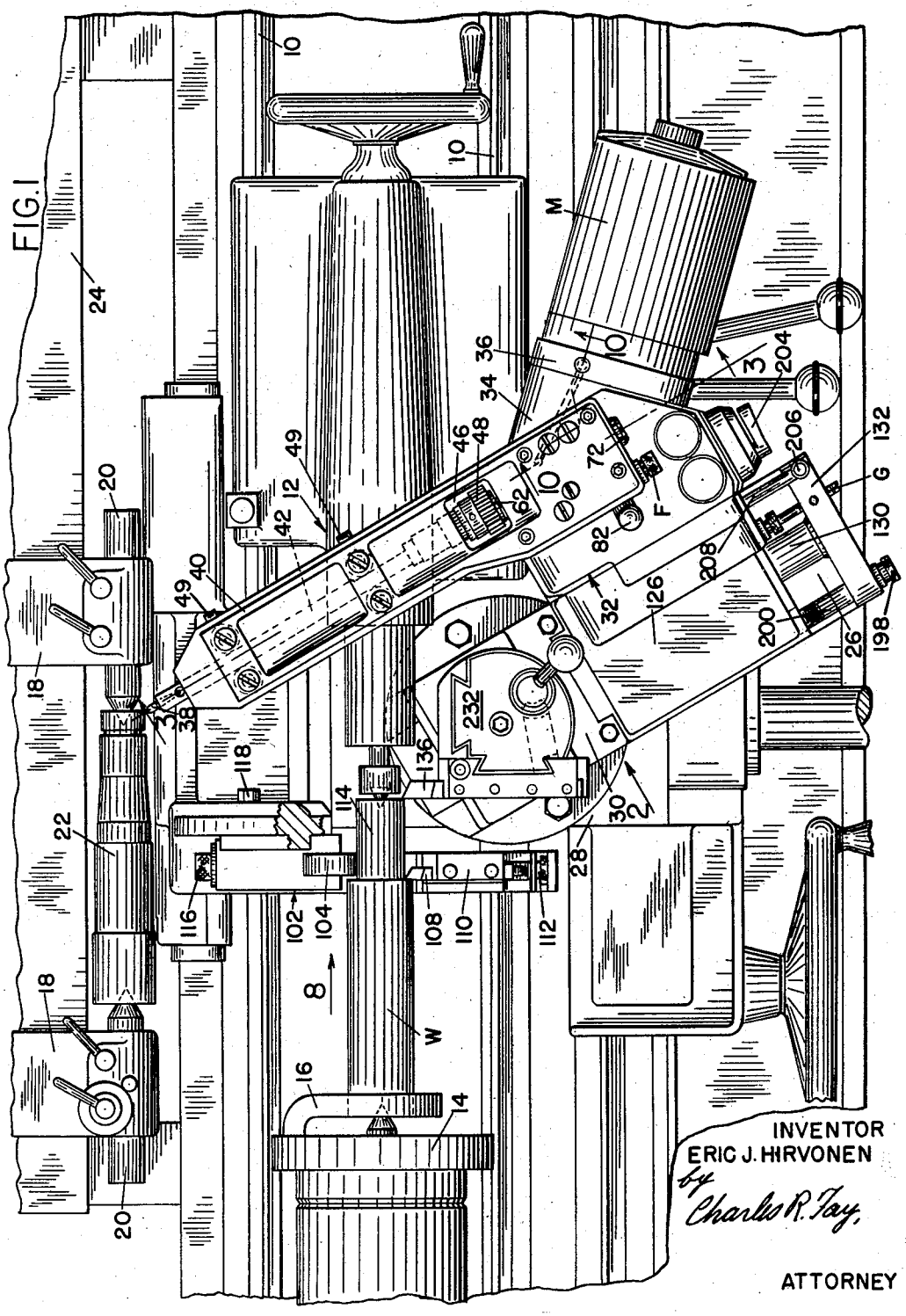
April 21, 1959 E. J. HIRVONEN 2,882,777

HYDRAULIC TRACING APPARATUS

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FIG. 1



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FIG. 2

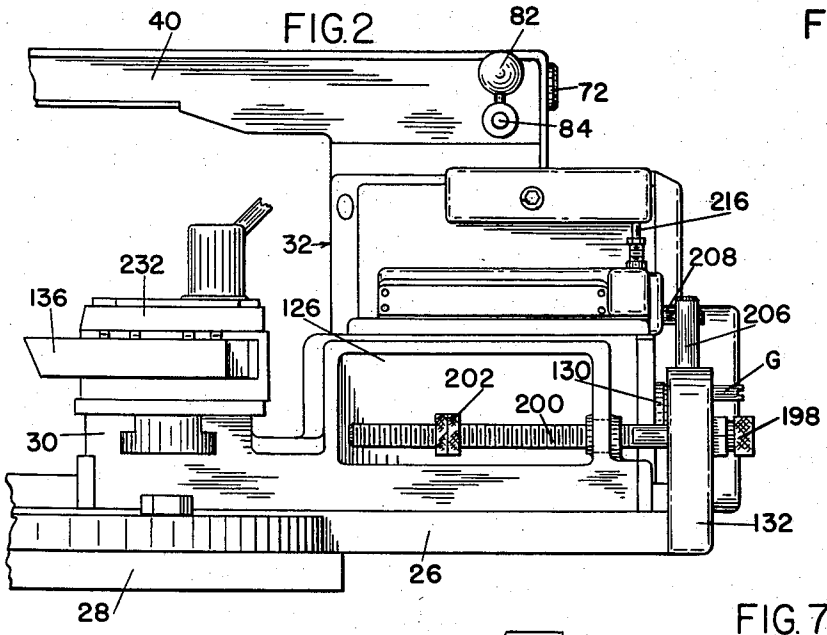


FIG. 26

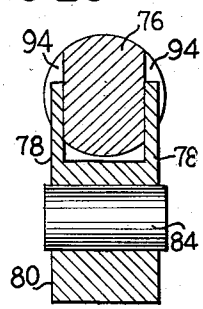


FIG. 5

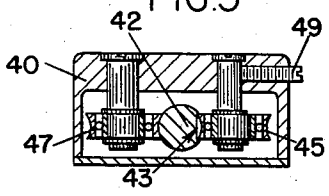


FIG. 7

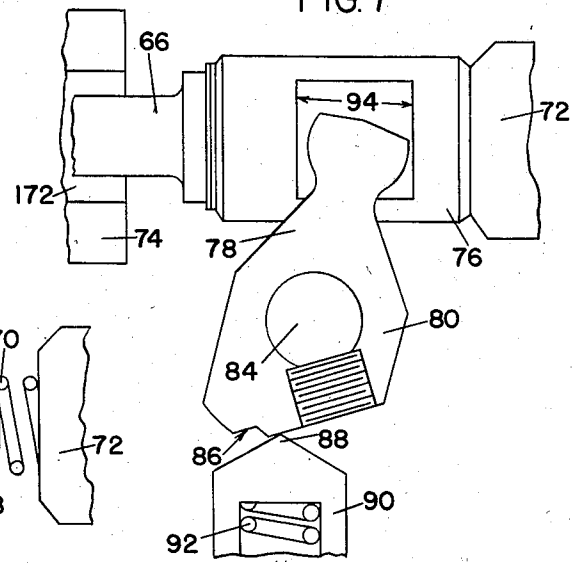
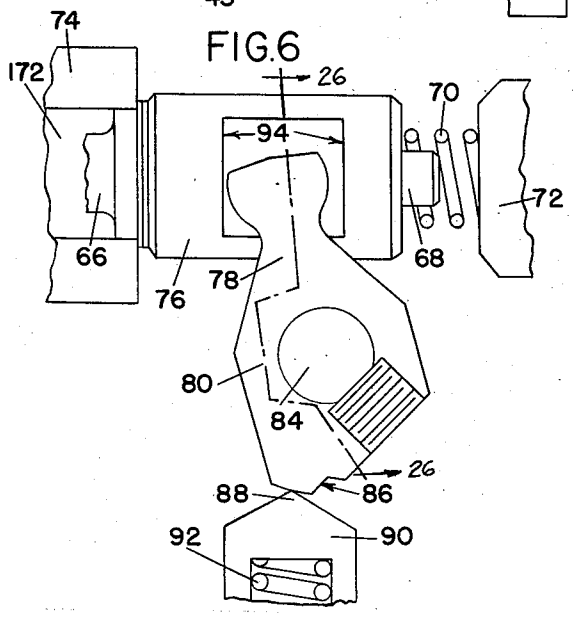


FIG. 6



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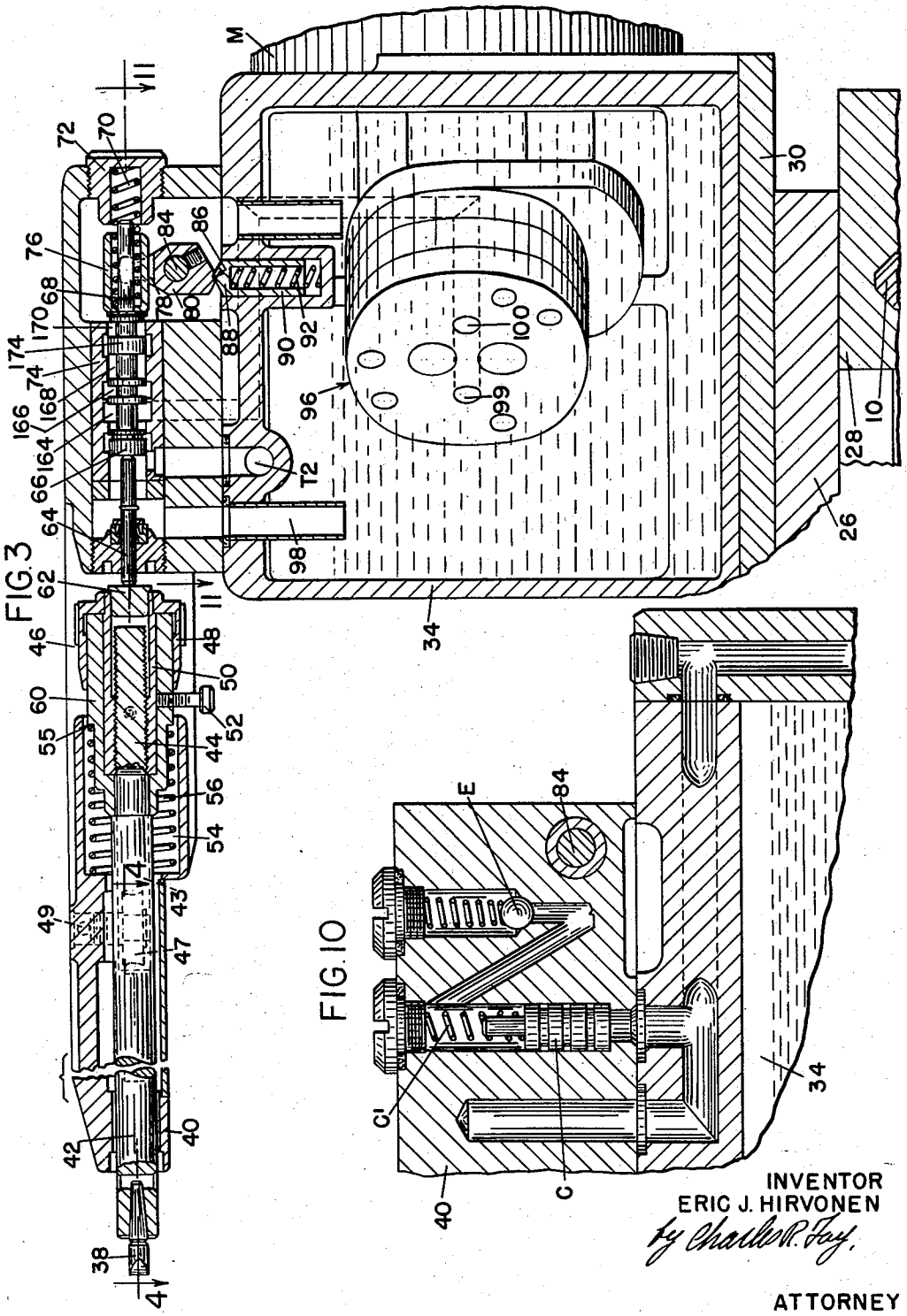


FIG. 3

FIG. 10

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FIG. 4

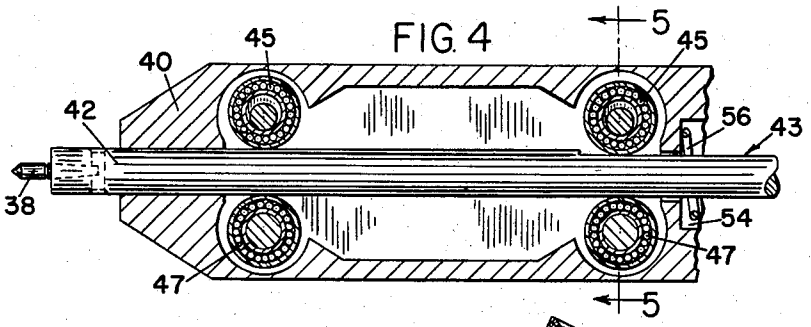


FIG. 8

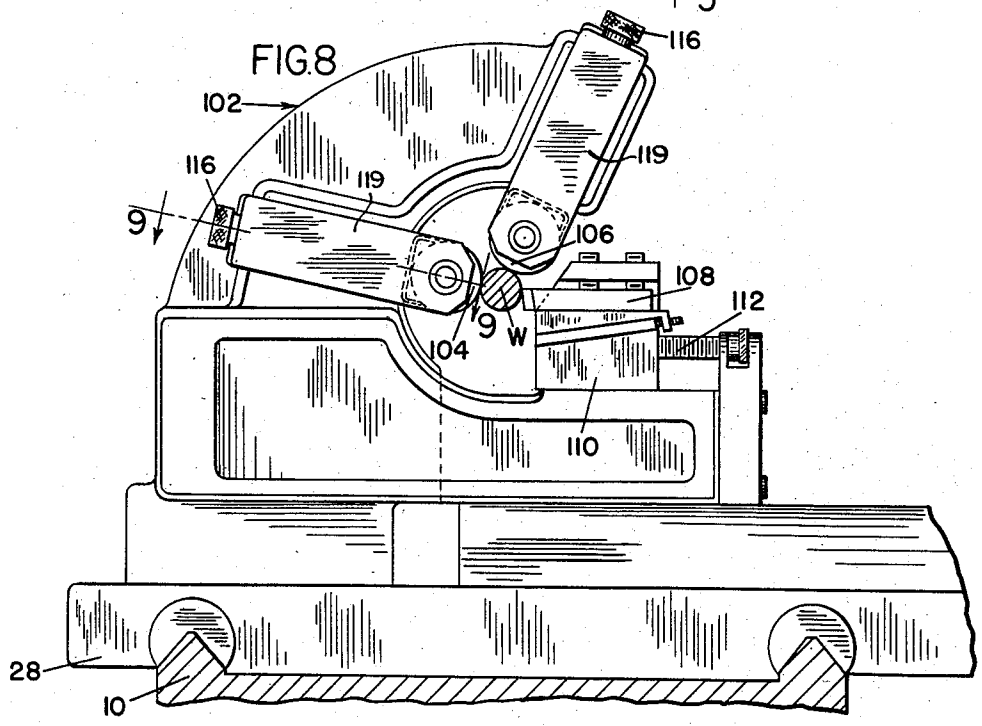


FIG. 15

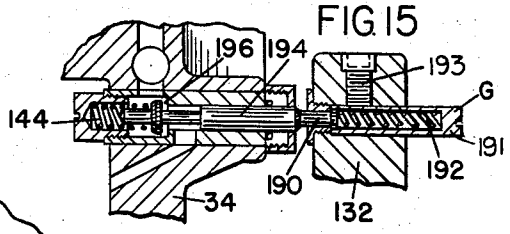
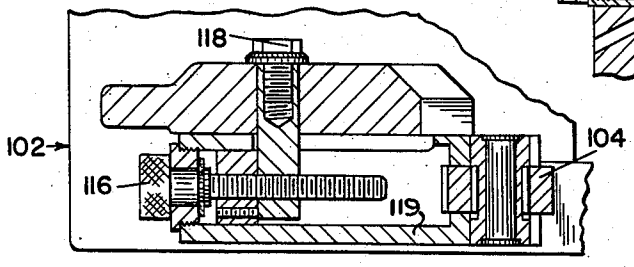


FIG. 9



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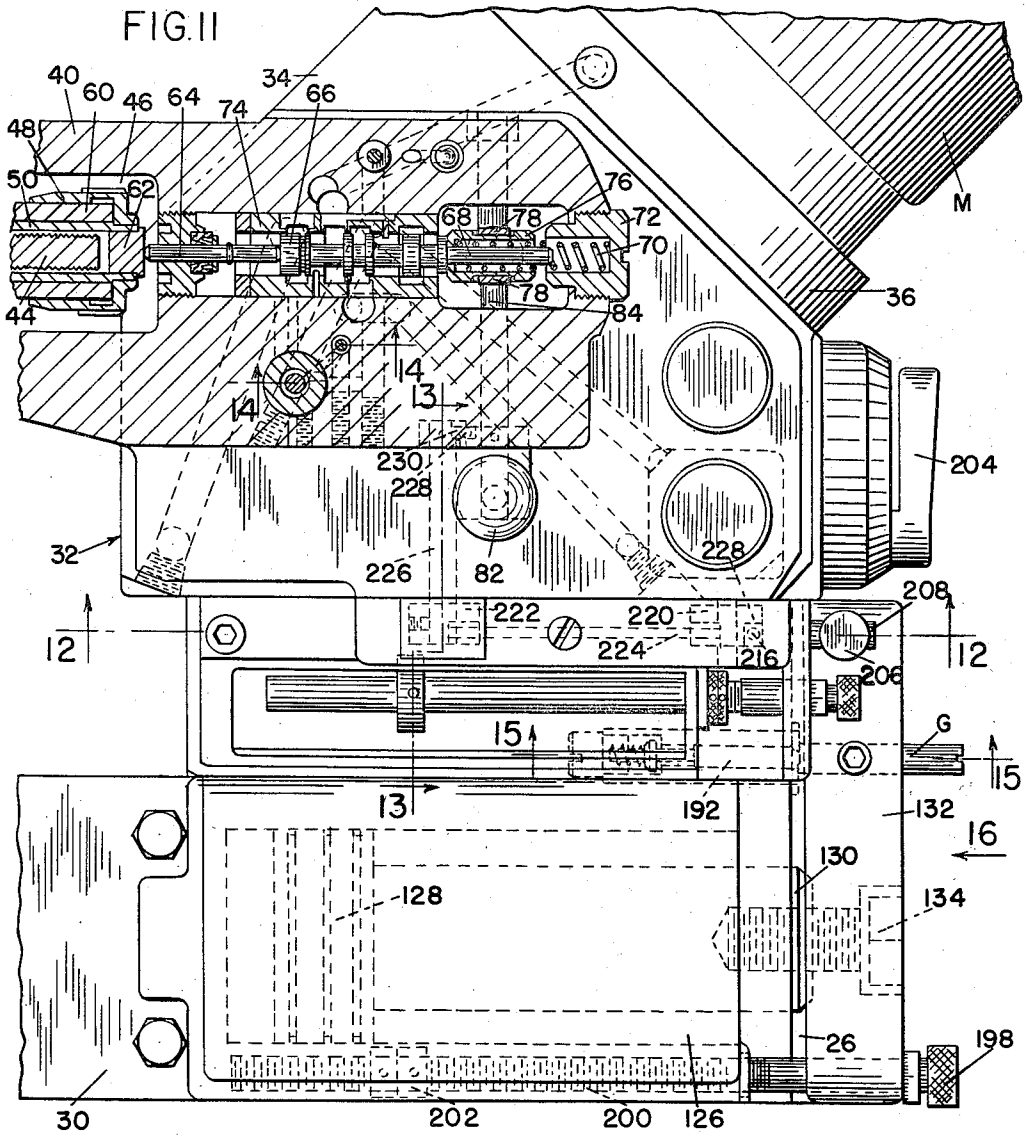
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FIG. 11



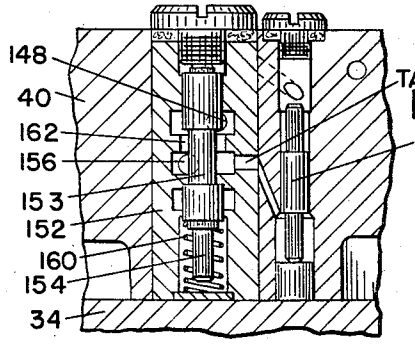


FIG. 14

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FIG. 12

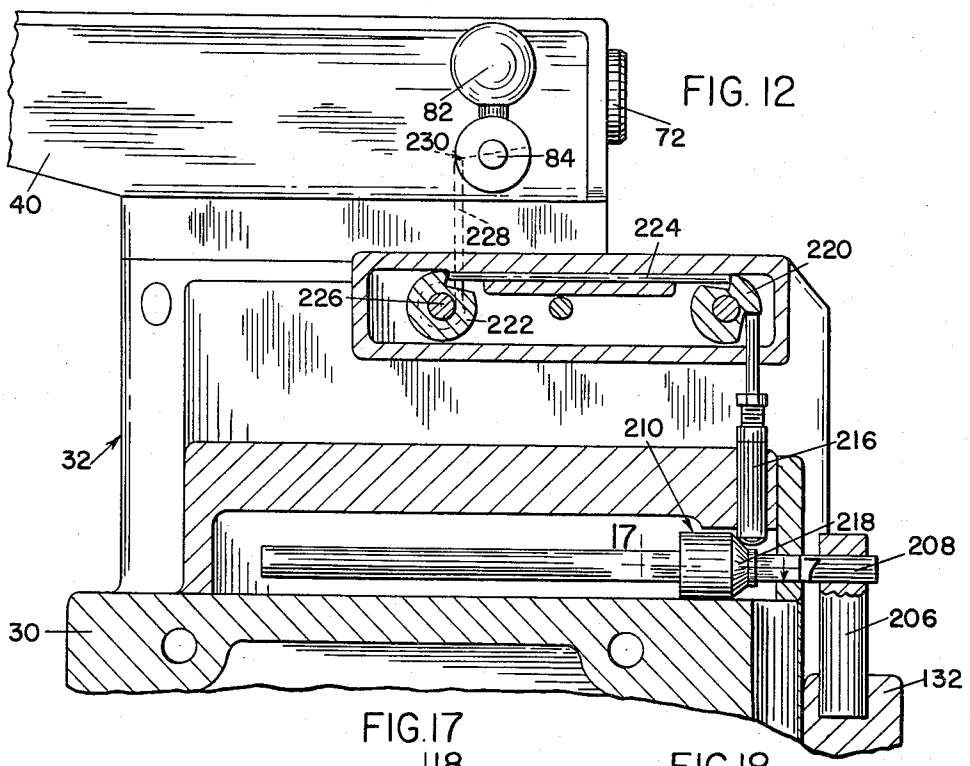


FIG. 17

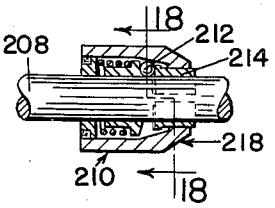


FIG. 18

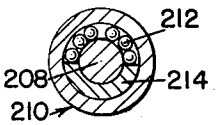


FIG. 13

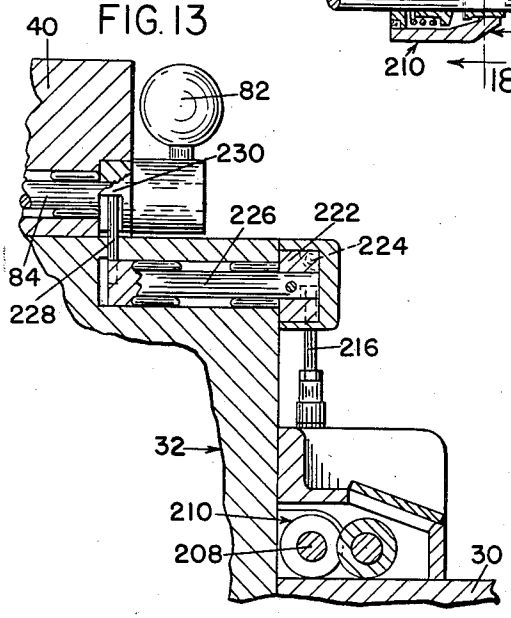
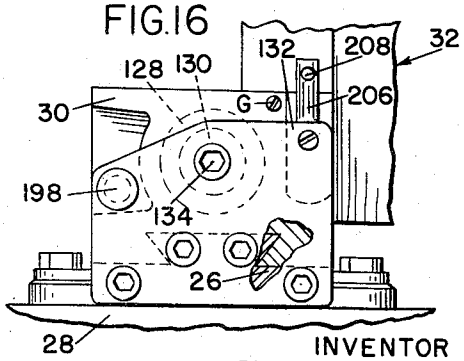


FIG. 16



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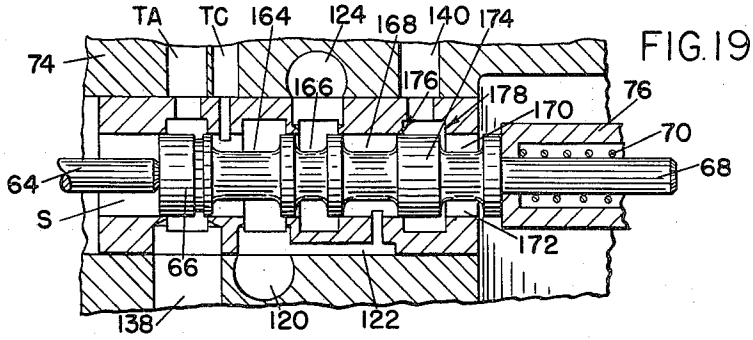


FIG.19

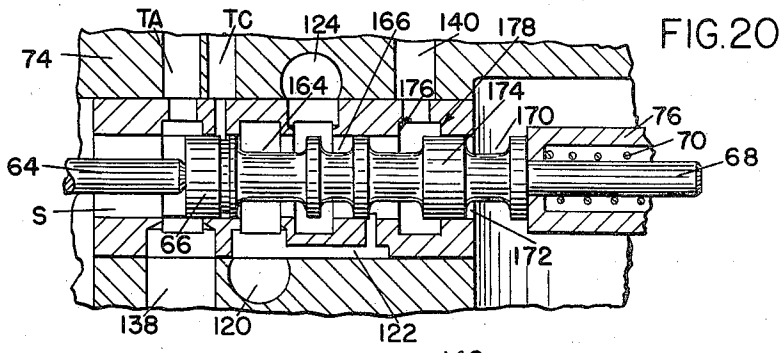


FIG.20

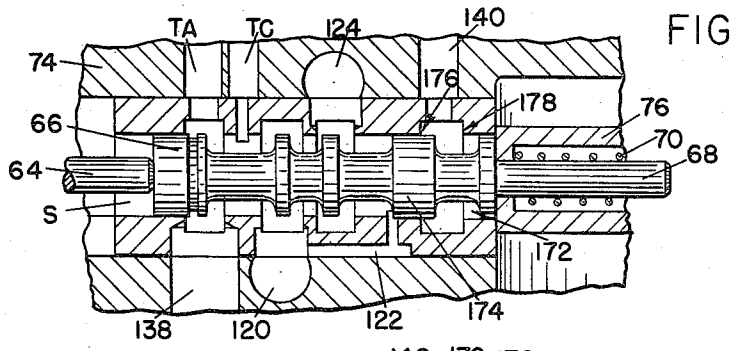


FIG.21

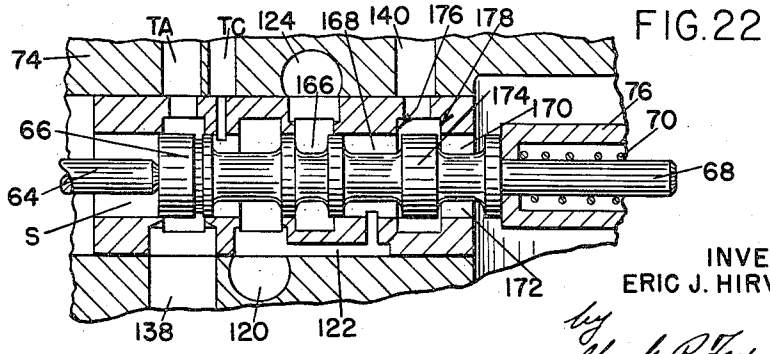


FIG.22

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FIG. 23

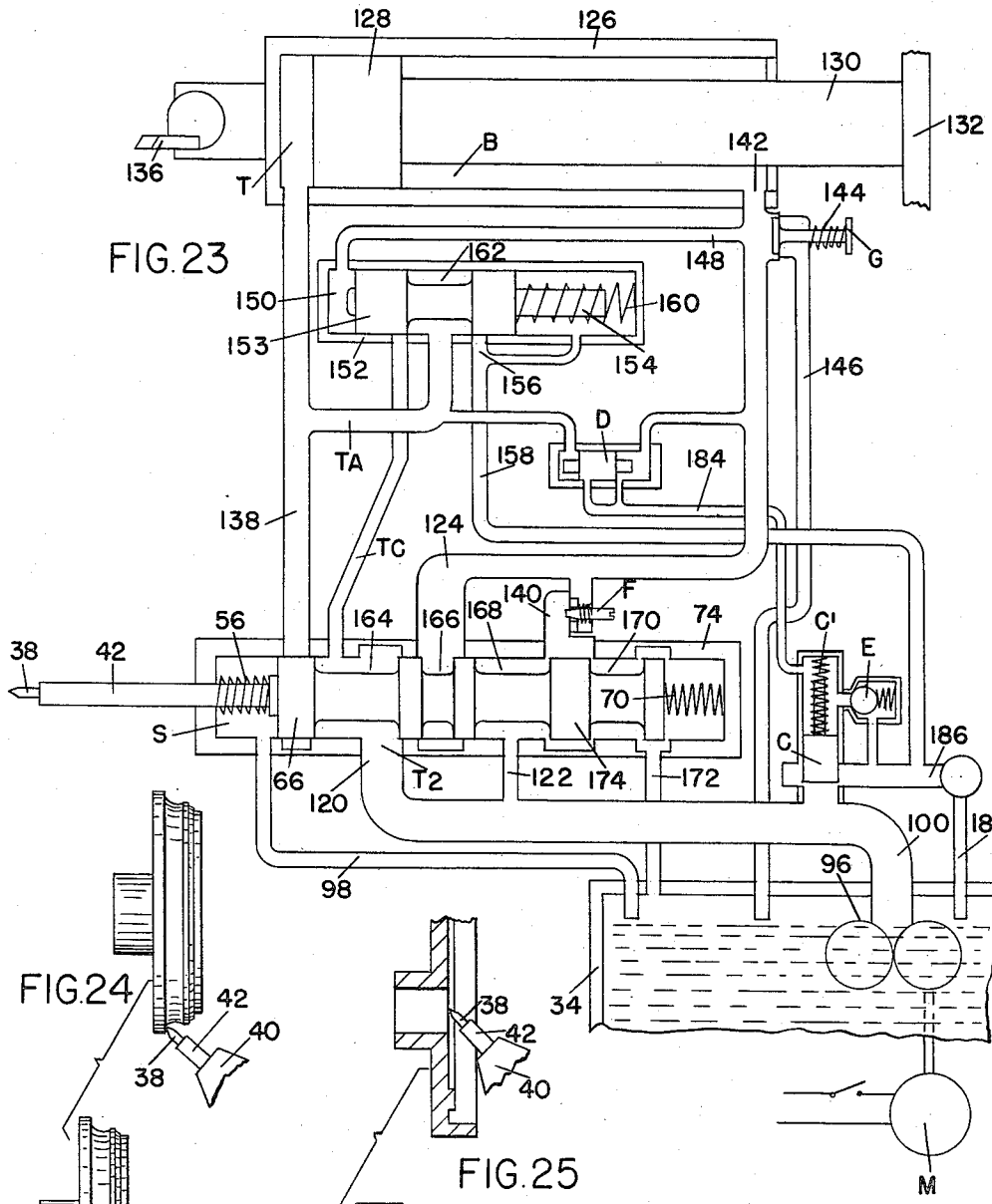


FIG. 24

FIG. 25

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United States Patent Office 2,882,777 Patented Apr. 21, 1959

2,882,777

HYDRAULIC TRACING APPARATUS

Eric J. Hirvonen, Worcester, Mass., assignor to Leland-Gifford Company, Worcester, Mass., a corporation of Massachusetts

Application November 3, 1955, Serial No. 544,760

10 Claims. (Cl. 82—14)

This invention relates to a new and improved hydraulic tracing apparatus, the principal object of which resides in the provision of a completely self-contained unit for attachment to a conventional machine tool such as an engine lathe, said unit being quickly and easily applied to the lathe or other machine tool and being adapted to be removed therefrom for operation of the lathe or machine tool in its customary manner; the provision of a self-contained tracing unit as above described including the tracing element, the copying tool, and fluid pressure means for moving the tool in accordance with the tracer element, said fluid system being completely incorporated in a self-contained unit which includes a prime mover such as an electric motor for operating the same, it being necessary only to mount the unit on the cross slide of a lathe, etc., and to plug the motor into a convenient electric outlet in order to convert the lathe into a copying lathe; and the provision of a hydraulic system for the unitary tracing apparatus as aforesaid in which the electric motor for the pump may be extremely small as compared with prior art devices, being in the nature of one-sixth horsepower or up to one-fourth horsepower for heavy-duty work, there being less heating of fluid from pumping.

Other objects of the invention include the provision of a tracing attachment for machine tools which is greatly improved as to accuracy of the work done and which completely does away with the prior art deficiencies of inaccuracies due to oil viscosity variation and overrunning on the part of the tool when an abrupt change is encountered by the tracer in the pattern or templet, the increase in accuracy of the novel apparatus resulting in completely finished work which is made in one pass only of the tool and in which the prior art necessity for returning is completely avoided; the provision of a tracing apparatus as above described including a greatly improved hydraulic circuit resulting in the greater accuracy recited above and including a main valve directly operated by the tracing element, said main valve controlling the pressure at one side of a piston in a power cylinder which moves the tool and the other main parts of the device, the pressure so controlled being arranged to in turn control a balancing valve, and the balancing valve controlling the admission of pressure to the other side of the piston in the cylinder, so that the advance or retraction of the tracing cutter or tool depends directly on the balancing valve, the latter being capable of compartively great changes in the control of the tool upon an extremely small change in the motion of the main valve under direct control of the tracing element.

Still further objects of the invention reside in the provision of means for rapid advance, feeding the tool for working, and rapid retraction thereof in the absence of operation of the tracing element; the provision of a pressure control for the system which instantly provides for great increase in pressure when demanded, said pressure control being completely automatically operated; the provision of easily operated means by the operator providing for fast return; the provision for a cycle of rapid advance of the tracing element and the tool to the work, and automatic means for instantaneously changing the hydraulic system to the normal tracing operation from the rapid advance upon contact of the tracing element with the pattern; the provision of automatic and adjustable stops of great accuracy for determining the terminals or limits of motion of the device; and in certain combinations and details of the hydraulic system with the tracing attachment as will appear more fully hereinafter.

Other objects and advantages of the invention will appear hereinafter.

Reference is to be had to the accompanying drawings, in which—

Fig. 1 is a plan view, partly in section, of the novel tracer unit in position on an engine lathe;

Fig. 2 is a slightly enlarged view in elevation of the tracer unit, looking in the direction of arrow 2 in Fig. 1 but showing certain of the parts in a different position;

Fig. 3 is an enlarged section on line 3—3 of Fig. 1;

Fig. 4 is a section on line 4—4 of Fig. 3;

Fig. 5 is a vertical section on line 5—5 of Fig. 4;

Figs. 6 and 7 are diagrammatic representations of the positions of the manual control;

Fig. 8 is an enlarged elevation, looking in the direction of arrow 8 in Fig. 1, part in section;

Fig. 9 is an enlarged section on line 9—9 of Fig. 8;

Fig. 10 is an enlarged section on line 10—10 of Fig. 1;

Fig. 11 is a section on line 11—11 of Fig. 3, certain parts being omitted;

Figs. 12 to 15 are sections on the corresponding lines of Fig. 11;

Fig. 16 is an elevation on a reduced scale with parts in section,(looking in the direction of arrow 16 in Fig. 11;

Fig. 17 is a slightly enlarged section on line 17—17 of Fig. 12;

Fig. 18 is a section on line 18—18 of Fig. 17;

Fig. 19 is an enlarged section showing the main valve in tool feeding position, certain parts being omitted;

Fig. 20 is a similar view showing rapid return;

Fig. 21 is a similar view showing rapid advance;

Fig. 22 is a similar view showing the tracing position;

Fig. 23 is a diagram showing the hydraulic system in tracing position;

Figs. 24 and 25 show representations of different forms of work which may be accurately copied by the tracer of this invention; and

Fig. 26 is a section on line 26—26 of Fig. 6.

Referring now to Figs. 1 and 2, the present invention is shown as applied to the ways of a conventional engine lathe. These ways are indicated at 10; the tail-stock is generally indicated at 12, the headstock at 14, and the work-driving dog at 16, the work being indicated generally by the character W. This lathe of course is provided with the usual cross-slide and on this cross-slide the unit or apparatus comprising the present invention is removably mounted by bolts or the like conventional fastening devices. By this means, the new unit may be given all the usual motions of the cross-slide.

At the back of the lathe, the same may be provided with removable template brackets 18 which provide centers 20 to clamp a template or pattern 22 in operative position for cooperating with the tracing attachment. These template brackets are provided with clamps, etc. for the centers, and also they may be mounted on a rail 24 detachably applied to the machine base for the purpose.

The unit comprises a tool slide base indicated at 26 and this base may be indexed upon the cross-slide indicated at 28 as is well-known in the prior art, so as to provide for different degrees of angularity of

adjustment thereof with respect to the work and the tracing element.

Rectilinearly slidably mounted on the tool slide base **26**, there is a tool slide **30**, and this tool slide may be said to mount substantially all of the tracer and tracer cutter constructions, including the hydraulic system and the automotive forces therefor. To this end, there is provided a housing or the like generally indicated at **32** and the main part of the hydraulic system may be located therein. To this housing, there is secured the oil sump, etc. **34** and the pump and the motor bracket **36**, the motor being shown at M and being mounted directly thereon, so that the entire pump, hydraulic system and motor is a single unit, all mounted on the tool slide **30** for movement therewith under control of the tracing element.

The tracing element is indicated by the reference numeral **38**, and it is located in a tracing arm **40** which provides a housing therefor. The details of the tracing element are best shown in Fig. 3. The tracing element comprises a replaceable tip located in the end of a rod **42**, which rod extends generally through the tracing arm **40** and terminates in a screw-threaded portion **44** at the rear end thereof.

The tracer rod **42** may be provided with a flat **43** against which bears one of a pair of adjustable ball-bearing rollers **45**. This prevents the rod from turning and it is backed up by similar but fixed ball-bearing rollers **47** at the opposite side thereof. The rollers **45** may be mounted on eccentric centers to adjust their position in and out laterally relative to the rod **42** in order to provide an accurate sliding guide means therefor, and set screws **49** are used to hold the adjustments.

The tracing arm **40** is provided with an aperature therein as at **46** and in this aperture there is located an accurate adjusting nut **48** which by means of an interiorly-threaded sleeve **50** in mesh with the threaded portion of rod **42**, may be utilized to extremely accurately adjust the position of the tip of the tracing element **38** with respect to the pattern **22** for a given position of the tracing arm. A thumb-nut **52** may be used to lock the adjustment and micrometer indicating means are provided for the convenience of the operator of the machine.

The tracing arm **40** is provided with an interior enlarged chamber at **54** containing a coil spring **56**, said coil spring finding a reaction point at one end of the chamber **54** and at the other end upon a shoulder **55** formed in an enlargement **60** attached to the rod **42**. The enlargement **60** is in the form of a sleeve which axially enters and is located within the nut **48**. The function of the spring **56** is to continuously press the tracing element to the right, as for instance in Fig. 3, so that a hub **62** at the center of the nut **48** is constantly in engagement with axially movable pin **64**, this pin translating the axial motion of rod **42** within the housing **40** to a main piston-type valve which is indicated at **66**. This valve is provided with lands and grooves and is reciprocable in nature.

The valve **66** is provided with an axially-extending stem **68** (see also Fig. 11) surrounded by a coil spring **70** held by a removable nut **72** located at the rear end of the tracer arm housing **40**. The spring **70** is stronger than its opposing spring **56** and as an illustration spring **56** may be a two-pound spring and spring **70** as a four-pound spring, so that the valve is normally held firmly against the thrust of the pattern. This provides for an exact sweep or passage of the tracer point **38** over the pattern, as well as providing for relative axial motion between the tracing rod **42** and the valve **66** relative to the valve housing **74**, to provide the variation in pressure to actuate the apparatus to displace the slide **30**.

A barrel or the like in the form of a sleeve at **76** surrounds the rod **68** and part of the spring **70**. This barrel or sleeve is provided with lateral depressions or notches therein which accommodate the arms **78** of a yoke **80** as shown in Figs. 3, 6 and 7, the sleeve **76** has three positions of adjustment as provided for by a handle **82** and shaft **84**, the latter rocking under influence of the handle so that the arms **78** contact the sides of the notches at **94** to move the sleeve. The handle is exposed at the side of the tracing arm housing for convenience of manipulation by the operator and provides manually-controlled rapid advance or rapid retraction of the unit, as well as the central position for the tracing action of the device.

As seen in Figs. 3, 6 and 7, the yoke **80** is provided with a holding notch **86** which engages a pointed end **88** on a latching slide **90** held in its uppermost position by the spring **92**. In the position shown in Fig. 3, the device is in the tracing position for normal operation; in the position of Fig. 6 the valve parts will be held in position for rapid advance, and in the position of Fig. 7 the valve **66** will be held in a position for rapid retraction. It is to be noted that the arms **78** do not contact the sides of the depressions **94** in Figs. 6 and 7, when the device is in the Fig. 3 position, i.e., in the tracing position, so that the tracing rod and valve **66** may move slightly to carry out the tracing operation, and so that no interference is encountered with respect to the yoke by reason of abrupt changes in the pattern, which of course will be communicated to the extending end **63** of the valve **66**. However, with the valve **66** in position of rapid advance, the yoke will snap the valve over to tracing position upon the tracer element **38** striking the pattern, and this action is automatic.

The pump is generally indicated at **96** in Fig. 3 and may be directly driven by the motor M, being located in its housing **36** and **34**. The reference numerals **98** and **99** show returns or drains and the pressure line is indicated by the reference numeral **100**. Some of the piping has been omitted from this figure to provide for clarity of illustration, but the pressure of the pump is directed to the passage T2 in Fig. 3 and thence proceeds as will be described hereinafter.

Referring now again to Fig. 1, there is shown a traveling rest generally indicated at **102**. This rest may be attached to the cross-slide and it travels longitudinally of the lathe by the conventional mechanism provided in engine lathes for this purpose. As best seen in Fig. 8, the traveling rest is positioned upon the ways **10** and it includes a pair of rollers **104** and **106** which ride upon the surface of the work W after the first cut has been made by a preliminary traveling tool indicated at **108**.

The tool **108** is mounted on a tool-holder **110** adjusted by means of the screw **112** and is mounted upon member **102** for translation with the tool rest and cross-slide, but just in advance of the rollers as clearly seen in Fig. 1. By this means, an accurate surface of revolution is provided at **114** for the rest to contact, and this ensures that the work shall be held exactly correctly with respect to the centers **20** of the pattern-holding mechanism, and this in turn results in accuracy of work performed, permitting high speed feed rates without deflection, without the usual variation caused by the prior art inaccuracies in holding between the pattern and the work itself. Each roller **104** and **106** may be provided with adjusting means as shown in Fig. 9, and this may comprise the thumb-screw **116** and the lock **118**, the thumb-screw traveling an L-shaped slide **119** on which the respective rollers are rotatably mounted.

Figs. 19 to 23 inclusive illustrate the principal parts of the hydraulic system. The motor M drives the pump **96** providing fluid pressure in the pipe **100** leading to the valve **66** at T2. There is a main branch **120** to the valve **66** and this has a small restricted passage at **122** that leads into the valve housing **74** at a different position.

A passage **124** leads from the valve housing **74** into

the cylinder indicated at **126** at the piston rod side thereof which is indicated at B, this standing for the bottom of the cylinder as respects the piston **128**, the other side of which is labeled T which stands for the top of the cylinder.

The cylinder **126** is fixed to and moves with the entire unit, the piston **128** being fixed on the rod **130** to a projection or flange **132** at the rear end of the tool-slide base **26**. This may be accomplished by means of a bolt or the like generally indicated at **134** (Fig. 11). Thus upon pressure at the bottom of the cylinder, the entire sliding tool unit will be retracted, and upon pressure being applied to the top of the cylinder, the tool will advance.

A passage **138** leads from the left-hand end of the valve housing **74** to the top of the cylinder and is in open communication with the passage labeled TA. Also, there is a passage of a more restricted nature labeled TC (see diagram Fig. 23), and there is another passage **140** which is provided with a feed control needle valve F of conventional type. Passages **138**, TC, **140** and **124** are all pressure passages but in certain conditions of valve **66**, passage **138** may go directly to the sump labeled S (see Fig. 20).

Passages **124** and **140** communicate and extend to lead into the bottom of the cylinder B as at **142**; adjacent this location, there is a valve generally indicated at G which is normally held closed by the spring **144** but which may be opened to direct the bottom of the cylinder directly to the sump as indicated by the pipe **146**.

Also adjacent this point, there is a branch pipe **148** that leads to one end **150** of a valve housing **152** having a piston valve **154** therein. The passage TC also leads into this passage centrally thereof, as also does passage TA in the relationship shown in Fig. 23, and there is a branched passage **156** leading to the sump through the passage **158**.

The valve **154** is provided with a spring **160** which constantly tends to move the same to the left. This valve is provided with a center passage **162** by which the passages TC and TA may communicate in varying degrees, depending upon the position of valve piston **154** under influence of the spring **160** and the pressure in the passage **148**, which pressure tends to move the valve **154** to the right against the spring tension.

The valve **66** is directly connected to the tracer control rod **42** and is provided with the opposing springs above described, these springs being indicated at **56** and **70**, for the purpose noted. The valve itself is provided with an annular passage at **164**, another at **166**, a third at **168**, and a fourth at **170**, and in addition there is a return to the sump at **172**.

The tracing condition will be described first, and this is shown in Fig. 22 wherein the representation of the valve **66** shows the fact that the passages **138** and TA are always in communication, regardless of the position of the valve. The pressure enters the port at **120** and passes into the passage TC, the lines at **138** and TA being cut off both from the sump and from the pressure. However, the branch pipe **122** leads pressure into the valve passage **168**; and with the parts in position shown in Fig. 22, the fluid is seen to pass by valve part **174** to the sump as by the passage at **172**. The valve part **174** is located between and closely adjacent the two shoulders **176** and **178** in the valve housing, so that a small amount of oil is conducted through the passage **140** past the metering valve F and to the bottom of the cylinder B.

An extremely small change in the position of the valve **66** is sufficient to change this relation. If the valve **66** be moved very slightly to the right, the small passage between the shoulder **176** and the part of the valve at **174** increases and the passage between this same part of the valve and the shoulder **178** decreases. This action raises the pressure at **140**, which means that the pressure is raised in the bottom of the cylinder B, whereupon the cylinder moves to the right an amount in ratio to the movement of the valve.

As soon as the cylinder **126** moves to the right, then the valve housing **74**, together with the entire slide and all the movable parts, also so moves, returning the shoulders **176** and **178** to original position relative to the valve part **174**, whereupon the original pressure situation is re-imposed and the tracing device will be again once more traveling a straight line with the cross-slide.

When the pressure rises as at **140**, it likewise rises in the passage **148** and this moves the valve **154** to the right against the action of the spring **160**. When in tracting position, the valve part **153** of valve **154** was positioned to allow a small passage of fluid from the passage TC to the passage TA, and thus into the top of the cylinder T, the sump being cut off, balancing the pressure in the bottom of the cylinder. But when the valve **154** is moved to the right as described, it actually narrows the small aperture existing from passage TC to the valve at **162**, so that the pressure at the top of the cylinder is correspondingly decreased, providing for the action aforesaid. It is to be noted that the size of the openings at **176** and **178** may be on the order of thousandths of an inch, and that extremely small differences will cause the changes described.

If on the other hand, the valve **66** should be moved to the left from the position of Fig. 22, the passage at the shoulder **176** is lessened in extent and that at **178** is increased, thus decreasing the pressure at **140** and at **142** and in the bottom of the cylinder. This action decreases the pressure at **150** with regard to valve **154**, and the spring **160** then tends to move valve **154** to the left, making the passage at TC larger, so that the pressure at the passage **162** to passage TC is allowed in increase through valve **66** and passage TA to the top of the cylinder, thus moving the entire apparatus to the left and causing tool **136** to make a deeper cut in the work.

The element G operates to open the bottom of the cylinder to the sump, whereupon pressure at the top of the cylinder will obviously cause the cylinder to be moved very rapidly to the left, relieving the pump of most of the pressure and avoiding heating. As explained above, the handle **82** may be manually operated to achieve instant pressure to move the yoke **80** to accomplish rapid return and rapid advance as desired without relation to the tracer element.

If it is desired to feed the tool without relation to the tracer, the valve **66** is placed in the position shown in Fig. 19 by knob **82**. In this case, the passage **140** is open to the sump; the pressure line **120** directly communicates with TC; by this means the passage TA is provided with pressure in order to allow the cylinder **126** to move continually to the left without interruption.

On the rapid return, the passage at **172** is closed. Pressure in the restricted passage **122** communicates directly with the passage **140** and the passage TC is cut off, there being pressure applied also through the line **124** combined with the pressure in **140** to rapidly withdraw the cylinder to the right in Fig. 23.

In the condition of rapid advance, the passage at **172** is again cut off as is the passage at **140**. The pressure at **120** is open to **138** and TA directly, which causes high pressure at the top of the cylinder, causing the same to move to the left rapidly.

There is provided a shuttle valve D, one side of which is open to passage TA and the other to passage **142**, TA and **142** leading to opposite sides of the piston **128**. When excess pressure is called for in either direction, the shuttle valve D will shift, thus applying pressure in the piping **184** which leads to an automatic pressure control device C. Excess pressure in the pipe **100** urges the piston in the device C upwardly against its spring C1 so as to pass such excess pressure to the pipe **186** to the sump by pipe **188**, the latter also providing for the sump return from the branch pipe **158**. Upon pressure being built up

above the piston in the automatic control C, this piston moves downwardly and allows build-up of pressure in the pipe **100** and throughout the system where called for, being directed to the side of the piston required, depending upon which side of the piston calls for the increased pressure. There is also a maximum pressure valve at E through which the pressure from passage **184** will leak when a certain high predetermined pressure is reached.

Fig. 15 shows in section a form of automatic control for the valve G. In this case, the tool slide base rear flange **132** is provided with a stop pin **190** movable in an adjustable cylinder **191** and backed up by a spring **192**. A setscrew **194** holds the cylinder in adjusted position. The tool slide housing carries with it a stop rod **193**, aligned with the member **190**, and backed up by the spring **144** which is weaker than spring **192**. The stop pin **190** will give upon contact therewith in order to open the valve as at **196** corresponding to the valve G in Fig. 23 in order to cause the fluid to be conducted directly to the drain upon arrival of the tool-slide at its rearwardmost position.

Also, the tool slide rear flange **132** carries a micrometer screw adjustment generally indicated at **198** controlling the screw-rod **200**. This screw-rod has an adjusting nut and lock-nut **202** for providing a limiting stop in the forward direction of the tool slide **30**. By the use of the micrometer head **198**, a very exact position of the end of the travel of the tool-slide is provided. The motor is provided with an "on" and "off" switch **204** and apropriate overload protection is provided with this switch.

Referring to Fig. 12, there is provided an adjustable control for converting the travel of the tool slide from rapid traverse to a feed position and this comprises a pin **206** mounted in the tool-slide base rear flange **132**, there being mounted thereon a forwardly-extending rod **208**, the main portion of which is located in the housing **32**. This rod is provided with an adjustable stop generally indicated at **210**, the details of which are illustrated in Figs. 17 and 18. This stop may be adjusted relatively to rod **208** by means of the spring and ball clutch therein generally indicated at **212**, the spring wedging the ball into gripping relationship upon being released by a sleeve **214** to position the stop **210** at a desired longitudinal position on rod **208**.

Cooperating with the stop there is a plunger rod **216** which is axially movable by the inclined surface **218** of the adjustable stop in order to rock an element **220**, and in turn rocking element **222** by means of a rod **224**. Upon rocking of element **222**, a shaft **226** is oscillated, in turn oscillating a rod **228** which is connected to the shaft **84** at an offset location as at **230**. As described above, shaft **84** controls valve **66**, see Fig. 7.

By this means, the device is automatically thrust into feed position at a certain adjusted location, i. e., at the end of the adjusted rapid traverse stroke and thereafter the device operates in the feed position of the main valve.

The tool post itself as illustrated generally at **232** is the same construction as illustrated in my copending application Serial No. 541,591 filed October 20, 1955, and with the construction recited above, extremely accurate work is performed not only with the more usual types of templates as illustrated in Fig. 1, but with the more difficult types of work to perform as illustrated in Figs. 24 and 25. It will be seen from these diagrams that the present tracer is capable of performing extremely accurate cuts on the concave surfaces shown therein and the interior surfaces as at **236** and **238** respectively.

It will be seen from the above that this invention carries out all of the objects stated above, and that as well as providing extreme accuracy, the unit is able to provide the same in many different types of work at lower cost due to simplicity of construction and to the fact that the hydraulic system allows for a much smaller motor to be used to provide the fluid pressure necessary; and furthermore such motor is mounted in a unitary manner with the rest of the device so that all that is necessary to do to convert any conventional engine lathe into a tracing lathe is to set up the template holding centers and to mount the unit of this invention on the cross-slide of the lathe, plugging the motor into an electric outlet. The device is extremely light-weight, economic, and small compared to devices of the prior art for the same purpose; and it is easily attached and removed from the lathe without the necessity of large motors, pumps and complicated fluid pressure systems which require support at remote locations at the back of the lathe, on the floor, etc.

The tracer point pressure is very light and even wooden templates can be used for speed and economy; use of the attachment is not limited to production work, as any piece can be used for a template to make a replacement part, using the micrometer nut on the tracing arm to compensate for wear or for grinding surfaces; thread chasing may be accomplished; and the invention provides for a power feed compound tool slide with rapid traverse and hydraulic feed, with an adjustable stop for shifting from rapid traverse to feed.

Having thus described my invention and the advantages thereof, I do not wish to be limited to the details herein disclosed, otherwise than as set forth in the claims, but what I claim is:

1. A tracing apparatus for machine tools comprising a tool, a relatively movable piston and cylinder to move the tool, a tracer for movement under influence of a pattern, a main valve actuated by the tracer, a balancing valve hydraulically actuated by the main valve, a source of hydraulic pressure and a hydraulic circuit for the cylinder and valves, the balancing valve being directly connected to the cylinder at one side of the piston, the main valve providing hydraulic pressure for control by the balancing valve for the one side of the piston, said main valve being connected directly to the other side of the piston and to one side of the balancing valve to move the latter according to the pressure at said other piston side as controlled by the main valve.

2. A tracing apparatus for machine tools comprising a tool slide, a tool thereon, a cylinder and piston to move the tool slide, a tracer for movement under influence of a pattern, and a hydraulic system for moving the tool slide in accordance with the motion of the tracer, said system comprising a balancing valve for variably admitting fluid under pressure to the cylinder at one side of the piston, a main valve for variably admitting fluid under pressure directly to the other side of the piston, means to control the position of the first valve under influence of the pressure at said other side of the piston, the position of the tool being controlled by the pressure at the other side of the piston and this pressure being controlled by the main valve, said tracer being connected to operate the main valve.

3. The tracing apparatus of claim 2 including means to communicate increased pressure at the other side of the piston to the first valve to move the latter, and means in the first valve to tend to close off pressure to the one side of the piston upon such movement.

4. The tracing apparatus of claim 2 including means to communicate increased pressure at the other side of the piston to the first valve to move the latter, and means in the first valve to tend to close off pressure to the one side of the piston upon such movement, the main valve moving with the tool slide and tending to move to original relationship relative to the tracer and main valve, to restore original pressure to the other side of the piston, and means to move the first valve to original position upon reduction of pressure thereon.

5. Tracing apparatus comprising a base, a tool slide thereon, a tracer element, a main valve operated by the tracer element, a source of fluid pressure, a balancing valve, said main valve supplying fluid pressure to the balancing valve, a cylinder and piston for moving the tool

slide in accordance with the tracer element, said main valve supplying fluid pressure to one side of the piston and to one side of the balancing valve, the latter supplying the fluid pressure from the main valve to the other side of the piston and being moved to supply alternatively less or more fluid according to the respective rise and fall of pressure at the one side of the piston as determined by the relative position of the tracer element and the main valve.

6. The tracing apparatus of claim 5 including means to control the pressure of the fluid, and means to operate the pressure controlling means to raise the pressure upon relatively large imbalance of pressure between the two sides of the piston.

7. The tracing apparatus of claim 5 including means to control the pressure of the fluid; and means to operate the pressure controlling means to raise the pressure upon relatively large imbalance of pressure between the two sides of the piston, said last-named means including a shuttle valve located between the two sides of the piston and alternatively connecting the respective piston side fluid pressure with the pressure controlling means.

8. The tracing apparatus of claim 5 including means to control the pressure of the fluid, and means to operate the pressure controlling means to raise the pressure upon relatively large imbalance of pressure between the two sides of the piston, said last-named means including a shuttle valve located between the two sides of the piston and alternatively connecting the respective piston side fluid pressure with the pressure controlling means, and a high pressure control valve associated with the shuttle valve and regulating the maximum pressure of the fluid system.

9. The combination of an engine lathe having ways and a cross-slide with a tool base to be removably secured to the cross-slide, a motor, a fluid pump driven thereby, a main valve, a balancing valve, a tracer element actuating the main valve, a cylinder and piston, a tool reciprocated thereby, the main valve varying the pressure at one side of the piston and the balancing valve varying the pressure at the other side of the piston in inverse ratio thereto, said balancing valve being connected to the said one side of the piston and being variably actuated thereby.

10. A tracer apparatus comprising a base adapted to be relatively traveled along a piece of work to be operated upon, a tool slide on the base to be reciprocatively actuated in and out relative to the work-piece as the base travels, the motion of the tool slide being under the control of a pattern for this purpose, a tool on the tool slide, a tracer arm movable with the tool slide, a movable tracer element on the tracer arm, a main piston valve movable by the tracer element relative to the tool slide, a source of fluid pressure leading to the main valve, a power cylinder and piston for moving the tool slide in accordance with momentary changes of position of the main valve relative to the tool slide, said main valve including means to vary the pressure in the cylinder at one side of the piston upon the occurrence of such momentary changes to cause motion of the tool slide to return the same and main valve to original relationship, a balancing piston valve having one side of its piston open to the said power cylinder at the said one side thereof for movement of the balancing valve by the variation in pressures, means yieldably opposing the pressure on the balancing valve, means leading fluid pressure to the balancing valve to be controlled thereby and leading from the balancing valve to the power cylinder at the other side of the piston thereof.

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