

Aug. 26, 1958

R. L. CURTNER
STRETCH AND WIPE FORMING APPARATUS WITH
TENSION, YIELD, AND ELONGATION CONTROL

2,849,048

Filed June 24, 1957

4 Sheets-Sheet 1

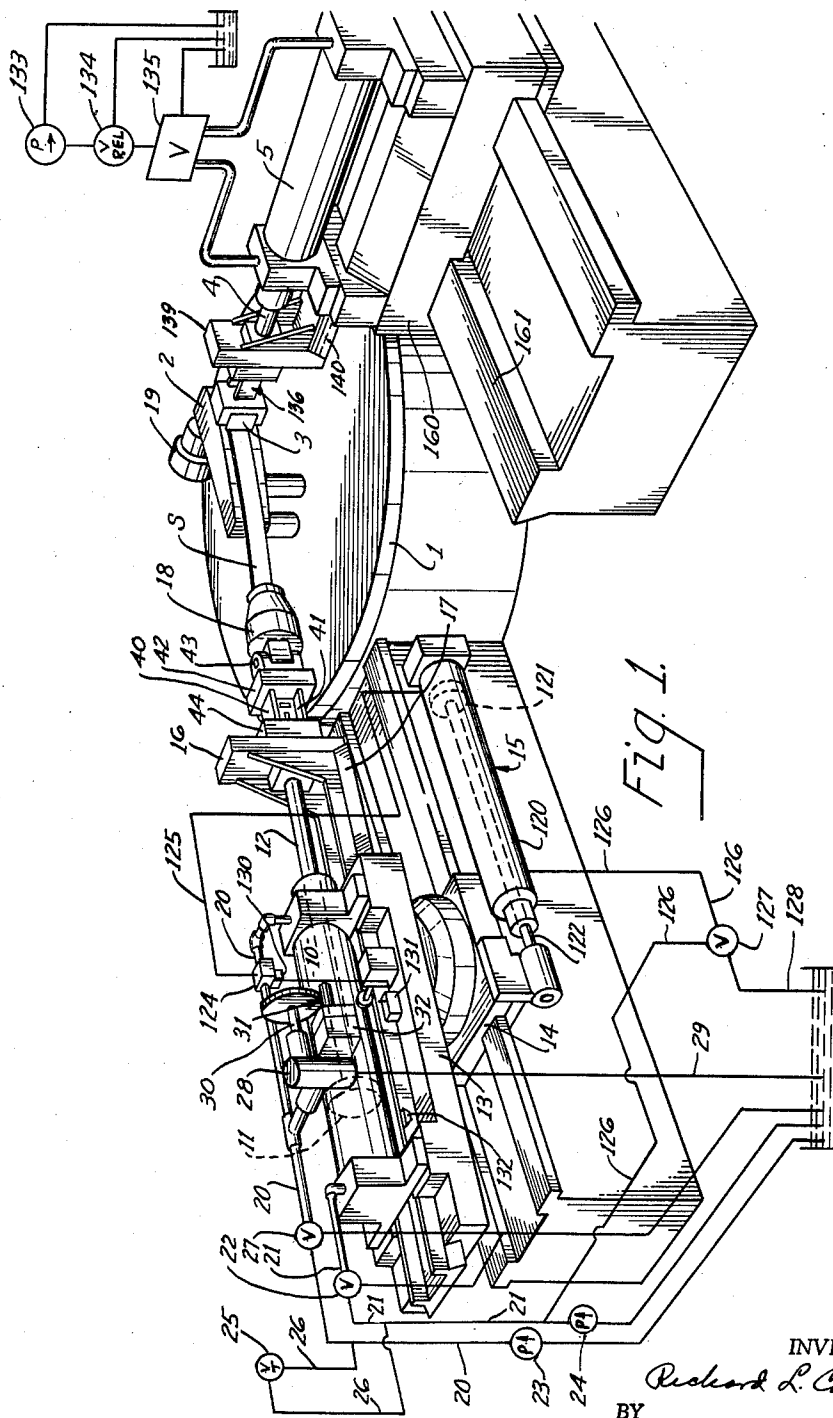


Fig. 1.

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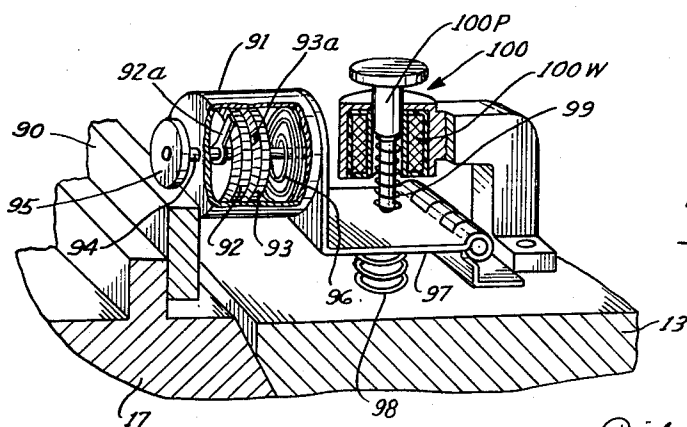
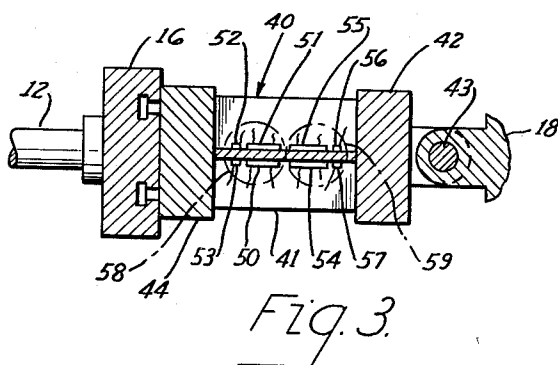
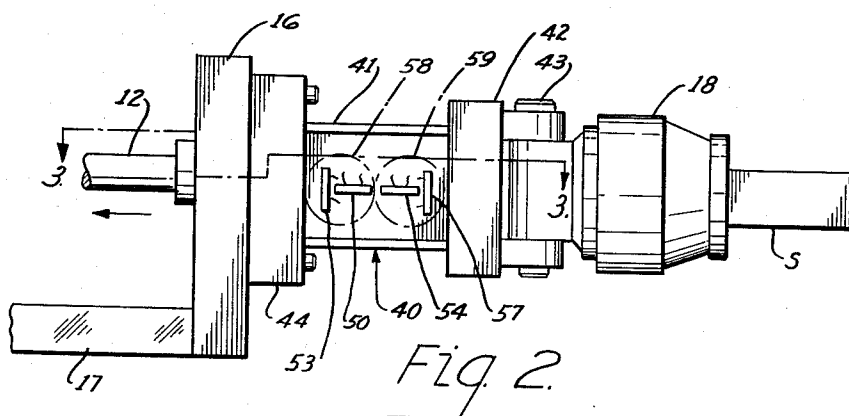
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4 Sheets-Sheet 2



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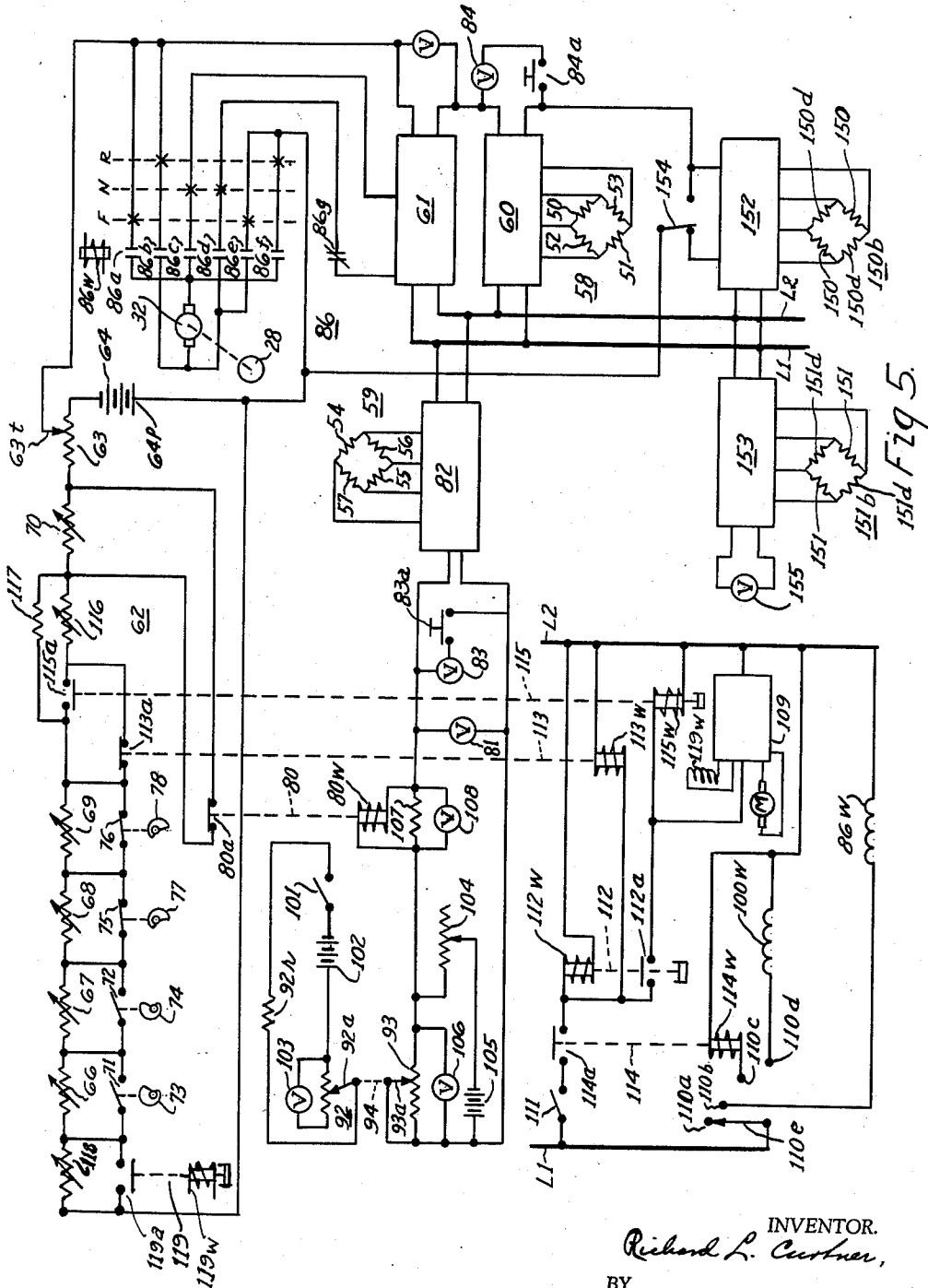
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WIDE FORMING ASSOCIATES

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STRETCH AND WIPE FORMING APPARATUS WITH
TENSION, YIELD, AND ELONGATION CONTROL

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4 Sheets-Sheet 3



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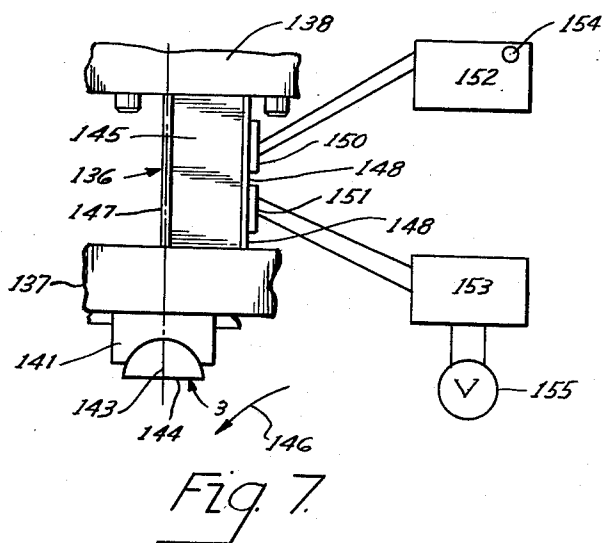
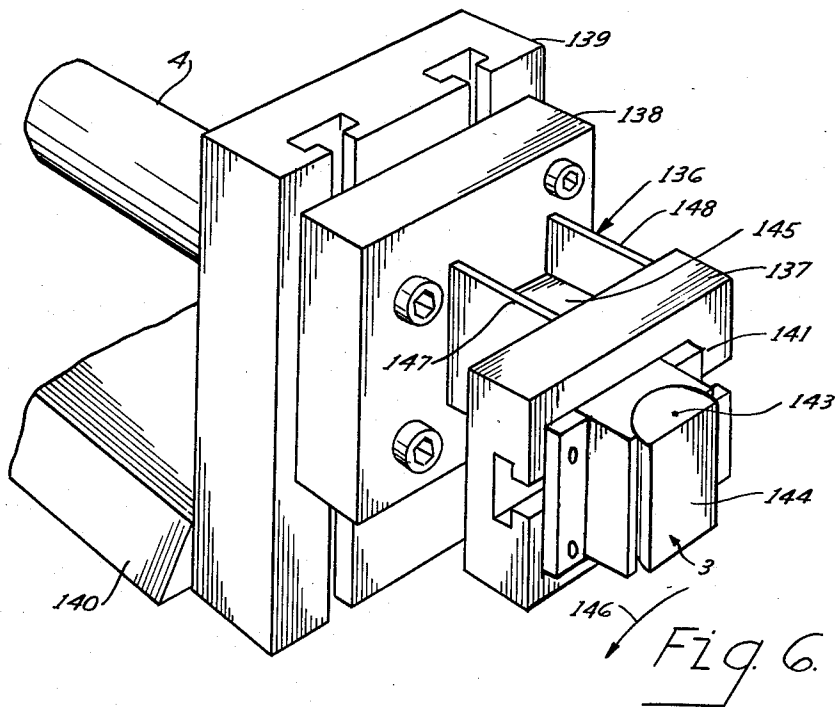
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4 Sheets-Sheet 4



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STRETCH AND WIPE FORMING APPARATUS WITH TENSION, YIELD, AND ELONGATION CONTROL

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Application June 24, 1957, Serial No. 667,376

10 Claims. (Cl. 153—40)

This invention relates to stretch and wipe forming apparatus and particularly to a tension, yield, and elongation control mechanism for determining the yield point of the stock and controlling the tension applied to stock throughout the stretch forming operation.

For the purposes of illustration, the present invention will be described as embodied in a stretch forming apparatus of the type disclosed in United States Patent No. 2,514,830, issued July 11, 1950, to Cyril J. Bath, with the dual cylinder structure disclosed in the copending application of Henry W. Hein and Zygmunt S. Fredericks, Serial No. 562,786, filed February 1, 1956, and entitled Metal Forming Machine, its application to other stretch forming apparatus being apparent from the illustrative example.

In the stretch forming of stock in apparatus such as disclosed in the above patent, one end of the stock is secured in a fixed position to a rotatable side face die about which it is to be stretch formed and the other end is gripped by a stretching head to which force is applied by a hydraulic piston and cylinder assemblage for tensioning the stock as the die is rotated relative to the head about an upright axis. The head is connected to the piston rod, and the cylinder is mounted for swinging about an upright axis offset from the axis of rotation by the die. Thus the pull exerted by the head on the stock can swing the piston rod and cylinder assemblage so that the line of pull is tangential to the side face of the die at the instantaneous point of contact of the stock and die face during the forming operation.

A large number of variable factors determine the pull exerted by the head on the stock. Among the more important of these are the static and dynamic coefficients of friction drag of the piston and its slide, the angles through which the stretch forming piston and cylinder assemblage must be swung about its upright axis by the pull on the stock during forming, the speed at which it must swing, the bending stresses due to overhang of the piston rod and parts attached thereto, and the extent to which, and speed at which, the piston must be extended or retracted. All of these and other factors impose frictional and binding stresses each of which may vary radically without regard to the other during the forming operation. These stresses can become decisive as to the amount of tensioning force applied to the stock and of resultant strains produced.

For example, if the die is so arranged on its rotatable support that it moves away from the cylinder during stretching, the frictional drag gradually increases due to the progressive extension of the piston rod relative to the cylinder, and this frictional drag and the tensioning force applied by the hydraulic fluid are cumulative. On the other hand, if, during the stretching, the die on the table approaches the cylinder so that the piston rod must be retracted, then the frictional resistance is no longer added to the pull exerted by the pressure fluid on the piston, but, on the contrary, is subtracted therefrom, thus reducing the tensioning force

applied on the stock by the piston. To illustrate, if a pull of 10,000 pounds with a frictional drag of 1,000 pounds were provided by the piston and cylinder assemblage, the stock would be subjected to 11,000 pounds as the piston was being extended by the pull on the stock by the die. On the other hand, the stock would be subjected to only 9,000 pounds if the piston were being retracted to offset movement of the die toward the assemblage, as in the latter case the hydraulic fluid, and not the stock, would be overcoming the 1,000 pound frictional drag. Thus, a constant pressure per square inch maintained on the piston would assure not constant tension, but on the contrary, variable tension.

Again, there are a large number of variable factors introduced by the hydraulic circuit itself, these being caused by changes in viscosity of the hydraulic fluid, by the speed at which the fluid must be fed into or vented from the cylinder by the volume of fluid to be handled, by the lengths and diameters of pipes and fittings, the crookedness of the path of flow, the distances the fluid must travel in reaching the cylinder and in being discharged therefrom, and the like.

It has been found impractical to control all of these variables individually but, in accordance with the present invention, the algebraic sum, or final resultant pull due to all of them is controlled. This is done by providing a control mechanism which measures directly the resultant tension applied to the stock, whether the pull exerted is due to friction, to flow characteristics, to the hydraulic pressure, or to combinations thereof. Whether a greater or smaller percentage of the total is due to one or more makes no difference inasmuch as only the resultant effect applied to the stock is measured and used for control.

However, this requires the interposition between the gripping head for the stock and the piston and cylinder assemblage of some tension sensing means, and this sensing means must be relatively compact and light so as to reduce the overhang and frictional drag and binding of the piston and cylinder and other cooperating parts and also so as to eliminate interference of any large amount of equipment at this location with the die itself as the head gripped end of the stock approaches the die. Further, the sensing means and remainder of the control must be such that they themselves do not introduce appreciable variable friction and flow factors.

Again, in the case of the present invention, the control of the tension applied is effected by control of only the discharge of pressure fluid from the main tension cylinder, or cylinders, if more than one is used, at a location close to the cylinder itself so as to reduce the variable elements which are introduced by long and complicated pipe and conduit systems.

In measuring the yield and elongation, and in controlling them, the variable factors must be considered and their effects eliminated or overcome as is the case in connection with tension control.

Heretofore, attempts have been made to control the tension applied by the stretch forming piston and cylinder assemblage by controlling the flow of pressure fluid from one side of the piston to the other. In the copending application of Hein and Fredericks, Serial No. 568,553, filed February 29, 1956, and entitled "Constant Tension Stretch Forming Machine," some success was obtained by utilizing, adjacent the stock gripping head, an auxiliary piston and cylinder control which controls a valve which, in turn, controls the main piston and cylinder assemblage. The most successful arrangement disclosed in this prior application is one in which a continuous low pressure, much below that required for the forming operation, is maintained at the head end of the cylinder so as to urge the piston continuously to extended position with sufficient force to about equal or overcome the maximum frictional

resistance or drag. With this arrangement the admission or discharge of pressure to the rod end of the cylinder is controlled by a valve which is operated mechanically in response to the extension and retraction of a piston of an auxiliary piston and cylinder assemblage arranged adjacent the gripping head and connecting it to the extension and retraction of a piston of an auxiliary piston and cylinder assemblage. This auxiliary piston and cylinder assemblage itself introduced variable factors which detracted from its practical performance and reduced its accuracy such that it was not suitable for extremely precise tensioning unless controlled and adjusted frequently by a highly skilled operator. Further, it was bulky and thus increased the overhanging load on the main stretch forming assemblage and interfered with the die near the end of the forming operation.

In accordance with the present invention, the control of the stretch forming piston and cylinder assemblage, for proper tensioning of the stock and for yield-elongation determination, is effected by the control of a relief valve connected between the rod end of the main stretch forming cylinder and the sources of hydraulic pressure fluid, the relief valve being of the type having a high discharge capacity with small resistance to flow and of which the discharge capacity can be adjusted rapidly and maintained accurately at the adjustment selected.

It has been found that by controlling only the relief valve, leaving the head end of the cylinder vented, or subject only to a low constant pressure, very effective tension control can be obtained, and the yield point, elongation after yield, and total elongation can be determined and controlled readily.

Further, in accordance with the present invention, the means for controlling the operation of the relief valve in response to the tension effective on the stock is provided by means of a structure in which the measuring and sensing device is very small, light, and compact with little or no overhang which can interfere with the die, in which there are no parts which must be moved relative to each other, and which, of itself, does not introduce appreciable variable factors in operation.

Specifically, the tension or pull applied to the stock at any instant is measured by means of a compact load cell interposed directly beneath the stock gripping head and the piston of the main stretch forming piston and cylinder assemblage, close to the head, combined with a small and compact strain gauge device, responsive to changes in the length of the load cell. The strain gauge supplies an electric control signal which, in turn, controls a motor mechanism which varies the pressure at which a balanced type relief valve operates to vent pressure fluid from the main stretch forming piston and cylinder assemblage.

The present apparatus is so arranged that a great portion of the working parts are standard equipment which can be purchased readily on the market and which, as purchased or in slightly modified form, can be connected to provide the present combination.

Accordingly, therefore, the present invention is directed to the control of a stretch forming machine such that the tension exerted on the stock automatically can be maintained constant at any predetermined pressures selected by the operator throughout different portions of the stretch forming cycle, regardless of the variation in frictional resistance, flow resistance, speed of stretch forming, and the like, that may occur in the basic stretch forming apparatus.

A more specific object is to accomplish this control and the measurement of yield elongation by means of a simple and effective apparatus in which little or no service is required and in which little or no bulk is added to that part of the basic structure which is movable with the piston of the stretch forming assemblage.

Another object is to provide a control and measuring

device by which the stress of the material at all points along its length can be determined as the forming progresses and thereafter can be duplicated accurately when desired.

Another object is to provide a compact and simple load cell and sensing combination having no parts which are movable relative to each other except by elastic deformation, and by which the strain can be translated into voltage vectors which operate control apparatus and indicating devices for controlling and indicating the stress exerted on the stock at all times during forming thereof.

Various other objects and advantages of the present invention will become apparent from the following description wherein reference is made to the drawings in which—

Fig. 1 is a diagrammatic fragmentary perspective view of a combined stretch and wipe forming apparatus showing the present invention embodied therein;

Fig. 2 is an enlarged side elevation of a load cell and strain gauge device forming part of the present invention, and showing the device attached to the stock gripping head and an adjacent part of the stretch forming apparatus;

Fig. 3 is a fragmentary horizontal sectional view taken on the line 3—3 in Fig. 2;

Fig. 4 is a perspective view, partly in section, showing a part of the yield-elongation measuring and control apparatus forming part of the present invention;

Fig. 5 is a wiring diagram and general diagrammatic illustration of the control of the present invention;

Fig. 6 is a fragmentary perspective view of a part of the stretch forming machine showing a wiping shoe and its associated load cell and strain gauge device; and

Fig. 7 is a fragmentary top plan view of the wipe shoe and load cell-strain gauge device associated therewith.

Referring first to Fig. 1, there is shown part of a combined stretch and wipe forming apparatus of the type illustrated in United States Letters Patent No. 2,514,830 and in the above identified pending application the stretch forming mechanism comprising essentially a rotatable table 1 on which is mounted a side face die 2 about which the stock S is to be stretch formed. If desired, concurrent stretch forming and wipe forming may be employed in which case a wipe forming shoe 3 is arranged to engage the stock for wiping it into contact with the side face die during stretch forming, the shoe 3 being applied to the stock by means of a piston rod 4 of a wipe forming piston and cylinder assemblage 5.

The stretch forming means comprises generally a first main piston and cylinder assemblage including a cylinder 10 and a piston 11 having a rod 12, the assemblage being arranged with the axis of the cylinder extending generally toward and away from the table 1. The piston and cylinder assemblage is mounted on a suitable turntable 13 so that it can swing, as a unit, about a vertical axis and align itself with the line of pull on the stock and maintain that line tangent to the die side face at the instantaneous point of contact of the stock and the die side face. The turntable 13 is mounted on a carriage 14 which is slidable along the frame of the machine toward and away from the main turntable 1 by means of a second stretch forming piston and cylinder assemblage 15, later to be described.

A suitable pedestal 16 is connected to the piston rod 12 and is mounted on a slide 17 which, in turn, is mounted on the turntable 13 for swinging with the piston 11 and cylinder 10 about the axis of the turntable 13 and for sliding movement with the piston rod 12 parallel to the axis of the piston 11.

Mounted on the pedestal 16 is a stock gripping head 18 which grips one end of the stock for the purpose of applying tension to the stock, the other end of the stock being gripped and held in fixed relation to the side face die by means of a suitable hydraulic gripping mecha-

nism 19 on the main turntable 1, or on the side face die 2.

Stretch forming pressure fluid is supplied to the cylinder 10 through a suitable line, such as a pipe or hose 20, which is connected to the cylinder at the rod end. Pressure fluid can be supplied to the head end of the cylinder 10 by means of a suitable line, such as a pipe or hose 21.

A structure of the type thus far described is fully disclosed in the above identified patent and is now well known in the art.

The admission of pressure fluid to the line 21 may be controlled by any suitable hand valve 22 or otherwise as the purpose thereof is to extend and retract the piston manually preparatory to connecting the stock to the head 17. The valve 22 is operable in one position to admit pressure fluid to the head end of the cylinder 10 and in another position to vent the head end of the cylinder 10 to a sump.

Pressure fluid is supplied through the line 20 from a convenient pump 23 at a volume and pressure greater than that required for the stretch forming of the stock S. The pressure fluid may be supplied to the line 21 by a pump 24 or from the pump 23 by way of a by-pass throttling valve 25 and line 26. A valve 27 may be provided in the line 20 for connecting the rod end of the cylinder 10 to a sump when desired.

Interposed in the line 20, between the fluid source and the rod end of the cylinder 10, is a relief valve 28 which preferably is of the well known balanced-piston type which can vent a large volume of pressure fluid at high pressure in a very short instant of time and with little resistance to flow. The relief valve 28 is connected to a return line 29 which leads to a suitable sump.

If desired, a constant pressure may be maintained from the separate pump 24 in the head end of the cylinder 10 so that the piston is urged continuously to the extended position against frictional resistance, the pressure, however, supplied through the line 21 for this purpose being less at all times than that supplied through the line 20 and preferably just enough to offset maximum frictional drag.

The relief valve 28 is one in which the pressure at which it discharges to sump is controlled by a needle which, in turn, is set by endwise movement of a stem 30. The stem 30 is threaded into the valve body so as to be moved endwise when rotated. The stem is rotated by a suitable gear train 31, which, in turn, is driven by a direct current reversible electric motor 32. Rotation of the stem 30 in one direction increases the pressure at which the valve 28 relieves and rotation of the stem in the opposite direction decreases the pressure at which the valve 28 relieves. Thus, by controlling the rotation of the motor 32, the pressure at which the relief valve 28 operates to vent the rod end of the cylinder 10 can be controlled.

The next problem that arises is how to control the motor 32 effectively in a fixed relation to the tension which is applied to the stock by the gripping head 18. For this purpose, a load cell and an electric sensing and measuring device are employed.

Referring to Figs. 2 and 3, the head 18 is connected to the pedestal 16 through the medium of a load cell 40.

In the preferred form illustrated in Figs. 2 and 3, this load cell comprises a relatively rigid metal member which may be in the form of a short length of I-beam 41. The I-beam 41 is fixedly bonded at one of its ends to a plate 42 to which the head 18 is connected by a trunnion 43 so that any pull exerted on the head 18 against the pull of the piston 11 tends to elongate the I-beam elastically endwise toward the die. The opposite end of the beam is fixedly bonded to a plate 44 which is secured fixedly to the pedestal 16. The I-beam 41 is disposed horizontally endwise and with its flanges at the top and bottom and with its web vertical.

The degree of elastic elongation of the I-beam 41 is a function of the pull on the head 18. Accordingly it is necessary to measure this elastic elongation or strain of the I-beam and to use the translated result of this strain to control the main stretch forming piston and cylinder assemblage.

The I-beam 41 provides a compact and efficient load cell of high capacity and one of which lateral surfaces are accessible close to its neutral axis. This is desirable because in the stretch forming of stock it happens that stresses are quite frequently exerted laterally of the line of pull. As a result, a pull on the stock applies to the head 18 not only a major component of force endwise of the stock, but also a minor component transversely of the axis of the piston, due to the axis of the cylinder 10 and piston 11 being misaligned with the line of pull on the stock from time to time. To swing the piston and cylinder assemblage by the pull exerted on the stock so that the axis of the assemblage is again brought into alignment with the line of pull on the stock against frictional resistance imposes a lateral pull on the head 18 which causes lateral deflection of the load cell.

Furthermore, there is some vertical deflection of the load cell due to its own weight and the weight of the head. Frequently, the stock is being stressed so as to curve it vertically and this imposes on the load cell a further component of force in a vertical direction which, too, tends to deflect the load cell. However, an I-beam has a sufficiently high modulus, and has surfaces at which measurements of strain can be obtained so near to the neutral axis, that these lateral and vertical deflecting forces are of no consequence in measurements taken on such surfaces.

The next step, then, is to provide a strain sensing device for translating the strain imposed on the cell by the piston 11, head 18, and stock S, into some type of signal for effecting control of the pull exerted on the head 18 by the main stretch forming piston and cylinder assemblage.

For this purpose, strain gauges of the general type disclosed in United States Letters Patent No. 2,292,549 are employed. A typical gauge of this type comprises a continuous filament of electrical conducting material which is extensible and contractible and of which the resistance varies in accordance with its extension and contraction. The wire is sinusoidal in form and is bonded adhesively to one face of a piece of flexible fabric, or paper or plastic sheet which, at its opposite face, is bonded securely to a body to be placed under stress so that the filament will be caused to elongate and contract with the elongation and contraction of the body. In this manner the strain on the body causes, in the filament, variations in the electrical resistance which are reflected in a change of voltage across the terminals of the filament. These changes can be amplified readily and, when amplified, can be evidenced by deflections of a voltmeter and can be used for control.

Generally, the strain gauges are in the form of rectangular "patches" of thin sheet material arranged with the filament so disposed that the peaks at the top and bottom of the sinusoidal curve are disposed toward the ends of the rectangle, not toward the sides.

In the illustrative example, two sets of these gauges are used. One set senses the strain on the load cell 40 and operates an indicator, such as a voltmeter or penmotor, in relation to the sensed strain, thus indicating the strain as a function of voltage. The other set senses a like strain on the load cell and operates the servomotor 32 in relation to the sensed strain for controlling the relief valve 28 in accordance with a function of voltage change, so as to maintain a predetermined tension on the stock S.

The particular load cell 40 and its strain gauges are calibrated so that the strain gauges accurately reflect the elastic elongation and contraction of the cell, and

hence the pull exerted thereby, as proportional voltage changes.

Referring to Figs. 2 and 3, each set of gauges comprises four gauges. Those in the set for the servo-motor 32 are indicated at 50, 51, 52 and 53, respectively, and those in the set for the tension indicator are indicated at 54, 55, 56 and 57, respectively.

The gauges of each group are connected in a bridge, as best illustrated in Fig. 5, each bridge including two active and two dummy gauges. Thus, in Fig. 3, one bridge 58 contains gauges 50 and 51 which are active and gauges 52 and 53 which are dummies. The other bridge 59 contains the gauges 54 and 55 which are active and gauges 56 and 57 which are dummies.

It is to be noted that the active gauges are disposed with their long dimensions endwise of the I-beam 41 so that the filaments are extended and contracted by the load cell as it is elastically elongated and contracted.

The so-called dummy gauges are disposed with their long dimensions vertical so that the filaments thereof are not extended or contracted in any manner by the load cell as it is elastically elongated and contracted.

Thus, the so-called "dummy" gauges are active in providing a bridge, but are not responsive to elongation and contraction of the cell as are the active gauges. They are placed on the I-beam adjacent the active gauges so that all gauges are subject to substantially the same temperature, weather, and mechanical conditions, thus reducing the possibility of false readings due to the active and dummy gauges being subjected to different localized conditions unrelated to the elongation and contraction of the I-beam, such as might occur were the dummy gauges positioned remote from the active gauges.

The areas to which the gauges are applied are carefully polished and cleaned. The gauges are applied to the web faces of the I-beam at a vertical position as near as may be on the neutral axis of the beam. Laterally of the I-beam, of course, they are offset laterally from the neutral axis. By arranging the gauges of each bridge in the manner illustrated, upon lateral deflection of the I-beam 41, any voltage changes which would occur due to the gauges being in slight laterally spaced relation from the neutral axis, balance and cancel each other out. Further, differentials in temperature, local interference, etc. which would otherwise cause false stress readings are offset and balanced out due to the locations of the gauges relative to the I-beam and to each other.

The bridge 58 is connected through amplifiers 60 and 61 in a null circuit with the motor 32, and the bridge 59 is connected through another amplifier 82 to a tension indicating voltmeter 81, as will later be explained. The amplifier 61 also serves as a power positioner for the motor 32.

The motor 32 is a direct current machine of the permanent field type and is reversible upon reversal of the polarity of the voltage impressed on its armature. It may be, for example, a motor rated at twenty-seven volts having a built-in speed reducer so that its output shaft turns at thirty-five revolutions per minute at rated voltage. The speed varies with the voltage, being very low at three volts and increasing very rapidly toward rated speed above twelve volts. The motor 32 may be coupled to the stem 30 of the relief valve 28 so that, for example, one revolution of the valve stem 30 changes the hydraulic pressure by two hundred pounds per square inch.

The null circuit includes amplifiers 60 and 61, and a potentiometer 62 having a tapped resistor 63 and is powered by a suitable direct current reference source, such as a battery 64. It thus provides a variable power supply means and a primary signal means for the operation and control of the motor 32. The null circuit includes, in addition to the resistor 63 and other resistors to be hereinafter described, a plurality of variable resistors 66, 67, 68, 69, and 70 all connected in series with each

other and with the resistor 63 across the terminals of the battery 64. The amplifiers 60 and 61 are connected in series with each other between the positive terminal of the battery 64 and a movable tap 63t of the resistor 63. The resistors 66 through 70 are provided for such cycle requirements as may be desired for various operations of the machine. In the illustrative example, it is assumed that it may be desired to increase the tension on the stock at two different amounts at certain cyclic positions during the forming cycle, to decrease the tension to two different amounts at certain other cyclic positions during the cycle, to decrease the tension automatically when the metal reaches the yield point, and to initiate the stretching operation at below normal tension and then quickly but uniformly bring the tension to normal so as to avoid work hardening which would instantly result from a sudden heavy jerk on the stock.

For these operations, the resistors 66 and 67 are shunted by normally open switches 71 and 72, respectively, which are arranged to be operated by adjustable cams 73 and 74, respectively. When the cams 73 and 74 cause closure of their associated switches 71 and 72, the resistors 66 and 67 are excluded from the circuit thereby unbalancing the null circuit by reducing the voltage between the terminal 64p and the tap 63t and demanding increased tension.

The resistors 68 and 69 are shunted by normally closed switches 75 and 76, respectively, which are arranged to be opened by adjustable cams 77 and 78, respectively, for placing the resistors 68 and 69 in the circuit to thus unbalance the null circuit by increasing the voltage between the terminal 64p and the tap 63t and demanding decreased tension.

Each of the cams 73, 74, 77, and 78 may be mounted on the table 1 for movement therewith, or driven in timed or positional relation with some moving part of the apparatus, as desired, depending on the cycle desired. For example, it may be desired to increase or decrease the tension at certain times, depending upon the severity of the die angle about which the stock is being formed or on the pressure being applied to the wiping shoe 3, and the like.

The cams may be adjustable in the usual sense and in the sense that the cam used for initiating a given increase or decrease in pressure, in any instance, may be removed and another substituted therefor for effecting a change in the initiation and maintenance of the increase or decrease, or the drive may be selectively sped up or slowed down. Again, if desired, electrical equivalents of the cams, such as limit switches and relays, may be employed.

The resistor 70 is shunted by normally closed contacts 80a of an electromagnetic relay 80, having a winding 80w. The resistor 70 is a tension-decrease-for-yield resistor, its function being to add resistance in the potentiometer circuit when the contacts 80a open and thus unbalance the null circuit in a direction to decrease the applied tension or hydraulic force when the stock is stressed to or slightly beyond its yield point.

For this purpose an operating winding 80w of the relay 80 is normally energized at a low voltage, as will later be explained, and when the voltage on the winding 80w is increased beyond a predetermined pick up value, the relay 80 picks up to cause opening of the contacts 80a.

With the structure thus far described, the tension applied to the stock can be so controlled as to remain substantially constant at the predetermined values chosen for different portions of the forming cycle.

For example, assume that the machine is at standing position and the tap 63t has been brought to a given resistance point along the resistor 63, the potentiometer 62 already having been calibrated for tension with the particular load cell and strain gauges.

In this condition, pressure fluid is being admitted to the rod end of the cylinder 10 through the line 20 and

the relief valve 28. Fluid pressure in the cylinder 10, at the rod end, is urging the piston 11 to the left, tensioning the stock S. The tension was increasing up to a low value and, as it did so, the load cell 40 was being elongated elastically, thus elongating the active gauges 50, 51, 54 and 55. As the elongation of the gauges 50 and 51 progressed, they reached a condition at which their modifying signals offset those of the primary signal means so that the null circuit came into balance. As this balance was being approached, the motor 32 was operating to increase the venting of pressure fluid by the relief valve 28. When balance was reached, the valve 28 had been adjusted so that the pressure of the fluid supplied by the pump 23 minus the pressure loss due to venting by the valve 28 plus the frictional drag of the stretch forming assemblage, was equal to the tension selected by the setting of the tap 63*t*. If this selected tension increases slightly due to mechanical unbalance, the null circuit is unbalanced so the motor 32 operates in a direction to increase the venting by the relief valve 28 and thereby reduce the hydraulic pressure. If the selected tension should be decreased by hydraulic unbalance, the null circuit is unbalanced so that the motor 32 operates in the opposite direction to decrease the venting by the relief valve 28 enough to raise the pressure effective on the rod end of the piston 11 and thus restore the selected tension.

Since the speed of the motor 32 decreases as the unbalance or differential voltage decreases, there is little over or under compensation with resulting hunting and hence the selected tension is maintained substantially constant. In actual practice, the amplifier 61 has an adjustable dead band so that the voltage increment can be adjusted so that the motor 32 will not start until a predetermined change in original voltage occurs, thus preventing over-sensitivity and instability of control.

The changes in tension are reflected also by a tension indicating voltmeter 81 connected across the output terminals of an amplifier 82 responsive to the duplicate bridge 59. A more sensitive voltmeter 83, is arranged in series with a normally open push button 83*a*, by which it is temporarily placed in the circuit during balancing of the amplifier. A similar voltmeter 84 is connectable across the terminals of the amplifier 60 by a push button 84*a*. Thus these amplifiers can be set in zero balance with each other in a well known manner.

A three-position reversing master switch 86 having contacts 86*a* through 86*f* is provided to selectively connect the motor 32 directly to the battery 64 and to the amplifier 61. When the switch 86 is in its forward position marked F, the contacts 86*a* and 86*e* are closed, as indicated by the crosses in horizontal alignment therewith, and the motor 32 is connected for forward operation directly from the battery 64. When the switch 86 is in the reverse position marked R, the contacts 86*b* and 86*f* are closed so that the motor 32 operates in the reverse direction directly from the battery 64. In the neutral position of the switch 86 marked N, the contacts 86*c* and 86*d* are closed to connect the motor 32 to the amplifier 61.

Elongation

In order to determine the yield point and measure the elongation at yield, a yield detecting and measuring device is provided.

As best illustrated in Fig. 4, a track 90 is provided on the slide 17 and extends endwise thereof. Mounted on the turntable 13, alongside the slide 17, is a housing 91 containing a pair of potentiometers 92 and 93. The potentiometers 92 and 93 have coaxial rotating arms 92*a* and 93*a*, respectively, driven by a common shaft 94. A wheel 95 is detachably mounted on the shaft 94 for rotation therewith and can be applied to the track 90 so as to roll therealong as the slide moves endwise. A spring 96 is connected to the shaft 94 and is operable to rotate

the shaft and wheel 95 to a starting or zero position when the wheel is disengaged from the track. The housing 91 is carried on a hinged support 97 so that it can be swung upwardly to remove the wheel 95 from contact with the track or downwardly to apply the wheel to the track. The support 97 normally is held raised in position, in which the wheel is out of contact with the track, by a spring 98. A spring 99 is arranged so that, when compressed sufficiently, it moves the support downwardly to wheel-engaging-position against the force of the spring 98.

A solenoid 100 having an operating winding 100*w* and a plunger 100*p* is connected on the turntable and is operative, when the winding 100*w* is energized, to cause the plunger 100*p* to compress the spring 99 sufficiently to overcome the spring 98 and to apply the wheel 95 to the track 90. Thus, when the wheel is in engagement with the track 90, any lineal movement of the track is translated into rotary motion of the arms of the potentiometers 92 and 93 and thereby changes the electrical resistance in electrical circuits now to be described.

The potentiometer 92 having an arm 92*a* is connected in series in a loop circuit with a fixed resistor 92*r*, an on-off switch 101, and a suitable direct current source such as a battery 102. A voltmeter 103 is connected across the potentiometer 92 so as to measure the voltage drop. In the zero position of the arm 92*a*, the effective resistance of the circuit is such that substantially no current flows from the battery 102. As the arm 92*a* is rotated clockwise by movement of the track 90 in the retracting direction of the piston rod, the resistance is reduced as is also the voltage drop across the potentiometer 92. This drop is indicated by the voltmeter 103 which may be calibrated to read directly the lineal movement of the track which is, in effect, elongation of the stock S.

Thus the potentiometer 92 and the meter 103 evidence total elongation occurring while the wheel 95 is applied on the track. As will later be explained, the wheel 95 is applied to the track 90 before the table 1 is rotated and while the yield point and elongation-over-yield are being determined by increasing the tension on the stock, the tension increase being caused by increasing the fluid pressure by manipulation of the tap 63*t* on the tension control resistor 63.

The other potentiometer 93 is connected across a suitable source of direct current voltage such as a battery 105 and in series with an adjustable resistor 104. The output of the amplifier 82 is connected in series with a resistor 107 across the terminals of the potentiometer 93. The winding 80*w* of the relay 80 is in parallel with the resistor 107. Also connected in parallel with the resistor 107 is a zero center voltmeter 108 which indicates elongation-above-yield. By adjusting the resistor 104, the signal from the potentiometer 93 can be adjusted to make it equal and opposite to the signal from the amplifier 82 at values of tension up to approximately three fourths of yield tension, for example. The balance is indicated by the zero position of the voltmeter 108.

As tension is increased by manual movement of the tap 63*t*, the meter 106 deflects to right, for example, as also does the meter 81. These deflect at a fixed ratio until, when the yield point of the stock is reached, the elongation deflection of meter 106 increases faster than the tension deflection of the tension control meter 81, thus evidencing that the yield point of the stock has been reached. The total tension is observed, at this time, on the meter 81. The total elongation, after yield, is evidenced by the meter 103. The fact that the ratio of tension to elongation has changed is indicated by the meter 108, which deflects in one direction when tension is increasing faster than yield and in the opposite direction when elongation is increasing faster than tension.

At slightly above yield point, there is a pronounced

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unbalance between the voltage of the amplifier 82 and the battery 105, the result of which causes sufficient voltage to be impressed on the winding 80w to energize it sufficiently to cause it to open the contacts 89a, thus introducing the resistor 70 into the null tension control circuit and unbalancing that circuit so that the servomotor 32 is operated to open the relief valve 28 enough to greatly reduce the tension on the stock in accordance with the preselected adjustment of the resistor 70.

Knowing the tension for the yield point, indicated by the meter 81, the operator sets the tap 63t a preselected safe amount above or below the tension for yield; for example, from 90% of the yield tension to 110% of yield tension, after which the metal can be safely formed under the tension control hereinbefore described.

The yield and elongation measuring and control circuits are rendered inoperative by lifting the wheel 95 from the track so that the spring 96 restores the potentiometers 92 and 93 to their starting positions.

Overall control

It is desirable to control the operation from a central control panel, for this purpose the circuit shown in the lower left-hand portion of Fig. 5 is employed. This circuit includes a suitable starter 109 for a reversible motor M which drives the table 1.

An appropriate power source for all of the circuits herein described is indicated by the lines L1 and L2. Connected to the line L1 is an arm 110e of a four-position selector switch 110 having contacts 110a through 110d engageable selectively by the arm 110e. The contact 110a is an off position. When the arm 110e engages the contact 110b, a circuit is completed for a solenoid 86w. As indicated diagrammatically in the drawing, the solenoid 86w, when energized, releases a latch on the switch 86 and permits it to be operated into its reverse and forward positions from its neutral or normal position. At the same time, it opens a normally closed contact 86g which disconnects the motor 32 from the power positive control amplifier 61. Thus only when the switch 110 completes a circuit through the contact 110b can the motor 32 be operated manually.

A starting switch 111 is arranged to complete a circuit for a time delay relay 112 and a control relay 113 when contacts 114a of a relay 114 are closed. The relay 114 is energized to close its contacts 114a when the arm 110e is in engagement with the contacts 110c thereby to energize an operating winding 114w of the relay 114. The relay 112 has an operating winding 112w and normally open contacts 112a. The relay 113 has an operating winding 113w and normally closed contacts 113a.

Closure of the contacts 112a completes a circuit to the starter 109 and for the winding 115w of a time delay relay 115 having a normally open contact 115a in the potentiometer circuit 62. The contacts 113a are also in the potentiometer circuit 62. When the contacts 113a are closed, and the contacts 115a are open, the potentiometer circuit 62 is completed through a resistor 116, but when both the contacts 113a and 115a are closed, the resistor 116 is paralleled by a resistor 117. The resistor 117 has a larger resistance than the resistor 116.

In operation, moving the arm 110e into engagement with the contact 110c causes the relay 114 to close its contacts 114a. With the contacts 114a closed, closure of the switch 111 energizes the relays 112 and 113 concurrently. The relay 113 responds instantly to open its contacts 113a thereby inserting the resistor 117 into the potentiometer circuit 62 and excluding the resistor 116. Since the resistor 117 has a larger ohmic value than the resistor 116, the resistance of the potentiometer circuit between the tap 63t and the battery terminal 64p is increased. This increases the voltage drop across this portion of the circuit and immediately causes the motor 32 to operate in a direction to reduce the tension. This

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sudden reduction in tension relieves the stock S from a sudden jerk or shock when the table is started.

After a time delay of a fraction of a second, the contact 112a closes to operate the starter 109 to energize the table motor M and also to energize relay winding 115w which, a fraction of a second after the motor starter 109 has become operative to start the motor, causes closure of the contacts 115a and thereby removes the resistor 117 from the tension control circuit 62 and reinserts the resistor 116 with the result that the original full tension is re-established. Thus the tension is quickly applied at reduced value and then progressively increased to full value without any sudden jerking and danger of overstressing or snapping of the stock.

As the table continues to rotate, the full normal selected tension on the stock is maintained, the selection depending on the setting of the tap 63t, the value of the resistors 66 through 70 and 116, and the movement of the cyclic tension varying cams or means 73, 74, 77 and 78. In some instances, it is desirable to maintain a predetermined tension on the stock, during rotation of the table, higher than the tension maintained when the table is not rotating. For this purpose, a variable resistor 118 is connected in series with the resistors 66 through 69 and in parallel with the normally open contacts 119a of a relay 119 having a winding 119w. The winding 119w is connected to the starter 109 so as to be energized therethrough when the starter is operative to energize the motor M. The relay 119 may be a time delay relay which, when energized, is operative to close the contacts 119a shortly after the relay 115 has operated to close its contacts 115a.

Thus, when the table starts, the tension is below normal. The tension is promptly brought up to the tension the stock would have at standstill by the shunting out of the resistor 117 by the relay 115, and then, an instant later, is raised to that higher tension desired during table rotation by shunting out of the resistor 118 by the relay 119. The contacts 119a remain closed so long as the starter 109 maintains the table driving motor energized and open when the starter 109 becomes inoperative. Thus there is a preselected reduction in tension when the table is stopped.

At times, the length of the piece is such that the second piston and cylinder assemblage 15 must be brought into play as the distance between the die 2 and head 18 is shortened by more than the stroke permitted the piston 11. In the form illustrated, for compactness, the assemblage 15 is arranged with a cylinder 120 fixed to the machine frame with its rod end away from the table 1. A piston 121 having a rod 122 affixed to the carriage 14 is provided in the cylinder 120 for resisting movement of the carriage toward the table 1 when pressure fluid is introduced into the head end of the cylinder 120. Ordinarily, two such assemblages 15 are used, one at each side of the machine, but, for convenience, one only is shown. A sequence valve 124 is connected in the line 20 between the relief valve 28 and the rod end of the cylinder 10. A branch line 125 leads to the head end of the cylinder 120 from the sequence valve 124. The valve 124 normally blocks the passage of pressure fluid to the cylinder 120.

A line 126 leads to the rod end of the cylinder 120 and to the pressure side of the lower pressure pump 24. A manual valve 127 is provided in the line to admit pressure fluid to the cylinder 120 or close the line 126 from the pump and vent the cylinder 120 to the sump through a return line 128, respectively.

The valve 124 may be operated by a solenoid 130 controlled by a limit switch 131 mounted on the turntable 13 and closed by a lug 132 on the slide 17. The lug 132 closes the switch 131 when the piston rod 12 has about reached its most extended position. When closed, the switch 131 energizes the solenoid 130 to throw the selector valve to open position to unblock the line 125

and admit the controlled fluid pressure to the head end of the cylinder 120, which thereby also comes under control of the tension control.

Ordinarily, in the starting position of the machine, the piston rod 122 is generally in its extended position.

When the stock is formed, the table switch selector switch 111 is opened. The tension on the stock is maintained by the control. When ready to do so, the tension may be reduced by setting the tap 63t to a lower tension. However, so as not to have to change the setting of the potentiometer tap 63t, the servo-motor control switch 86 is rendered operative by connecting the arm 110e to contact 110b and is used for operating the servo-motor 32 to set the relief valve 28 to lower pressure, independently of the automatic control circuit. After the table stops, the gripping head 18 and clamp 19 are released in the conventional manner.

When the switch 111 is opened, the windings 112w, 113w and 115w are deenergized, opening contacts 112a to deenergize the motor starter 109, closing contacts 113a and opening contacts 115a thereby to reduce the resistance in the tension control circuit and thereby reduce the effective hydraulic pressure in the cylinders.

Operation

Starting with the table 1 stationary, the stock S is first installed by manual control of the head 18 and clamp 19. Next, the manual servo-motor control switch 86 is operated to tension the stock just beyond the tension required to eliminate slack.

Arm 110e is then set on contact 110d which energizes the winding 100w of solenoid 100 for applying wheel 95 to track 90, and causes relay 114 to open contact 114a, so that table 1 cannot be driven. The yield meter 103 and elongation-above-yield meter 108 are observed and each is brought to zero position.

Next, the tension is increased gradually until the elongation-above-yield meter 108 deflects to right showing that yield elongation is increasing faster than tension, as indicated by meter 81.

Thereupon, voltage relay 80 operates to open its contacts 80a reducing the tension on the stock by introducing the resistor 70 which had been adjusted in advance.

Next, the potentiometer tap 63t is operated to adjust for the tension desired. Next, set selector arm 110e is placed on the contact 110c. This opens the circuit at 110d and causes the solenoid 100 to release the wheel 95 from track 90 so that the relay 80 closes contact 80a to re-establish standard signal in the tension control circuit. Also it causes the solenoid 114 to close contacts 114a so that the circuit of Fig. 5 is again ready for starting.

The table 1 is then started by closing selector switch 111. Thereupon relays 112 and 113 are energized at once, and 113 opens contacts 113a to increase the resistance in the circuit 62 and thereby to reduce tension on the stock S so as to prevent a sudden full load tension and resultant work hardening of the stock. Relay 112 then operates to close contacts 112a to energize the table starter motor 109 and energize the time delay relay 115 which, a fraction of a second later, closes contacts 115a to restore the resistor 116, instead of the resistor 117, in the circuit, thus restoring standard tension. Energization of the starter 109 energizes the winding 119w of the time delay relay 119, causing it to close the contacts 119a and shunt the resistor 118 out of the circuit 62, thus increasing the tension to a predetermined value higher than standstill value, except insofar as it may be varied cyclically by the resistors 66 through 69. If no such increase is desired, the resistor 118 may be set at zero resistance.

When the table 1 has rotated enough to extend fully the piston rod 12, a lug 132 on the slide 17 closes the limit switch 131 and thereby causes operation of the

sequence valve 124 so that the assemblage 15 is connected to line 20 by way of the line 125 and valve 124 and the assemblage 15 then operates under control of the tension control circuit.

The table is stopped by opening switch 111, and the control maintains the hydraulic pressure so that tension remains fixed.

The tension is reduced by adjusting the potentiometer tap 63t, or by the manual control of the servo-motor by the switch 86.

The cams 73 through 78 having been selected and adjusted beforehand, the tension will increase and decrease, as preselected, as the forming cycle proceeds.

Thus, by means of a control mechanism combining a simple load cell and strain gauges with a servo-motor which controls a relief valve in the pressure fluid supply line, control of the stress and strain on the stock can be maintained at preselected values throughout the forming operation.

The yield point of the stock and its elongation above yield can readily be determined from essentially the same control mechanism by addition thereto of a potentiometer driven by a wheel which translates the lineal elongation of the stock into a voltage vector reflecting elongation which is then opposed to and balanced with a voltage vector reflecting applied tension, so that the over-balanced or voltage differential reflects the elongation above yield.

In some instances it is desirable to use combined wipe forming and stretch forming. However, the frictional drag and binding of the wipe shoe on the stock also imposes a tension on the stock in the same direction as that imposed by the head 18.

The total pressure applied by the wipe forming shoe may be regulated by supplying preselected pressure to the head end of the cylinder 5 from a pump 133 through an adjustable relief valve 134, a four-way valve 135 being provided for venting the head end of the cylinder 5 and applying the pressure fluid to the rod end for retracting the shoe 3.

Instead of varying the pressure applied by the wipe shoe by the automatic tension control, the applied pressure of the wipe shoe is controlled by manual adjustment of the relief valve 134 and the resulting tension applied to the stock by the wipe shoe is compensated for by changing the hydraulic pressure to the piston 11 of the stretch forming piston and cylinder assemblage.

This is accomplished in the following manner.

A load cell 136 is provided and is in the form of an I-beam with rigid end plates 137 and 138, respectively, permanently bonded thereto at the opposite ends, respectively, of the I-beam. The plate 138 is connected to a pedestal 139 of the wipe forming assemblage for movement vertically thereof and in fixed position in the direction of wiping. The pedestal is carried on a slide 140 and is connected to the piston rod 4 for movement therewith axially of the cylinder 5. The wiping shoe 3 is rockably mounted on a support 141 which is connected in fixed adjusted position on the plate 137.

Preferably the shoe 3 and support 141 have complementary cylindrical or spherical surface of which the center of curvature 143 is disposed near the wiping face 144 of the shoe 3, preferably forwardly thereof.

The load cell 136 is disposed with its web 145 horizontal and extending endwise in the direction of thrust of the piston rod 4.

Assuming the rotation of the table 1 is as indicated by the arrow 146 in Figs. 6 and 7, the friction of the shoe 3 on the stock tends to pull the shoe 3 to the left and bend or flex the load cell 136 about its left hand flange 147 and thus elongate the right hand flange 148.

To obtain the maximum elongation of the flange 148 for a given lateral thrust on the shoe 3 to the left in Fig. 7, the flange 147 is positioned to take as directly as possible the thrust of the shoe 3 against the die by

the rod 4. For this purpose, the shoe is positioned in the plate 137 so that its center of direct thrust, which is through or close to the center 143, is aligned endwise of the I-beam 136 with the flange 147.

Thus the flange 148 is relieved of much of the direct thrust but is fully responsive to thrusts on the shoe laterally of the shoe 3 and load cell 136. Vertical force components do not apply because the cell can float vertically.

If the direction of table rotation, indicated by arrow 146 is reversed, the shoe 3 must be disposed with the center point 143 in alignment with the flange 148. If the shoe face is symmetrical, this can be done by disconnecting the plate 138 from the pedestal 139 and rotate it 180° about the axis of the piston rod 4, and replacing it in the rotated position.

On the outer face of the web 148, balanced across the vertical neutral axis, are pairs of strain gauge patches 150 and 151. The gauges 150 are connected in a bridge 150b with two dummy gauges 150d, and the gauges 151 are connected in a bridge 151b with two dummy gauges 151d, and each bridge is connected to the input side of an associated amplifier 152 and 153, respectively. The output side of amplifier 152 may be connected in the tension control circuit in series with the amplifier 60 by means of a switch 154. The amplifier 152 is adjustable for equivalence with the amplifier 60. In one of its positions, the switch 154 completes the control circuit without the amplifier 152.

The amplifier 153 is connected to a voltmeter 155 which is adjusted to equivalency of operation, for a given signal intensity, with the meter 81.

Thus, as the drag on the shoe 3, due to rotation of the table to the left in Fig. 7, increases, a corresponding elastic elongation of flange 148 occurs. This is reflected electrically as voltage changes by the gauges 150 and 151, and this voltage is amplified by amplifiers 152 and 153.

When the output of the amplifier 152 is connected in the control circuit, its signal and that of the amplifier 60 are additive. Thus the servo-motor is responsive to the 40 nor the load cell 136 produces a signal voltage less than zero.

For example, if the tensioning on the stock due to the shoe 3 is rising, the resultant tension signal is added to that of the load cell 40 in the circuit and the relief valve 28 is operated to increase the venting sufficiently so that the hydraulic and friction pull by the stretch forming assemblage plus that of the wipe shoe equal the total tension desired.

Reversely, should the pull of the shoe 3 decrease, compensation would be made by increasing the pull exerted by the stretch forming assemblage.

In some instances, dies are so shaped that the side face at some locations no longer moves predominantly tangentially of the shoe face but intersects the shoe face at an abrupt angle. Thus a force is imposed on the shoe as a direct thrust, urging it in a direction transversely of its path of reciprocation. This force can become so great as to cause a locking angle as fully set forth in Maize Patent No. 2,342,745.

In such instances, it becomes readily apparent to the operator, from the meter 155 and from the angle between the face of the die and shoe, that the table should be stopped temporarily while the face is nearly tangential to the shoe 3, and the shoe reciprocated along the die to a location at which the tangential relation will be restored upon rotation of the table.

For this purpose, the wipe forming assemblage is mounted on a carriage 160 which is reciprocable by suitable power means, not shown, along a guide track 161, and can be stopped and secured in any position along the track.

If it is desired to apply the shoe in the stretching direction, return it out of contact with the stock and re-

peat the operation a number of times, such may be done as the tension is maintained by the stretch forming assemblage while the shoe is inoperative and compensates for the pull by the shoe when the shoe is operative.

In the illustrative example, the control of the stretching of the metal, whether the stretching force is due to the direct pull of the stretch forming assemblage or to the direct pull of stretch forming assemblage plus the frictional pull of the wipe forming assemblage, is by varying the pressure of the fluid supplied to the stretch forming assembly.

In any instance in which it is desired to form stock only by wipe forming so that only the stretching force is due to the frictional pull or drag of the wipe forming shoe, the stretch forming assemblage may be used for wipe forming. In such case, the pipe 20 is connected to the head end of the cylinder 10 and the pipe 21 to the front end; the wipe shoe 3 and its load cell 136 are substituted for the stretch head 18 and its cell 40; the turntable 13 is locked against rotation, as disclosed in United States Patent No. 2,514,831, issued July 11, 1950; and the bridges 150 and 151 are connected in the control circuit in substitution for the bridges 58 and 59.

A like result can be obtained by disconnecting existing pressure fluid circuit of the wipe forming cylinder 5 from the cylinder 5, then connecting the pipe 20 to the head end of the cylinder 5 and substituting in the control circuit, the bridges 150 and 151 for the bridges 58 and 59.

Thus, whether the stretch forming assemblage is used alone for tensioning the stock solely by a direct pull thereon, or the wipe forming assemblage is used alone and stretches the stock due to frictional forces, or the two are used together, or the stretch forming assemblage is reconnected and thereby stretches the stock by frictional stretching forces, the tensioning of the stock is controlled by the present invention.

Thus the tension applying assemblage and the wipe assemblage are coordinated for use together.

Since the tension is initially applied at low value and then increased to that desired, by introducing a preselected false control signal upon starting the table, the stock is not subjected to sudden shocks which work harden it almost instantly and before its normal sustaining forming stress is supplied.

All of these operations are controlled by use of voltage vectors which are translated into valve settings in the hydraulic circuit and are evidenced by voltmeter or pen-motor readings.

As a result of this structure, full information as to the stress of each work piece at all points along its length are ascertainable and the duplication of any piece formed of which the stress record has been made, can easily be duplicated.

Having thus described my invention, I claim:

1. In a metal forming machine for forming a length of metal stock against a curved face die progressively unidirectionally from one part of the curved face to another part while the stock is held under tension endwise, at least adjacent the instantaneous line of tangency of the stock and curved face, and including a die having a curved face, tool means operatively connected to the stock and adapted to apply endwise tension to the stock, fluid pressure operated piston and cylinder assemblage means connected to the tool means for tensioning the stock through the medium of the tool means in relation to the pressure of working fluid supplied to the assemblage means, means supporting the die and assemblage means for relative movement for progressively unidirectionally applying the stock against said curved face of the die, power driven means to effect said relative movement, a fluid circuit for supplying pressure fluid to the assemblage means, and settable valve means in the fluid circuit settable in different operating positions for controlling the pressure of the operating fluid supplied to the assemblage means; load cell means operatively interposed be-

tween the assemblage means and tool means so as to be strained substantially only by the tensioning forces applied by the tool means to the stock, reversible electric motor means operable when energized for setting said valve means in said different operating positions, strain gauge means operable, when in an energized signal circuit, to produce changes in electrical signals in the circuit in response to certain changes in the condition of the strain gauge means, electric circuit means including a circuit connecting the motor means and strain gauge means for operation of the motor means in response to changes in the electric signals produced in the electric circuit means by the strain gauge means, and said strain gauge means being connected to the load cell means so that said changes in the condition of the strain gauge means are produced in relation to changes in the strain of the load cell means.

2. The structure according to claim 1 characterized in that said settable valve is a relief valve means which is connected in the fluid circuit means supplying pressure fluid to the assemblage means and is otherwise unconnected with the assemblage means.

3. The structure according to claim 1 characterized in that the assemblage means is a stretch forming piston and cylinder assemblage, the tool means is a stock gripping head adapted to grip one end of the stock and apply tension thereto at said gripped end so as to tension the stock endwise from said gripped end at least to said instantaneous line of tangency of the stock and die face, said relative movement is one in which the stretch forming assemblage is moved bodily, generally transversely of its axis, and said load cell means is connected between the head and stretch forming assemblage so as to elongate and contract in relation to the tension applied to the stock.

4. The structure according to claim 1 characterized in that assemblage means comprises a stretch forming piston and cylinder assemblage and a wipe forming piston and cylinder assemblage, the tool means comprise a stock gripping head on the stretch forming assemblage and adapted to grip one end of the stock and apply tension thereto endwise of the stock at the gripped end so as to tension the stock endwise from said gripped end at least to said instantaneous line of tangency, and also a wipe forming shoe on the wipe forming assemblage, the load cell means comprise a load cell interposed between the stretch forming assemblage and stock gripping head and a load cell between the wipe forming assemblage and the wipe shoe, and the strain gauge means comprises strain gauges on the cells, respectively, and connected in said circuit means so that the signal of the wipe forming strain gauge is subtracted from the signal of the stretch forming strain gauge, the motor means is operated in response to the difference in the signals, said relative movement is one in which the stretch forming assemblage is moved bodily, generally transversely of its axis, and said load cell means is connected between the head and stretch forming assemblage so as to elongate and contract in relation to the tension applied to the stock.

5. The structure according to claim 1 characterized in that said circuit includes auxiliary means for causing preselected signals therein for causing operations of the motor means other than in response to changes in signals caused by the strain gauge means.

6. The structure according to claim 1 characterized in that said electric circuit is a direct current null balance circuit, and the motor is a direct current motor which is energized when the circuit is unbalanced and is reversible by reversal of polarity of the unbalanced circuit.

7. The structure according to claim 6 characterized in that said circuit is adjustable for balance at different preselected setting of the settable valve means, and selective means are provided for causing in said circuit preselected signals related to the operating positions of preselected elements of the machine.

8. The structure according to claim 7 characterized in 75

that said selective means are operated by movable means mechanically driven by a moving element of the machine.

9. The structure according to claim 5 characterized in that the electric circuit includes control means to start and stop the power driven means, and the auxiliary means is adapted to supply a signal for reducing the fluid pressure in the assemblage means below the maximum to be called for by the signal of the strain gauge means before the control means becomes operable to start the power driven means, and to remove the signal in a short delayed timed relation to the starting of the power driven means.

10. In a metal forming machine for forming a length of metal stock against a curved face die progressively from one part of the curved face to another part while the stock is held under tension endwise, at least adjacent the instantaneous line of tangency of the stock and curved face, including a die having a curved face, a gripping head adapted to be connected to the stock to apply endwise tension to the stock, a fluid pressure operated stretch forming piston and cylinder assemblage connected to the head for tensioning the stock through the medium of the head in relation to the pressure of the working fluid supplied to the assemblage, a wipe forming piston and cylinder assemblage, a wipe forming shoe thereon, fluid circuit means for supplying pressure fluid to the assemblages, settable valve means in the circuit settable in different operating positions for controlling the pressure of the operating fluid supplied to the stretch forming assemblage, load cells operatively interposed between the stretch forming assemblage and gripping head and between the wipe forming assemblage and wiping shoe, respectively, so as to be strained substantially only by the tension forces effective on the head and wipe shoe, respectively, reversible power operated means operable for setting said valve means in said different operating positions, variable power supply means connected to the power operated means for rendering the power operated means operable in accordance with changes in the power supplied, means to render the power supply means operative to change the power supplied in response to changes in certain signals supplied to the power supply means, signal means to supply said signals, strain sensing means operable to produce signals which modify said last mentioned signals in response to changes in the condition of the strain sensing means, said strain sensing means being connected to the load cells, respectively, so that said changes in the condition of the strain sensing means are produced in relation to changes in the strain of the load cells, respectively, said strain sensing means being operatively connected to the signal means so that the modifying signals which they are supplying are the signals of the strain sensing means of one of the forming means minus the signals of the strain means of the other one of the forming means, means supporting said assemblages for movement relative to the die for progressively, unidirectionally applying the stock against the die face, power driven means to effect said relative movement, and said load cell of the stretch forming assemblage being connected between the stretch forming assemblage and head so as to elongate and contract in relation to the tension applied to the stock by the stretch forming assemblage.

References Cited in the file of this patent

UNITED STATES PATENTS

65	2,426,830	DeForest	Aug. 26, 1947
	2,445,682	MacGeorge	July 20, 1948
	2,477,854	Baker	Aug. 2, 1949
	2,514,830	Bath	July 11, 1950
	2,612,774	Zener	Oct. 7, 1952
70	2,675,701	Bidwell	Apr. 20, 1954
	2,676,638	Wheeler	Apr. 27, 1954
	2,756,590	Clifford	July 31, 1956

FOREIGN PATENTS

581,095	Great Britain	Oct. 1, 1946
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,849,048

August 26, 1958

Richard L. Curtner

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 11, line 23, before "for" insert -- and --; column 15, line 41, after "responsive to the" insert -- sum of the two output voltages. Neither the load cell --; column 18, line 65, list of references cited, for the patent number "2,426,830" read -- 2,426,390 --.

Signed and sealed this 13th day of January 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents