SPARK EROSION MACHINE

No DOUBT every model engineer has broken small, and sometimes not so small, taps and drills in components—with anything from a muffled grunt to a tantrum and throwing the bit through the workshop door—oh! for a spark erosion machine!

A spark erosion machine works as the name implies, by creating numerous small sparks between an electrode and the workpiece. Each spark is a miniature explosion and blows away a small piece of the work and the electrode—as you will know if you've got a small screwdriver across a live mains plug at some time! As the electrode is also worn away this must be expendable and by using suitable materials the electrode wear can be made considerably less than the workpiece; fortunately copper is a good general purpose material for most work, particularly steels. These machines have been with us for many years now and for those lucky enough to have access to one, usually at work, the broken tap problem is easily solved. However, all commercial machines are very expensive and most of them will do much more than the average model engineer requires. The one to be described is very simple and can be made by any model engineer with a little knowledge of electrics and the usual abilities with a small soldering iron.

The emphasis is on "small", as the rate of removal of material is dependent mainly on the current available; this model gets very slow when asked to handle an electrode more than about ⅛ in. square. It is intended mainly for removing broken drills and taps up to about ¼ in. and making irregular shaped holes, either through or blind. The machine comprises three parts, a motorised head which carries the electrode, an electronic drive and power unit and an electrolyte tray and circulating system. The heart of the system, which "makes it", is the type of motor used. Most commercial machines use hydraulics; this uses a relatively new design called a stepping motor.

As its name indicates, the motor moves in discrete steps in response to electrical pulses and can then be virtually instantaneously stopped and reversed. The speed is constant and readily controllable by the frequency of the drive pulses. This motor is mounted on a simple bracket and the shaft is extended in the form of a leadscrew. This drives a small slide on which is mounted, via an insulating block, a small chuck carrying the electrode. To obtain a fast response and hence improve the cutting rate, all the moving parts should be as light as possible and backlash should be kept small. This head is usually mounted vertically and if most model engineers are as short of space as I am this machine will not qualify for a permanent space on the bench. Consequently, when needed, I mount the head in the drilling machine and bolt the work tray to the table—one then has a convenient vertical adjustment also.

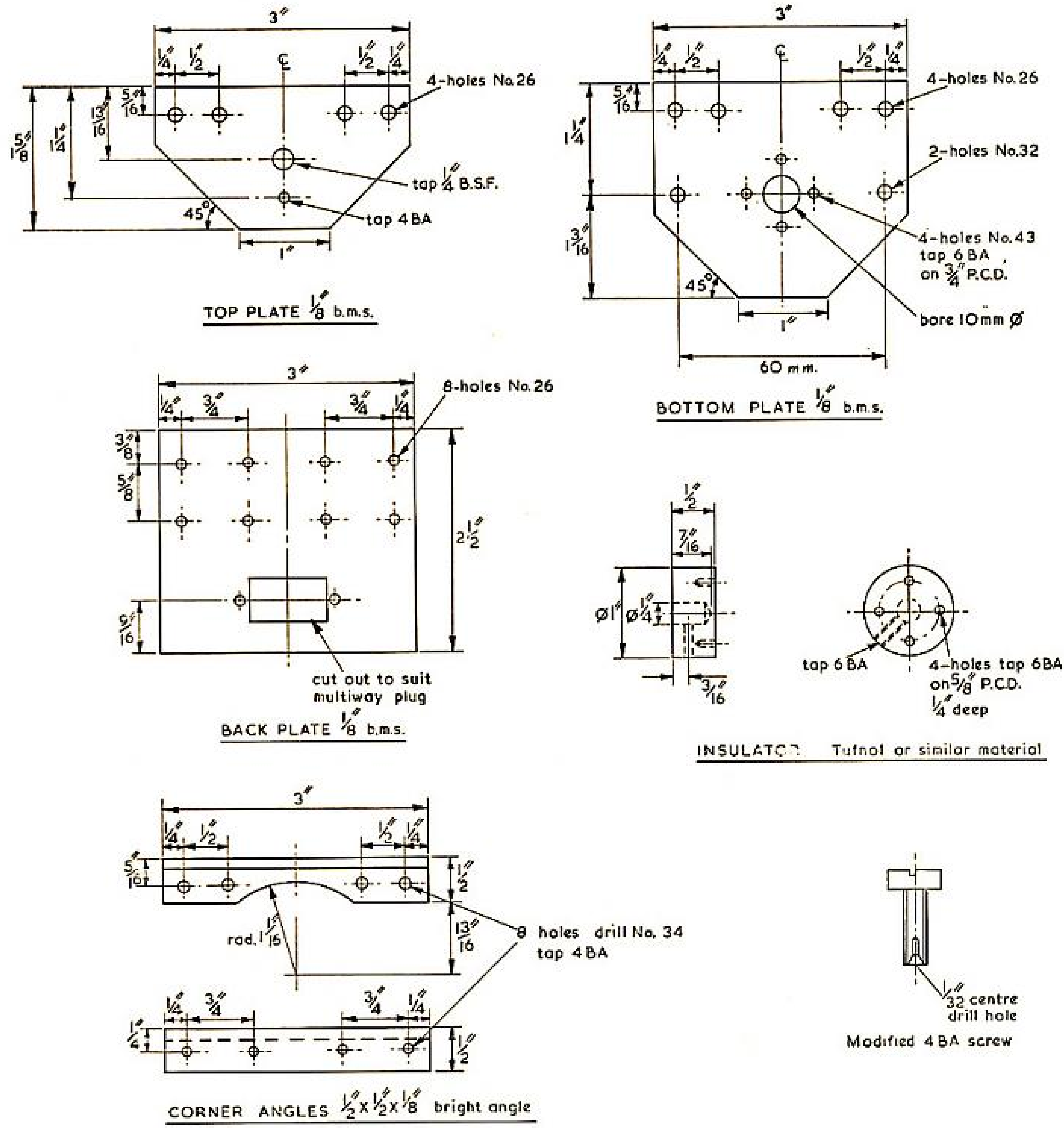
The drawings of the head are generally self-explanatory and it is very simple to make, the most important and difficult item being the coupling of the motor to the leadscrew. The leadscrew *must* run true when the motor is rotated and to this end the coupling has no grub screws; it should be a good fit on both shafts and held by a spot of Loctite.

The leadscrew thread is not critical and if 40 t.p.i. is used it can be lathe cut and cleaned up to size with a die. A small ball is used at the top of the motor shaft to control end-float and an anti-backlash nut can be incorporated in the larger motor version to advantage—the extra friction is not desirable with the small motor. The whole slide assembly must, of course, be free, but with no side shake. Two designs of head are shown; the larger one uses a larger, more powerful (and more expensive) motor, but both can be driven from the same electronic box. To take advantage of the larger electrodes this motor could handle, a bigger power supply would be required, but even without this it has some advantages in greater robustness of the slides etc.

A circlip made from one coil of a spring is used to prevent the chuck assembly falling out if it is inadvertently motored right off the leadscrew. Limit switches are not fitted, as their complication outweighs their advantages in this application. Stepper motors are not damaged by being stalled for long periods and the torque of the motor is insufficient to damage the leadscrew etc. The screw may jam if inadvertently wound to the top, but when it has been run in and is nice and free it will "unjam" itself in a few moments on reversal.

The drawing shows a pin chuck mounted to take the electrode; this obviously can be altered to suit individual constructors' whims.

The second item is the motor drive unit and power supply. The stepping motor is driven by a four-phase electrical signal which is generated by an electronic logic system from a 12 V D.C. supply, the smaller motor taking .70 amp and larger one 1.1 amp from this supply; in addition the logic unit takes 25 amp at +5 V which is stabilised from

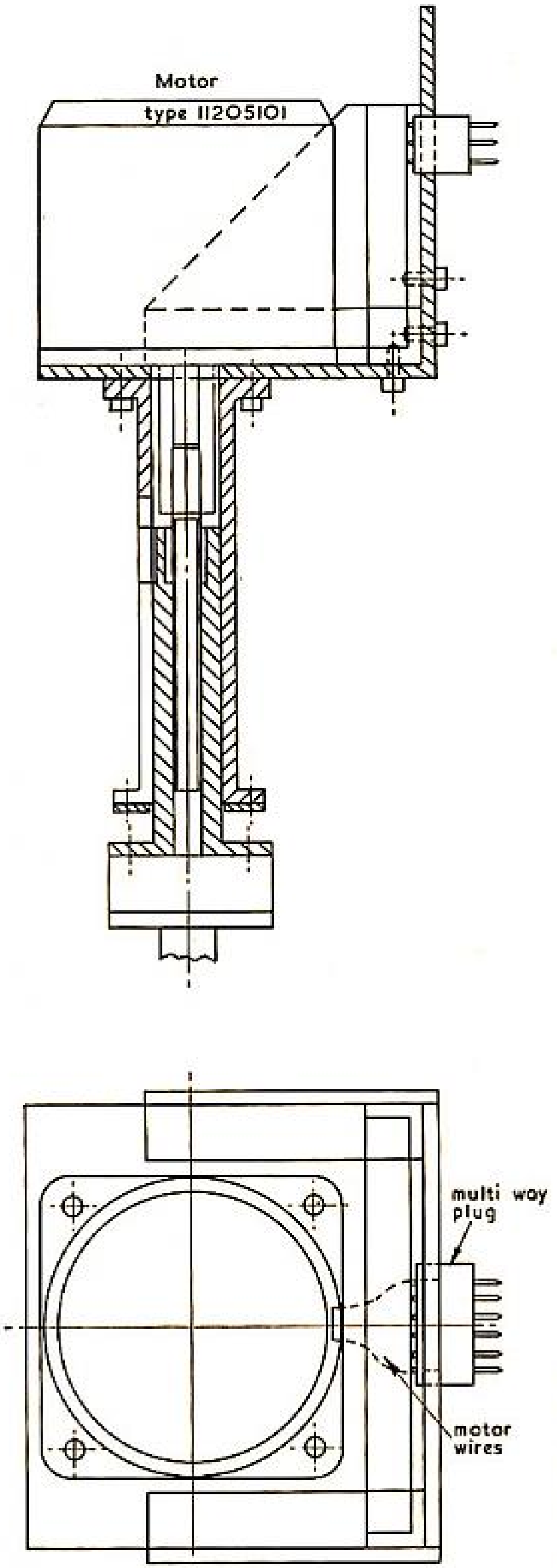


EROSION HEAD FOR SMALL MOTOR

the +12 V rail. The pulses which feed the logic unit are generated by a very simple unijunction oscillator "S" and resistor R_3 controls their frequency and hence the motor speed.

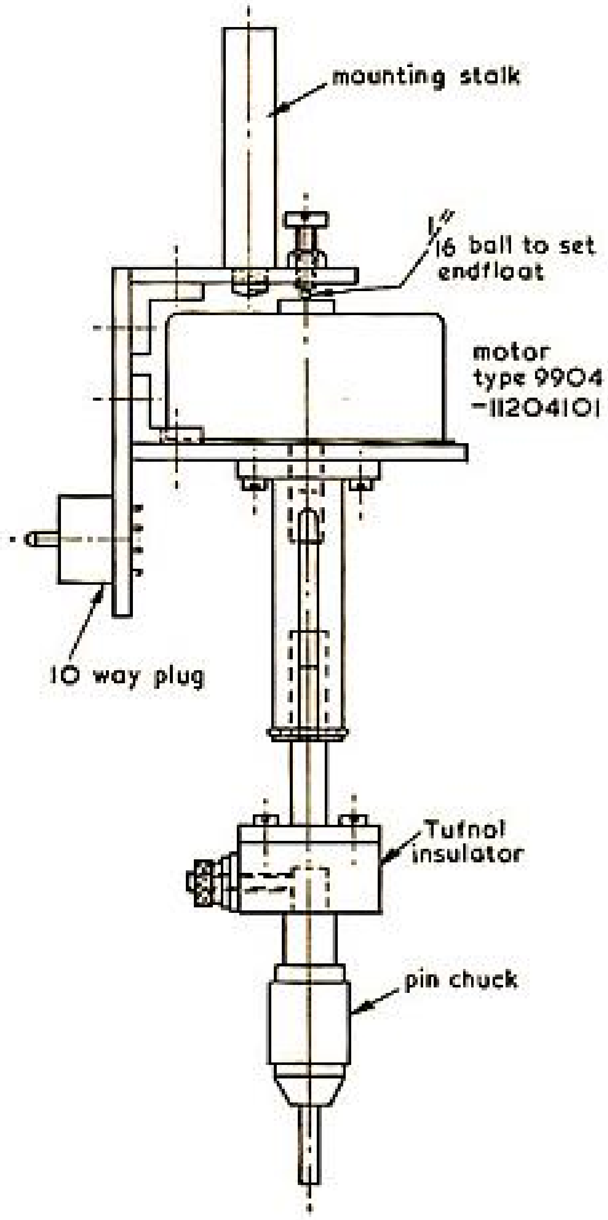
The motor direction is determined by a voltage into the logic unit at D, zero volts is arranged to raise the head and +5 V to lower the head. Consequently when the electrode is clear of the job it is at a high voltage and causes the head to descend. When it makes contact, the electrode voltage drops to zero and the head is instantly reversed. The stepping motor does not overrun. This process continues and each time the electrode leaves the job, capacitor C_1 charges up to the supply voltage through resistor R_2 and a spark occurs when the electrode next touches the job.

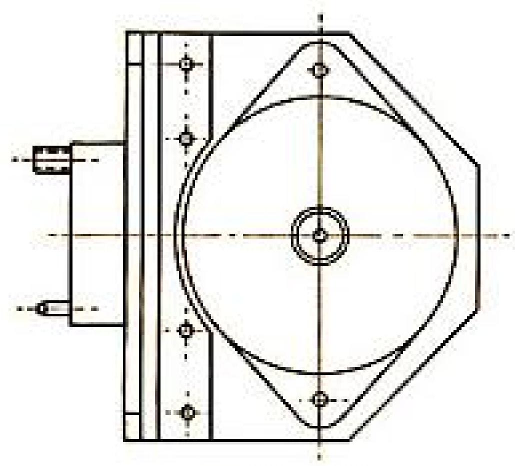
The rate of penetration depends on the energy stored in capacitor C_1; a larger one or higher voltage gives faster penetration, but a poorer surface finish. For safety reasons it is not usual to run the



SPARK EROSION MACHINE HEAD USING TYPE 11205101 MOTOR

All fixings 4 BA and 6 BA cap screws



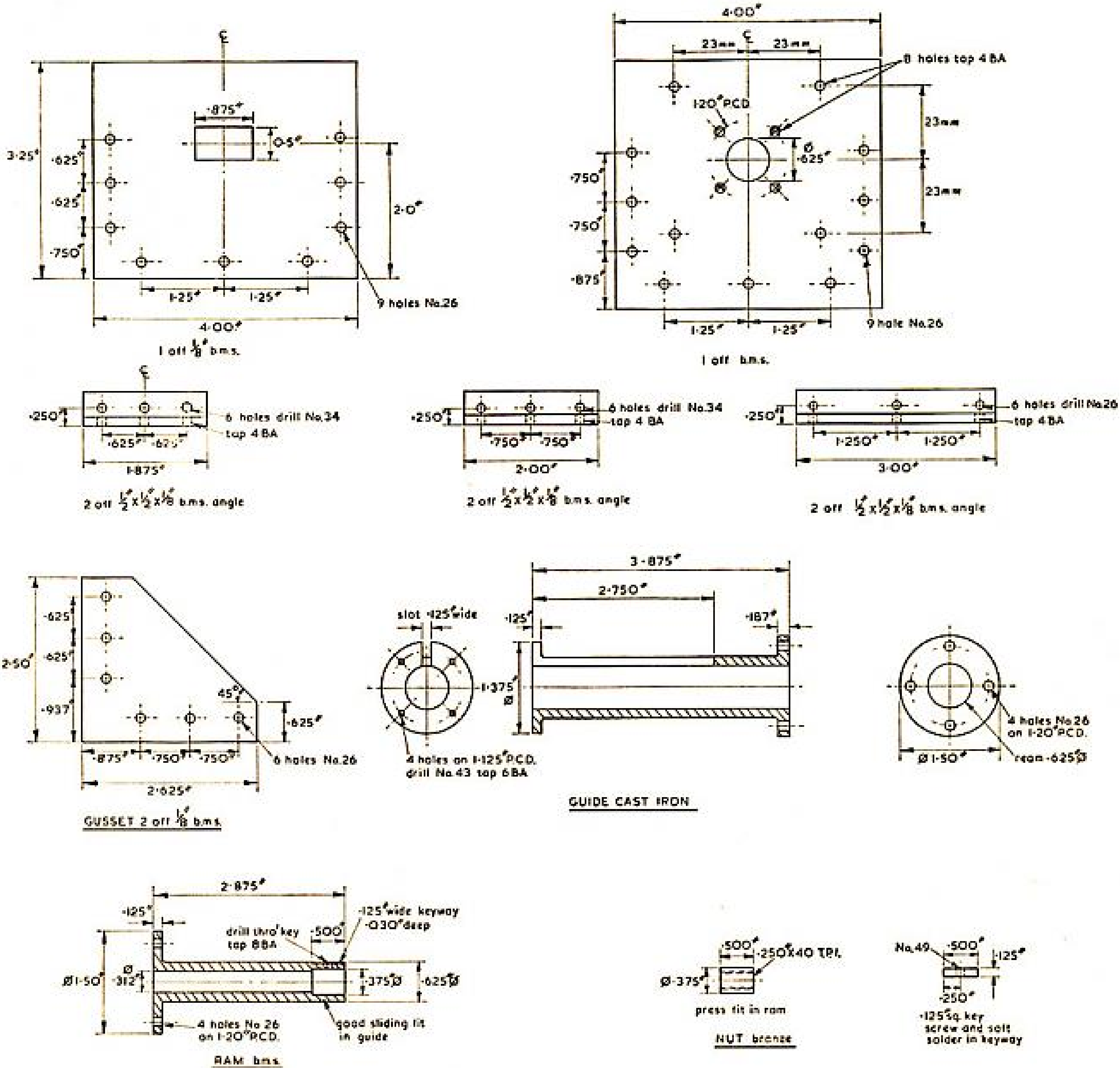


PLAN : top plate removed

electrode above about 200 V; most commercial machines run around 100-150 V.

This system is, of course, the simplest and most basic one; large machines generate distinct pulses of energy controllable in frequency and duration, but this complication is not warranted for our application.

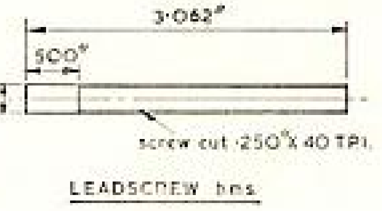
The circuit diagram will show all the parts required for this unit. Some constructors with an interest in electronics will no doubt have many of the items. The transformer used in the prototype was an old valve radio transformer, the two heater windings

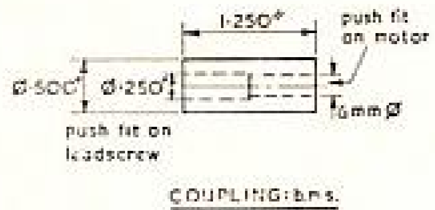


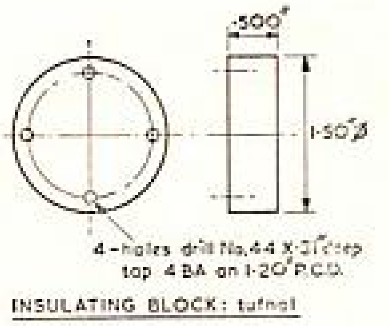
in series being convenient for the low voltage supplies and half the 250-0-250 V secondary rated at 100 mA for the electrode supply; however this gives an electrode voltage of some 300 volts and care is needed if nasty shocks are to be avoided—the lower voltage should be used for general safety.

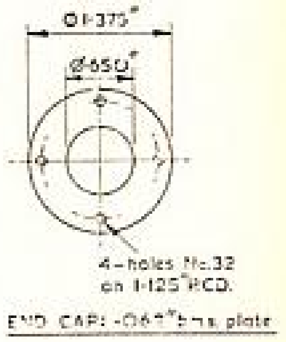
The power unit circuit shows the discharge capacitor as 2μF; this is satisfactory, but it speeds things up if another one, up to 8 or 12μF, is available and is connected when required straight across the electrode and work—it also works better with reasonably short leads, say 12 in. or so. Special capacitors are made for this sort of work, but standard paper insulation types work quite well and they are fairly cheap at surplus stores. The voltage rating must be at least 300 for a 150 V transformer winding. Two controls are provided on the box—mains on-off and head raise and lower. This latter control also disconnects the electrode power in the raise position and reconnects it in the lower position.

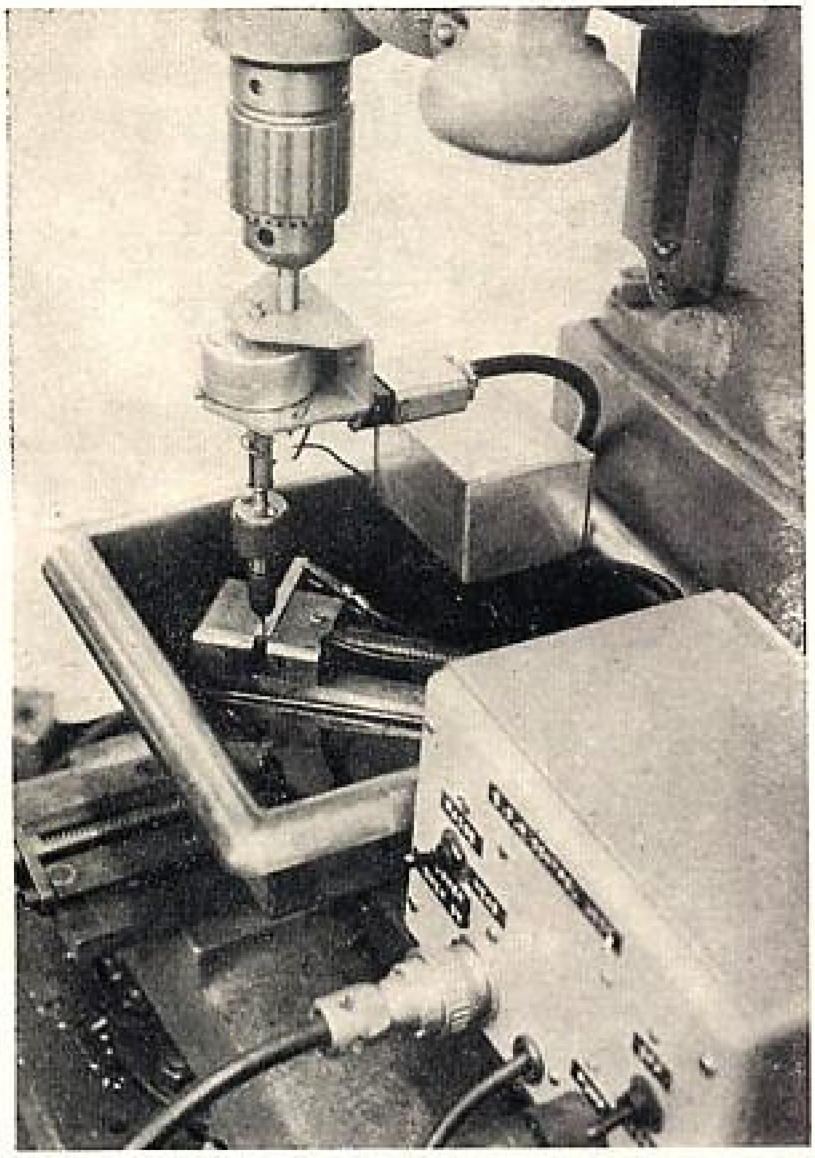
The last item is the work holder and dielectric supply. To extinguish the spark rapidly and wash away debris from the working point, spark erosion machines always use a dielectric; this is usually ordinary paraffin, although more recently, to reduce fire risks, a light mineral oil is sometimes used. I've never had a fire with paraffin, but a handy

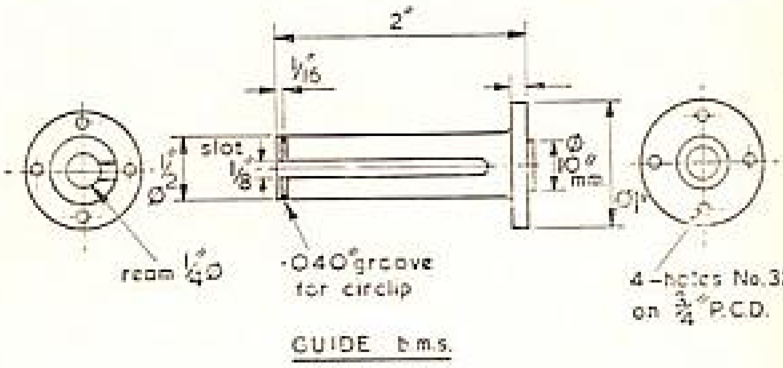


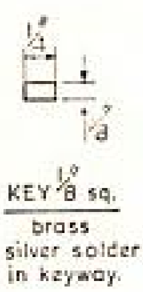


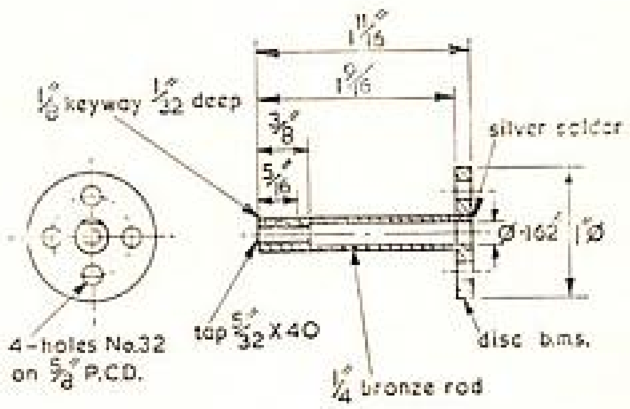


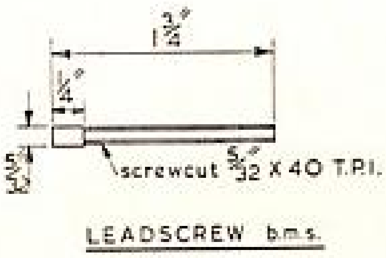


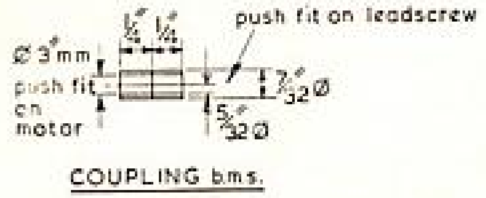

The spark erosion machine in use.











fire extinguisher is a wise precaution. The work may be fully submerged, or the paraffin may be poured over the work. If working submerged a means of agitating the dielectric is still required and one cannot see what is going on so easily, as the dielectric becomes black in no time, but it does stop it splashing around. I use a very small centrifugal pump to pour the dielectric over the work—one made the wrong direction of rotation for a small petrol engine many years ago—they come in useful if kept long enough! This one has a rotor about ⅝ in. dia., and it is driven with one of the small surplus induction motors now available, coupled by a bit of plastic tube between the shafts. The pump is bolted in the corner of the tray with its motor above. The type of electric pump used for car windscreen washers would probably be satisfactory but I have not experimented with one of these. The work must be clamped down and earthed to the power unit—it is surprising how quickly a small vice and component will wander about under the light pecking action of the electrode.

Operation of the machine is very straightforward. The head is fitted in a suitable mounting, such as a pillar drill chuck as previously mentioned, which is locked to prevent rotation and the work tray clamped to the table with the work held in a small vice.

A copper electrode about 1 in. long and shaped to that of the required hole is mounted in the pin chuck. The electrode should be about .005 in. less than the final hole size required.

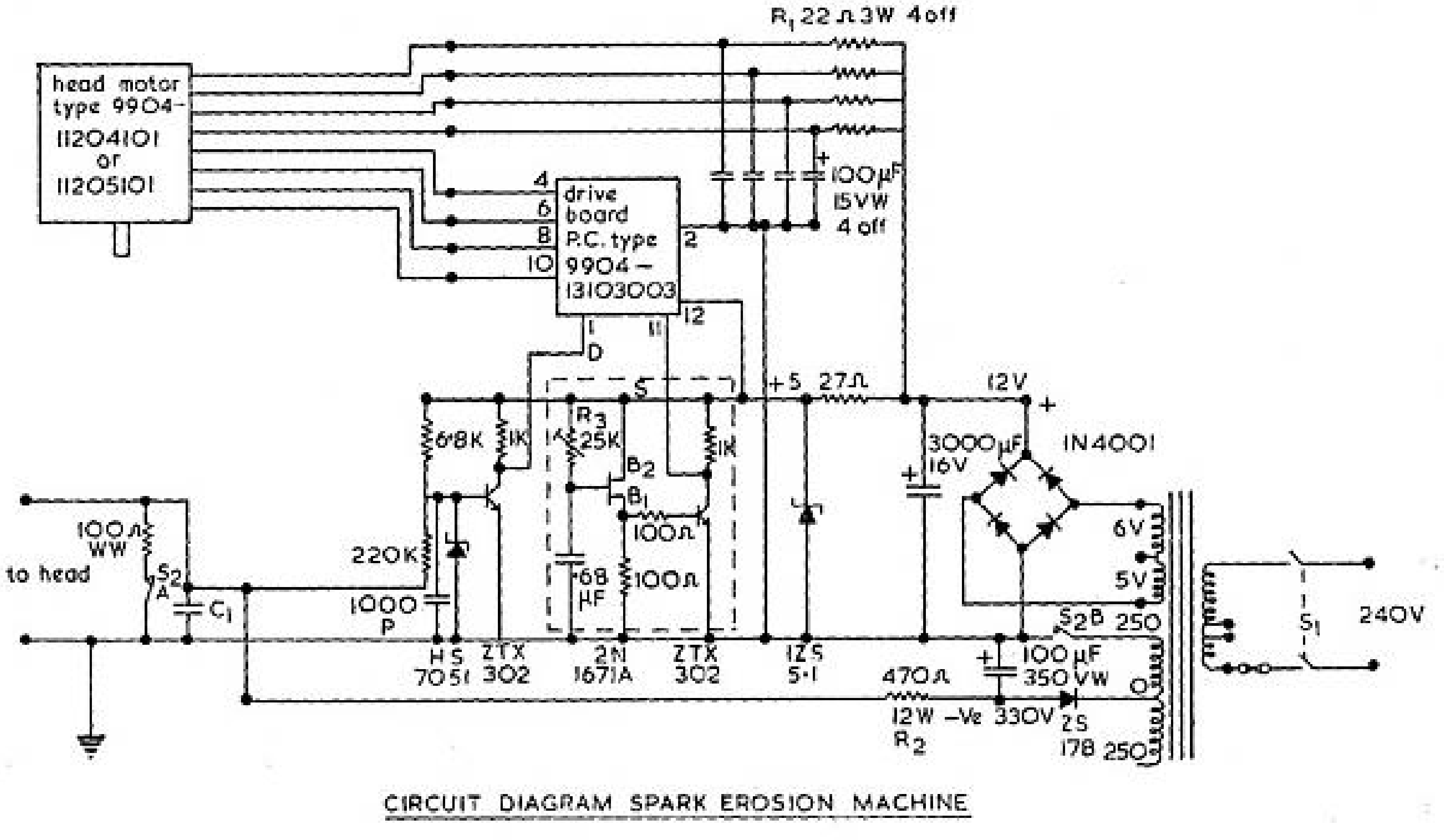
About 1 in. of paraffin is put in the tray and the pump delivery pipe arranged to pour the paraffin directly over the required hole position. Switch on the mains unit and switch it to "lower head" which should now bring the electrode down until it touches the work, when it will spark away and after each spark the motor will momentarily reverse and come down again. Once one is happy that it is performing properly it can be left to its own devices—don't let it come through the job and then carry on through the bottom of the tray though!

When doing deep blind holes the hole will tend to accumulate debris and an occasional complete withdrawal and re-entry will improve cutting. If deep holes have to be cut the process can be speeded up by drilling away most of the metal and using the electrode to shape and size the hole only.

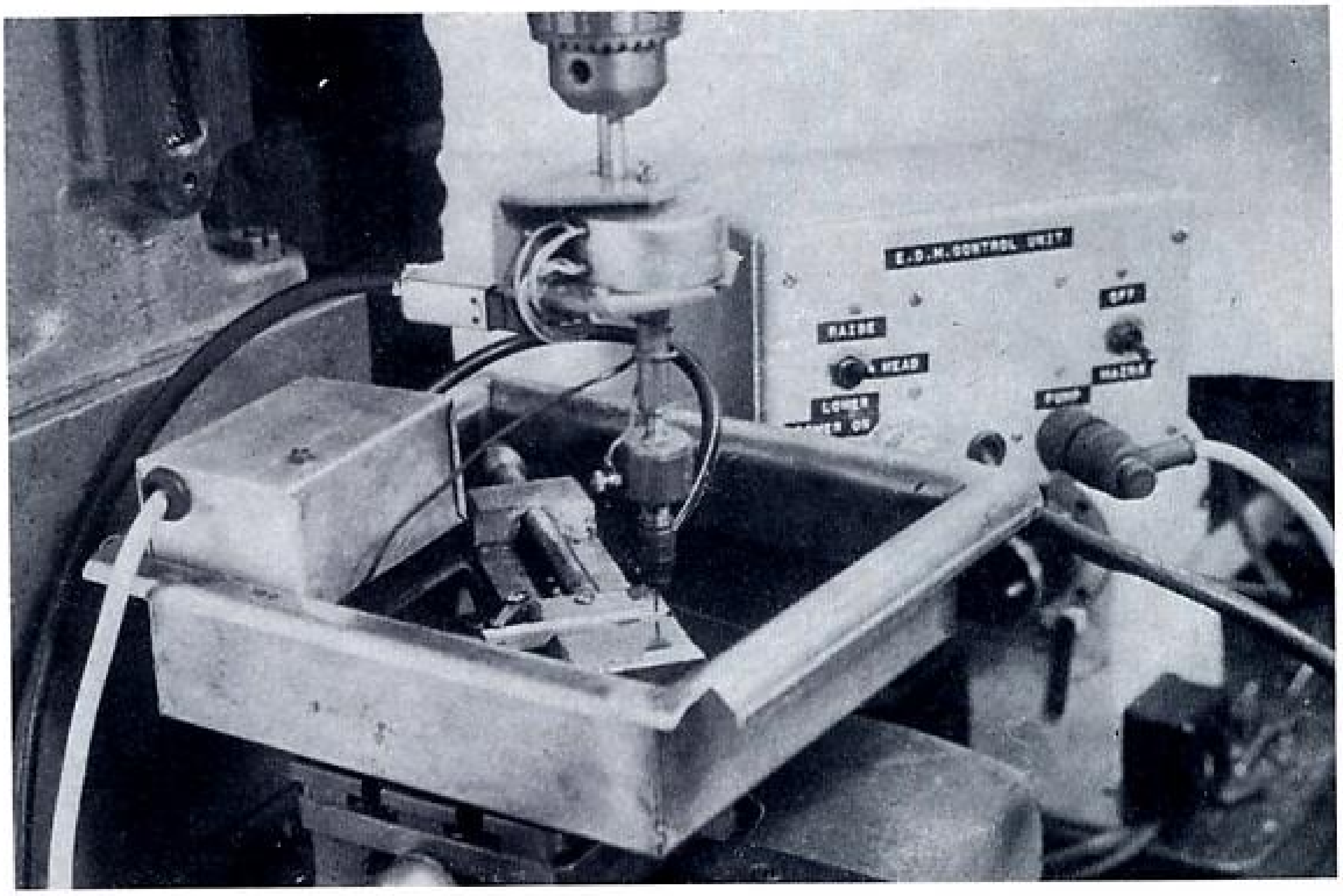
In the sparking process, the electrode will become worn and tapered. This portion should be periodically cut off to maintain the hole shape true and parallel; this may need to be done several times if an accurate parallel hole is desired. Of course, practically any conducting material can be machined in this way; hard steels in fact cut quicker than brass or copper.

Removing broken taps and drills is, of course, likely to be its main use, and when removing a tap more than about ¼ in. O.D. the electrode may be made hollow; it will then remove the lands of the tap without having to cut the centre and thus speed the job up. Hollow electrodes have sometimes been used to feed the dielectric down the centre; however, this does not always improve the cutting rate for some unexplained reason and it is often worth trying different electrode configurations and materials if one is after faster work. However, as model engineers this aspect is not usually of much importance.

As this machine is rather different from other purely mechanical machines described over the years in *M.E.* many would-be constructors may be put off by the electronic "black box". To help out, arrangements are being made for a small company



CIRCUIT DIAGRAM SPARK EROSION MACHINE



The spark erosion machine in operation.

to put on the market a kit of parts for this item, which will include the stepping motor. These may be purchased as a basic kit or with the printed circuit card only wired and tested or as a complete wired and tested control box.

Transformer:
Primary: 200-240 V
SEC (1) 11.3 V.
SEC (2) 250 V.
Ex-valve type radio:
Use 6.3 V and 5 V windings and half of 250-0-250 winding.
If motor runs in wrong direction interchange 4 and 6 with 8 and 10 in pairs.
Head must descend with S_2 A open.

Motor type 11204101 R_1 — 22 Ω 3 W

Motor type 11205101 R_1 — 15 Ω 3 W
C_1 2μF to 16 F.
R_2 may be made up of several lower wattage wire-wound resistors.
Note S_2 A closed when S_2 B open.
S_1 — mains switch.
S_2 — raise-lower switch.
Drive board requires socket type FO50/037/01012.

Motor connections:	*Pin No.*
Yellow front coil	4
Grey front coil	6
Yellow rear coil	8
Grey rear coil	10

Black front coil, Red front coil, Black rear coil, Red rear coil } Any order to R^1