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(54) ELECTRICAL DISCHARGE MACHINING APPARATUS

(71) We, AMCHEM COMPANY LIMITED a British Company of Albion Road, Sileby, Leicestershire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electrical discharge machining apparatus and in particular to such an apparatus for simultaneously machining a plurality of small holes, typically a few thousandths of an inch in diameter. The invention is concerned also with a method of refeeding one or more electrodes in an electrical discharge machining apparatus.

Electrical discharge machining depends upon the very high temperature of a spark to melt material, such as metal, from the surface of a workpiece. The sparks are produced at a high rate (typically 15,000 to 30,000 per second) by either a resistance-capacitance electrical system or a rotary impulse generator.

It is known to produce a plurality of coincident sparks from mutually insulated electrodes to enable a common workpiece to be machined by all the electrodes.

A typical multi-feed electrical discharge machining apparatus includes a plurality of electrodes mounted in a cartridge for guided movement relative to a machine bed upon which a workpiece, or a succession of workpieces are carried. Erosion of the electrode tips occurs during machining and the eroded length of electrode must be replaced if satisfactory machining is to be achieved in a subsequent machining operation. Erosion is a particlular problem in the case of small, wire-like electrodes having a diameter of a few thousandths of an inch.

Hitherto one method used to replace eroded electrode, or refeeding the electrode as it is known in the art, consists of an operator manually releasing the electrodes in the cartridge, sliding the electrodes towards the workpiece and reclamping the electrodes at the cartridge. Clearly this method is time-consuming and thus expensive.

In another known method of refeeding, wheels are provided for positively driving the electrodes forward relative to the cartridge towards a workpiece at the end of a machining operation. One disadvantage to the use of wheels is that, in practice, it is difficult to set the pressures of the wheels on the electrodes sufficiently highly as to drive the electrodes forward, whilst at the same time allowing slipping contact once the surface of the workpiece is reached. A further disadvantge of this method of refeeding is that refeeding is comparatively slow, since the speed of refeeding is controlled by the speed of rotation of the wheels.

In accordance with one aspect of the present invention there is provided a method of refeeding one or more electrodes in an electrical discharge machining apparatus in which the or each electrode is located in a cartridge spaced from a nose guide of the apparatus with part of the length thereof supported in the nose guide and extending towards a workpiece to be machined, and which comprises advancing said cartridge towards said nose guide whilst retaining frictional contact upon the or each said electrode in such a manner as to allow the or each electrode to be slidably received back in said cartridge upon the tip or tips of the or each electrode striking the workpiece.

In accordance with another aspect of the present invention there is provided an electrical discharge machining apparatus for machining a workpiece comprising an electrode cartridge arranged to contain at least one electrode, the cartridge being mounted for rectilinear movement with respect to a nose guide of the apparatus with part of the length of the or each electrode supported in the nose guide, a clamp releasably clamping the or each electrode in the cartridge and means offering frictional resistance to the passage of the electrode or electrodes through the cartridge, means being provided for advancing the cartridge and the electrode or electrodes towards the nose guide, the electrode or electrodes being received

back into the cartridge against the resistance offered by said frictional resistance means upon striking the workpiece.

The invention will now be described further by way of example with reference to the accompanying drawings in which:—

Figure 1 is a general perspective view of an electrical discharge machining apparatus embodying the present invention,

Figure 2 is an enlarged perspective view of part of the apparatus shown in Figure 1, including the cartridge,

Figure 3 is a perspective view, partly in section, of a mechanism for causing the cartridge to slide relative to the machine bed and the nose guide of the electrical discharge machining apparatus, and

Figure 4 illustrates diagrammatically part of a control system for controlling the sequence of operation of the apparatus illustrated in Figures 1 to 3.

The electrical discharge machining apparatus illustrated in Figure 1 has a single head shown generally as 130 mounted on a flat 132, two other flats 132 being provided on the machine top or bed to enable the apparatus to carry up to three heads. 134 is a rotary indexing plate assembly to which a workpiece is clamped, the plate 134 being indexable as required by a stepper motor 136 in known manner. The indexing plate assembly is firmly secured to a plinth 135 by bolts 139.

A cartridge, to be described with respect to Figure 2, is mounted on a column 138. The cartridge is rectilinearly adjustable in a manner to be described and may also be vertically and rotatably adjusted by a threaded spindle assembly 135A and a dial 137 respectively.

140 is a tape carrying electrical conductor which connects with and affords an electrical supply to a printed circuit board 18 of the cartridge. 142 are hydraulic pipes for the hydraulic circuitry to the cartridge slide (to be described later) and 144 is a flexible tube which carries dielectric fluid for electrical discharge machining from a dielectric tank within the machine (not shown) to an electrode nose guide 46. Dielectric fluid is iniected into the nose guide and caused to trickle down each of the machining electrodes. 145 is an aperture in the bed of the apparatus and leads to a dielectric tank, thus allowing dielectric fluid to be returned to the tank and thence recirculated. 148 is a machine control console.

The cartridge, which may be best seen from Figure 2, is mounted on an aluminium slide 16 which is itself mounted for reciprocal movement with respect to the nose guide 46 of the electrical discharge machining apparatus. The slide 16 includes a longitudinally extending groove 14.

The cartridge consists of two plates 10 and 12, made of Perspex (Registered Trade Mark), which are removably received in the groove 14. A plurality of parallel glass tubes are bonded to the plate 10 in two tube sections. The first section, at a position remote from the nose guide 46, includes a plurality of roughly machined tubes 20, the second section being spaced from the first section and including a plurality of accurately machined glass tubes 26.

Means offering frictional resistance to the passage of electrodes through the tubes is arranged between the two tubes sections. In the illustrated cartridge, but shown only in Fig. 2, the means comprises a friction pad device shown generally as 24. The pad includes a pair of spaced studs between which a clamp plate 27 is adjustably supported by means of knurled nuts 31. The facing surfaces of the clamp plate 27 and that of the plate 10 opposite thereto are surfaced with a frictional material. It may thus be seen that when electrodes 22 pass between the two layers of frictional material, the frictional pressure exerted on the electrodes may be adjusted as required by turning the knurled nuts 31.

The printed circuit board 18 is mounted in the groove 14, the board conductors lying below the plate 10, but passing between the plates 10 and 12 so that they lie in parallely spaced relationship on the plate 12. The spacing of the conductors is such that an electrode 22 emerging from the glass tubes passes over a respective conductor and makes electrical contact therewith. Thus the plate 12 is stepped up relative to the plate 10 by an amount corresponding to the wall thickness of the tubes 26.

The cartridge is positioned in the electrical discharge machining apparatus of Figure 1 so that the electrodes emerging from the glass tubes pass through the nose guide 46 of the electrical discharge machining apparatus. It will be appreciated that there is no physical connection between the cartridge and the nose guide other than by way of the electrodes themselves.

A clamp pad shown generally as 28 in Figure 2 is mounted on the slide 16 and includes a post 30 which pivotally mounts an arm 32 at a pivot 33. The free end of the arm 32 is bifurcated and receives the piston rod 36 of a single-acting hydraulic cylinder 34. A helical spring 38 mounted around the rod 36 is arranged to normally clamp the electrodes, but the clamping pressure may be released by actuation of the hydraulic cylinder 34 when it is desired to feed the electrodes through the cartridge.

A further clamp 40 is mounted adiacent the nose 46 and is normally in a released condition. The clamp 40 may be actuated, however, to clamp the electrodes by actua-

tion of an hydraulic cylinder 48 as will be described later.

As may be seen from Figure 3, the cartridge including its slide 16 forms part of the cylinder 164, Fig. 4 of a double-acting piston and cylinder assembly, the piston 150 of which is fixed so that the cartridge and slide can move rectilinearly relative thereto.

Hydraulic fluid is supplied to the piston and cylinder assembly through a pair of opposed conduits, one of which 152 may be seen in Figure 3. The fluid is led along a passage 154 towards the piston 150 but is then directed into an expansible chamber 156 via radially-directed ports 158. It will be appreciated that the above comments apply to both sides of the piston 150 so that, as the chamber 156 to the right of the piston 150 is expanded, the volume to the left of the piston is decreased and the slide 16 thus moved to the right, as viewed, and is therefore retracted. Conversely, when fluid is supplied to the chamber 156 to the left of the pistton, the right hand chamber is decreased in volume thus casing the slide 16 to move to the left, as viewed, and to advance towards a workpiece. It is this piston and cylinder assembly which is used for refeeding the electrodes, as will be described later.

In addition to the above hydraulic circuitry an additional hydraulic cylinder 160 is provided and this is used as a rapid advance cylinder for initially bringing the electrodes into contact with the workpiece.

Figure 3 also shows four eccentrically-mounted knurled studs 162 which are used for mounting a cartridge in a quick release fashion into the groove 14 of the slide 16. The studs 162 were omitted from Figure 1 of the drawings for the sake of clarity.

When a workpiece is to be machined the rapid advance cylinder 160 brings the electrodes into a machining position and thereafter is not used. Machining is then effected but after each machining operation the cartridge is indexed forward by the piston and cylinder assembly towards a workpiece, clamped to the plate 134, and the nose guide 46 so that the distance between the nose guide and the cartridge decreases progressively as machining continues.

In the control system illustrated in Figure 4, the piston of the piston and cylinder assembly is shown diagrammatically at 150 and the cylinder which carries the electrode cartridge at 164. The position of the cylinder 164 relative to the piston is hydraulically controlled by a servo-valve 166. The switching of the servo-valve itself is electrically controlled by a position transducer 168 connected to the cylinder 164. The position transducer provides a voltage proportional to the position of the cylinder (and therefore of the cartridge) and this voltage is compared with a variable reference voltage derived from a reference source, a motorised potentiometer 170. Conveniently the motorised potentiometer is mounted in a control cabinet remote from the apparatus proper.

After comparison of the voltage derived from the position transducer 168 with the output of the motorised potentiometer 170, the resultant signal is fed to a switch 172 the position of which is selectable by a timer ((not shown). With the switch in the position illustrated, the cylinder is permitted to continue movement towards a workpiece for a predetermined time, set by the timer, until all the electrodes are judged to have physically touched the workpiece. The main electrode voltage is then switched to the workpiece through the switch 172 so that machining may commence.

In operation the electrodes are manually inserted into the glass tubes and caused to pass through the various clamps and into the nose guide 46. The ends of the electrodes are advanced to a position in contact with a workpiece surface by means of the rapid advance cylinder 160, the clamp 28 then being operated so as to clamp the electrodes in that position. In practice there is a sufficient gap between the tips of the electrodes and the workpiece in that position to allow machining, so that machining is effected in known manner with a dielectric fluid, such as ionized water or paraffin, being caused to pass through the nose 46 through apertures (not shown) and drip down the electrodes onto the workpiece being machine. Should the electrodes short onto the workpiece, however, the cartridge is caused to move backwards by a small distance, typically 0.010 inches, to create a gap between the electrodes and the workpiece in which a spark may be formed.

During machining, particularly in the case where electrodes of only a few thousandths of an inch diameter are used, the electrodes wear unevenly so that it is necessary to realign the tips of the electrodes if machining is not to be impaired. After machining has been completed, therefore, the clamp 28 is released and the cartridge indexed forwards by means of the control system discussed so as to close the gap between the cartridge and the nose guide 46. At the same time, because of the frictional resistance created by the friction pad device 24, the electrodes 22 are forced forward and on to the surface of a new workpiece to be machined. Once the electrodes have touched that surface, however, continued forward movement of the cartridge overcomes the frictional resistance of the friction pad device 24 so that the electrodes 22 remain stationary until the cartridge completes its forward movement, any forward movement of the cart-

ridge once the electrodes have touched the workpiece being accommodated by the electrodes being received back into the tubes.

The clamp 28 is then re-applied by the control system so that the electrodes are again held in fixed relationship within the cartridge. Thereafter, if necessary, the control system causes the cartridge to move back a small distance as previously described to allow sparks to be created between the tips of the electrodes and the workpiece.

One advantage which the invention offers is that none of the electrode lengths are wasted. After a number of refeeding operations, however, the gap between the nose guide 46 and the cartridge is insufficient to permit a further refeed operation. In these circumstances the control system operates the clamp 40 by means of the hydraulic cylinder 48 the clamp 28 is released and the cartridge moved backwards so that the gap between the nose guide 46 and the cartridge is increased to a fixed distance determined by a limited stop so that further lengths of electrodes are exposed. The clamp 40 is then released and the clamp 28 reapplied so that the apparatus is free for further machining.

Whilst the tubes bonded to the plate 10 have been described as made from glass, metal tubes may be used in which they may also provide electrical connection to the relevant electrode.

WHAT WE CLAIM IS:—

1. A method of refeeding one or more electrodes in an electrical discharge machining apparatus in which the or each electrode is located in a cartridge spaced from a nose guide of the apparatus with part of the length thereof supported in the nose guide and extending towards a workpiece to be machined and which comprises advancing said cartridge towards said nose guide whilst each said electrode in such a manner as to retaining frictional contact upon the or allow the or each electrode to be slidably received back in said cartridge upon the tip or tips of the or each electrode striking the workpiece.

2. An electrical discharge machining apparatus for machining a workpiece comprising an electrode cartridge arranged to contain at least one electrode, the cartridge being mounted for rectilinear movement with respect to a nose guide of the apparratus with part of the length of the or each electrode supported in the nose guide, a clamp releasably clamping the or each electrode in the cartridge and means offering frictional resistance to the passage of the electrode or electrodes through the cartridge, means being provided for advancing the cartridge and the electrode or electrodes towards the nose guide, the electrode or electrodes being received back into the cartridge against the resistance offered by said frictional resistance means upon striking the workpiece.

3. An apparatus as claimed in Claim 2 which includes a column on a machine top or bed upon which the cartridge is mounted.

4. An apparatus as claimed in Claim 3 in which the cartridge is mounted on a slide and is vertically and rotatably adjustable on the column by means of a threaded spindle assembly and a dial respectively.

5. An apparatus as claimed in Claim 2, 3 or 4 in which the means offering frictional resistance to the passage of the electrode or electrodes through the cartridge comprises a friction pad which is mounted in frictional contact with an electrode or electrodes when received in the cartridge.

6. An apparatus as claimed in Claim 5 in which the frictional pressure exertable on the electrode or electrodes is adjustable.

7. An apparatus as claimed in any one of Claims 2 to 6 in which a workpiece to be machined is supported and clamped on a rotary indexing plate assembly the plate of which is indexable by a stepper motor.

8. An apparatus as claimed in Claim 7 in which the rotary indexing plate assembly is secured firmly to a plinth on the machine top or bed.

9. An apparatus as claimed in any one of Claims 2 to 8 in which the clamp which releasably clamps the or each electrode in the cartridge includes an arm, one end of which is pivotally mounted, the other end being clamped resiliently into contact with the or each electrode, but being releasable by actuation of a hydraulic cylinder when it is desired to feed the electrode or electrodes through the cartridge.

10. An apparatus as claimed in any one of Claims 2 to 9 in which a further clamp is provided adjacent said nose guide and on the side thereof adjacent said cartridge, said further clamp normally being in a released condition to allow an electrode or electrodes to pass therethrough but being actuable to clamp the electrode or electrodes when it is desired to move the cartridge back and away from the nose guide.

11. An apparatus as claimed in Claim 10 in which the further clamp is actuable by means of a hydraulic cylinder.

12. An apparatus as claimed in Claim 4 or any claim appendant thereto in which the cartridge and the slide on which it is mounted form the cylinder of a double acting piston and cylinder assembly, the piston of which is fixed so that the cylinder is capable of rectilinear movement relative thereto.

13. An apparatus as claimed in Claim 12 in which hydraulic fluid is supplied to the piston and cylinder assembly through a pair

of opposed conduits which lead into expansible chambers on respective sides of the fixed piston via radially-directed ports.

14. An apparatus as claimed in Claim 12 or 13 in which the cartridge is mounted in a quick-release manner to the slide by means of eccentrically-mounted knurled studs secured to the slide.

15. An apparatus as claimed in any one of Claims 2 to 14 in which a rapid-advance cylinder is provided for initially bringing an electrode or electrodes in the cartridge into contact with a workpiece.

16. A method of refeeding one or more electrodes in an electrical discharge machining apparatus substantially as herein described with reference to and as illustrated in the accompanying drawings.

17. An electrical discharge machining apparatus substantially as herein described with reference to and as illustrated in the accompanying drawings.

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1569561 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

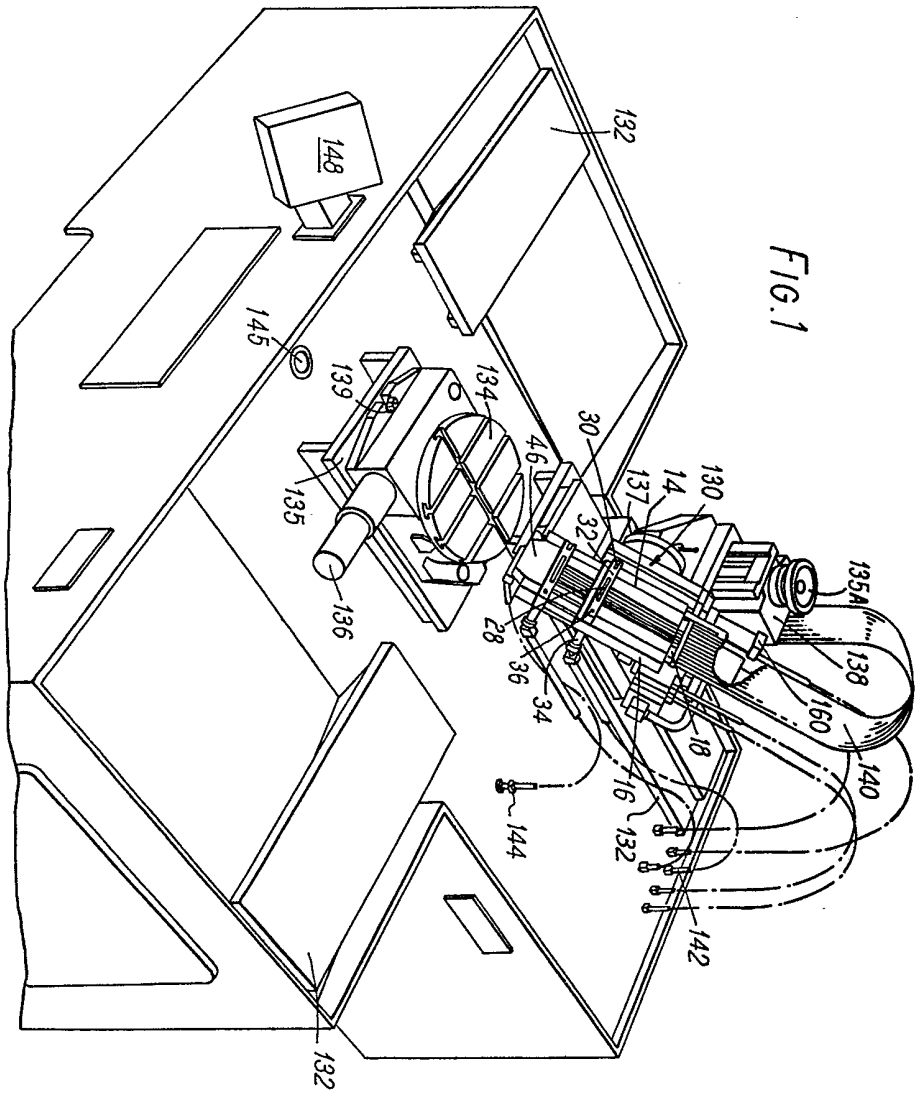


FIG. 1

1569561 COMPLETE SPECIFICATION
4 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 2

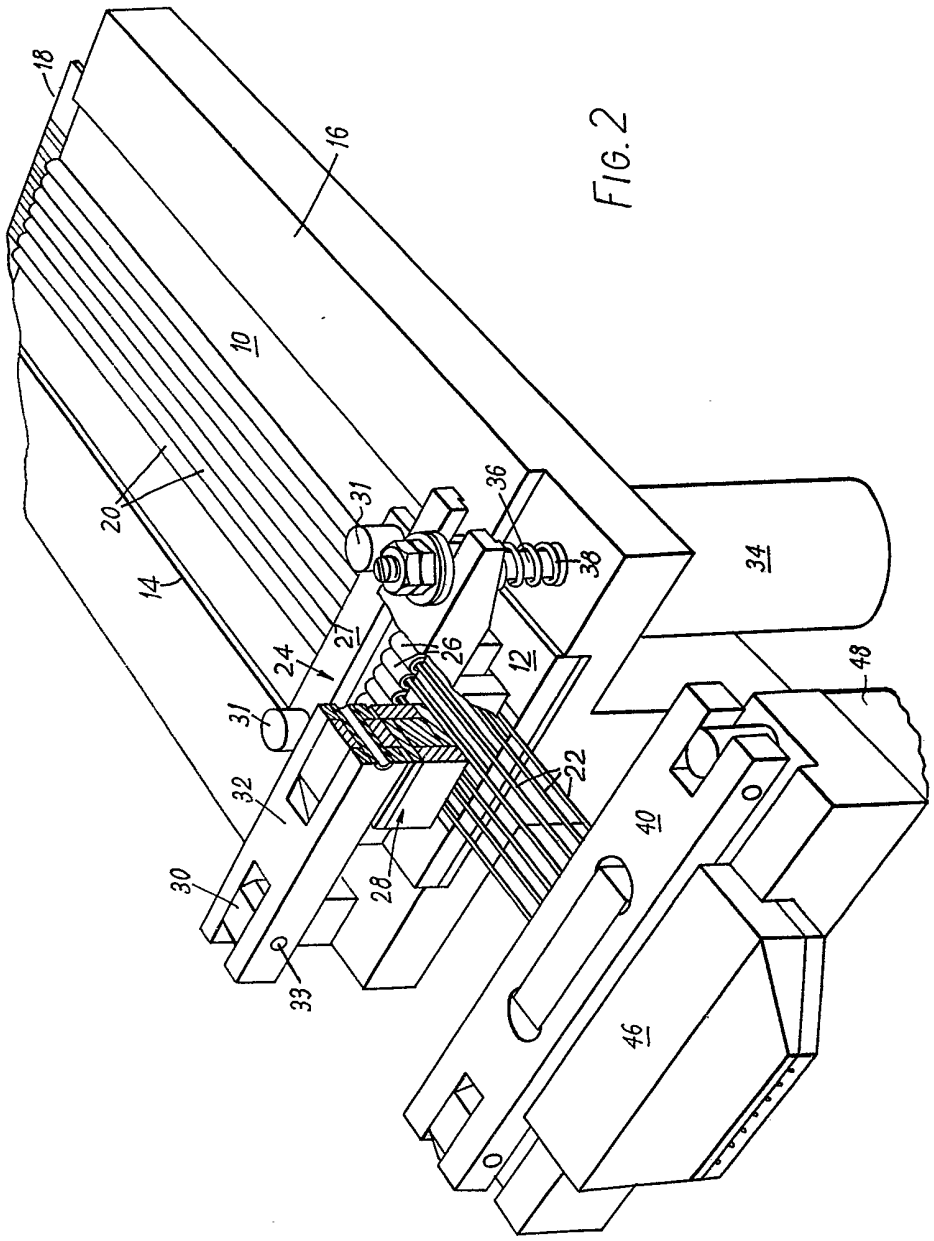
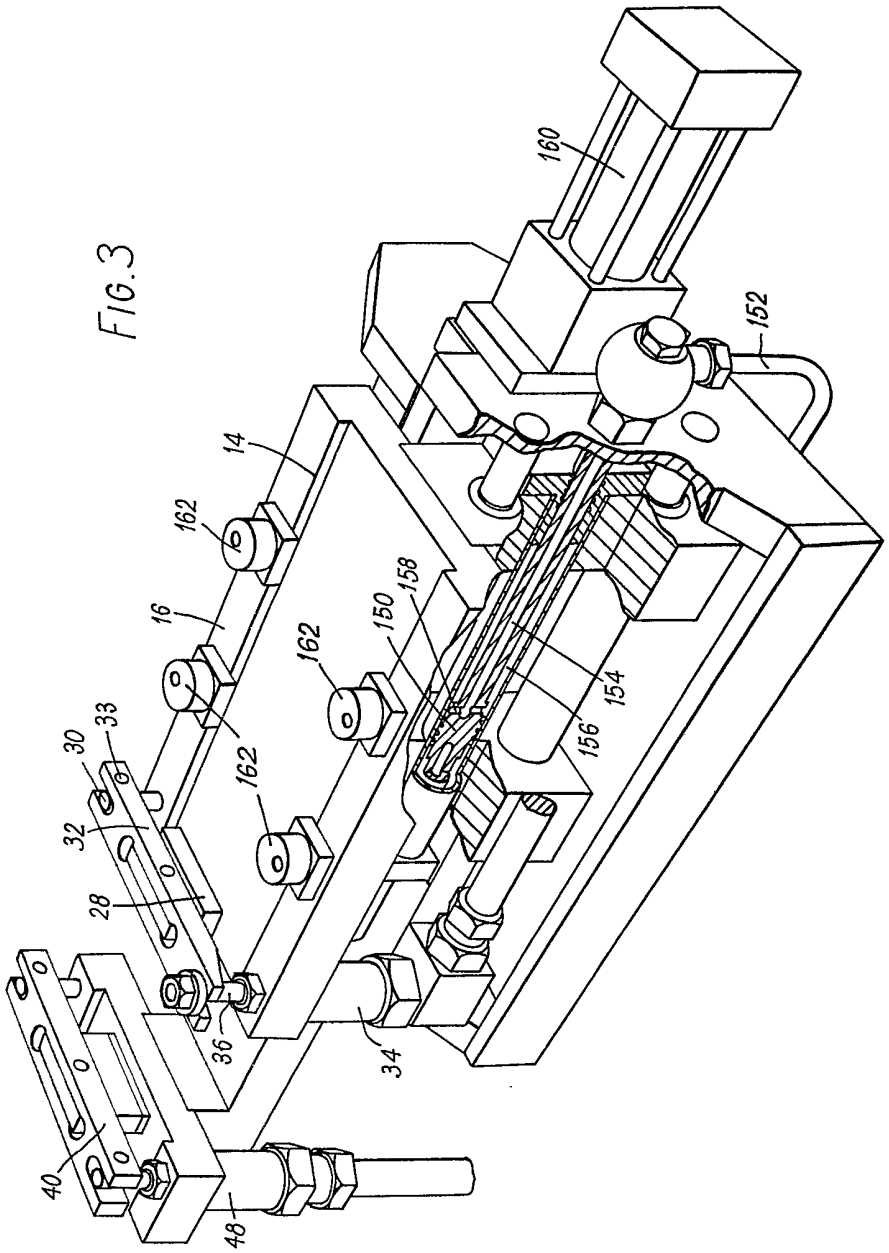


FIG. 2

FIG. 3



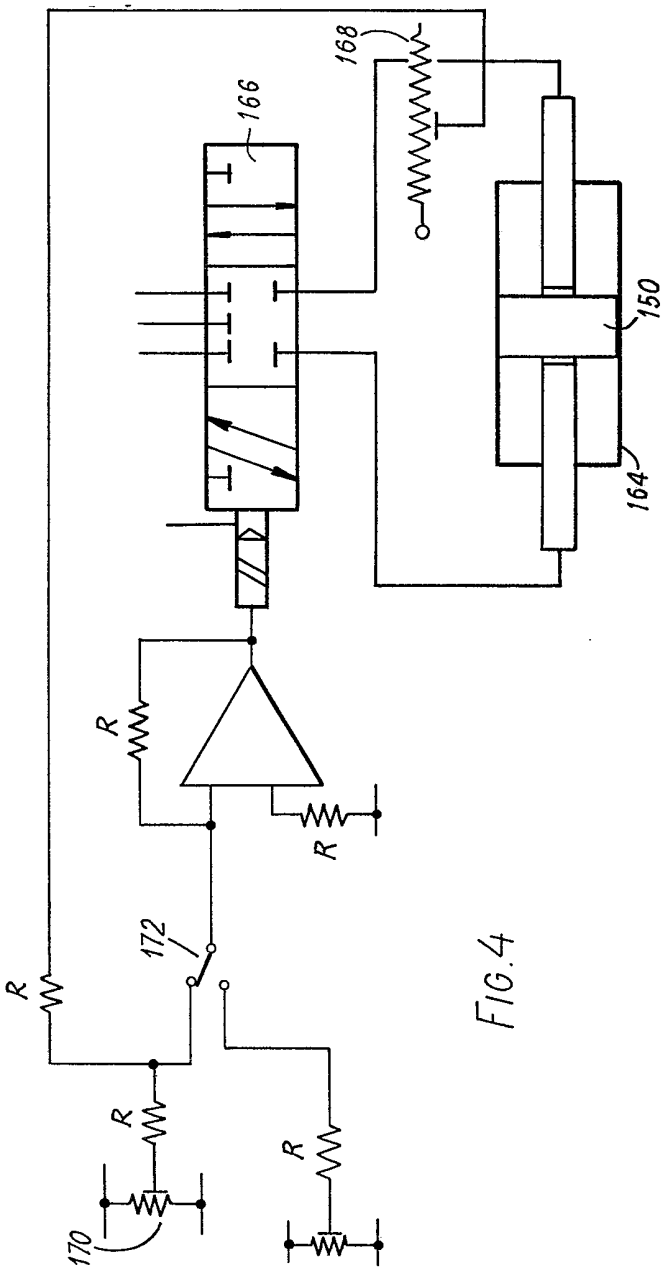


FIG.4