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 [22] Filed **Mar. 7, 1967**
 [45] Patented **Aug. 31, 1971**
 [73] Assignee **Ford Motor Company**
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2,561,654	7/1951	Eller.....	318/20.270
2,670,456	2/1954	Naylor.....	318/20.270
3,178,717	4/1965	Fengler.....	250/202
3,366,934	1/1968	Kelsey.....	318/20.160
3,384,797	5/1968	Benton.....	318/20.120
3,398,452	8/1968	Little.....	318/20.105
2,781,848	2/1957	Thomas.....	346/33 MC
3,024,396	3/1962	Peckjian.....	346/33 MC

OTHER REFERENCES

Gomolak, Better and Faster Design By Machine, Electronics, June 1, 1964, pgs. 64-71

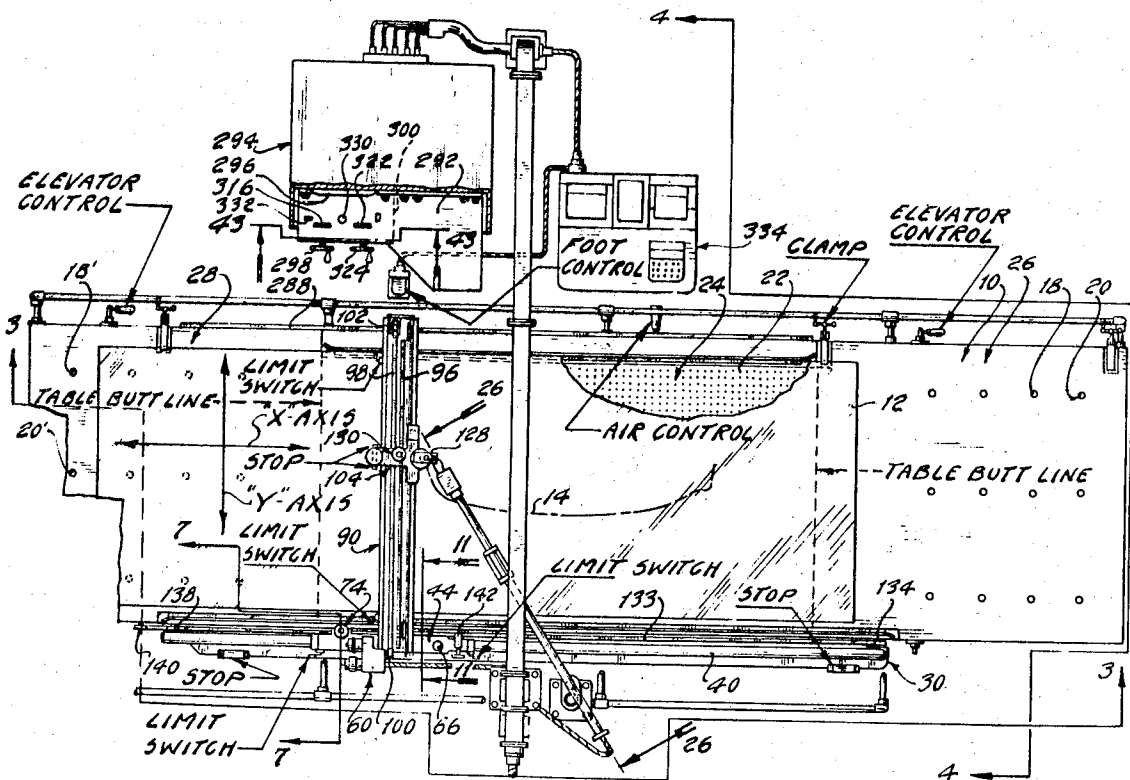
Primary Examiner—Robert L. Griffin

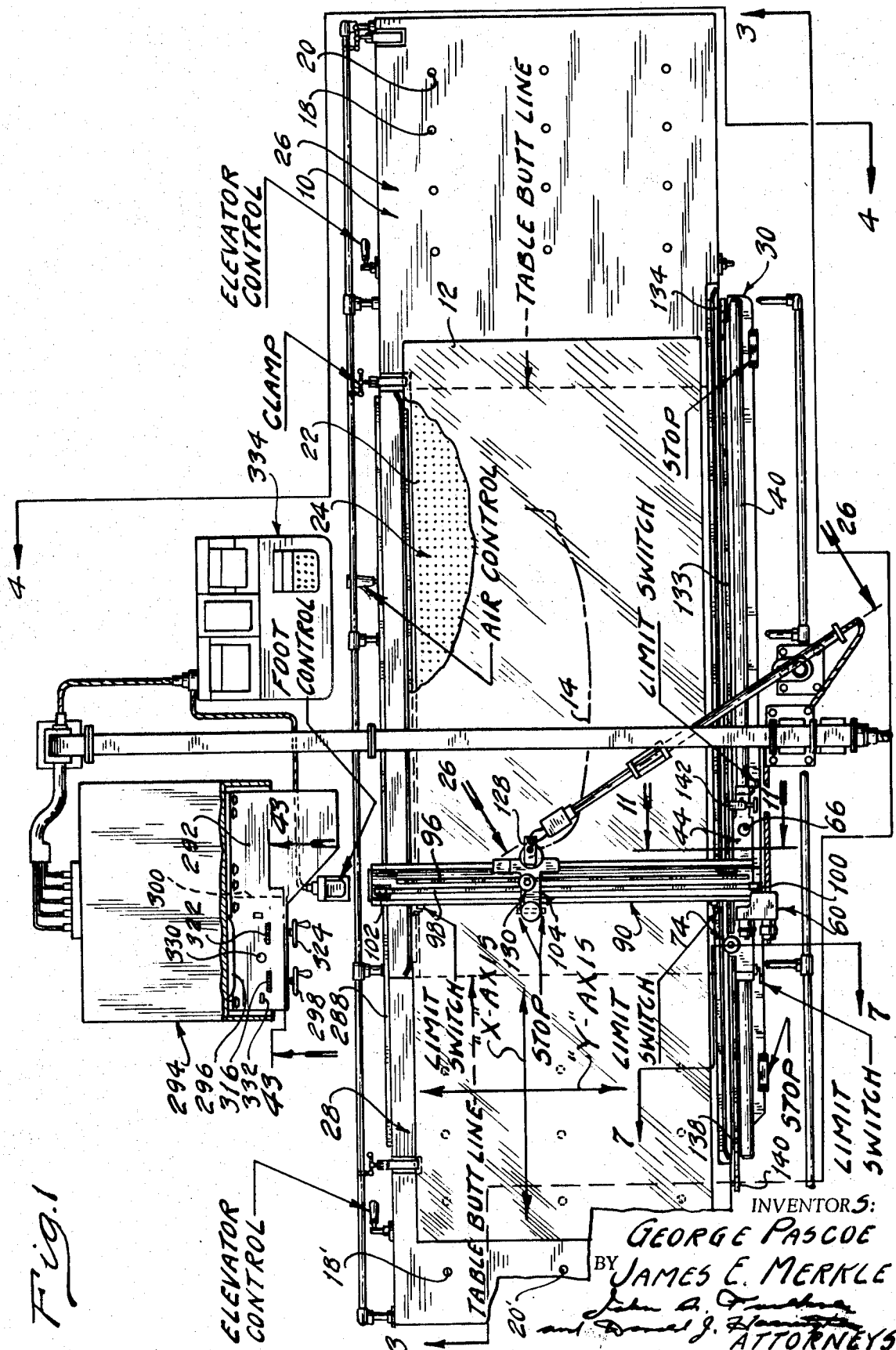
Assistant Examiner—Joseph A. Orsino, Jr.

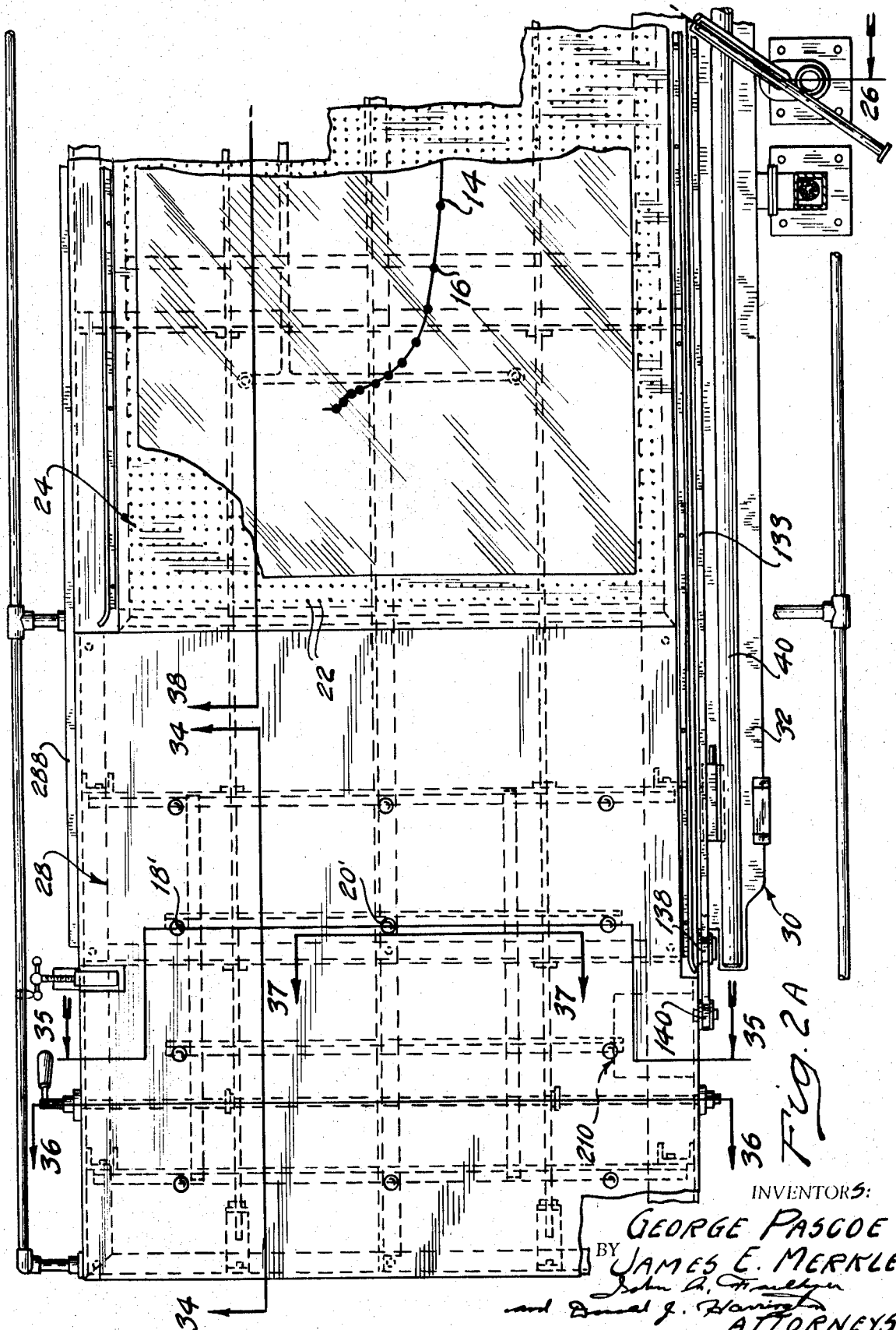
Attorneys—John R. Faulkner and Donald J. Harrington

[54] **GRAPHIC DATA SYSTEM FOR SCANNING AND RECORDING TWO-DIMENSIONAL CONTOURS**
 1 Claim, 61 Drawing Figs.
 [52] U.S. Cl. 178/6.8,
 250/202, 318/568, 318/577
 [51] Int. Cl. H04n 7/18,
 G05b 1/06
 [50] Field of Search..... 250/202;
 318/20.105, 20.108, 20.110, 20.120, 20.160,
 20.270, 568, 569, 577; 178/6.8; 346/33 MC
 [56] **References Cited**
UNITED STATES PATENTS
 2,473,424 6/1949 Grabau..... 318/20.160

ABSTRACT: This specification describes a coordinatograph system in which point data on a two-dimensional contour drawing may be located and registered in a data recording medium where the data may be used, with the aid of a specially programmed computer, to prepare a control tape for a numerically controlled machine tool.







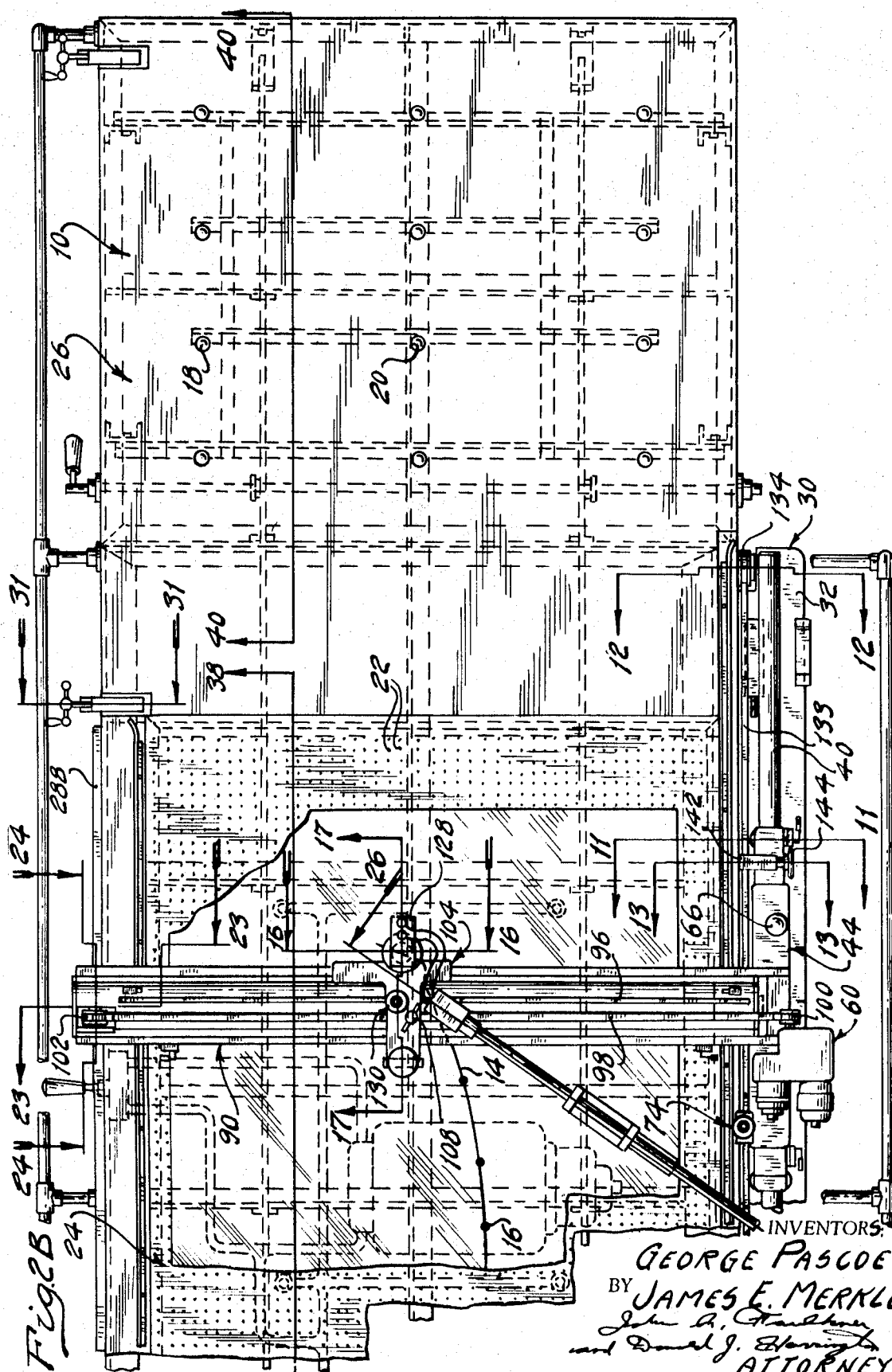


Fig. 3A

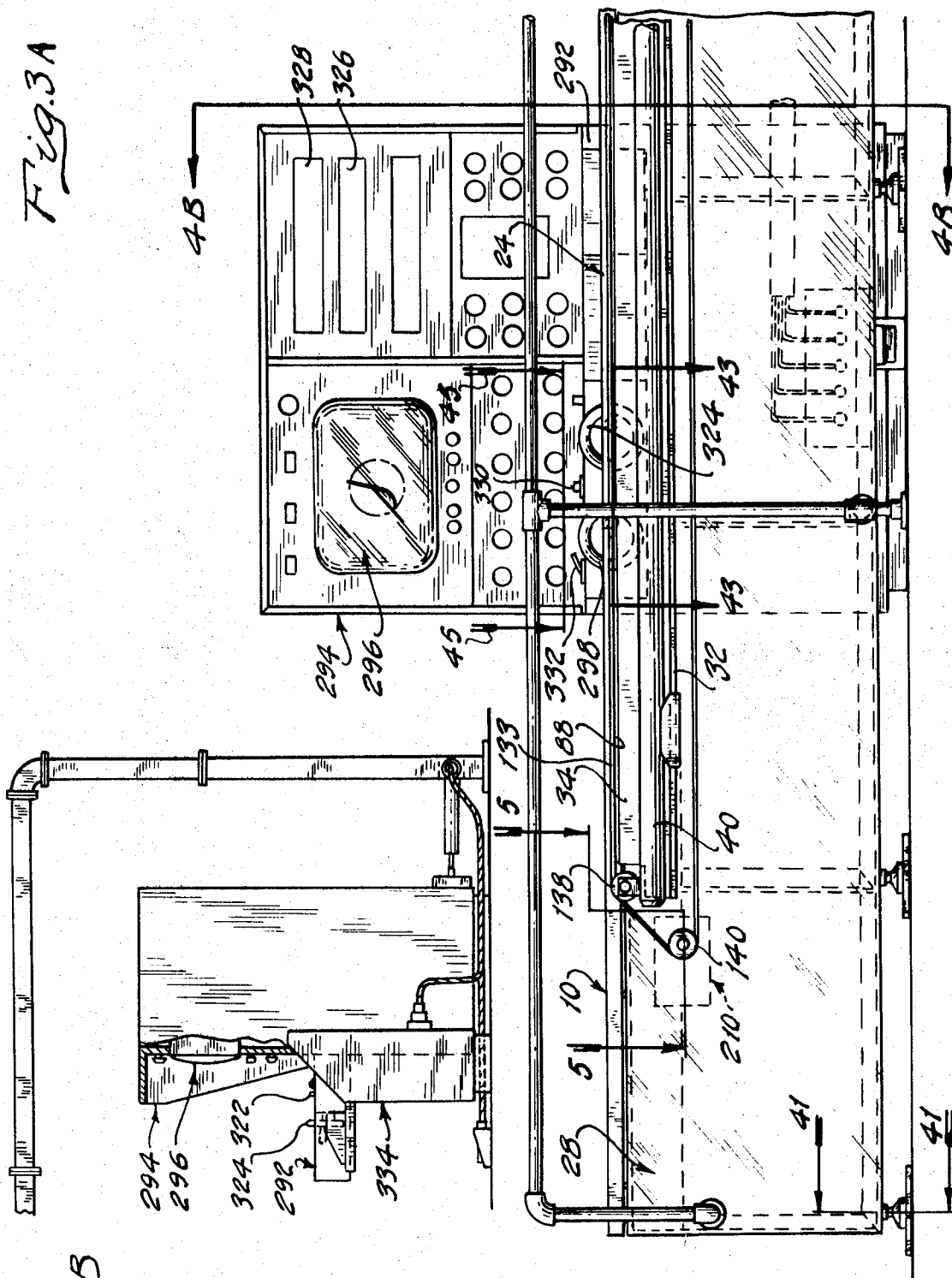
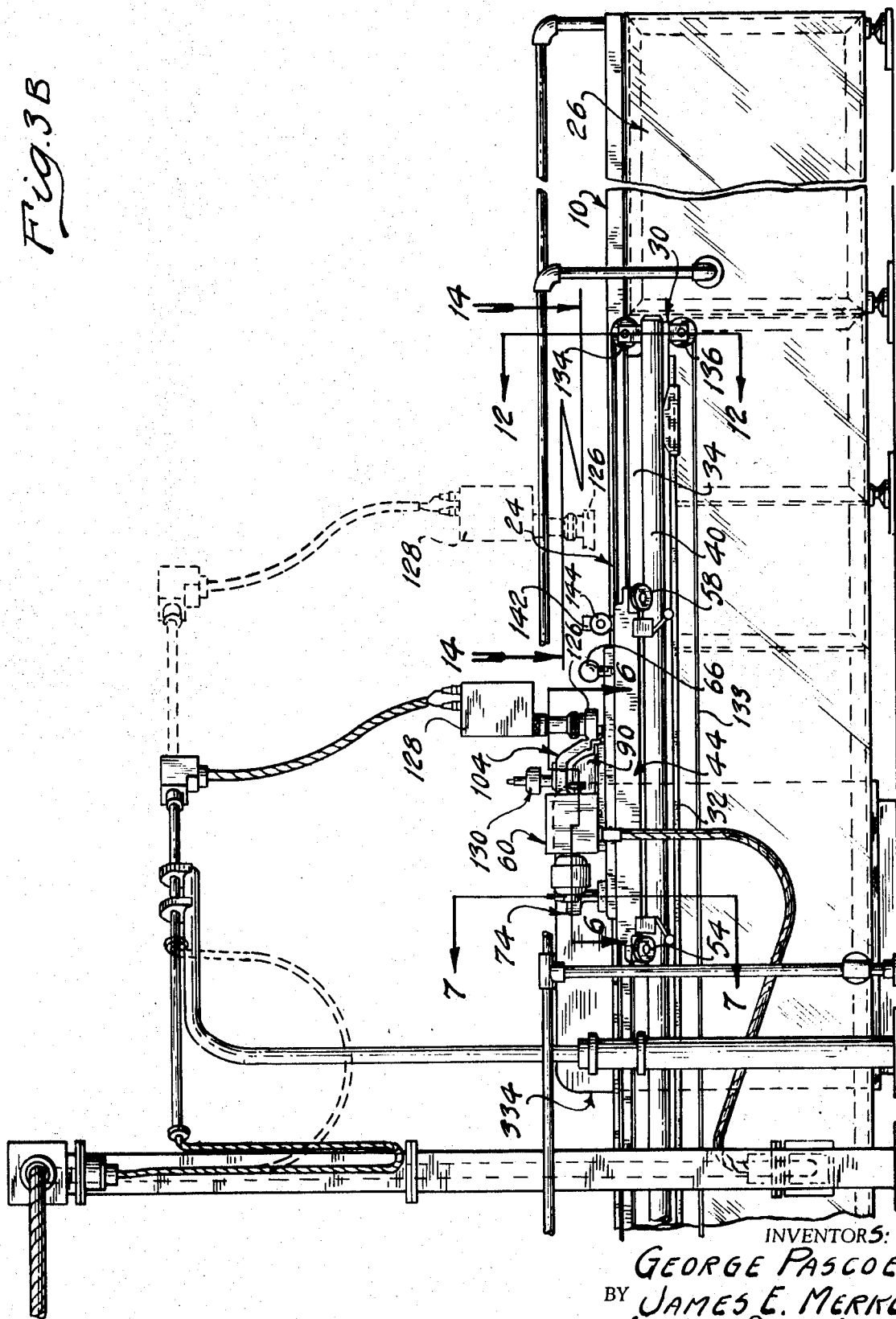


Fig. 4B

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Fig. 3B



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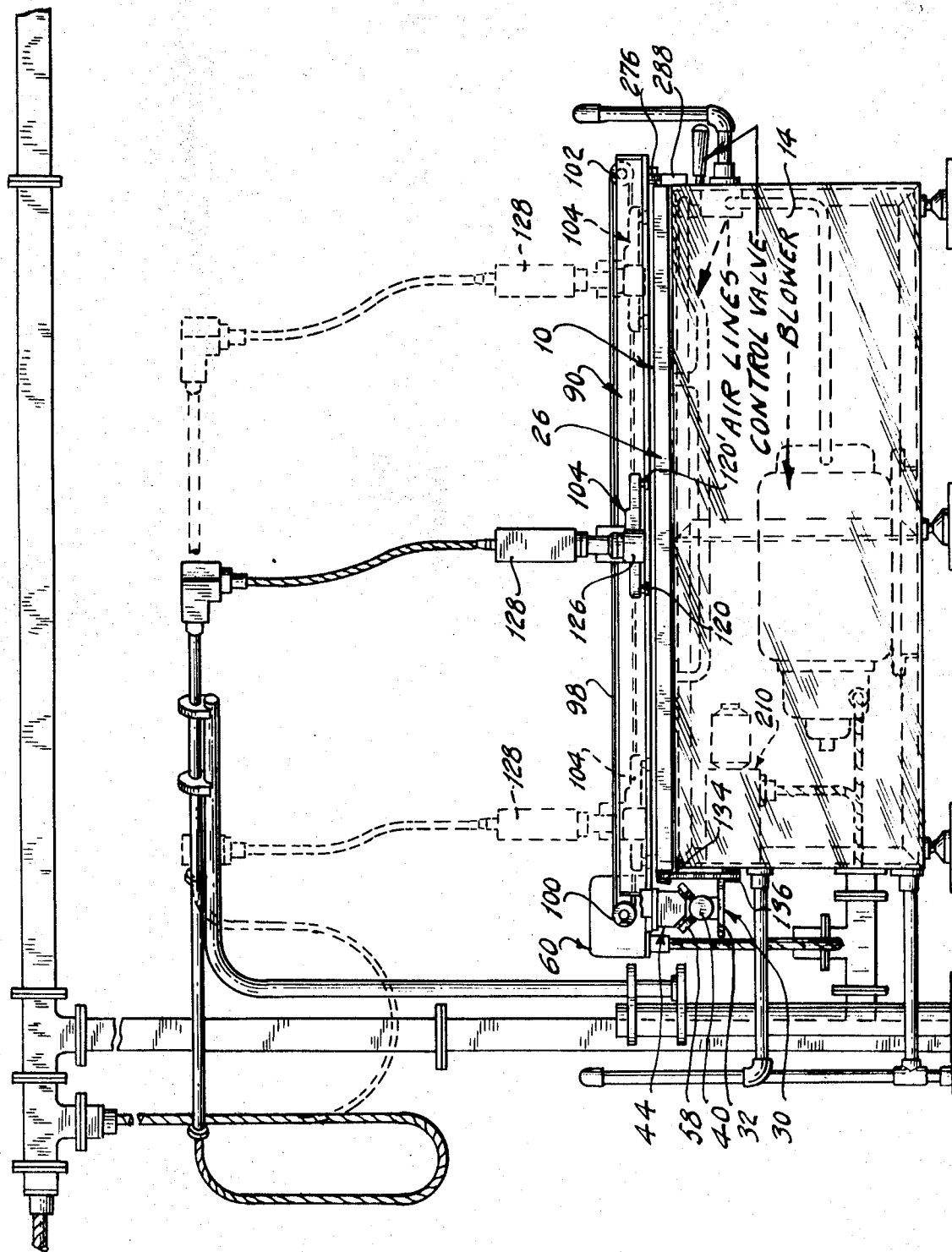


Fig. 4A

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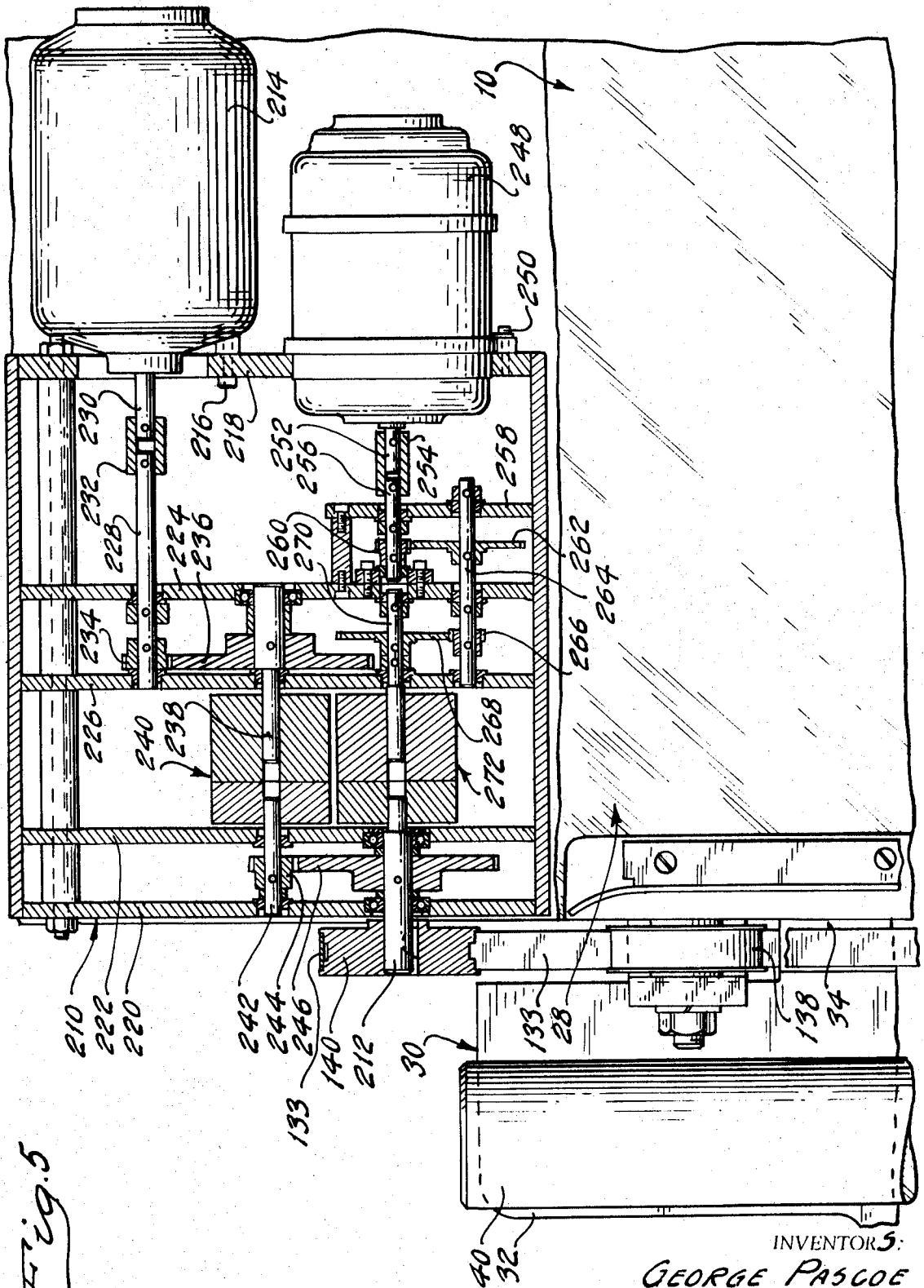


Fig. 5

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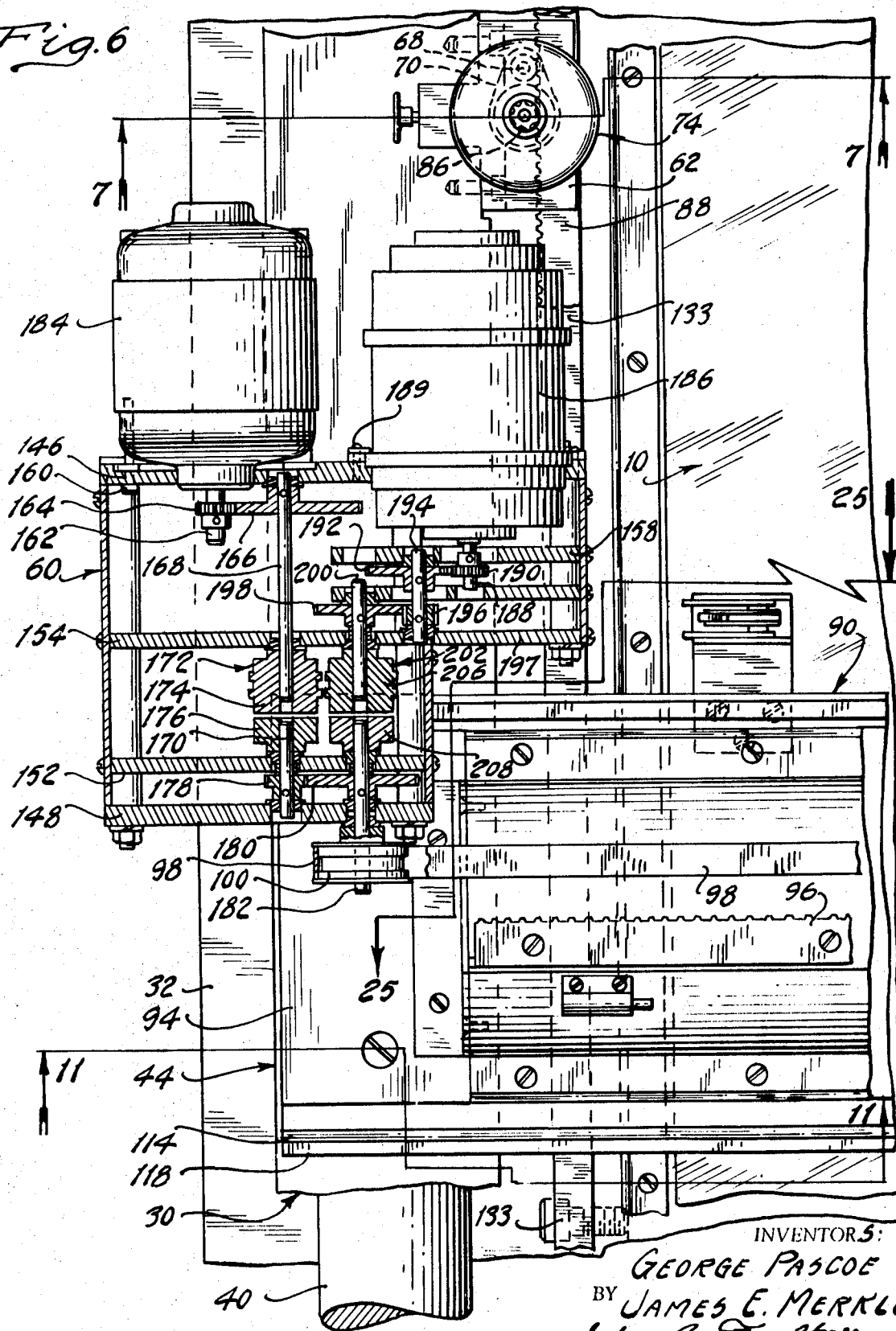
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Fig. 6

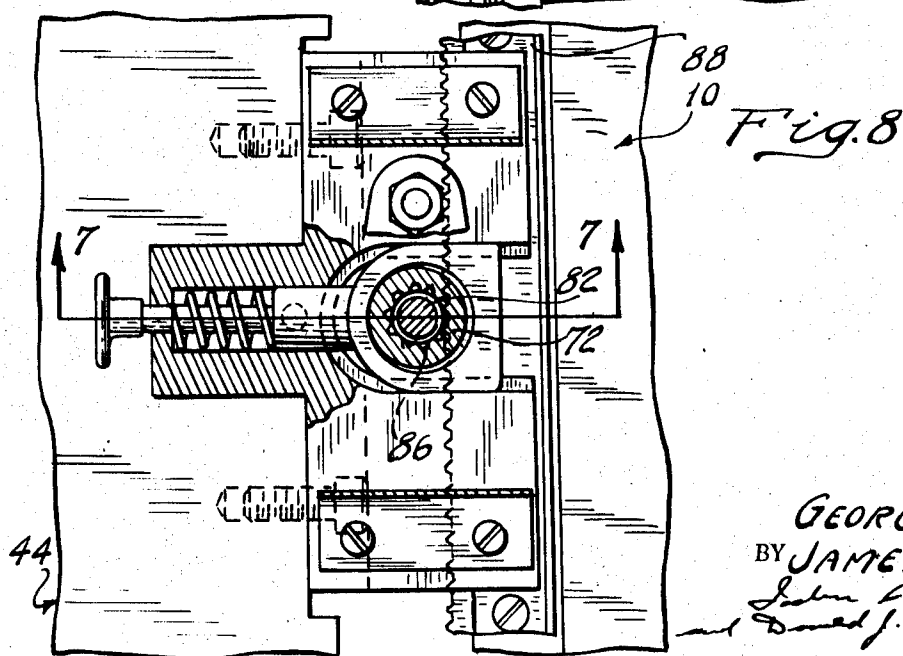
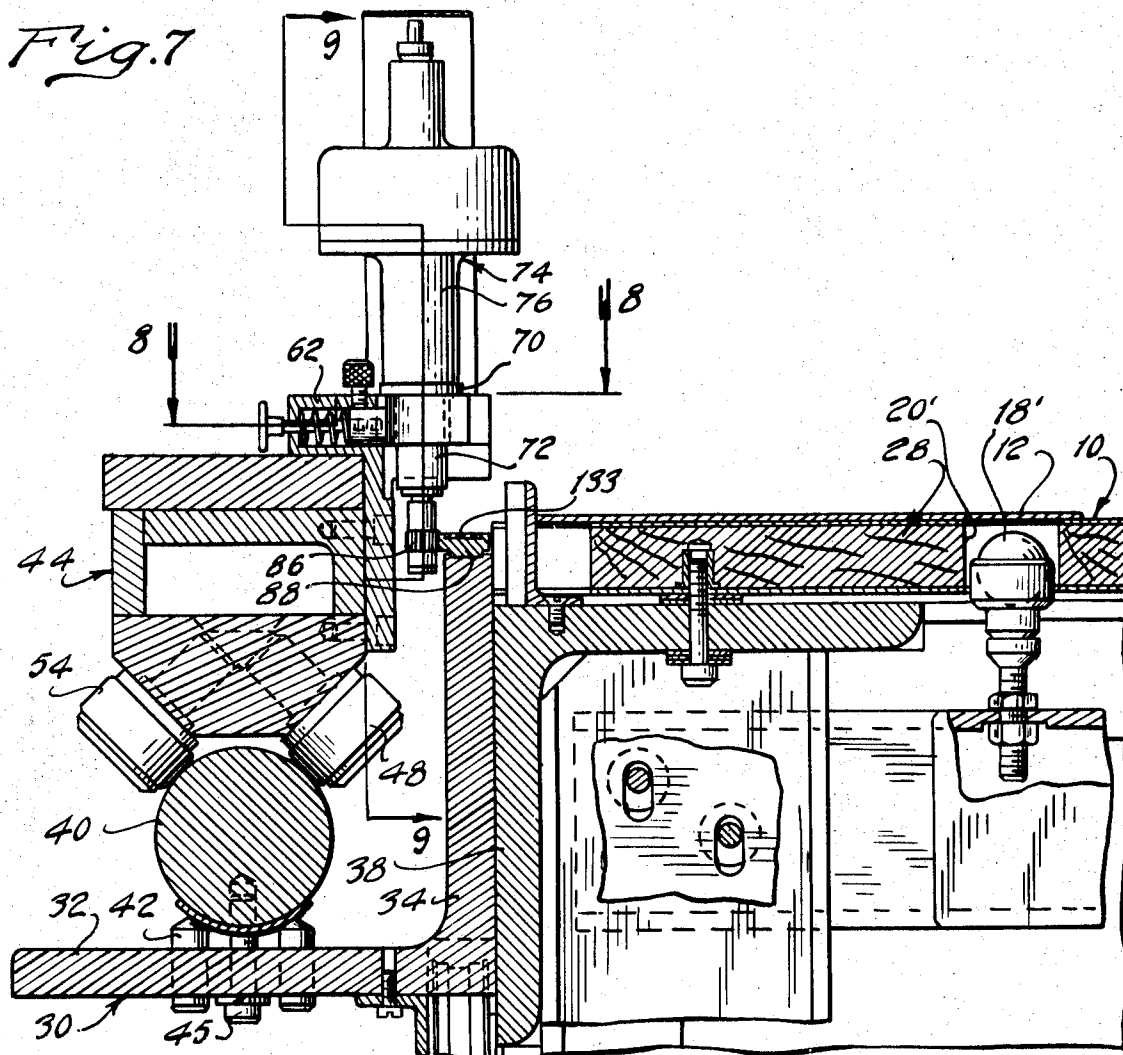


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Fig. 9

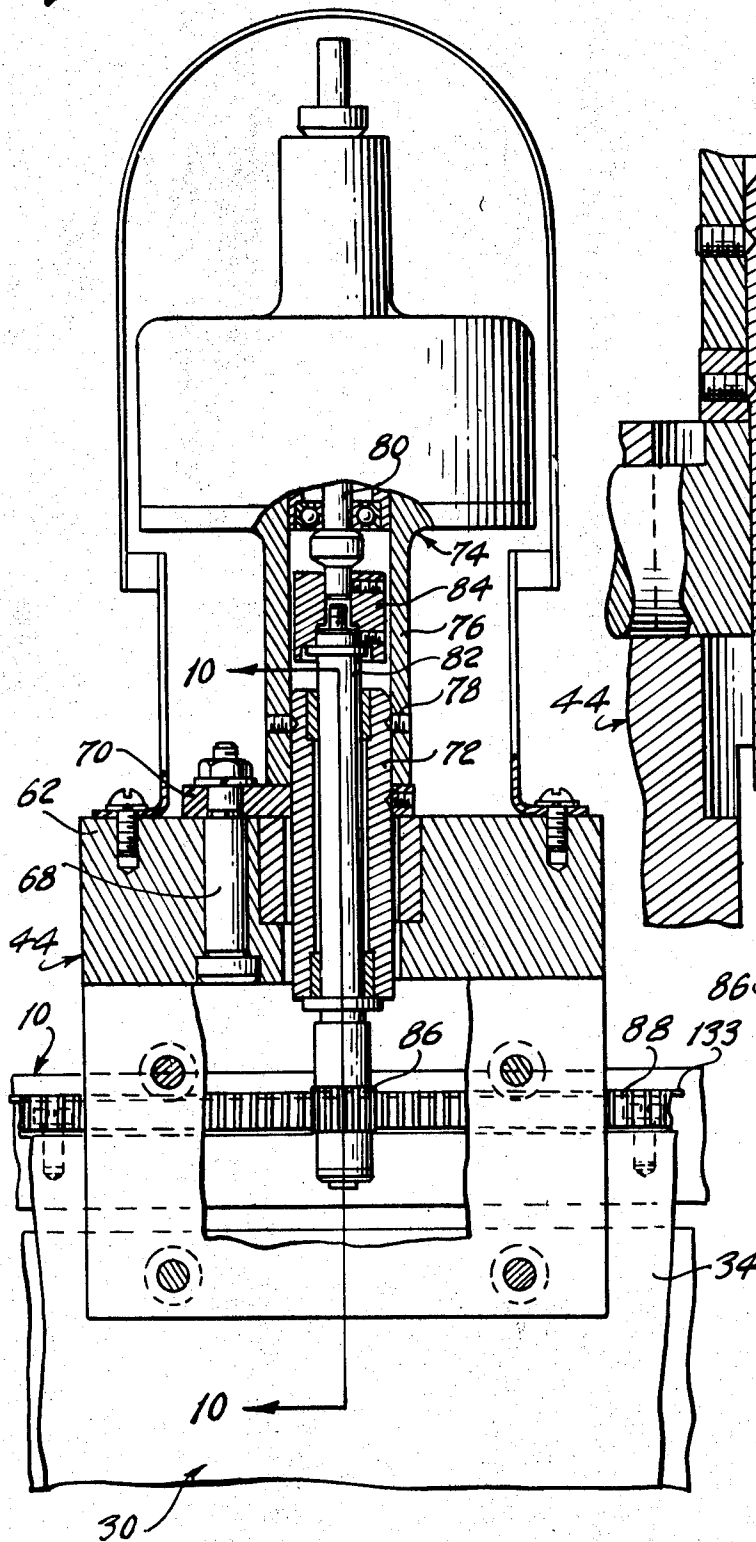
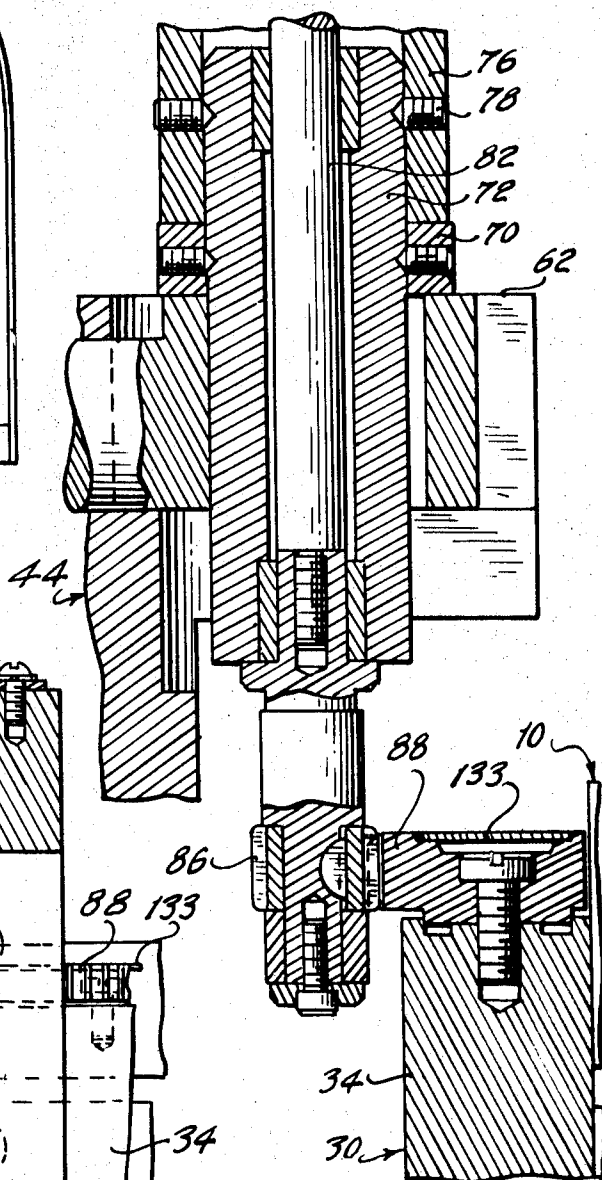


Fig. 10



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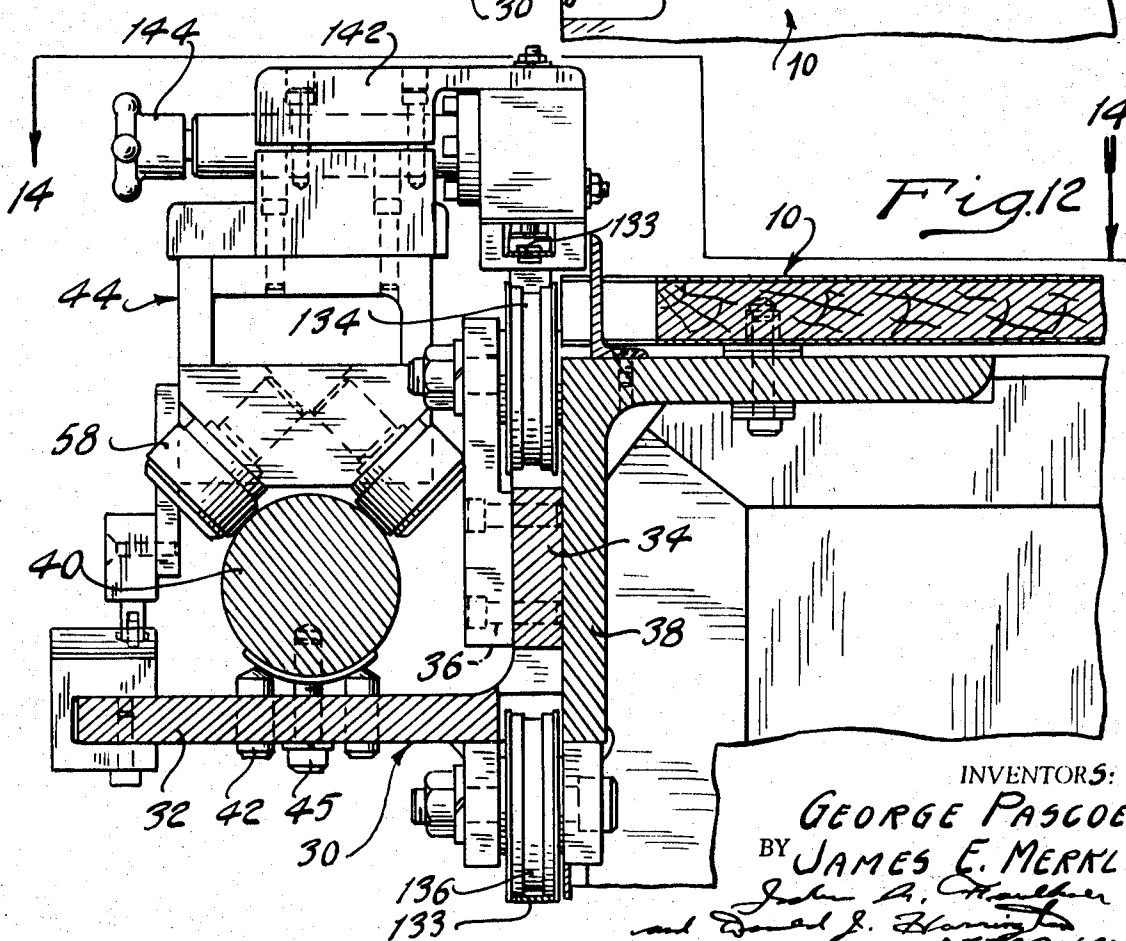
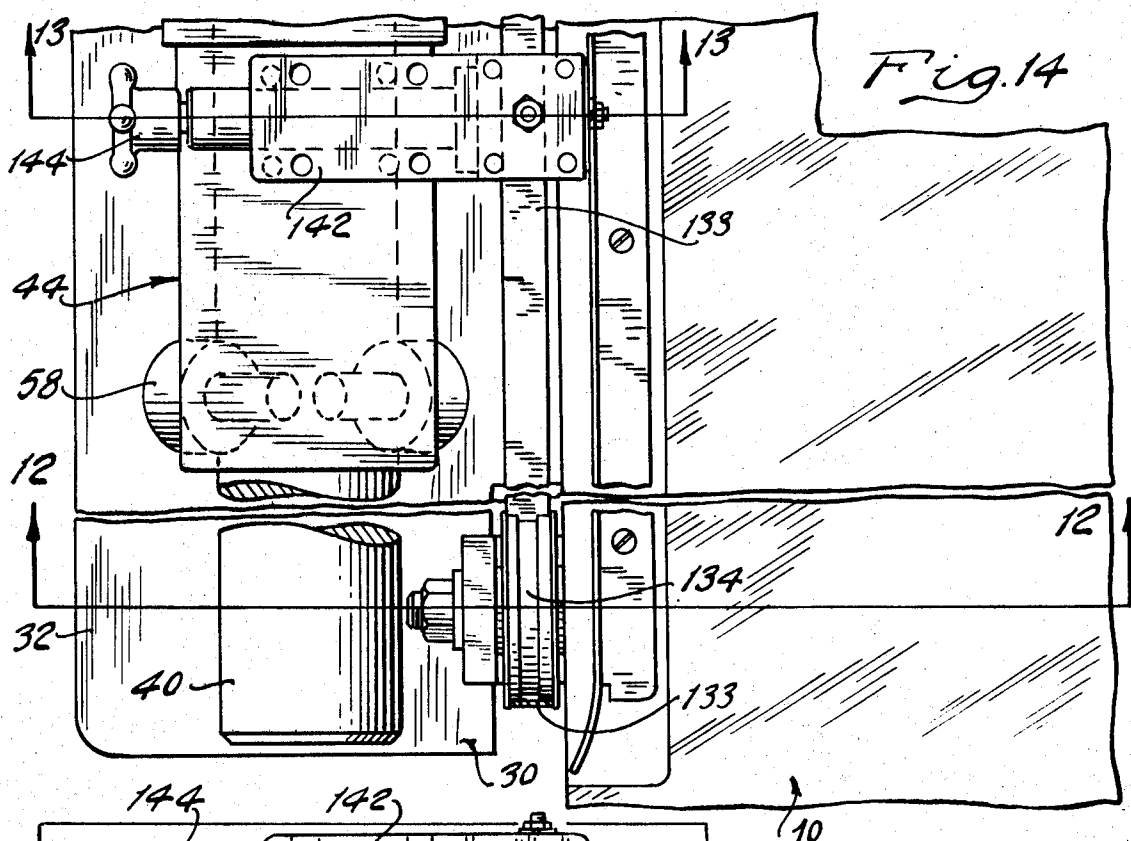
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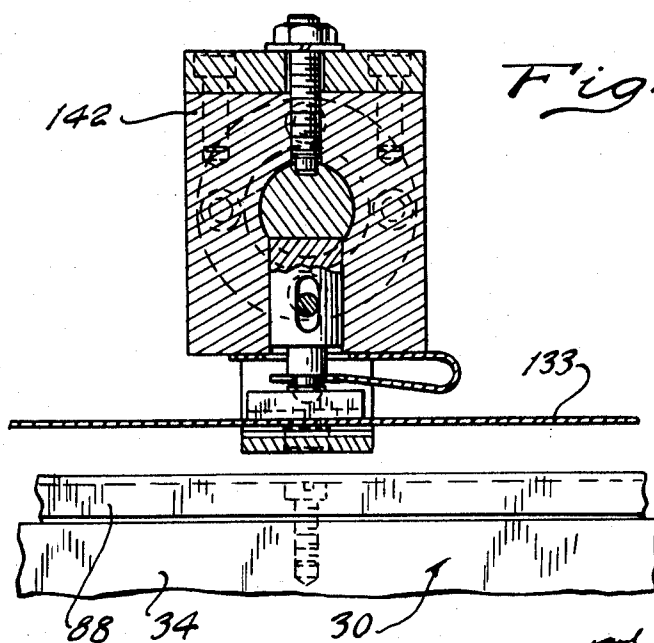
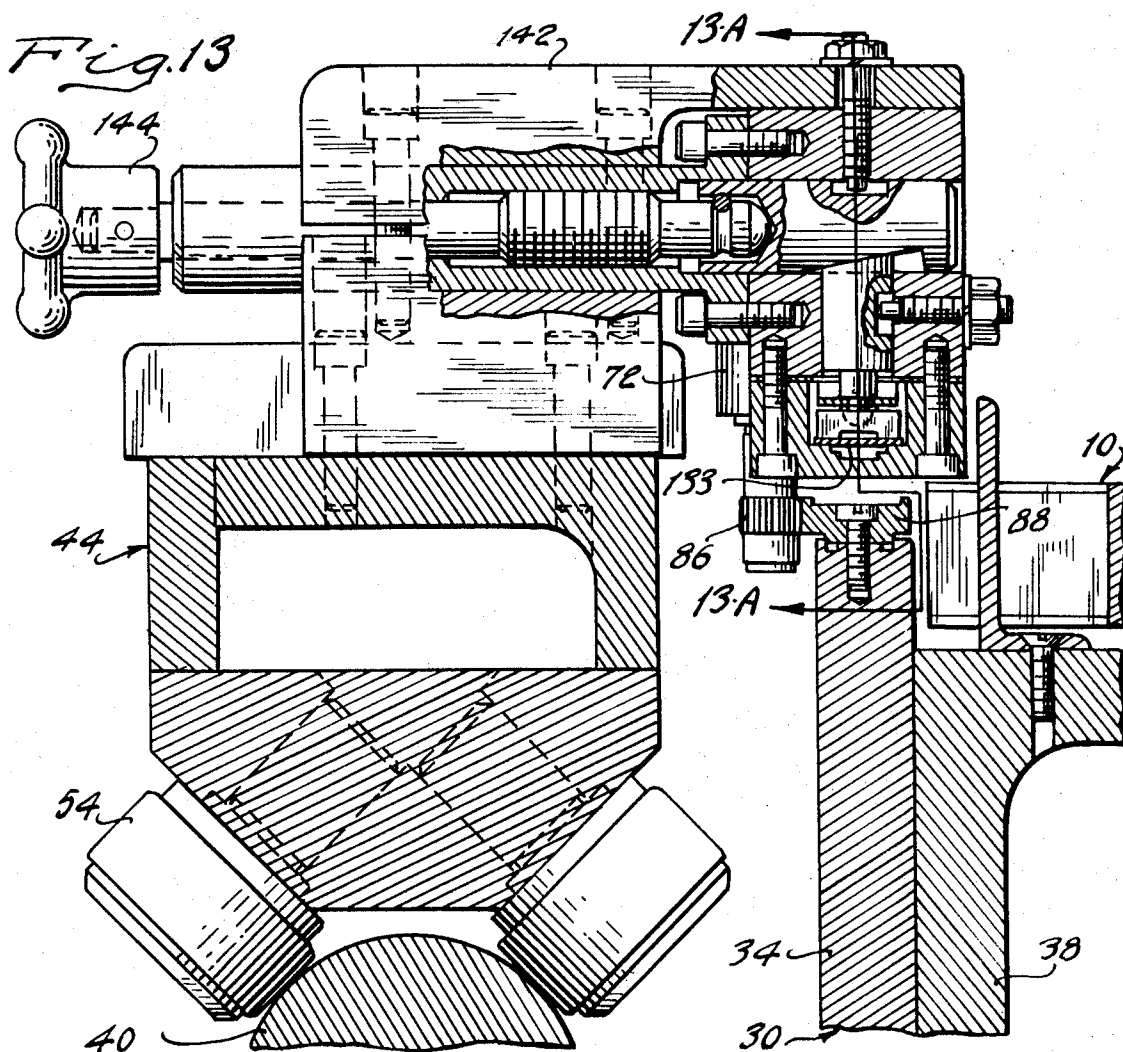


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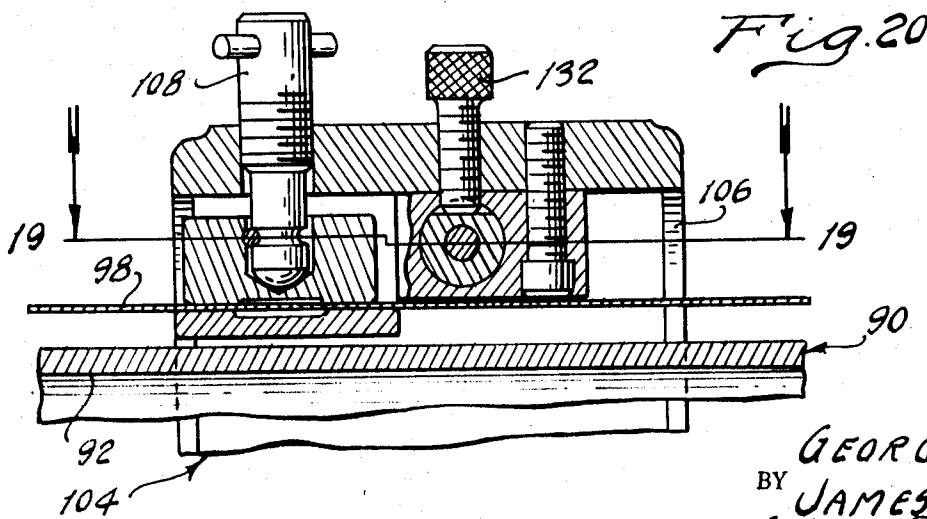
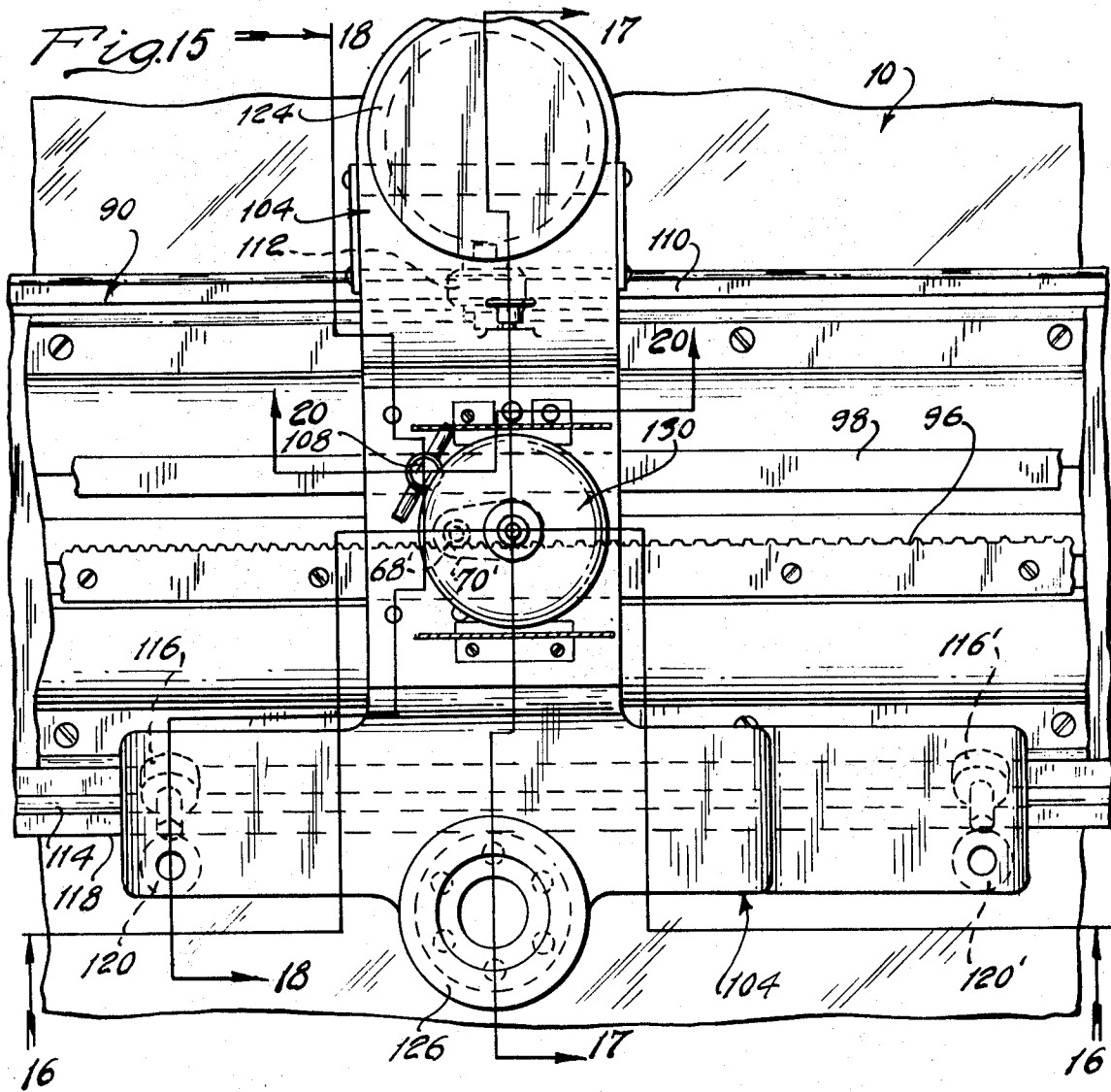
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Fig. 16

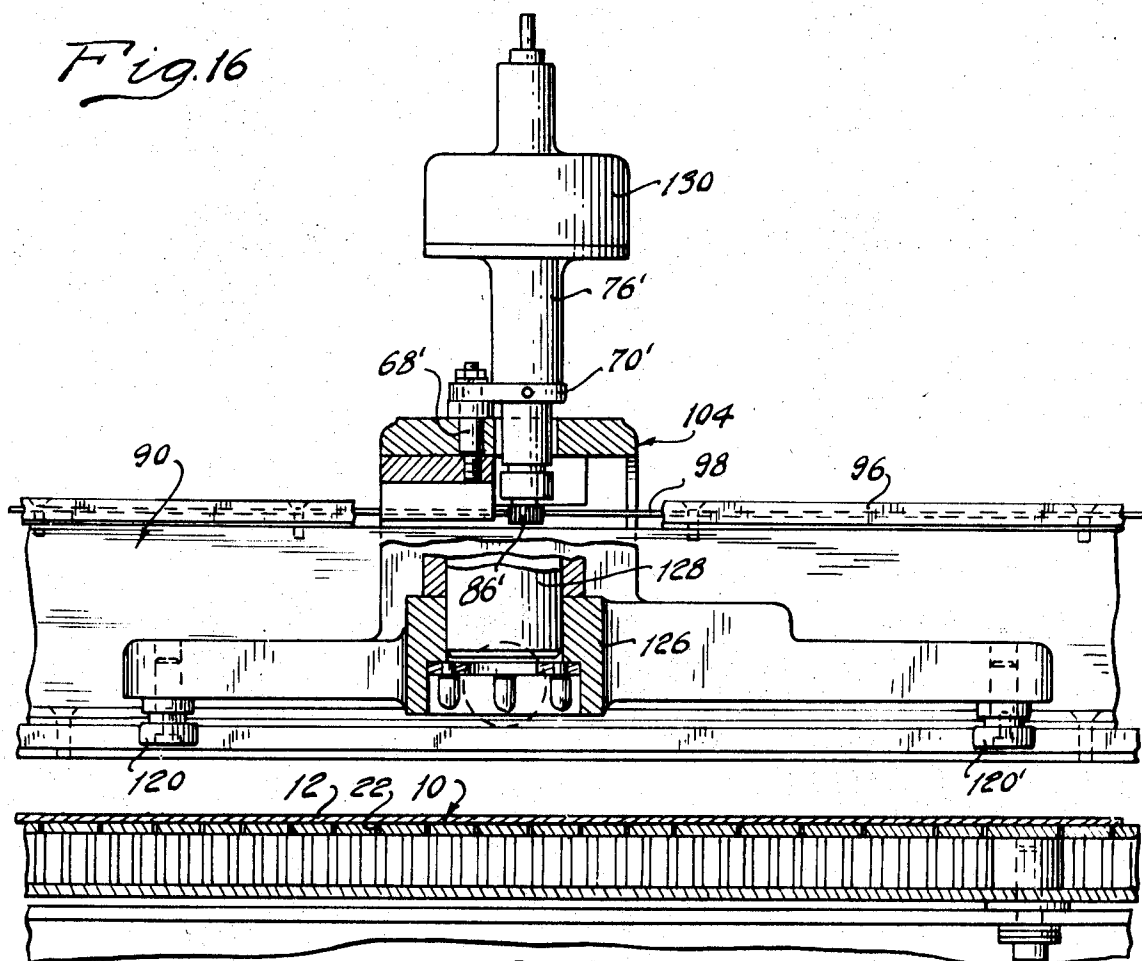
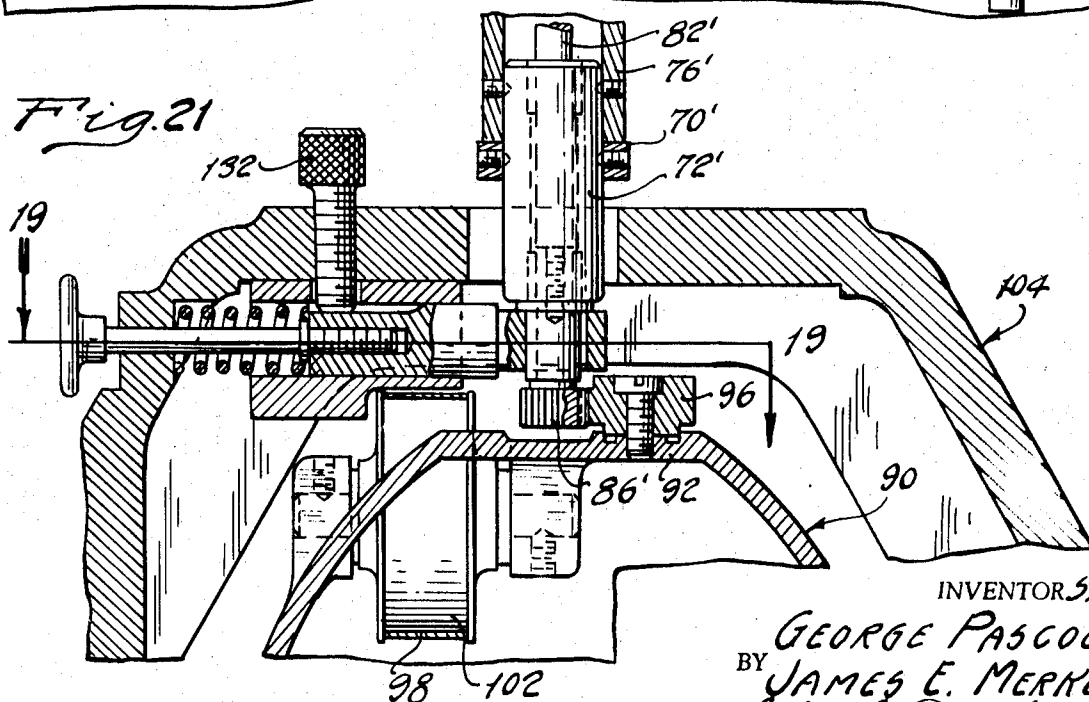


Fig. 21

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Fig. 18

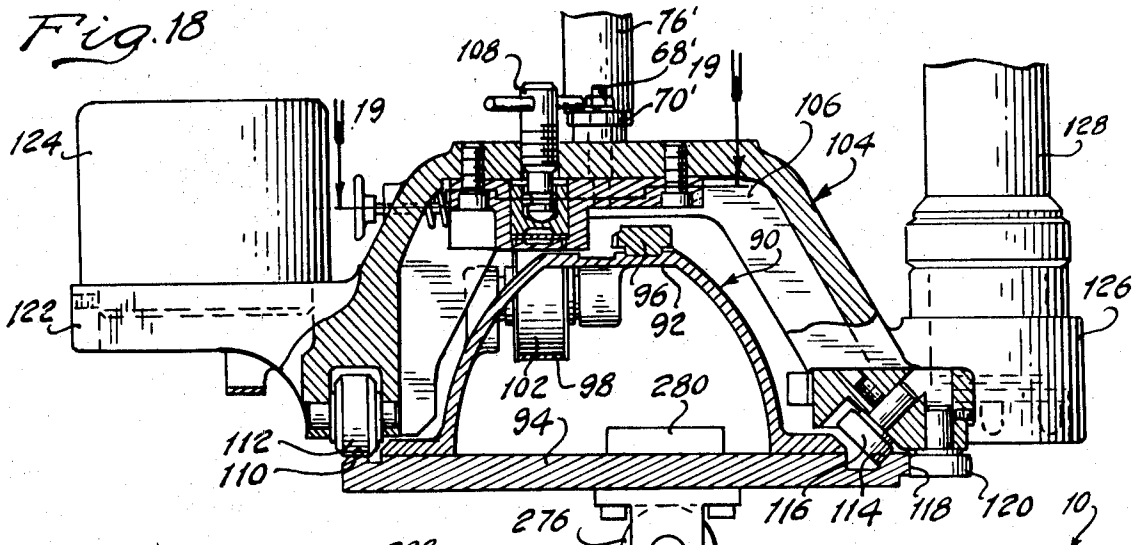


Fig. 17

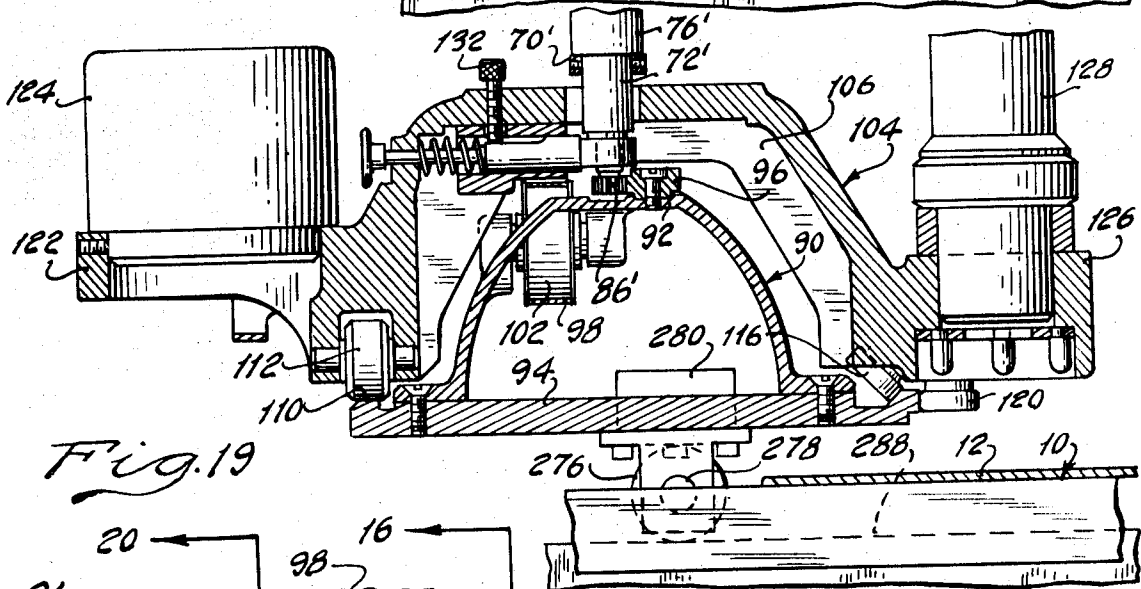
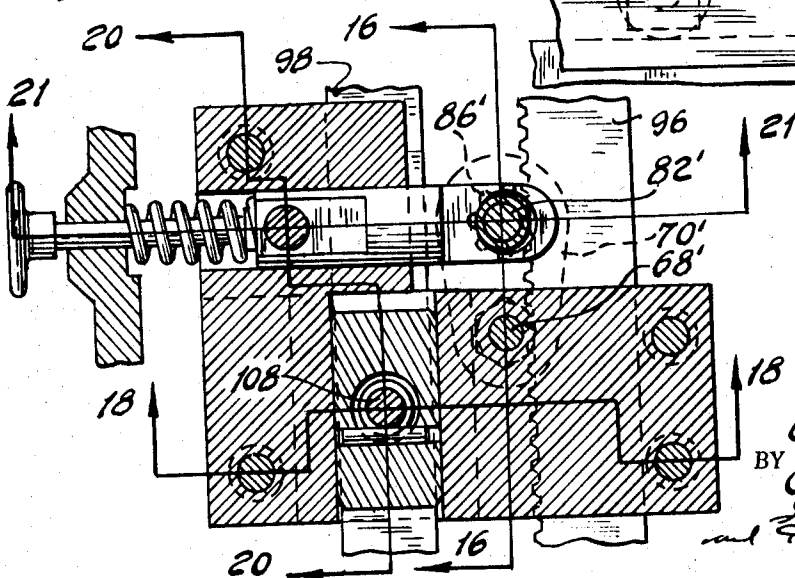


Fig. 19



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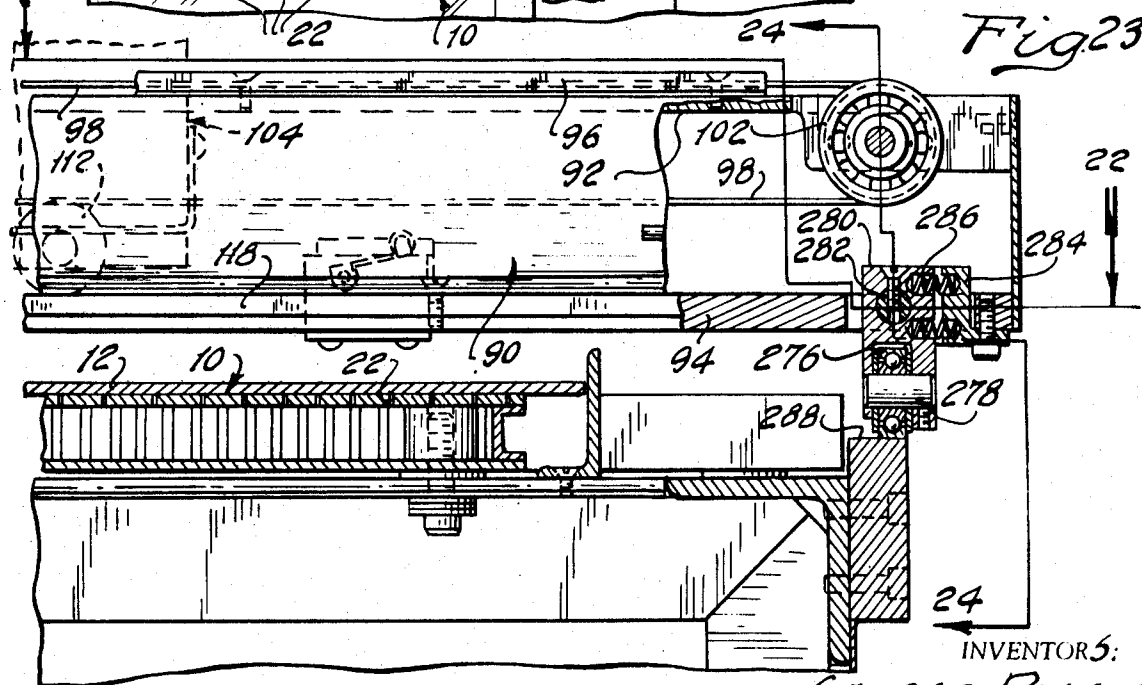
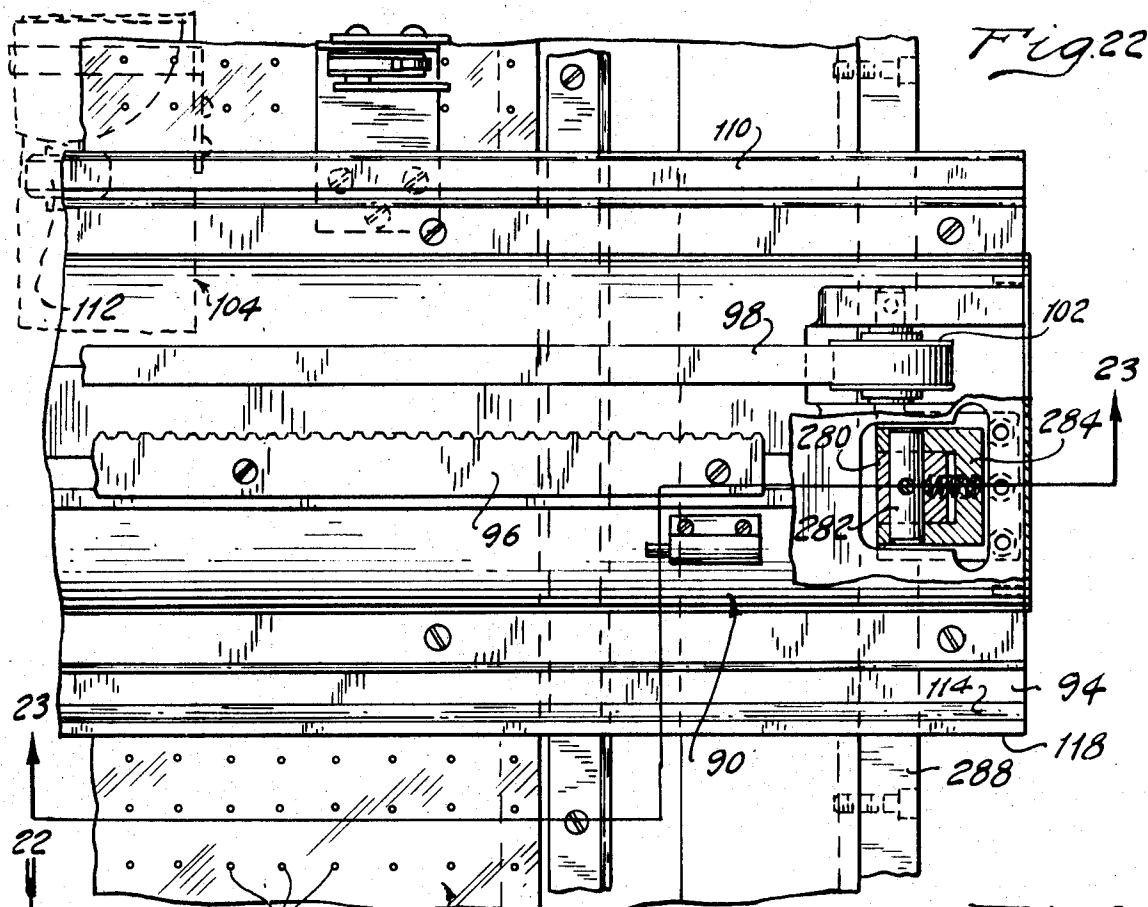
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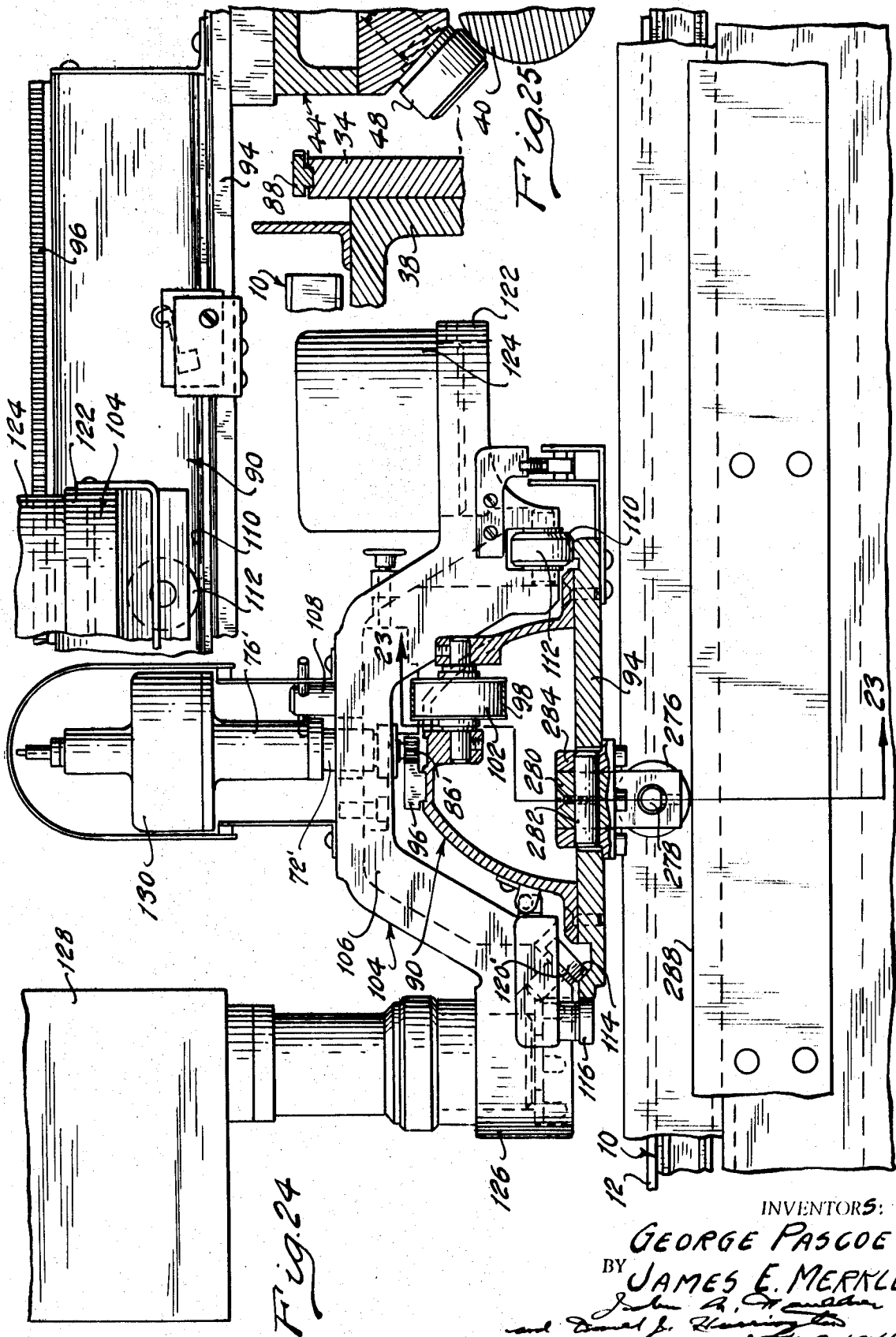
INVENTOR'S:

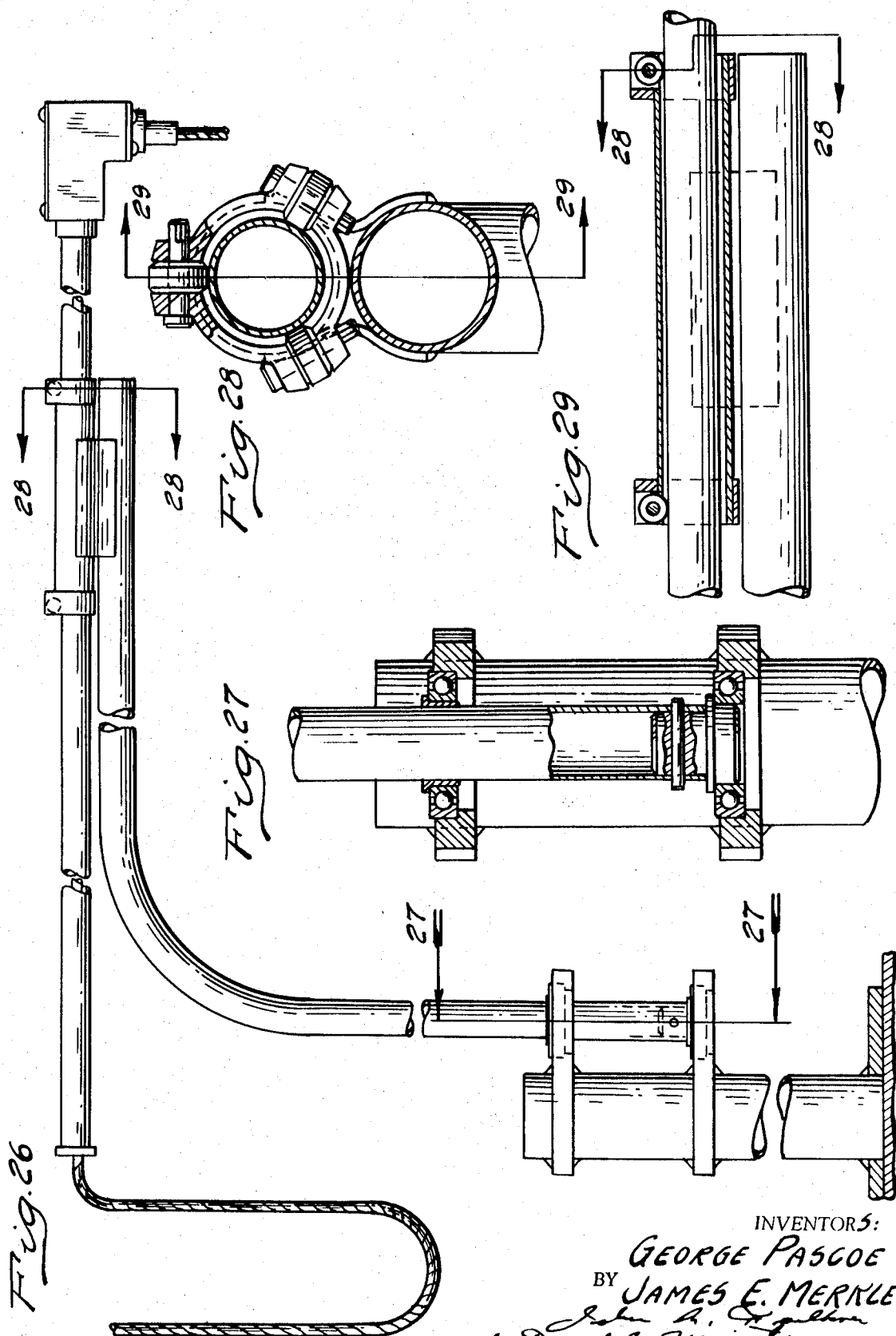
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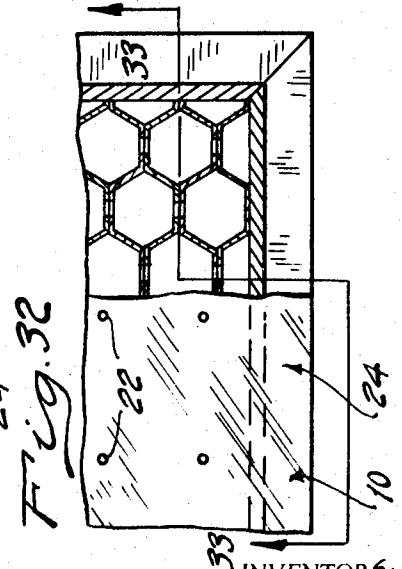
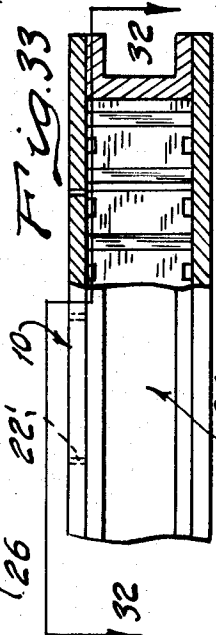
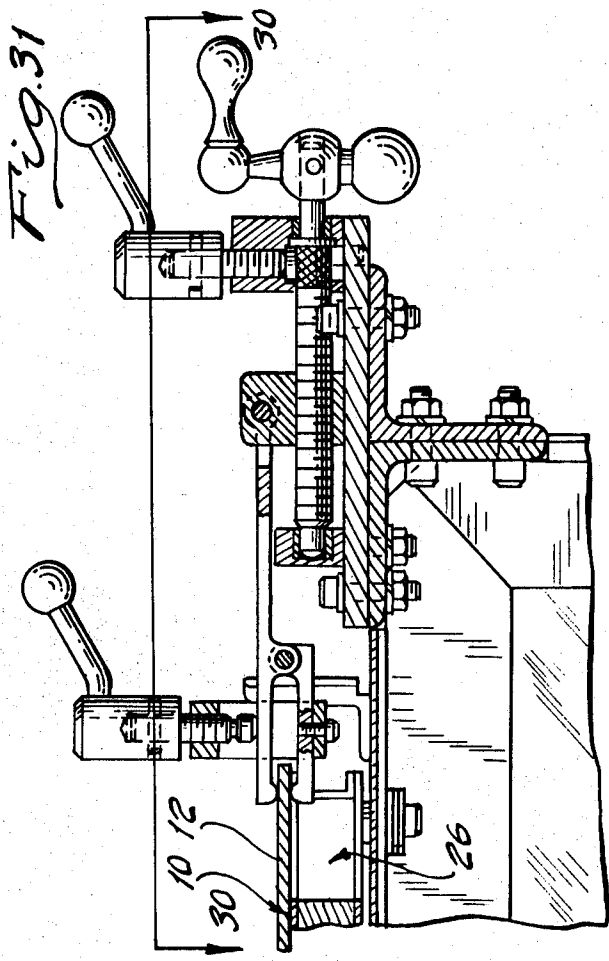
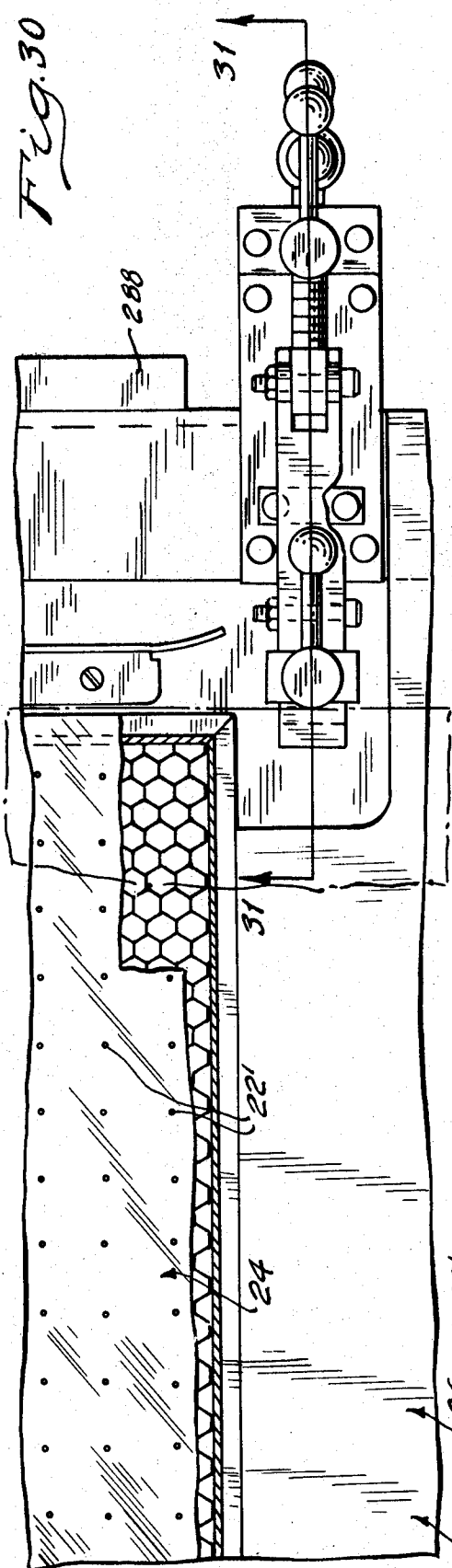
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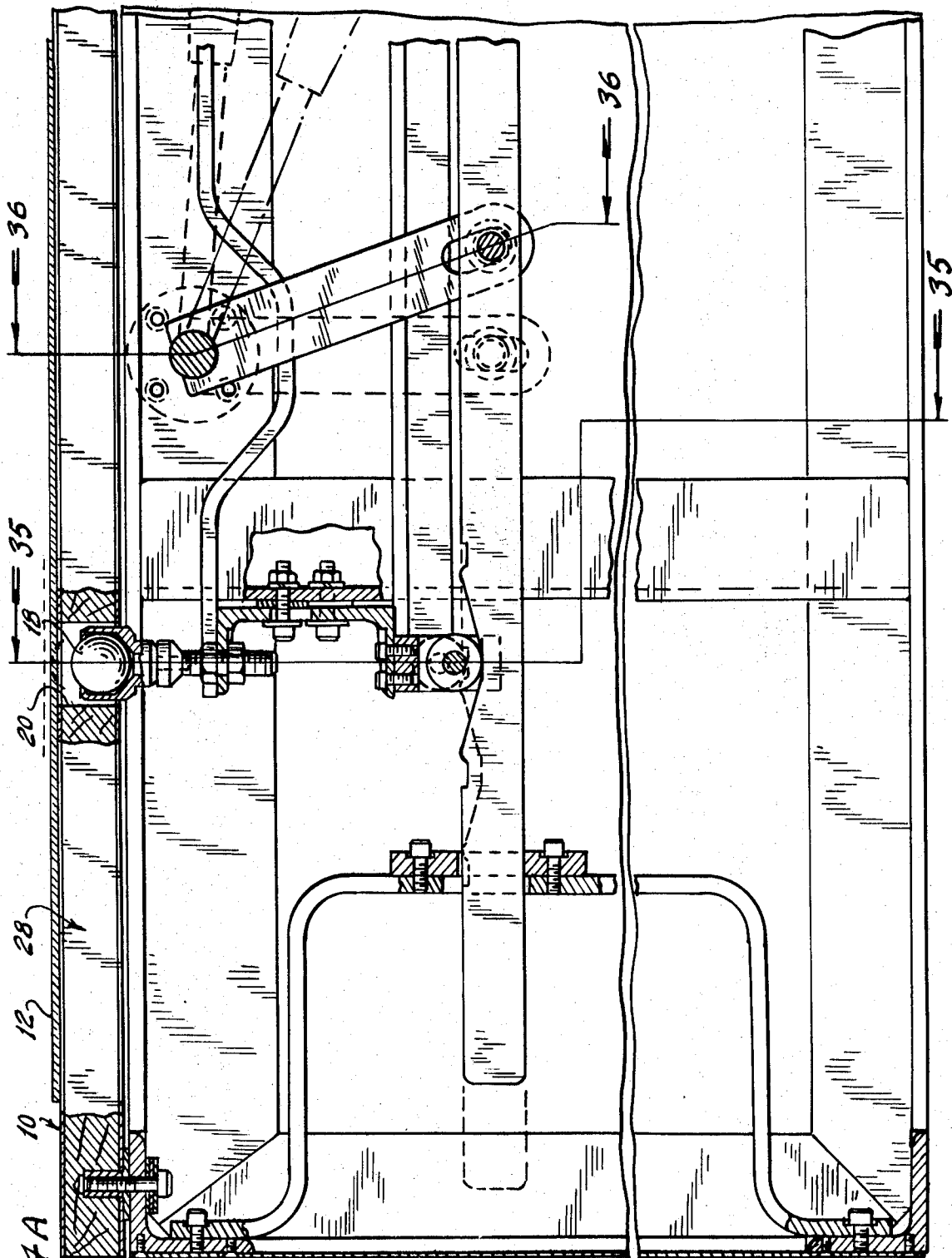




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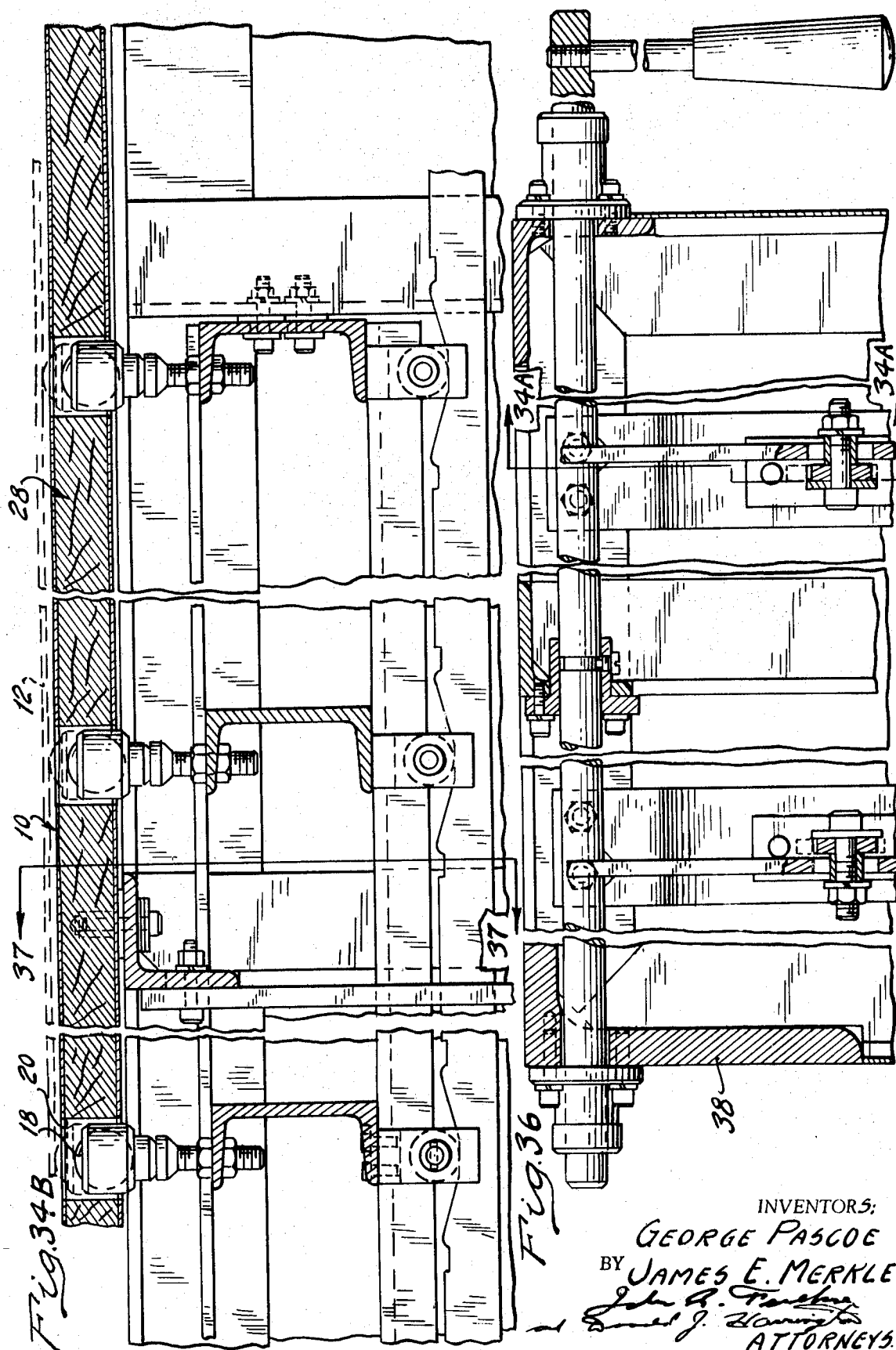
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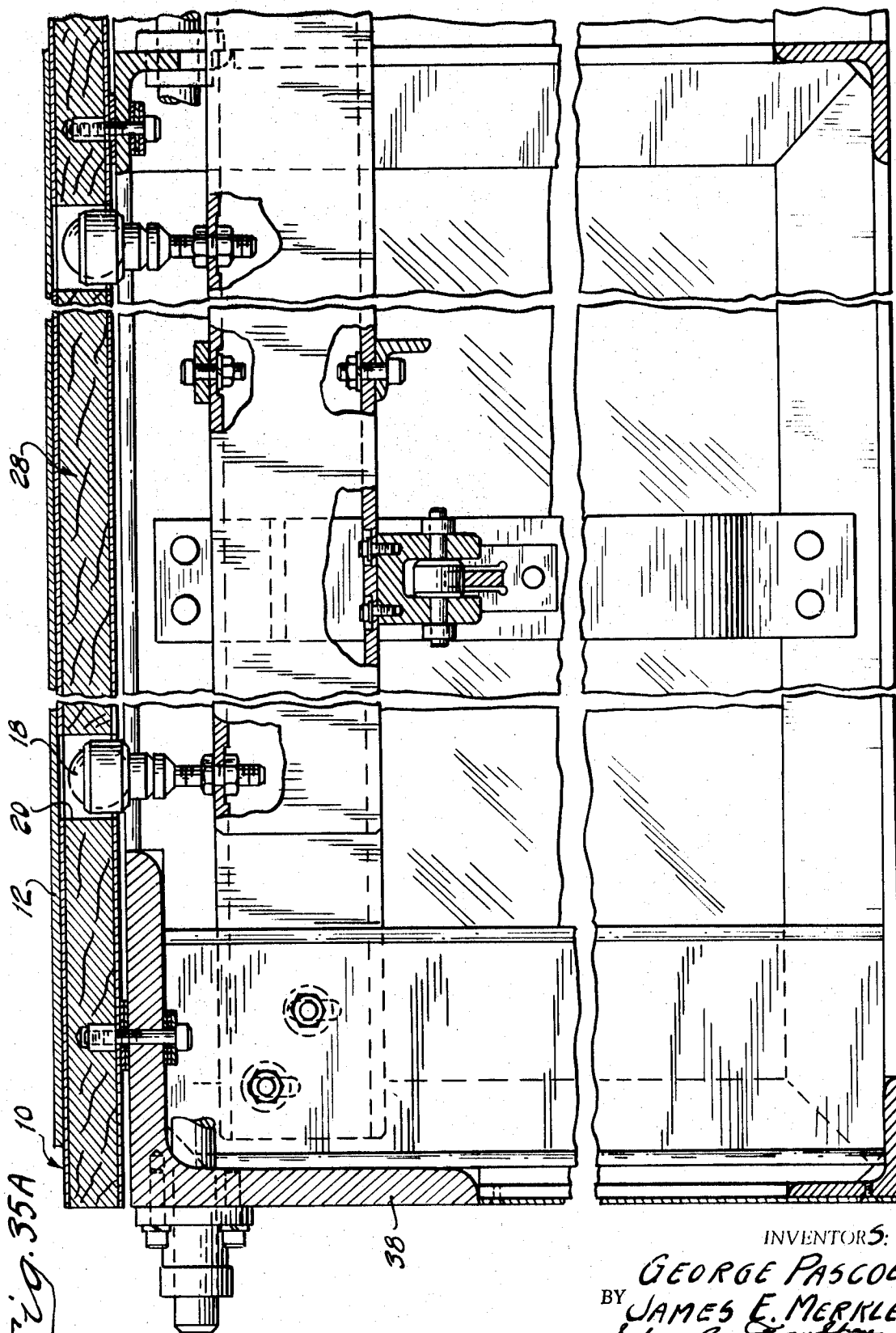


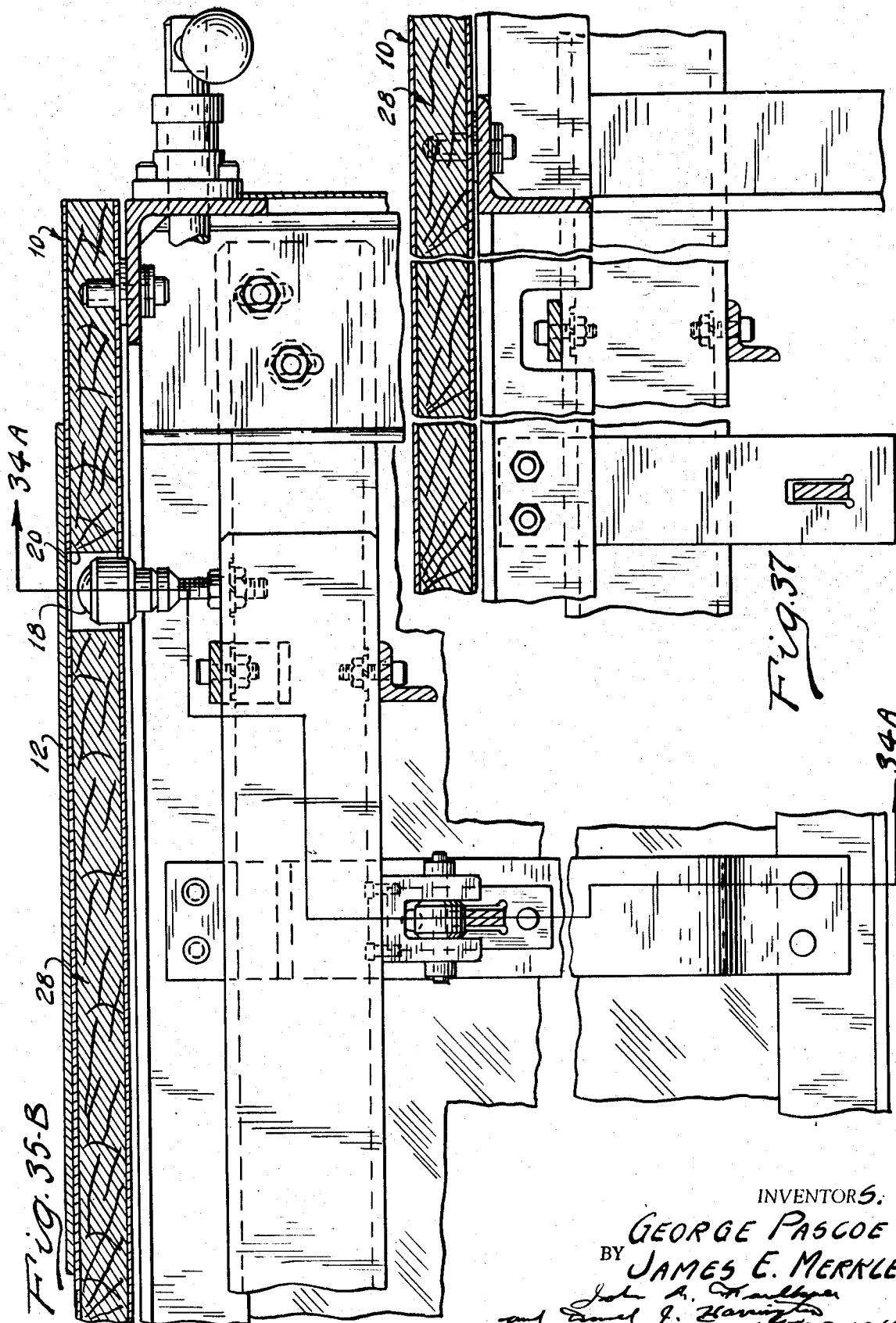
Fig. 35A

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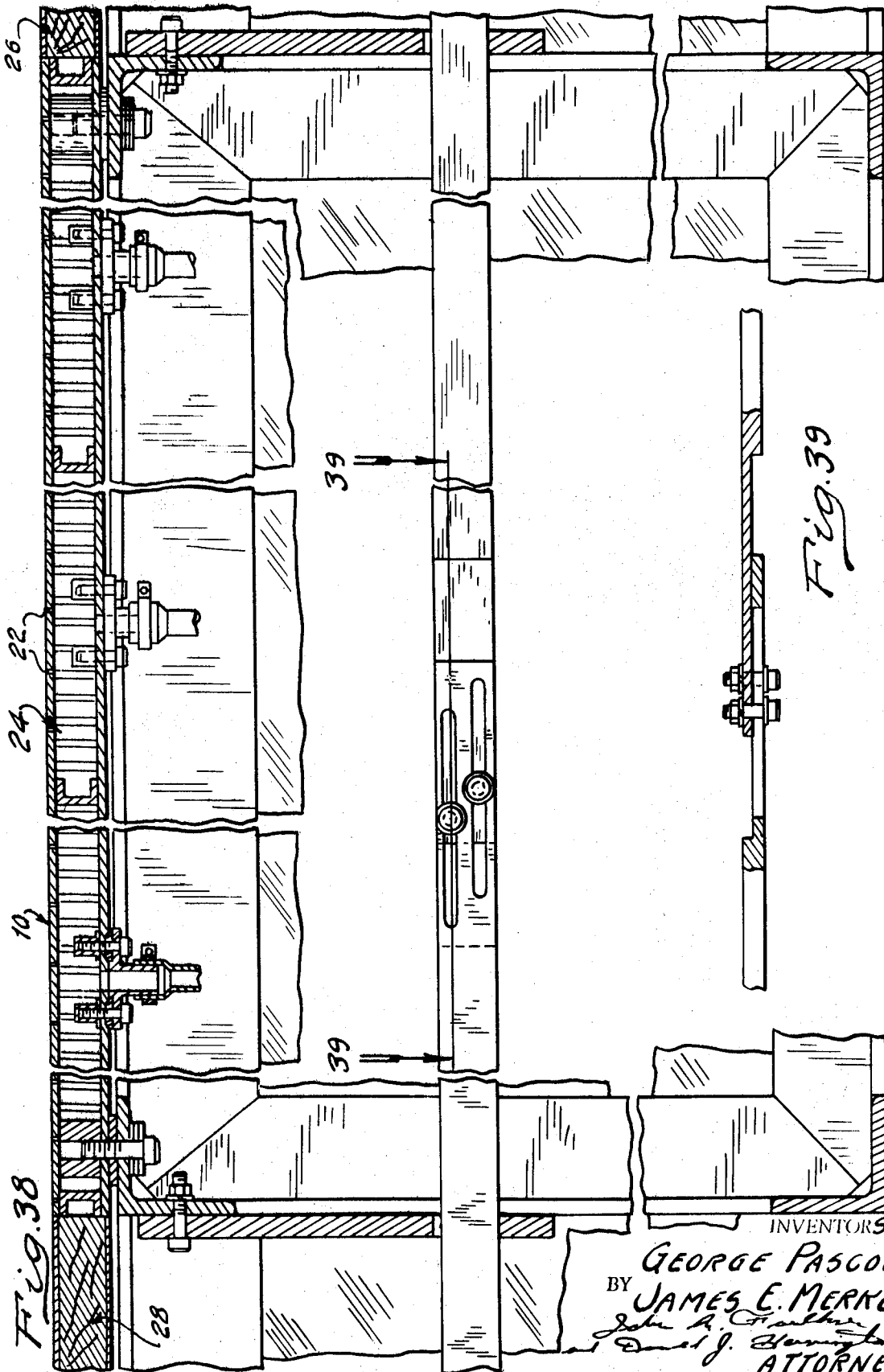
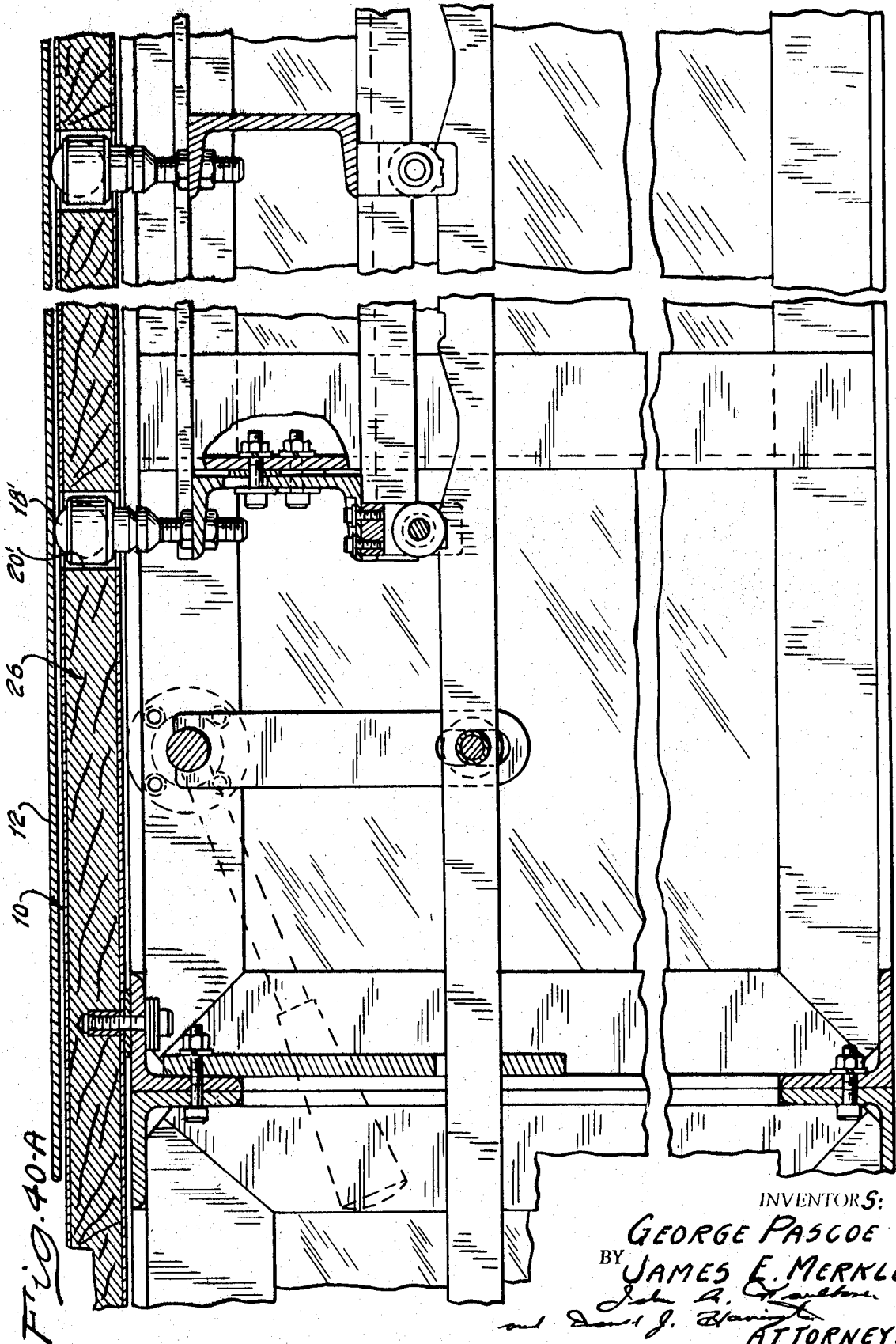


Fig. 38

Fig. 39

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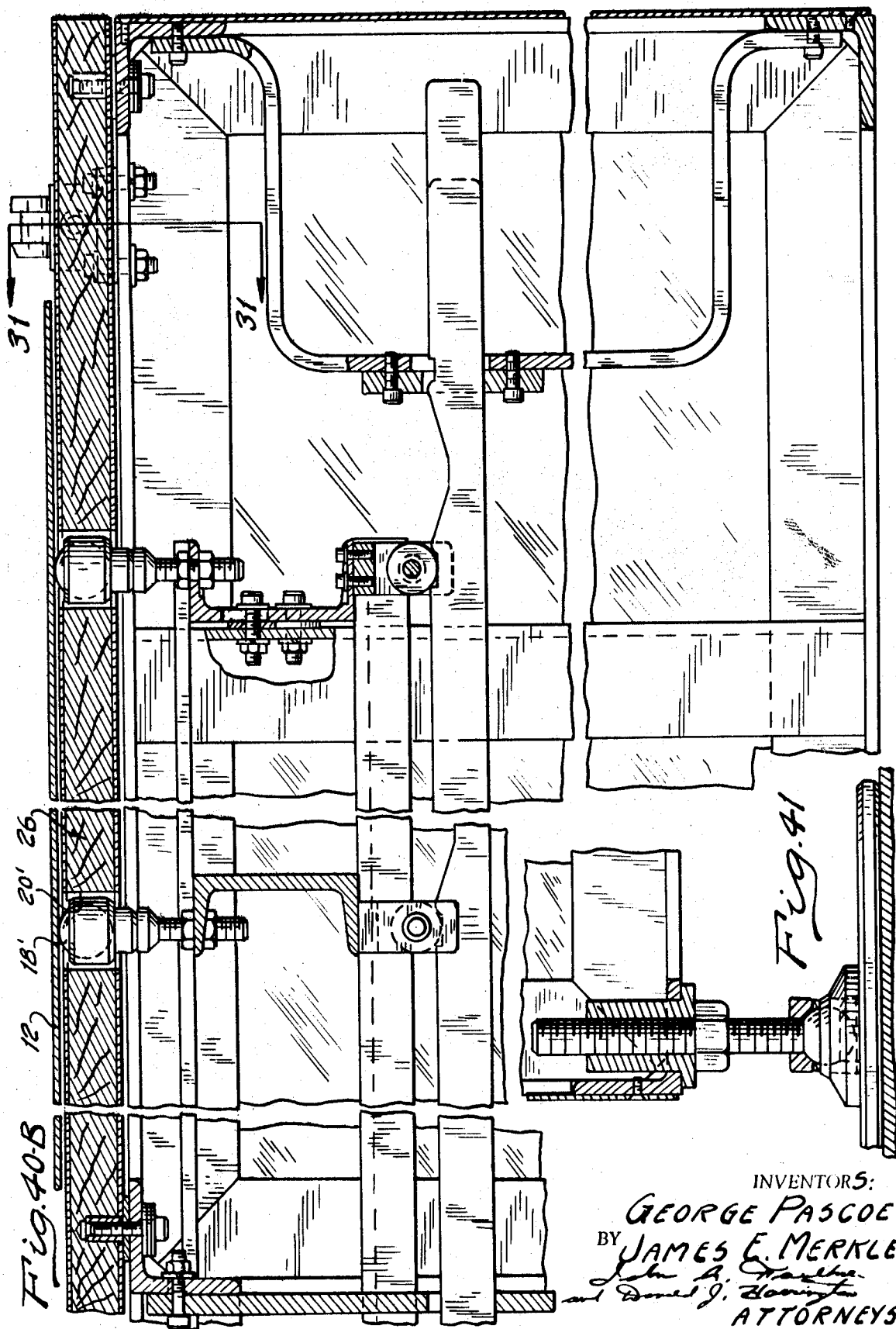


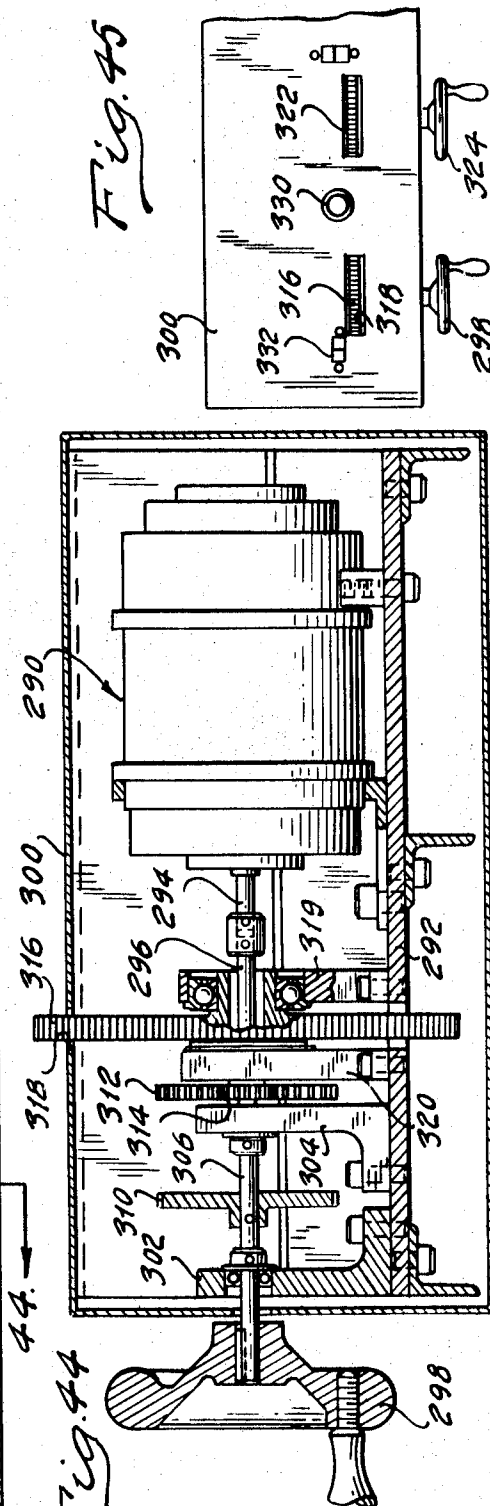
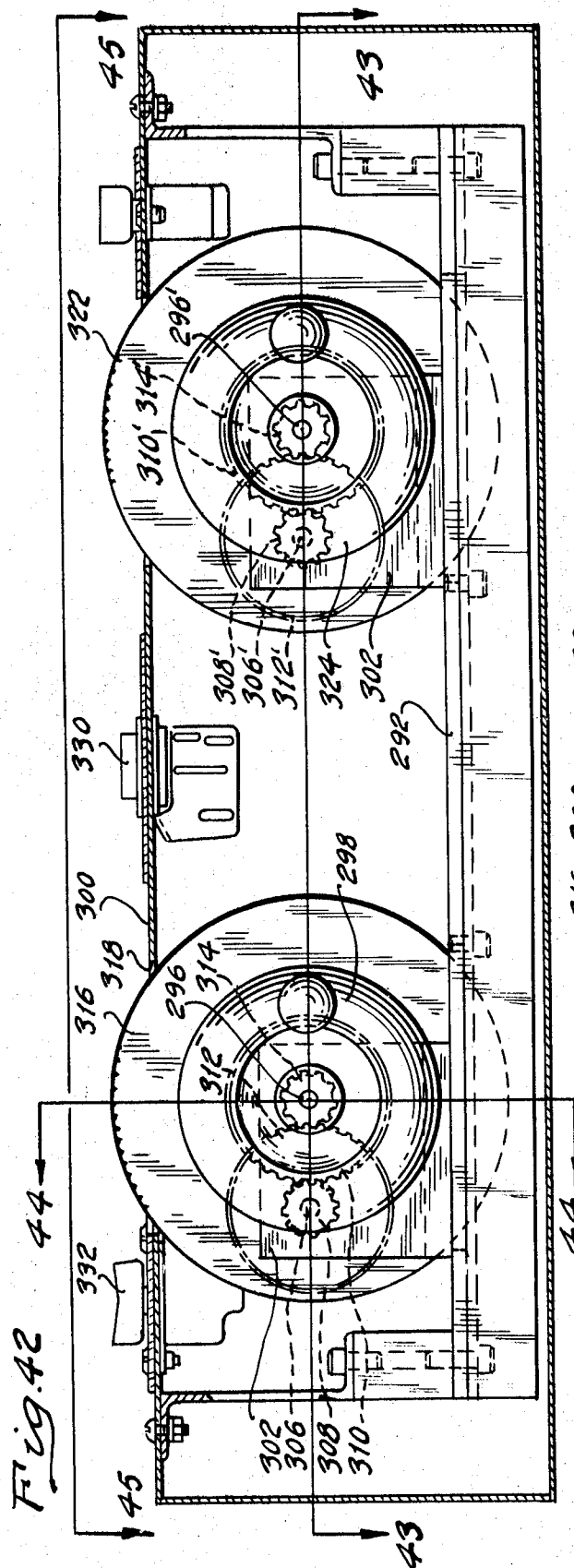
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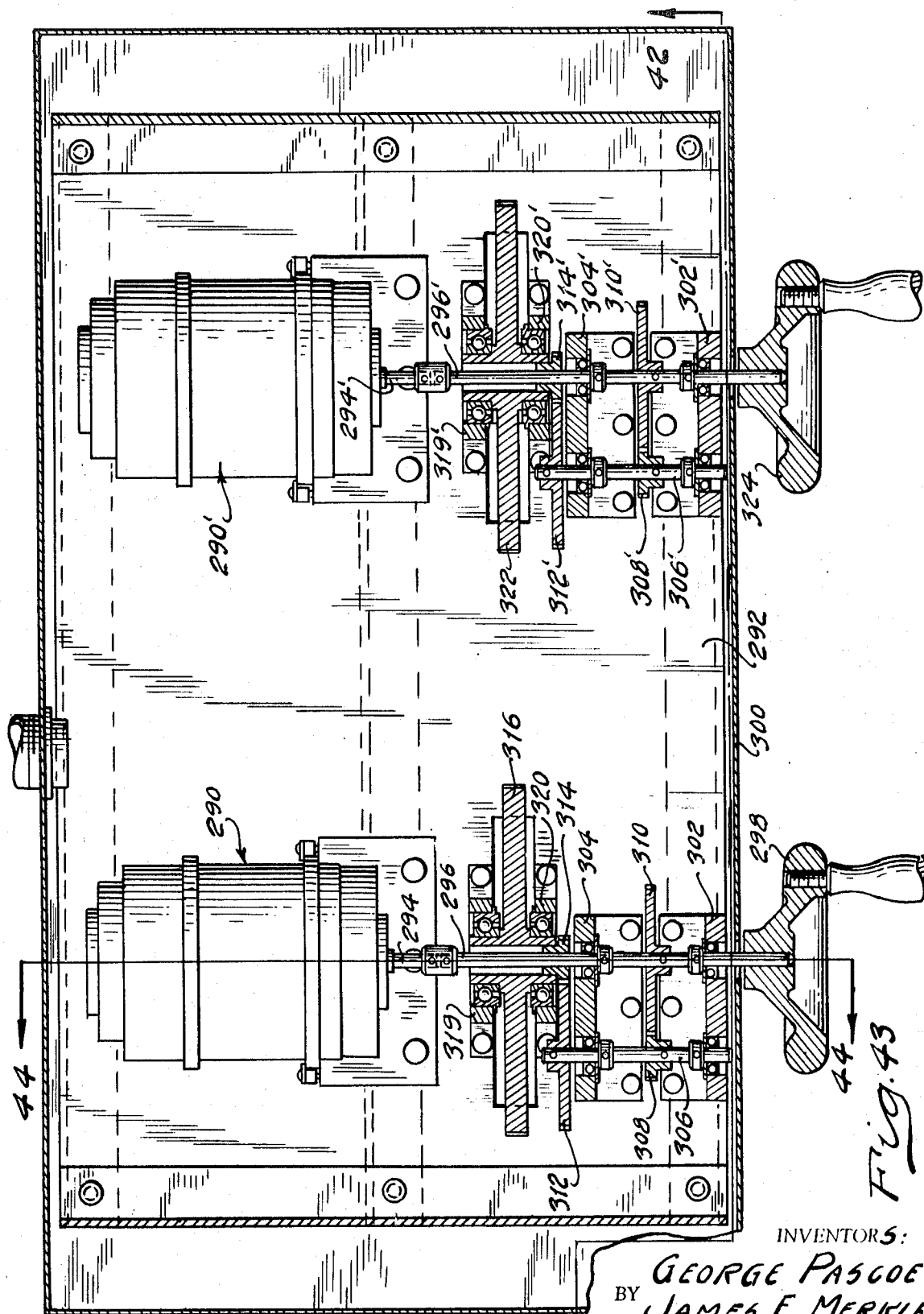


Fig. 43

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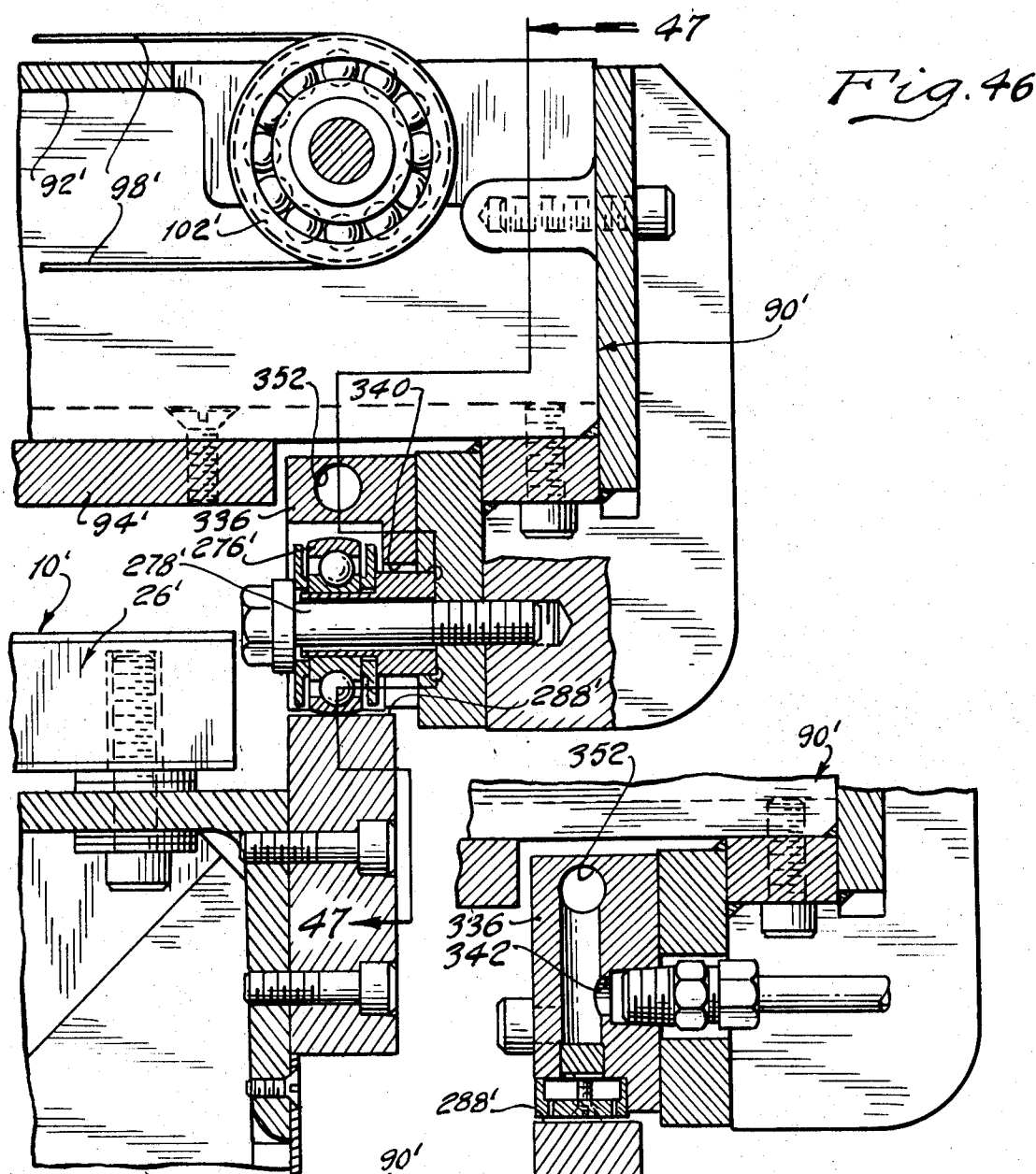


Fig. 46

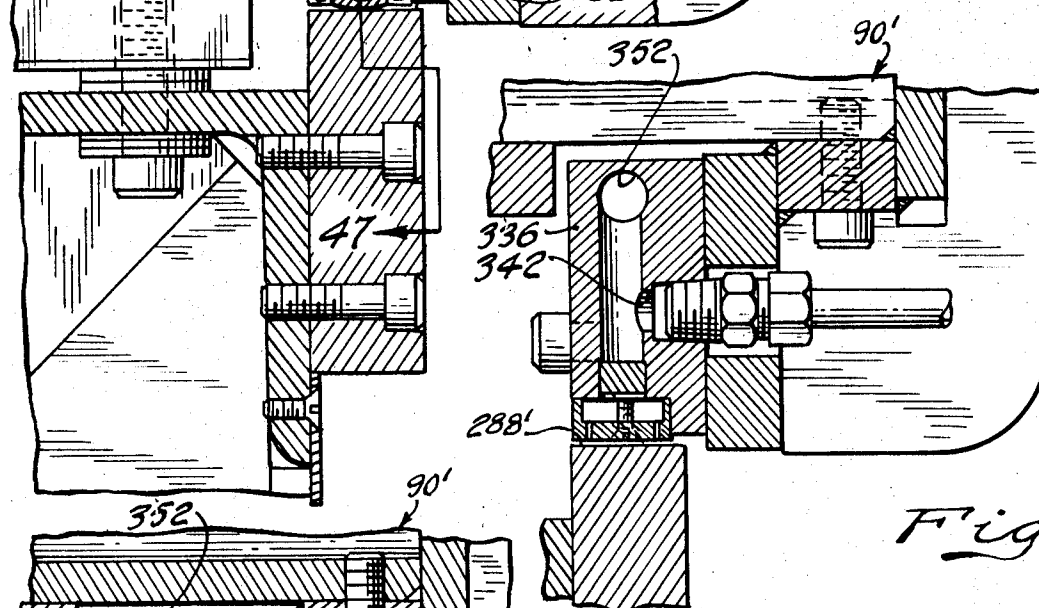


Fig. 49

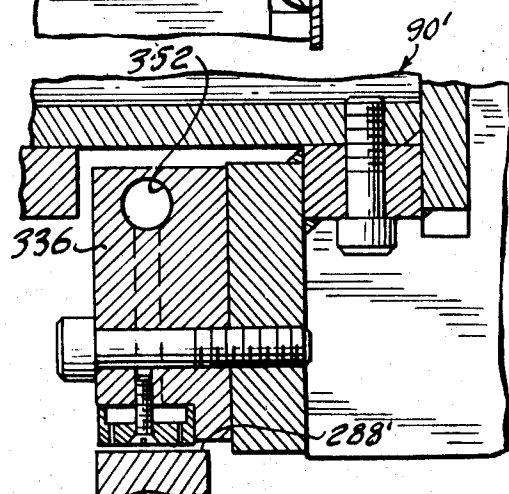


Fig. 50

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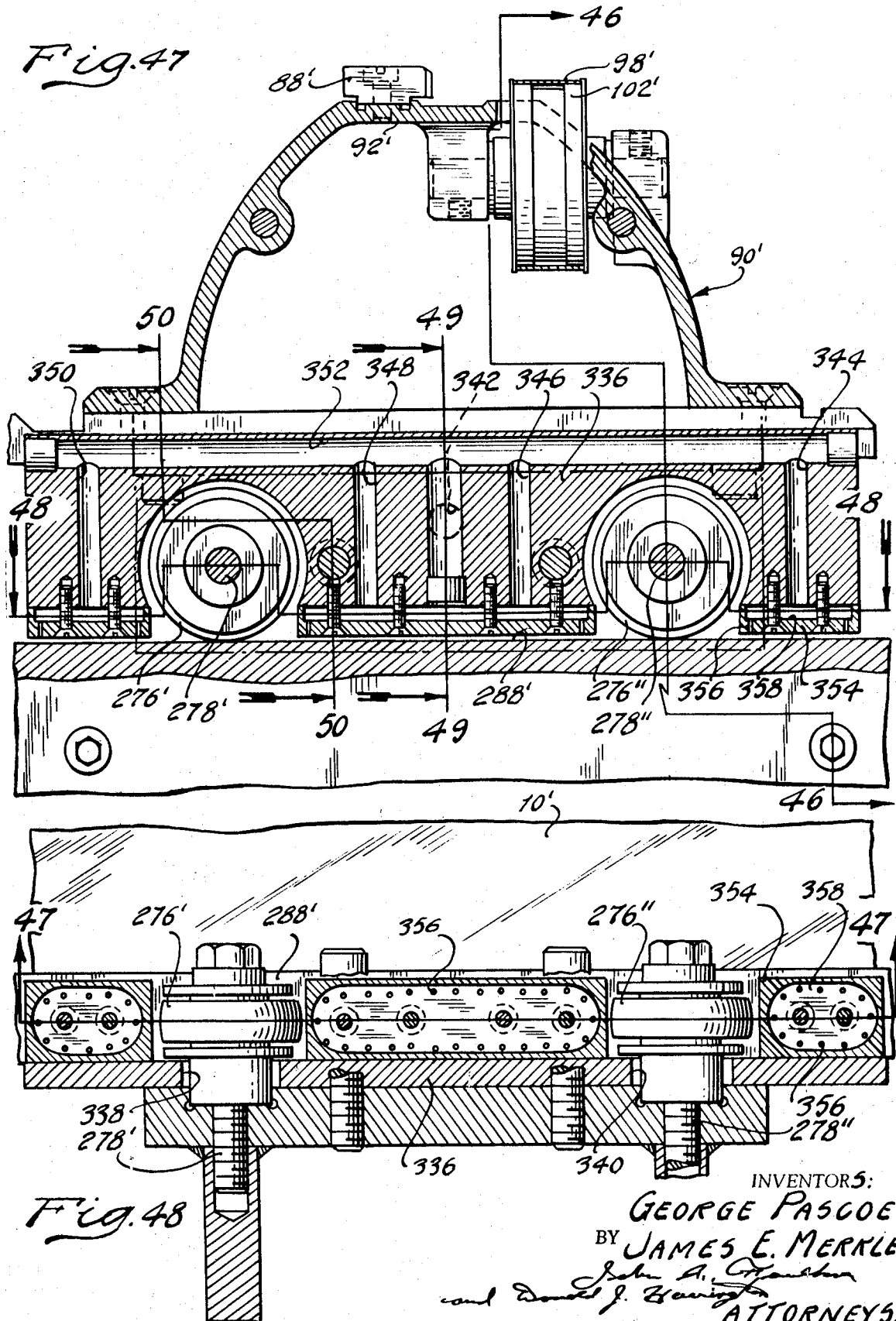
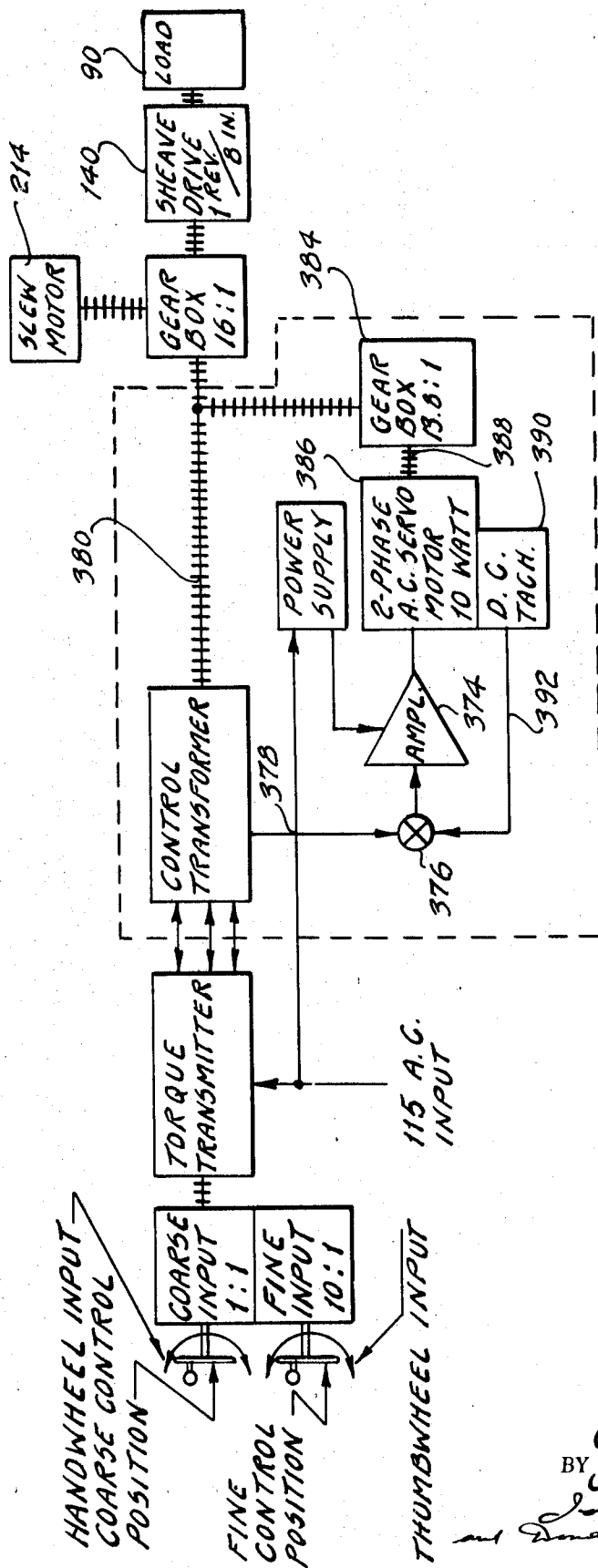
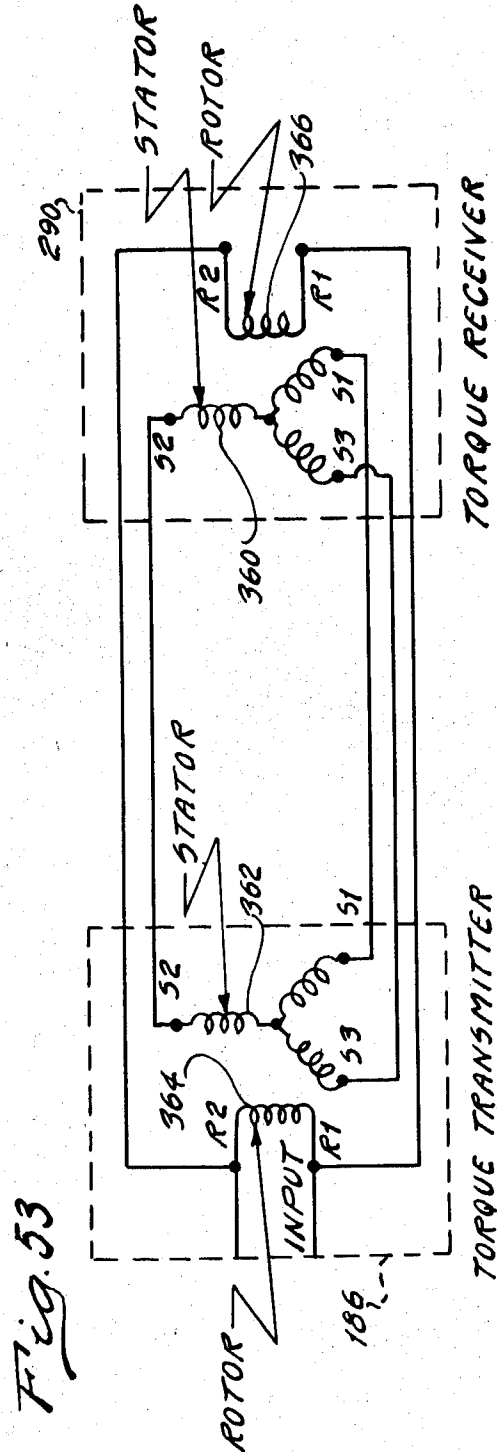
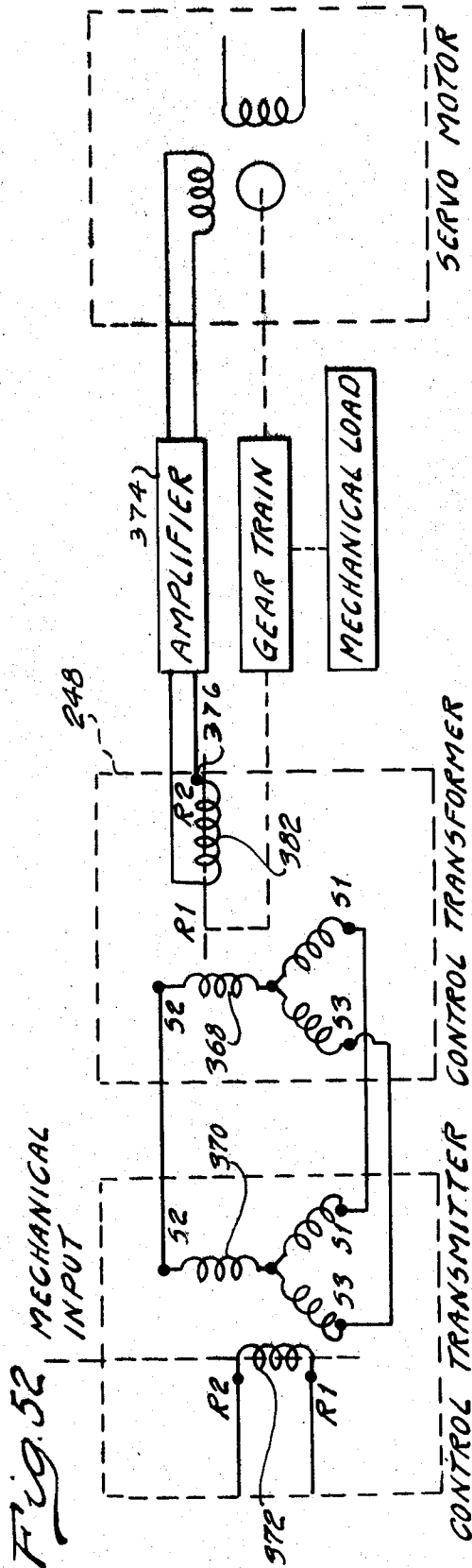


Fig. 51
(X-AXIS)

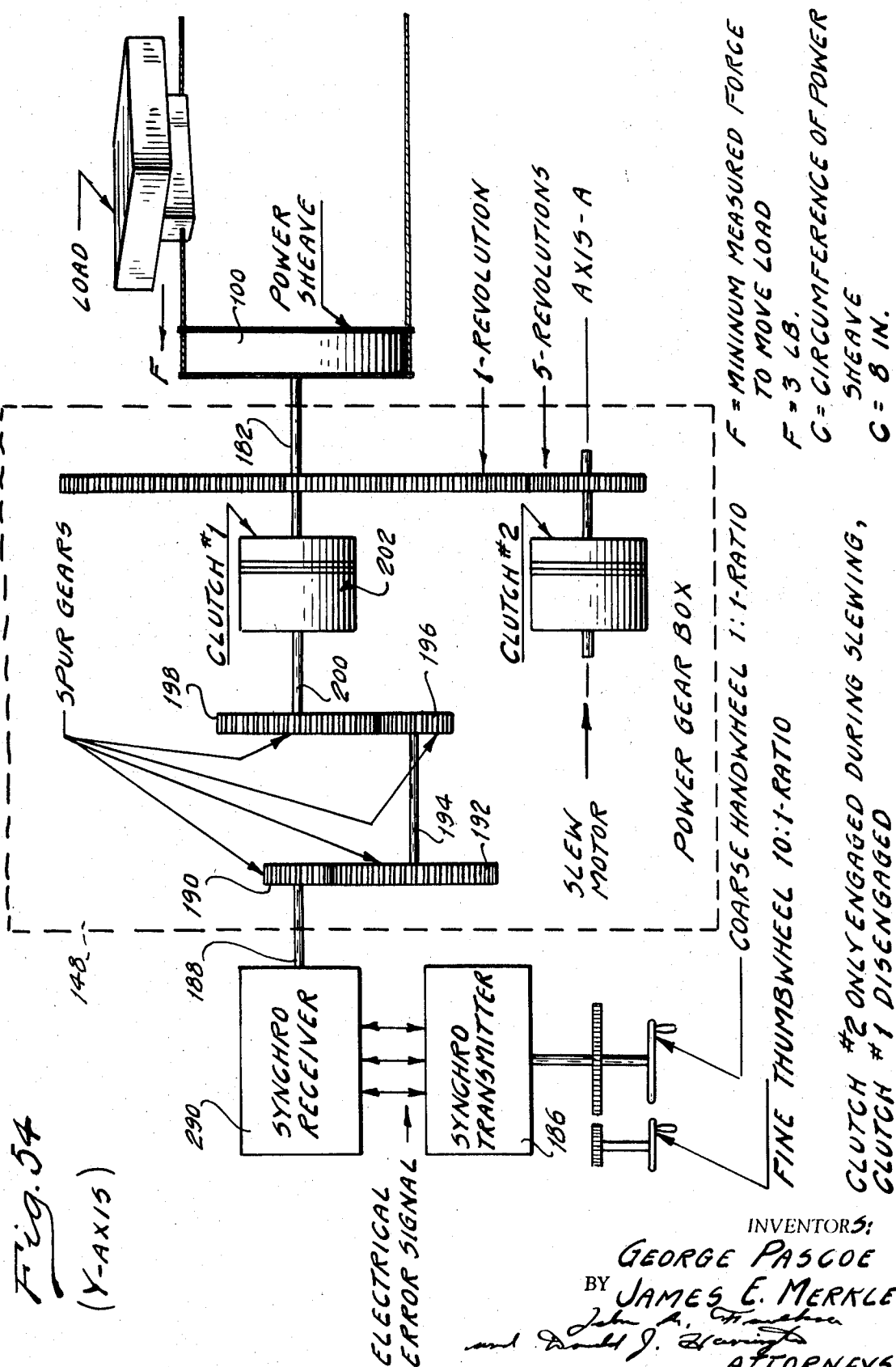


- NOTE:
1. ALL VELOCITY RATIOS, INPUT/OUTPUT
 2. MECHANICAL COUPLING = +++++
 3. ELECTRICAL COUPLING = ———→

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GRAPHIC DATA SYSTEM FOR SCANNING AND RECORDING TWO-DIMENSIONAL CONTOURS

BRIEF SUMMARY OF THE INVENTION

Our invention relates generally to data processing for numerically controlled machine tools. It relates more particularly to improvements in reading, recording and digitizing the coordinates of points in a two-dimensional contour.

The structure to which our instant improvements relate is known as a coordinatograph system. This includes a measuring instrument for measuring the coordinates of any given point along a two-dimensional contour plotted on a two-dimensional surface layout. Provision is made for reading coordinate values for each point as a locating probe or a scanner moves into registry with any given target point on the contour.

In our improved structure provision is made for supporting a two-dimensional draft on a horizontal surface. A carriage assembly mounted over the draft is adapted to move in the direction of a first coordinate axis. The carriage assembly supports a scanner in the form of a television camera that is mounted to scan the contour as the carriage assembly is shifted over the draft. The carriage assembly has a principal axis that corresponds to a second coordinate axis, and the camera is adapted to be movably mounted on the carriage assembly for shifting movement in the direction of the second coordinate axis.

An electrical impulse generator carried by the camera-mounted structure is adapted to generate an electrical impulse for each increment of movement of the camera-mounted structure with respect to the carriage assembly in the direction of the second coordinate axis. A second electrical impulse generator carried by the carriage assembly adjacent one margin of the draft registers with a relatively fixed portion of the assembly as it generates an electrical impulse for each increment of movement of the carriage assembly in the direction of the first coordinate axis.

Electrical impulses are delivered through electrical conduits to an electronic counter which adds or subtracts the impulses for each coordinate value, depending upon the direction of movement of the camera and the direction of movement of the carriage assembly. A resultant or net coordinate value for each point then is delivered to the control system for a conventional card punch apparatus. The data that is registered on punch cards is a record of the intelligence obtained from the two-dimensional draft which can be transmitted to a preprogrammed computer used in preparation of a control tape for a numerically controlled machine tool. The method for utilizing the data obtained by the coordinatograph is disclosed in copending application Ser. No. 577,997, filed Sept. 8, 1966, now U.S. Pat. No. 3,548,173 which is assigned to the assignee of our instant invention. Reference may be had to that copending disclosure for the purpose of supplementing this disclosure.

The contour data system of our invention is a semiautomatic contour reading mechanism in which a probe in the form of a television camera scanner can be moved with the aid of a television monitor to a reference point from which the coordinate values of any point on the contour can be referred. A manually controlled semiautomatic drive for the carriage assembly permits the operator to control from the television monitor control station the position of the television camera scanner as he prepares the system for receiving and registering the coordinate data for any given point on the contour.

As the carriage is moved by the operator in this fashion with reference to the previously determined zero point or reference point, the magnetic pickups previously described generate one electrical impulse for each 0.001 inches movement both in the direction of the first coordinate axis and in the direction of the second coordinate axis. For purposes of this disclosure, the coordinate axes will be referred to as the "X" axis and the "Y" axis. The impulses thus generated are added and sub-

tracted by an electronic counter when the operator locates on the television monitor the scanner target.

When the desired point on the curve is reached, the operator at the monitor station can depress a switch which actuates the control system for a card punch apparatus so that the latter receives the output data of the electronic counter. Successive points along the contour are located by reference coordinates in this fashion.

Spacings of a relatively wide span are adequate when the contour is relatively flat. Closer spacing of the measuring points is required as the radius of curvature of the contour decreases. After the coordinate points are received, the coordinates of points intermediate the measured points can be established with interpolation by employing a curve-fitting process which is described in the previously mentioned copending disclosure. It will be described briefly here, however, merely for reference purposes.

The improvements of our invention are adapted especially for use in a coordinatograph for use with automotive body drafts. These drafts are prepared in preliminary form on paper from data obtained from a three-dimensional clay model body contour from which a three-dimensional die must be prepared. The surface point data is obtained from established section and character lines by means of a bridge-type measuring device which carries probes so that it can be moved over the clay model. The position of the probe is recorded by calibrated axes on the bridge and then transferred to a body draft.

The draft comprises a geometrical surface development of the clay model. Template contour lines are traced from the draft and the contour lines then are transferred to aluminum sheet stock. A reproduction of the body draft tracing is placed over the aluminum stock and the measured points are transferred to the stock with a hand-punching tool.

The punch marks are connected by the appropriate graphic contour curves. Any surface point discrepancies on the original clay model later can be corrected in a preliminary fashion at this stage of the operation.

The aluminum sheet stock draft plates used in body work, of necessity, have large dimensions and are heavy. The plates are supported on a flat draft table of sufficient width to accommodate the span of the plate, which may be 5 feet or more in extent. This requires a relatively long span that the carriage must cover. The carriage assembly is in the form of an end-supported beam with its supports at each edge of the table. The scanner camera, the "Y" axis impulse generator and the camera mounting structure are supported at locations intermediate the end supports for the carriage assembly. The weight of the carriage assembly itself, in addition to the weight of the camera and the camera mounting structure, produces beam loads that tend to deflect the carriage assembly. A deflection in the carriage assembly will cause inaccurate readings as the operator scans the contours on the draft plate.

It is an object of our invention to provide a coordinatograph in which provision is made for avoiding undesirable deflections due to the extended distance between the end supports for the carriage assembly.

It is another object of our invention to provide an improved coordinatograph system of the type above described wherein the "X" axis coordinate and the "Y" axis coordinate of various points along the contour over which the carriage assembly traverses can be registered by developing electrical impulses that are a measure of the incremental movement of the carriage-mounted scanner in the directions of both coordinate axes.

In certain prior art coordinatograph systems provision is made for driving the carriage assembly by means of a suitable servomotor or by means of a hand-operated drive screw or other hand-operated driving mechanisms. The driving effort is imposed on the carriage assembly at one of its ends adjacent a carriage assembly end support. The two end supports for the carriage assembly must be adapted to permit shifting movement of the carriage in the direction of the "X" axis as the

scanner registers with the contour lines on the draft plate. This manifestly introduces a frictional force at each end support which must be overcome by the driving motor or by the hand-operated driving mechanism for the carriage. As the driving mechanism is actuated, the friction at the remote end of the carriage assembly tends to cause the carriage assembly to move or become askewed with respect to a true "Y" axis direction.

In automotive body work, as explained previously, the transverse dimension of the draft plate is relatively large and, therefore, the askewing action, or displacement of the carriage assembly out of parallel relationship with respect to the "Y" axis, becomes substantial. This introduces an error in the readings that are obtained. It is an object of our invention, therefore, to provide a coordinatograph having a carriage assembly in which provision is made for avoiding an undesirable displacement of the carriage assembly from its proper working relationship with respect to the "Y" axis as the carriage assembly is shifted in the direction of the "X" axis.

According to another feature and object of our invention, provision is made in the form of a remote control motor circuit for adjusting the carriage assembly in both the "X" axis direction and the "Y" axis direction in a semiautomatic fashion. This involves an operator-controlled electrical impulse generator mounted adjacent a television monitor that receives a scanner signal from the television camera scanner. The "X" axis and "Y" axis position controls thus can be operated as the operator follows on the monitor the path of motion of the scanner over the draft plate without the necessity for interrupting his view of the monitor screen. This comprises a "Y" axis carriage drive assembly and an "X" axis carriage drive assembly which receive independently from the operator-controlled console the signals that are generated by the "X" axis impulse generator and the "Y" axis impulse generator.

It is another object of our invention to provide a remote drive control of the type above set forth including a first motion input element for effecting a coarse adjustment of the carriage assembly and a second motion input element for effecting a fine adjustment. In this way the time required to locate the scanner over the target area is considerably reduced without any sacrifice in accuracy.

It is a further object of our invention to provide an improved drive for adjusting the scanner in the direction of each principal axis wherein the operator can operate either the coarse drive or the fine adjustment while visually aiming the scanner at the target point.

DESCRIPTION OF THE VIEWS OF THE DRAWINGS

FIG. 1 is a plan view of our improved coordinatograph with a draft plate clamped in place and the scanner camera shifted to the left.

FIG. 2A is an enlarged plan view of the left side of the structure of FIG. 1.

FIG. 2B is an enlarged plan view of the right side of the structure of FIG. 1.

FIG. 3A is a side elevation view of the left end of the coordinatograph system.

FIG. 3B is a side elevation view of the right end of the coordinatograph system.

FIG. 4A is an end view of the structure of FIGS. 1, 2A, 2B, 3A and 3B.

FIG. 4B is a transverse view as seen from the plane of section line 4B—4B of FIG. 3A.

FIG. 5 is a sectional view as seen from the plane of section line 5—5 of FIG. 3A.

FIG. 6 is a sectional view as seen from the plane of section line 6—6 of FIG. 3B and section line 6—6 of FIG. 11.

FIG. 7 is a sectional view as seen from the plane of section line 7—7 of FIGS. 3B and 6.

FIG. 8 is a sectional view taken along the plane of section line 8—8 of FIG. 7.

FIG. 9 is a sectional view taken along the plane of section line 9—9 of FIG. 7.

FIG. 10 is a sectional view taken along the plane of section line 10—10 of FIG. 9.

FIG. 11 is a sectional view taken along the plane of section line 11—11 in FIGS. 1, 2B and 6.

FIG. 12 is a sectional view taken along the plane of section line 12—12 in FIGS. 2B and 3B.

FIG. 13 is a sectional view taken along the plane of section line 13—13 in FIGS. 2B and 14.

FIG. 13A is a sectional view taken along the plane of section line 13—13A in FIG. 13.

FIG. 14 is a sectional view taken along the plane of section line 14—14 in FIGS. 12 and 3B.

FIG. 15 is a plan view of a portion of the carriage for the scanner camera.

FIG. 16 is a sectional view of the carriage taken along the plane of section line 16—16 of FIGS. 2B and 15.

FIG. 17 is a sectional view of the carriage taken along section line 17—17 of FIGS. 2B and 15.

FIG. 18 is a sectional view of the carriage taken along the plane of section line 18—18 of FIGS. 15 and 19.

FIG. 19 is a sectional view of the carriage taken along section line 19—19 of FIGS. 18, 20 and 21.

FIG. 20 is a sectional view taken along the plane of section line 20—20 of FIGS. 15 and 19.

FIG. 21 is a sectional view taken along the plane of section line 21—21 of FIG. 19. It shows an enlarged view of the rack and pinion which is seen also in FIG. 17.

FIG. 22 is a partial plan view as seen from the plane of section line 22—22 of FIG. 23.

FIG. 23 is a sectional view as seen from the plane of section line 23—23 of FIGS. 2B, 22 and 24.

FIG. 24 is a sectional view as seen from the plane of section line 24—24 of FIGS. 2B and 23.

FIG. 25 is a sectional view as seen from the plane of section line 25—25 of FIG. 6.

FIG. 26 is an elevational view showing the electrical lead line for the carriage as seen from the plane of section line 26—26 of FIGS. 2A, 2B and 1.

FIG. 27 is a sectional view as seen from the plane of section line 27—27 of FIG. 26.

FIG. 28 is a sectional view taken along section line 28—28 of FIGS. 26 and 29.

FIG. 29 is a sectional view as seen from the plane of section line 29—29 of FIG. 28.

FIG. 30 is a plan view, partly broken away, as seen from the plane of section line 30—30 of FIG. 31.

FIG. 31 is a sectional view taken along the plane of section line 31—31 of FIG. 30.

FIG. 32 is a sectional view, partly in plan, taken along section line 32—32 of FIG. 33.

FIG. 33 is a sectional view, partly in elevation, taken along the plane of section line 33—33 of FIG. 32.

FIG. 34A is a sectional view of the draft plate lifting device as seen from the plane of section line 34—34 of FIG. 2A and section line 34A—34A of FIGS. 36 and 35B.

FIG. 34B is a sectional view, which is a continuation of FIG. 34A, taken along the plane of section line 34B—34B of FIG. 2A.

FIG. 35A is a sectional view of the draft table as seen from the plane of section line 35—35 of FIGS. 2A and 34A.

FIG. 35B is a continuation of the sectional view of FIG. 35A.

FIG. 36 is a sectional view as seen from the plane of section line 36—36 of FIGS. 2B and 34A.

FIG. 37 is a sectional view as seen from the plane of section line 37—37 of FIG. 2A.

FIG. 38 is a longitudinal sectional view taken along the plane of section line 38—38 of FIGS. 2A and 2B.

FIG. 39 is a sectional view taken along the plane of section line 39—39 of FIG. 38.

FIG. 40A is a longitudinal sectional view taken along the plane of section line 40—40 of FIG. 2B.

FIG. 40B is a continuation of the view of FIG. 40A.

FIG. 41 is a sectional view of a support pad taken along the plane of section line 41—41 of FIG. 3A.

FIG. 42 is an elevation view, partly in section, as seen from the plane of section line 42—42 of FIG. 43.

FIG. 43 is a sectional view taken along the plane of section line 43—43 of FIGS. 1, 3A and 42.

FIG. 44 is a cross-sectional view of a carriage adjustment mechanism as seen from the plane of section line 44—44 of FIG. 42.

FIG. 45 is a partial plan view of the mechanism of FIG. 44 as seen from the plane of section line 45—45 of FIG. 42.

FIG. 46 is a cross-sectional view of a first form of carriage beam as seen from the plane of section line 46—46 of FIG. 47.

FIG. 47 is a longitudinal sectional view of a modified form of the cantilevered end of the carriage beam as seen from the plane of section line 49—47 of FIG. 46.

FIG. 48 is a sectional view taken along the plane of section line 48—48 of FIG. 47.

FIG. 49 is a sectional view as seen from the plane of section line 49—49 of FIG. 47.

FIG. 50 is a view of the bearing structure of FIG. 47 as seen from the plane of section line 50—50 of FIG. 47.

FIG. 51 is a schematic diagram of the electrical carriage adjusting mechanism for the "X" axis.

FIGS. 52 and 53 are schematic diagrams of the circuitry for the torque transmitter and the control transformer for the circuit of FIG. 51; and

FIG. 54 is a diagram of the gearing for the circuit of FIG. 51 for the "Y" axis adjustment.

PARTICULAR DESCRIPTION OF THE INVENTION

As indicated in FIG. 1, the coordinatograph includes a draft plate supporting table 10 on which is positioned an aluminum sheet draft plate 12. The surface of the draft plate, indicated in FIGS. 2A and 2B, is formed with reference lines 12. The contour on the body draft plate is shown by reference character 14. It is plotted in the manner previously described by using data points obtained from characteristic lines on a three-dimensional clay model. A zero point on the draft plate is established and all points on the contour 14 are defined with reference to the zero point and the "X" and "Y" axes.

The measured points on the contour 14 that are scanned by the coordinatograph are shown in FIG. 2A at 16. At locations of small radius of curvature on the contour 14 the points 16 are spaced relatively close together. A wide spacing, however, is permissible at regions of the contour that are relatively flat.

Coordinatograph table 10 has a flat surface and a supporting bed that rests on a secure foundation. Draft plate supporting bearing balls 18 and 18' located in spaced openings 20 and 20' in the table 10 are used for the purpose of floating the draft plate during its assembly on the table 10. The balls can be raised and lowered by an appropriate cam mechanism so that they extend above the upper surface of the table 10 for engagement by the undersurface of the draft plate 12. The balls rotate as the plate 12 is shifted into position on the table 10. After the plate is appropriately positioned, the balls 18 and 18' can be withdrawn within the holes 20 and 20' by retracting the actuating lever mechanism.

The table 10 can be provided also with air jets, some of which are visible at 22. Air under pressure can be admitted to a manifold that communicates with the jet openings 22. The draft plate 12 then can be supported hydrostatically as a film of air provides a relatively friction-free support. After the plate 12 is suitably positioned, pressure supplied to the manifold, which communicates with the jets 22, can be reduced to a subatmospheric value thereby creating a vacuum which tends to secure the plate 12 firmly against the surface of the table 10.

The jets 22 are located in a center section of the table top 10. The center section is shown at 24 in FIG. 3A and two continuous end sections are shown respectively at 28 and 26 in FIGS. 3A and 3B. Each of the end sections 26 and 28 is

formed with the openings 20 or 20' to permit convenient loading of the aluminum draft plate 12 on the table top 10.

Bolted to one side of the base and extending longitudinally in the direction of the horizontal axis and indicated in FIG. 1 is an "L" shaped structural channel 30. It includes a horizontally extending portion 32 and a vertically extending portion 34 (FIG. 7), the latter being bolted by means of bolts 36 (FIG. 11) to the sidewall 38 for the base. A carriage supporting bar 40 of solid circular cross section is carried by mounting pins 42 located in openings formed in the channel portion 32. A clamping bolt 45 extending through the channel portion 32 threadably engages the bar 40 and holds the latter in fixed relationship with respect to the channel 30 as the bar 40 engages the mounting pins 42. Similar pins are at each end of the bar 40.

The carriage cross member 44, which comprises a generally solid bar of metal, the ends of which are formed with milled flats 46 and 48 (FIG. 11), carries a pair of stub shafts 50 and 52 which register with openings formed in the flats. These carry bearing wheels 54 and 56 which are mounted on the outward ends of the shafts 50 and 52, respectively, by bearings. These wheels 54 and 56 engage the cylindrical outer surface of the bar 40. A corresponding set of bearing wheels is located at the opposite end of the cross member 44 as indicated at 58 (FIG. 12).

Carried on top of the cross member 44 is a "Y" axis drive assembly 60 which will be described subsequently in detail. Assembly 60 is supported on a base plate 62, which in turn is bolted to the top of the cross member 44 (FIGS. 6 and 7). Prepositioning of the cross member 44 in an "X" direction can be accomplished by the operator as he engages a hand grip 66 (FIG. 2B). This is secured to the top of the member 44.

A pivot stud 68 (FIG. 6) is carried by the support 62. It in turn supports a bracket 70 which is adapted to oscillate about the axis of the pivot stud 68. The bracket 70 supports a mounting shaft 72 (FIG. 7). An impulse generator 74 is provided with a hollow stem 76 which is received over the shaft 72 and held in place by set screws 78 (FIG. 9).

The impulse generator is in the form of a torque receiver which receives the generated voltage from a voltage source in the form of a torque transmitter under the operator's control, as will be described subsequently. The receiver 74 includes an armature having an armature shaft 80 (FIG. 9) which is coupled to a pinion shaft 82 by a suitable coupling device 84. Pinion shaft 82 is journaled within the support shaft 72 and is joined at its lower end to a drive pinion 86.

Supported on the vertical portion 34 of the "L" shaped channel 30 is a geared rack 88 which is adapted to be engaged by the pinion 86 carried by the cross member 44. The support bracket 70 can be oscillated about the axis of the pivot stud 68 to effect engagement and disengagement of the pinion 86 with respect to the rack 88.

An operator-controlled cam mechanism carried by the carriage assembly adjacent the support 70 is used to effect this adjustment.

The carriage assembly includes a beam 90 (FIGS. 17, 18, 21, 24) which extends in the "Y" axis direction. One end of the beam is carried by the cross member 44. It is comprised of a structural member of substantial depth in cross section as shown at 92. The open end of the member 92 is secured to a base plate 94, which in turn is bolted to the cross member 44. A gear rack 96 secured to the upper end of the member 92 extends in the direction of the "Y" axis. A steel band 98 (FIG. 22) extends over the member 92 in a direction parallel to the rack 96. One end of the band 98 is trained over a drive pulley 100 which forms a part of the "Y" axis drive mechanism 60. Another pulley 102 (FIG. 24) is rotatably journaled at the other end of the beam 90 to support and band 98. The band 98 circles both pulleys 100 and 102 and is trained through the member 92 to provide a continuous belt drive. The belt or band is secured to a television camera scanner support 104 comprising a yoke 106 which extends over the top of member

92. Yoke 106 carries an operator-controlled cam mechanism 108 which clamps the yoke 106 to the steel bank at 96. Thus when the band 98 is driven by the drive pulley 100, motion is imparted to the yoke 106 in the "Y" axis direction.

The beam plate 94 is formed with a track 110 extending along one margin thereof. This track is engaged by the yoke supporting roller 112 journaled at the base of the yoke. The opposite margin of the beam has formed thereon a trackway 114 which is situated on a bias with respect to a normal plane (FIG. 24). It is engaged by a roller 116 carried on the opposite end of the yoke 106. The right-hand margin 118 of the beam is engaged by a roller 120 pivotally mounted for rotation about a vertical axis. The rollers 112, 116 and 120 provide a rolling support for the yoke and traverse displacement in the direction of the "X" axis with respect to the beam is prevented.

The side of the yoke 106 adjacent the track 110 is formed with a platform 122 on which is supported a counterweight 124 (FIG. 18). The opposite end of the yoke 106 is formed with a support 126 for a television scanner unit 128. The so-called line of vision for the lens of the camera 128 is situated in a direction normal to the plane of the draft plate.

Supported by the top of the yoke 106 is an impulse generator 130 (FIG. 16) which is similar to the impulse generator 74 described previously. It is formed with a pinion shaft and a pinion 86' which engages drivably the rack 96. The parts of generator 130 that have counterpart elements in generator 74 have similar reference numerals with prime notations. The pinion 86' can be moved into and out of engagement with respect to the rack 96 as the operator appropriately adjusts a cam element shown generally at 132. The generators 130 and 74 can be formed of known components, and they can be calibrated to generate a voltage impulse for each increment of travel. In this instance it is desirable to produce an impulse for every incremental displacement of 0.001 inches in either the "X" direction or the "Y" direction, as appropriate.

The band 133 extends the direction of the "X" axis and is trained over pulleys 134 and 136 located at the right-hand end of the center table support 24. At the opposite end of the table support 24 is found another idler pulley 138 over which the band 133 is trained (FIG. 3A). The band then passes over a drive pulley 140 (FIG. 5) journaled on the table support. The band 133 makes a complete circuit as it returns in the "X" axis direction to the idler point 136. The cross member 44 is secured to the band 133 by means of an operator-controlled locking element 142 which is carried by the cross member 44, as indicated. Driving member 42 includes a cam operator 144 which is adapted to apply and release the clamping members of the element 142, thereby permitting the carriage 44 to clamp and disengage selectively the band 133.

The "Y" axis carriage drive assembly includes a housing having spaced walls 146 and 148 (FIG. 6) which are secured by bolts 150 to the plate 62. Situated between the walls 146 and 148 are intermediate walls 152, 154, 156 and 158. The slew motor 184, which is a conventional AC motor, is mounted by bolts 160 to the wall 146. Its armature shaft 162 carries a drive pinion 164 which engages a gear 166 connected to an intermediate shaft 168 journaled in bearing openings formed in the wall 146 and 154. Shaft 168 can be coupled to another intermediate shaft 170 by means of an electric clutch coupling 172. These include selectively engageable friction members 174 and 176, the latter being connected to the shaft 170 and the former being connected to the shaft 168. Shaft 170 has pinned thereto a drive pinion 178, which engages the power output gear 180 connected to a power output shaft 182. Shaft 182 extends through a bearing opening formed in the wall 148 and through another bearing opening formed in intermediate wall 152. The outwardly extending end of shaft 182 carries the previously described drive pulley 100.

When the coupling shown at 172 is applied, a torque delivery path is established between the armature motor 184 and the drive pulley 100. This drive is used to establish a rapid traverse of the carriage over the draft plate. It is not used as

the operator scans the draft for purposes of obtaining the coordinate of selected points on the draft.

A synchronous motor 186 also is carried by means of bolts 188 on the wall 146. Its armature shaft 188 carries drivably a drive pinion 190 which engages in turn a zero backlash gear 192. This gear is in turn pinned to shaft 194, which is received within bearing openings formed in the intermediate walls 158 and 154. Shaft 194 drivably carries also pinion 196 which engages another zero backlash gear 198. This, in turn, is connected to intermediate shaft 200 and journaled in intermediate walls 154 and 156. An electrically operated shaft coupling 202 connects selectively the shaft 200 with power output shaft 182 which, as mentioned earlier, is journaled within bearing openings formed in intermediate wall 152 and in wall 148. When the coupling 202 is energized and the coupling 172 is deenergized, a mechanical drive separate be established between the motor 182 and the power output shaft 182 and drive pulley 100 as the operator actuates a companion electrical unit in the control station, as will be described subsequently. In this fashion motion can be imparted to the television camera supported by the beam for the carriage assembly. As readings are being made, this motion is adapted to move the camera, scanning it over the line contours on the graph plate and thereby causing the impulse generator 130 to produce useable signals for each increment of travel. The motor 118 can be connected to a separate circuit and energized and deenergized selectively to permit rapid traverse of the television camera.

The "X" axis carriage drive assembly is generally similar to the "Y" axis carriage drive assembly. It includes a housing 210 (FIG. 5) which is located by preference, within the table support section 28. The drive pulley 140, which is mounted on output shaft 212, is situated externally of the table portion 28.

An AC slew motor 214 is mounted by means of bolts 216 on the first end wall 218 of the housing 210.

Shaft 212 is journaled in bearing openings formed in a second end wall 220 and in intermediate wall 222 of the housing 210.

In addition to the intermediate wall 222, the housing 210 includes two additional intermediate walls 224 and 226. These carry bearing supports for an armature shaft extension 228 which is connected directly to the armature shaft 230 of the motor 214. Shaft 228 is coupled to the armature shaft 230 by a coupling 232.

A drive pinion 234 is carried by the shaft 228. It engages drivably a gear 236 connected to intermediate shaft 238. This shaft is journaled rotatably in bearing openings formed in walls 224 and 226.

A selectively engageable electric coupling 240 situated between the intermediate walls 222 and 226 is adapted to establish a frictional driving connection between the shaft 238, and another intermediate shaft 242 journaled in bearing openings formed in end wall 220 and intermediate wall 222. This shaft 242 carries drive pinion 244 which engages drivably power output gear 246. Power output shaft 210 is pinned to the gear 246.

A synchronous motor 248 (FIG. 5) is bolted by bolts 250 to the wall 218. Its armature shaft 252 is connected by means of a coupling 254 to an intermediate shaft 256, the latter in turn being supported in bearing supports carried by intermediate wall 224 and a fourth intermediate wall 258.

Drive pinion 260 is carried by the shaft 256. It engages a gear 262, which is pinned to a countershaft 264 supported on bearing supports carried by walls 258, 224 and 226. A second drive pinion 266 is pinned to the shaft 264. It engages a power output gear 268 carried by shaft 270 journaled by intermediate walls 226 and 224.

An electromagnetic coupling, similar to the coupling 240, is provided at 272 to establish selectively a connection between shaft 270 and power output shaft 212.

When the coupling 240 is deenergized and the coupling 272 is energized, the synchronous motor 248, which is energized by the driver-operated console to be described subsequently,

develops a torque that is transmitted to the speed-reducing drive train defined in part by the gears 262 and 268. Controlled motion of the carriage in the "X" axis direction then can be accomplished. If the coupling 272 is deenergized and the coupling 240 is energized, it is possible to obtain a rapid traverse by simply energizing the AC slew motor 214. The electrical circuitry for the motors 214 and 248 are independent of each other.

The end of the beam 90 that is remote from the cross member 40 is supported by a roller 276 (FIG. 23) which is journaled on a pin 278. The pin 278 in turn is carried by a support 280 which is pinned by means of a pin 282 to an adapter 284. This adapter is bolted to the underside of the base plate 94 of the beam 90. Springs 286 are used to eliminate deflections fully due to tolerances. Pulley 276 is adapted to ride on a trackway 288 which is carried by the table margin and situated in an "X" axis direction.

The cross-sectional depth of the beam 90 with this construction is sufficient to avoid undue deflections that would adversely influence the readings obtained by the operator when he moves the television camera carrier over the draft plate.

A suitable voltage generator for the "Y" axis drive assembly is shown at 290 (FIGS. 43 and 44.). It is mounted within a console cabinet 292 situated within a control console 294. This includes a television monitor pickup 296 (FIG. 1) which receives the signals from the camera 128 and permits the operator at the console to view the contour lines on the draft plate and to locate precisely the camera over the desired points on the contours on the draft plate.

The housing 292 contains the energizers for both the "X" axis carriage assembly and the "Y" axis carriage assembly. The "X" axis elements have similar reference characteristics but prime notations are added.

The generator unit 290 is supported by the base of the cabinet 292 and its armature extends in a generally horizontal direction.

The armature shaft 294 is coupled to drive shaft 296 which in turn is directly connected to an operator-controlled hand wheel 298, the latter being located on the outward side of the housing 292. It can be rotated by the operator to effect rotation of the armature shaft 294, which in turn creates electrical impulses that are received by the synchronous motor.

The housing 292 is surrounded by a sheet metal console cover 300. A forward wall 302 of the housing 292 journals shaft 296. Shaft 296 is journaled also by an intermediate wall 304. Journaled also in the walls 302 and 304 is a countershaft 306. Pinned to this shaft is a drive pinion 308 which drivably engages gear 310. Shaft 296 is pinned directly to the gear 310. Connected also to shaft 306 is a drive gear 312 which meshes with gear 314. This in turn is connected to a hand wheel 316 which extends radially through a slot 318 formed in the sheet metal cover 300.

Hand wheel 316 is journaled by bearing supports carried by walls 319 and 320 of the housing 292. The periphery of the hand wheel 316 can be engaged by the operator when a fine linear adjustment of the "Y" axis position is desired. Coarse adjustments are obtained by rotating the hand wheel 298. A direct connection between the wheel 298 and the armature shaft 294 permits rapid adjustment of the "Y" axis position. Motion of the hand wheel 316 for fine adjustments is reduced by the speed-reducing gear.

A torque transmitter unit 290' for the "X" axis drive assembly is contained in the console housing 292. It resembles the "Y" axis unit previously described, although the electrical signal unit itself is in the form of a torque transmitter rather than an impulse generator. Like the "Y" axis unit, however, the "X" axis controls include a fine adjustment hand wheel 322 for effecting a fine adjustment of the armature shaft position. Coarse adjustment can be obtained by an operator-controlled hand wheel 324.

As the impulse generator for the "Y" axis carriage moves in a "Y" axis direction, the impulses are registered upon an electronic counter 326 (FIG. 3A) in the operator's control con-

sole. A corresponding counter 328 is provided for the "X" axis coordinates. As the impulse generator for the "X" axis carriage assembly sends impulses to the console, the counters 326 and 328 provide a visual display for both the "X" axis position and the "Y" axis position after the camera has been positioned for readings with respect to a given origin on the body draft. As the "X" axis impulse generator moves in a positive "X" axis direction with respect to the origin, the readout unit or recorder 328 will add numerically the impulses that are generated for each 0.001 inches movement. The readout unit will subtract readings as the "X" axis carriage assembly moves in a negative "X" axis direction. The reading that is displayed on the recorder 328 thus is an indicator of the net amount of "X" axis travel.

Corresponding readings are received by the readout unit 326 for the "Y" axis position. It adds and subtracts impulses depending upon the direction of movement of the "Y" axis carriage assembly.

The operator can position the camera scanner over the desired point on the contour line and, after it is centered as determined by the relative position between the camera and the target point shown on the television monitor, the operator can depress an "X" axis button 330 and a "Y" axis button 332 (FIG. 3A) which triggers and energizes the position digitizer circuit for the control and registers the "X" axis coordinates and the "Y" axis coordinates for the target point on conventional computer punch cards. This is done by a conventional card punch machine 334 (FIG. 1).

When characteristic points are located in terms of their "X" and "Y" coordinates in this fashion, the net result is represented by a stack of punched computer cards produced by the punch machine. This data then is fed into the previously described computer routine wherein a parabolic curve is fitted between the measured points to obtain a continuous definition of the contour for the characteristic lines on the draft plate.

Under some circumstances it is desirable to eliminate entirely any friction that may be due to the roller end support provided by the roller 276 at the outboard end of the beam 90. If friction at this point becomes a problem, it is possible that the friction forces will cause slight errors in the "X" axis readings due to the resulting inflection of the beam 90. We have provided, therefore, an alternate means for end-supporting the beam 90 (FIGS. 47, 48, 49, 50). This includes an air bearing having an air manifold block 336 which can be bolted to the unsupported end of the beam 90', bolt openings 338 and 340 being provided for this purpose. Parts of the beam 90 that have counterpart elements in the previously described beam 90 have similar reference characteristics but prime notations are added.

The block 336 is formed with an air manifold having an air intake port 342 which communicates with internal passages 344, 346, 348 and 350. Each of these passages extends vertically and they communicate with a main distributor passage 352. Air cushion plates 354 are bolted to the underside of the manifold block 336. These plates are provided with air jet openings 356, each of which communicate with an air-distributing groove 358 formed in the plate 354. The inner surface of the plate 354 engages the surface of the track 288' carried by the margin of the supporting bed for the draft table top.

As air is admitted to the port 342 (FIG. 47), a film of air is produced between the undersurface of the plates 354 and the bearing surface 288' of the bearing track. This causes the overhanging end of the beam 90' to be supported by the film of air which is substantially frictionless. In this way the friction forces normally associated with the supporting roller can be eliminated.

The drive system for the "Y" axis carriage is shown schematically in FIG. 54. It includes the synchrotransmitter and synchroreceiver described previously. The output from the synchroreceiver is transmitted through the gearing and the clutch elements to the power sheave. The magnitude of the torque transmitted by the synchrotransmitter is proportional

to the electrical error signal which is a measure of the voltage introduced in each unit.

The electrical connection between the synchrotransmitter and the synchroreceiver is illustrated schematically in FIG. 53. The stator windings 360 of the torque receiver 290 and the stator windings 362 of the synchrotransmitter 186 are stationary and are connected together in a three-wire circuit. The rotor 364 of the synchrotransmitter 186 has applied thereto a signal voltage which may be 110 AC volts. These rotor windings are connected in parallel fashion to rotor windings 366 of the torque receiver 290. Rotor 366 is connected to the load, which in this case is the input gear 190, and the input rotor 364 is connected to the operator-controlled hand wheels.

The receiver rotor will accurately and instantaneously indicate or follow any position movement assumed by the rotor 364. There is an inherent lag, however, due to the fact that the rotor 366 will be subjected to friction and inertia loads. But since the "Y" axis carriage assembly has a reduced degree of extraneous loads of this type, the system illustrated schematically is satisfactory.

The magnitude of the torque that is received is proportional to the displacement of one rotor shaft with respect to the other and is commonly referred to as an error signal. For every physical position of the rotor, there is a corresponding voltage established in the stator windings and in the output rotor. The three output lead voltages have relative magnitudes and polarities that define the angular position of the rotor shaft with respect to the stator windings as voltage is applied to the synchrotransmitter rotor. The "X" axis carriage drive, however, has associated with it increased inertia loads and friction loads due in part to the relatively large mass that must be driven. The "X" axis drive assembly, therefore, includes a control transformer identified at 248 (FIG. 52) and a control transmitter similar to the one described with reference to the "Y" axis carriage assembly. The control transformer includes a stator 368 which is connected by means of a three-wire connection to the stator winding 370 of the control transmitter. The rotor windings 372 of the control transmitter are energized in the usual fashion with an input voltage, such as 110 AC volts. This rotor is rotated by the operator, as explained previously. The output windings for the control transformer 248 are connected to an amplifier 374 (FIG. 51) through a summing point 376. The voltage in connection 378 extending from the rotor windings to the summing point is a measure of the error signal as determined by a position feedback. This position feedback is represented by a mechanical connection 380 in the schematic diagram. This connection is established between an intermediate gear box output element and the rotor 382 of the control transformer 248. The amplified error signal is distributed to a two-phase AC servomotor which powers the gearbox shown at 384. The motor itself is shown at 386. It is connected mechanically by mechanical connection 388 to the input element of the gear box 384.

The amplifier 374, by preference, includes a gain control for reducing the amount of the displacement between rotor 382 and rotor 372 to a specified value. A DC tachometer unit

390 may be used to generate a speed signal which is fed through line 392 to the summing point 376, thereby opposing the error signal in line 378 when the displacement of the rotor 382 tends to occur too suddenly. The system illustrated can be made to have a sensitivity of 3° relative displacement between the front wheel input shaft and the "X" axis drive pulley 140.

Having thus described our invention, what we claim and desire to secure by United States Letters Patent is:

1. A contour data recording system comprising a draft plate supporting table, a coordinate "X" axis and "Y" axis carrier assembly comprising a carriage beam extending over the plane of said table in close proximity thereto and in parallel disposition therewith, said beam being situated with its principal geometric axis in the direction of the coordinate "Y" axis, a cross member supporting one end of said beam, said cross member being movably mounted on said cable on one margin thereof, the direction of motion of said cross member being parallel to the "X" axis direction, an electrical impulse generator carried by said beam and drivably coupled thereto whereby it is adapted to generate an electrical impulse voltage for each incremental movement thereof in a "Y" axis direction, a carrier movably mounted on said beam and supporting said impulse generator, an optical scanner carried by said carrier, a second impulse voltage generator carried by said cross member, said second impulse generator being coupled drivably to said table where it is adapted to generate a voltage impulse for each incremental movement of said beam in an "X" axis direction, two driving and two driven electrical units, one of said driven electrical units being connected to said cross member and the other being connected to said carrier, operator-controlled drive means for driving said driving electrical units whereby manual "Y" axis adjustments and manual "X" axis adjustments of said scanner can be accomplished, the drive means for driving said driving electrical units comprising both a coarse adjustment hand element and a fine adjustment hand element adapted to be connected drivably to said driving electrical units, said drive means including speed reducing torque transmission elements between one of said fine adjustment hand elements and its associated driving electrical unit to permit increased sensitivity in the adjustment of said scanner in the "Y" axis direction, said cross member comprising a pair of rollers spaced at a substantial span in the "X" axis direction, a rail mounted on one side of said table, said rollers engaging said rail and movable therealong during "X" axis adjustments and means for supporting the opposite end of said beam comprising a relatively friction free bearing between said beam and said table, the bearing at said opposite end of said beam comprising an air pressure manifold carried by said beam, an air bearing surface carried by said table, said manifold having a flat surface situated in juxtaposed relationship with respect to said table bearing surface, at least one air jet extending through said manifold surface and means for supplying pressurized air to said jet whereby a relatively friction-free air cushion is established between said manifold and said table bearing surface.

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