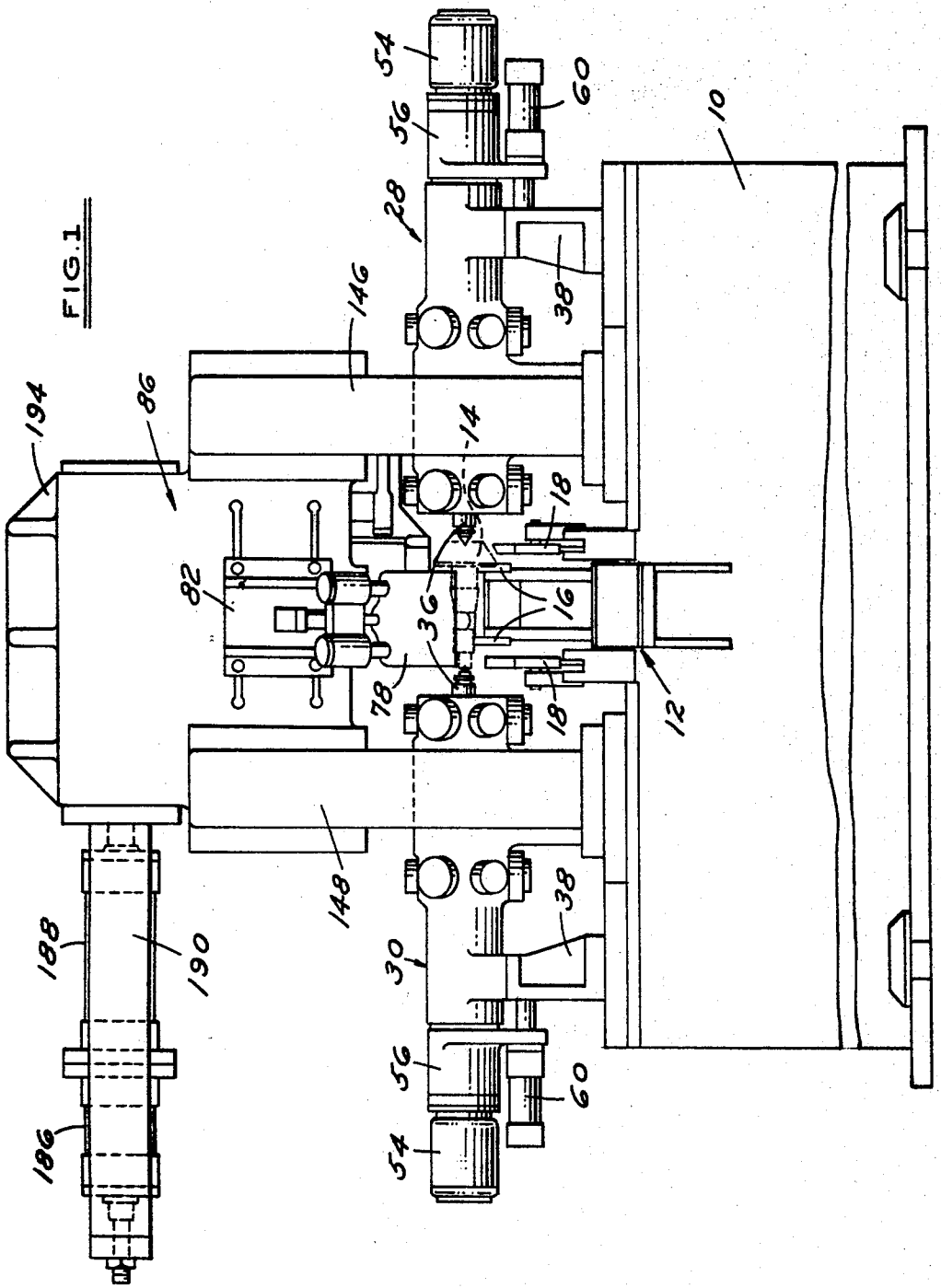
Oct. 28, 1969 D. L. JUDGE ET AL 3,474,650

STRAIGHTENING MACHINE

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FIG. 1



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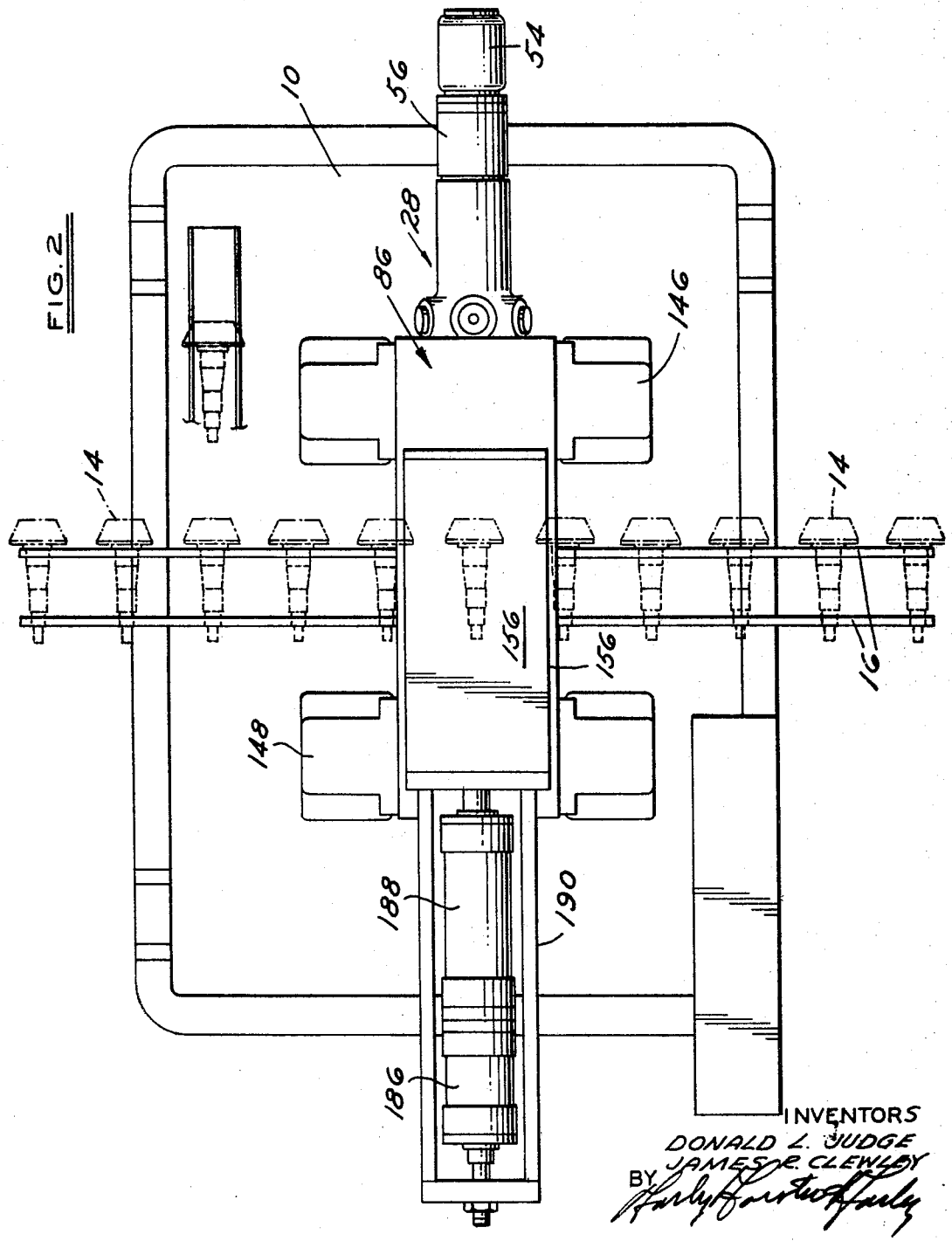
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STRAIGHTENING MACHINE

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FIG. 2



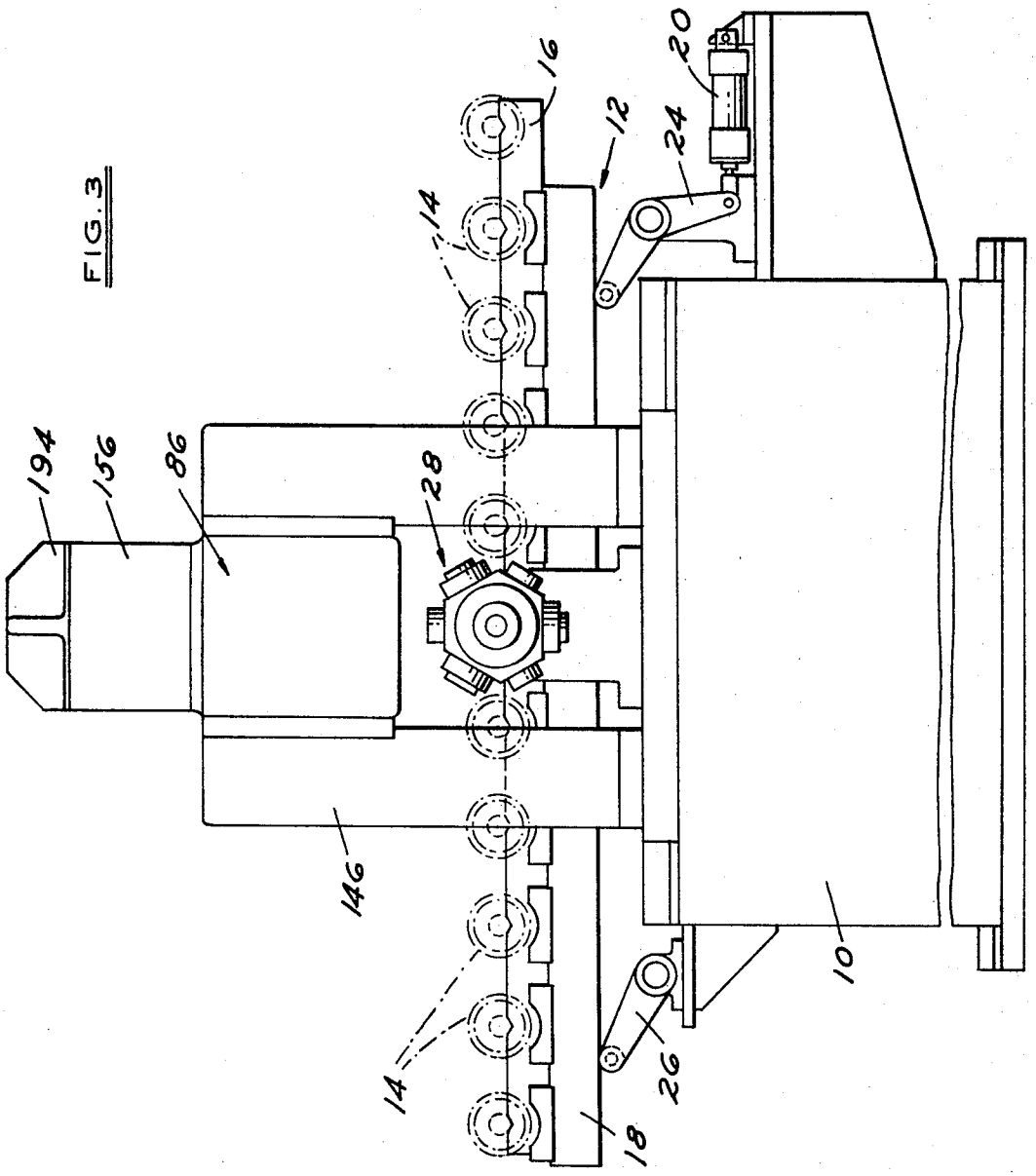
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Oct. 28, 1969 D. L. JUDGE ET AL 3,474,650

STRAIGHTENING MACHINE

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FIG. 3



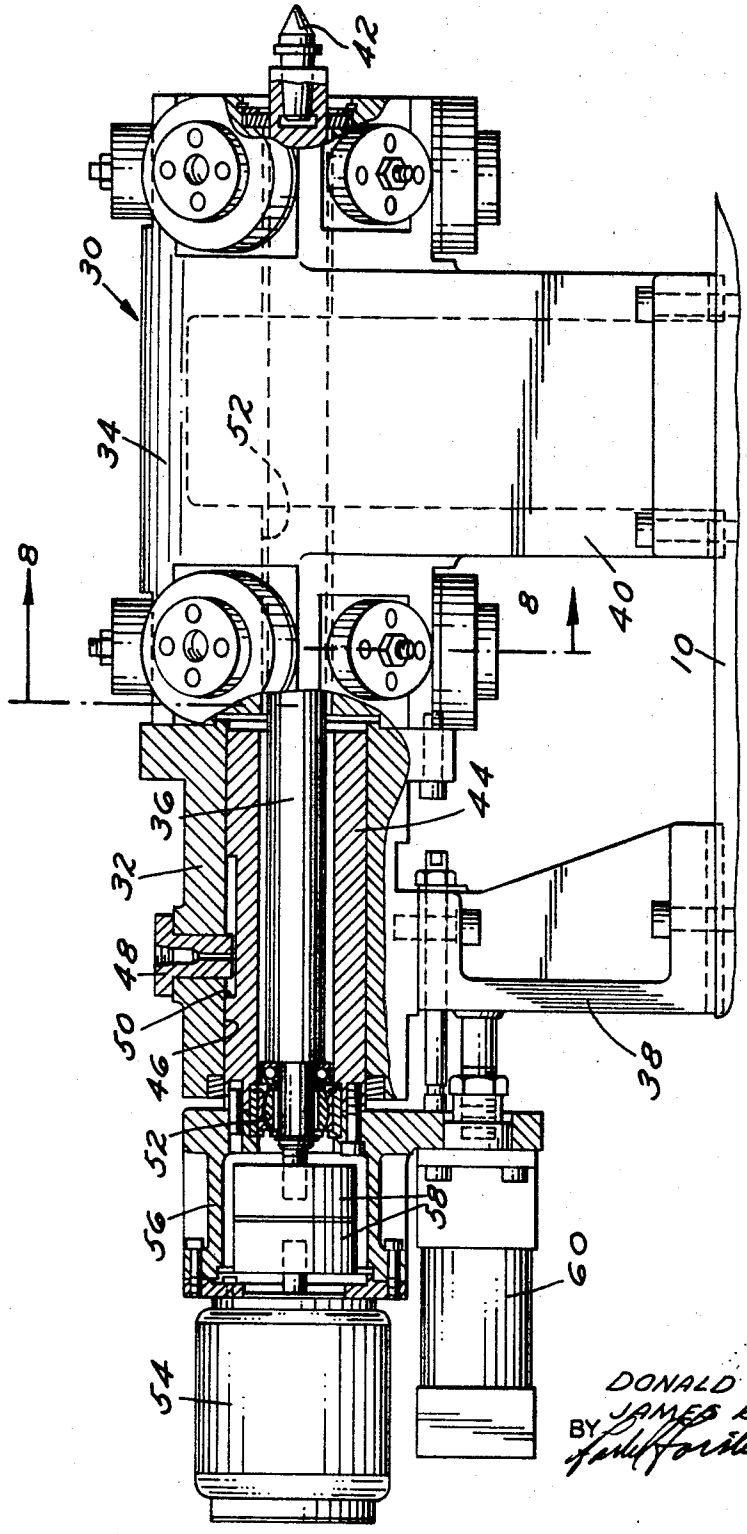
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STRAIGHTENING MACHINE

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FIG. 4



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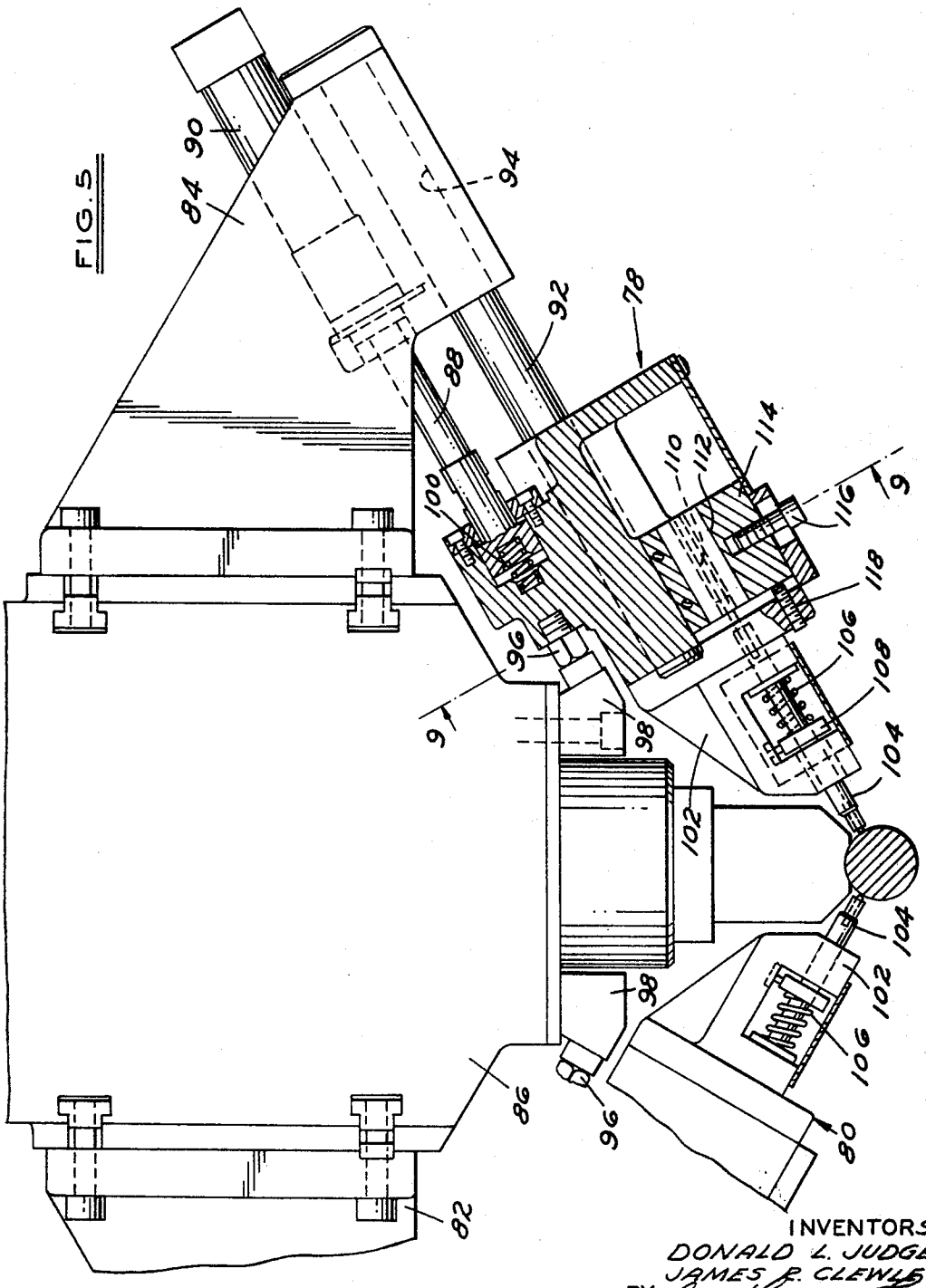
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STRAIGHTENING MACHINE

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FIG. 5



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STRAIGHTENING MACHINE

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FIG. 6

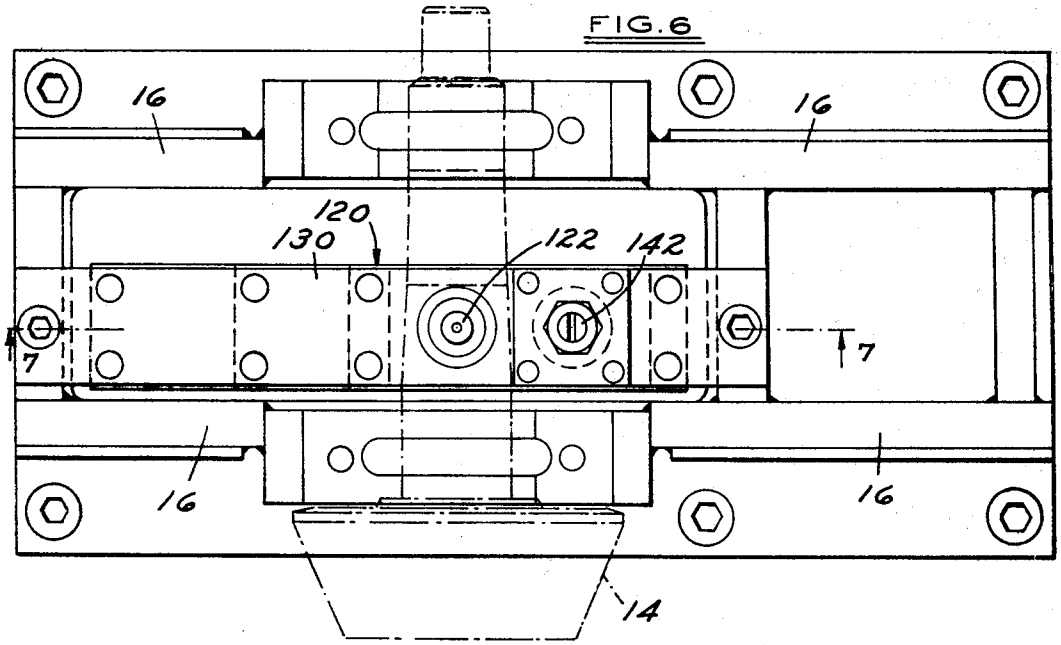
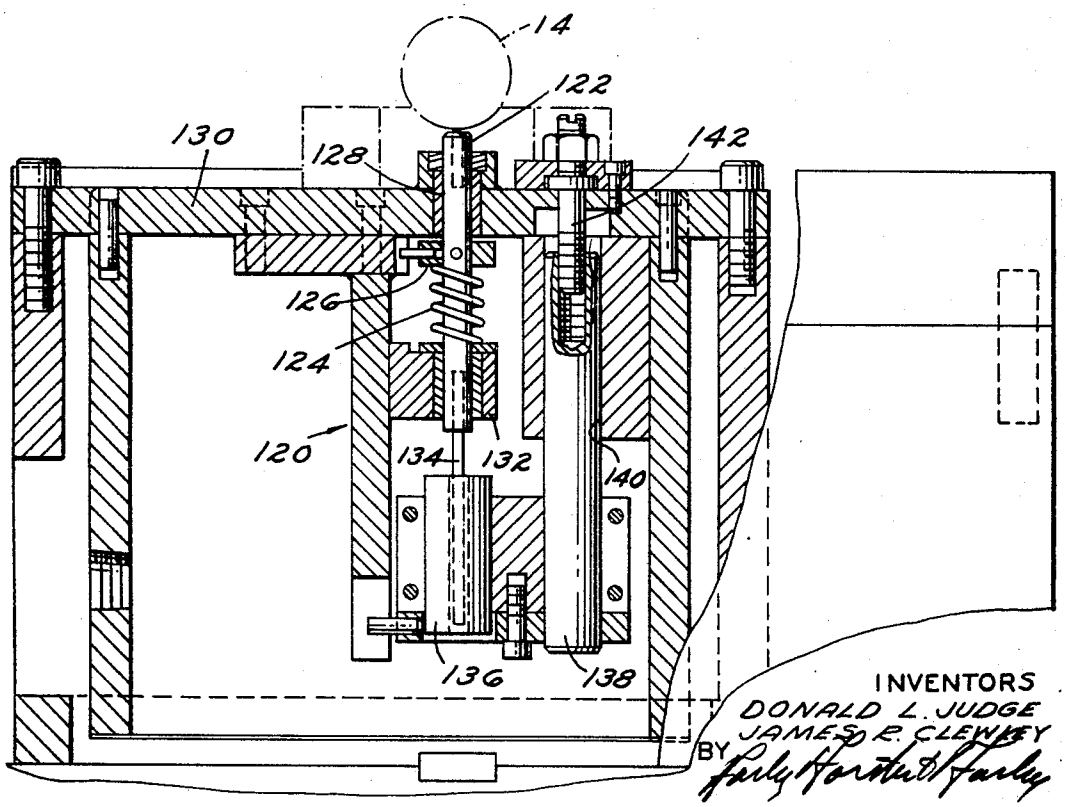


FIG. 7



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STRAIGHTENING MACHINE

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FIG. 8

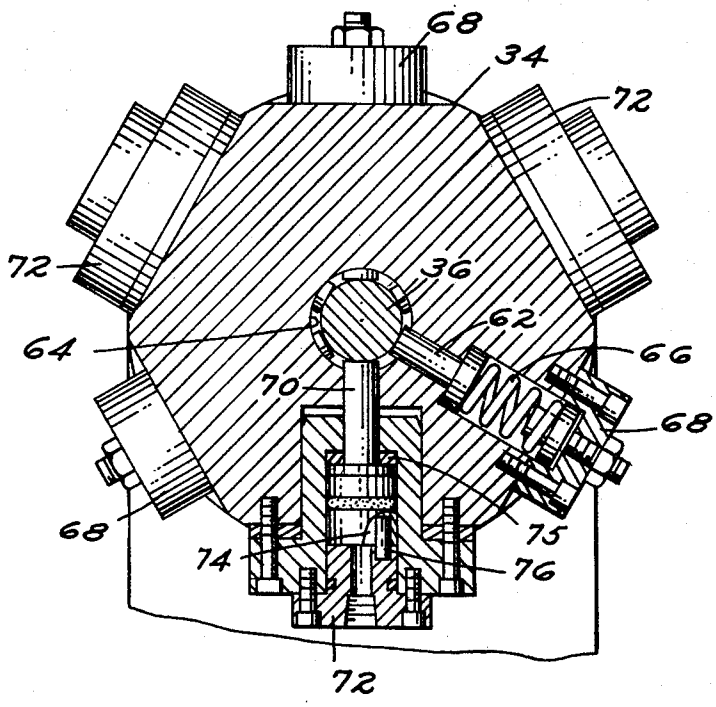
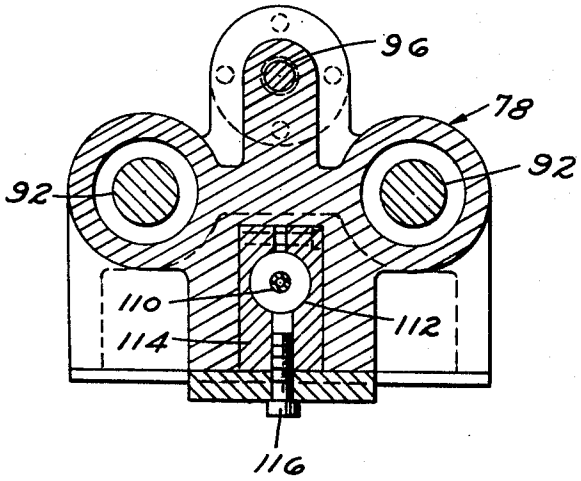


FIG. 9



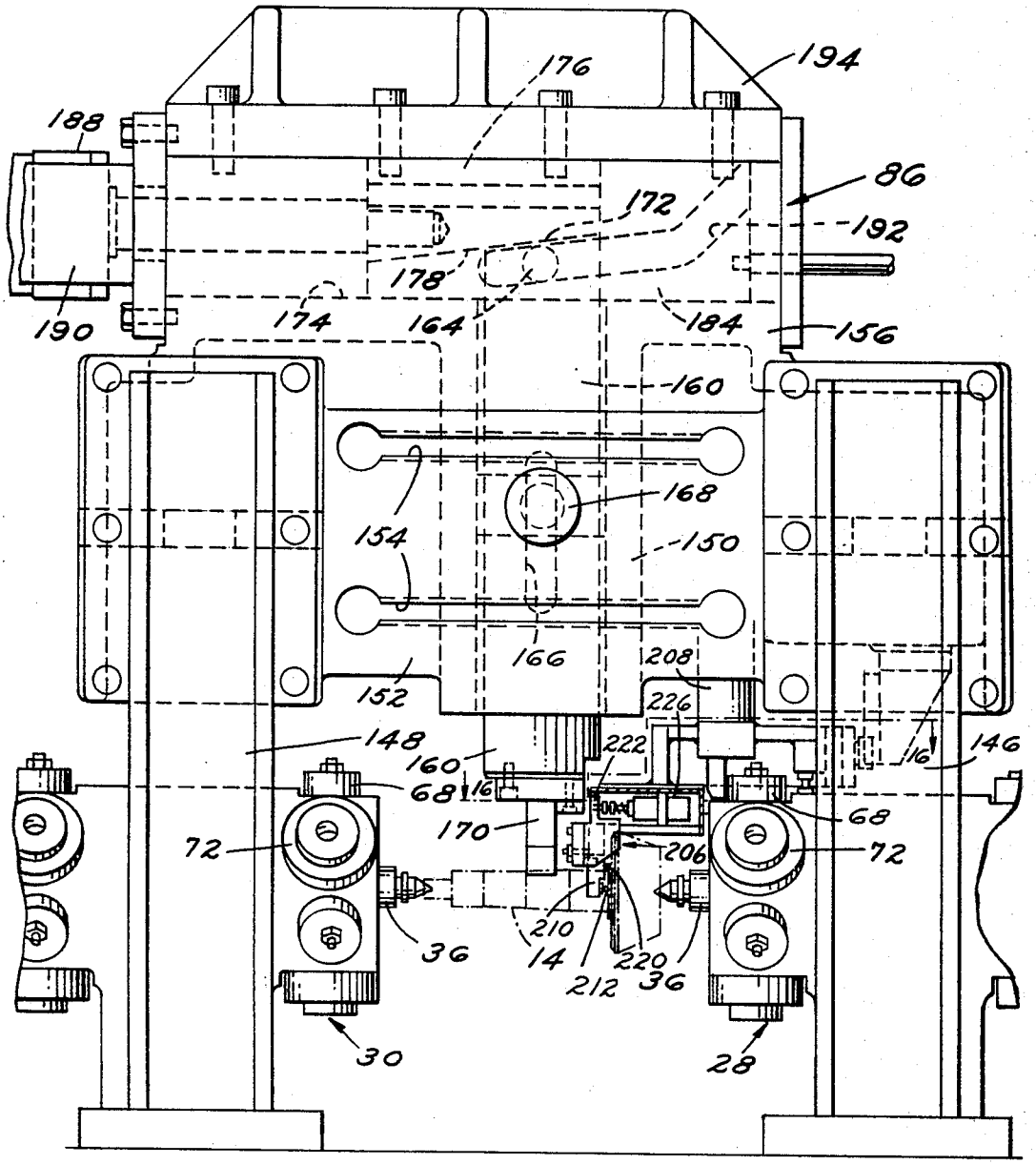
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STRAIGHTENING MACHINE

Filed May 19, 1967 18 Sheets-Sheet 8

FIG. 10



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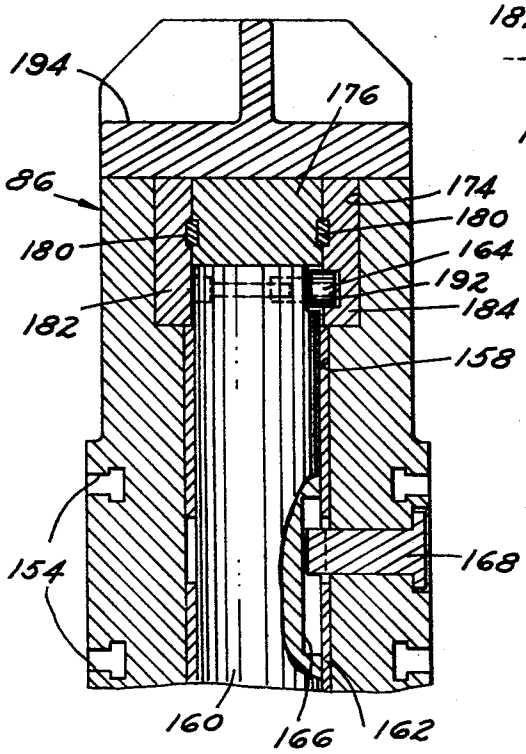
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STRAIGHTENING MACHINE

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FIG. 12



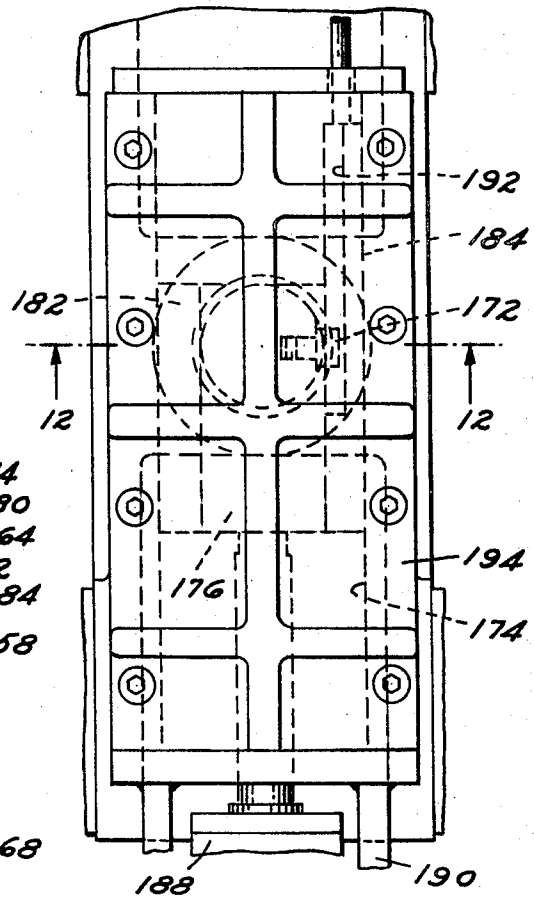
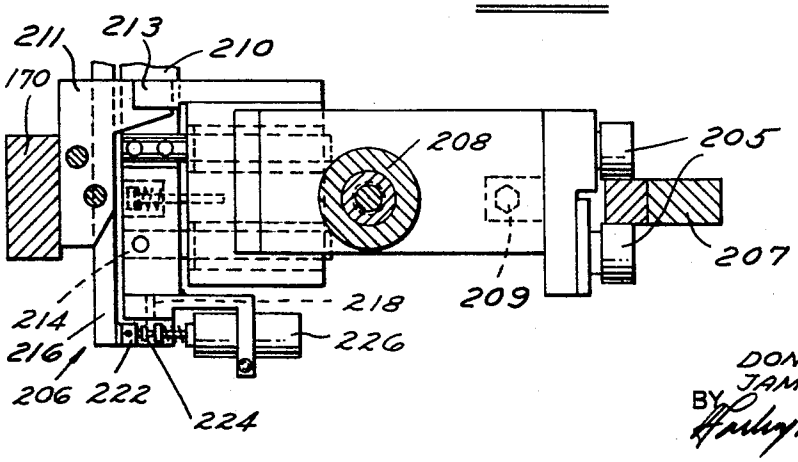


FIG. 11

FIG. 16



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STRAIGHTENING MACHINE

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FIG.13

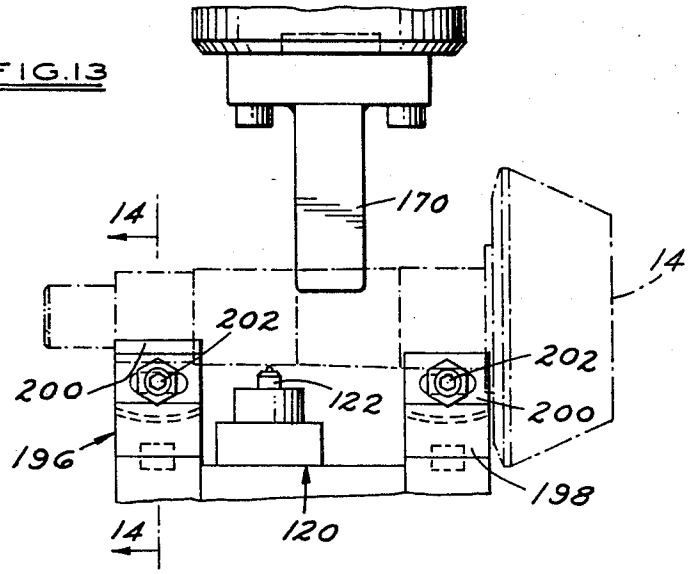


FIG.15

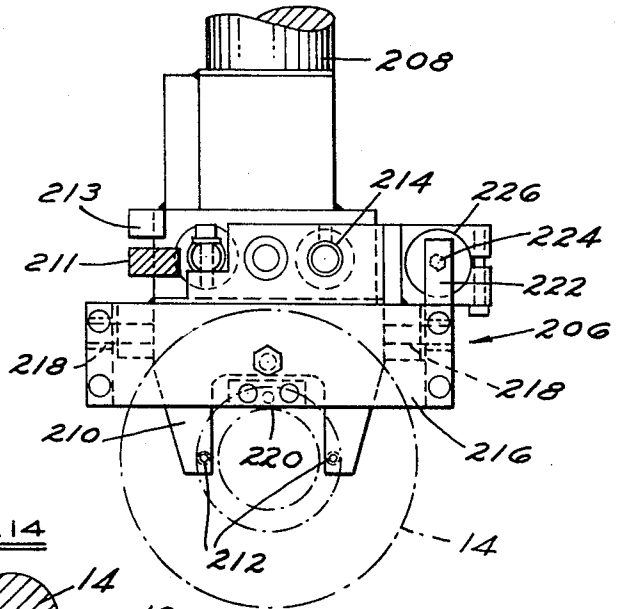
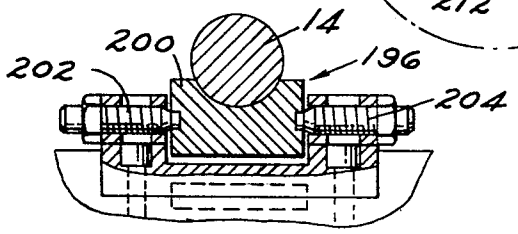


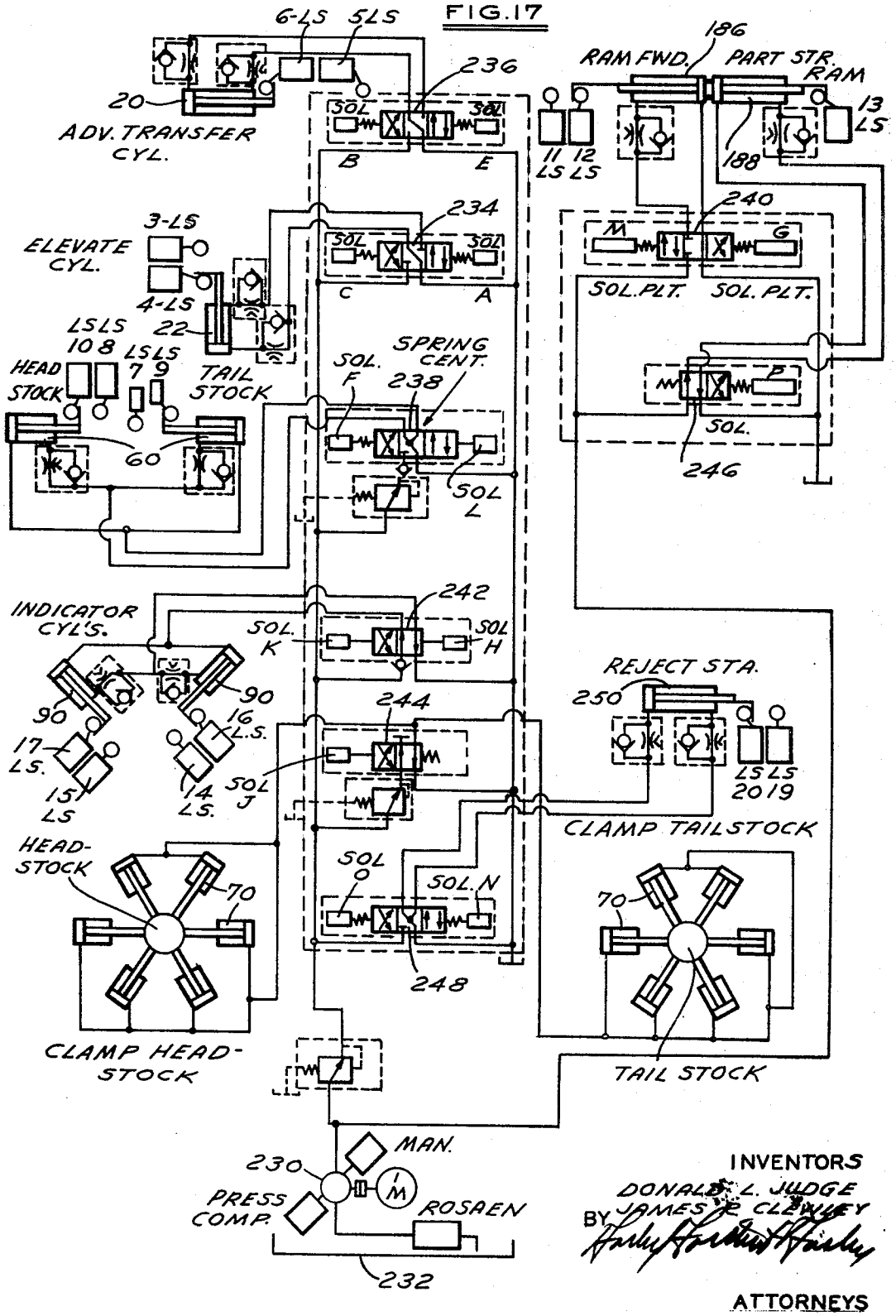
FIG.14



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FIG. 17



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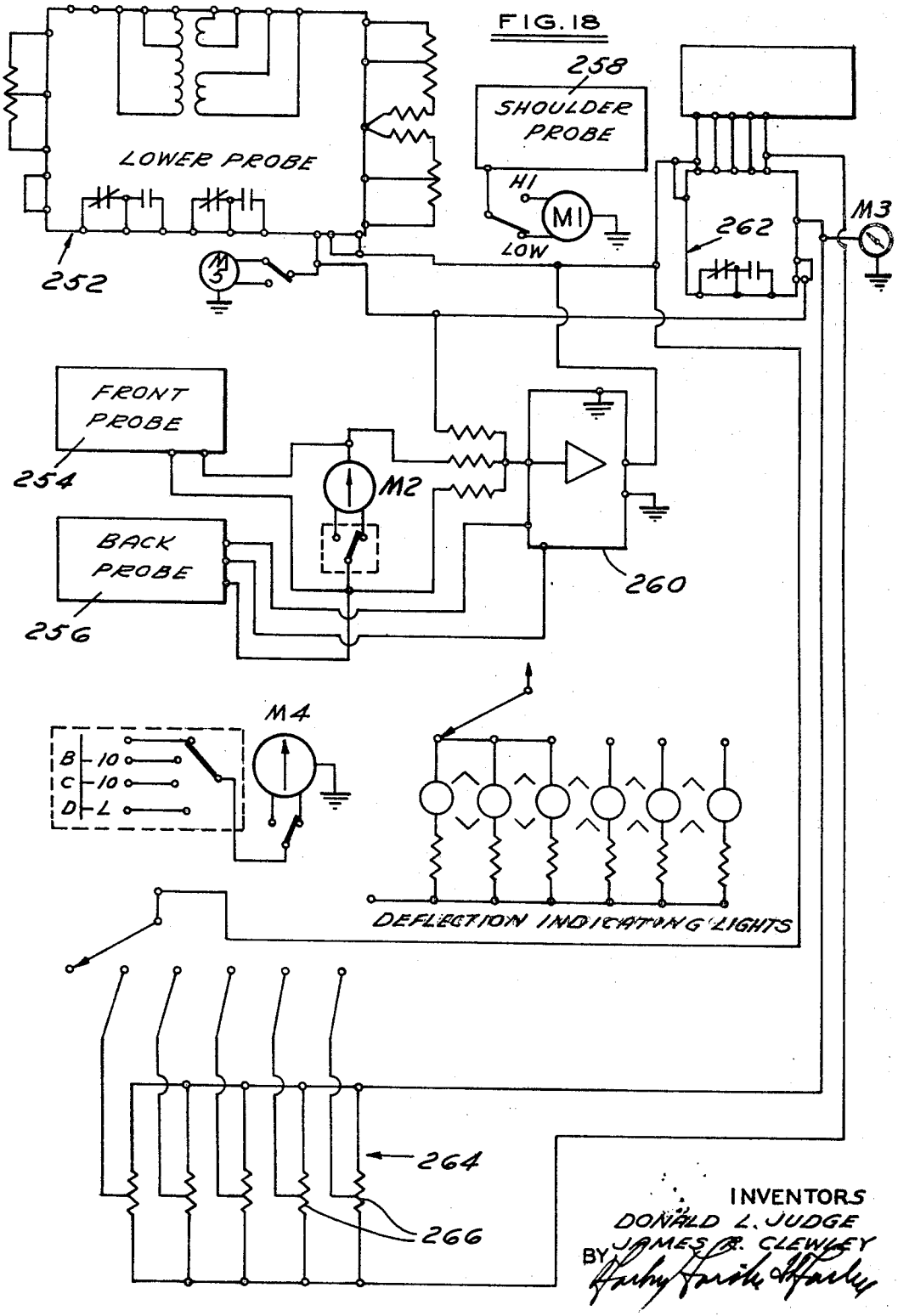
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STRAIGHTENING MACHINE

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FIG. 18



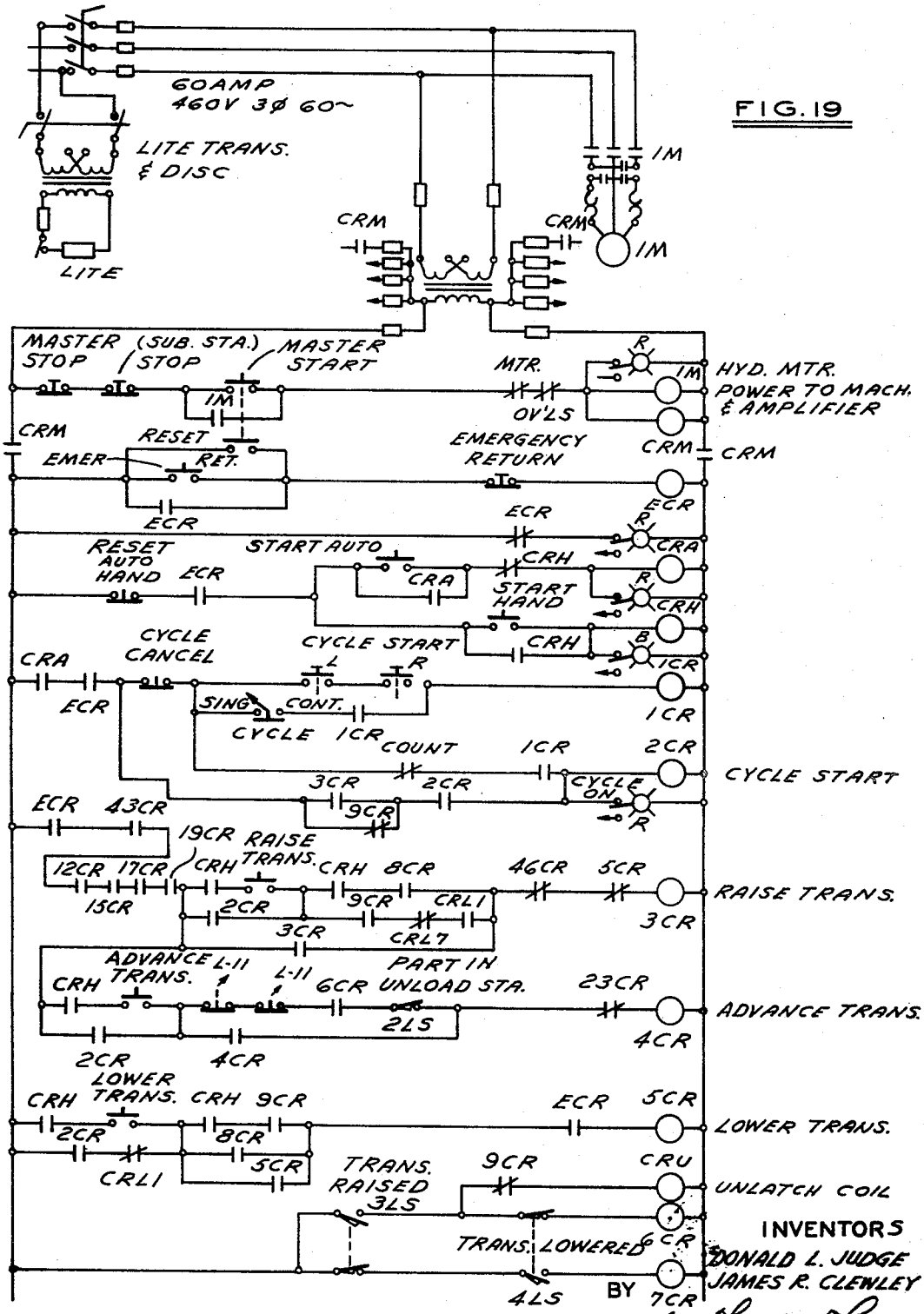
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STRAIGHTENING MACHINE

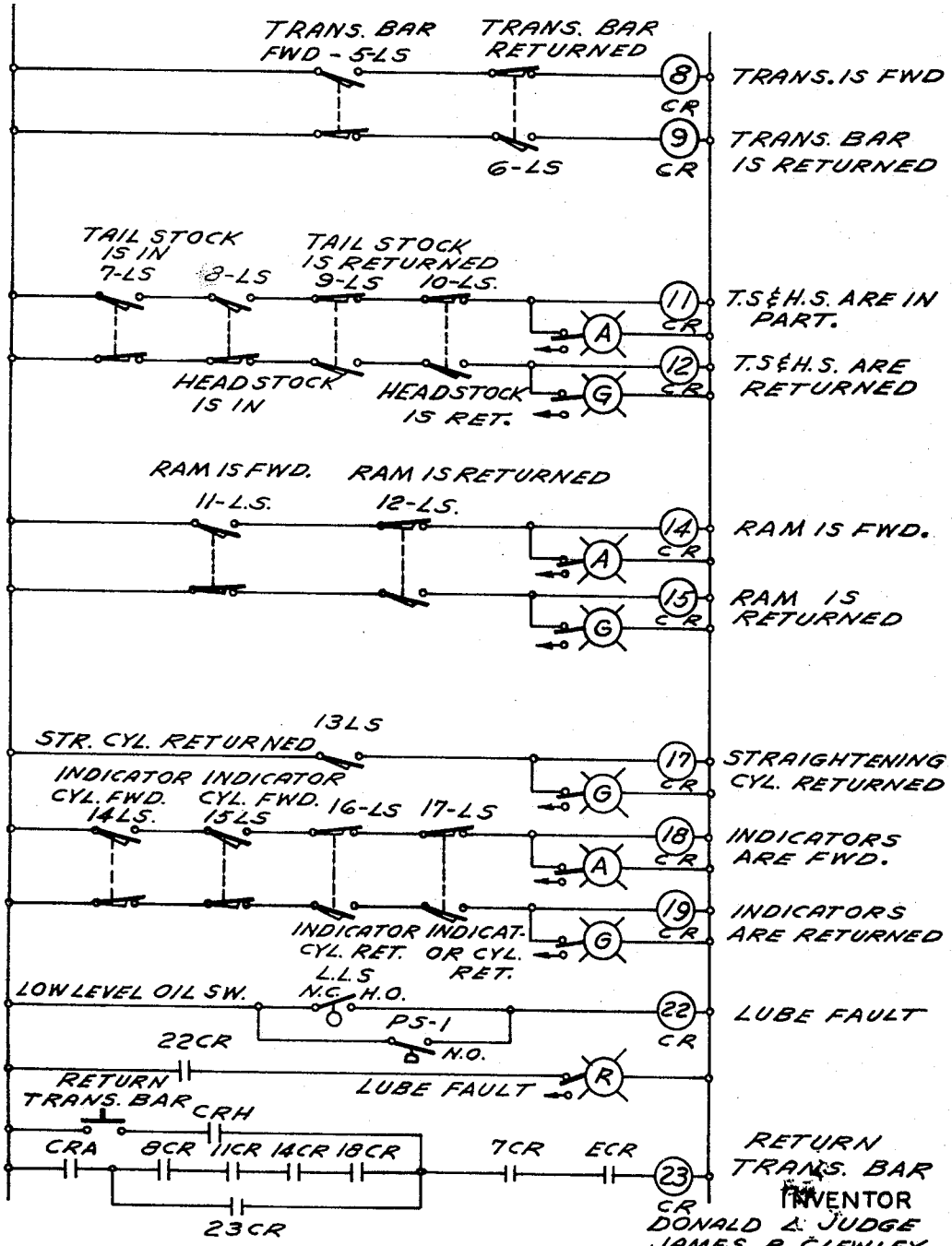
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FIG. 19



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FIG. 20



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STRAIGHTENING MACHINE

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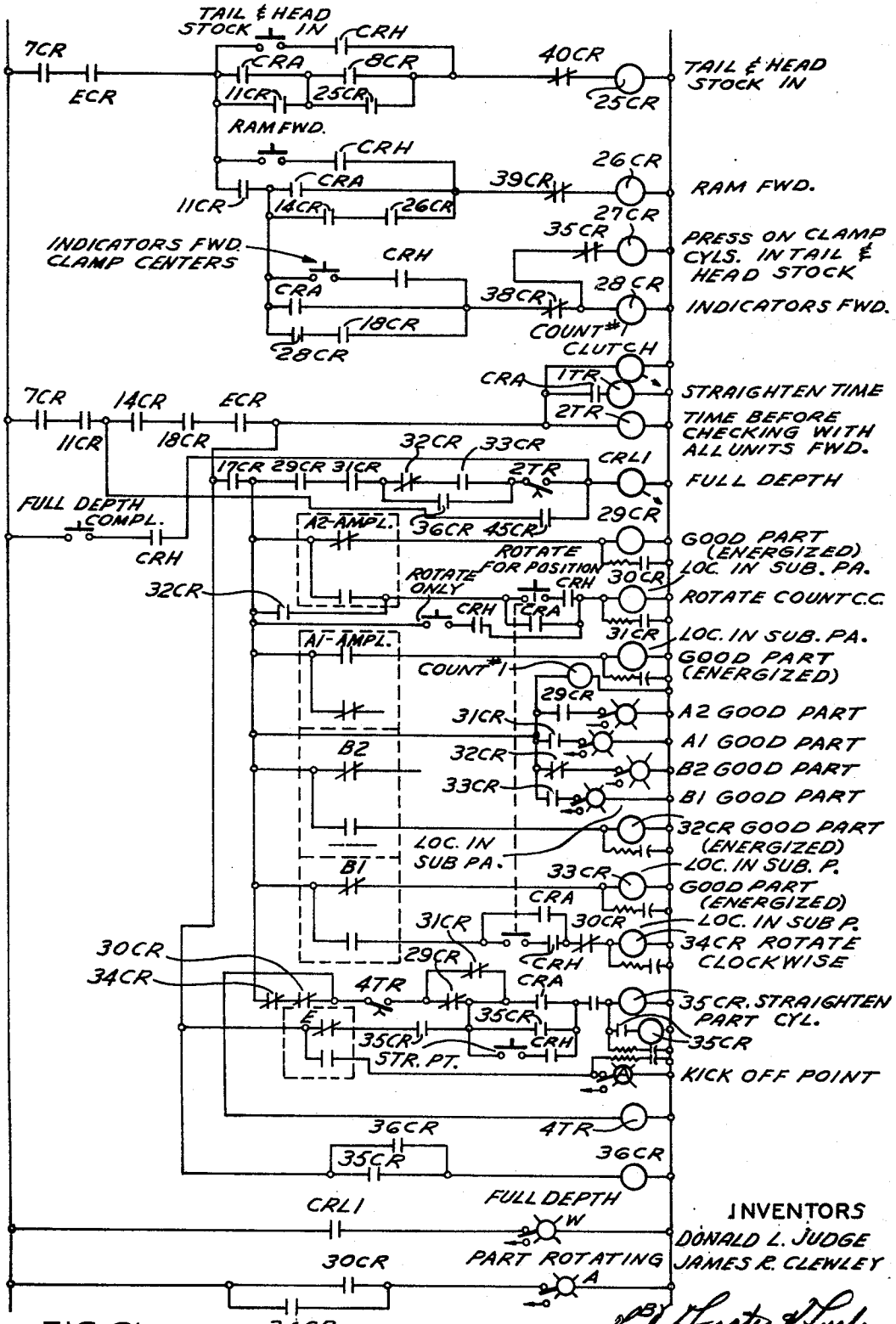
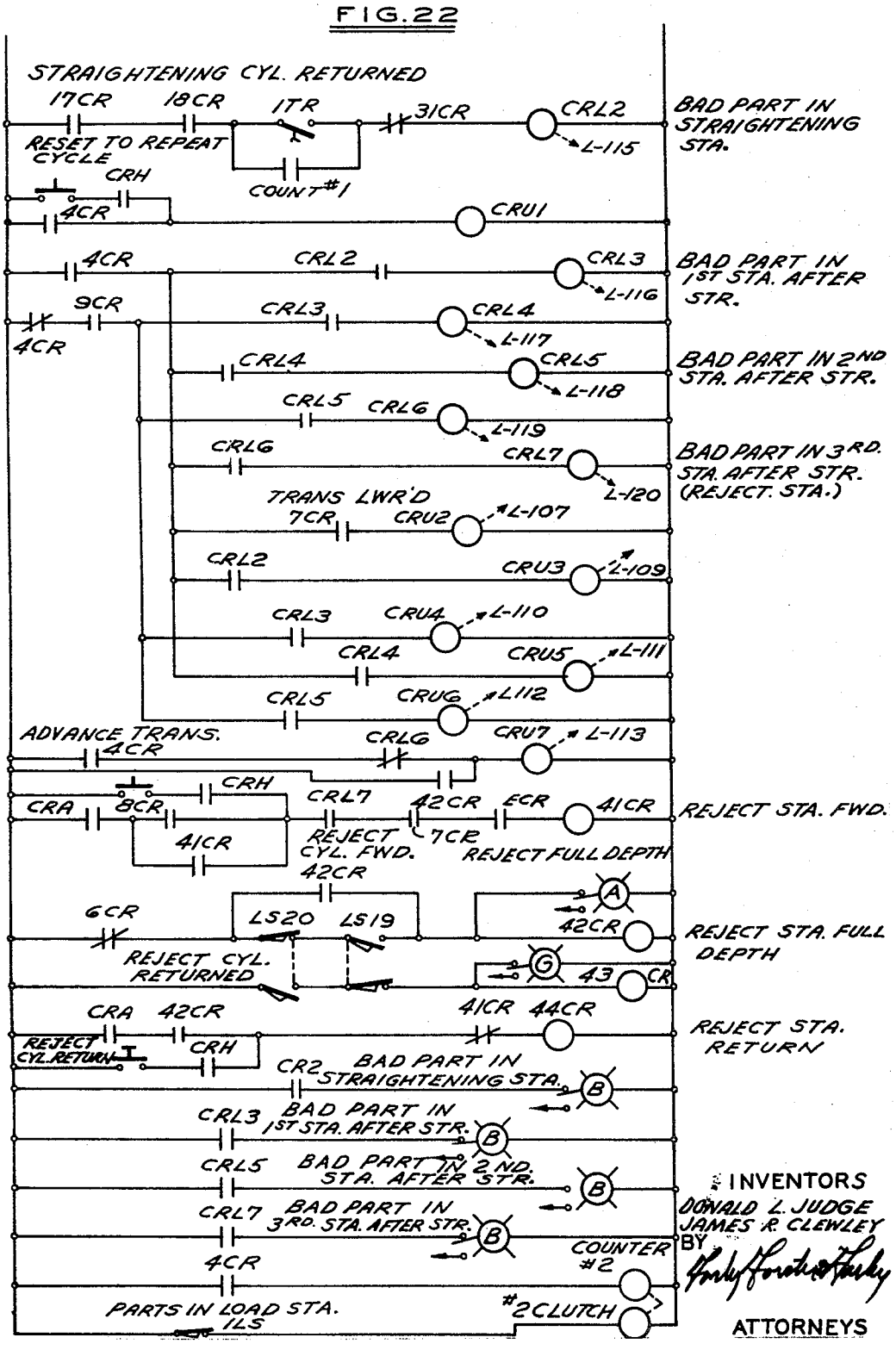


FIG. 21

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FIG. 22

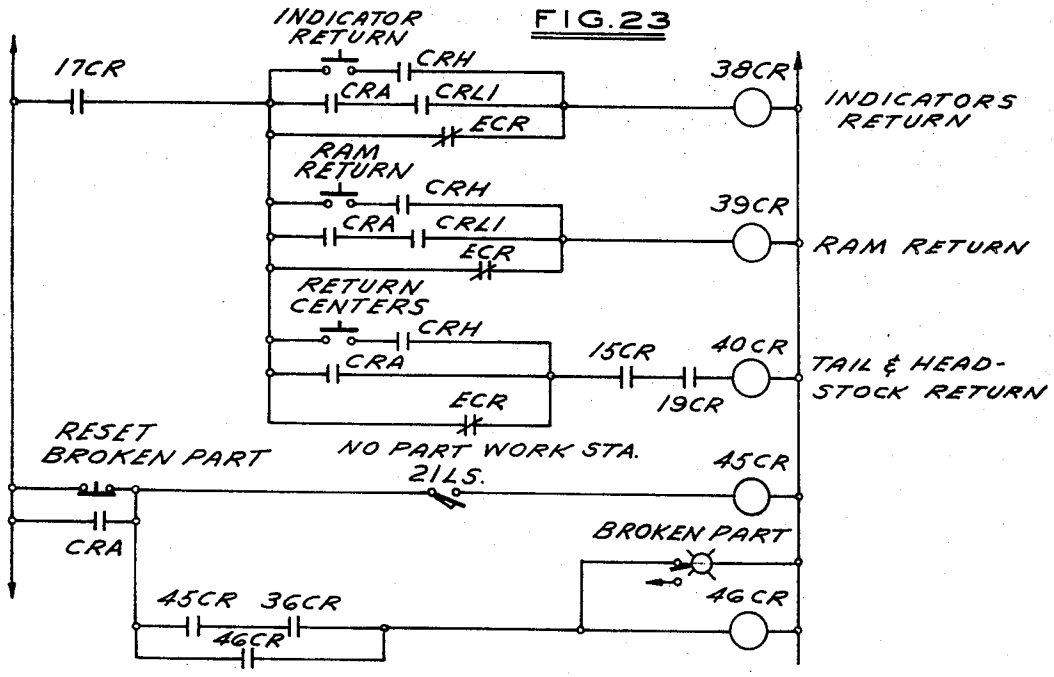


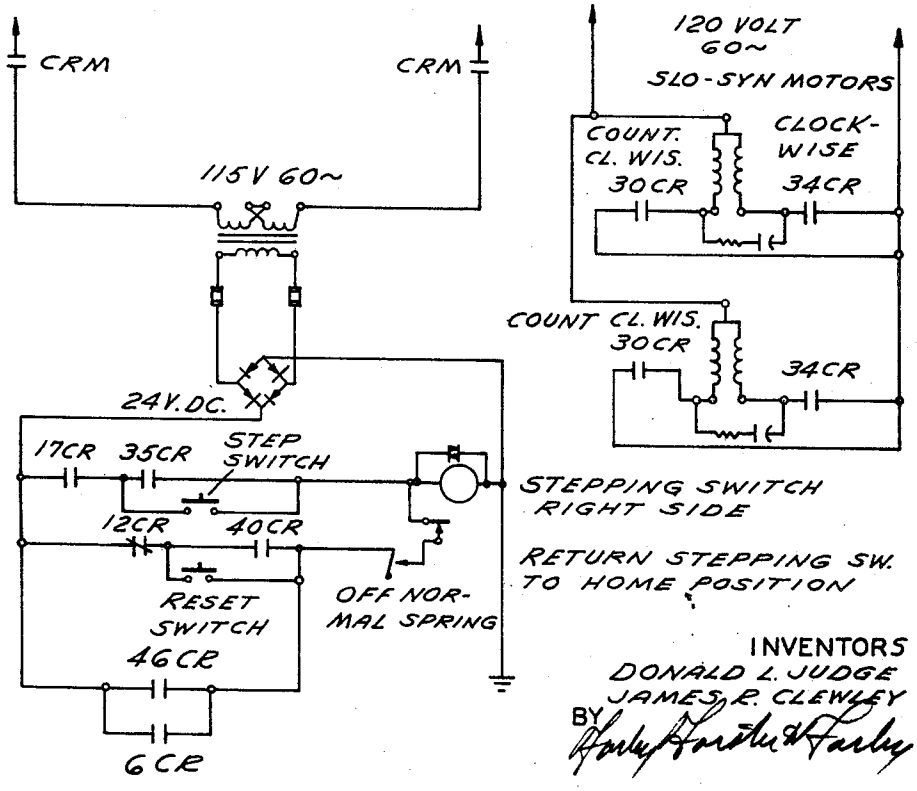
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STRAIGHTENING MACHINE

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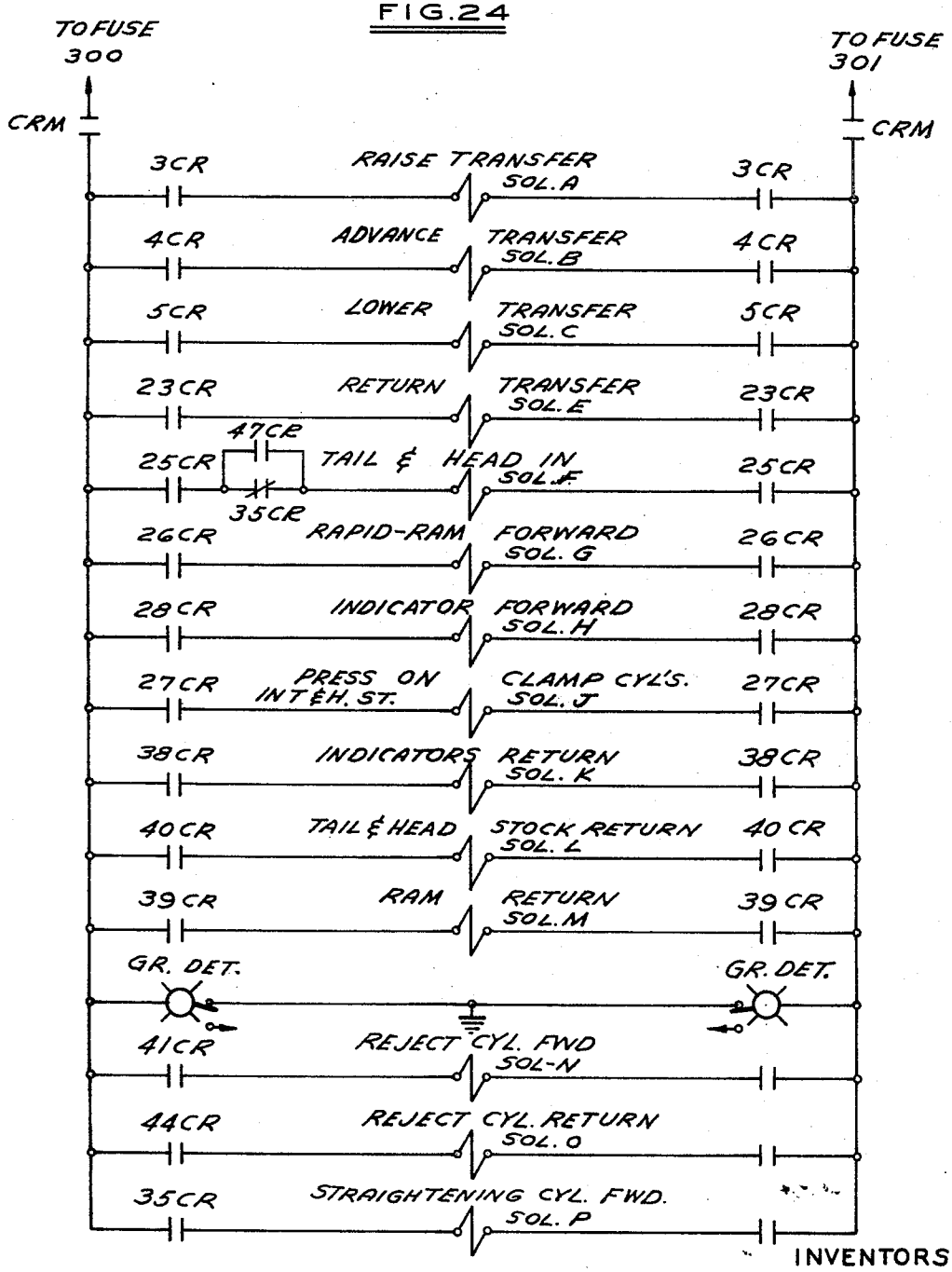
FIG. 23





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FIG. 24



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United States Patent Office 3,474,650
Patented Oct. 28, 1969

3,474,650

STRAIGHTENING MACHINE

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Filed May 19, 1967, Ser. No. 639,832
Int. Cl. B21b 37/00; B21j 7/26
U.S. Cl. 72—12 18 Claims

ABSTRACT OF THE DISCLOSURE

A machine for automatically inspecting parts, detecting axial distortion, positioning the plane of distortion for correction relative to a power operated ram, and automatically making correction by successive programmed deflections of the part in the plane of distortion through its true axis, unil a sraightened part results when deflection is released.

BACKGROUND OF THE INVENTION

The present invention relates to means and methods for automatically detecting axial distortion in a part and making the necessary correction within prescribed tolerances at reasonably high production rates.

Axial distortions are commonly introduced into rotational parts that are green ground to include bearing surfaces, gear faces, and the like when they are subsequently heat treated. This is particularly true with axle shafts of any length and gear head members including a shaft part of smaller dimension where there are variations in material cooling rates.

In most rotational parts, axial distortion is commonly found by rotating the part, noting any eccentricity, and making the necessary correction either while the part is rotating or afterwards. With certain parts, if correction is attempted while the part is rotating, overstressing may result in brittle or broken work pieces. If correction is made with the part stationary, normally under manual control, time is lost in locating the distortion, determining the amount of correction required, and in manually regulating the amount of bending of the work piece to that required to make it straight.

SUMMARY OF THE INVENTION

This invention is directed to a means and method for detecting the presence and radial plane of axial distortion in a rotational part, and for correcting the part automatically and immediately thereafter without moving the part to another location and without requiring that the amount of distortion be predetermined.

The present invention makes use of a comparative detection system which includes three circumferentially spaced differential probes to determine the presence and relative location of the plane of distortion.

The rotational part is straightened by deflecting it in the plane of the distortion through the true rotational axis a predetermined amount as necessary for it to spring back to a true straight position, as gauged by the differential probes. To accommodate the relative differences in metallurgical structure and circumferential size, which affect the recovery of parts within their elastic limits, a series of deflections of increasing incremental amounts is automatically provided to assure the straightening of all parts after one or more of the programmed deflections.

In the particular machine hereinafter disclosed for practicing this invention, a transfer line delivers parts sequentially to a straightening station of the machine where each is picked up, centered and examined to determine both the presence and relative location of any axial distortion beyond prescribed tolerances. If correction is needed, it is automatically repositioned, rotationally, relative to an overhead ram used in the straightening process. By use of the three probes mentioned, the part is turned through the shortest distance to dispose the plane of distortion vertically and crowned upwardly. When the ram is actuated, the part is set down on rocker supports to permit deflection beyond the true rotational axis. The part is inspected after each deflection and if it is not within tolerances the ram is signalled to deflect the part agains, once, twice or more times as necessary to straighten it. Although provision may be made for a progressive series of twenty or more deflections, usually four or five is sufficient since the metallurgical composition of the part and its relative size are the determining factors rather than the extent of initial distortion.

DESCRIPTION OF THE DRAWINGS

The numerous objects and advantages to be gained in the practice of this invention will best be understood and appreciated from the detailed description of a preferred embodiment as shown by the accompanying drawings wherein:

FIG. 1 is a front elevation of a differential drive pinion straightening machine embodying the various features of the present invention.

FIG. 2 is a top plan view of the machine.

FIG. 3 is a side elevation of the machine.

FIG. 4 is an enlarged partially sectioned front elevational view of one of the work positioning devices shown in FIG. 1.

FIG. 5 is an enlarged partially sectioned side elevational view of the straightening ram and upper inspection probes.

FIG. 6 is an enlarged top plan view of the work bed with a work part shown in phantom outline as received thereover.

FIG. 7 is an enlarged cross-sectional view of the work bed of the previous drawing figure, as seen in the plane of line 7—7, and showing the lower inspection probe in greater detail.

FIG. 8 is an enlarged cross-sectional view, showing certain details of the positioning device of FIG. 4 as seen in the plane of line 8—8 thereon.

FIG. 9 is an enlarged cross-sectional view of one of the upper probes as seen in the plane of line 9—9 in FIG. 5.

FIG. 10 is an enlarged front elevational view of the straightening ram mechanism, with the lower bed and upper inspection probes omitted.

FIG. 11 is a fragmentary top plan view of the straightening ram mechanism of the last mentioned drawing figure and shows the ram cylinder centrally thereof in dotted outline.

FIG. 12 is a cross-sectional view taken in the plane of line 12—12 of the last mentioned drawing figure and shows the ram cylinder in greater detail.

FIG. 13 is a fragmentary front elevational view of the anvils which receive and support the work piece for

straightening and shows the end of the straightening ram as disposed thereover.

FIG. 14 is a cross-sectional view of one of the anvil members as seen in the plane of line **14—14** of FIG. 13.

FIG. 15 is an enlarged side elevational view of the shoulder probe of the straightening machine, as positioned relative to the back face of a work part shown in phantom outline.

FIG. 16, on the preceding sheet of drawings, is a top plan view of the shoulder probe as seen in the plane of line **16—16** in FIG. 10.

FIG. 17 is a schematic presentation of the hydraulic system of the straightening machine.

FIG. 18 is a schematic presentation of the amplifier circuit of the disclosed straightening machine.

FIGS. 19–24 are consecutively related schematic illustrations of the electrical system.

DETAILED DESCRIPTION

The machine shown by the drawings and hereinafter described is for inspecting and straightening automotive differential drive pinions having integral shafts subjected to axial distortion both in the shaft and relative to the gear head as a consequence of heat treating in the course of normal production to harden work surfaces.

The machine includes a base **10** on which is provided work transfer means **12** for receiving individual work parts **14** and moving them sequentially towards a position where they are inspected and straightened when necessary.

The transfer means **12** is of the walking beam type and is best shown in FIGS. 2 and 3. It includes a pair of stationary side rails **16** with a pair of walking beam members **18** disposed in close parallel spaced relation thereto and operated by power cylinders **20** connected to bell crank and lever arms **24** and **26** which are engaged to the beam members and move them up, forward, down and back in the conventionally known manner to move a series of work parts forward together.

Head and tail stock engaging devices **28** and **30**, shown in FIG. 1 are mounted on the base **10** and are aligned on opposite sides of the transfer means **12** for axial engagement with work parts received therebetween. They are similar in construction and operation and will be described with respect to the tail stock engaging device shown in FIG. 4.

The head and tail stock engaging devices each include housing parts **32** and **34** which are secured together and have an arbor or spindle **36** that extends through both of them. The housing parts are mounted on or formed to include supports **38** and **40** to position the spindle at the height of the work parts on the transfer rails **16** and each spindle includes a center-point fitting **42** for centering engagement in the live centers in the ends of work parts to be received therebetween.

The housing part **32** includes a sleeve member **44** that carries the spindle and is reciprocal within a bore **46** as limited by a fixed stop **48** received in a guide slot **50** in the sleeve. The spindle is mounted in spaced concentric relation within the sleeve member and includes a ball and socket arrangement **52** at its outermost end permitting limited relative movement in the sleeve and axial rotation.

Rotational drive is imparted to the spindle **36** by a drive motor **54**, mounted on a housing **56** secured to the end of the sleeve member **44**, and through a flexible drive coupling **58** provided in the housing.

A power cylinder **60** is mounted on the housing **56** and has the piston rod part engaged to the support **38** to reciprocate the sleeve member and its spindle fore and aft.

The housing part **34** through which the spindle **36** extends is formed to provide centering support for the spindle at spaced locations as best shown by FIG. 8. The centering supports are provided in a common radial plane at each end of the housing **34** and include centering pins **62** which intersect the bore passage **64** through which the spindle passes. They are radially disposed and are backed by compression springs **66** in spring cups **68**, and are strong enough to carry the weight of the spindle when engaged with a work part but will allow for rotation of the spindle and will yield to straightening forces imposed on the work part, as later described.

To assure more precise centering of the spindle, clamping pins **70** are provided between the centering pins, in the same radial plane, and are activated by hydraulic fluid pressure. The pressure fittings **72** for the clamping pins are interconnected to assure equal pressure and each is provided with a chamber area **74** of like size and a stop collar **75** to limit travel. The pins designated as **76** are pressed into fittings **72** and act like a key to keep clamping pins **70** from rotating. As later described, the clamping pins serve to positively locate the spindles **36** for establishing a reference axis when the work parts are being inspected for axial distortion.

The work parts are inspected for axial distortion while supported on the spindles **36** by the two upper probing members **78** and **80** which are alike and are best shown by FIG. 5, and a third lower probing member **122** best shown in FIG 7.

The two upper probing members are mounted on supports **82** and **84** projecting out from the front and back sides of the ram housing **86** directly over the work part and are directed down and in under the housing for engagement with the work parts from relatively opposite sides. They are mounted on the ends of piston rods **88** of power cylinders **90**, provided on the supports, and are guided for reciprocal movement on a radial line relative to the axis of the work part by guide rods **92** received in guide holes **94** in the supports. Each probing member is provided with an adjustable stop **96** for engagement with a shoulder stop **98** on the ram housing to limit forward travel to a predetermined extent that assures contact with the work piece and a cushion stop **100** is provided for the piston rod connection so that the stroke imposed by the power cylinder will not adversely affect the terminal positioning.

An extension **102** on the forward end of the probing member accommodates and guides the actual probe **104** which is biased outwardly by a spring **106** and collar arrangement **108**. An extension **110** on the inner end of the probe is received centrally through a transducer coil **112** which is retained by a locking collar **114** held by a fastening screw **116** and is adjustable by a screw **118** to relatively position it for signal generating purposes in the detection system provided and which will now be described.

The two probing members **78** and **80** are pre-set relative to a master part so that the extent to which each probe causes its terminal extension **110** to penetrate the transducer coils **112** is the same and the coils are operatively inter-connected to generate a relative displacement signal when the probes are not in equally balanced positions. Thus the probes serve as a means of detecting a difference in their relative positions which indicates axial distortion in the work part and, by electrical means which differentiates between the two probes, the relative side of the distortion with respect to the true axis of the part is also determined.

Except for situations where the axial distortion is located on the center line between the two probes **104**, the upper detection probes are able to sense both the existence and direction of production work piece distortion and by suitable electrical connections with reversible drive motors **54**, of the head and tail stock engaging devices, are able to cause the work part to be rotated through the shortest distance required to centralize the plane of axial distortion bowed upwardly as required for straightening in which position the upper probes will balance.

The third probing system **12** is disposed directly under the work piece, as best shown in FIGS. 6 and 7, and includes probe **122** biased by a spring **124** and collar **126** to project through a guide bushing **128** in a mounting

plate **130** and has its lower end received through another guide **132** and including an extension **134** received in a transducer coil **136**. The coil is mounted on a post **138** that is guided in a bore **140** and is axially adjustable by means of the locking adjustment screw **142** for positioning the coil relative to the signal inducing extension of the probe **122**.

In use, the third probe is connected into the detection system with the other two probes when the two probes indicate a balanced condition. Like the other probes, the third probe is initially set to a master part and will cooperate to indicate if there is distortion beyond tolerance and whether the part is bowed towards or away from the probing member. If the part is bowed upwardly with the upper probes balanced it is in position for correction; otherwise, the third probe will signal for rotation of the part through 180° to properly dispose it for straightening.

Referring now to FIGS. 1–3, and more particularly to FIG. 10, the housing **86** for the ram, which is used to correct distortion in the work parts, includes a large casting mounted on columnar supports **146** and **148** relatively over the inspection and straightening station. The columnar supports straddle the work engaging devices **28** and **30** and are on each side of the work transfer means **12**. The overhead housing **86** includes a vertically disposed part **150** connected to the columnar supports by strengthening webb sections **152** with tee slots **154** provided in the front and back of the ram housing for the purpose of attaching supports **82** and **84** and include a transverse part **156** which extends across the supports and directly over the vertically oriented cylindrical part.

As best shown in FIG. 12, a cylindrical bore **158** is provided within the vertical part of the overhead housing **86** and a ram cylinder **160**, in a liner **162**, is provided in the bore for reciprocal movement relative to a work part when disposed thereunder. The ram cylinder includes a guide follower **164** at its upper end, used to control the movement of the ram, a guide slot **166** in its side which cooperates with a shoulder stop pin **168** to keep the ram cylinder properly oriented in the bore, and a striker **170** at its lower end for engagement with the work part (shown in FIG. 10).

The upper end of the ram cylinder **160** extends into the transverse housing, part **156**, within a guide passage **174**, and has its uppermost end formed to include an inclined cam surface **172** for actuation by a cross-feed mechanism which includes an actuating shoe **176** with a like cam surface **178** on its underside. The cross-feed mechanism also includes a pair of cross slides **182** and **184**, having the cam surfaced actuating shoe locked therebetween, by key members **180**, and with the slide **184** extending beyond the end of the shoe and including a guide slot **192** receptive of the follower **164** on the upper end of the ram cylinder.

The cross feed mechanism is actuated by a pair of power cylinders **186** and **188** which are mounted in a supporting frame **190** that projects beyond one end of the housing part **156**, as best seen in FIGS. 1 and 2. One of the power cylinders is used to advance the cross feed mechanism, and particularly the slide **184**, so that the guide slot **192**, which is formed at its leading end for a rapid descent, will advance the ram cylinder by means of the follower **164**, to a ready position. The other power cylinder is used to provide a short stroke driving the actuating shoe **176** across the ram cylinder **160** and forcing the ram cylinder down and its striker **170** into engagement with a work piece.

The second stroke of the ram cylinder **160** is accurately controlled by the second power cylinder so that work parts received thereunder, and which have the high point of their distortion disposed upwardly, can be bent straight by deflection between its ends that will result in having its longitudinal axis coincide with its true rotational axis.

The work parts must be positively supported near opposite ends to allow for deflection of the work parts sufficient to correct the distortion detected. For this purpose, a pair of anvils **196** and **198** are provided under the ends of the work part, in place of the transfer rails **16**, right under the ram housing **144**. As shown by FIGS. 13 and 14 they include seating members **200** formed to the general contour of the work part and having trunnion supports **202** and **204** which enable them to rock inwardly towards each other as the work part is deflected downwardly between them. The force of the ram stroke is thus distributed between the two anvil seating members and through their trunnion support pins, which are capable of carrying the load, and enables the deflection required with minimum resistance.

In the normal sequence of machine operation, the work parts are placed on the anvil seats by the work transfer means, picked up for inspection and then seated by the ram for correction. The work centering spindles **36** remain engaged with the work part during correction and are allowed to yield in the course of the corrective ram stroke, by the centering pins and springs in the head and tail stock engaging devices, and then center the part once more for re-examination.

After deflection of the work parts, residual distortion is detected by the probing device **120** disposed under the work parts and which has its probe **122** biased for engagement with the underside of the work part to indicate the extent to which the longitudinal axis of the part and its true rotational axis coincide. Should there still be distortion, over acceptable tolerances, the machine is cycled automatically for further correction, as will be described in discussing the control circuits.

FIGS. 15 and 16 show a shoulder probing device **206** which is particularly useful with work parts, such as the gear part shown, where the rotational axis of the shaft part must be true with respect to a part of larger section. Although shown as a fourth probing device, it may serve the purpose of the third probing member in detecting the centerline disposition of distortion and any residual distortion. However, in the present instance it is used as a final check against distortion during a last revolution of the part before it is finally accepted.

The probing device **206** is mounted on a post **208** projecting down from the ram housing and which serves to position it relative to the work part shoulder face to be gauged. A pair of followers **205** engaging opposite sides of a vertical rail **207** guide the vertical travel and an adjustable stop **209** determines the lowermost position. The ram cylinder **160** includes a part **211** on its lower end, near the striker **170**, which is disposed to engage an arm **213** on the probing device to lift it vertically when the ram cylinder is fully retracted but which does not interfere with the positioning of the probing device during the corrective stroke of the ram.

The probing device **206** includes a forked member **210** which straddles the work part shaft and includes two locator pins **212** on its ends for engaging the shoulder face to be inspected. The forked part is rotatably pivotal about the axis of a supporting pin **214** and guided by the pin and biased for movement in and out relative to the shoulder face being inspected. It also carries a member **216** pivotal about a cross axis on pivot pins **218** with a probing member **220** that extends between and through the forked arms for engaging the work face being inspected. The movement of the probing member, caused either by its engagement with the work face or by movement of the yoke member on which it is carried, is translated to an arm **222** on one end of the cross member with a feeler **224** which activates a transducer **226** provided on the stationary part of the mounting fixture. Thus, when a true part is rotated, three point contact is maintained and no signal is induced in the transducer; otherwise, the forked member will be backed off and the center probe will move in and out with the eccentricity of the shoulder face.

The various power cylinders mentioned are operatively interconnected in the straightening machine as shown by the schematic of the hydraulic system in FIG. 17.

Motor IM operates the pump **230** to draw from the reservoir **232** and supply hydraulic fluid to the system. When solenoid A is energized, valve **234** provides fluid under pressure to the power cylinder **22** to elevate the walking beams of the transfer system. As the transfer beams are raised and in their final position limit switch **3**–LS is closed and activates solenoid B to which it is operatively connected. This causes valve **236** to supply fluid under pressure to the power cylinder **20** which advances the work transfer beams, causing them to open **6**–LS and close **5**–LS which energizes solenoid C and actuates the valve **234** to lower the transfer beams and complete the work transfer operation.

When **4**–LS and **5**–LS are closed at the same time, solenoid F is energized and causes control valve **238** to supply fluid under pressure to the head and tail stock cylinders **60**. When **7**–LS and **8**–LS are closed, solenoid G is energized and valve **249** causes fluid flow to power cylinder **186** to advance the straightening ram to its ready position. Solenoid H is also energized at the same time and causes valve **242** to actuate the power cylinders **90** and advance the inspection probes. The same limit switches also cause solenoid J to be energized and valve **244** to actuate hydraulic clamping pins **70** in the head and tail stock devices.

When all of the power units mentioned are forward, and their limit switches are closed, solenoid E is energized to activate valve **236** and effect the return of the transfer bars by means of the power cylinder **20**.

Whenever straightening a work part is required, provision is made in the electrical circuit to de-energize solenoid J and shift valve **244** so that pressure is off the clamping pin **70**, and pressure is also removed from head and tail stock valve by de-energizing hydraulic valve solenoid F.

When the work part has been positioned for straightening, as will be described in discussing the electrical system, solenoid P is energized and activates valve **246** to supply fluid under pressure to the cylinder **188** that drives the ram down. The fluid supplied to the power cylinder **188** controls the depth to which the ram is allowed to go in straightening a part and is therefore closely controlled as will later be shown and described with respect to the electrical circuit.

After a part is straightened, solenoids K and M are energized in the electrical system to retract the indicators and the ram by shifting valves **242** and **240**. As **16**–LS, **17**–LS and **12**–S are closed, by the retracting movement of the power cylinders **90** and **186**, solenoid L is energized to shift valve **238** and retract the head and tail stock spindles.

A reject station is provided in the work transfer system whereby parts which can not be corrected by the machine are progressed from the straightening station to a position where they must then be removed before the automated cycle will continue. This is accomplished by a latching relay which causes solenoid N to be energized when the transfer bars move forward and down and activates valve **248** controlling power cylinder **250** to remove the work part. As the reject cylinder closes LS–**19** it energizes solenoid O to shift the valve and retract the cylinder for the next time it is needed.

FIG. 18 shows the amplifier circuit for the straightening machine and which will be briefly described before discussing the overall operation. This is the control circuit which includes the transducer coils **112**, **136** and **226** of the probing devices and enables the signals they produce to be amplified and compared in the detection of axial distortion in a work part and in positioning the work part for correction.

Amplifier relay circuits are provided for each of the probing devices and are similar to the one identified as **252** for the lower disposed probing device **120**; the others being shown in block diagram form and identified as **254** and **256** for the overhead probing devices **78** and **80**, and **258** for the shoulder probing mechanism. Each of the amplifier relays is connected to an intermediate unit **260** for comparing the signals of the different probes to average the diameter, indicate the location of distortion in a work part during inspection and signal the rotation necessary to relocate the part with the high point disposed relative to the ram for correction. As mentioned earlier, this is accomplished by having the composite signal operative of the self synchronizing reversible motors **54** on the work engaging devices **28** and **30**. By relay circuits in the electrical system, the upper probes will determine whether the rotation required is clockwise or counterclockwise and will call for the rotational movement of the work part in such direction until the signals of the upper probes are balanced and the lower probe signal indicates the distortion is crowned upwardly.

A relay holding circuit amplifier **262** is also provided and is operatively connected between the signal discriminating unit **260** and a stepping or like switching device **264** which sequentially provides different adjustable resistances **266** in the ram control circuit for causing incremental increases in the distance the straightening ram travels when successive corrective strokes are required to eliminate distortion in the work part. This is accomplished by balancing stepping relay controlled voltages against the transducer controlled voltage of the lower probe to actuate the hydraulic valve **246** solenoid P to stop the ram stroke at progressive probe displacement positions. Although only five steps are shown it will be appreciated that twenty or more may actually be used. Similarly, the indicator lights for visual indication of the deflection being imposed will be appreciated as in the electrical circuit later disclosed.

Suitable voltage reading meters **M1**, **M2**, **M3**, **M4** and **M5** are provided respectively for balancing all three probes at zero relative to a master part, measuring the balance of the upper probes relative to each other, setting the successive straightening steps, balancing individual probes against the master, and indicating the position of the lower probe only

The overall operation is best described with reference to the electrical circuit of FIGS. 19–24.

The master start button is depressed to provide power to IM and CRM relays which starts the hydraulic motor, closes contacts for the DC power supply, provides power to the amplifier circuit, closes corresponding contacts in appropriate relay and solenoid circuits and energizes the emergency return relays. With all units returned from previous cycles, the unloading station empty, and a part in the load station to close limit switch CRL–**1**, the start button is depressed to energize the CRA relays. For continuous cycling, the selector switch is moved to the designated position and the two cycle start switches are depressed to energize **1**CR. With a part in the loading station, **2**CR is energized and the automatic cycle starts.

With all units returned, CRL–**1** in and CRL–**7** out, **2**CR closes **3**CR which energized the solenoid A that activates the lift cylinder **22** of the transfer system. In their elevated position the transfer bars close **3**LS which energizes **4**CR. This energizes the solenoid B that activates the forward transfer solenoid **20** and the CRL–**1** latch drops out as the transfer bar moves forward. When the forward movement of the transfer bar closes **5**LS, it energizes **5**CR and solenoid C controlling the lowering movement of cylinder **22**.

The contact relay **25**CR is energized when the transfer bar is forward and lowered, causing **5**LS and **4**LS to be closed, and it in turn energizes solenoid F which activates the tail and head stock cylinders **90** and causes them to move into position to engage and lift a work part off the anvils where it has been left by the transfer bars. As the head and tail stock spindles close **7**LS and **8**LS, the

relays CR26, CR27 and CR28 are closed and solenoids G, H and J are energized to move the ram into its ready position, bring the indicator probes in, and clamp the head and tail stock spindles by activating the clamping pins 70.

With all units forward, 23CR is closed and energizes solenoid E to effect the return of the transfer bars. Timing switch ITR is also energized, for limiting the overall correction time, along with timing switch 2TR which controls the time before checking starts.

The probing devices 78 and 80 are in service when the timing switch 2TR is out and any significant difference in their signals, in the amplifier circuit, indicates the side of the work part which includes the high point of the axial distortion. They signal for release of the clamps and a clockwise or counter-clockwise rotation of the part until the proble 120 indicates the upward vertical disposition of the eccentricity. If the upper probe signals are balanced but probe 120 provides a negative signal, beyond tolerance, it indicates the high point is down and the drive mechanism is signalled to effect a rotation of 180°. When the high point is up, 4TR and 35CR are energized; with the latter causing solenoid G to be activated and the straightening ram to be actuated. The 4TR relay contacts allow time for a recheck after the straightening and if the part is still bad, the timing cycles are used to enable the part to be repositioned, if necessary, and another straightening stroke to be made.

In each instance, the straightening ram moves a predetermined amount as determined by the relay holding circuit of amplifier 262 which controls the amount of hydraulic fluid that is supplied to the power cylinder 188 and determines the travel of the ram. If the part does not check out after the first ram stroke, successive strokes are provided for increasing incremental amounts until the part is straight or the cycle is completed to indicate a part beyond straightening, broken or otherwise to be rejected.

When a part registers as straight, within accepted tolerances, contacts 17R, 29CR, 32NC, 33NO and 2TR are time closed. The slo-syn motors 54 then turn the part one complete revolution for a runout check by the shoulder probe 206. If the part checks out, CRL–1, 38CR and 39CR are energized, solenoid K retracts the indicators and solenoid M retracts the ram cylinder. When the indicators close their return limit switches, CR40 is energized to activate solenoid L and retract the head and tail stock spindles.

Should the machine indicate a bad part, after the full cycle, CRL–2 will be in so that when the transfer bar elevates and closes 4CR, CRL–3 will be energized to indicate a bad part in the straightening station. As the transfer bar returns, with CRL–3 in, it closes CRL–4. As it advances, it closes CRL–5 and the bad part is indicated as in the second station after straightening. This continues through CRL–6 and 7 where the part then rests in the reject station. The next transfer movement closes 7CR and 8CR and energizes 41CR to activate the reject cylinder 250 through solenoid N. When the reject cylinder trips 19LS, 42CR is energized, CRL–7 is de-energized and CR44 is closed to effect the rejection of the bad part by whatever means is desired.

A check against moving the bad parts off the machine with the straightened parts is provided by requiring that CRL–7 be open before the transfer bar can elevate again.

The electrical circuit shown by FIGS. 19–24 also includes means for operating each of the progressive steps manually by closing certain contacts with manually operated switch means, safety circuits for power failures and lube faults, and indicator light circuits for visual checks. These are readily identified by the legends provided on the drawings and are not considered to need individual description.

From the foregoing description, it will be appreciated that the straightening method of this invention includes determining the presence of axial distortion in a work part by relating its longitudinal axis to an axis of true rotation through its live centers, provided when the part is first formed, locating the radial plane of the distortion and then deflecting the part between its ends and in the plane of distortion through its true rotational axis sufficiently for it to spring back within its elastic limits to a true straight condition.

A series of increasing incremental deflections are provided for in the present machine to accommodate the differences in radial dimensions of different parts which affect their modulus of elasticity and also the location of their true rotational axis when they are set down on the anvil seats for correction. The first stroke is programmed to correct a work part of maximum tolerance dimension and/or minimum elasticity since such parts will have minimum spring back corresponding to the first deflection displacement of the lower probe. Successive bending increments are set to accommodate the range of work piece variations in size and metallurgical elasticity with a minimum number of ram strokes consistent with straightness tolerances and the avoidance of over correction requiring reorientation of the workpiece, thereby maximizing the straightening production rate. Occasionally, when metallurgy of the part results in over-correction, successive ram strokes, as in the case of the present pinion example, may continue after reorientation of the part without resetting the stepping relay 264. However, with other parts experience may dictate a desirability for resetting the programmed increments after any reorientation as may be readily accomplished by a modification in the control circuitry obvious to those skilled in the art.

The actual amount of initial distortion is of no consequence since the deflection imposed on the work parts is controlled by increments of displacement of the lower probe relative to the fixed position of the anvil seats. Thus, a series of one to five ram strokes may be programmed to normally bring most parts of the type illustrated to within acceptable tolerance although 20 or more steps may be provided, if they are required.

The detection system accommodates variations in the relative cross-sectional dimension of the work part since it incorporates a differential means of sensing distortion. The overhead and lower probes are preset to a master part to assure balance in their composite readings and they will balance out with a part of large or small cross-sectional size that has no distortion. The lower disposed probing device serves the further purpose of controlling the incremental ram strokes and in checking for residual distortion after each ram stroke to signal further corrective action as required. The shoulder probe is used as a final checking device against relative distortion between the shaft and a shoulder section of the pinion. It may also be used to call for further deflection of the work part shaft that will actually introduce distortion in the shaft that will result in a relative straightness within acceptable tolerances for both the shaft and larger sectioned part.

It will be appreciated that the work engaging spindles are kept in engagement with the work parts at all times after their initial contact and until the straightening is completed. By having the spindles able to yield during the ram stroke and immediately center the part afterwards, considerable time is saved and a production output rate of 285 parts an hour and greater is possible for the disclosed machine.

While a particular preferred embodiment has been shown and described in detail, it will be understood that numerous modifications may be resorted to without departing from the scope of the following claims.

We claim:

1. The method of straightening rotational parts having axial distortions beyond accepted tolerances, and comprising; determining the presence of axial distortion and the radial disposition thereof relative to the true rotational axis, automatically positioning parts for corrective

deflection in accord with the determinations made relative thereto, and automatically deflecting the part in the radial plane of distortion through and beyond the true rotational axis.

2. The method of straightening rotational parts having axial distortions beyond accepted tolerances, and comprising; comparatively determining both the presence and radial disposition of axial distortion in a rotational part, automatically rotating the part the shortest rotational distance to dispose said distortion for corrective deflection, and automatically deflecting the part in the radial plane of distortion through and beyond the true rotational axis.

3. The method of inspecting rotational parts for axial distortion and straightening the parts to within acceptable tolerances, and comprising:

supporting a part for rotation about its true rotational axis,

differentially inspecting the part in a plane of reference normal to its true rotational axis for a comparative determination of the presence of axial distortion and its radial location,

automatically repositioning the part the shortest rotational distance for disposing the plane of distortion relative to corrective means,

deflecting the part in the radial plane of the distortion a predetermined distance through the true rotational axis therefor,

and alternately re-inspecting and deflecting the part in increasing incremental amounts to within prescribed tolerances.

4. A machine for straightening a work piece having axial distortion, and comprising;

means for centering a work piece relative to a true rotational axis therethrough,

means for gauging the work piece for detecting the radial plane of axial distortion therein,

and means operatively responsive to said last mentioned means for deflecting the longitudinal axis of the work piece beyond the true rotational axis and in the radial plane of said distortion.

5. The straightening machine of claim 4,

said detecting means including circumferentially spaced probes radially disposed relative to the true rotational axis of said work piece and operatively interconnected for differentially locating and providing a signal indicating the plane of said distortion,

and means responsive to said signal for repositioning the work piece relative to the deflecting means for correcting the detected distortion therein.

6. The straightening machine of claim 4, including:

means for detecting residual distortion in the work piece following corrective deflection and operatively connected to said deflecting means for effecting successive actuation thereof in increasing incremental amounts as required for correction within prescribed tolerances.

7. The straightening means of claim 6,

said residual distortion detecting means including one of the detecting means first mentioned.

8. The straightening means of claim 6,

said residual detecting means being operatively connected with said first mentioned detecting means and disposed apart therefrom for locating the plane of distortion relative to said deflecting means.

9. The straightening means of claim 8,

said residual detecting means being disposed opposite said deflecting means and said first mentioned detecting means being provided equidistantly therefrom and on relatively opposite sides thereof.

10. A machine for straightening a part having axial distortion and comprising;

means spaced apart for receiving and supporting a work part therebetween and disposing the work part for rotation about its true rotational axis,

a power actuated ram disposed between said supporting means for engagement with the work part and for radial deflection thereof relative to the true axis of the work part,

a pair of probes provided on relatively opposite sides of said axis and disposed for engagement with a work part and radial movement relative to said axis,

means interconnected between said probes for differentiating between the radial positions thereof relative to said axis, upon their engagement with a work part, and for detecting the presence and location of axial distortion in said work part,

means responsive to said detecting means for repositioning the work part about its true rotational axis with the high point of the axial distortion therein disposed between said ram and the true axis of said work part,

means responsive to said repositioning means for actuating said ram to deflect said work piece a predetermined distance through its true rotational axis for straightening work parts of minimum cross-sectional tolerance,

a third probe reciprocal relative to said axis and disposed for engagement with said work part for detecting residual distortion following deflection by said ram,

and operative means connected between said third probe and said ram for effecting successive actuation of said ram in increasing incremental amounts for straightening work parts of successively greater cross-sectional size.

11. The straightening machine of claim 10,

said third probe being disposed opposite said ram and being connected to said differentiating and detecting means for assistance in the determinations made thereby.

12. The straightening machine of claim 10,

said differentiating and detecting means being in series connection with said repositioning and ram actuating means for checking and repositioning said work part as required prior to each successive deflection thereof.

13. In a machine for straightening work parts having axial distortion and including a power actuated ram for bending such work parts straight, the improvement comprising;

means spaced apart for receiving and supporting a work part disposed horizontally therebetween and with the power actuated ram disposed centrally thereover,

and said supporting means including a pair of anvil members having trunnion supports permitting rocking movement thereof in the course of bending said work part by said rams.

14. The improvement of claim 13,

said anvil members being contoured to receive said work part seated thereon and for rocking movement relative to said trunnion supports.

15. In a machine for detecting axial distortion in a rotatable work part and providing for straightening thereof at the same work station, the improvement comprising;

head and tail stock spindle means spaced apart and for center point and engagement with opposite ends of a work part received therebetween for disposing said work part for rotation about its true rotational axis,

pivotal means supporting the outer ends of said spindles and allowing limited freedom of movement for the work part engaging ends thereof,

and means for centering the work part engaging ends of said spindles in the course of distortion detection and for yielding laterally for distortion correction.

16. The improvement of claim 15,

said last mentioned means including power actuated clamps radially disposed relative to said spindles for centering and locking engagement therewith.

17. The method of claim 3 including the secondary inspection of runout of a workpiece surface relative to said

true rotational axis, and continuing deflecting the part in increasing incremental amounts until tolerance requirements relative to said runout are also satisfied.

18. The straightening machine of claim **6** including secondary means for detecting runout of a work piece surface relative to said true rotational axis, and control means responsive to said secondary means for continuing operation of said deflecting means until tolerance requirements relative to said runout are also satisfied.

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