture of the closed end of the metal blank being drawn is avoided through novel association of the metal blank with the punch and die structures which perform the drawing operations.

A further object is to provide an improved press for the deep drawing of metal articles without annealing wherein the stresses of the drawing operation are uniformly distributed throughout the circumference of the metal blank to permit substantial increases in the percentage of reduction of metal blanks during the drawing operation as compared with standard practices and without experiencing metal rupture.

Still a further object of the invention is to improve the art of deep drawing of metal articles through improved means for the presentation and transfer of the metal blank with respect to the operation carried out in the drawing die.

Another object of the invention is to provide a novel drawing press in which the ram of the press is preferably horizontally disposed and the punch structure is supported and moved along a horizontally supported, vertically disposed structure with concentricity and alignment of the punch structure being provided by a novel arrangement of telescoping punches and punch carriers.

A still further object is to provide a novel press for performing a sequence of drawing operations during a single stroke of the press in which movement of the ram is transferred to the metal blank through a series of independently supported and independently guided punch carriers, the carriers having common guide and common support structures as well as telescoping and nested association for augmenting parallelism of the punch carriers on their common support structure.

A still further object of the invention is to provide a deep drawing press having a series of punch carriers which are independently supported and relatively movable, the carriers being spaced for both unitary and relative movement, with respect to each other, by the ram of the press through the control of fluid cushions.

A further object of the invention is to provide a press of the design described in the preceding paragraph wherein the fluid cushion structure also functions to control the pressure on the metal blank during each drawing operation.

Another object is to provide a hydraulic deep drawing press in which novel coordination of hydraulic means is provided for controlling punch and pressure pad means during the sequential operation of the metal drawing structure.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention are more fully apparent from the following specification and the appended claims:

FIG. 1 is a side elevational view of the press at the start of the "down" stroke with the hydraulic system diagrammatically shown in dotted outline, and only one of each element of each of the three spacer systems being associated with each of the plates of the moving plate system,

FIG. 2 is a view similar to FIG. 1 and shows the moving plate system at the finish of the "down" stroke of the press,

FIG. 3 is an enlarged fragmentary portion of the moving plate system of the press, as shown in FIG. 1 but taken from the opposite side, with all of the spacer elements of the three spacer systems shown in place,

FIG. 4 is an enlarged fragmentary portion of the fixed plate system of the press as shown in FIG. 1 taken from the opposite of the press,

FIG. 5 is a vertical, cross-sectional view taken on line V—V of FIG. 3 of the moving plate system of the press,

FIGS. 6, 7, and 8 are views similar to FIG. 5 taken on lines VI—VI, VII—VII, and VIII—VIII, respectively, of FIG. 3,

FIG. 9 is a vertical, cross-sectional view taken on line IX—IX of FIG. 18 of the fixed plate system of the press,

FIG. 10 is a sectional detail showing the association of a plate and its tension and guide rod,

FIG. 11 is a detail view of the mounting structure for opposite ends of the tension and guide rods,

FIG. 12 is a sectional detail of a fixed spacer element,

FIG. 13 is a sectional detail of the "back" stroke spacer element,

FIG. 14 is a sectional detail of a hydraulic cushion,

FIG. 15 is a sectional detail showing the association of the telescoping punches with a redrawing die,

FIG. 16 is a fragmentary, elevational view partly shown in broken section showing the relative positions of the plates of the moving and fixed plate systems of the press at the time of the initial drawing operation immediately following the shearing of the work blank,

FIG. 17 is a view similar to FIG. 16 showing the commencement of the first redrawing operation and illustrating the transfer of the work blank from one punch to the next,

FIG. 18 is a view similar to FIG. 16 showing the work blank through the drawing operations and partially through the ironing operation,

FIG. 19 is a diagrammatic view of the valve mechanism associated with certain of the moving plates,

FIG. 20 is a diagrammatic view of the hydraulic systems of the press,

FIG. 21 is a diagrammatic showing of the progressive forming of the work blank in a modified form of press having five drawing operations and one ironing operation,

FIG. 22 is a diagram view of the pressure pattern of the hydraulic system during the stroke of the press forming the work blank of FIG. 21,

FIG. 23 is an enlargement of a portion of the diagram of FIG. 22 more clearly indicating the pressure impulses,

FIG. 24 is a view similar to FIG. 5 of a modification showing a plurality of telescoping punch sets, and

FIG. 25 illustrates a modified form of support for the moving plates.

The principles of the invention have application to a wide range of metals. In practice it has been found possible to deep draw steel, aluminum and brass on the same tools with equal success with only adjustments in hold-down pressures being required in changing from one metal to another. Stainless steel, copper, zinc, as well as some of the recently developed space age metals, are also capable of being drawn with minor changes in tooling and pressure adjustments used for the more ductile metals mentioned above.

BASIC PRESS STRUCTURE

When the apparatus for carrying out the improved process of deep metal drawing takes the form of a horizontally disposed hydraulic press, as in the case of the illustrated embodiment of the invention, the basic structure of the press preferably comprises a reinforced concrete base **10** on which a pair of reinforcing and wear plates **12** and **14** are rigidly mounted and constitute the structure referred to in the appended claims as the supporting surfaces. At one end of the base **10** is a reinforced cylinder mounting plate **16**, and at the other end is located a reinforced press base plate **18**.

Plates **16** and **18** are rigidly mounted in any suitable manner on the reinforcing plates **12** and **14** with their opposed vertical faces **20** and **22** accurately flat and parallel to each other and accurately disposed at 90° to the plates **12** and **14** which are equally flat with their upper surfaces preferably disposed in the same plane.

The combination guide rods and tension members **24** are all straight and mutually parallel, and have portions **26** at opposed ends which are mounted in countersunk bores **27** in the faces **20** and **22** with the distance between the end portions **26** of each of the members **24** and the depth of the bores **27** being held the same, within a few thousandths of an inch, to insure that the plates **16** and **18** are parallel to each other as well as perpendicular to the members **24**. (See FIG. 10.) To enable the members **24** to function as tension members as well as spacing members, any suitable means may be employed for affixing the ends **26** of the members **24** to the vertical plates **16** and **18**, such as socket brackets **19** in which the ends **26** are received with a close fit, with the ends **26** being tapped to receive the cap screws **21** extending through holes in the plates **16** and **18**.

MOVING PLATE SYSTEM

The moving plate system of the press may take many forms. One practical arrangement is herein illustrated in which several plates are provided, one for each drawing punch, a ram plate to which the power ram is attached on one side and from which a drawing punch extends from the opposite side, and a plate for the pressure pad and/or a portion of the blanking punch depending on whether presheared blanks or strip or square sheared stock is being run in the press. In the description to follow, the press will be described with a blanking operation being carried on in the press, although it will be understood that circular presheared blanks may be loaded in the press and the blanking operation deleted.

In one sense, the moving plates, mentioned in the preceding paragraph, are supported on the guide rods and tension members **24**. More specifically, the ram and punch plate **28**, punch plates **30** and **32**, and blank and pad plate **34** are all provided with openings **36** in which bushings **37** are inserted, the openings **36** being preferably provided at the four corners of the plates with the members **24** being received within the bushings **37** with a close sliding fit. Clamps **37'** hold the bushings **37** in place. (See FIG. 9.)

Each of the plates **28**, **30**, **32** and **34** is provided at its lower corners with suitable support members **38** capable of sliding or rolling on the reinforcing and wear plates **12** and **14**. Preferably, the members **38** are located and removably attached at the lower opposite corners of the aforesaid plates and are adjustably related to their associated plates through the use of shims, and the like, to permit fine vertical regulation to bring about the desired situation in which the members **24** support the plates **28**, **30**, **32** and **34**, and these same plates in another sense support the members **24**.

SPACER MEANS FOR THE MOVING PLATE SYSTEM

The plates **28**, **30**, **32** and **34** are controlled as to their relative approach movements and their respective relative positions at the conclusion of the "down" and "back" strokes of the press by three different and independent spacer systems.

One system of spacers is in the form of abutments which are imposed between adjacent plates to determine the minimum spacing between such plates on relative approach movement. Another system of spacers is connected between adjacent plates for returning the plates to their relative positions at the conclusion of the "back" stroke of the press. These spacers will be called "back" stroke stop spacers. The third system of spacers preferably takes the form of hydraulic cushions which are imposed between adjacent plates **28**, **30**, **32** and **34** and have two different operation states, a "locked" state in which they function as a rigid thrust column structure between adjacent plates and a regulated state during which the effective length of the cushion as a spacer is reduced under the control of valving means to permit regulated relative approach movement between adjacent vertical plates.

In the interest of rigidity, augmentation of parallelism, maintenance and accessibility for adjustment, each of the three types of spacers mentioned above is completely independent in structure and functions from the other. However, it is anticipated that two or more of these three systems may be combined into a single system capable of performing the same functions as the three systems described in the preceding paragraph.

To describe each of the three spacer systems in more specific detail and with respect to the illustrated embodiment of the invention, the "down" stroke stop spacers in their simplest form may be no more than a block of steel, as indicated at **40**, having the vertical faces thereof at opposed ends parallel with each other. Each plate **30**, **32** and **34** is provided with a plurality of such blocks preferably equally disposed about the longitudinal axis *a—a* of FIG. 1, only one of such blocks being shown in FIG. 1 associated with each said plate, for purposes of clarity. In practice, the vertical faces of each of the plates **28**, **30**, **32** and **34** are machined parallel to each other with a high degree of accuracy. As the vertical faces of each of said plates are also parallel to the corresponding opposite faces of adjacent said plates, this arrangement permits all the "down" stroke stop spacers **40** associated with the same adjacent plates to be of the same identical length. The mounting of the spacers **40** to the vertical face of one of the adjacent pair of plates may be done in any suitable manner, such as by a cap screw **41** located in a horizontal hole in the plate to which the spacer **40** is attached and engaged in a threaded hole in one of the abutment ends of the spacer **40**, as shown in FIG. 11. In this manner the vertical face on one end of each spacer **40** may be rigidly clamped to the vertical face of its associated plate, and the opposite end of the spacer **40** presents an abutment surface which is parallel to the surface of the plate with which that end of the spacer **40** engages. The simple attachment arrangement of each spacer **40** to its associated plate also provides for the convenient use of washer-like flat shims of the same thickness to be disposed between the spacer **40** and the face of the plate to change the effective length of each spacer **40** associated with the same plate.

The specific structure of the "back" stroke stop spacers for locating each plate **30**, **32** and **34** relative to each other, as well as relative to the plate **28**, at the conclusion of the "back" stroke of the press, may take many and varied forms. Such spacers are indicated at **42** and they are of a design that does not interfere with the relative movement of the vertical plates with respect to each other during the "down" stroke of the press, yet on the "back" stroke of the press the spacers **42** act as the means for returning the plates **30**, **32** and **34** in definite relationship to each other on the return of the ram plate **24** at the conclusion of the "back" stroke of the press.

In the illustrated form, each spacer **42** comprises a rod **44** fixedly attached in any suitable manner at one end to a plate of the moving plate system of the press and having a free sliding fit in a bushing **46** carried on and aligned with opening **48** in an adjacent plate. Abutment head **50**, preferably adjustable by use of shims between head **50** and rod **44**, is attached to the opposite end of the rod **44**.

When adjacent plates approach each other on the "down" stroke of the press, the rod **44** will slide through the bushing **46** in opening **48** with relative movement taking place between the head **50** and the outer face of the bushing **46**. On the "back" stroke of the press, movement of the ram plate **28** will provide the necessary relative movement for the head **50** to be engaged by the outer face of the bushing **46**. On such engagement between the opposed faces of the bushing **46** and head **50**, the rod **44** will be tensioned and the movement of one plate will be progressively transferred to the next adjacent plate.

The spacers **42**, associated with adjacent plates of the moving plate system, are preferably equally disposed about the longitudinal axis *a—a* of FIG. 1, as in the case of the spacers **40**. Each spacer **42** associated with each pair of adjacent plates is preferably of substantially the same effective length so as to complement the parallelism of the plates **30, 32** and **34**.

By having the rods **44** of equal effective length and parallel to the guide rods and tension members **24**, as well as to each other, and having the abutting faces of the bushings **46** and heads **50** parallel to each other and to the faces of the moving plates, movement of the plates **30, 32** and **34** by the ram plate **28** on the "back" stroke of the press is accomplished without disturbing the parallelism of the components of the press. It will be appreciated that flexible cables or chains of the proper lengths may be attached between adjacent members of the moving plate system of the press which would perform a function similar to that attributed to the rods **44** and associated structure as above described, except for the "guide pin effect" of the rods **44**.

HYDRAULIC CUSHIONS

The third spacer system of the press is more complex as to both structure and function than the systems of the spacers **40** and **42**. Because of this fact, the hydraulic cushions which characterize the spacer means of the third system, although all are similar in function and construction (as in the case of spacers **40** and **42**) each set of cushions associated with each of the plates **28, 30** and **32** will be identified and described through the use of separate reference characters.

In general, each cushion comprises a cylinder which is fixedly mounted on its associated plate of the moving plate system and functions as an integral part thereof. As a functional part of each cylinder, a piston is provided which extends into the cylinder as well as out of the cylinder. That portion of the piston which projects from the cylinder performs the function of a thrust member of adjustable length which spaces the plates of the moving plate system as well as controls their relative sequential movement in an approaching direction on the "down" stroke of the press. The cylinders of the set of hydraulic cushions associated with each of the above-mentioned plates are preferably equally distributed about the longitudinal axis *a—a*, as in the case of the spacers **40** and **42**.

In specific detail, one set of hydraulic cushions **52** is mounted on the plate **28**, another set of cushions **54** is mounted on the plate **30**, and a third set of cushions **56** is mounted on the plate **32**. Each set of cushions **52, 54** and **56** comprises cylinders **58, 60** and **62**, and pistons **64, 66** and **68**, respectively. It will be noted that the cushions of each set are the same as to length, and that each set of cushions is different from the other as to length. The difference in length of the cushions is determined by the necessary spacing of the plates of the moving plate system when that system is being advanced by the ram as a thrust column of constant length. As will be hereinafter described in more detail, hydraulic fluid is admitted to the cylinders **56, 60** and **62** to act on the ends of the pistons **64, 66** and **68**, respectively, to extend the pistons **64, 66** and **68** to their extended positions, which positions are preferably determined by the effective lengths of the spacers **42**. Thus, fluid pressure in the cushions **52, 54** and **56** acts to

place the rods **44** of spacers **42** under tension by acting to separate plates **28, 30, 32** and **34**.

When the hydraulic fluid is trapped in the cushions **52, 54** and **56** by suitable valve means, the pistons thereof will function as relatively solid thrust columns disposed between the plates **28, 30, 32** and **34**. By regulating the flow of fluid from the cushions by suitable valve means, the cushions will collapse and the effective length of the pistons **64, 66** and **68** will be reduced to permit the plates of the moving plate system to approach each other.

It should be understood that the ram pressure of the press is impressed on the metal forming tools of the press through the hydraulic cushions **52, 54** and **56**. When the cushion **56** has collapsed to the point at which the spacers **40** on plate **34** abut the plate **32**, the limit of relative approach movement between the plates **32** and **34** has been reached. Likewise, when the cushion **54** has collapsed to a point at which the spacers **40** on plate **32** abut the plate **30**, the limit of relative approach movement between the plates **32** and **30** has been reached. A similar situation exists when the collapse of the cushion **52** permits the spacers **40** on the plate **30** to engage the plate **28**. On sequential collapsing of the cushions **52, 54** and **56**, the "working load" being applied to the metal forming tools will be transferred by the "locked" cushions and the collapsing cushions will hold the plates ahead in the moving plate system together when they have reached their position of complete approach, which position is determined by the spacers **40** being engaged by adjacent plates. The further function of the cushions **52, 54** and **56** will be described in connection with the function of the punches of the plates of the moving plate system as pressure pads.

TELESCOPING PUNCHES

Each of the plates **28, 30** and **32** supports a tubular punch **70, 72** and **74**, respectively, the punches being nested one within the other with a close sliding fit. As the punches will normally be of tool steel, to avoid a galling, that may be experienced with a steel-to-steel fit, nonferrous bushings **75** are preferably employed between the punches.

The amount of reduction in the diameter of the work blank between drawing operations is such that the tubular punches **70, 72** and **74** have sufficient wall thickness to make them structurally rigid. They are rigidly connected to their respective plates of the moving plate system in any suitable manner with their longitudinal axes being common to the axis *a—a* of FIG. 1. As shown each punch **70, 72** and **74** has a series of tapped holes **76** at its inner end for receiving screws **77** for attaching the punches to the plates. The plates **30, 32** and **34** have openings **78** concentric with the punches to permit the telescoping assembly of the punches to extend through the plates with clearance, as well as permitting the plates to have relative approach movement.

When the press is at the end of its "back" stroke and in the position from which the "down" stroke is initiated, the forward ends **80, 82** and **84** of the punches **70, 72** and **74**, respectively, are preferably disposed in the slightly stepped position shown in FIG. 4. This arrangement permits a slight amount of creeping of the punches relative to each other without the tendency to crown the bottom of the metal article being obviated. The stepped arrangement of the punches has the further advantage of providing a slight amount of lag in the sequential functioning of the punches so as to make the timing of the punch movement less critical.

FIXED PLATE SYSTEM

The number of plates in the fixed plate system and the tools mounted on the plates thereof will usually be determined by the number of plates in the moving plate system and the article that is to be formed by a single continuous stroke of the press. If blanking is to take place in the press, then the first fixed plate will mount the blanking operation as well as the first draw. The following fixed plates may be tooled for a redrawing or ironing operation or a combination thereof. If the metal article being formed is to have a detailed bottom, then the innermost punch of the telescoping punch assembly will be shaped on its outer end to perform the detailing operation in cooperation with a detailing die carried by the last fixed plate, or the base plate **18**, as may be desired. Preferably, the base plate **18** is apertured to enable the same to carry a drawing or ironing die, as well as a stripper mechanism where detailing of the bottom of the formed article is not to be performed.

In the illustrated form of the invention, the fixed plate system of the press comprises the plates **86**, **88**, **90** and **92**, all having clearance holes **94** therein of different sizes with their centers located on the axis *a—a* of FIG. 1. The fixed plates are of rigid construction and are provided with holes **36** at their four corners with bushings **37** to receive the guide and tension members **24** with a close sliding fit so as to permit adjustment of the fixed plates along the members **24**. As in the case of the plates of the moving plate system, rigidity, parallelism and concentric alignment is important. To that end the vertical faces of each plate **86**, **88**, **90** and **92** are parallel to each other, as well as to the faces of the other fixed plates. Located between each of the plates **86**, **88**, **90** and **92** and between the plate **92** and the base plate **18** are sets of spacers **98** equally distributed about the axis *a—a* of FIG. 1. The spacers **98** have a length which depends on the necessary spacing of the plates to form the metal article and they usually are of increasing length in the direction of the "down" stroke of the press. However, the spacers **98** of each set are preferably of the same length so as to hold the plates **86**, **88**, **90** and **92** parallel with the ends of the spacers **98** abutting the opposite vertical surfaces of adjacent plates. Cap screws **100** may be employed to connect the plates **18**, **86**, **88**, **90** and **92** into a rigid complex of parallel plates horizontally aligned on the members **24**, as well as being vertically supported from the supporting surface of the base **10** of the press through adjustable leveling screws **101**.

BLANKING, DRAWING, IRONING AND DETAILING DIES

When a circular blank is to be punched from strip stock or square cut stock S, a blanking punch **102** in the form of a flat ring is mounted on one face of the plate **34** in any suitable manner. The blanking die **104** is mounted on the opposite face of the fixed plate **86** and takes the form of an annulus which presents a shearing edge to the blank punch **102**. The first draw die **106** is nested within the blanking die **104**. A flat vertical face **108** on the drawing die **106** provides a hold down surface with which the flat surface **109** of the blanking punch **102** co-acts as a pressure pad to control the marginal portion of the sheared blank B during the first draw operation. In all of the following redrawing operations, the telescoping punches of the press perform the function of pressure pads on the progressively drawn work blank B.

Plates **88** and **90** are shown with redraw dies **110** and **112**, respectively, while the plate **92** has an ironing die **114** on one side and a stripper mechanism **116** on the opposite side. A die **118** is shown mounted on the inside surface of the base plate **18** for detailing the bottom of a metal article being formed. It will be understood that the work blank will be carried through the redrawing die **112** and the ironing die **114** on the punch **70** mounted on the moving plate **28**. Also, the punch **70** will detail the bottom of the work blank in the die **118** at the end of its "down" stroke, and the completed work blank will be stripped off the punch **70** by the mechanism **116** on the "back" stroke of the press.

The punch **74** mounted on the moving plate **32** will continue through the drawing die **106** to its fully approached position relative to the redrawing die **110**, at which position the end **84** will perform the function of a pressure pad in conjunction with the face **111** of the die **110**. When the travel of the punch **74** is arrested by spacer **40** on plate **34**, the punch **72** on the moving plate **30** will draw the work blank in the redrawing die **110** and continue to its fully approached position relative to the redrawing die **112**, in which position the end **82** of the punch **72** will perform the function of a pressure pad.

CONTROL OF PRESSURES AND STRESSES ON WORK BLANK

The present invention is primarily concerned with the deep drawing of metal articles without annealing in which the ratio of height to diameter of the work blank at the conclusion of the drawing operation, performed during a single continuous stroke of the press, is substantially greater than has been heretofore performed in commercial practice. A ratio of height to diameter exceeding 4 to 1 and up to 8 to 1 has been obtained under practical commercial operating conditions. When one or more ironing operations are performed in the press following the last redrawing operation, the ratio of height to diameter of the work blank may readily be in the order of 8 to 1 through 15 to 1. Thus, it will be appreciated that the telescoping punches will of necessity be of extreme length in order to perform the drawing, ironing and stripping operations in the fixed plate area of the press. This is especially true where the diameter of the finished metal article exceeds six inches.

Due to the heat generated by the drawing and ironing operation performed by a single and continuous stroke of the press, thermal expansion of the punches will take place which will affect the performance of the press. When the press has been out of operation for any substantial length of time and the temperature of the telescoping punches has returned to substantially room temperature, adjustment of the spacers of the press at that time to correctly locate the ends of the punches relative to the drawing dies will result in an improper adjustment when the punches are brought up to the temperature at which the punches obtain during prolonged operation of the press. To avoid this situation, an elongated fully enclosed thermostatically controlled electrical resistant heating unit **120** is shown located within the innermost punch **70** of the assembly of the telescoping punches. The unit **120** is shown connected to an electrical outlet **122** for convenient attachment to a source of electrical energy when the press is not in operation. In this manner the punches are maintained at a temperature corresponding to the operating temperature and start-up adjustments are avoided.

According to the invention the work blank B in all drawing operations is preferably drawn over a relative gradual radius **124** with minimum clearance being provided between the drawing die and the punch, as compared to standard practice, to cause the work blank to have an inside diameter, very close to the outside diameter of the punch, preferably, to the point of punch hugging. In practicing the invention, it has been found that the clearance **126** between the drawing die and the punch in each drawing operation may be the same and good results are obtained when this clearance is in the order of 60–70 percent of the clearance recommended by standard handbook practice with light gauge material. For example, whereas standard practice may call for a clearance at **126** of 2.3 times the thickness of the stock being drawn, according to the present invention the clearance used is, preferably, in the order of 2.2 times the thickness of the stock.

Whereas it has been the practice heretofore to increase the clearance **126** in subsequent redrawing operations because of the tendency of the work blank to thicken at the top during each following drawing operation, the objects of the present invention are best obtained by maintaining substantially the same clearance **126** in all subsequent redrawing operations, and effecting at least a slight amount of ironing action on the top area of the work blank in each drawing operation.

The ironing operation, mentioned in the preceding paragraph, at the top of the work blank, results from the fact that the reduction in clearance over standard practice provides an interference fit between the punch and drawing die and the thickened top portion of the work blank. During the sequence of drawing operations being carried out in accordance with the present invention by a single continuous stroke of the press, the top area of the work blank that is ironed will be greater in each successive drawing operation.

As will be more fully discussed hereinafter, the process of the present invention results in what appears to be a reduction in the amount and/or the rate of work and strain hardening of the work blank in obtaining the same reduction in blank diameter heretofore experienced under generally accepted commercial practice. Under the practice of the present invention, in addition to the apparent lower rate of work or strain hardening, a high degree of uniformity of work hardening is maintained circumferentially of the work blank with the avoidance of overworked localized areas which would have a tendency to initiate metal rupture in following redrawing operations, or would necessitate annealing of the work blank before performing secondary operations on the work blank B after removing the same from the press. In the following paragraphs the structural factors which are believed to contribute to the circumferential uniformity of the work or strain hardening of the work blank are reviewed:

The initial movement of the moving plate system along the guide and tension members **24** rigidly couples the same to the rigid mass of the fixed plate system through the medium of the guide pins **128** on the moving plate **34** entering the bushings **130** in the fixed plate **86** with a close tolerance sliding fit. As the drawing operations are being carried out in sequence in the press, the mass of the moving plate system is becoming more compact as it moves toward the area in which the drawing operations are being carried out. This increase in compactness is due to the relative approaching movement of adjacent moving plates under the control of the hydraulic cushions and has the effect of augmenting the rigidity, parallelism, and concentricity of the components of the moving plate system.

The telescoping association of the punches of the press, coupled with the rigid parallelism of the moving plate system which supports the punches, results in the punches being concentrically presented to the drawing dies with a high degree of accuracy. This concentric relation between the punches and the dies is maintained throughout the several drawing operations performed in the press during a single continuous stroke thereof. As a result, excellent control of the metal of the work blank becomes a possibility when this relationship is combined with the movement of the work blank from one punch, with pilot action, through the drawing die and back on the next punch. This factor plus a tendency toward punch hugging of the work blank and the ironing of the top area of the work blank in each drawing operation, all seems to contribute to the circumferential uniformity of the work or strain hardening of the work blank.

With highly polished drawing dies in a process having the structural and functional features described above, total reduction of blank size in the order of 80% has been successfully carried out during a single continuous stroke of the press under conditions of commercial practice without metal rupture, and at the conclusion of the drawing operations effecting such a high reduction, the metal of the work blank is still capable of withstanding forming operations on the open end of the work blank, such as a beading operation, without first annealing. Also, it has been possible in the practice of the present invention to have successive reductions in the redrawing operations, each in the order of 25% to 30% in lieu of the practice of carrying out reductions in redrawing on a severe sliding scale such as 25%, 15% and 10%.

In the light of the results obtained by the present invention, it is practical to have a reduction in the first drawing die **106** in the order of 40% and to perform redrawing in each of the drawing dies **110** and **112** with reductions in the order of 25%. Using three redrawing dies, this practice will give a total reduction in blank sizes without annealing of approximately 75% and if four redrawing operations are used, the total reduction may be in excess of 80%. These results may be compared with standard practice giving total reduction possible under conditions of commercial practice in the order of 55% before annealing.

Another area of departure of the process herein disclosed over standard practice relates to the speed of drawing the metal in the press. Whereas, heretofore conventional practice has indicated speeds in the order of 45 feet to 70 feet per minute, excellent results have been obtained according to the invention with drawing speeds in the order of 100 feet per minute.

RATE OF WORK OR STRAIN HARDENING

It appears that in the process of metal forming as carried out in accordance with the present invention the rate of work hardening is materially reduced over the rate that is experienced when the same work blank is processed over the same tools but with an interruption between each operation in lieu of all the operations being carried out during a single continuous stroke of the press.

In an effort to establish the reduction in the rate of work hardening, numerous microphotographs have been taken of work blanks which have been sheared and drawn from the same strip of stock as produced at the mill. Some of these work blanks were drawn in a press constructed and operated according to the invention by being completely formed by a single continuous uninterrupted "down" stroke of the press. Other work blanks were formed by interrupting the "down" stroke of the same press after the first drawing operation and then thereafter completing the following drawing operations. Some of these blanks were removed from the press following the first drawing operation and were then transferred to conventional drawing tools to complete the drawing operations, the reductions of the conventional drawing tools corresponding to those of the omitted drawing operations in the press of the invention, whereby the total amount of deformation of the metal would be substantially the same in the articles completely formed in the press of the invention as in the articles partially formed in such a press and then completed on conventional tooling.

The remaining workability of the work blanks processed according to the present invention, as compared to the work blanks finished on conventional tooling, clearly suggests a lower rate of work hardening. However, the comparison of grain structure in microphotographs has failed to fully account for the substantial increases in remaining workability of the work blank and the substantial increase in total reductions that can be obtained in commercial practice by following the teaching of the present invention.

It should be appreciated that the availability of the remaining workability of the work blank at the conclusion of the drawing and ironing operations is of great commercial importance when secondary operations are to be formed on the metal article. This available workability enables such operations to be performed directly on removing the article from the draw press and without the necessity of subjecting the same to an annealing operation.

CONTROL SYSTEM FOR HYDRAULIC CUSHIONS

It will be appreciated that with the sets of hydraulic cushions **52**, **54** and **56** mounted on and moving with the plates **28**, **30** and **32** of the moving plate system of the press, the supply of hydraulic fluid to and from the cushions and the control of hydraulic fluid pressure in the cushions during unitary as well as relative movement of such plates should be carried out, if possible, without resorting to an involved hydraulic system which would materially increase the cost of the press and its maintenance. The quantity of hydraulic fluid required in large size presses of the type contemplated by the present invention and the rapidity with which the fluid must be transferred relative to the cushions during the operation of the press, without overheating or foaming of the fluid, aggaravtes the problem.

First, it should be noted that the hydraulic system for the flow of fluid to and from the supply and the control of the hydraulic cushions is separate and distinct from the hydraulic system that may be employed to actuate the ram on the "down" and "back" strokes of the press. This is true, although the forces exerted by the ram on the moving plate system create the working pressure in the hydraulic cushions.

Preferably, the hydraulic fluid employed in the hydraulic cushions **52**, **54** and **56** is transferred between the cylinders **62** and the supply **132** through large size flexible hose lines **134** which are attached at one end to the valve structure of the moving plates **28**, **30**, **32** and **34** and at their opposite ends to one or more suitable supply tanks. These lines are supplied and supported in such a manner as to avoid abrasion as their ends attached to the plates travel back and forth during the operation of the press.

To eliminate as much piping and external manifolding as possible, each of the moving plates **28**, **30**, **32** and **34** has passages **136** and they each act as a manifold for delivery of hydraulic fluid to the set of cushions associated with each of these plates. Mounted on top of each of the ported plates is a hydraulic manifold **138** for the hydraulic connection of the passages **136** of the plates with a main control valve **140**. Plates **30** and **32** carry pressure switching valves **142** on their sides. Each of the mentioned valves has a manually actuated knob **144** for effecting pressure changes. In the operation of the press of the present invention, it is usually only necessary to make adjustments in pressures through manipulation of the knobs **144** in changing from one material to another of the same gauge. Aluminum, brass and steel articles, for example, fabricated from stock of the same gauge have been successfully drawn over the same dies by merely changing the operating pressures of the hydraulic cushions **52**, **54** and **56** associated with the moving plates of the moving plate system.

Each of the passages **136** of the plates of the moving plate system has a connection with the longitudinally extending passage **148** in each piston **68** of each hydraulic cushion. The outer end of each piston **68** has a sealed connection with the passage **136** in the plate to enable hydraulic fluid to flow to and from the cylinder **62** through the passage **148** in the piston **68**. When the fluid is trapped or locked in the cylinder **62** by the valve **142**, each cylinder **62** and each piston **68** will collectively function as a thrust column of fixed length between adjacent plates of the moving plate system. When the valve **140** is triggered by the pressure switching valve **142**, as will hereinafter be described in more detail, the fluid is metered from the cylinder **62** through the passages **148** and **136** and the piston and hydraulic cushion collectively defined by the cylinder **62** and piston **68** will collapse under controlled conditions to enable adjacent plates of the moving plate system to approach each other.

SWITCHING VALVE FUNCTION

In order to more fully describe the function of the switching valves **142**, let it be assumed that the hydraulic pressure system for operating the ram **150** is capable of exerting 50 tons of force on the ram **150**, which force is in turn directed through the semirigid connection **152** to the plate **28**. The main valve **140** under the conditions assumed would be adjusted to maintain in excess of 50 tons of force, or a pressure such that each of the four hydraulic cushions associated with each of the plates **28**, **30** and **32** is capable of exerting back pressure in excess of 12.5 tons.

At this point it should be noted that preferably the main control valve **140** of the plate **34** does not have a switching valve **142** connected to it. Instead, it is a self-contained pressure regulating valve and functions to maintain a constant pressure in the cushions of the set of cushions **56** disposed between the plates **32** and **34** sufficient only to hold the sheared work blank B from wrinkling while the first drawing operation is being performed.

Let it be assumed that the valve **140** of plate **34** is set at a pressure at which the set of four cushions **56** will exert a total of 15 tons of hold-down pressure available in the pressure pad structure in the first drawing operation. This 15 tons of pressure is constant and it will be maintained through the entire first drawing operation. When the 15 tons of hold-down pressure is substracted from the 50 tons of available force of the ram **150**, the remaining 35 tons is available for the first drawing operation with the ram **150** delivering only the amount of force resisting its "down" stroke movement. It will be understood that a constant back pressure in the order of 20 to 100 pounds per square inch is imposed on the hydraulic fluid supply **132** which keeps the hydraulic cushion full of fluid and the valves of the hydraulic system of the hydraulic cushions in a working condition. When the hydraulic cushions are full of fluid and such fluid is locked or trapped therein, it causes each of the hydraulic cushions **52**, **54** and **56** of the set located between the plates **28**, **30**, **32** and **34** to function as a thrust column of fixed length until the movement of the plate **34** is arrested and the pressure of the ram **150** on the moving plate system overcomes the pressure setting of the valve **140** on the plate **34**, thereby causing the fluid trapped in the set of cushions **56** to be expelled therefrom permitting the plate **32** to approach the plate **34**.

As the moving plate system is advanced as a unit by the ram **150** at the start of the "down" stroke of the press, the guide pins **128** on the plate **34** enter the bushings **130** on the plate **86** to rigidly couple the plate **34** to the plate **86** just before the blanking punch **102** engages the strip stock S and forces the stock S against the cutting edge of the blanking punch **102**. The cutting edge of the blanking punch **102** must have enough shear angle on it to allow the strip stock S to be blanked with a force less than 15 tons, otherwise the set of cushions **56** will start to collapse and the work blank will be engaged by the punch **74** before the work blank B is completely sheared and the face **109** of the blanking punch is in a position to function as a pressure pad.

Assuming the plates **34** and **86** have approached each other to complete the shearing of the work blank B from the strip stock S and the face **109** of the blanking punch **102** carried on plate **34** is exerting 15 tons of pressure on the marginal portion of the work blank B sheared from the strip stock S, the spacers **40** located between the plates **34** and **86** have become effective and have limited the approach movement of the plate **34** toward the plate **86**. By so doing, the spacers **40** have stopped the plate **34** in a position spacing the face **109** of the blanking punch **102** from the face **108** of the first drawing die **106** on the plate **86** a distance approximating the thickness of the strip stock from which the work blank B has been sheared. This function of the spacers **40** provides "stop arrested blank-holding" for the workpiece or blank.

With the unitary movement of the moving plate system having advanced all the plates **28**, **30**, **32** and **34** to the point at which the spacers **40**, between the plates **34** and **86**, have arrested further "down" stroke movement of the plate **34**, the set of cushions **56** which has been spacing the plates **32** and **34** will start to collapse under the force being exerted by the ram **150** which is in excess of the 15 tons of pressure pad action being exerted on the spacers **40** between the plates **34** and **86**. This pressure reacts against any tendency for the marginal portions of the sheared work blank B to wrinkle and thicken during the first drawing operation. Under the influence of such pressure the face **109** of the blanking punch **102** provides "pressure blank-holding" for the workpiece or blank.

As the set of cushions **56** collapses, hydraulic fluid in the cylinders **62** will be forced out through the longitudinal passages **148** in the pistons **68** into the passage **136** of the plate **34** and through the control valve **140** to the supply **132**, the flow of fluid between the valve **140** and the supply **132** being against the supply pressure created by the air pressure of 20–100 pounds per square inch upon the hydraulic fluid in the supply **132**.

With the initial collapsing movement of the cushions **56**, the plate **32** and its associated drawing punch **74** will be advanced to move the punch **74** into contact with the sheared work blank B imposed on the face **108** of the drawing die **106** carried on the fixed plate **86** of the fixed plate system. With the unitary movement of the moving plate system now confined to the plates **28**, **30** and **32**, the continued "down" stroke of the ram **150** will start the first drawing operation by advancing the punch **74** through the drawing die **106** of the plate **86**.

In FIG. 16 the relative positions of the plates **32**, **34** and **86** is shown with the first drawing operation partially complete. The extent that the plate **32** has approached the plate **34** is indicated by the distance the head **50** of the "back" stroke spacer **42** has been projected from the face of the bushing **46** supported on the vertical face of the plate **32**. It is also to be noted that the pressure switching valve **142** carried on the plate **32** is approaching its actuator **154** on the plate **34**.

FIG. 17 shows the relative position of the plates **32**, **34** and **86** after the completion of the first drawing operation and at the start of the first redrawing operation in the drawing die **110** carried on plate **88**. The spacers **40**, between the plates **32** and **34**, are now active to limit the "down" stroke approach of the plates **32** and **34**, the collapse of the cushions **56** having terminated, and the pressure switching valve **142** having engaged its actuator **154** on the plate **34** to "unlock" the fluid in the set of cushions **54** spacing the plates **30** and **32**. Collapsing action of the cushions **54** will initiate the first redrawing operation as the "down" stroke of the moving plate system, now confined to the plates **28** and **30**, continues.

It is in connection with the first redrawing operation that the drawing punch **74** of the first drawing operation takes on the dual function of a pilot and a pressure pad for the following drawing operation. This dual function has been described in detail heretofore in regard to that shown in FIG. 15. To function properly as a pressure pad, the end **84** of the punch **74** must be maintained a proper distance from the face **111** of the first redrawing die **110**. It is one of the functions of the spacers **40** located between the plates **32** and **34** to provide such spacing. As the length of the spacers **40**, between the plates **32** and **34**, is determined without regard to the longitudinal thermal expansion of the punch **74**, pinching of the work blank may result of a magnitude that will cause rupture of the work blank during the first redrawing operation. It is for this reason that it may be found desirable, as herein proposed, to maintain the telescoping punch assembly at a controlled temperature at all times to avoid start-up adjustment or metal rupture from thermal expansion when operating temperatures have been reached in a production run.

CLEARANCE HOLES IN MOVING PLATE SYSTEM

As heretofore mentioned, for the sake of clarity, in FIGS. 1 and 2 only one spacer element of each of the three spacer systems for the moving plate system has been illustrated. However, in FIGS. 3, 4, 15, 17 and 18 such spacer elements are all shown in the actual number used in the press and as they appear in side elevation.

In FIGS. 5, 6, 7 and 8 these cross-sectional views are taken on the sectional lines of FIG. 3 so that the spacer elements omitted in FIGS. 1 and 2 all appear in FIGS. 5, 6, 7, 8, 16, 17 and 18.

Of the elements of the three spacer systems shown in FIGS. 12, 13 and 14, only the spacer elements of FIGS. 13 and 14 necessitate that the plates **28** and **30** of the moving plate system be provided with clearance holes in order to permit the plates **28** and **30** to move from the position of FIG. 1 to the position of FIG. 2 on the "down" stroke of the press.

In FIG. 7 is shown clearance holes **50'** for the heads **50** of the spacers **42** attached to the plate **32**. Also, in FIG. 7 is shown the clearance holes **56'** in the plate **30** to permit passage of cylinder **62** of the cushions **56** mounted on the plate **32**. FIG. 8 shows the clearance holes **54'** in the plate **28** for the passage of the cylinders **60** of the cushions **54** mounted on the plate **30**.

FIGS. 5, 6 and 7 indicate the distribution on the plates **30**, **32** and **34** of the spacer elements of the three systems illustrated in FIGS. 12, 13 and 14. The elements are shown as being used in sets of four associated with each of the plates **30**, **32** and **34**. Preferably, they are as equally distributed as possible about the axis *a—a* and in this manner assist in maintaining parallelism of the plates **28**, **30**, **32** and **34**. Obviously, the number of spacer elements in each set may be varied as may their location on the plates.

MULTIPLE SETS OF TOOLS

The design of the press of the present invention lends itself to unlimited enlargement of the plates carrying the dies and punches where it is desired to produce more than one drawn article during each stroke of the press. For example, to adapt the press to the economical manufacture of inexpensive seamless cans for use in the packaging of food and beverages, a great many sets of telescoping punches could be mounted on the plates of the moving plate system of the press with corresponding sets of dies located in the fixed plate system of the press. In lieu of the plate **28**, for example, carrying only one punch **70**, it could carry a great many punches, the number depending on the size of the can to be drawn and the practical and economical limitation on the size of the press.

FIG. 24 illustrates a modified form of the invention in which three sets of telescoping punches are shown installed in the press in lieu of the single set of telescoping punches employed in the form of the invention of FIG. 1. FIG. 24 is a cross-sectional view corresponding substantially to FIG. 5. It will be noted that the sets of punches each comprises punch **70'**, **72'** and **74'**, and that these sets are grouped around the central axis of the plate **34'** in lieu of being located concentric with the axis in the manner of the single set of telescoping punches of FIG. 5. The primed reference characters of FIG. 24 indicate the same parts designated in FIG. 5 with corresponding unprimed reference characters.

THEORIES OF THE INVENTION

In order to provide a possible explanation for the unexpected results obtained in the commercial practice of the present invention in the production of metallic articles fabricated from sheet metal by a single continuous uninterrupted stroke of the press, such articles have been fully investigated through the use of microphotographs, by residual stress analysis, and determination of mechanical properties.

For the purpose of making comparison between articles fabricated by employing the invention and articles fabricated in accordance with well established commercial practices heretofore employed, every possible precaution has been taken to obtain substantially identical test blanks. Such blanks have been drawn on substantially identical tooling, one set of tooling being employed in a press constructed according to the invention and another set of tooling being used in conventional drawing press apparatus.

In analyzing the results obtained in comparative tests, metal rupture, metal splitting, degree of work hardening, remaining workability of the drawn article and uniformity of mechanical properties have all been factors of principle importance for consideration from a commercial point of view.

As heretofore stated, the studies that have been made in regard to comparative tests have indicated that there has been a reduction in the degree of work hardening (in terms of remaining workability) in the fabrication of metallic articles in accordance with the principles of the present invention, as compared with the amount of work hardening that is experienced when metallic articles are subjected to the same amount of metal deformation when carried out in accordance with existing conventional practices.

Investigation as to residual stresses appears to indicate that the press and process of the present invention tends to minimize the accumulation of residual stresses of a nature detrimental to deep-drawing of metallic articles.

Example No. 1

This test was conducted on sheet metal blanks certified by the metal producer as being substantially identical in all respects. The blank size was 12.25″, the stock thickness .045″, the material 1008 low carbon draw quality steel, and the finished can had an outside diameter of 4″ and a height of 8¾″. The first draw die, first redraw die and second redraw die and radii of ¼″, 5⁄16″ and ½″, respectively, while the corresponding punches had diameters of 6.73″, 4.82″ and 3.91″, respectively.

Sample D.—Blanks according to the preceding paragraph were placed in a press constructed according to the invention and having a set of nested punches consisting of the three punches indicated above. The cans were formed with one continuous uninterrupted stroke of the press, the speed of the stroke being approximately 50 feet per minute. Punch and die clearances and all other constructional and functional features of the present invention, as heretofore set forth in this specification, were observed in this test. The drawn articles resulting from the test showed no splitting or metal rupture and were otherwise completely satisfactory as to finish, lack of surface defects and other qualities required of drawn metallic articles for commercial purposes.

Sample D31.—The procedure set forth under Sample D was modified by stopping the press at the completion of the first draw and removing the can from the first draw punch. Eighteen hours later the can in the same condition as it was when it was removed from the punch was installed on the first draw punch and the "down" stroke of the press was continued to complete the first and second redrawing operations. In every case splitting of the can was experienced at the top of the can, the splits occurring, for the most part, in the valley between the earing on the upper edge of the can and generally taking place at the time of stripping of the can from the punch, indicating excessive work hardening with a resulting brittleness that would not withstand the action of the jaws of the conventional stripping mechanism.

Example No. 2

The conditions were the same as set forth in Example No. 1, except the material being tested was low carbon aluminum killed steel in lieu of drawing quality steel.

Sample K21.—Procedure was the same as in Sample D of Example No. 1 with the same result, namely, no splitting or metal rupture.

Sample K29.—Procedure was the same as in regard to Sample D31 of Example No. 1 with the same result, namely splitting of the can was experienced.

Example No. 3

The conditions were the same as set forth in Example No. 1 except the material was commercial quality low carbon steel.

Sample C.—Procedure was the same as in the case of Sample D of Example No. 1 with the same result, namely, no splitting or metal rupture.

Sample C27.—Procedure was the same as in Sample D31 of Example No. 1, with the same result, namely, splitting of the can.

Example No. 4

A test was run on a press constructed and operated in accordance with the invention, the press being one used in regular commercial production. In this press the moving plate system comprises a set of five telescoping punches having diameters of 14″, 10.7″, 8.5″, 6.5″ and 5.2″ for carrying out the first draw, four redraws and an ironing operation, all performed within approximately seven seconds during a 91″ continuous uninterrupted "down" stroke of the press.

The drawing dies carried in the fixed plate system of the press had clearance with the punches which followed the principles of the invention with the radius of the first drawing die being ¼″ and the radii of the following four redrawing dies being 5⁄16″. FIG. 21 of the drawing depicts the work blanks as they are run in this particular test, while FIGS. 22 and 23 indicate the pressure pattern obtained with the tooling and material used in this test.

The material used was Alcoa aluminum alloy 3003–0 (dead soft) in the form of 19″ presheared circles of .040″ stock. In the ironing operation which followed the fourth redraw and took place on the 5.2″ diameter punch, the wall of the can was ironed from a thickness of approximately .040″ to a finished wall thickness of .027″. The finished can had an outside diameter of 5.25″ and a height of 22″.

All cans run during this test were without rupture or splitting, and they had an excellent finish free from defects of all kinds. On removing the cans from the press, the tops of the cans were slightly trimmed in an amount required to remove the earing at the upper edge of the can, and the workability at the trimmed line was such that a ⅛″ diameter outside bead was provided in the top of the can, as a secondary operation, by forming the trimmed top edge through 270° without effecting rupture or cracking of the metal at any point, without annealing.

As taken from the press, the cans were tested to determine the dimensions and mechanical properties. The locations on the cans where the dimensions and mechanical properties were determined in making up the following tabulation appear in the lowermost illustration of FIG. 21. Typical tabulation of dimensions and mechanical properties of such cans follows:

Location on can	Tensile	Yield	Percent elongation in 2″	Wall thickness
aw	32.5	30.3	4.0	.0265
bw	33.5	30.8	4.0	.0270
cw	33.1	30.5	4.5	.0270
dw	30.7	28.2	3.5	.0270
Bottom	18.2	13.1	32.0	.0405

The tensile and yield determinations are given in the above in thousandths of pounds per square inch.

Example No. 5

This test was run on a press constructed and operated in accordance with the invention, the press being one used in regular commercial production. The set of five telescoping punches had diameters of 14", 10.7", 8.5", 6.5" and 4.5" with the first draw die having a radius of ¼", the first, second, and third redraw dies each having a radius of 5/16", and the fourth redraw die having a radius of ⅜".

The material for this test was the same as in Example No. 4 except the thickness of the stock was .050" and the ironing operation performed on the 4.5" punch following the fourth redraw operation, reducing the wall of the finished can to .040".

The 23" diameter presheared circles of 3003–0 aluminum alloy (dead soft) were placed in the press and drawn and ironed in one continuous uninterrupted "down" stroke of the press to produce finished cans having diameters of 4.58" and heights of 38". The total reduction in the five draw operation was in excess of 80%. It will be noted that the ratio of diameter to height in the cans thus produced was approximately 1 to 8. Cans produced in this test contained no ruptures or splits of any kind and possessed the same high finish, excellent surface quality and available workability set forth in respect to Example No. 4. The speed of the "down" stroke of the press was approximately 70 feet per minute, and the punch to die clearance followed the principles of the invention heretofore described.

Example No. 6

This test was conducted under the same conditions as Example No. 4, using the same punches and dies, the only departure residing in the substitution of Alcoa aluminum alloy 3003–H19 (full hard) for the aluminum alloy 3003–0 (dead soft). The results obtained in this test were the same as those set forth in Example No. 4 in respect to lack of rupture or splitting. If anything, the finish was even better and the workability, after the removal of the can from the press, without annealing, permitted the rolling of the same bead mentioned in Example No. 4 with the same excellent results. These results with full hard material were completely unexpected and are unexplainable when viewed in the light of existing commercial practices. Upon checking the mechanical properties of cans produced under this test from 3003–H19 aluminum alloy, it was found that the bottom of the can, as indicated in FIG. 21, had maintained its full hardness and the wall of the can was above full hard. A tabulation of the mechanical properties of a typical can run in this test as determined by the Aluminum Company of America follows:

	Yield	Tensile	Elongation
Top:			
Across grain	28.4	30.5	4.0
With grain	29.7	33.5	4.0
Across grain	27.5	30.2	4.0
With grain	30.0	33.3	4.0
Across grain	26.4	30.0	4.0
With grain	28.3	31.8	4.0
Bottom:			
Across grain	25.7	29.5	4.5
With grain	28.0	29.2	4.5

Heretofore it has been considered commercially impossible to deep-draw full hard material. The advantage of doing so becomes obvious from the above tabulation which indicates that the mechanical properties of the drawn article are substantially the same throughout the undrawn bottom and the drawn side walls. The results indicated by Example No. 6 represents a substantial advancement in the art of deep-drawing, particularly with reference to the manufacture of metallic pressure vessels.

Example No. 7

In an attempt to determine the upper limits of the improvement in workability of drawn and ironed metallic articles processed in accordance with the invention, the tooling used on the press in running example No. 5 was modified to permit the use of sheet material of .100" thickness. This was accomplished by using the same punches as set forth in Example No. 5 and substituting larger dies in the first draw and following four redraw operations. The ironing die of Example No. 5 was enlarged to reduce the wall of the article to .60" and a second ironing die was added to reduce the wall of the finished article to .040".

As in the case of Example No. 5, the material being drawn and ironed was 3003–0 (dead soft) aluminum alloy, and the diameter of the work blank in the flat sheet was 23". Without removing the work blank from the telescoping punch assembly and without annealing or resorting to any other form of conventional means heretofore employed for restoring workability following work hardening, it was possible to draw and iron the 23" diameter work blank into a finished can having an inside diameter of 4.5" and an over-all length of 66" without metal rupture or splitting of any kind. The quality of the finish and lack of surface defects was equal to that noted in regard to Example No. 5. The speed of the stroke of the press and the radii of the dies were as indicated in Example No. 5.

A can formed as described in the preceding paragraph was cut lengthwise and Rockwell readings taken on the 30–T Scale with a load of 30 kg. using a 1/16" ball. Starting 4" from the bottom of the can, readings were taken at 4" intervals with the final being taken 2" from the open top of the can. The readings were as follows: 26, 28, 27.5, 27.5, 28.5, 29, 30, 29, 30, 28, 28, 29.5, 30, 30, 30 and 31.

Whereas, in Example No. 5 the ratio of diameter to height of the drawn and ironed can was approximately 1 to 8, in Example No. 7 this ratio was increased to approximately 1 to 15 without metal rupture or splitting and with the article after being drawn and ironed possessing remaining workability to a degree clearly indicating that the upper limits of workability of the material processed in accordance with the invention, as set forth in Example No. 7, had not been reached.

HYDRAULIC SYSTEM OF THE RAM

While it is anticipated that means other than fluid pressure may be employed to actuate the ram **150**, in the commercial form of the invention the ram **150** is a direct extension of the piston **156** located in the cylinder **158**, the length of which determines the maximum stroke of the ram **150**. Preferably, the fluid pressure that is directed against the piston **156** on the "down" stroke of the press is of a pulsating character, whereby the ram **150** and the plates of the moving plate system transfer high frequency fluid impulses to the telescoping punches throughout the "down" stroke of the press.

In practice, the fluid pressure for effecting the "down" stroke of the press throughout movement of the ram **150** may be provided by means of pumps **160** and **162** of the axial piston type, in which one or more axial pistons provide positive displacement of fluid each revolution of the pump. In such pumps, each piston will provide a pressure impulse on each rotation. Pumps of this kind, such as manufactured by Dennison Engineering Division, when supercharged, as by pump **164**, are designed to be operated in the order of 1800 r.p.m. Usually, such pumps have a plurality of axial pistons, with the ones used on the presses of the present invention having seven axial pistons and being capable of delivering 5,000 p.s.i. at 50 g.p.m. and 100 g.p.m., respectively. To analyze the pressure pattern during the "down" stroke of the press, shown in FIGS. 22 and 23, a high speed electronic analyzer was used, manufactured by the Aeroquip Corportion of Jackson, Mich., and sold under the trademark Hydrauliscope. This apparatus translates the output of a pressure pickup to vertical deflection on a cathode-ray oscilloscope. To obtain the pressure pattern of FIGS. 22 and 23, the pressure pickup was subjected to the fluid pressure acting on the piston **156** of the ram **150**. FIG. 23 is a reproduction of the curve traced on the screen of the cathode-ray tube during a complete "down" stroke of the press when tooled to produce the drawn and ironed article depicted in the sequence of steps of FIG. 21 and described under Example No. 4.

Referring to FIG. 22, the "down" stroke of the press was completed in seven seconds. The pressure pattern indicates the pressure peak *d* of the first draw to be approximately 1900 pounds per square inch acting against the ram **150**. The first redraw pressure peak *rd* indicates a similar maximum pressure. It will be noted that both of the pressure peaks of the first draw and the first redraw took place within the first second of operation of the press. This indicates a relatively shallow first drawing operation, and this fact is confirmed by referring to FIG. 21 wherein the sheet metal strip S is reduced to form the work blank B. Between the pressure peak *rd* of approximately 1900 pounds per square inch of the first redraw operation and the pressure peak *rd*2 of approximately 1750 pounds per square inch of the second redraw operation, a greater time interval is indicated than between the pressure peaks *d* and *rd*. This indicates a lengthening of the article which is taking place during the first redraw operation, and this is apparent by referring to the form of the work blank B1 of FIG. 21.

FIG. 22 indicates that the pressure peaks *rd*2 and *rd*3 of the second and third redraw operations, respectively, took place at approximately 1750 pounds per square inch, while the pressure peak *rd*4 of the fourth redraw operation took place at approximately 1400 pounds per square inch. The time interval between each of the adjacent maximum pressure peaks of the redrawing operations is shown as progressively increasing, indicating the progressive lengthening of the article, bearing in mind that it is desirable to delay the start of one drawing operation until the previous one has been completed. Also, it is desirable to avoid delaying the following drawing operation once the previous drawing operation has been completed, as to do otherwise would of necessity extend the length of the press unnecessarily. In FIG. 21 the work blank B has taken the form of B**1**, B**2**, B**3** and B**4** at the conclusion of the first, second, third and fourth redraw operations, respectively.

The ironing operation in the press of the invention is indicated at *i* in the pressure pattern of FIG. 22 and takes place at approximately 750 pounds per square inch. At the completion of the ironing operation, the pressure drops to approximately 500 ounds per square inch as indicated at *e*, with a maximum pressure peak of the entire "down" cycle of the press approximately 2450 pounds per square inch at the time the bottom of the article is detailed at the end of the "down" stroke. The work blank B following the ironing operation has taken the form B**5** of FIG. 21.

In both FIGS. 22 and 23 between the pressure peaks pressure impulses **166** have been indicated. In these figures no attempt has been made to depict the frequency of these impulses, although the same can be determined with electronic analyzer apparatus mentioned above. In tests that have been conducted on the presses of the present invention using the pumps of the type above described, the impulses of a frequency in the order of 60 cycles per second or more were present, and were indicated on the pressure pattern in the form of a band having a width depicting amplitudes covering a pressure range in the order of 200 pounds.

Referring to FIG. 23, it will be understood that this is an enlargement of the upper left hand corner of FIG. 22. The frequency of the pressure impulses making up the wide band of the traced pressure pattern during the sweep of the "down" stroke of the press is determined by the design of the pumps employed in the hydraulic system for actuating the ram and the speed at which the pumps are driven. These impulses are transferred to the ram **150** and hence to the plates and punches of the moving plate system of the press, the transfer of the impulses between adjacent plates being through the hydraulic cushions, as well as through the nested arrangement of the punches.

While it is a theory of the present invention that the high frequency impulses imparted to the metal-forming components of the press constitute one of many factors contributing to the unexpected results flowing from the present invention, acceptable commercial results have nevertheless been obtained during experiments when an accumulator was attached to the hydraulic system of the ram in a deliberate effort to reduce the magnitude of such impulses.

Those skilled in the art will appreciate that by studying and comparing pressure patterns as depicted in FIG. 22 taken with different materials being run in the press and under different conditions of regulation, that the pressure patterns so obtained and compared will be useful in adjusting and operating the press of the invention in commercial use.

To determine the extent the pressure impulses on the ram **150** were transferred to the press structure closely associated with the punches, the pressure pickup of the electronic analyzer above mentioned was shifted to the fluid system of the hydraulic cushions **56** of the plate **34**. The pressure patterns taken at this location were very similar to those shown in FIGS. 22 and 23, and the width of the pressure pattern traced clearly indicated the existence of impulses **166** of approximately the same frequency and magnitude as those determined when the pickup was located in the hydraulic pressure system of the ram **150**.

When the press of the invention was operated without any material being drawn or ironed, under conditions of operation otherwise the same as prevailed when the pressure patterns of FIGS. 22 and 23 were obtained with material being drawn and ironed in the press, it was found that the maximum pressure peaks traced were only slightly lower. On the average, the maximum pressure peaks of the pressure pattern covering the full sweep of the "down" stroke of the press, without material being formed, was less than 100 pounds below the maximum pressure peaks when the material was being deformed.

The low load yield of the metal of the work blank B to the drawing and ironing operations, as indicated in the preceding paragraph, is deemed to indicate a softening of the metal by two phenomena having cumulative effects and which offer a possible explanation for the unusual results flowing from the present invention as manifested, for instance, in the aforesaid Examples 6 and 7.

One phenomenon that may contribute to the apparent low load yield of the metal of the work blank B in the press of the invention relates to the effect of softening produced by high frequency vibration. Where metal being drawn has been subjected to the effects of a macrosonic vibrator, one explanation for the softening effect is that the grain boundaries absorb sufficient energy through inelastic scattering of ultrasonic waves that the scattering atoms approach melting temperatures within milliseconds with the stress required to cause their mobility being suddenly reduced. It is a claim of this invention that the pressure impulses produced by the pumps supplying the fluid pressure for actuating the ram **150** are functioning in a comparable manner.

The other phenomenon, also deemed to contribuite to the low stress yielding of the metal to deformation, pertains to the step of carrying out the deformation of the metal of the work blank B during a single, continuous and uninterrupted rapid stroke of the press without appreciable dissipation of the internally generated heat between the acts of deformation.

It appears that the advantages of combining high frequency pulsation of the tooling of a deep-drawing press with sequential deformation of the metal taking place in one rapid, continuous uninterrupted stroke of the press has not been heretofore contemplated, or the improvements resulting therefrom anticipated.

Always, it should be understood, as heretofore mentioned in regard to many of the departures of the present invention over previous processes and apparatus, that many factors contribute to the improvements flowing from the invention. For example, it has been established that the piloting of the work blank B from one punch to the other during the redraw operations is extremely important particularly in regard to the forming of high-strength alloys. To give full recognition to this fact, the reduction taking place in the first draw die is preferably less than heretofore considered good practice. This departure from standard practice has been taken in order to increase the amount of reductions that take place following the first drawing operation during the redraw operations, at which time the work blank is transferred from one punch to the next.

In the operation of the particular press of the invention on which the pressure patterns of FIGS. 22 and 23 were taken, a 400 horsepower electric motor was used to drive two axial piston-type pumps having capacities of 50 and 100 g.p.m. at 5,000 p.s.i. at 1750 r.p.m. The fluid pressure thus provided was directed into a cylinder having a 6″ ID and against the piston directly connected to the ram of the press.

By substituting a gear pump of 150 g.p.m., but of lower pressure capacity, for the pumps mentioned in the preceding paragraph, the cost of the hydraulic pressure system of the ram may be materially reduced. However, in making this substitution, some of the benefits of the high frequency vibrations of the fluid pressure system produced by axial piston pumps may be sacrificed. In such event, the use of transducer means for effecting vibrations, acting directly on either or both of the hydraulic systems of the press, is anticipated to effect a low load yield of the work blank B to deformation in the press. For example, hydraulic vibrators of the type presently used commercially to test the fatigue of materials may be coupled with the press to impart vibrations as high as 500 cycles per second as compared with the pressure impulses in the order of 200 cycles per second that are obtainable with one or more axial piston-type pumps having seven pistons and operating at 1750 r.p.m. Such a pump is described in U.S. Pat. 2,608,158.

For a more detailed explanation of the effects of macrosound upon metal, reference may be had to an article entitled, "Ultrasonic; An Aid to Metal Forming?" appearing in the April 1964, issue of Metal Process, page 97, published by the American Association of Metals, Mt. Morris, Ill. This article deals with the effect of high frequency vibration in producing in metal a low load yield to deformation without affecting such mechanical properties as ductility. Thus, the results of the present invention are not anticipated.

HYDRAULIC SYSTEM OF MOVING PLATES

It will be observed from a study of FIGS. 5, 6 and 7 that the locations of the passages **136** do not follow a definite pattern but are dependent to a great extent on the location of transverse clearance holes in the plates **30**, **32** and **34**. As a result, it may be necessary in practice to drill two or more intersecting holes in the plates and then plug the ends of some of such holes in order to provide a connecting fluid passage **136** between one edge of the plate and a passage **148** of a hydraulic cushion. Also, it is not always possible to have all of the passages **136** exit from the same edge in plates **30**, **32** and **34**. In FIG. 5 this has been possible, while in FIGS. 6 and 7 two outside connections **168** are shown carried on the vertical edges of plate **32** and connecting the passage **136** between the two lower hydraulic cushions and the manifold **138** at the upper edge of the plate.

The manifold **138** of the valve **140** and its associated valve body **170** carried on each of the plates **30**, **32** and **34** may correspond in general construction and function to that disclosed in U.S. Pat. 2,938,718, issued to F. M. Williamson. As there is no switching valve associated with the plate **34**, the valve **140** on that plate may correspond substantially to that shown in U.S. Pat. 2,938,718. However, on plates **30** and **32**, which both carry a switching valve **142**, the valve **140** is so adjusted as to operate under the control of the switch valve **142**. Such an arrangement is diagrammatically shown in FIG. 19.

Referring to FIG. 19, the manifold **138** on top of the plate **32** connects with the passage **136**, which in turn extends to and communicates with the passage **148** of the hydraulic cushions associated with the plate **32**. The valve body **170** of the valve **140** is mounted on the manifold **138**, and has a bore **172** which aligns with the port **174** in the manifold **138** in communication with the passage **136**. A sleeve **176** is disposed in the bore **172** and it is provided with teardrop-shaped ports **178** opening into an annular passage **180**, which in turn communicates with the passage **182** connected to the hydraulic fluid supply **132** through the flexible lines **134**. An unloading valve **184** is disposed in the sleeve **176** with a spring **186** being provided to hold it to its seat in a position closing the ports **178**. The small port **188** in the valve **184** communicates the fluid pressure of the hydraulic cushions created by the ram **150** of the press to the switch valve **142** through the port **190** and passage **192**.

Switching valve **142** has a spool valve **194** with a plunger **196** at one end which is adapted to engage the adjustable abutment **154** of the adjacent plate **34** to shift the valve **194** to the left against the tension of the spring **196** from the position shown in which the valve **194** is blocking the passage **192** to lock the fluid in the hydraulic cushions **54** and, thus, prevent approaching movement of the adjacent plates **32** and **34**. When the valve **194** is shifted to the left, the passage **192** is brought into register with the annular passage **198** and fluid pressure flow takes place through the port **200** into passage **202** and, hence, to the port **204**. The valve **206** operates to close the port **204**, with the amount of fluid pressure required to lift the valve **206** from its seat being determined by the tension of the spring **208**.

The knob **144** may be actuated to vary the tension of the spring **208** of the switching valve **142**. Lifting of the valve **206** from its seat in the port **204** will enable the flow of fluid in passage **136** to raise the unloading valve **184**, opening the ports **178**, to return the fluid trapped in the hydraulic cushions **56** to the supply **132** as the cushions start to collapse and the plates **32** and **34** are able to approach each other. Adjustment of the tension on the spring **208** by the knob **144** will determine the resistance to collapsing being provided by the fluid in the hydraulic cushions **54**. When the unloading valve **184** is under the control of a switch valve **142**, the valve **210** may be used to trigger the unloading valve **184** under conditions exceeding the regulation of the valve **142** such as overload. In practice, the tension of the spring **212** of the valve will be greater than the tension of the spring **208** of the regulating valve **206**.

To enable the fluid returning to the supply **132** to be handled rapidly and with relatively small lines, two passages **182** are preferably provided in the valve body **170** for that purpose. It will be understood that the fluid pressure supply **132** is under constant pressure as the result of air pressure applied to the surface. This pressure is sufficient to return the fluid to the hydraulic cushions **54** and to maintain the valve mechanism in working condition. This pressure is in the order of 20–100 pounds and returns the fluid past the ball valve **214** to the passage **136** leading to the hydraulic cushions **54**. This fluid is also directed through the passages **216** to react against the spool valve **194** when in the position shown.

The flexible hose lines **134** are disposed above the press and connect with manifolds **218** which in turn communicate with the conduit **220** leading in one direction to the filters **222** and outlet **224** and in the opposite direction to the discharge **226** of the supply **132**. Check valves **228** cause fluid flowing from the supply **132** to flow through the filters **222** and fluid flowing from the cushions to flow to the inlet **226** to by-pass the filters. In this manner a circulation of cooled fluid to the cushions is provided. It will be understood that the lines **134** and manifolds **218** are so arranged above the press as to permit the plates of the moving plate system to move back and forth during the operation of the press without detrimental affect upon the lines **134**.

VERSATILITY AND ECONOMIES EFFECTED BY THE INVENTION

In addition to the improvements that are obtained in total reduction of the work blank when processed according to the present invention, without intermediate annealing, many other economies are effected. For example, by performing several operations during one continuous uninterrupted stroke of the press, handling, cleaning and lubrication of the work blank between operations is avoided. When the cost of tooling of a drawn metallic article in a conventional manner is compared with the cost of tooling the same article for production under the present invention, the tooling cost of the latter is substantially less and economies in this regard in the order of 50% are not unusual.

The construction of the support structure for presses of the design herein disclosed may take many forms and no atempt has been made to illustrate the same. In practice, I-beams may be embedded in the concrete of the base **10** on which the wear plates **12** and **14** may be supported and attached in any suitable manner. In a similar way, the reinforcing plates **16** and **18** may be anchored to the base **10**.

The specific form of a stripper mechanism **116**, shown in FIG. 9, forms no part of the present invention. It is anticipated that many forms of stripper mechanism may be employed for removing the work blank from the innermost punch at the conclusion of the drawing and ironing operations.

It will be appreciated that the present invention is not limited to the fabrication of round section shells, cans, tubes, and the like. Metallic articles of other shapes may be produced.

Further, it is anticipated that the over-all length of the press of the present invention may be reduced by having some or all of the plates of the fixed plate system movable relative to the punches on the plates of the moving plate system.

Presses constructed as herein disclosed have exceptional versatility. By means of changing the length of the spacers **40** a few thousandths of an inch, a thicker or thinner wall of the finished work blank will result. For example, changing the length of a spacer **40** .010″ will effect a change in wall thickness in the order of .001″–.002″. The length of a work blank may be increased without the changing of punches and dies by increasing the diameter of the blank size and changing the length of the spacers **98** of the plates of the fixed plate system whereby one operation is finished before the next operation is commenced. To run material of this thickness, only the drawing dies need to be changed. In changing from one material to another of the same thickness, only the hold-down pressure on the face of the drawing dies needs to be adjusted, and this is accomplished by the simple operation of turning the knobs **144**.

In commercial deep drawing of a metallic part wherein the part is transferred from a die of one press to a die of another press with an annealing operation taking place between the drawing operations, it is often necessary to trim the part between the drawing operations. The trimming of the part is an additional operation and it also increases the blank size required to produce the finished drawn part. The process of the present invention avoids all trimming operations between the drawing operations and as a result permits the use of a minimum blank size.

Having thus described our invention, what we claim as new and patentable is:

1. In a deep-drawing press, a larger drawing die, an outer punch for drawing the work blank in said larger die, a smaller drawing die, an inner punch for redrawing the work blank in said smaller die, said punches and dies being all longitudinally aligned for the drawing of the work blank through said dies during one continuous stroke of the press, said inner punch telescoping with said outer punch and having a nested relation with said outer punch during the drawing operation in said larger die, the end of said outer punch and a face of said smaller die defining opposed surface portions, spacer means for spacing said surface portions an amount approximating the wall thickness of said work blank to provide "stop arrested blank-holding" for the work blank, pressure means acting upon said outer punch and resisted by said spacer means to provide "pressure blank-holding" for the work blank, regulating means controlled by the movement of said punches for effecting relative movement between said punches to project said inner punch to redraw the work blank in said smaller die by transferring the same from said outer punch, between said surface portions, and through said smaller die on to said inner punch, and means for holding said punches in their nested relation during the drawing operation in said larger die.

2. In a deep-drawing press as defined in claim **1**, separate, relatively movable plate means for carrying said punches and said larger die, said spacer means being carried by one of said plate means and being disposed between said plate means to provide an abutment structure to limit relative approach movement between said plate means, and means for supporting said smaller die in fixed spaced relation to said larger die.

3. In a deep-drawing press as defined in claim **2**, said spacer means being in the form of a plurality of abutment elements distributed about the longitudinal axis of said dies and punches.

4. In a deep-drawing press as defined in claim **2**, said regulating means including hydraulic cushion means located between adjacent said plate means for controlling the projection of said inner punch.

5. In a deep-drawing press as defined in claim **1**, heat exchange means for regulating the length of said outer punch to maintain the distance between said opposed surface portions relatively constant for compensating for the thermal expansion and contraction of said outer punch.

6. In a deep-drawing press as defined in claim **1**, heat exchange means located within said inner punch for the thermal regulation of the length of said outer punch to maintain the distance between said opposed surface portions relatively constant.

7. In a deep-drawing press, a movable plate system, a fixed plate system, telescoping drawing punches carried by said moving plate system, drawing dies carried by said fixed plate system and longitudinally aligned with each other and with said punches and supported in fixed spaced relation to each other, said moving plate system comprising a pair of adjacent plates, each plate carrying one of said punches with one of said pair of plates being perforated to permit the passage of the punch carried by the other plate of said pair of plates on relative approach movement between said pair of plates, spacer means for said adjacent plates, said spacer means including means of fixed operating length to limit the relative approach between said plates on the "down" stroke of the press by functioning as abutment structure between said adjacent plates, said spacer means also including means for spacing said adjacent plates on the "back" stroke of the press, said spacer means further including means of adjustable operating length for maintaining said adjacent plates in relatively fixed spacing relation during a portion of the unitary movement of said systems toward each other in "down" stroke of the press, and ram means acting on said moving plate system to effect unitary movement thereof relative to said fixed plate system.

8. In a deep-drawing press as defined in claim **7**, said means of adjustable operating length being in the form of a collapsible thrust column disposed between said adjacent plates, and means for controlling the collapse of said column.

9. In a deep-drawing press as in claim **7**, said means of adjustable operating length being in the form of a collapsible hydraulic fluid thrust column disposed between said adjacent plates, and means for controlling the collapse of said column.

10. In a deep-drawing press as defined in claim **7**, said means of adjustable operating length being in the form of a collapsible hydraulic fluid cushion disposed between said adjacent plates, valve means for locking fluid in said cushion to provide the same with the characteristics of a thrust column of fixed length, said valve means being regulatable to release the fluid in said cushion to cause the same to collapse.

11. In a deep-drawing press as defined in claim **7**, said moving plate system having adjacent pairs of adjacent plates with said pairs having a common plate, each of said plates of said adjacent pairs carrying one of said telescoping punches, each plate of one of said pairs being apertured to permit the passage of the punches carried on the plates of the other of said pairs to permit relative approach movement between each of said plates of said pairs of adjacent plates on the "down" stroke of the press, spacer means for the plates of said adjacent pairs of plates to control the maximum and minimum spacing of said adjacent plates of said pairs on the "down" stroke of the press, said spacer means including means for spacing said adjacent plates of said pairs on the "back" stroke of the press to align said punches preparatory to the initiation of a "down" stroke of the press, and ram means for effecting movement of said moving plate system relative to said fixed plate system and for effecting relative movement between the plates of said pairs of adjacent plates.

12. In a deep-drawing press as defined in claim **11**, said spacer means for effecting maximum and minimum spacing of said pairs of adjacent plates including means of regulatable length.

13. In a deep-drawing press as defined in claim **11**, means upon one pair of adjacent pairs of said plates being actuated on the approach movement of said one pair of plates for controlling said spacer means for initiating the approach movement of the other pair of said adjacent plates in sequential relation to the movement of said punches relative to each other and to said drawing dies.

14. In a deep-drawing press as defined in claim **11**, said spacer means for effecting maximum and minimum spacing of said pairs of adjacent plates including means of regulatable length, and means upon one pair of adjacent pairs of said plates being actuated on the approach movement of said one pair of plates for controlling said spacer means for initiating the approach movement of the other pair of said adjacent plates in sequential relation to the movement of said punches relative to each other and to said drawing dies.

15. In a deep-drawing press as defined in claim **11**, said spacer means for effecting maximum and minimum spacing of said pairs of adjacent plates including hydraulic cushion means, and means upon one pair of adjacent pairs of said plates being actuated on the approach movement of said one pair of plates for controlling said spacer means for initiating the approach movement of the other pair of said adjacent plates in sequential relation to the movement of said punches relative to each other and to said drawing dies.

16. In a deep-drawing press as defined in claim **11**, said spacer means for effecting maximum and minimum spacing of said pairs of adjacent plates including hydraulic cushion means, said hydraulic cushion means being located between pairs of adjacent plates, and valve means on a plate of one of said pairs for controlling the approach movement of the other of said pairs of plates.

17. A deep-drawing press comprising a moving plate system, a fixed plate system, drawing punches and drawing dies carried by said systems in longitudinal alignment whereby sequential drawing operations are carried out during a single and continuous "down" stroke of the press, said moving plate system having an adjacent pair of plates, a hydraulic cushion for spacing said pair of plates, said cushion comprising a cylinder attached to one plate of said pair, piston structure in said cylinder having an extension engaging the other plate of said pair, one of said plates and said cylinder having a hydraulic connection between them, said hydraulic connection being in the form of a conduit defined within the wall of said plate and connected at one end with the interior of said cylinder, the other end of said conduit being connectable to a hydraulic fluid supply.

18. A deep-drawing press comprising a moving plate system, a fixed plate system, drawing punches and drawing dies carried by said systems in longitudinal alignment whereby sequential drawing operations are carried out during a single and continuous "down" stroke of the press, said moving plate system having an adjacent pair of plates, a hydraulic cushion for spacing said pair of plates, said cushion comprising a cylinder attached to one plate of said pair, piston structure in said cylinder having an extension engaging the other plate of said pair, one of said plates and said cylinder having a hydraulic connection between them located in said piston structure and its extension.

19. A deep-drawing press as defined in claim **17**, said other plate having valve means carried thereon having a hydraulic connected with said first hydraulic connection.

20. A deep-drawing press as defined in claim **19**, a hydraulic fluid supply, and flexible conduit means extending between said valve means and said supply.

21. A horizontally disposed-deep drawing press for metal articles comprising a rigid elongated horizontally disposed base, horizontally disposed support surface means rigidly associated with said base, uprights at opposite ends of said base and fixedly supported thereon, transversely spaced guide means disposed in parallelism with each other as well as with said support surface means and anchored at opposite ends to said uprights, punch carriers in the form of rigid vertically disposed plates guided for horizontal movement on said guide means and having their lower portions vertically supported on said support surface for horizontal movement along said support surface means, said carriers each having a horizontally disposed punch projecting to one side thereof, the punches of adjacent carriers being horizontally aligned with at least one punch being tubular to permit the punch of the adjacent carrier to telescope therein with a sliding fit, a power ram for imparting horizontal movement to at least one of said carriers along said first and second means, spacer means for spacing said carriers on said guide means and along said support surface means for transferring movement imparted to one of said carriers by said ram to the next adjacent carrier, said spacer means being regulatable as to length, means to regulate the length of said spacer means to selectively move said carriers with either unitary or relative movement on movement of said power ram, die carriers in the form of vertical plates having metal forming rings supported therein and disposed in horizontal axial alignment with said telescoping punches, said die carriers being aligned on said guide means and vertically supported on said support surface means, and die spacer means located between and abutting adjacent die carriers.

22. A press as defined in claim 21 wherein said guide means take the form of tension rods on which said punch and die carriers are supported in rigid parallelism.

23. A press as defined in claim 21 wherein said die spacer means is also disposed between one of said die carriers and one of said uprights whereby said die carriers and said die spacers collectively define a rigid horizontally disposed thrust column reacting against said base through one of said uprights.

24. A press as defined in claim 22 wherein said die spacer means is also disposed between one of said die carriers and one of said uprights whereby said die carriers and said die spacer means collectively define a rigid horizontally disposed thrust column reacting against said base through one of said uprights.

25. A press as defined in claim 21 wherein said metal forming rings are removably supported in openings defined in said die carrier.

26. A press as defined in claim 21 wherein said punch and die carriers have parallel vertical surfaces with which said punch and die spacing means abut to augment the parallelism of said carriers.

27. A press as defined in claim 22 wherein said punch and die carriers have parallel surfaces, vertically disposed to said support surface means, with which said punch and die spacing means abut to augment the parallelism of said carriers.

28. A press as defined in claim 22 wherein said die spacer means are also disposed between one of said die carriers and one of said uprights, said die carriers being in the form of vertical plates and said metal forming rings being removably supported in openings defined therein, said punch and die carriers having parallel and vertical surfaces with which said punch and die spacer means abut to augment the parallelism of said carriers.

29. A horizontal metal forming press comprising a base having uprights at opposite ends, combination tension and guide rods horizontally supported between said uprights in mutual parallelism, horizontally disposed supporting surface structure associating with said base, a plurality of punch carriers guided on said rods adjacent one of said uprights and directly supported on said surface structure, a plurality of die carriers located on said rods adjacent the other of said uprights and directly supported on said surface structure, a horizontally disposed punch attached to each punch carrier with the punches of adjacent carriers telescoping with each other with a snug fit whereby adjacent carriers collectively support said punches, a die attached to each of said die carriers, the dies of adjacent carriers being horizontally aligned with said punches, a ram for imparting movement to said punch carriers along said rod while said carriers are vertically supported directly on said surface structure to bring said punches into metal forming relation with said dies, spacer means disposed between said carriers to space the same along said rods, certain of said spacer means being regulatable as to length, and means to regulate the length of said certain spacer means to move said punch carriers with either unitary or relative movement on movement of said ram.

30. A horizontal metal forming press comprising a base having uprights at opposite ends, combination tension and guide rods horizontally supported between said uprights in mutual parallelism, horizontally disposed supporting surface structure associating with said base, a plurality of punch carriers guided on said rods adjacent one of said uprights and directly supported on said surface structure, a plurality of die carriers located on said rods adjacent the other of said uprights and directly supported on said surface structure, a horizontally disposed punch attached to each punch carrier with the punches of adjacent carriers telescoping with each other with a sliding fit whereby adjacent carriers collectively support said punches, a die attached to each of said die carriers, the dies of adjacent die carriers being horizontally aligned with said punches, and a ram for imparting movement to said punch carriers along said rod while said punch carriers are vertically supported directly on said surface structure to bring said punches into metal forming relation with said dies.

31. A press as defined in claim 29 wherein spacer means are disposed between said carriers to space the same along said rods.

32. A press for drawing metal comprising a set of relatively movable punch carriers, a set of telescoping, axially aligned punches supported by said punch carriers for unitary movement as well as individual sequential relative movement, a set of axially aligned and axially spaced drawing dies, a set of fixed drawing die carriers, a common support structure for said punch and die carriers, collapsible thrust means disposed between adjacent carriers of said punch carrier, means for imparting unitary movement to said sets of punches and punch carriers on said common support, and means on said punch carriers for collapsing said thrust means and actuated by the movement of said punch carrier on said common structure to control the sequential collapsing of said thrust means with an accompanying sequential movement of said punches relative to each other and relative to said dies.

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