

June 26, 1962

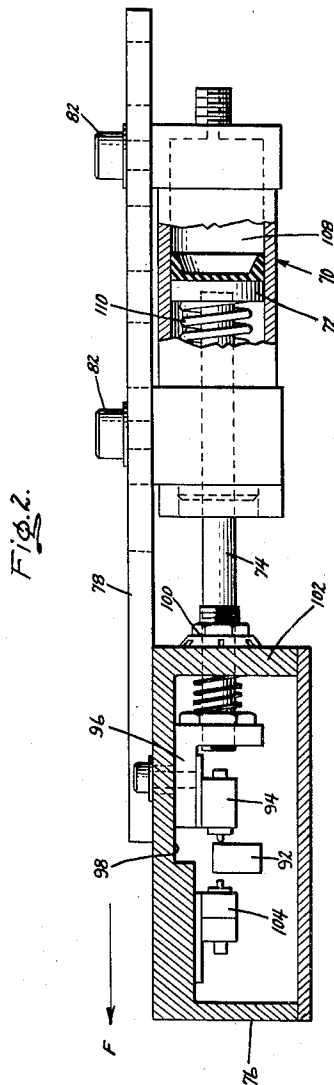
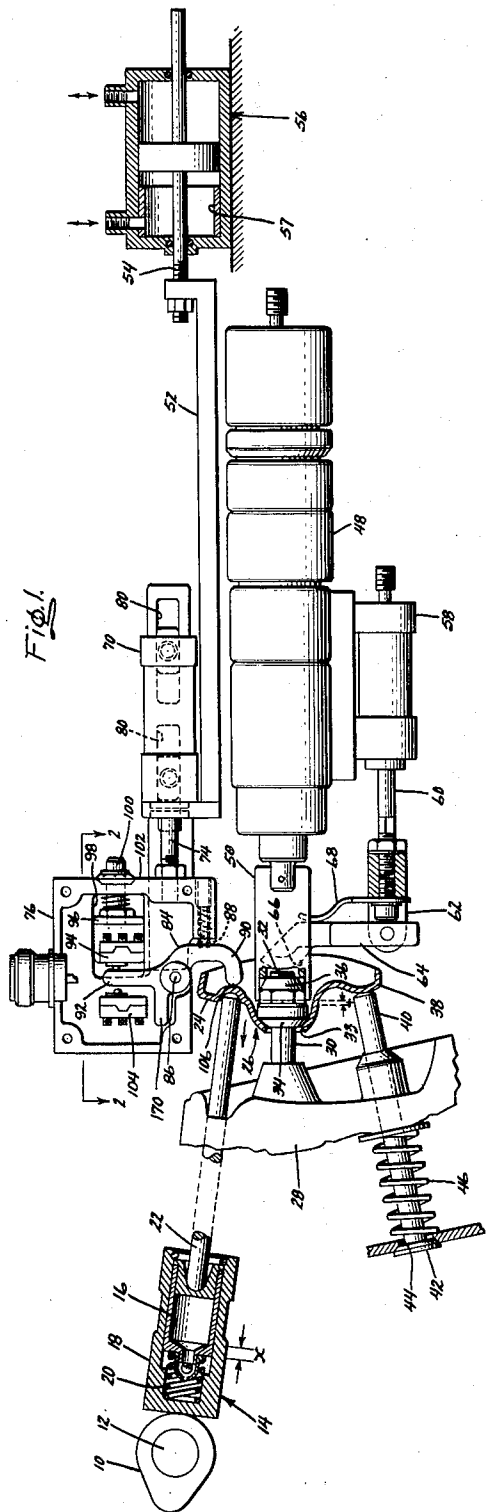
J. M. LEWIS

3,040,422

MICROMETER APPARATUS

Filed June 2, 1958

3 Sheets-Sheet 1



Inventor:
John M. Lewis,
by *Lust & Link*
Attorneys.

June 26, 1962

J. M. LEWIS

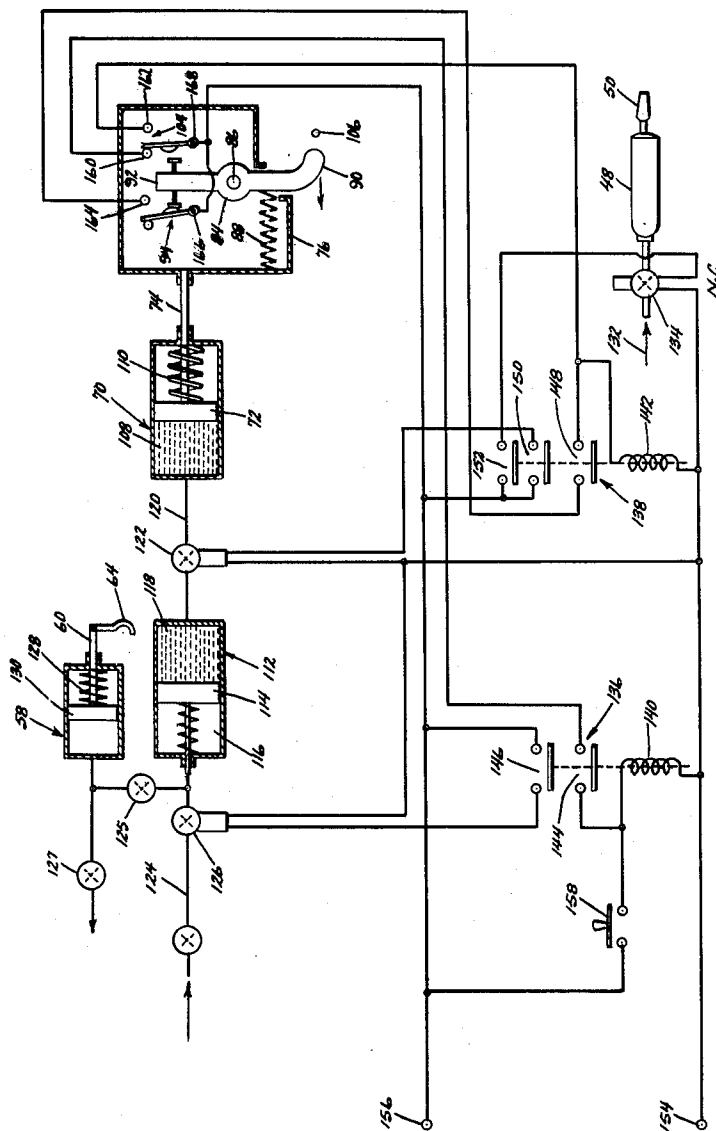
3,040,422

MICROMETER APPARATUS

Filed June 2, 1958

3 Sheets-Sheet 2

Fig. 3.



Inventor:
John M. Lewis,
by *Lust & Irish*
Attorneys

June 26, 1962

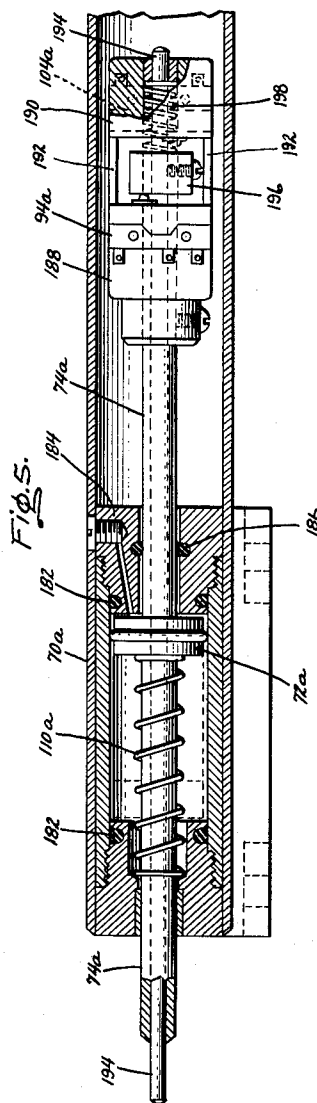
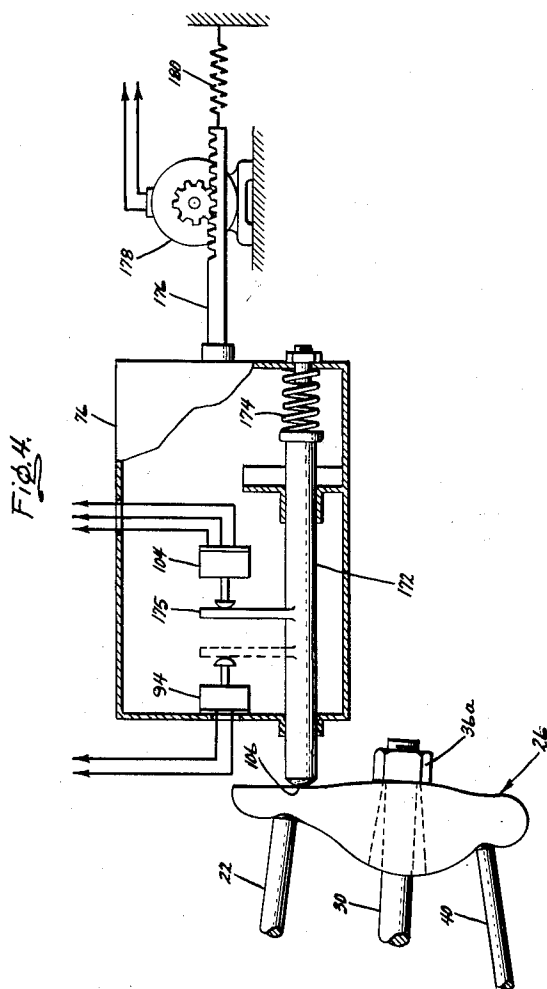
J. M. LEWIS

3,040,422

MICROMETER APPARATUS

Filed June 2, 1958

3 Sheets-Sheet 3



Inventor:
John M. Lewis,
by *Lust & Irish*
Attorneys.

1

3,040,422

MICROMETER APPARATUS

John M. Lewis, Fort Wayne, Ind., assignor to J. C. Thompson Tool & Die, Inc., Fort Wayne, Ind.

Filed June 2, 1958, Ser. No. 739,285

26 Claims. (Cl. 29-240)

The present invention relates to micrometer apparatus and method, and more particularly to an apparatus for adjusting or setting valves and hydraulic valve lifters in reciprocating type internal compustion engines.

Reciprocating internal combustion engines utilize valves for controlling the introduction of fuel to and exhaustion of burnt fuel from the cylinders, these valves being controlled in opening and closing by tappets, push-rods or the like which are operatively engageable with rotary timing cams on a cam shaft. In one design of engine, a rocker arm is interposed between the tappet (or push-rod) and the stem of the valve, this rocker arm being pivotally mounted on a fixed support and rocked in response to operative engagement of the tappet with the timing cam. This rocking motion of the rocker arm causes alternative opening and closing of the intake and exhaust valves.

It is essential in securing proper operation of the engine that the push-rods and tappets be adjusted with respect to the respective timing cams so as to cause the intake and exhaust valves to open and close at the proper points in the combustion cycle, and to this end, some type of adjustment is usually provided for adjustment.

Modern-day engines utilize hydraulic valve lifters in combination with push-rods for securing improved operation of the engine; however, it is essential that the lifter be adjusted to its mid-travel position in order to realize the available optimum performance. The rocker arms used in conjunction with the hydraulic valve lifters are pivotally mounted on fixed studs extending from the engine block, nuts being received on these studs and adjustable to force the rocker arms into operative engagement with the respective push-rods and the push-rods in turn against the piston in the hydraulic valve lifter. By adjusting the stud nuts to the proper position, the piston in the hydraulic valve lifter is moved to its mid-travel position in its cylinder. The only method known to applicant for adjusting these valve lifters is the one wherein the stud nuts are turned downwardly a sufficient distance to bottom the piston in its cylinder to obtain a starting point from which an adjustment may be made. This is necessary because of the cumulative manufacturing tolerances in the mechanism parts. The stud nuts are then adjusted rearwardly, or, in other words, unscrewed, a fraction of a revolution, the pitch of the threads in the stud nuts being relied upon to provide the adjustment needed to move the valve lifter piston to its mid-travel position. This method of adjustment is, of course, subject to error inasmuch as the threads on the stud nuts are not precision formed. Also, this stud nut adjustment is effected manually by a workman, who relies upon his judgment as to how far the nut is turned. Thus, adjustment of the valve lifter is not accurately achieved, resulting in a sacrifice of engine performance.

This manual method of adjustment is further subject to the criticism that in the original manufacture of the engine, it is slow and tedious and therefore consumes considerable labor, which is expensive.

It is, therefore, an object of this invention to provide an apparatus for adjusting or setting the valve mechanism of an internal combustion engine in a minimum of time and with a degree of precision which is independent substantially of manufacturing tolerances.

It is another object of this invention to provide an ap-

2

paratus for adjusting a valve assembly which is automatically operable and achieves the adjustment with micrometer precision.

It is still another object of this invention to provide a micrometer apparatus automatically operable to provide a precision measurement from a reference point in space, which is automatically located, to a second point spaced therefrom.

Other objects will become apparent as the description proceeds.

To the accomplishment of the above and related objects, my invention may be embodied in the forms illustrated in the accompanying drawings, attention being called to the fact, however, that the drawings are illustrative only and that specific change may be made in the specific constructions illustrated and described, so long as the scope of the appended claims is not violated.

In the drawings:

FIG. 1 is a side elevation of one embodiment of this invention, in part section, showing a valve assembly of an internal combustion engine immediately following an adjustment;

FIG. 2 is a fragmentary sectional view taken substantially along the section line 2-2 of FIG. 1;

FIG. 3 is a schematic diagram of the electrical pneumatic and hydraulic system used in conjunction with the apparatus of FIG. 1;

FIG. 4 is a fragmentary, diagrammatic illustration in part section showing a second embodiment of this invention; and

FIG. 5 is a longitudinal sectional view of still another embodiment of the invention.

Referring to the drawings, and more particularly to FIG. 1, a conventional valve assembly of a typical overhead valve, internal combustion engine is shown as comprising the usual timing cam 10 mounted for rotation on a cam shaft 12. In operative engagement with the timing cam 10 is a conventional hydraulic valve lifter 14 which comprises a piston 16 reciprocable in a cylinder 18 and a compression spring 20 interposed between the piston and the cylinder. A push-rod or tappet 22 is engaged at its lower end with the head of the piston 16 and at its upper end with one arm 24 of the usual rocker arm 26. The rocker arm 26 is pivotally or rockably mounted on the motor block 23 by means of a stud 30 threaded on its upper end portion 32. The rocker arm 26 is conventionally a rigid, sheet-metal stamping which is formed with a clearance hole 33 at the base of a convex or dished portion, this hole 33 receiving the stud 30. In engagement with the inside of the dished portion is a contour washer or collar 34 contoured convexly or spherically to fit the inner surface of the dished portion so that the rocker arm is free to swing or pivot in the plane of the drawing. A locking and adjusting nut 36 is threaded on the stud portion 32 until it engages the collar 34 to secure the rocker arm against removal from the stud 30.

The right-hand arm 38 of the rocker arm 26 engages the upper end of the valve stem 40. The valve stem 40 carries the usual valve head 42 which operates to open and close the companion port 44 in the cylinder head. A valve spring 46 normally retains the valve head 42 closed and functions in the usual manner.

In operation and with all parts properly assembled and adjusted, rotation of the timing cam 10 produces reciprocation of the valve lifter 14 and its push-rod 22. This action is transmitted to the rocker arm 26, causing it to rock about the mounting stud 30 and in turn to cause reciprocation of the valve 42. The forces of the two springs 20 and 46 coact to provide a constant up-

ward force on the rocker arm 26 which holds the latter into assembly against the contour washer 34.

Conventional hydraulic valve lifters, such as the one just described, must be properly adjusted in order to achieve proper operation thereof. Since the valve lifter is composed of a cylinder 18 and piston 16 and the piston 16 must be free to reciprocate in opposite directions from a mid-travel position, it is obviously necessary that the piston 16 be originally adjusted or set in its cylinder 18. This adjustment is achieved, according to one method, by turning the stud nut 36 downwardly on the mounting stud 30 until the piston 16 is bottomed in the cylinder 18. In other words, the lower end of the piston 16 is abutted against the lower end of the cylinder 18. The nut 36 is next turned upwardly, or, in other words, unscrewed, a sufficient distance to permit the spring 29 to move the piston 16 to its mid-travel position. Knowing the pitch of the threads, it may be predetermined that a partial revolution of the nut 36 will position the piston 16 at its mid-travel point in the cylinder. In other words, after tightening the nut 36 to the point at which the piston 16 is bottomed in its cylinder, a three-quarter reverse turn of the nut will set the piston 16 at its mid-travel position, assuming, of course, that the pitch of the threads is such as will provide this adjustment. Another method is to turn the nut 36 downwardly three-quarters of a turn from the point at which slack in the assembly is taken up, again relying on thread pitch for accuracy.

These methods of adjustment have been used primarily for the reason that manufacturing tolerances in the various parts are cumulative and cannot be predicted with any fair degree of accuracy prior to the assembly operation, unless, of course, they are precisely measured. Since, in the mass production of automotive engines, it is of prime concern to the economy of manufacturing that precision requirements be kept to a minimum, it being considerably more time-consuming and expensive to manufacture a part with a high degree of precision, all the parts used in the conventional valve-operating mechanisms, in the interests of economy and insofar as possible, are manufactured with only a low degree of precision.

The present invention provides an apparatus and method which operate in a manner which is the antithesis of the prior methods; i.e., in the adjusting operation, the nut 36 is merely turned downwardly in a single operation until the piston 16 is properly set to its mid-travel position. In achieving this adjustment, it is not necessary partially to return or unscrew the nut 36 in order to secure adjustment, nor is it necessary to rely on thread pitch for securing a length of adjustment.

The apparatus of this invention comprises a conventional nut or stud driver 48 having a rotary wrench or socket 50 which fits the nut 36. Preferably, this stud driver 48 is powered by an air motor, but, of course, this invention is not limited thereto. Such stud drivers conventionally incorporate torque-limiting means which automatically control the rotation of the socket 50 when reactionary torques in excess of a predetermined value are encountered. Suffice it to say, the stud driver used in this invention is conventional and is available on the open market.

The stud driver 48 is securely mounted on a steel or the like frame 52. To the upper end of this frame 52 is secured a piston rod 54 of a reciprocable air motor 56, the cylinder of this motor being stationary and fixedly secured to some suitably rigid framing structure (not shown) which is fastened directly to or with respect to the engine 28. By means of this mounting arrangement, the motor 56 may be operated to produce selective reciprocatory movement of the frame 52 with respect to the engine 28 and all of the parts mounted thereon. A stop sleeve 57 inside the cylinder 56 limits protraction of

the piston and its rod 54 to prevent over-travel of the frame 52.

On one side of the frame 52 is mounted a reciprocating type air motor or cylinder 58 having a reciprocable plunger 60 extending from the end thereof. A clevis 62 is mounted on the lower end of the plunger 60 and pivotally mounts a clamping arm 64, preferably bifurcated at its outer end to straddle the wrench or socket 50 and the nut 36. As shown, the outer ends of the furcations 66 are offset downwardly slightly and are engageable with the upper respective portions of the rocker arm 26. This engagement is assured by a suitably preformed bar spring 68 which is secured to the plunger 60 to bear against the clamping arm 64. The arm 64 is therefore yieldably urged counterclockwise about its pivot.

Of importance is the fact that the force exerted by this bar spring 68 as it operatively bears against the clamping arm 64 and the rocker arm 26 is insufficient to cause any compression of the spring 29 in the hydraulic valve lifter. The primary purpose of this clamping arm 64 is to force gently the rocker arm 26 downwardly into engagement with the ends of the valve stem 40 and push-rod 22 and, in turn, to produce a firm but gentle engagement of all the valve-operating parts. This takes up any slack motion in the assembly. Of course, since the valve spring 46 is much stronger than the lifter spring 29, neither of the two springs 46 and 29 will be compressed by the clamping spring 68 nor will the piston 16 be moved.

The air cylinder 58 is operable to protract the clamping arm 64 into engagement with the rocker arm 26 as well as to retract the clamping arm from engagement therewith.

On the side of the frame 52 opposite the air cylinder 58 is fixedly mounted a hydraulic cylinder 70 which reciprocably receives the usual piston 72 (see FIG. 2). Secured to and extending from the piston 72 is the usual piston rod 74, this piston rod carrying on its outer end a housing or supporting member 76 which is characterized as a "sensing head." This "sensing head" is preferably formed of aluminum or the equivalent to maintain the inertia at the lowest possible level. In order to prevent the "sensing head" from rotating with the piston 72, a reciprocable guide or support 78 is secured at one end to the back side (see FIG. 2) of the sensing head 76 and at its other end is provided with two spaced, longitudinally extending slots 80. These slots receive suitable pins or guide blocks secured to the side of the cylinder 70, a slight clearance being provided between these pins 82 and the respective slots 80. By means of this mounting arrangement, reciprocating movement of the piston rod 74 produces the same movement of the sensing head 76, since the supporting guide 78 is capable of longitudinal, sliding movement with respect to the cylinder 70.

As seen more clearly in FIG. 1, the sensing head 76 carries internally thereof a sensing finger 84 which is a common lever pivoted intermediate its ends on a pin 86 mounted transversely in and movable with the sensing head 76. A compression spring 88, fitted in a suitable socket in the sensing head 76, extends into engagement with the lower arm 90 of the sensing finger, tending to pivot the latter in a clockwise direction. The upper arm 92 of the sensing finger normally engages and holds open an electrical or micro-switch 94. This micro-switch is of the single pole, single throw variety, and is normally spring-biased to a closed position. However, by reason of the engagement of the arm 92 therewith, the switch is held open.

This switch 94 is mounted for adjustment inside the sensing head 76, this mounting being provided by means of a suitable bracket 96 which is slidably received in a milled groove 98 in the back wall of the sensing head 76. A precision micrometer 100 having a shaft extending through the end of the wall 102 of the sensing head 76 is connected to the bracket 96 such that adjustment

of the micrometer 100 will effect reciprocatory movement of the bracket 96 in its trackway or groove 98. The micro-switch 94 is secured to the bracket 96 and will, of course, move therewith. By this means of adjusting the switch 94, it is possible to alter the point inside of the sensing head 76 at which the arm 92 will engage the switch. A second single pole, double throw switch 104 is mounted directly on the rear wall of the sensing head 76 on the side of the arm 92 opposite the switch 94. This switch 104 is spaced from the arm 92 when the latter is engaged with the switch 94, and is so positioned that counterclockwise movement of the finger 84 about its pivot will cause engagement of the arm 92 with the switch 104. The two switches 94 and 104 are spaced sufficiently far apart that in moving the arm 92 first out of engagement with the switch 94 and secondly into engagement with the other switch 104, the switch 94 will be disengaged or actuated prior to engagement or actuation of switch 104. The same sequence of disengagement and engagement in reverse order follows when the arm 92 moves from the switch 104 to the switch 94. The spacing of these two switches determines the length of measurement by the apparatus.

As seen in FIG. 1, the lower arm 90 of the sensing finger is hook-shaped with the end engaging the upper surface of the rocker arm 26 at a point 106 adjacent the upper extremity of the push-rod 22. The reason for this engagement will be explained further in the following.

Considering for the moment only the operation of the sensing head 76, its primary function is to locate a position in space, e.g., the point 106 at which the arm 90 engages the rocker arm 26. This locating function is accomplished in the following manner. The hydraulic cylinder 70 is operable to protract the sensing head 76 in the direction of the arrow F, as shown in FIG. 2. Hydraulic fluid under pressure introduced into the cylinder chamber 108 bears against the piston 72, resulting in movement of the sensing head 76. The return spring 110 bearing against the opposite side of piston 72 retracts the piston and the sensing head 76 when the hydraulic pressure in the chamber 108 is relieved.

In starting operation, the piston 72 is fully retracted and no hydraulic pressure is present in the chamber 108. The sensing head 76 is thereby positioned rearwardly a distance sufficient to space the sensing arm 90 from the rocker arm 26. In this position, the arm 92 engages switch 94. Upon introduction of liquid under pressure to the chamber 108, the sensing head 76 is moved forwardly until the sensing arm 90 engages the rocker arm 26 at point 106. Continued protractile movement of the sensing head now results in swinging the sensing finger 84 about its pivot 86 until such time as engagement with the switch 94 is broken and engagement with the switch 104 is made. Suitable electrical and hydraulic circuitry properly coupled to the two switches 94 and 104 as well as to the hydraulic cylinder 70 results in immediate stopping and locking of the piston 72 as well as the sensing head 76 in position. In this position, the sensing arm 90 is engaged with point 106 on the rocker arm and the arm 92 in operative engagement with the switch 104. As already stated, and this is important with respect to the proper operation of the invention, the sensing head 76 is locked in position. The means for locking the sensing head will be explained later on.

The point 106 may now be said to be established or located in space, and insofar as the further operation is concerned, the mechanism will effect an accurate measurement axially downwardly of the push-rod 22 from this point 106. By threading the stud nut 36 downwardly, as explained earlier, the rocker arm 26 will also be moved downwardly. This movement is in a direction away from the sensing arm 90, and the sensing head 76 being locked, the arm 90 will swing clockwise about its pivot 86, causing the arm 92 to leave the switch 104 and engage the

switch 94. The moment the switch 94 is engaged, the electrical and hydraulic circuitry, to be described hereinafter, stops the stud driver 48, thereupon stopping the threading action of the nut 36. The operation of adjustment is now complete, the lifter piston 16 having been depressed to its mid-travel position, and the hydraulic cylinder 70 is deactuated, permitting the sensing head 76 to retract under the force of the return spring 110.

In FIG. 3 is illustrated, in schematic form, the electrical pneumatic and hydraulic system which is used to effect the operation of the apparatus thus far described. The hydraulic system comprises a variable volume cylinder 112 having a reciprocable piston 114 which defines two variable volume chambers 116 and 118, respectively, on opposite sides thereof. The chamber 118 is connected by a hydraulic line 120 to the chamber 108 of the cylinder 70, a normally open hydraulic valve 122 being series-connected in the line 120. This valve 122 is equipped with the usual electrical solenoid or electromagnetic actuator which is selectively operable to open and close the valve.

The chamber 118, line 120 and the chamber 108 of this hydraulic system are filled completely with hydraulic fluid, with all air or compressible fluids being exhausted or bled therefrom. Thus, movement of the piston 114 toward the right results in corresponding movement of the sensing piston 72. By closing the valve 122, the hydraulic fluid is locked in the chamber 108, thereby preventing the piston 72 from moving. Rearward movement is prevented, because the hydraulic fluid is non-compressible. Forward movement is prevented by reason of the spring 110 and air or atmospheric pressure bearing on the right-hand face of the piston 72.

The chamber 116 of the cylinder 112 is pneumatic, meaning that it is adapted to receive air under pressure for effecting movement of the piston 114. An air line 124 is connected to this chamber 116, a normally closed air valve 126 being connected in series with this line. This air valve 126 is electrically operated, being equipped with a solenoid or suitable electromagnetic actuator which is selectively operable to open the valve upon the receipt of an energizing voltage. The clamping cylinder 58 is pneumatically operated and is connected to the line 124 through a one-way ball check valve 125 or the equivalent. The return spring 128 bearing against the clamping piston 130 exerts a retracting force thereon and otherwise prevents protractile movement of the piston unless air under pressure is applied thereto. A manually operable exhaust valve 127 connects to the cylinder 58 for controlling the release of pneumatic pressure in the cylinder.

Of importance is the fact that the clamping cylinder 58 is designed to be faster acting than any other of the apparatus components. By this is meant, now referring to FIG. 1, when the apparatus is first actuated, the clamping cylinder 58 operates first to move the clamping lever 64 into engagement with the rocker arm 26. Thereafter, the sensing head 76 is protracted to effect engagement of the sensing finger with the rocker arm. While this sequential operation is achieved preferably by simply selecting a clamping cylinder 58 which is faster acting than the other apparatus components, the use of restrictions or valves in the pneumatic and hydraulic lines of the system at desired locations will effect the same end result. For example, a restriction could be inserted between the chamber 116 and the line 124 which will prevent the piston 114 from moving as rapidly as the clamping piston 130.

By opening the valve 126, air under pressure admitted to the line 124 will result in protraction of the piston 114. This results in displacement of the hydraulic fluid in the chamber 112 which flows through the valve 122 and line 120 into the chamber 108. This displaced fluid then protracts the piston 72. Relieving this air pressure admitted to the line 124 or exhausting the pressure through the valve 126 permits the return spring 110 in the cylinder 70 to force the piston 72 rearwardly, thereby displac-

ing the liquid rearwardly into the chamber 118. A second air line 132 is coupled to the stud driver 48 through a normally closed air valve 134 which may be of the same design as that of valve 126. Air pressure admitted to this line 132 and fed to the stud driver 48 effectuates forceful rotation of the wrench or socket 50.

The electrical circuitry of the system will now be described. Two electromagnetic control relays, indicated generally by the reference numerals 136 and 138, are provided with the usual actuating coils 140 and 142, respectively. The relay 136 is provided with two normally open switches 144 and 146, respectively, while the relay 138 is provided with three normally open switches 148, 150 and 152, respectively. The coil 140 is connected across the power line terminals 154 and 156 through a normally open starting switch 153. The normally open switch 144 is series-connected between the upper end of the coil 140 and the stator contact 160 of the switch 104. The switch 146 is connected in series with the electrical actuator of the valve 126 and the lines extending from the power terminals 154 and 156.

The coil 142 of the relay 138 is connected in series with the terminal 154 and the stator contact 162 of switch 104. The normally open switch 148 is also connected in series with this stator contact 162 and in addition to the normally open contact 164 of the switch 94.

The normally open switch 150 is connected in series with the electrical actuator of the valve 122 and the power line terminals 154 and 156. The normally open switch 152 is connected in series with electrical actuator of the valve 134 and the two terminals 154 and 156. The armature contacts 166 and 168 of the two switches 94 and 104, respectively, are connected together and to the terminal 156. As mentioned earlier, the movable arm or armature of the switch 94 is spring-biased to engage normally the stator contact 164, and the movable arm of the switch 104 is spring-biased normally to engage the stator contact 160. The spring 88 in the sensing head normally urges the sensing finger into engagement with the switch 94 so as to hold the armature out of engagement with the fixed contact 164.

The operation of the electrical system may now be explained. Closure of the switch 153 results in energizing the coil 140 and closure of the two switches 144 and 146. The switch 144 establishes a hold-in circuit for the coil 140 via the switch 104. Closure of the switch 146 results in actuation of the air valve 126, opening it and permitting air under pressure to be admitted to the cylinder chamber 116 and to cylinder 58 through valve 125. The valve 125 is spring-biased to closed position and automatically opens only when air pressure is applied thereto from line 124. The valve 125 prevents reverse flow from the cylinder 58. The clamping cylinder 58 is first to operate fully, movement of the piston 114 in the cylinder 112 following displacing the liquid in the chamber 118 to the sensing cylinder chamber 108. This results in protraction of the sensing head 76 until the sensing finger 90 engages the fixed or stationary point 106, at which time the finger 90 is pivoted clockwise, resulting in closure of the switch 94 and shifting of the armature in switch 104 from the contact 160 to the other contact 162. The moment switch 104 is thus actuated, an energizing circuit is established to the relay coil 142 and the relay coil 140 is de-energized, opening the two switches 144 and 146. The cylinder 58 remains actuated, however. The switches 148, 150 and 152 close, the switch 148 providing a hold-in circuit for the coil 142 via the switch 94. Closure of the switch 150 results in actuation and closure of the hydraulic valve 122, thereupon locking the hydraulic fluid in the chamber 108. This prevents the sensing piston 72 from moving either forwardly or rearwardly and, of course, stops movement of the sensing head 76. In this position of the sensing head, the finger 90 is in engagement with the fixed or reference point 106.

Closure of the switch 152 results in establishing a circuit to the valve 134, opening it and admitting air under pressure to the stud driver 48. The socket or wrench 50 is now caused to rotate, as explained earlier.

Now referring briefly to FIG. 1, as the wrench 50 rotates, the nut 36 will be turned downwardly on the stud 30. This results in the reference point 106 moving in a direction away from the sensing arm 90, thereupon permitting the sensing arm to swing about its pivot 86 in a direction which permits the armature of the switch 104 to finally break engagement with the contact 162 and make an engagement with the contact 160. Nothing happens when this switch 104 moves from its contact 162 to its other contact 160, since the switch 94 establishes a hold-in circuit for the relay 138. Continued pivoting of the sensing arm 90 causes the arm 92 next to engage the switch 94 and to break the engagement with the contact 164. The moment this happens, the entire system is deactuated or otherwise stopped, the relay 138 being de-energized, thereupon opening the hydraulic valve 122 and closing the air valve 134. The adjustment of the stud nut 36 is now complete, and it has been moved downwardly on its stud 30 a distance corresponding to the distance which the sensing finger 92 travels in breaking its engagement with the switch 104 and finally opening the switch 94. Thus, the distance which the nut 36 may be threaded on the stud 30, or, in other words, the distance which the nut 30 may be moved downwardly toward the engine block 28, is gauged and corresponds to the spacing between the two switches 94 and 104. In order to release the clamping cylinder 58, the valve 127 is operated to exhaust the air pressure from the cylinder.

The following will be an explanation of the operation of the invention in connection with adjusting the hydraulic valve lifter of FIG. 1.

Ignoring for the moment the adjusting apparatus and considering only the valve-operating mechanism which comprises the valve lifter 14, the push-rod 22, the rocker arm 26, the mounting stud 30, and the valve stem 40, the valve lifter 14 and the valve assembly 40, 42, 46 are first installed in the engine. In this installation, the push-rod 22 is first engaged with the piston 16 of the valve lifter and positioned substantially as shown in the drawing. Next, the rocker arm 26 is passed over the stud 30 until it engages and rests on the upper ends of the push-rod 22 and the valve stem 40. The rocker arm will assume substantially the position as shown in the drawing. The contour washers 34 is assembled and the nut 36 is started on its threads. This is all that is required prior to the use of this invention.

During this assembly of the valve-operating parts, the apparatus of this invention is, of course, retracted or otherwise removed from the working area by means of the power cylinder 56 which carries the frame 52. Immediately following this rough assembly work, the cylinder 56 is actuated, causing the frame 52 to move downwardly along a centerline which places the wrench 50 over the nut 36. In this position, the clamping cylinder 58 as well as the sensing cylinder 70 are fully retracted, the sensing head 76 being spaced rearwardly from the position illustrated and the clamping arm 64 being similarly spaced rearwardly.

The switch 153 of FIG. 3 may now be closed. This results in the actuation of the air cylinder 58 which moves the clamping arm 64 into engagement with the rocker arm 26. The force of the clamping arm against the rocker arm moves the push-rod into firm engagement with the lifter piston 16, and the upper end of the valve stem 40 is assured, taking up all slack motion therebetween.

With the rocker arm 26 so held in position by means of the clamp 64, the sensing head 76 moves forwardly or outwardly from the cylinder 70 until the sensing arm 90 touches the rocker arm at the indicated point 106. The spring 88 which bears against the sensing arm 90 being weaker than the hydraulic lifter spring 20, the sensing

arm 90 will now begin to swing counterclockwise with continued forward movement of the sensing head 76. This counterclockwise movement will continue until the arm 92 engages the switch 104, resulting in actuation of the valve 122 and locking of the sensing head 76 in position. Since the micro-switches 104 are relatively fragile and expensive, a third arm engageable with a stop on the sensing head may be provided on the sensing finger 84.

At the moment of this locking, the apparatus has effectively determined the spatial position of the rocker arm 26, or, in other words, has established the point 106 as a spatial reference from which a measurement may now be taken with respect to the engine.

As already explained, the moment the switch 104 is actuated, the stud driver 48 is energized, causing rotation of the wrench 50. This threads the nut 36 downwardly on the stud 30, causing a corresponding downward movement of the rocker arm 26. Since the valve spring 46 is relatively strong, only the lifter spring 20 will be compressed. Compression of this lifter spring results from downward movement of the push-rod 22 with the rocker arm 26 and corresponding movement of the lifter piston 16. When the rocker arm 26, or, more precisely, the point 106, has moved downwardly a distance which permits the sensing finger to move from the switch 104 to the switch 94, the lifter piston 16 will have been moved downwardly a distance corresponding to the spacing between the two switches 94 and 104. With the actuation of the switch 94 and the valve 127, the system is deactuated; stopping the stud driver 44 and causing the entire apparatus to retract by means of fluid pressure admitted to the power cylinder 56. This completes the adjusting operation of the lifter piston 16, this adjustment being completely independent of manufacturing tolerances in the various valve-operating parts, since the apparatus establishes a reference point in space and makes a measurement from this reference point. For example, if the push-rod 22 were an eighth of an inch longer than that shown, the sensing head 76 would nevertheless provide a measurement of the same length or distance. Thus, manufacturing tolerances in the valve-operating parts may be appreciably relaxed, thereby leading to substantial economies in the production of these parts. Also, relaxation of tolerance requirements reduces appreciably the number of parts rejections, thereby lowering the overall cost. Still further, since the apparatus of this invention is, for all practical purposes, fully automatic, it is able to complete an adjustment in a matter of seconds, which normally requires an operator or workman considerably more time by the prior method.

From the foregoing, it will now be apparent that the method of this invention comprises the steps of first clamping the rocker arm 26 for the purpose of taking up any slack motion in the push-rod 22 and other valve-operating parts. Next, the sensing head 76 establishes the spatial position of the rocker arm 26 from which an adjustment may be measured. Thirdly, the rocker arm 26 is adjusted downwardly until the lifter piston 16 reaches its mid-travel position, at which point the sensing head 76 completes its measurement from the reference point and stops the operation of the mechanism. This method of adjustment effects an accurate and precise setting of the valve-operating parts. While the method has been described as being particularly adapted to the adjustment of hydraulic valve lifters, it will of course appear obvious to persons skilled in the art that the same method may be employed in adjusting other mechanisms, for example, the conventional screw-type, valve tappets.

A second embodiment of the present invention is shown in FIG. 4. Like numerals will indicate like parts. The sensing head of this embodiment employs as a sensing finger a plunger or reciprocable member 172 which projects through the end wall of the sensing head 76 and is spring-biased outwardly by a compression spring 174. An arm 175 extends laterally from the plunger 172 and

is movable between and engageable with the two switches 94 and 104. The sensing head 76, instead of being operated by means of a hydraulic cylinder, is mounted on a rack 176 engageable by a pinion of a reversible electric motor 178. A return spring 180 may be connected between the end of the rack 176 for exerting a retracting force thereon to insure complete withdrawal of the sensing head 76 from the rocker arm when the adjusting cycle has been completed.

The plunger arm 175 normally engages the switch 94, as illustrated by the dashed outline of the arm, by means of the spring 174. When the motor 178 is energized to advance the sensing head 76 toward the rocker arm 26, the outer end of the plunger 172 will engage the rocker arm and will move rearwardly with respect to the sensing head 76 as the latter continues to advance. Eventually, the arm 175 engages and actuates the switch 104 which is connected to suitable, conventional circuitry for de-energizing the motor 178 and for locking or clamping a brake on the motor to hold the sensing head 76 in position. The stud nut 36a having a convex underside is next turned downwardly on the stud 30, moving the rocker arm 26 away from the sensing head 76. This permits the plunger arm 175 to disengage the switch 104 and engage the switch 94. The switch 94, as in the case of FIG. 3, is connected into disabling circuitry which provides an indication or system operation terminating the adjustment of the nut 36a.

A more refined design and arrangement of the apparatus shown in FIG. 4 is found in the third alternative embodiment of this invention, as illustrated in FIG. 5. In this embodiment, the hydraulic sensing cylinder 70a receives a reciprocable piston 72a to which is secured and passed through a tubular piston rod 74a. Suitable O-ring seals 182 are provided in the opposite ends of the cylinder 70a to prevent the escape of pressure liquid. The return spring 110a bears against the piston 72a urging it to its illustrated retracted position. The cylinder 70a is provided with an end plug 184 centrally bored to slidably receive therethrough the extended piston rod 74a. Again, a suitable O-ring seal 186 is provided between this plug and the piston rod 74a to prevent the escape of pressure liquid from the cylinder. On the right-hand end of the coaxially extended piston rod 74a is received a first carrier block 188. This carrier block may be cylindrical in shape with a flat on one side, this flat having mounted thereon the micro-switch 94a. This switch 94a may be identical to the switch 94 of FIGS. 1, 2 and 3. Spaced from the first carrier block 188 is a second carrier block 190 which is also provided with a flat on one side for mounting the second switch 104a. Suitable pins or mounting means may be used for securing the two carrier blocks 188 and 190 together. Thus, the two carrier blocks 188 and 190 are fixedly secured to the piston rod 74a and will therefore move with the piston 72a.

A sensing rod or pin 194 is telescopically received through the piston rod 74a and projects outwardly as shown from the left-hand end of the piston rod as well as from the right-hand end as shown. The carrier block 190 is provided with an enlarged bore which receives the right-hand end of the pin 194 so that the pin is capable of free-sliding movement relative to the piston rod 74a as well as the two carrier blocks 188 and 190.

On the sensing pin 194 and in the space between the two carrier blocks 188 and 190 is mounted and secured a sensing cam 196 which is held normally in operative engagement with the switch 94a by means of a compression spring 198. This sensing cam 196 is also operatively engageable with the switch 104a when the sensing pin 194 is moved toward the right relative to the piston rod 74a.

In this embodiment of FIG. 5, the piston rod 74a in combination with the carrier blocks 188 and 190 may be functionally compared to the sensing head 76 of FIG.

1. The cylinder 70a is fixedly mounted on a frame the same as the cylinder 70 of FIG. 1. In operation, hydraulic fluid under pressure is admitted to the right-hand side of the piston 72a which forces the latter toward the left and carries with it both the piston rod 74a and the sensing pin 194. When the sensing pin 194 engages the work-piece such as the rocker arm 26, the sensing pin is moved rearwardly with respect to the piston rod 74a until the switch 94a is de-actuated and the switch 104 is actuated. When this happens, the liquid in the cylinder 70a is locked or otherwise prevented from escaping and the work-piece (rocker arm 26) is moved in a direction away from (toward the left) the end of the sensing pin 94. This permits the sensing pin to move leftward relative to the piston rod 74a under the force of the spring 198, which eventually results in deactuation of the switch 140a and actuation of the switch 94a. When this occurs, a positive indication is produced that the adjusting operation has been completed.

Preferably, the carrier block 190 is provided with an adjusting screw for varying the spacing between the two blocks 188 and 190. By this means, the micrometer adjustment made possible by means of the relative movement between the sensing pin 194 and the piston rod 74a may be preset to that desired.

In some instances, the embodiment of FIG. 5 is preferred over that of FIG. 1. Note, for example, that the sensing finger 84 of FIG. 1 is swingable about a pivot 86. Also note that the push-rod 22 moves axially, or, in other words, linearly. By reason of the arcuate motion of the point of contact of the sensing finger 84 with the rocker arm 26, the rectilinear movement of the push-rod 22 cannot be linearly related to the angular movement of the finger 84. In the embodiment of FIG. 5, a full, linear relationship exists, because the sensing pin 194 moves in substantially the same direction or parallel to the direction of adjustment of the push-rod 22, whereupon sensing pin movement 194 is directly, linearly related to the adjustment of the push-rod 22 over any distance through which an adjustment might be made. Thus, the micrometer of FIG. 5 is capable of providing linear adjustments over a longer distance than is true of the embodiment of FIG. 1. However, the apparatus of FIG. 1 is preferred in those instances in which space limitations require that the cylinder 70 be offset from the work-piece (26), as is true in setting the rocker arm 26.

The fundamental principles of this invention are capable of being utilized in the provision of micrometer apparatus which performs no function other than to measure distances from a reference point in space. For example, the apparatus of FIG. 1 could have eliminated therefrom the stud driver 48, and an indicator light or the like could be substituted in series with the switch 152 of FIG. 3 instead of the valve 134. Thus, when the micrometer apparatus responded to the manual threading of the stud nut 36 onto the stud 30, the indicator light would flash on, indicating that the adjustment is complete. The apparatus thus becomes a micrometer capable of finding a reference point in space and providing a precise measurement from this reference point.

Of particular importance in this invention is the provision of a hydraulic cylinder as the device for operating the sensing heads 76 and 70a. This hydraulic cylinder (cylinders 70 and 70a) is preferably small in size, approximately one (1) inch in diameter and four (4) inches in length. Being of such small size, only a small amount of hydraulic fluid is required to displace the piston (72, 72a). This small amount of fluid obviously possesses only negligible inertia so that over-shooting due to the momentum of the moving parts is either nonexistent or negligible. This makes it possible, merely by closing the hydraulic valve 122 of FIG. 3, to stop immediately and position precisely the sensing head 76. The oil being incompressible, the sensing head cannot be moved rearwardly after the valve 122 is closed. Also, the sensing

head cannot be moved forwardly because of atmospheric pressure bearing against the piston. As will now be apparent, this negligible inertia in the hydraulic system contributes greatly to the preciseness with which measurements may be taken, and since the present invention is directed to the principle of preciseness of measurement, the use of hydraulics in moving and locking the sensing head in adjusted position becomes important.

While the present invention has been explained in connection with the adjustment of hydraulic valve lifters in reciprocating engines, it will of course appear as obvious to a person skilled in the art that the apparatus is useful for adjusting other types of mechanism. In any event, the present invention is accurately operable irrespective of manufacturing tolerances in the parts being adjusted, this feature being doubly significant in the respect that first the adjusting operation is substantially automatic and, secondly, requires less accurately fabricated parts in the assembly being adjusted. Many other advantages and attributes will appear as obvious to a person skilled in the art.

What is claimed is:

1. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder mounted on said frame and having a reciprocable piston rod, a sensing head fixedly secured to said piston rod for reciprocable movement therewith, said sensing head comprising a housing, a lever pivotally mounted intermediate its ends in said housing and having one end projecting therefrom in a direction transverse to the direction of piston rod movement, an arm on said lever extending at an angle therefrom, a stop in said housing engageable by said arm when said lever is pivoted in one direction, a spring in said housing bearing against said lever tending to pivot it in the opposite direction, two electrical switches mounted in said housing on opposite sides, respectively, of the other end of said lever, said switches being alternatively engageable and actuable by said other lever end when said lever is pivotally moved, said spring normally holding said lever into operative engagement with one of said switches, a micrometer screw adjustably received through one wall of said housing and carrying said one switch for adjustment with respect to said lever and the other switch; a rigid guide bar secured at one end to said housing and being operatively mounted on said frame for reciprocable movement in a direction parallel to the movement of said piston rod, the mounting of said bar on said frame comprising at least one slot in said bar which slidably receives a mounting stud extending from said hydraulic cylinder, a rotary stud driver mounted on said frame along a line substantially parallel to the line of movement of said sensing head, said stud driver including a rotary air motor for driving the same, both said one end of said lever and said stud driver being operatively engageable with a work-piece, a pneumatic clamping cylinder mounted on said frame and having a plunger reciprocable along a line substantially parallel to the line of movement of said sensing head; said clamping cylinder including a clamping arm pivotally mounted on the outer end of said plunger and extending in a direction transverse to the axis of said plunger, said clamping arm being disposed adjacent said one end of said lever so as to be operatively engageable with said work-piece, said hydraulic and pneumatic cylinders being parallel with the protractile movements of said piston rod and plunger being in the same direction whereby said one lever end and said clamping arm operatively engage the same portion of said work-piece, a bar spring on said plunger engageable with said clamping arm and preformed to pivot the latter in said protractile direction, and a reciprocable device connected to said frame for moving the latter substantially rectilinearly in a direction parallel to said protractile direction.

2. The apparatus of claim 1 and including means for actuating said clamping cylinder, said hydraulic cylinder

and said stud driver, said means comprising said two electrical switches, said switches being of the single pole, double throw type normally thrown to one of the two operating positions, the movable contacts of said switches being connected together and in turn connected to one terminal of a two terminal power source, two electromagnetic control switches, one control switch having a coil which is connected at one end to the other terminal of said source and at the other end to said one terminal through a manually controlled switch, said one control switch having two normally open switches, one of said normally open switches being connected in series between said other coil end and the normally closed stator contact of one of said electrical switches, a first electromagnetic pneumatic valve which is normally closed, said pneumatic valve being connected in series with the other normally open switch and said two source terminals, the other of said electromagnetic control switches having first, second and third normally open switches and a coil which is connected at one end to said other terminal and at its opposite end to the normally open stator contact of said one electrical switch, said normally open stator contact of said one electrical switch being connected in series with said first switch of said other control switch and the normally open stator contact of the other electrical switch, a normally open electromagnetic hydraulic valve connected in series with the second switch of said other control switch and said two terminals, a second normally closed electromagnetic pneumatic valve connected in series with said third switch of said other control switch and said two terminals, a pneumatic pressure line connected in series with said second valve and said stud driver, a pneumatically operated hydraulic cylinder connected in series with and between said first pneumatic valve and said hydraulic valve, a pneumatic pressure line series connecting said first pneumatic valve to said clamping cylinder, a hydraulic line series connecting said pneumatically operated hydraulic cylinder and said hydraulic valve to said hydraulic sensing cylinder, a return spring in said sensing cylinder urging said piston rod in a retractile direction, said clamping cylinder being faster acting than the other apparatus components so that said plunger when actuated protracts ahead of said piston rod, whereby said clamping arm first operatively engages the work-piece followed by the operative engagement therewith of said sensing lever and said stud driver, said two electrical switches being spaced from said other lever end respective distances which provide sequential actuation thereof by said other lever end.

3. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder mounted on said frame and having a reciprocable piston rod, a sensing head fixedly secured to said piston rod for reciprocable movement therewith, said sensing head comprising a housing, a lever pivotally mounted intermediate its ends in said housing and having one end projecting therefrom in a direction transverse to the direction of piston rod movement, a spring in said housing bearing against said lever tending to pivot it in one direction, two electrical switches mounted in said housing on opposite sides, respectively, of the other end of said lever, said switches being alternatively engageable and actuable by said other lever end when said lever is pivotally moved, said spring normally holding said other lever end into operative engagement with one of said switches, a micrometer screw adjustably received through one wall of said housing and carrying one of said switches for adjustment with respect to said lever and the other switch; a rigid guide bar secured at one end to said housing and being operatively mounted on said frame for reciprocable movement in a direction parallel to the movement of said piston rod, the mounting of said member on said frame comprising at least one slot in said member which slidably receives a mounting stud extending from said hydraulic cylinder, a rotary stud driver mounted on said frame along a line substan-

tially parallel to the line of movement of said sensing head, said stud driver including an air motor for driving the same, both said one end of said lever and said stud driver being operatively engageable with a work-piece, a pneumatic clamping cylinder mounted on said frame and having a plunger reciprocable along a line substantially parallel to the line of movement of said sensing head; said clamping cylinder including a clamping arm pivotally mounted on the outer end of said plunger and extending in a direction transverse to the axis of said plunger, said clamping arm being disposed adjacent said other end of said lever so as to be operatively engageable with said work-piece, said hydraulic and pneumatic cylinders being parallel with the protractile movements of said piston rod and plunger being in the same direction whereby said one lever end and said clamping arm operatively engage the same portion of said work-piece, and a spring on said plunger engageable with said clamping arm and preformed to pivot the latter in said protractile direction.

4. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder mounted on said frame and having a reciprocable piston rod, a sensing head fixedly secured to said piston rod for reciprocable movement therewith, said sensing head comprising a housing, a lever pivotally mounted intermediate its ends in said housing and having one end projecting therefrom in a direction transverse to the direction of piston rod movement, a spring in said housing bearing against said lever tending to pivot it in one direction, two electrical switches mounted in said housing on opposite sides, respectively, of the other end of said lever, said switches being alternatively engageable and actuable by said other lever end when said lever is pivotally moved, said spring normally holding said lever into operative engagement with one of said switches; a rigid guide bar secured at one end to said housing and being operatively mounted on said frame for reciprocable movement in a direction parallel to the movement of said piston rod, the mounting of said member on said frame comprising at least one slot in said member which slidably receives a mounting stud extending from said hydraulic cylinder, a rotary stud driver mounted on said frame along a line substantially parallel to the line of movement of said sensing head, said stud driver including an air motor for driving the same, both said one end of said lever and said stud driver being operatively engageable with a common work-piece, a pneumatic clamping cylinder mounted on said frame and having a plunger reciprocable along a line substantially parallel to the line of movement of said sensing head; said clamping cylinder including a clamping arm pivotally mounted on the outer end of said plunger and extending in a direction transverse to the axis of said plunger, said clamping arm being disposed adjacent said other end of said lever so as to be operatively engageable with said work-piece, said hydraulic and pneumatic cylinders being positioned in parallel with the protractile movements of said piston rod and plunger being in the same direction whereby said one lever end and said clamping arm operatively engage the same portion of said work-piece, and a spring on said plunger engageable with said clamping arm and preformed to pivot the latter in said protractile direction.

5. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder mounted on said frame and having a reciprocable piston rod, a sensing head fixedly secured to said piston rod for reciprocable movement therewith, said sensing head comprising a housing, a lever pivotally mounted intermediate its ends in said housing and having one end projecting therefrom in a direction transverse to the direction of said piston rod movement, a spring in said housing bearing against said lever tending to pivot it in one direction, two electrical switches mounted in said housing on opposite sides, respectively, of the other end of said lever, said switches being alternatively engageable and actuable by said other lever end when said lever is pivot-

ally moved, said spring normally holding said lever into operative engagement with one of said switches; a rotary stud driver mounted on said frame along a line substantially parallel to the line of movement of said sensing head, said stud driver including an air motor for driving the same, both said one end of said lever and said stud driver being operatively engageable with a common work-piece, a pneumatic clamping cylinder mounted on said frame and having a plunger reciprocable along a line substantially parallel to the line of movement of said sensing head; said clamping cylinder including a clamping arm pivotally mounted on the outer end of said plunger and extending in a direction transverse to the axis of said plunger, said clamping arm being disposed adjacent said other end of said lever so as to be operatively engageable with said work-piece, said hydraulic and pneumatic cylinders being positioned in parallel with the protractile movements of said piston rod and plunger being in the same direction whereby said one lever end and said clamping arm operatively engage the same portion of said work-piece, and a spring on said plunger engageable with said clamping arm and preformed to pivot the latter in said protractile direction.

6. The apparatus of claim 5 and including means for actuating said clamping cylinder, said hydraulic cylinder and said stud driver, said means comprising said two electrical switches each having a movable contact, said one switch being a single pole normally closed switch which is held open by the engagement therewith of said one lever arm, the other switch being of the single pole, double throw type normally thrown to one of its two operating positions, the movable contacts of said switches being connected together and in turn connected to one terminal of a two terminal power source, two electromagnetic control switches, one control switch having a coil which is operatively connected across said terminals, said one control switch having two normally open switches, one of said normally open switches being connected in series with said coil and the normally closed stator contact of said other electric switch, a first electromagnetic pneumatic valve which is normally closed, said pneumatic valve being connected in series with the other normally open switch and said two source terminals, the other of said electromagnetic control switches having first, second and third normally open switches and a coil which is connected at one end to said other terminal and at its opposite end to the normally open stator contact of said other electrical switch, said normally open stator contact being connected in series with said first switch of said other control switch and said one electrical switch, a normally open electromagnetic hydraulic valve connected in series with the second switch of said other control switch and said two terminals, a second normally closed electromagnetic pneumatic valve connected in series with said third switch of said other control switch and said two terminals, a pneumatic pressure line connected in series with said second pneumatic valve and said stud driver, a pneumatically operated hydraulic cylinder connected in series with and between said first pneumatic valve and said hydraulic valve, a pneumatic pressure line series connecting said first pneumatic valve to said clamping cylinder, a hydraulic line series connecting said pneumatically operated hydraulic cylinder and said hydraulic valve to said hydraulic sensing cylinder, a return spring in said sensing cylinder urging said piston rod in a retractile direction, said clamping cylinder being faster acting than the other apparatus components so that said plunger when actuated protracts ahead of said piston rod, whereby said clamping arm first operatively engages the work-piece followed by the operative engagement therewith of said sensing lever and said stud driver, said two electrical switches being spaced from said other lever end respective distances which provide sequential actuation thereof by said other lever end.

7. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder mounted on said frame and hav-

ing a reciprocable piston rod, a sensing head fixedly secured to said piston rod for reciprocable movement therewith, said sensing head comprising a support, a lever pivotally mounted intermediate its ends on said support and having one end projecting in a direction transverse to the direction of movement of said member, two electrical switches mounted on said support on opposite sides, respectively, of the other end of said lever, said switches being alternatively engageable and actuable by said other lever end when said lever is pivotally moved, said lever normally operatively engaging one of said switches, a stud driver mounted on said frame, said stud driver including a motor for driving the same, both said one end of said lever and said stud driver being operatively engageable with a work-piece, a clamping mechanism mounted on said frame and having a member movable in a direction substantially parallel to the line of movement of said sensing head, said clamping member being disposed adjacent said other end of said lever so as to be operatively engageable with said work-piece, and means yieldably urging said member in a direction to engage said work-piece.

8. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder mounted on said frame and having a reciprocable member, a sensing head fixedly secured to said member for reciprocable movement therewith, said sensing head comprising a support, a lever pivotally mounted intermediate its ends on said member and having one end projecting in a direction transverse to the direction of member movement, two electrical switches mounted in said housing on opposite sides, respectively, of the other end of said lever, said switches being sequentially engageable and actuable by said other lever end when said lever is pivotally moved, said lever normally operatively engaging one of said switches, a stud driver mounted on said frame, said stud driver including a motor for driving the same, both said one end of said lever and said stud driver being operatively engageable with a common work-piece, and a clamping mechanism mounted on said frame and having a yieldable clamping member movable in a direction substantially parallel to the line of movement of said sensing head, said clamping member being disposed adjacent said other end of said lever so as to be operatively engageable with said work-piece.

9. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a return spring in said cylinder urging said piston in a retractile direction which tends to reduce the size of said chamber, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston, mechanism for closing and opening said valve; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger having two arms, said sensing finger being pivotally mounted intermediate said arms on said supporting member, two electrical switches on said supporting member on opposite sides, respectively, of one of said arms, said one arm being sequentially engageable with said switches, means urging said one arm normally into operative engagement with one of said switches, said arm being movable out of operative engagement with said one switch and into operative engagement with the other switch, means adjustably positioning said one switch with respect to said one arm, the other arm of said lever extending in a direction transverse to the direction of movement of said sensing head, said other arm being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in prox-

imity to said other arm, said clamping element adapted operatively to engage said work-piece, means operative to move said clamping element substantially parallel to the direction of movement of said sensing head; a stud driver on said frame and having a driving tool disposed in proximity to said sensing finger and said clamping element, first means selectively actuating said clamping mechanisms, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, third means operative in response to actuation of said other switch by said one arm for closing said valve and locking the liquid in said sensing cylinder and for actuating said stud driver, and fourth means operative in response to actuation of said one switch by said one arm for opening said valve and deactuating said stud driver.

10. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a return spring in said cylinder urging said piston in a retractile direction which tends to reduce the size of said chamber, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger having two arms, said sensing finger being pivotally mounted intermediate said arms on said supporting member, two electrical switches on said supporting member on opposite sides, respectively, of one of said arms, said one arm being sequentially engageable with said switches, means urging said one arm normally into operative engagement with one of said switches, said arm being movable out of operative engagement with said one switch and into operative engagement with the other switch, the other arm of said lever extending in a direction transverse to the direction of movement of said sensing head, said other arm being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in proximity to said other arm, said clamping element being adapted operatively to engage said work-piece, means operative to move said clamping element substantially parallel to the direction of movement of said sensing head; a stud driver on said frame and having a driving tool disposed in proximity to said sensing finger and said clamping element, first means selectively actuating said clamping mechanism, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, third means operative in response to actuation of said other switch by said one arm for closing said valve and locking the liquid in said sensing cylinder and for actuating said stud driver, and fourth means operative in response to actuation of said one switch by said one arm for opening said valve and deactuating said stud driver.

11. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger having two arms, said sensing finger being pivotally mounted intermediate said arms on said supporting member, two electrical switches on said supporting member on opposite sides, respectively, of one of said arms, said one arm

being sequentially engageable with said switches, means urging said one arm normally into operative engagement with one of said switches, said arm being movable out of operative engagement with said one switch and into operative engagement with the other switch, the other arm of said lever extending in a direction transverse to the direction of movement of said sensing head, said other arm being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in proximity to said other arm, said clamping element adapted operatively to engage said work-piece, means operative to move said clamping element in the direction of movement of said sensing head; a stud driver on said frame and having a driving tool disposed in proximity to said sensing finger and said clamping element, first means selectively actuating said clamping mechanism, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, and third means operative in response to actuation of said other switch by said one arm for closing said valve and locking the liquid in said sensing cylinder and for actuating said stud driver.

12. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger pivotally mounted on said supporting member, two electrical switches on said supporting member on opposite sides, respectively, of said finger, said finger being sequentially engageable with said switches, means urging said finger normally into operative engagement with one of said switches, said finger being movable out of operative engagement with said one switch and into operative engagement with the other switch, said finger extending in a direction transverse to the direction of movement of said sensing head and being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in proximity to said finger, said clamping element being adapted operatively to engage said work-piece, means operative to move said clamping element substantially parallel to the direction of movement of said sensing head; a stud driver on said frame and having a driving tool disposed in proximity to said sensing finger and said clamping element, first means selectively actuating said clamping mechanism, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, and third means operative in response to actuation of said other switch by said one arm for closing said valve and locking the liquid in said sensing cylinder and for actuating said stud driver.

13. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger movably mounted on said supporting member, two electrical switches on said supporting member on opposite sides respectively of said finger, said finger being sequentially engageable with said switches, means urging said finger

normally into operative engagement with one of said switches, said finger being movable out of operative engagement with said one switch and into operative engagement with the other switch, said finger being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in proximity to said finger, said clamping element being adapted operatively to engage said work-piece, means operative to move said clamping element substantially parallel to the direction of movement of said sensing head; a stud driver on said frame and having a driving tool disposed in proximity to said sensing finger and said clamping element, first means selectively actuating said clamping mechanism, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, and third means operative in response to actuation of said other switch by said finger for closing said valve and locking the liquid in said sensing cylinder and for actuating said stud driver.

14. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger movably mounted on said supporting member, two electrical switches on said supporting member on opposite sides respectively of said finger, said finger being sequentially engageable with said switches, means urging said finger normally into operative engagement with one of said switches, said finger being movable out of operative engagement with said one switch and into operative engagement with the other switch, said finger being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in proximity to said finger, said clamping element being adapted operatively to engage said work-piece, means operative to move said clamping element substantially parallel to the direction of movement of said sensing head; first means selectively actuating said clamping mechanism, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, and third means operative in response to actuation of said other switch by said finger for closing said valve and locking the liquid in said sensing cylinder.

15. Micrometer apparatus comprising a frame, a hydraulic sensing cylinder having a piston reciprocable therein, said piston defining a variable volume chamber in said cylinder, a piston rod secured to said piston and extending from said cylinder, a hydraulic pressure line connected to said cylinder and communicating with said chamber, a normally open hydraulic valve connected in series with said hydraulic line for controlling pressure liquid delivered to said chamber and the position of said piston; a sensing head which is reciprocable with said piston and comprising a supporting member which is fixedly secured to said piston rod, a sensing finger movably mounted on said supporting member, two actuating devices on said supporting member on opposite sides respectively of said finger, said finger being sequentially engageable with said actuating devices, means urging said finger normally into operative engagement with one of said actuating devices, said finger being movable out of operative engagement with said one actuating device and into operative engagement with the other actuating device, said finger being adapted to engage a work-piece; a clamping mechanism on said frame and having a clamping element disposed in proximity to said finger, said clamping element being adapted to operatively en-

gage said work-piece, means operative to move said clamping element substantially parallel to the direction of movement of said sensing head, first means selectively actuating said clamping mechanism, second means delivering liquid under pressure to said hydraulic valve for advancing said piston and said sensing head, and third means operative in response to actuating of said other actuating device by said finger for closing said valve and locking the liquid in said sensing cylinder.

16. In micrometer apparatus, a hydraulic cylinder which receives a piston for reciprocation, a tubular piston rod secured to said piston and coaxially extending through the cylinder ends, a return spring inside said cylinder which bears against one side of said piston and urges said piston in a retractile direction, two carrier blocks on one end of said piston rod, said blocks being axially spaced apart with respect to said rod, two switches mounted on said blocks respectively, a sensing pin slidably received by and projecting from the opposite ends of said piston rod, a sensing cam fixed to said sensing pin and positioned in the space between said blocks, said cam being alternatively operatively engageable with said switches respectively, a spring bearing against said cam for urging it into engagement with one of said switches, a hydraulic line connected to said cylinder for supplying pressure liquid thereto and against the other side of said piston for moving the latter in a protractile direction, and a hydraulic valve in said line for controlling the opening and closing thereof.

17. In micrometer apparatus, a hydraulic cylinder which receives a piston for reciprocation, a tubular piston rod secured to said piston and coaxially extending through the cylinder ends, two carrier blocks on one end of said piston rod, said blocks being axially spaced apart with respect to said rod, two switches mounted on said blocks respectively, a sensing pin slidably received by and projecting from the opposite ends of said piston rod, a sensing cam fixed to said sensing pin and positioned in the space between said blocks, said cam being alternatively operatively engageable with said switches respectively, a spring bearing against said cam for urging it into engagement with one of said switches, a hydraulic line connected to said cylinder for supplying pressure liquid thereto and against the side of said piston for moving the latter in a protractile direction, and a hydraulic valve in said line for controlling the opening and closing thereof.

18. In micrometer apparatus, a motor, a sensing head mounted for reciprocation and operatively connected to said motor, a sensing plunger mounted on said sensing head for reciprocable movement relative thereto, two spaced apart switches mounted on said sensing head, an arm on said plunger which extends into the space between said switches, said arm being alternatively and operatively engageable with said switches, spring means urging said arm into engagement with one of said switches, and means connected between said switches and said motor for controlling the operation of the latter.

19. Micrometer apparatus comprising supporting means, a sensing element movably mounted on said supporting means, a positioning mechanism mounted on said supporting means connected to said sensing element and operative to move the same from a first position to a second position in engagement with a work piece thereby establishing a reference location in space, first means carried by said mechanism and actuated by said sensing element responsive to movement of the same to said second position thereof for locking said mechanism against further movement, second means carried by said mechanism and actuated by said sensing element responsive to movement of the same to said first position thereof for unlocking said mechanism, third means for yieldably urging said element towards said second position, a clamping device mounted on said supporting means adjacent said element and having a member movable to engage said work piece, said clamping device

including means coupled to said mechanism for moving said member in the same direction as said element moves when approaching said second position, and a power operated tool mounted on said supporting means and having a tool part engaging said work piece adjacent said element and member, said tool having drive means coupled to said first means and actuated thereby responsive to actuation of said first means.

20. Micrometer apparatus comprising supporting means, a work piece on said supporting means and having limited movement with respect thereto in one direction, a clamping device on said supporting means movable to engage said work piece for moving the same to the limit of movement in said one direction, a sensing element movably mounted on said supporting means and operatively engageable with said work piece, a positioning mechanism mounted on said supporting means and carrying said sensing element, said mechanism being operative to move said sensing element toward and away from said work piece, means mounting said sensing element on said mechanism for alternative movement relative to said mechanism in said one direction and in an opposite direction responsive to engagement with said work piece, first means carried by said mechanism and actuated by said sensing element responsive to movement of the same in said opposite direction for locking said mechanism against further movement, second means carried by said mechanism and actuated by said sensing element responsive to movement of the same in said one direction for unlocking said mechanism, and a power driven tool mounted on said supporting means and adapted to do work on said work piece, said tool having an operative connection with said first means and being actuated thereby in response to actuation of said first means by said sensing element.

21. Micrometer apparatus comprising supporting means, a work piece on said supporting means and having limited movement with respect thereto in one direction, a clamping device on said supporting means movable to engage said work piece for moving the same to the limit of movement in said one direction, a sensing element movably mounted on said supporting means and operatively engageable with said work piece, a positioning mechanism mounted on said supporting means and carrying said sensing element, said mechanism being operative to move said sensing element toward and away from said work piece, means mounting said sensing element on said mechanism for alternative movement relative to said mechanism in said one direction and in an opposite direction responsive to engagement with said work piece, first means carried by said mechanism and actuated by said sensing element responsive to movement of the same in said opposite direction for locking said mechanism against further movement, and second means carried by said mechanism and actuated by said sensing element responsive to movement of the same in said one direction for unlocking said mechanism.

22. Micrometer apparatus comprising supporting means, a work piece on said supporting means, a sensing element movably mounted on said supporting means and operatively engageable with said work piece, a positioning mechanism on said supporting means and carrying said sensing element, said mechanism being operative to move said sensing element toward and away from said work piece, means mounting said sensing element on said mechanism for alternative movement relative to said mechanism in one direction and in an opposite direction responsive to engagement of said element with said work piece, first means carried by said mechanism and actuated by said sensing element responsive to movement of the same in said opposite direction for locking said mechanism against further movement, and second means carried by said mechanism and actuated by said sensing element responsive to movement of the same in said one direction for unlocking said mechanism.

23. Micrometer apparatus comprising: supporting means; power means on said supporting means and having a reciprocal element; a sensing head comprising a supporting member secured to said reciprocal element and reciprocal therewith, a sensing element movably mounted on said supporting member, two actuating devices on said supporting member, and means normally urging said sensing element into a first position in operative engagement with one of said actuating devices, said sensing element having a portion adapted to engage a work piece, said sensing element being movable from said first position into a second position in operative engagement with the other of said actuating devices responsive to engagement with said work piece; a clamping mechanism on said supporting means comprising a clamping element adapted operatively to engage said work piece adjacent said sensing element, and means operative to move said clamping element substantially parallel to the direction of movement of said sensing head; means for actuating said clamping mechanism thereby to move said clamping element into engagement with said work piece; means for actuating said power means thereby to move said sensing element into engagement with said workpiece; means coupling said second actuating device and said power means for locking said reciprocal element against further movement responsive to actuation of said second actuating device; and said power means for unlocking said reciprocal element responsive to actuation of said first actuating device.

24. The combination of claim 23 further comprising a power tool on said supporting means comprising a tool element engaging said work piece adjacent said sensing element and clamping element, and drive means for said tool element coupled to said other actuating device and actuated responsive to actuation of said other actuating device.

25. Micrometer apparatus comprising: supporting means; a hydraulic cylinder on said supporting means and having a piston reciprocally disposed therein, a tubular piston rod secured to said piston and coaxially extending through the cylinder ends, a return spring inside said cylinder which bears against one side of said piston and urges same in a retractile direction, two carrier blocks on one end of said piston rod, said blocks being axially spaced apart with respect to said rod, two switches mounted on said blocks, respectively, a sensing pin slidably received within said piston rod and having portions respectively projecting from the opposite ends of said piston rod, a sensing cam secured to one of said sensing pin portions and positioned in the space between said blocks, a spring bearing against said cam for urging the same and said sensing pin into a first position with said cam in engagement with one of said switches, the other portion of said sensing pin being adapted to engage a work piece, said sensing pin being movable from said first position into a second position with said cam in engagement with the other of said switches responsive to engagement of said sensing pin with said work piece; a hydraulic line connected to said cylinder for supplying pressure liquid thereto against the other side of said piston for moving the same in a protractile direction thereby to move said other sensing pin portion into said second position, and a hydraulic valve in said line for selectively controlling the opening and closing thereof, said valve being coupled to the other of said switches and actuated thereby to close said valve thereby to lock said piston against further protractile movement responsive to actuation of said other of said switches, said valve being further coupled to said one of said switches and actuated thereby to open said valve thereby to unlock said piston responsive to actuation of said one switch.

26. Micrometer apparatus comprising: supporting means; a motor on said supporting means, a sensing head mounted for reciprocation on said supporting means and

operatively connected to said motor, a sensing plunger mounted on said sensing head for reciprocal movement relative thereto, two spaced apart switches mounted on said sensing head, said plunger having an arm which extends into the space between said switches, spring means urging said arm into a first position in engagement with one of said switches, said plunger having a portion adapted to engage a work piece, said plunger being movable from said first position into a second position with said arm in engagement with the other of said switches responsive to engagement of said plunger with said work piece; means for selectively actuating said motor thereby to move said sensing head so that said plunger moves into said second position; means coupling said other switch and said motor for locking the same and said

5

10

15

sensing head against further movement responsive to actuation of said second switch; and means coupling said first switch and said motor for unlocking the same responsive to acuation of said first switch.

References Cited in the file of this patent

UNITED STATES PATENTS

1,807,591	Fleischli -----	June 2, 1931
1,918,528	Fleischli -----	June 18, 1933
2,086,667	Fletcher -----	July 13, 1937
2,544,522	Bertelensen -----	Mar. 6, 1951
2,602,361	Meyer -----	July 8, 1952
2,714,759	Wangenheim -----	Aug. 9, 1955
2,820,283	Anderson -----	Jan. 21, 1958