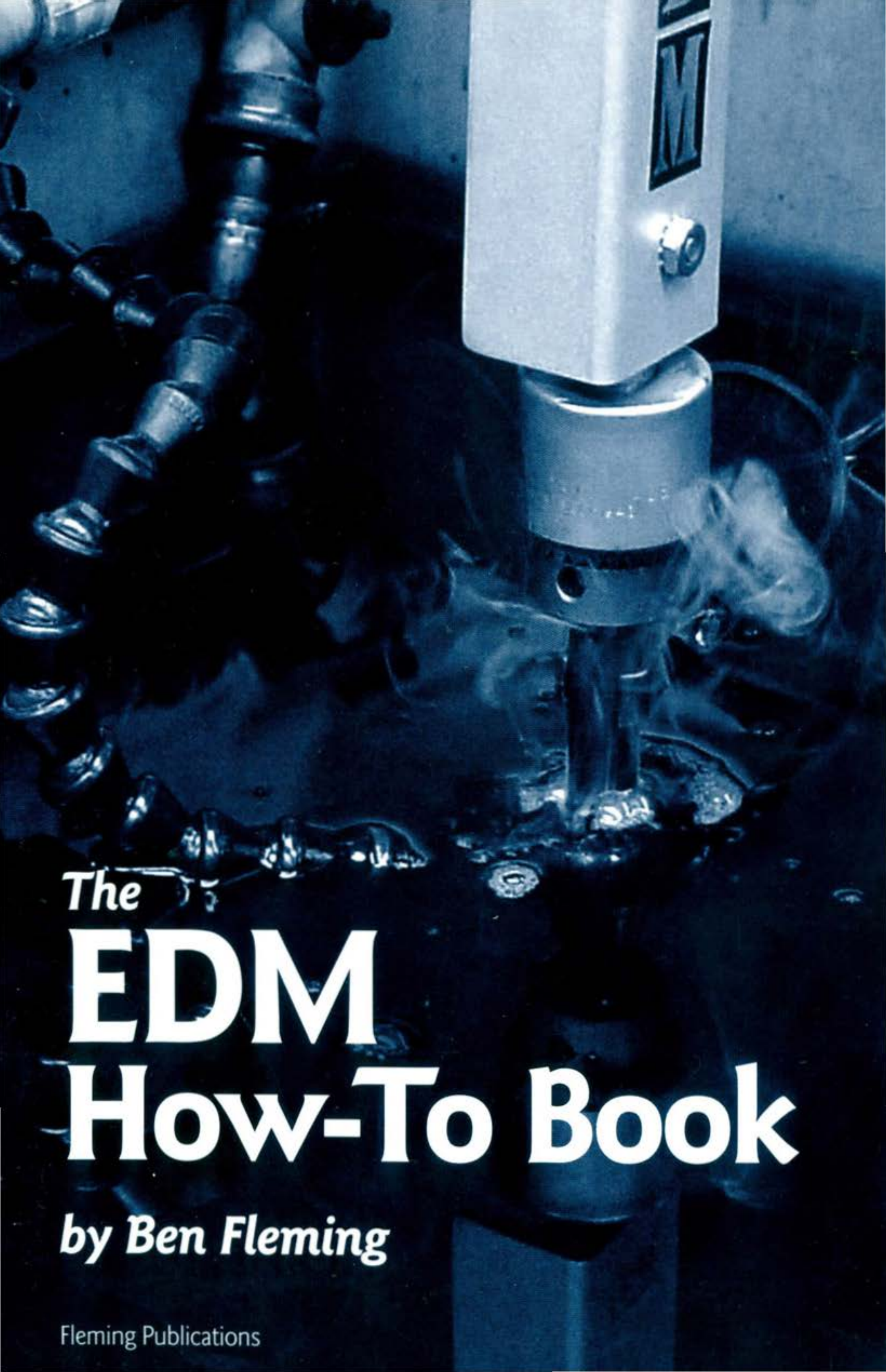

The EDM How-To Book

by Ben Fleming

Fleming Publications

Disclaimer and License Agreement

The author of this book, Benjamin Fleming is **NOT** a professional engineer, nor has he had any formal training in the design of EDM (Electrical Discharge Machine/ing) technology or apparatus.

The designs found herein require the use of voltages and currents known to

KILL PEOPLE!

The said Fleming as well as the distributors of this publication assume no liability for injury to person/s or property that may result from the building, testing or operations of designs described in this publication. The intent of this publication is for

EDUCATIONAL PURPOSE ONLY

****

License agreement

By purchasing The EDM How To Book, it entitles the purchaser the right to build an EDM of this design for personal use only

The design outlined in this text is not to be built and sold for gain or profit without agreement from the author, Benjamin Fleming. All violators of this agreement will be aggressively prosecuted.

In other words, you cannot go into business building this machine without my approval. If you want to do that, manufacture and sell your own design.

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Preface

I have seen articles published in the past on building an RC-type Electrical Discharge Machine (EDM) for home and/or small shops. Most of these designs, in my opinion, are far too complex. The intent of this book is to make available to the do-it-yourselfer my years of experience building very simple, yet highly effective automated, RC type EDM machines.

Some of the topics covered in this book are:

1 Theory of the EDM process,
2 Explanation of circuit operation,
3 Building the generator,
4 Building an automatic control system,
5 Building a low cost, gearmotor slide
6 Building a full functioning dielectric tank and filtering system,
7 EDM techniques and tooling.

The book is laid out to construct the EDM in the following building sequence, though it may be built in any order.

1. Control circuit
2. Generator circuit
3. Servo head
4. Dielectric tank

Should any readers develop a more advanced EDM, I would be happy to correspond with you regarding its development. It is my hope that you will find this book interesting, as well as a valuable resource in your quest to know more about the EDM process.

A brief EDM history

The Russians are usually given credit for discovering the EDM process in 1943. Lazarenko is the name that is associated with the process first called Spark Erosion, more recently referred to as Electrical Discharge Machining (EDM).

In 1770's, the English scientist Priestley discovered the eroding effect of electrical discharges. More than one hundred year was to pass before some practical use was made of the discovery.

During an investigation of how to suppress the erosion of electrical switch contacts, the Soviet scientists B. R. Lazarenko and N. I. Lazarenko had an idea. Why not use the destructive effect of the electrical charge in a controlled manner for machining recently developed metals that where proving to be difficult to machine. Soon thereafter, they developed a working procedure with spark erosion, where an electrical discharge in a dielectric liquid takes place between two conductors.

The Lazarenko's developed what early on came to be called a Lazarenko circuit. Today it is referred to as a relaxation, or RC circuit. It was used for a long time in the building of generators for spark erosion-machines. This type of generator is used even today in some machines to obtain a near-mirror finish using the EDM process. The generator described in this book is an RC circuit based on the design developed by the Lazarenko's.

EDM resources

EDM Kit

Should there be enough interest I plan to make available a PC board and perhaps an EDM kit in the near future. Contact me for available of the board and kit.

EDM Patent Book available

I have about 1000 copies of a book compiled from a Patent search I did of EDM systems. The Book is titled:

EDM PATENTS
1960's-1990's

They are available for $14 each;
which includes shipping. (U.S. only)
Contact me for overseas shipping charges.
See contact information below

Yahoo group

A Yahoo group has been formed to assist builders.
http://groups.yahoo.com/group/EDMHomeBuilders

The premier EDM publication in the USA is titled
EDM Today
http://www.edmtoday.org/
Phone number: 973-831-1334
The publication is available on line and as a free magazine

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Introduction

This book will show you how you can have EDM capabilities in your shop for a minimal amount of time and dollars invested. You ask, why should I would want another metal cutting machine when I have a lathe, mill, and other metal working tools? For one thing, you will have capabilities not provided by other metal cutting methods. This opens up moneymaking opportunities. One is the precision removal of broken taps and drills. It's possible to burn a broken tap, drill, or an easy out from a piece of aluminum (or other metals) without touching the previously formed threads. Other practical applications are, the squaring of milled corners or burning odd shaped blind and through holes, even making cuts in **carbide** is possible with and EDM !

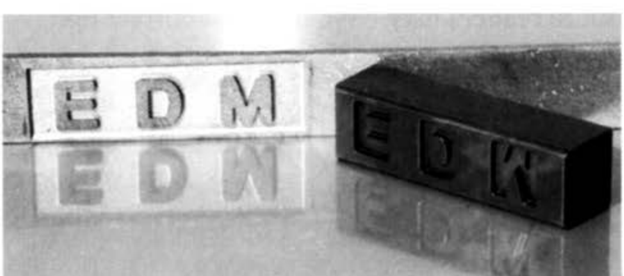
Suppose a seven-sided hole is needed in a piece of hardened steel. With a ram EDM, it is a walk in the park. For the artisan, carve your initials or a design on the end of an electrode (negative or positive) and then burn it into the workpiece. The EDM opens up a completely new world of machining capabilities; your imagination is the only limit, so go for it!

My introduction to the world of EDM (Electrical Discharge Machine or Electrical Discharge Machining) came at, of all places, a yard sale where I purchase two boxes of old Popular Science and Popular Mechanics magazines. In one of the magazines, the basic theory of the EDM process was described along with details of how to build a manually operated EDM. I built the little machine and really became obsessed with the EDM process.

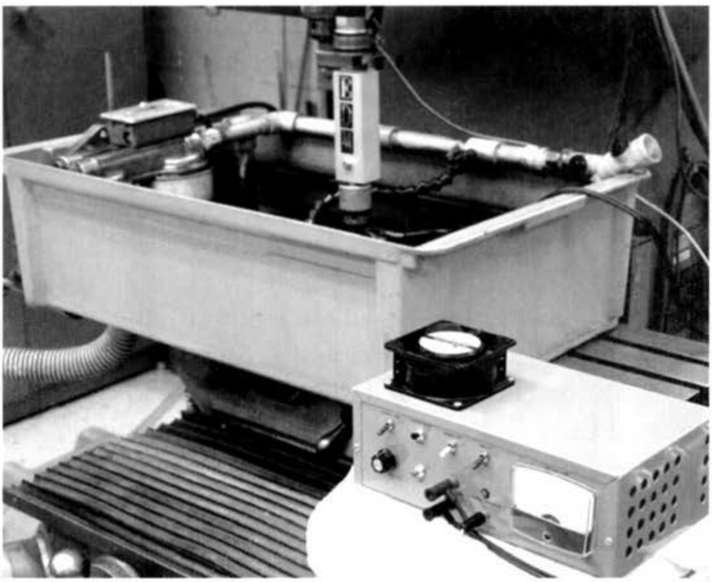
I soon discovered that **these machines would cut anything that conducts electricity!!** I had been exposed to machine tools in high school and at a technical college, but had never seen anything like this! From that meager beginning, the first attempts were made to find additional information on the design of EDM power supplies and control systems. It didn't take long to discover that there is almost no information on EDM generator design available to the public.

Many of you may have attempted to delve into the mysteries of the EDM generator and control circuits and found the same lack of published information. The large EDM manufacturers certainly are not going to tell you anything about generator/control circuit design. I know that from personal experience as one EDM company engineer told me, "the kind of information you are seeking is proprietary and only actively worked on by about 20 people in the U.S."

This book is, in part, an attempt to fill the EDM knowledge void. In this book I will give you hands on, step-by-step information needed to build a simple, low cost, automated EDM system. This kind of information can be found in very few places. I spent about 2 1/2 years, and a lot of trial and error building my first automated ram EDM. Since that time, I have built many different versions of the EDM, including both RC (resistor capacitor) and with limited success, pulse machines. My research on pulse machines continues and in the future, I hope to publish a book on building such a machine.



The photo below shows the finished EDM system described in this book. This setup was used to burn the EDM logo (previous page and back of the book) into the file. You will be able to do the same thing once you finish building the EDM!

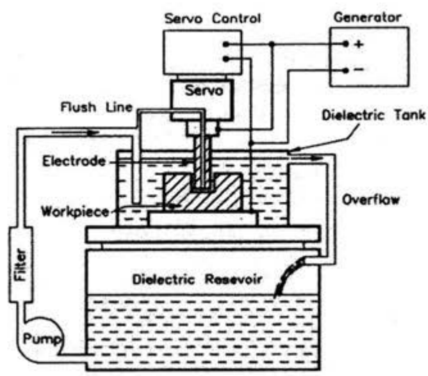


All attempts have been made to ensure that no technical mistakes have been made in the text of this book Should any readers discover short coming please advise so that future readers may have the most correct text .

Chapter 1

Principles of EDM operation

Electrical Discharge Machining (EDM) is a process that uses electrical discharges from an electrode to erode an electrically conductive material. As a result, it is possible to erode or "burn" the shape of the electrode into the workpiece. The drawing is a schematic of a typical EDM system. An EDM system is comprised of a generator, also known as a power supply, a servo system (servo and servo control), a dielectric tank, and filtration system. (NOTE: the term generator was used in the early days of EDM work. More recently it has been replaced with the term "power supply." To minimize confusion during building the term generator will be used when it pertains to the high power section of the EDM power supply)



The workpiece is placed in the dielectric tank and affixed to a metal plate in the tank. The tank is filled with a hydrocarbon dielectric fluid (such as kerosene), which ionizes in the presence of an electrical field. The dielectric fluid breaks down electrically (i.e. conducts), after a short ionization period, assuming the electrical field intensity is high enough. The electric field is created by applying a voltage between the electrode and the workpiece (known as the gap).

The breakdown of the dielectric fluid is much like the breakdown of air when a large voltage is supplied from the coil in an automotive ignition system to the spark plug. However, since in EDM the gap is typically held to only a few thousands of an inch, the applied voltage does not need to be very large for an EDM "spark" to occur. Typical **operating gap voltages** for EDM machines are in the range of 25-50VDC though the ionization voltage may be quite a bit higher.

The servo system maintains the appropriate separation of the electrode and workpiece as determined by the operator setting the desired gap voltage on the EDM generator. The gap voltage feeds back to the servo control system so that the proper separation of the electrode and workpiece can be maintained. As each spark is discharged from the electrode (the cutting tool) to the workpiece, a small amount of metal is vaporized and a crater is left in the workpiece. The dielectric fluid quickly cools the vaporized metal. The solidified metal partials, known as swarf, are removed from the work area by the circulating of the dielectric oil, and the filtering system traps the metal partials.

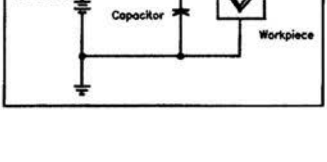
The EDM burning process is repeated thousands of times each second. As the workpiece is eroded away by the repeated discharges, the electrode descends under the servo system control. As a result of millions of electrical sparks melting small quantities of metal, it is possible to erode various shapes into any material that will conduct electricity Even some semiconductor materials may be machined via this process. Generally speaking, the hardness of the workpiece has little effect on the burn; this is one of the biggest advantages of the EDM process.

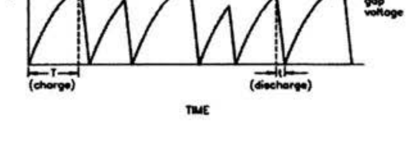
Some people are concerned about the possibility of fire when using EDM equipment and a petroleum based dielectric fluid. It is essential that the end of the electrode (where the sparks are being produced) always remains immersed in at least 1" of dielectric fluid. As long as the sparks are under the fluid, the fire hazard is minimal. To start and maintain a fire you need three things: (1) heat, (2) fuel, and (3) oxygen. If any of these is missing, you will not have a fire. By keeping the sparks immersed, the supply of oxygen is eliminated and the fire hazard is virtually non-existent.

Generator design

The description below maybe a bit technical for those not familiar with electronic lingo, but hopefully you will be able to glean enough information to have a basic understanding of the different design concepts. The EDM generator is what controls the electrical discharges. It's essential that between the discharges, the dielectric oil be given time to recover. If this off time is too short, a dc arc will develop instead of a spark. The energy supplied by the generator will simply go into heating up the electrode, workpiece, and fluid, and not into vaporizing the workpiece material.

There are two basic types of EDM generators: RC (resistance-capacitance) and pulse. RC generators are rugged, simple to use, low in cost, and have good burn stability. The figure below (left) shows a block diagram of an RC generator. The RC generator consist of a DC supply, a series resistor, and a capacitor, parallel with the electrode

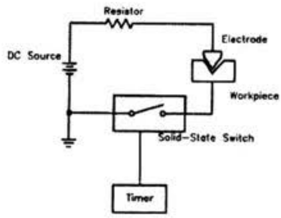




workpiece gap. When the generator's power is turned on, the capacitor charges through the series resistor and, eventually, the gap voltage becomes large enough to break down the dielectric fluid. The energy stored in the capacitor is rapidly discharged through the gap.

The figure on the right (page 3) shows a typical waveform of an RC generator. The waveform indicates the discharge time (t) is much shorter than the charge time (T). Each discharge is a single spark. The series resistance in the generator can be changed to vary the charge time, which will affect burn rate and burn stability. The amount of material removed for each spark depends on how much energy is stored in the capacitor.

The operator usually has several capacitance values that may be switched in and out of the circuit. The higher the capacitance, generally, the higher the metal removal rate. The disadvantage of higher capacitances is that the higher energy per spark creates a poorer surface finish on the workpiece because the crater size is larger. Some people speak bad of RC machines because of the high erosion rate on the electrode. I will agree, it is quite a bit higher than with the newer designed pulse machines, but it is not nearly as bad as it used to be. The main reason for the improvement is the higher quality in electrode materials available now. This is true in particular with the available graphite electrode material. I recommend using graphite electrodes with the RC machine described in this book. Today most commercially available generator designs are pulse, although there are special applications where the RC design is superior. The



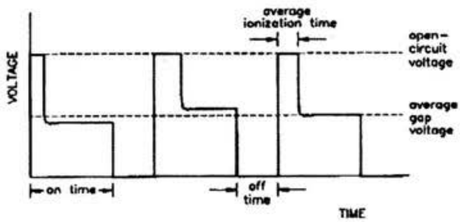


figure above (left) shows a block diagram of a pulse system. The corresponding gap voltage waveform is shown (to the right). A solid-state switch (i.e. transistor or fet), switches power on and off to the gap. Once the solid-state switch closes, it takes a small period of time for the dielectric oil to ionize and then the discharge takes place. The solid-state switch then opens to give the dielectric oil time to recover.

For pulse systems, the surface finish is controlled by adjusting the on time and the current level. Although quite a bit more complicated than RC designs, the big advantage of pulse generators is that electrode wear can be greatly reduced under certain machining conditions and metal removal rates improved. The primary disadvantage of pulse systems compared to RC systems, is that the burn in some cases tends to be less stable and requires a much, much more sophisticated control system to give good performance.

For small home shops, where the EDM is used occasionally for odd jobs the simplicity of design and much lower cost of the RC generator usually outweighs the disadvantages. The generator outlined in this book is an RC design. Should there be sufficient demand, perhaps later writings will include a pulse design EDM machine.

Chapter 2

Getting started

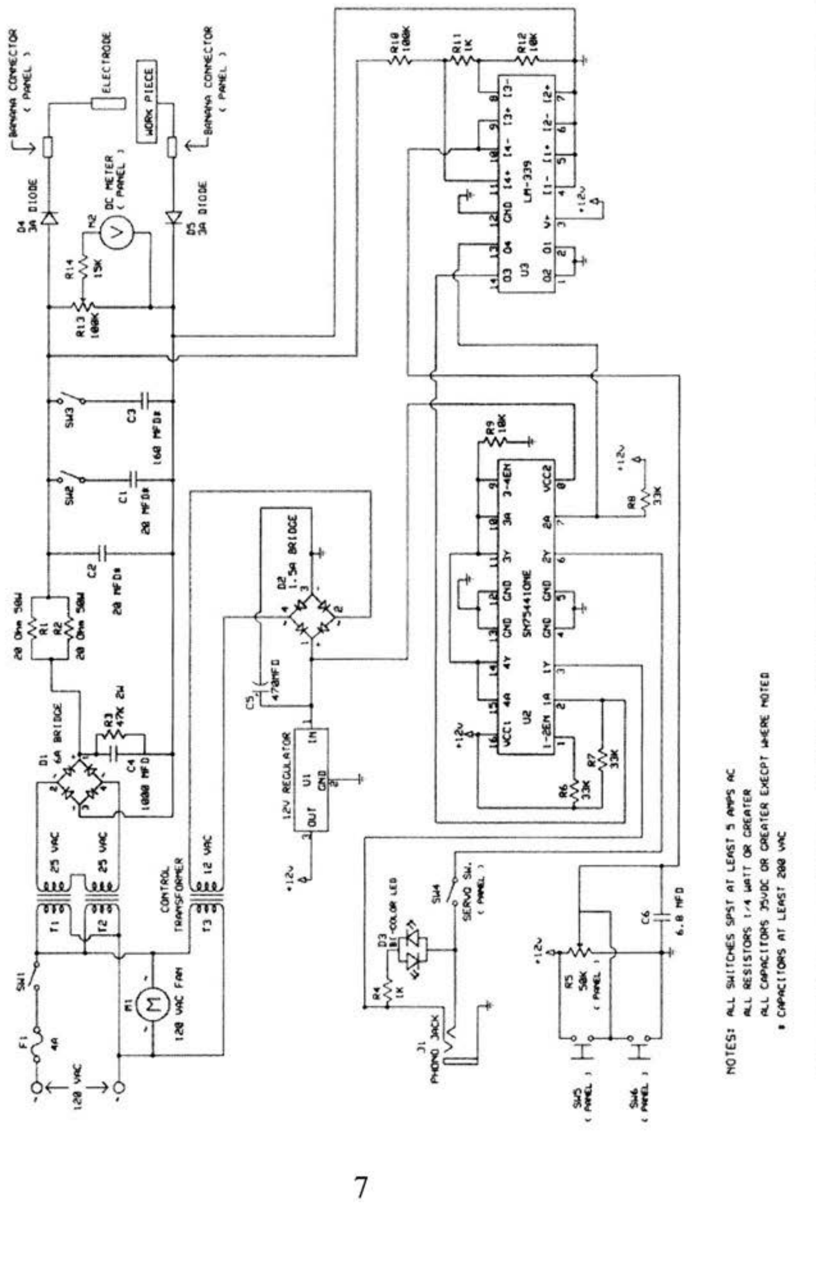
I anticipate that there will be more machinists with minimal electronic experience attempting to building the EDM, than there will be electronics persons with minimal machining abilities. Assuming this is most likely the case, I have opted to give a detailed step-by-step description of how to build the control system and generator. Metal working persons with minimal electrical/electronic skills you should be able to successfully complete the project if you can,

1. Follow written instructions closely
2. Perform sound electrical connections on a P.C. board
3. Be able to read and understand simple electrical schematic diagrams.
4. Understand how to use a VOM/multimeter

On page 7, find the complete schematic diagram of the EDM machine. This should prove helpful when wiring the power supply. If you are not familiar with reading schematics, a little time in the library brushing up on schematics should prove helpful. Reading schematics can be a little tricky; for example, connections shown on schematics are not necessarily how they are physically wired. The schematic shows only how the circuit is "electrically wired."

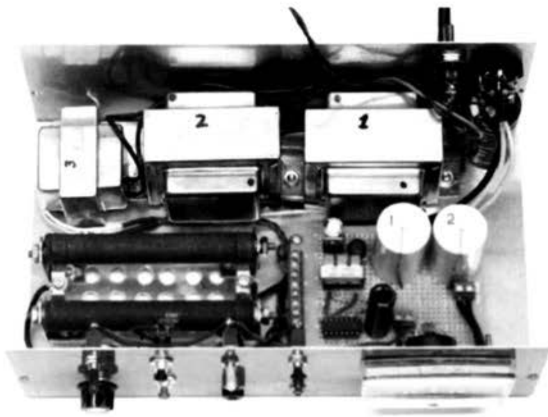
In the Appendix of the book you will find a complete list of parts (electronic and mechanical) which are needed to build the EDM as well as sources for these parts. A Glossary of EDM terms is also included.

The completed EDM schematic diagram



Physical layout and brief overview of the generator

All of the electronics required for the EDM are located in an electronic project box. The photo below shows the placement of the major components in the box.



The output of the transformers, in the back center, is sent to a full wave bridge rectifier where it is converted to DC. A filter capacitor (back right hand corner) is used to help smooth out the D.C. power. Two resistors are mounted in the front (left hand corner) of the generator enclosure. The control board (front right hand corner) houses the low voltage power supply as well as the actual control system. This board also has the finishing and coarse cut capacitors (needed to do the actual EDM cutting) mounted on it.

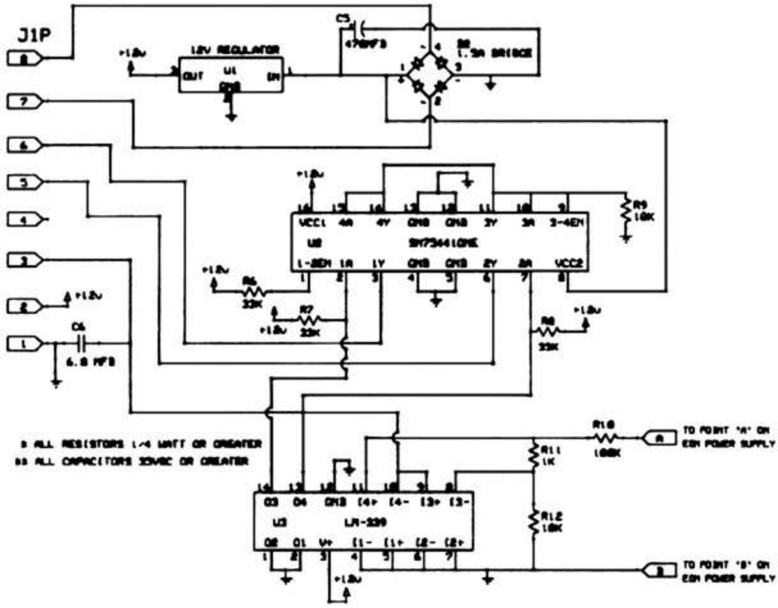
With the present availability of low cost IC's (integrated circuits), it is possible for a person with minimal electronic knowledge and skills to build a very powerful control system for an EDM machine. A tremendous amount of electronics get packed in the small IC's of today; the only items needed to control the complex IC circuitry are a few external components, which you will be installing.

Understanding the control circuit operation

The control circuit, see schematic page 10, is a window comparator circuit built around a LM 339 IC (integrated circuit). This IC chip samples the voltage drop across the EDM gap (points "A" and "B" lower right hand corner of the schematic) and then compares that to a reference voltage, which is set manually by the operator. Should the gap voltage be higher or lower than the reference voltage, a signal is sent to the servomotor driver chip (SN754410NE) to advance or retract the electrode.

The actual mechanical movement is accomplished via a DC servomotor positioning a ball slide, to which the electrode is attached. Once the gap voltage and the reference are the same, a null occurs. In this condition, the EDM generator continues to apply power to the gap, but the servomotor control system does not turn the motor on to move the electrode. As the workpiece erodes, a physically larger gap between the electrode and the workpiece results. The larger gap requires a higher voltage to continue the burn. The control system senses the elevated voltage (drop) and advances the electrode, (via the ball slide), until the reference voltage and gap voltage come into an agreement.

Should an electrical short occur between the electrode and workpiece the gap voltage will drop below the reference voltage. The comparator signals the servomotor to mechanically retract the electrode, i.e. break the short. Once broken, the gap voltage is higher than the reference. The servomotor physically advances the electrode until and arc is established and the gap voltage and the reference reach the afore mentioned null.



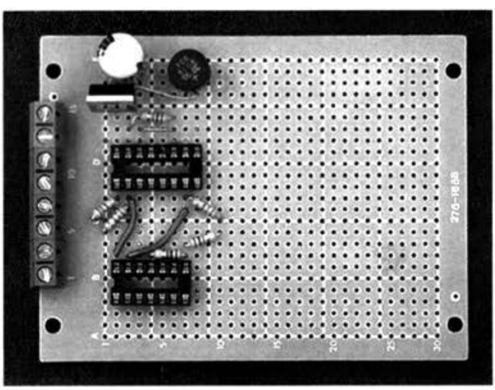
Source of required parts

A large percentage of the parts used for the generator and control circuit are available from Radio Shack stores, which are located in most communities throughout the U.S. If the parts are not available through Radio Shack, sources are given (U.S.) for the needed items. If you prefer, virtually all the electronic items may be purchased from electronic mail order supply houses, such as Allied and Newark Electronics. The first order of business is to obtain the needed electrical items; see Appendix for list.

The control circuit and part of the low voltage power supply are built on a Radio Shack **Universal Component Printed Circuit board,** hereafter referred to as a **PC board**. The PC board is full of holes (see following photos) to insert various electronic component wire leads into. One side of the board contains copper traces to solder components to. The other side is without these conductive traces. In this text, the copper trace side of the board is referred to as the bottom of the board. Before soldering, rub the copper traces with steel wool to clean the copper; this prepares it to receive the solder. If you are not familiar with soldering electrical connections on PC boards, I suggest purchasing a second (sacrificial) board and practice soldering. If to much heat is applied to the copper traces they will release from the board.

Board population

The process of installing electronic components on the board is referred to as **populating the board**. How the board is populated is up to the individual builder. The photo below shows an overview of the major components of the control circuit. The description that follows in this book will be based on this board layout. Along the left hand side of the board are the four (eight actual connections points) **PC board terminals** that provide a physical means of connecting most of the control circuit to other parts of the EDM system.

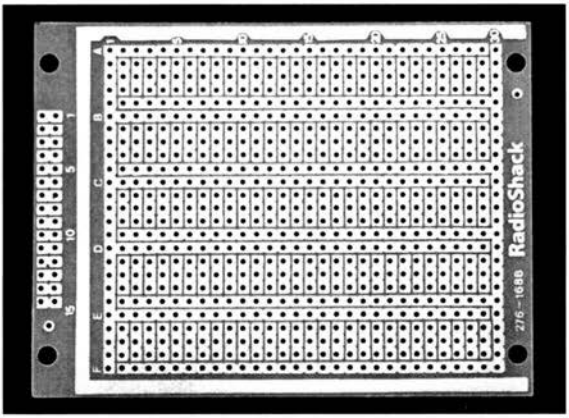


The 14-pin DIP (**D**ual **I**nline **P**ackage) socket for the LM 339 comparator IC, is located in the lower left hand section of the board. Above this, is the 16 pin DIP for the SN754410NE servomotor driver IC.

Immediately above the 16 pin DIP are three components. The first, in a rectangle package, is a 12VDC regulator. Just in front of the regulator, is a round 470 mfd 35VDC filter capacitor. The small round black package to the right is a 1.5 amp silicon bridge rectifier that delivers DC power for the control system and servomotor.

Bottom side of the PC board

The photo below shows the bottom side of the board with two types of copper traces visible. There are traces with three holes in each trace. In the text, I refer to these as "***stand-alone-three-hole trace***". These traces are not connected to other traces. There are two longer traces that are not connected to each other or the stand-alone traces, but run around the outside, and through middle sections of the



board. These traces are used to carry the positive (+) and negative (-) power from the low voltage supply to the components on the board.

The traces forming the **"T's",** as seen in the photo at points B, C, D, and E (etched in copper on the board), will be the positive (+) trace. On the top side of the board, the screened white lines indicate these traces. The other traces (parallel to the positive) which form **"T's"** on the opposite end of the board, is the negative (–) trace.

Construction tips

1. After each solder connection is made, visually inspect the board (under a magnifying glass, if necessary) and make sure, only the traces and components that are meant to be connected are the ones actually soldered. Make sure that bare wires are not exposed to points not intended to be connected. Pay particular attention that the + & - traces are not shorted together.

2. Continually check that the correct pins are connected on the IC sockets. Have a second person verify the connections. This attention to detail will save MUCH heartache in troubleshooting later.

3. Before each task, a [ ] box will be found. Once the operation is performed place an [**X**] in the box. This will assist in making sure all required tasks are completed.

4. An excellent source for uninsulated jumpers is the clipped ends of component leads.

5. Use "solder wick" (also known as desoldering braid) to remove excess solder, should a solder bridge occur.

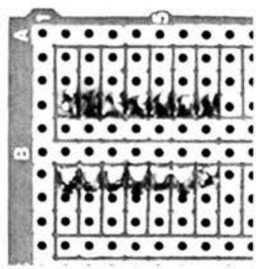
Chapter 3

Control circuit construction

[ ] During the building phase, the DIP sockets **should not** have the IC chips in them.

[ ] Begin populating the board by inserting both the DIP sockets into the board with the small notch (or dot) in the sockets facing the left side of the board.

[ ] The 14 pin DIP straddling power traces at "B", see the following photo.



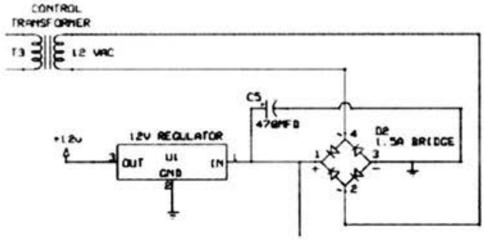
[ ] The 16 pin DIP straddles the traces at "D".

[ ] Solder all the DIP pins to the stand-alone-three-hole- traces as seen in the photo above.

[ ] Four PC board terminals are inserted along the left side of the board. The terminals have a locking tongue and groove system that mate with the adjacent terminal. Make sure these are matched and locked in place before soldering.

Installing the control board power supply

The schematic see page 15 (right) is of the power supply on the control board. The next item to install is a 7812 twelve-volt regulator (U1) Radio Shack (276-1771). Looking at the regulator from the front (black plastic side), the pins from left to right are **I**nput, **G**round, and **O**utput



[ ] Bend the pins of the regulator so that the legs go into the following traces, see photo above (left). The **I**nput pin goes in a stand-alone- three-hole trace; the **G**round pin goes in the negative (-) power trace, and the **O**utput pin goes in the positive (+) power trace (at location "E") on the board. Solder all in place.

[ ] Immediately in front of the regulator, the 470-mfd filter capacitor (C5) is inserted in the board. This component is **polarity sensitive**, the negative (-) leg (indicated on capacitor side) must be placed in the negative (-) power trace. I used the most outboard negative trace in this instance. The positive (+) leg of the capacitor goes into the opposite end of the three-hole trace the **I**nput leg of the regulator is placed in (i.e. they share a common stand-alone-three-hole trace); solder all in place.

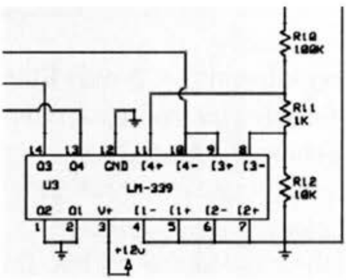
[ ] Place the rectifier (D2) on the board to the right of the filter capacitor and regulator. The two AC leads and the positive (+) leads are positioned so they go into separate stand-alone-three-hole traces. The negative (–) lead is inserted into a negative (-) trace; solder in place.

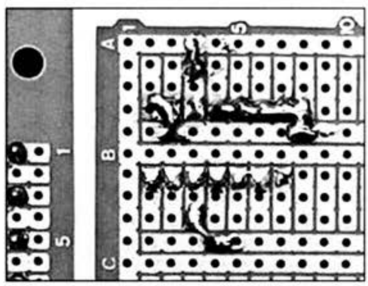
[ ] A jumper goes from the capacitor/regulator (common) stand-alone-three-hole trace to the positive (+) lead of the rectifier.

Wiring the DIP sockets

[ ] Both DIP sockets are numbered CCW (counter clockwise) when viewing the socket from the **top side** of the board (i.e. pin one is in the left corner).
Note: caution that you do not confuse the pin number locations as you turn the board over to make solder connections. This is a VERY EASY mistake to make, even for well-seasoned builders.

[ ] Start wiring on the 14-pin DIP socket located in the lower left hand corner of the board. The schematic below shows wiring diagram cut from the finished circuit drawing.





[ ] Pins 4, 5, 6, & 7 are soldered together and go to the negative (-) trace.

[ ] Pins 1, 2, & 12 connect to the negative (-) trace.

[ ] Pin 3 attaches to the positive (+) trace.

[ ] Pins 8, 9, 10, 11, 13 & 14 are **not connected** at this time, though the drawing shows connections.

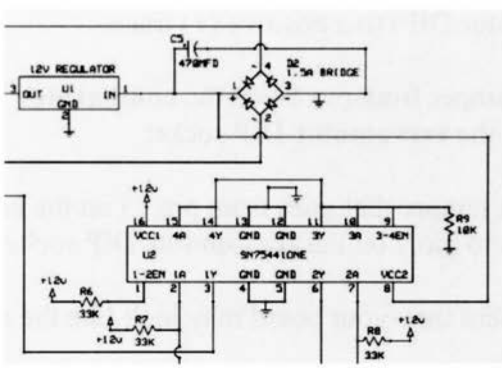
The photo (above right) shows the actual connections to the traces that should be made if you are using the Radio Shack board. At first glance, the photo above may appear to be a mess, but it really is quite orderly. Starting in the upper left hand corner, note that pins 1, 2, 4, 5, 6, 7, & 12 are tied to the negative (–) trace; pin 3 is connected to the positive (+) trace.

[ ] On the top side of the board insert a 10,000 (10K) ohm resistor (R12) from pin 8 to a ground trace.

[ ] A 1000 (1K) ohm resistor (R11) is inserted between pins 8 & 11.

[ ] Next, jumper between DIP pins 9 & 10.

[ ] Solder the 6.8 mfd capacitor (non Radio Shack capacitor) from pin 10 to a negative (-) trace.



In the next sequence of operations, most of the wiring of the 16-pin **servomotor** DIP socket is accomplished. The schematic above was taken from the finished circuit drawing.

[ ] Pins 4, 5, 12, 13 (servomotor DIP) go to the negative (–) trace.

[ ] Pin 16 (servomotor DIP) is soldered to a positive (+) power trace.

[ ] Pins 9,10,11,14 &15 (servomotor DIP) are tied together.

[ ] A 10,000 (10K) ohm resistor (R9) goes from pin 15 (servomotor DIP) to a negative (–) trace.

[ ] Pin 8 goes to the positive (+) side of the **rectifier, not** the output of the voltage regulator, or positive (+) power trace,

[ ] A 33,000 (33K) ohm "pull up" resistor (R7) is soldered between pin 2 and the positive (+) trace.

[ ] A 33,000 (33K) ohm "pull up" resistor (R8) is connected between pin 7 (servomotor DIP) and the positive (+) trace.

[ ] A 33,000 (33K) ohm "pull up" resistor (R6) goes from pin 1 (servomotor DIP) to a positive (+) trace.

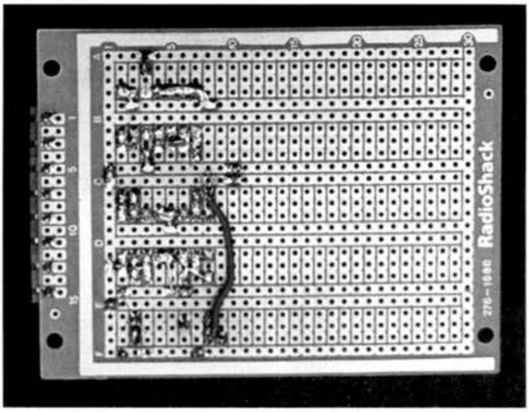
[ ] Run a jumper from pin 14 on the **comparator** DIP socket to pin 2 on the **servomotor** DIP socket.

[ ] Solder a jumper that goes from pin 13 on the **comparator** DIP socket to pin 7 on the **servomotor** DIP socket.

At the present time your board may look like the photo on page 19.

Connecting the control circuit to the PC terminals

In the next operations, connections are made from the components mounted on the board to the **PC board terminals,** which are along the left hand side of the board. I will refer to the terminals in **ascending order** with terminal number 1 being in the lower left hand corner of the board,



see the schematic on page 20 for a more complete understanding.

The way the PC board terminals are designed, it's necessary to run many of these connections on the trace (bottom) side of the board.

[ ] From **PC terminal #1** run a black plastic insulated wire to any negative (-) trace on the board.

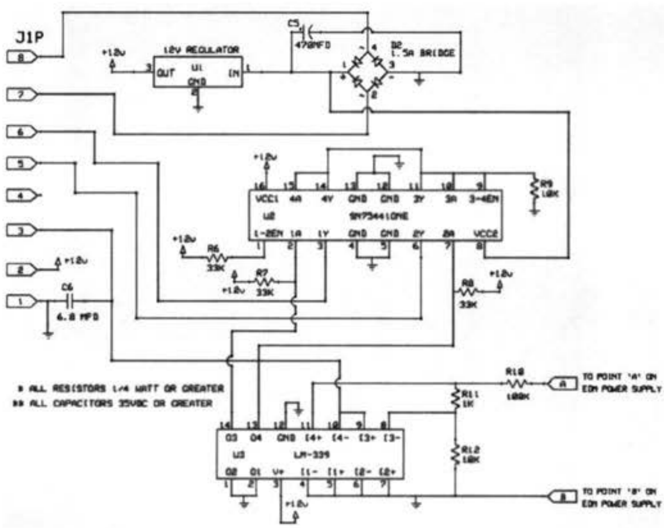
[ ] From **PC terminal #2** a connection is made with a red plastic coated wire to any positive (+) power trace.

[ ] From **PC terminal #3** a jumper goes to pin 10 (pins 10 & 9 should already be soldered together) on the **comparator** DIP.

[ ] **PC terminal #4** has no connections made to it.

[ ] **PC terminals 5 & 6** have wires running to pins 3 & 6 on the **servomotor** DIP. Which wires go to which terminals is not critical.

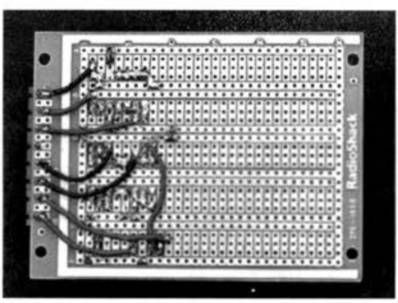
[ ] **PC terminals 7 & 8** have two lengths of plastic insulated wire going to the two pads through which the AC legs of the

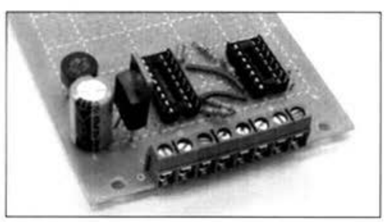


small 1.5 amp rectifier are inserted. Since it is AC being supplied to the rectifier, the connections are not critical.

At this point, the basic control circuit is **finished**!!!! It is wise to double check all the wiring at this time.

Photos of the completed control circuit board



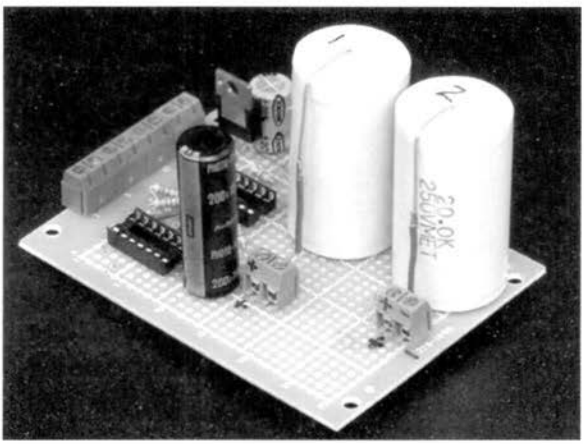


Now that the control circuit is basically finished, the next task is to build the actual EDM generator.

Chapter 4

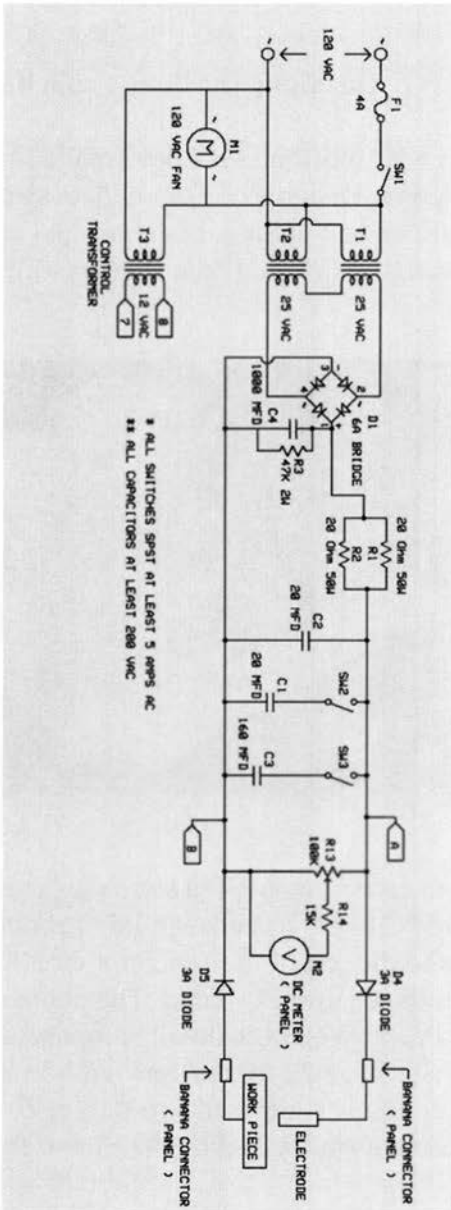
Installing finishing capacitors

As with most things, I have made some compromises in the generator design to accommodate space, cost, and simplicity. The end product is a simple, yet rugged design that will work fine in the home shop as well as many small job shops.



The capacitors used to store the “cutting” charge as well as the PC board terminals used to connect these capacitors to the rest of the generator circuit, are physically located on the control PC board. The photo above shows the completed control board with all components mounted (less the IC’s). See page 22 for the generator schematic. The EDM finishing circuit is composed two (large) 20 mfd “finish cutting” capacitors, located on the back right corner of the

The complete generator schematic



board. Two capacitors are used to give a wider choice of surface finishes and speeds when performing finishing cuts.

The capacitors used are not available via Radio Shack. The only economical source I know for the preferred capacitors is

Parts Express
http://www.partsexpress.com/
1-800-338-0531

The part number is 027-436. They are listed as 20 mfd polypropylene capacitor, cost less than $5.00 each (2005).

[ ] Insert one lead of each 20 mfd capacitor (C1 & C2) into a negative (-) power trace.

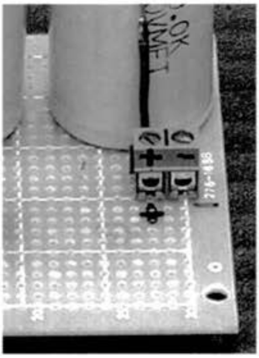
The capacitor placed closest to the bridge rectifier is capacitor C1; the one adjacent to it, near the board's edge, is capacitor C2. The orientation of the capacitors is not critical (they are not polarity sensitive). The other lead of the capacitors are bent over the top of the capacitors and inserted into individual stand-alone-three-hole traces. It's necessary to extend the length of this lead in order to make the connection; see photo on page 21.

[ ] Solder all the leads to the traces to hold everything securely in place.

[ ] Solder the leads of the capacitors in the negative (-) trace together so that they are parallel. The two leads going to the stand-alone-three-hole traces **are not** connected together

The capacitor leads are soldered together so the current pulses during the capacitors discharge will be carried primarily via the capacitors leads, and not by the thin copper traces (which could possibly burn apart like a blown fuse).

The next step is to mount a single (two connections) PC board terminal (not shown on the schematic) on the extreme right hand side of the board, just below the finishing capacitor C2; see photo below. This PC board terminal is referred to as the **Gap Terminal Connector**. It has a positive (+) and negative (-) terminal, which connects directly to the work gap.



[ ] One leg of the Gap Terminal Connector is inserted into the negative (-) control board trace. On the Radio Shack PC board, this connection will be on the right hand side as viewed in the photo above. Mark the board to indicate the polarity of this side of the connector. The other side of the terminal, goes into a stand-alone-three-hole trace.

[ ] Solder the negative lead (or a jumper) from one of the parallel connected finishing capacitors, to the negative (-) side of the Gap Terminal Connector. (The negative side of both the high and low voltage power supplies are electrically at the same potential, this is the connection that ties the generator circuit and the control circuit together.)

[ ] The other side of the Gap Terminal Connector has two

connections made to it (on the bottom side of the board). It is also a good idea to mark the board indicating this is the positive (+) connection, see photo on page 24.

[ ] The first of these two connections is a jumper wire, which connects to capacitor C2's stand-alone-three-hole trace. If proper planning is used in constructing the Gap Terminal Connector, a positive (+) lead may be inserted into the stand-alone-three-hole trace used by the capacitor, thus eliminating the need for the jumper. Finish capacitor C2 is always connected across the gap; see schematic on page 22.

[ ] The second connection to the positive (+) side of the Gap Terminal Connector is a 100,000 (100K) ohm resistor (R10), which solders to terminal 11 on the **comparator** DIP, see schematic page 20. In most cases, the resistor leads will not be long enough to reach the Gap Terminal Connector. Either lengthen the lead, or solder the resistor into a stand-alone-three-hole trace. Then jumper from that trace to the Gap Terminal Connector trace. Be sure and insulate the resistor leads to prevent any possibility of shorting.

Installing the coarse cut capacitor

The C3 capacitor, needed for making coarse EDM cuts, is not available via Radio Shack. Unfortunately, I do not have a reliable source to refer you to for purchasing this capacitor. If possible, this electrolytic capacitor should be a **photo or strobe flash** capacitor. It should have radial leads in order to make mounting simple and to conserve board space. The ratings should be a minimum of 125VDC 100 mfd. A higher voltage and capacitance is preferred, but usually means the capacitor will be larger. The one I am using is 200VDC @160 mfd.

The company listed below frequently has these capacitors in stock. If not available, keep checking back with them.

All Electronics Corp.
1-888-826-5432
http://www.allelectronics.com

Another option is to us a photo flash capacitor from a disposable camera. I picked up a couple of cameras free from the local photo developer. The capacitors I got from these camera's were rated for 150 mfd at 330VDC. They charge to 300VDC in the camera.
If you choose to use these capacitors make sure they are fully discharged (short across the leads) before removing them from the camera, other wise you could be in for a real shock!

The weakest link

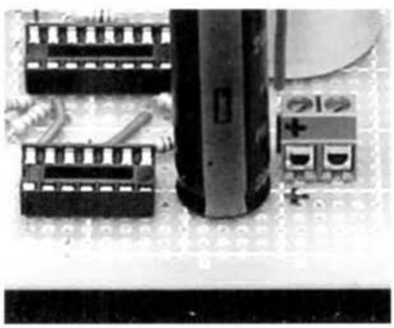
By using an electrolytic photo flash capacitor, it is possible to have a "high mfd rated capacitor" that has proven to work well in this application; it is cost effective and yet small enough to mount on the control board.

All electrolytic capacitors that I know of, even the photos flash (or strobe flash) capacitors, are not really designed for this particular application, and many times they will be pushed to their design limits and beyond. There is always the potential that the electrolytic capacitor will heat up and fail, even rupture. I have built quite a few of these small EDM machines and have only had one photo flash capacitor fail. Nevertheless, you should be aware that this is the weakest link in the generator design. I feel it is a justifiable risk to take, in order that the cost and size of the EDM generator may be reduced.

The C3 photo flash capacitor is mounted near the LM339 comparator; see photo below. This leaves a void on the right hand side of the board, for the optional panel meter (see Chapter 7).

[ ] Mount the coarse cut C3 electrolytic photo flash capacitor on the board. Remember, it is polarity sensitive. Make sure the negative (-) lead is inserted into the negative (-) power trace and the other lead goes into a stand-alone-three-hole trace.

[ ] Use a short length of insulated wire (at least the diameter of the capacitors leads) to jump the negative (-) lead of the photo flash capacitor to the negative (-) leads of C1 & C2 finishing capacitors or, it may be connected directly to the negative side of the Gap Terminal Connector; electrically it is the same point.

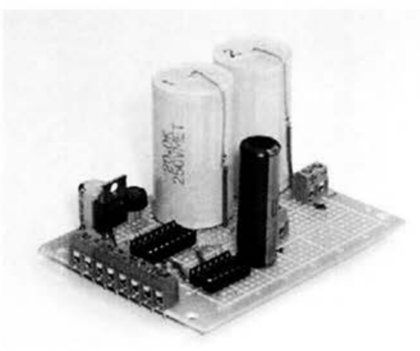


[ ] To the right of the photo flash capacitor, install a PC board terminal connector, as shown in the photo above. This terminal will be called the **Capacitor Switching Terminal**. The two terminals of the Capacitor Switching Terminal connector should be soldered into two individual stand-alone-three-hole traces. (It is through the Capacitor Switching Terminal that the coarse and fine cut capacitor switches are connected.)

[ ] Connect the positive (+) lead of the photo flash capacitor to the Capacitor Switching Terminal **closest to the photo flash capacitor**. Mark this terminal polarity (+), for future reference, see photo page 27.

[ ] The other side of the Capacitor Switching Terminal is connected via insulated jumper to the stand-alone-three-hole trace of finishing capacitor C1. At this point all finishing and coarse cutting capacitor leads should be connected.

This completes all the wiring need for the control board; later tests are conducted to ensure it is wired properly. When you consider that the complete control circuit and a large part of the EDM generator are located on this small board it is in my opinion quite remarkable, see photo of completed board below.



At the writing of this book I am working on a design for an EDM that is almost as simple and will be much more efficient and compact than this design. Early test are encouraging. Hopefully time will prove it to be a good design. From the first time I saw an EDM machine I wanted to build a simple 10 amp unit that would fit in a shoe box.

Chapter 5

Generator box selection and preparation

Looking through most of the sources for electronic enclosures, I was shocked at the prices being quoted ($50+) for boxes. I was able to find only one box of the minimum size needed (3 1/2 x 6 x 10") with a reasonable price tag. I am not very happy with the box as it does not look as professional as I would like. If any builder knows of a better selection for a reasonable price, please let me know. The box is available from Allied Electronics (see Appendix)

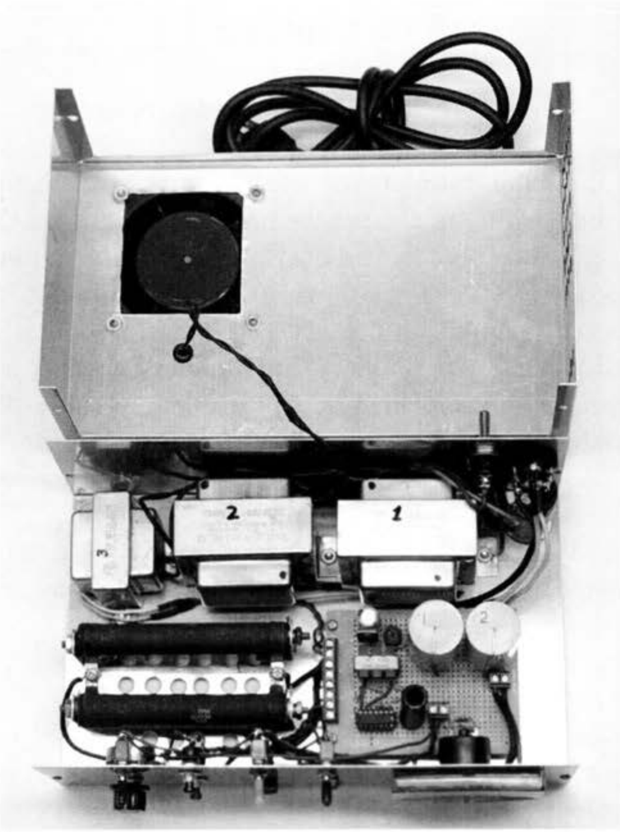
A suggested layout of the box, including the top of the box, is shown in the photo on page 30. Before drilling or cutting any of the mounting holes in the box it is a good idea to have the components in hand to actually measure and verify the required size. No components are to be permanently mounted in the box at this time, but components should be positioned in the box to verify locations.

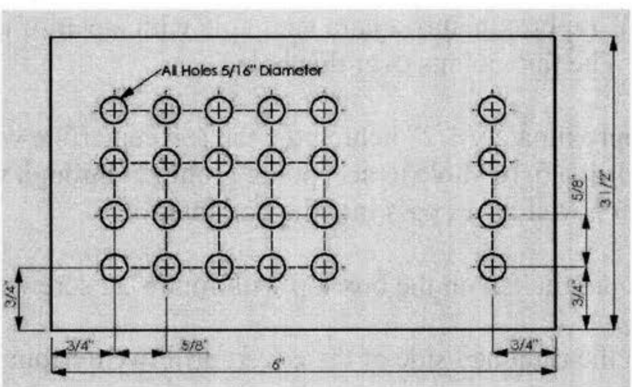
[ ] Work starts on the box top. In the front left hand corner, cut a hole to permit the 3" Radio Shack (273-242) cooling fan (120VAC) to draw cool air out of the enclosure. The fan bolt pattern is square 2 13/16 center-to-center holes. I cut a 2 7/16" (approximate) square vent hole with a pair of tin snips. The fan mounts over this hole.

[ ] Approximately 1/2" behind the fan (on centerline with the fan), drill a 5/16" hole to accept the grommet through which the fan power wires pass into the box interior.

[ ] Mount the fan on the box top with four 6-32 screws.

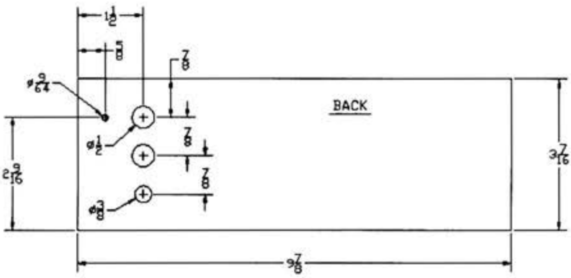
[ ] On the right had side of the cover, drill twenty-four 5/16


2
1
3


All Holes 5/16" Diameter
5/8"
3 1/2"
3/4"
3/4"
3/4"
5/8"
3/4"
6"

holes as per the drawing on page 30. This forces the air to be drawn through entire generator before exiting.

[ ] Mark and drill three holes on the left hand side of the box rear, as seen in the drawing below.



The 115V Radio Shack (275-603) SPDT on-off switch mounts in the top hole. A Radio Shack (270-362) panel mounted fuse holder in the second hole. The bottom hole will accept either a plastic strain relief or a vinyl grommet, Radio Shack (64-3025). A 115VAC Radio Shack (61-2859) power cord enters the generator box through this last opening. DO NOT drill the small 9/64" rectifier-mounting hole at this time.

Chapter 6

Positioning the rectifier and filter capacitor

The generator requires a hefty filter capacitor (C4), which is not available from Radio Shack. The capacitor used should be rated for at least 160VDC and 450 mfd. Do not substitute a smaller capacitor. More mfd capacity is good, but it must fit in the space. I am using a radial capacitor (160VDC 1000 mfd) purchased from Allied (see Appendix).

[ ] The filter capacitor (C4) is placed vertically against the back wall, to the right of the AC power switch and fuse holder; see above photo. The actual physical location of the bridge rectifier is determined by the height of the selected filter capacitor. The rectifier is a Radio Shack (276-1181).

[ ] If the specified Allied filter capacitor is used, drill a 9/64 mounting hole approximately 1 9/16" above the box bottom. Otherwise drill a hole about 1/2" above the top of the selected capacitor to mount the rectifier via a 6-32 screw.

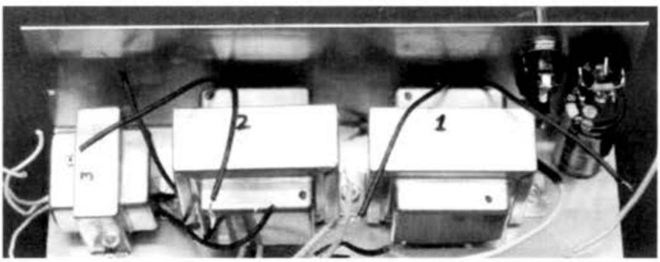
Selecting the transformer

In my opinion, an almost ideal transformer for a small EDM application would be a single transformer capable of delivering 70-75VAC at 5 amps or higher. The transformer should also have a separate 12VAC winding to supply power to the control circuit.

Lacking the preferred transformer, two Radio Shack (273-1512) 25VAC CT (2.0 amp) transformers were chosen (transformers 1 & 2 in photo below are T1 & T 2) The small Radio Shack (273-1365) transformer (T3) supplies power to the control circuit. The large power transformers are wired in series, on the secondary side, to obtain the required voltage.

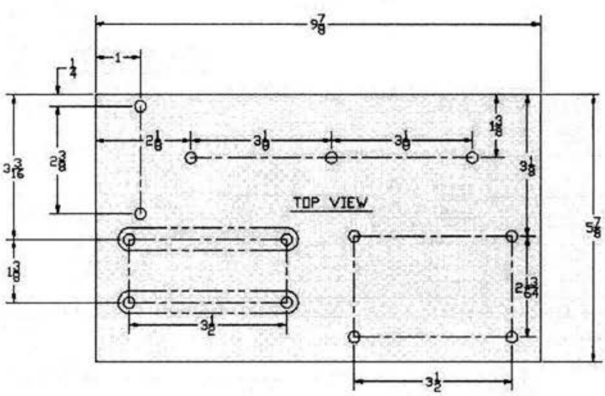
The drawing below shows the bottom of the box and a suggested dimensioned layout for the Radio Shack parts.

[ ] If the Radio Shack transformers are used, follow the dimension on the drawing but drill the transformer mount holes out to 13/64". The center bolt captures both transformer's overlapped feet, see photo below.



[ ] With components in hand verify hole locations then drill as required. I recommend standing transformer off the back wall about 1/8" (wiring run and cooling).

BOX BOTTOM



BOX BOTTOM
ALL HOLES 9/64

[ ] The small control transformer T3, is turned 90 deg. and stands off the power transformer about 3/8", see drawing.

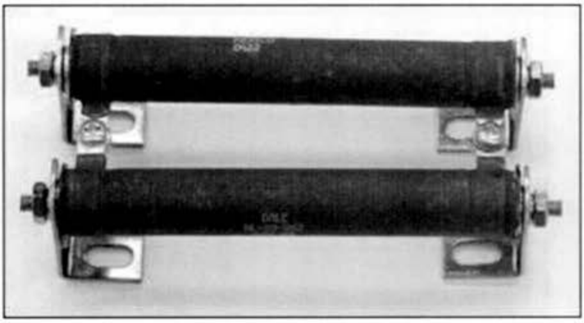
Control board location

The control board is located in the front right hand corner of the box on four Radio Shack (276-1381) standoffs.

[ ] Should you decide to install a meter (optional), see Chapter 7. The exact board location is determined by the needed clearance for the meter chosen. If an analog meter is not used, the dimensions on the drawing will be correct for the four 1/8" holes to mount the Radio Shack board.

Power resistors

The two 20 ohm 50watt silicone fixed power resistors see photo, (R1 & R2) used in the generator are connected in parallel forming a 10-ohm 100-watt resistor bank. Two resistor and two mounting kits, are required. The resistors may be purchased from Allied Electronics (see Appendix)



[ ] The power resistors connect in parallel using two 6-32 screws. This will eliminate the possibility of solder joint failure as the resistors heat up.

[ ] Cut the threaded mounting rod to a five inches length.

[ ] Assemble the resistors on the mounting hardware. Space is at a premium in the box, so turn the mounting legs inward; this will place the mounting bolts holes under the resistors.

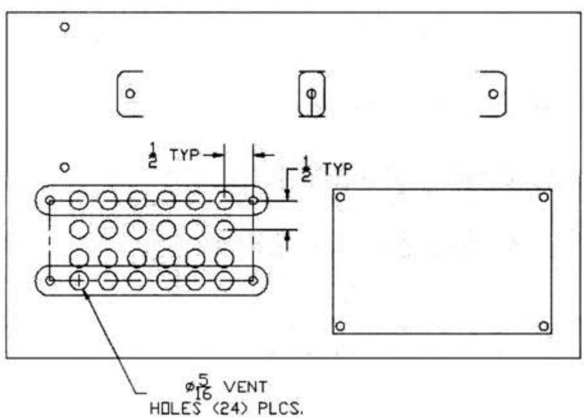
[ ] Position the assembled power resistors in the box to verify the four mounting hole locations as per drawing on page 33.

[ ] Drill holes for mounting the power resistors.

To provide for the removal of heat generated primarily by the resistors, vent holes are needed in the bottom of the box.

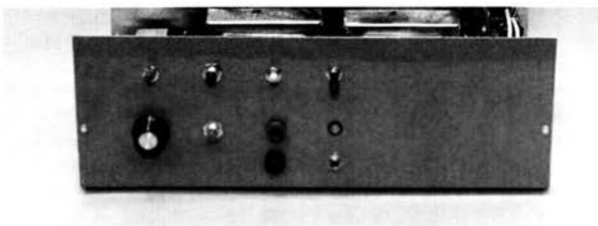
[ ] As per the drawing below drill twenty-four 5/16” vent holes in the box bottom.

[ ] Debur all holes or a nasty cut may result.



Front panel layout

The controls on the front panel maybe mounted in any configuration pleasing to the builder. The photo below and the drawing on page 37 show the layout I chose. The switches (starting in the upper left hand corner of the box) from top to bottom, and left to right, are as follows:



1. Coarse capacitor switch (SW3) Radio Shack (275-324).

2. Reference potentiometer (R5) 50K ohm Radio Shack (271-1716). A Radio Shack knob (274-402), or similar, is used to terminate the shaft.

3. Servo rapid down switch (SW5) Radio Shack (275-1547)

4. Servo rapid up, switch (SW6) Radio Shack (275-1547)

5. Finish cut capacitor switch (SW2) Radio Shack (275-324)

6. Red positive (+) power out Radio Shack (274-725)

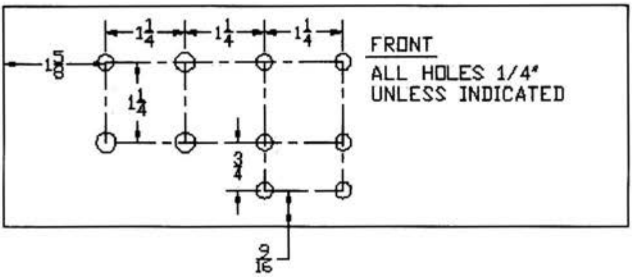
7. Black negative (-) power out Radio Shack (274-725)

8. The servo on off switch (SW4) Radio shack (275-324)

9. Servo LED (**L**ight **E**mitting **D**iode) holder Radio Shack (276-079), the Led is a bicolor (D3) Radio Shack (276-012)

10. The servo output power jack (J1) Radio Shack (274-246) is a three-conductor 1/8" stereo audio panel-mount jack. The plug that goes into the jack is a three-conductor 1/8" stereo Radio Shack (274-284) audio plug.

[ ] Layout the box as per drawing below and drill the required holes. Be sure and verify the sizes with components.



[ ] Install four self-sticking rubber feet Radio Shack (64-2346) to the four corners of the box bottom. This will lift the box and provide good air flow for cooling.

[ ] Before the final wiring of the generator, decide if a meter will be used. If so drill holes as required by the meter

Chapter 7

Panel meter option

As previously indicated, the analog panel meter **is not** needed for successful operations of the EDM machine. Should you elect to install a meter, the mounting hole locations in the front panel are critical, as there is a potential interference problem with the control board if the meter is mounted to low. Radio Shack sells an analog meter (Radio Shack 22-410). I don't know how long they may carry it as Radio Shack appears to be cutting back on much of their inventory and analog meters are one of the causalities of the digital revolution.

Reasonably priced meter are frequently sold by surplus electronic houses (see Appendix) the problem is that their inventory is not consistent.

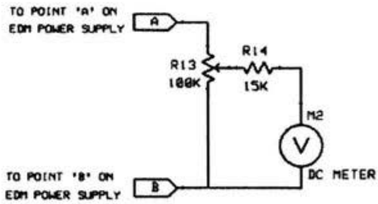
To fit a meter to the particular project box being used the meter selected should be approximately the physical size indicated below. Once purchased, it's up to you to determine the size and location of the hole to cut in the box front panel. The specification for the meter I used is as follows.

Physical size 2 3/4x 2 1/4 x 1 7/8"
Full Scale Value 15VDC
Internal Resistance 85 ohms

Wiring the meter into the generator circuit

The following section should be referred to when it is time to wire the meter into the generator circuit. The meter is connected to the generator via a voltage divider i.e. R13 see schematic on page 22. The meter reads a voltage drop across the voltage divider. It is almost impossible for me to give you resistor values for the divider network, as I do not know the specification for the meters that may be used. Might I suggest a simple approach that should work for most meters with specification similar to the Radio Shack meter I used.

[ ] Purchase a small 100,000 ohm potentiometer, Radio Shack 271-284 or similar. The potentiometer will have three legs to solder.



[ ] With the generator unplugged, solder the two most outside legs of the potentiometer to the output of the generator. The generator voltage for the meter potentiometer may be picked up on the control board at the Gap Terminal Connector (+,-) connections). The potentiometer could be soldered on the control board in three individual stand-alone-three-hole traces (it is up to you how to mount the voltage divider potentiometer/ resistors) with the required wires running from these traces to the panel meter. I actually installed a PC board connector on my control board, so the meter could be quickly disconnected if I needed to remove the board.

[ ] Use a VOM, measure from the center terminal on the potentiometer to the side that connects the negative (black banana plug) side of the generator. Rotate the potentiometer to get a zero, or near zero, reading between the center terminal and the ground terminal.

[ ] Between these two low resistance terminals connect wires that run to the meter. Some meters will have a + - indicated on the meter terminals; if so, connect accordingly. You may find some meters have a series resistor that is connected between the potentiometer center terminal and the meter; if your meter requires this resistor, install it. Even if it does not come with a series resistor, a 15,000 (15K) resistor in series with the meter, it is a good idea to because it helps to limit the current and perhaps, save your meter.

[ ] Once connected, momentarily turn the generator switch on. If the meter swings up scale, the connections are correct. If the meter pegs further to the left, the wire connections to the back of the meter need to be reversed.

[ ] With the meter wired correctly, turn the generator on and slowly rotate the potentiometer knob until full scale deflection (or what ever desired deflection is obtained) is indicated on the meter. This is a cheap and dirty, yet simple, way of setting the meter up for full scale (or less) deflection.

One of the problems with using a potentiometer in the meter circuit is, after a period of time, the wiper terminal on the potentiometer collects dirt, especially in a machine shop environment, which will cause the meter to possibly give erratic readings; a fixed resistor avoids this problem.

Some people make custom calibrated faces for the meter; most often, this is accomplished using a computer graphics program. The new face maybe glued to the meter face behind the needle. Using this face-changing method and the potentiometer calibration suggested above, it is possible to adjust the meter to read virtually any voltage you wish.

Chapter 8

Wiring the generator and installing components

It is time to permanently wire the generator components.

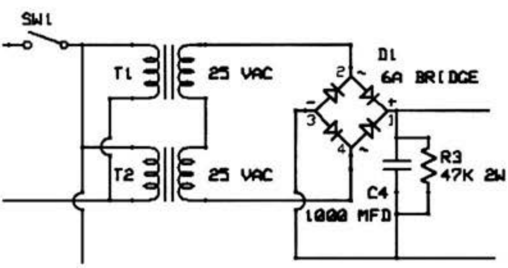
[ ] Begin by soldering the center terminal (assuming the Radio Shack switch spec. is used) on the AC power switch (SW1) to either one of the adjacent terminals, effectively making this switch a SPST switch

NOTE: Some builders may wonder why I chose a SPDT switch. The particular Radio Shack (275-603) SPDT switch was chosen because of a space limitation in the generator box. The correct switch would be a SPST of the proper size.

[ ] Mount the two power transformers T1 & 2 securely in the box with three 6-32 screws and nuts. Position the transformers so the black primary wires face the back wall.

[ ] Mount the control transformer, T3, with two 6-32 screws. The black primary wires should face the power transformers.

[ ] On transformers T1 & 2, clip off (close to the transformer) and save both black center tap wires



[ ] The rectifier (D1) is held securely on the back panel with a 6-32 screw; see above photo. To aid in heat dissipation sand all the paint from the case in the area that will have contact with the rectifier. Apply Radio Shack (276-1372) or similar, heat-sink grease for good thermal contact.

[ ] Note which terminals are AC and DC on the rectifier; these markings may not be visible once mounted.

[ ] Install the AC switch (SW1), the fuse holder (F1), and the AC power cord grommet in the rear panel.

[ ] Cut the female end off a Radio Shack (61-2859) AC power cord. Strip the covering back about five inches, exposing the three inner wires.

[ ] Cut and save a two-inch length from the end of the black (or blue) wire.

[ ] Strip the black and white (blue and brown) wire ends back 1/2", exposing the wire. Strip the green wire back about 1".

[ ] Thread the cord through the panel grommet, and tie a knot to act as a strain relief (if a strain relief is used, the knot is not necessary).

[ ] Secure the green wire under a screw holding the transformer in place.

[ ] Solder the hot side, the black wire (or blue) of the line, to the fuse terminal.

[ ] From the remaining terminal of the fuse holder (F1), solder an insulated jumper, (using the previously cut black transformer center tap wire), to one of the terminals on the AC switch.

[ ] The (black) primary wires from each transformer connect in parallel see schematic on page 41. Pull the black primary wires from transformers T1& 2 forward; make sure the wires from each transformer are not crossed. Select the left most wire from each transformer; twist these together. Select the remaining two primary wires and twist them together.

[ ] The (black) primary wires from transformer T3 connect in parallel with the primary power transformer wires. There should be three primary transformer wires going to each side of the AC line.

I recommend that all the 115VAC connections be covered with heat shrink tubing (Radio shack #278-1627) to keep a clean look in the box. An alternative is to use screw-on wire nuts (Radio Shack #64-3057) to secure the connections.

[ ] If using shrink tubing, slide it over the wires and solder one set of three (transformer) primary wires to the AC line.

[ ] The black center tap wire (saved earlier) is soldered to the AC switch lug and connects to the remaining bundle of three black primary transformer wires.

[ ] After the solder joints are cool, slide the heat shrink tubing (or wire nuts) over the connections to insulate them. **Do not shrink in place at this time**.

[ ] Install a 4-amp Radio Shack (270-1066) fuse in the holder.

Testing the primary transformers wiring

The next operation will test the system to insure there are no short circuits.

[ ] Make sure that the secondary wires from the transformers do not touch each other or any part of the generator box.

[ ] Check that the short stubby black center tap wires are not making electrical contact with the case.

BEFORE PERFORMING THIS TEST, OR ANY OTHER TEST, WHERE THE GENERATOR CASE IS OPEN AND ACCESS TO 115VAC IS POSSIBLE, MOVE SLOWLY AND THINK THE PROCESS THROUGH BEFORE TAKING ANY ACTION. AFTER THE TEST IS OVER, ALWAYS UNPLUG THE GENERATOR AS WELL AS TURN THE AC SWITCH OFF.

REMEMBER AC POWER CAN AND WILL KILL YOU!

[ ] Plug the generator in and turn on the AC for five seconds.

[ ] Turn off and unplug the AC cord.

[ ] Verify that the fuse is not blown. If it is, there is a problem with the wiring. Go back and check the wiring.

[ ] Do not proceed with the generator wiring until the problem has been resolved.

Wiring and testing the transformers secondaries

[ ] Strip the insulation back 1/2" on the four yellow secondary wires from T1& 2 transformers.

[ ] Observe the **physical sequence** of the wires that emerge from the secondary side of the transformer housing. It should be yellow, black (center tap stub) yellow. The second yellow wire on transformer T1 is temporarily connected to the first yellow wire from transformer T2.

To verify that this connection is correct, a voltage reading is taken using a voltmeter (VOM) more commonly known today as a multi-tester or multimeters. Low cost meters that will perform all the operations needed in building the EDM machine, are available from most hardware and home improvement stores; prices range from $10 up (2005). I prefer the digital meters as they give you a precise," no questions ask" reading.

[ ] Make sure that the remaining wires from the transformers do not touch each other, or any part of the generator box. Set the VOM on the AC range, at least 100VAC.

[ ] Using alligator clips (Radio Shack #278-001), connect the VOM leads to the two remaining transformer yellow leads.

[ ] Plug the AC cord in, and turn the AC switch on; the VOM should read approximately 56VAC. If not, the outside-most wire on transformer T2 needs to be connected to the inside-most wire on transformer T1. Do not proceed until the desired voltage, approximately 56VAC, is obtained.

[ ] The temporarily connected common wire to each transformer is now permanently connected together, via soldering and shrink tubing, or wire nut.

Wiring the rectifier and filter capacitor

[ ] Bend the DC leads, from the rectifier (D1), in such a fashion that they are able to be soldered to the respective terminals of the filter capacitor (see photo on page 41). The negative (-) terminal is connected to the negative (-) terminal on the capacitor; the same is true with the positive (+) connection The filter capacitor (C4) is actually held in place by the rectifier leads soldered to the capacitor terminals.

[ ] A 47K 2-watt (R3) Radio Shack (900-0558) bleeder resistor (used to discharges the capacitor at shutdown) is soldered in parallel with the filter capacitor terminals.

[ ] The two yellow wires from transformers T 1 & 2 are soldered to the AC terminals of the rectifier. Exercise caution in this operation, as the AC and DC connections to the rectifier MUST NOT contact each other. It is a good idea to install heat shrink, on the yellow leads to avoid accidental contact, **do not shrink** in place at this time.

Testing the rectifier output voltage

[ ] Plug the AC cord to power and turn the AC switch on. Measure **across the filter capacitor terminals**. A reading of approximately 77VDC is normal.

[ ] Leave the power on for ten seconds, then turn the switch off and unplug the AC cord.

[ ] Feel the sides of the filter capacitor (do not touch the capacitor terminals); if it feels hot, there is a problem. The most likely error is not having the polarity connection between the rectifier and capacitor correct.

Installing front panel components

[ ] Install all the switches, make sure all the switches turn "on" and "off" in the same direction.

[ ] Install the remaining connectors, potentiometer (R5), jacks, etc. in their respective holes **note instructions below**.

[ ] Before mounting the potentiometer (R5), cut the shaft off, leaving approximately 3/8" remaining beyond the threads.

[ ] Place the potentiometer (R5) in its panel hole and rotate the potentiometer so that the three solder connection lugs face to the right, or toward the location of the control board.

[ ] Install the plastic LED (**L**ight **E**mitting **D**iode) holder, but **do not** put the bicolor LED into the holder at this time.

Installing control board and resistor bank.

[ ] Secure the 10 mm stand-off insulators on the control board's and mount the control board in the generator box.

[ ] The power resistor bank (R1 & 2) is positioned over the ventilation holes and held in place with four 6-32 screws.

Chapter 9

Final wiring and testing

[ ] From transformer T3 select the two yellow wires, (if it is a 24VAC center tapped select a white and yellow wire). Strip the insulation back 1/4" on both wires, and secure one wire under terminal #8 and the other wire under terminal #7, on the PC board terminal strip.

[ ] A test is conducted to make sure the power supply circuit on the control board is working correctly. Voltage readings are taken on both DIP sockets and the PC terminal connector strip. All readings are considered good if they measure + or - a few tenths of a volt. Make sure all voltages are present and correct before proceeding.

First voltage test of the control board

[ ] All readings are taken with the negative side of the VOM connected to terminal #1 on the PC terminal strip. An alligator clip connected to this terminal and the VOM lead make life much simpler when doing these checks.

The following voltages are read on the LM-339 socket.

[ ] #3 pin 11.8VDC

[ ] #13 pin 11.8VDC

[ ] #14 pin 11.8VDC

The following voltages are read on the servo drive DIP pins.

[ ] #1 pin 11.8VDC

[ ] #2 pin 11.8VDC

[ ] #7 pin 11.8VDC

[ ] #8 pin 17.5VDC

[ ] #16 pin 11.8VDC

If the tested voltages differ from those listed, a check of the circuit wiring is in order. Start with the output of the small rectifier mounted on the control board and see if a DC voltage is present at that point. Make sure the filter capacitor is properly connected. If there is no DC voltage, check the input to the rectifier; it should be reading 14VAC

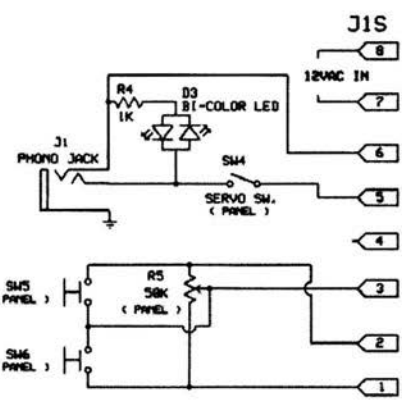
Wiring the rapid up down servo push switches

Refer to the schematic below when wiring this section. This schematic mates with the one on page 20.

The two push button switches (SW5 & 6) on the front panel provide a means for activating the rapid up and down movement of the ram; use at least 22 gauge wire for these connections. The push button switches are connected in parallel with potentiometer (R5) and PC terminals 1, 2 & 3.

[ ] A jumper wire connects from one solder lug on the upper push button switch (SW5) to a lug on the lower switch (SW6). From this common lug, a jumper goes to the center lug on the potentiometer (R5), i.e. all three lugs are connected together. **Do not** solder the potentiometer connection at this time.

[ ] The remaining lug on the top switch (SW5) has a jumper that connects to the top-most solder lug on the potentiometer (R5). **Do not** solder the potentiometer (R5) connection at this time.



[ ] The remaining lug on the bottom switch (SW6) has a jumper that connects to the bottom-most solder lug on the potentiometer (R5). **Do not** solder the potentiometer connection at this time. PC board terminals 1, 2, 3, 5, and 6 are all wired using at least 22-gauge wire. The opposite ends of these wires connect to-solder lugs on various electrical components.

[ ] A wire from PC terminal 3 connects to the center solder lug on the potentiometer (R5). Two wires connect to this terminal; solder in place at this time

[ ] A wire from PC terminal 1 connects to the bottom solder lug on the potentiometer (R5). Two wires connect to this terminal; solder in place at this time.

[ ] A wire from PC terminal 2 connects to the top solder lug on the potentiometer (R5). Two wires connect to this terminal; solder in place at this time.

[ ] No connections are made to PC terminal 4.

Wiring the servo plug and LED

[ ] From PC terminal 5, a wire is routed to a lug on the servo on/off switch (SW4), solder in place.

Given the small space available in the chose enclosure, I decided to use a 1/8" stereo jack for J1. There are other more professional types of plugs that may be chosen for this application. No matter what jack is selected the two wires passing through the panel **should not** be in electrical contact with the box. The common stereo female jack chosen has five solder connections. Terminals 2 and 5 are the connections to use. If you are unclear which terminals on the jack to connect, conduct the following test.

[ ] Insert the plug into the jack, and remove the plug cover exposing three connectors, **disregard the longest one** that is used as a strain relief and common ground. Conduct a continuity check (use a VOM) from the remaining two connections to find which terminals to use on the jack.

[ ] From the servo on/off (SW4) lug, a connection is made to lug 2 (or 5) on the servo plug (J1); **do not** solder at this time.

[ ] The remaining lug on the servo plug (J1), connects to PC terminal 6 on the board.

The bicolor LED (D3) wires in parallel with the jack (J1).

[ ] A 1K ohm Radio Shack (271-1321) resistor (R4) is connected in series with one of the LED leads.

[ ] Insert the LED (D3) in the plastic panel holder and solder the remaining lead of the resistor (R4) to one of the servo jack's solder lug (J1).

[ ] The other LED (D3) lead is soldered to the other servo jack's (J1) lug. There should now be two connections each to the servo jack (J1) terminals 2 and 5.

Wiring the coarse /finish capacitor switches

[ ] Solder an insulated wire to one of the lugs of the coarse capacitor switch (SW3), and route it to the **Capacitor Switching Terminal** closest to the photo flash capacitor. This should be marked with a (+) as shown in the photo on page 27.

[ ] The remaining coarse capacitor switch (SW3) solder lug is not connected at this time.

[ ] Solder an insulated wire to one of the lugs of the finish capacitor switch (SW2), and route it to the remaining Capacitor Switching Terminal. There should be one vacant terminal, insert the wire and tighten.

[ ] solder a jumper from the remaining lugs on the coarse (SW3) and finish capacitor switches (SW2), tying them together.

The banana plug and gap terminal connector

The red banana (+) plug has three connections, the connecting wires should be, 22 gauge or larger.

[ ] One of the wire to the red banana plug should be at least, 18 gauge. It goes from the red banana plug to the output of the power resistor bank (screw connection R1 & 2).

[ ] The next wire from the red banana plug connects to the common connector between the coarse and finish capacitor switches (SW 2 & 3). The third connection will be made shortly.

Two wires connect to the Gap Terminal Connector;
I recommend using two conductor stranded insulated wire.

[ ] Cut a 6 1/2" length of two conductor cord, separate the wire back about 1" and strip each end approximately 1/4". Tin the copper wire with solder.

[ ] Insert one end of the cord into each terminal of the Gap Terminal Connector. You should have the polarity of this connector indicated by an earlier marking. One side of the Gap Terminal Connector should be marked positive (+) and the other negative (-); verify the correct markings.

[ ] Of course, all connections are critical for successful operation, but the next four connections are especially

CRITICAL, if not, correct Smoke will escape!! Don't you know everything runs on smoke it is only when you let it out that problems start happening☺.

[ ] The wire from the negative (-) side of the Gap Terminal Connector is connected to the black banana plug.

[ ] The wire from the positive (+) side of the Gap Terminal Connectors is to the red banana plug.

[ ] Do a VOM continuity test to verify the connections.

[ ] From the two conductor cord, cut an 8" length of cord, separate the wire about 1', and strip each end approximately 1/4". Tin the copper wire with solder.

[ ] One side of this cord solders to a diode rated for at least 3 amps. 200 PIV(Radio Shack 276-1144). The solder connection is made to the **NON** "banded end" of the diode, (insulate with shrink tubing). The banded end of the rectifier solders to the negative terminal on the filter capacitor (C4), (which also connects to the 6-amp power rectifier).

[ ] The opposite end of this wire solders to the black banana plug i.e. the diode is in series between the filter capacitor and the black plug.

[ ] The second wire also has a diode (Radio Shack 276-1144) soldered in series with it (use shrink tubing to insulate). In this case, the **NON** "banded end" of the diode solders to the positive (+) side of the filter capacitor (C4). The other end of the wire terminates at the **input** of the parallel 20-ohm power resistors (R1 & 2).

[ ] Use a VOM and do a continuity test to make sure the individual wires are going to the right locations.

Wiring is now complete, assuming you are not mounting the optional meter

[ ] If a meter is being used, go to chapter 7 for a description of how to wire the meter.

[ ] Turn the generator box upside down and shake it to remove any solder and wire clippings that may have dropped into the box.

Control board and power supply voltage test

Before conducting the next test, remove the I.C. chips from the DIP sockets if they have been installed.

[ ] Plug the generator in and turn on the AC power switch.

[ ] Switch the VOM to the AC range and read between PC terminals 7 & 8 on the control boards (left hand side); it should read approximately 13.5VAC.

[ ] With the VOM in the DC range, read the voltage across the banana plugs (red & black) it should be approximately 77VDC.

The next test is to take readings on both DIP sockets and the PC terminal connectors to make sure correct voltages are present. **All test measurements are taken with the negative side of the VOM connected (use an alligator clip) to the negative (black) banana jack.** All readings measured should be + or – a few tenths of a volt.

The following voltages are read on the LM-339 socket.

[ ] #3 pin 11.8VDC

[ ] #8 pin 6.8VDC

[ ] #11 pin 7.5VDC

[ ] #13 pin 11.8VDC

[ ] #14 pin 11.8VDC

The following voltages are read on the servo drive DIP pins.

[ ] #1 pin 11.8VDC

[ ] #2 pin 11.8VDC

[ ] #7 pin 11.8VDC

[ ] #8 pin 17.5VDC

[ ] #16 pin 11.8VDC

The next voltage readings are taken on the PC terminal strip.

[ ] Terminal #2 11.8VDC

[ ] Terminal #3 will vary from about 0 to 11.8VDC as the potentiometer shaft is rotated.

[ ] Turn the AC power switch off.

Voltage test of the LM-339 output's

[ ] Assuming the voltage reading were with in specifications install the LM-339 chip in the DIP socket. The IC is inserted in the socket with the "U" shaped notch on the chip facing the PC terminal strip.

[ ] The following voltages should be read on the **SERVOMOTOR DIP** socket while rotating the potentiometer shaft 360 deg.

[ ] #2 pin, the voltage should vary from near 0 to 11.8VDC.

[ ] #7 pin, the voltage should vary from near 0 to 11.8VDC.

[ ] Turn the generator off.

[ ] The servomotor drive chip **must be** mounted in a heat sink. (see Appendix). Apply a liberal amount of thermal heat sink compound to the chip before installing the heat sink.

[ ] Hold the IC with the "U" shaped notch on the chip's end facing to the left, then slide the heat sink in place on the chip.

Testing the output of the servomotor driver

[ ] Insert the SN754410NE servo driver I.C. in it's socket. Make sure the "U" shaped notch on the chip's end is facing the PC terminal strip on the left hand side of the board.

[ ] Turn the generator on; flip the servo switch (SW4) to the on position. Slowly rotate the potentiometer (R5) knob. The LED (D3) should switch from red to green (or vice versa). There should be a spot in between where the LED is turn off.

[ ] Next, test the push button switches (SW5 & 6). One push switch should cause the LED to glow green (servo down) the other push switch should cause the LED to glow red (servo up). Make a note which switch controls which LED color.

[ ] Turn the generator off.

Making the generator leads

The power leads connect the generator to the workpiece. The leads are made from a length of 18 gauge zip (lamp) cord.

[ ] Separate the wire about six inches on each end, and then strip the insulation from each wire back 1/4". The two ends are soldered into two banana plugs (Radio Shack 274-730). The opposite end of the cord has one each, 10 amp car battery charger clips (Radio Shack 270-343 and Radio Shack 270-344) attached. Make sure the red banana plug and the red 10-amp clip are on the same wire, repeat the same with the black

Simulate testing generator shorted condition

[ ] Plug the generator leads into the banana plugs, keeping the clip ends separated. There will be 77VDC present across them when the generator is turned on, so **be careful.**

[ ] Turn both capacitor switches (SW2 & 3) off.

[ ] Turn the servomotor switch on (SW4).

[ ] Turn the generator AC switch on (SW1).

[ ] Rotate the potentiometer (R5) to get the LED (D3) to glow green.

[ ] Short the generator clips together; expect an "electrical crack" as the leads are shorted. The LED (D3) should turn red. Break the short; the LED should turn green. This indicates the generator and control circuit are working correctly. Your LED colors may be reversed.

Setup and testing the servomotor

If the servomotor is finished (page 74) the following electrical connections are made using a suitable length (3ft+) of two conductor stranded wire at least 22 gauge.

[ ] Solder the wires to the two short terminals of the 1/8" stereo plug. The remaining long strain relief is crimped around the wire but **no** electrical connection is made to it. Thread the plastic cover over the connections.

[ ] Solder the remaining ends of the wires to the two terminals on the DC motor.

[ ] Plug the motor connection into the generator's jack. Rotate the potentiometer (R5) to cause the LED (D3) to glow green. The servomotor should drive the slide down (green means go to work). Rotate the potentiometer (R5) to cause the LED (D3) to glow red; the slide should retract. If the movement of the slide is opposite what is described, the solution is simple; reverse the wires that connect to the DC motor. The wire reversal will cause the slide to drive in the correct direction. Be careful not to retract the slide too far toward the motor, **this design does not have limit switches**, the motor will stall and may destroy the servo drive chip.

Cooling fan hookup

The last item to wire is the 3" cooling fan (M1). Make sure the generator is disconnected from the 120VAC line.

[ ] Two cooling fan wires pass through the box; cover these wires connected to the junction where the three black transformer primary wires connect to the 120VAC line. Slide the shrink tubing from around the two connections and solder the cooling fan wires in place (five wires total). Once soldered, let the joint cool; slide the shrink tubing in place and shrink around the connections.

Finishing touches

[ ] The only thing that remains is to label the controls, make sure they are marked correctly; verify before labeling. Label makers such as DYMO are available now for less than $25 (2005). By using black on clear tape, it is possible to make a very professional looking label for the controls. The generator is now officially finished!!! Read chapter 14 before proceeding with your first burn.

Chapter 10

EDM servo head overview and options

The Servo head consist of a DC gearmotor , which rotates a leadscrew causing a slide, or ram (used interchangeably in EDM lingo), to move up and down. The DIY slide outlined in the text is similar to the low friction ball slides being used in most commercial machines.

To the moving slide/ram, is attached a block called the platen; the platen is electrically isolated from the metal slide. Electrodes are attached to the platen via clamps, chucks, etc.

Servo head option

There are two options suggested in this book for the servo head. One is to build a head as outlined later in the text, the second is to purchase an off-the-shelf aircraft trim servo. Modify it slightly, and wala, you are in business.

The advantage is:

1. It is almost a plug and play servo, which permits getting an EDM machine operational quickly.
2. If you do not have minimal shop tools or skills to build a servo head, then it may be your best choice.
3. It is small and light (4 oz.) enough to mount on a dial indicator magnetic base for doing EDM work in remote locations.

The disadvantage is;

1. It is an expensive item (in my opinion, but then again, I am known as a tight wad).

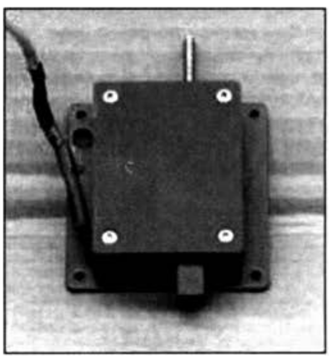
2. The servo ram travel is limited, but even with the small travel; a lot of EDM work may be done. This is especially true if the head is mounted to an existing milling machine or drill press quill which will permit large travel movements.
3. The ram it self is rather small, which will decrease its rigidity, and makes it more of a challenge to attach electrodes to it.

The aircraft trim servo may be purchased direct from the manufacturer, the Ray Allen Company, (see Appendix). There are two versions that I have used successfully

T2-10A has 1" travel $119

T2-12A has 1.2" travel $139

The T2-12A I have is shown below (prices 2005).



The square ram extends from the bottom; the rising stem (stationary) lead screw extends from the top. A rotating nut driven by a small D.C. motor inside the servo, causes the ram to rise or fall depending on the electrical polarity applied to the DC motor. The T2-10A does not have a lead screw protruding through the top of the servo case.

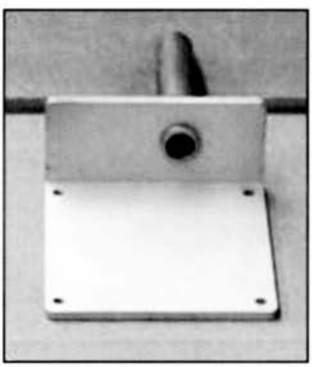
On the version of the T2-12A, that I have, which is several years old now, the ram is machined flat on the end with a hole drilled and threaded through the ram's center.

Evidently, the present version (on the website) shows the ram with a hole drilled at a right angle through the ram. If this is the case, the electrode-holding device will need to be mounted differently than what I show.

Fabrication of a mount for the T2-10A & 12A servo

I had a piece of aluminum extrusion in the scrap box that the "L" shaped 1 1/2" x 3" x 1/8" mount was cut from, see photo below left.

[ ] Any piece of rectangular tubing or angle iron of the needed size will work, or you may bend a piece of sheet metal to achieve a 90 deg angle. The four mounting screw holes are on a 2 3/8" square.



[ ] I placed the centerline of the ram on the centerline of the drill press/milling machine spindle. To do this, the 1/2" mounting post is positioned 1 11/16" from the right side and centered over the lead screw. If the T2-12A servo is used, the mounting post must have a clearance hole for the rising stem, see above photo. The photo on the right above shows the complete EDM ram located on the centerline of the machine tool.

A simple electrode-holding device for beginning EDM experiments is a 3/8" drill chuck. It works well for cuts where a single electrode is all that is required. Should you get involved in more advanced EDM work, this holding method will not be satisfactory. It does not permit the electrode to be removed from the holder, and then replaced in the exact same position. The shortcomings of this type of holder will become more evident as you read the latter sections of the book on Indexing electrodes.

[ ] Most small replacement drill chucks are mounted with a 3/8-24 thread. The chuck is attached to the ram via a 3/4" length of 3/8-24 thread rod. (A 3/8-24 bolt maybe purchased and a 3/4" length of the threaded section cut off.)

[ ] Drill a 3/16" hole completely through the center of this threaded rod. Through this clearance hole, a 1" long 10-32 screw is inserted and threaded into the end of the plastic ram securing the threaded rod to the ram.

[ ] The chuck is threaded in place as seen in the photo.

Chapter 11

The shop built servo head

I have developed a very low cost, easy to fabricate, servo head using a modified "drawer slide". The accuracy is excellent, if care is given to detail during construction. Frankly, I have been impressed with the precision, which can be achieved given the time, cost, and technical skill required to fabricate the servo ram. The servo head as described has a maximum travel of 2 5/16". It is possible to get even more travel by extending the lengths of the slide and lead screw.

The advantages of this head are:

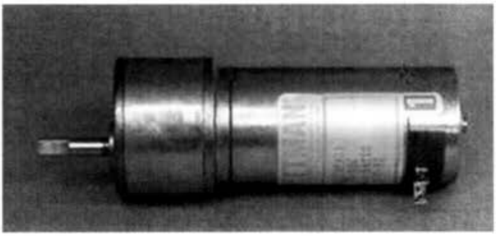
1. Very low cost.
2. Ram travel can be customized to your application.
3. The rams construction is very rigid.
4. It's possible to have a large platen to attach the electrode holder to.

The disadvantages are:

1. It will require time to build the head.
2. Some shop tool and basic skills are required.
3. The lead screw requires precision lathe work.

Servo gearmotor selection

Most of the plans for building EDM machines I have seen use **stepper motors**!! Why anyone would do this is beyond my understanding!! It greatly increases the complexity of the design and I see no advantage in most cases. I use a small, very simple, and rugged gear reduction D.C. motor. The photo below is of a Pittman gearmotor purchased via surplus supplier,(see appendix). There are lots of manufacturers of these small gearmotors. Names you will see are: Barber-Colman, Von Weise, Merkle, Korff, Molon.



Basically, you want to make sure that it is a DC gearhead motor and operates on 12VDC (no more than 24VDC) the output rpm of the gearbox on my motor is

80rpm's. If your motor is 20 rpm above or below this, at the designed working voltage, it will still work fine for this application. These motors may be found in many surplus houses; prices of most motors $15-$25 (2005).

DIY servo construction

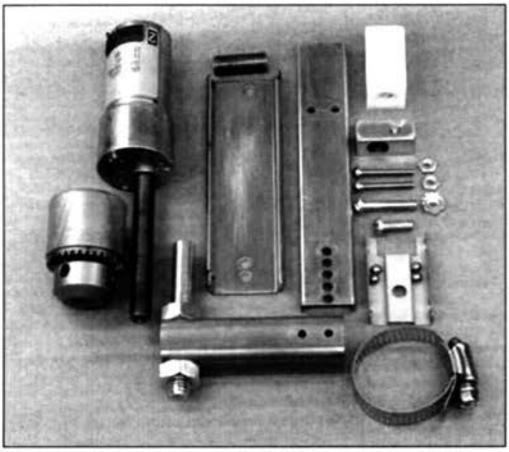
The ram's slide is based on a "center under mount drawer slide," purchased from a Lowe's home center store. It is a Knape & Vogt KV1129PZC16 rated for 35 pounds. I do not think it is important to purchase this particular slide, but the slide must be the ball type. Some slides appear to be built to closer tolerances than others. If possible, before purchasing, extend the slide to its maximum length to check for rigidity. If there is play, reject it, and select another one.

These slides have four parts. I have assigned names to the following items:

1. Outside traveling slide,
2. Inside stationary slide,
3. Ball bearings,
4. Ball retainer cage.

The purchased drawer slide has 12 steel bearings, but only four are needed to build a good compact EDM ram.
The photo on page 66 (left hand) shows all the parts required to build the head. The photo on the right shows the assembled head.

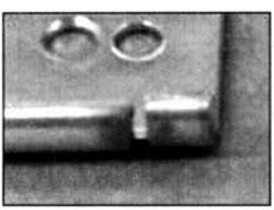
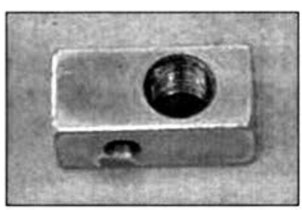
[ ] Completely dissemble the slide and cut the following lengths from the slide.
5 1/2" length of the smaller width inside slide.
4 1/2" length of the wider width outside slide.

[ ] The ball retainer cage should be cut so that there will be a minimum of four balls spaced at least 1 1/8" apart.

[ ] About 1/8" from the end of the wide traveling slide, cut (hacksaw) a slot as seen in the photo (left) below repeat this for the opposite end of the same slide.

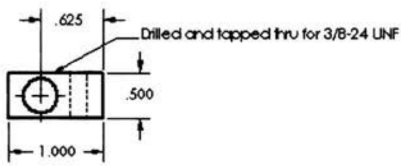
[ ] Using a file and sand cloth, remove all burrs, paying particular attention to the area of the cut slots.

Lead screw nut

Suitable material for the lead screw nut is a 1" length of 1/2" square steel key stock. The preferred material is brass see photo above on the right.

[ ] From the end of the stock, move over 5/8", drill and tap a 3/8-24 hole through the center of the stock. The correct drill for this operation is a "Q" drill, lacking that a 21/64" drill will work, assuming you have a sharp tap. Other thread pitches will work, though I have not experimented with pitches coarser than 20 t.p.i. (threads per inch).



[ ] Rotate the stock 90 deg., 5/16" from the end on the center line, drill and tap a 10-32 hole through the material.

The lead screw

It is critical that the 3/8-24 (or whatever thread pitch is selected) lead screw be fabricated accurately to get the smoothest operation. In most cases, this means using a lathe. If possible, the lead screw should be held in a collet during the machining process, to ensure the most precision. Should you not have the skills or facilities, consider having the work done by a high school or technical school shop class. **NOTE** If you are unable to get the work done I am willing to manufacture the needed screw for a reasonable fee, see my address/email in the front of the book.

[ ] The diameter and length of the gearmotor output shaft needs to be known, for this operation. Cut a length of 3/8" cold roll steel 4 3/4" long. Drill and ream a sliding fit hole in one end of the stock to accommodate the length of the motor output shaft, the motor I am using has a 3/16" shaft.

I suggest two methods of attaching the lead screw to the motor output shaft; determine which method will be used.

Method #1 setscrew

The most common method of securing a screw and shaft together is with a setscrew. The disadvantage of using this arrangement is that it tends to pull the lead screw slightly off the centerline, causing binding as the slide moves throughout its travel.

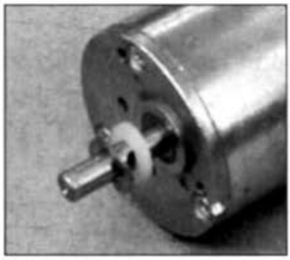
[ ] A #4-40 setscrew hole should be drilled and tapped at right angles to the previously reamed hole.

Method #2 glue

If built correctly, the torsional loads on the lead screw are not great, so I prefer to use a two-part epoxy glue for attaching the lead screw to the motor output shaft. The disadvantage is that if the parts need to be disassembled, it makes life difficult. The advantage of using glue as the connecting agent, is it virtually eliminates the binding problems explained in method #1.

[ ] Single point threads, on a lathe, for a distance of 3 3/4" on the lead screw. Use the previous made lead screw nut to test the fit. You are trying to get the least backlash (play) possible without binding. No sloppy fit is acceptable here!

[ ] Once completed, cut the lead screw to a length of 2 3/4". The remaining 1" threaded piece should be squared on the ends (use the lathe to square it). This will be used later to mount the electrode holder to the platen.



Whether you choose to attach the lead screw with glue or a setscrew, it is necessary to remove the motor output shaft endplay. This is accomplished by installing a nylon washer, see photo above (which acts as a bearing surface) and a wavy washer between the motor housing and lead screw. The wavy and nylon washer are sold by most hardware stores in the specialty fastener section. If you cannot locate the wavy and nylon washers, they may be purchased from either of the following companies.

http://www.smallparts.com
http://www.pic-design.com/

[ ] If attachment method # 1 is used, place the lead screw on the motor shaft, partially squeezing the wavy washer (i.e. preloading the shaft), then tighten the setscrew against the shaft, hopefully the shaft has flats on it.

If attachment method #2 is used the following steps are necessary.
[ ] Make sure all surfaces are cleaned with acetone or another similar degreaser.

[ ] Place the nylon and wavy washer on the shaft.

[ ] Put a two part epoxy glue, such as JB weld, in the lead screw hole and cover the motor shaft with glue as well.

[ ] Place the motor and leadscrew assembly between the jaws of a vice (or "C" clamp) and squeeze until the wavy washer is partially collapsed.

[ ] Leave the motor in the clamping device and let the glue fully cured, usually 12 hours, read the glue instructions.

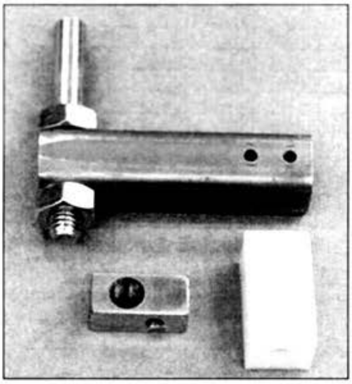
The platen

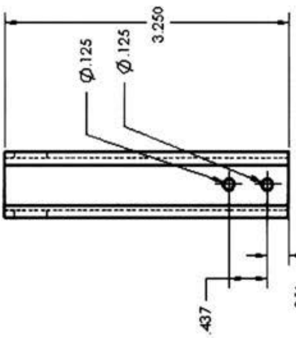
The platen (see the white plastic block in the photo below) electrically isolates the electrode from the ram. A small piece of plastic was found in the scrap box (delrin preferred) to use as the platen.

[ ] I machined a piece 3/4" square x 1 1/4" long. In one end, a hole 1/2" deep is drilled an tapped for 3/8-24 threads.

[ ] Measure down 1/2" from the opposite end and drill (at 90 deg) a 3/16" clearance hole thru for a #10-32 screw.

Mounting arm





The mounting arm , was made from 3/4" square steel tubing 3 1/2" to 5 1/2" long, length and diameter not critical.

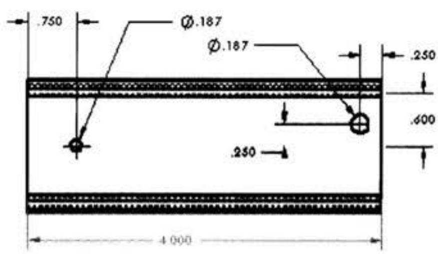
[ ] Move 5/8" from one end, and drill a 3/8" thru hole. At 90 deg. to this hole, on the opposite end, drill two 1/8" holes spaced 7/16 apart. See photo and drawing on page 70.

[ ] The actual mounting post is made from a 3" long 3/8" bolt with the head removed.

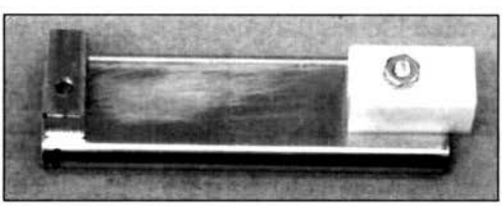
[ ] Debur holes and assemble as per the photo.

Final slide preparation

[ ] The wider of the two slides is the traveling (moving) slide. Mark and drill a 3/16" hole 1/4" from the top of the slide (this hole is off set 1/4" from the centerline). The lead screw nut is attached at this location.

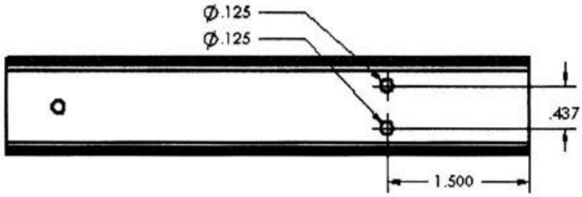


[ ] Measure from the bottom of the slide 3/4", on the center line, drill a 3/16" hole. It's through this hole the plastic insulating block is attached with a #10-32 screw, see photo.



A second screw may be added for rigidity. This would involve drilling an extra hole in the slide and plastic platen.

[ ] Layout and drill stationary slide as per the drawing below.



[ ] Using a square, position the mounting arm and the slide 90 deg. to each other and secure in place with two screws, you may want to tack weld to guarantee no movement.

Slide assembly

[ ] Slide assemble can be a little tricky. First, remove all dirt and metal chips from the bearings and bearing surfaces.

[ ] Start by holding two balls in the ball retainer cage, and insert them into the traveling slide on the mounting post end. of the inside stationary slide.

[ ] Push the traveling slide forward until it is time to install the last two balls.

[ ] With the balls in position, slide the traveling slide further into the stationary slide, The photo on page 75 shows the slide in the fully extended position (i.e. the wider traveling slide has traveled the full length of the stationary slide).

[ ] When the slides are assembled and lubed with a light oil or grease, the movement should be silky smooth; if not clean and reassemble.

[ ] Once the two slide are in position and smooth movement is noted, squeeze the two 1/8” metal tangs cut on the traveling slide slightly closed. This will keep the balls and ball retainer captive in the moveable slide.

[ ] Double check the squareness of the slides and the mounting arm, if not tack welded in place.

Electrode holder

A simple electrode holding device for beginning EDM experiments is a 3/8” drill chuck. It works well for cuts where a single electrode is all that is required. Should you get involved in more advanced EDM work, this holding method will not be satisfactory. It does not permit the electrode to be removed from the holder and then replaced in the exact same position.

Most hardware stores sell replacement chucks for a hand drill. Experience indicates most of these chucks use a 3/8-24 threaded stud to attach them to the drill.

[ ] The 1" length of material cut from the lead screw is used to attach the electrode holder to the plastic electrical isolation block. Thread the stud into the back of the drill chuck and also into the drill and taped platen

Gearmotor mounting

[ ] Thread the lead screw nut up the lead screw to within 1/4" of the gearmotor housing. On most gearmotors, the output shaft is off the motor centerline. This permits a very a simple self-centering method of aligning the motor and the lead screw nut.

[ ] To accomplish this, simply rotate the motor housing until the outside of the gearbox lays squarely near the top in the groove of the small stationary slide; see (left) photo page 75.

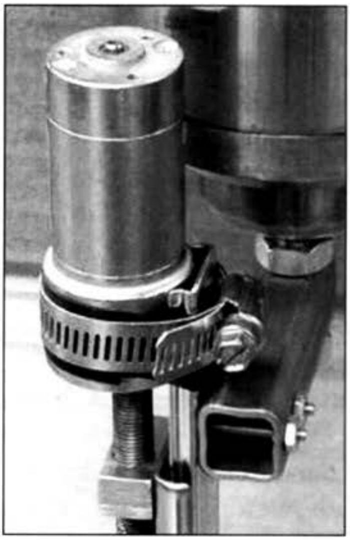
[ ] Install a hose clamp around the slide and motor, and tighten.

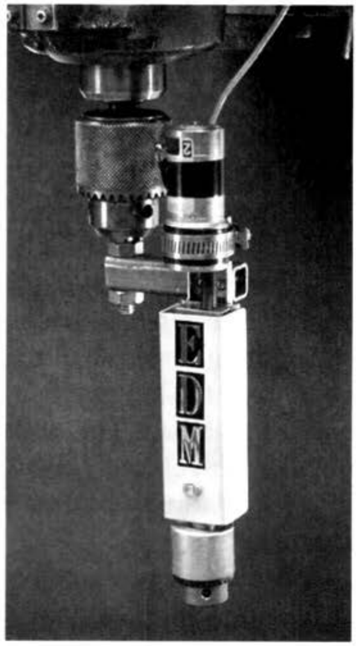
[ ] Connect the motor to the EDM generator, if it is finished, see page 58 for details on wiring the motor. If not finished connect to a battery or other 12VDC source.

[ ] Run the slide back and forth and adjust the position of the motor, if necessary, until no binding is evident.

Note: **Without slide limit stop switches** (not covered in this text) **it is possible to run the slide into the gearmotor housing and stall the motor. This stall also has the potential of destroying the generator motor driving chip.**

The servo is complete, see the photo on page 75 (right) the finished head is shown with an aluminum cover over the slide to dress it up a little.





Chapter 12

Dielectric tank overview and construction

A well designed dielectric tank and filter system do several things:

1. It contains the dielectric fluid around the workpiece.
2. Provides a method to accurately secure the workpiece.
3. Circulates clean filtered dielectric fluid to the gap.
4. Electrically isolates the electrical discharge from other parts of the machine

5. Provides a rapid method for filling/draining and storing the dielectric fluid.

For serious EDM work, a tank needs to have a pump, filters, and a work holding plate. The photos and descriptions in this section are of a (rather large) tank that has proven to be of a very versatile design. After 8 years of use in portable, as well as stationary applications, there are few, if any, changes that I would make to the design.

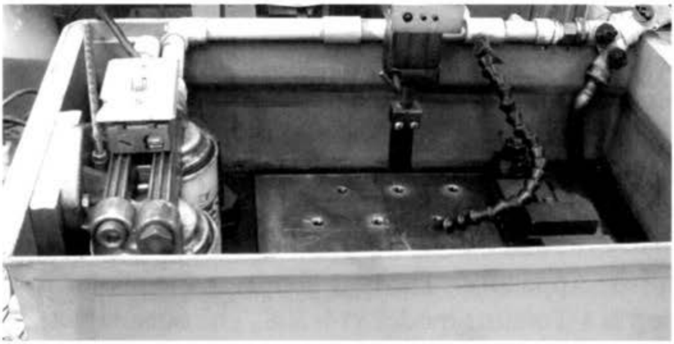
I can not over stress the importance of have a good dielectric filtering and flushing system for your EDM. A good flushing system will make a poor EDM generator look good, a poor flushing system will make a good EDM generator look bad. **The dissatisfaction with many home built EDM machines I think comes from a poorly designed, or nonexistent, dielectric cleaning and flushing system.**

Use ideas presented here and build a good dielectric tank to suite your particular needs. Before getting into details of how it is built, I would like to suggest a possible alternative.

Building the dielectric tank

The photo on page 77 shows an overview of the EDM tank in my shop. In the center of the photo, notice a black electrode mounted in a square ram. Disregard this particular ram. This particular tank is part of a self-contained stationary EDM in my shop. The focus in this section is building the dielectric tank only, **not the ram.**

The tank shown, holds 5+ gallons of dielectric fluid and is large enough to accommodate most of the EDM work I do. The dielectric fluid, when not being used, is stored in a 6 gallon plastic tank (not shown) under the workbench. The dielectric is quickly transferred from storage to the work tank



by applying low-pressure (1-3 psi.) compressed air to the sealed storage tank, forcing fluid into the work tank. Once filled, a simple valve inside the work tank is closed containing the fluid. To empty, the valve is opened and the fluid drains by gravity back to the storage tank.

If compressed air is not available, another option for automated storage is to use the circulating pump in the work tank to pump the dielectric to a storage container **above** the work tank. When the work tank needs filling, a valve is opened and the work tank is filled by gravity. Using the pump method, the transfer of dielectric fluid is much slower than using compressed air. But this method does not require any holes to be cut in the work tank .

Tank selection

To accomplish precision EDM work, it is necessary to accurately hold the workpiece in the tank via clamps, vice, etc. This necessitates a metal plate be attached to the tank bottom. I prefer to glue the plate in place and not penetrate the work tank boundary anymore than necessary.

The glue method rules out the use of polyethylene containers, as there are no common glues that adhere to this very slick flexible plastic commonly found in kitchenware.

The tank material of choice is fiberglass, which glues adhere to very well. The fiberglass containers that I recommend are intended to be used for commercial storage and transport of parts. They are manufactured by Molded Fiber Glass Tray Co

The product line is called Toteline, and they come in various sizes and colors. Several industrial supplier sell the tank, (see Appendix). The tank shown in the photos in this section is a Toteline model 814-308. The outside dimensions are 25 3/4"X 15 3/4" X 7 5/16". If this tank is too large for your application, their web site lists several smaller size tanks. I recommend staying with the 814 series of tanks, which have four flat walls, making it easy to mount the filtering system.

Using the Toteline model # 814-308 permits a respectable 12" X 15" work plate; a two-filter filtering system, along with associated plumbing; and a dielectric pump; all of which, may be housed inside the tank. Using this in-tank design, filters maybe changed without spilling dielectric fluid outside the tank. For a portable EDM system, having virtually everything contained inside the tank has some real advantages during use, as well as storage. Given these advantages, this system is not for everybody; some have space concerns and elect to use a smaller tank and/or position the filter/s and pump external to the tank; it's your choice.

Tank fill and drain

The dielectric tank described, has only one hole drilled through the tank below the dielectric fluid line. A thru-hull connector, and a bilge hose from the pleasure boat market, make it possible to fill and drain the tank thru this one hole. The thru-hull connector is available in straight and 90° configurations. The larger diameter thru-hull connectors are usually referred to as Cockpit Drains, see following photos. They are better in most cases, as it will speed the filling and emptying of the work tank.

The connector and matching bilge hose are available at most boat and marine supply houses. If there is not a local source for these parts, check the Attwood Marine web site (see Appendix) and look under pump accessories for the needed items.

[ ] Drill a hole in the bottom or side of the tank (hole saws work great) to accept the size connector purchased. I placed the drain in the bottom of the tank (see photo below and on page 80) to ensure the complete draining of the tank. Even with a bottom drain about 1/4" dielectric stands in the tank when empty. If a portable EDM system is built, a hole in the side of the tank may be the best choice. The disadvantage of using a bottom drain location is that it may pose a problem when mounting the tank on a flat surface, such as a milling or workshop table.

[ ] If you are duplicating the described tank, the hole location is in the tank bottom, front left hand corner. Measure inside the tank 1 1/2" from left wall, 4 1/2" from front wall. Knowing this precise location will be important when installing the fill valve.

The photo below shows the top side of the thru-hull drain. Notice the tapered angle of the opening in the drain thru-hull connector. This was not cut by me, but is the way this particular connector was made. This angle works great in conjunction with the valve to form a good seal. Even if the thru-hull connector purchased does not have the angle, as long as the opening is smooth, it should provide a seal to keep the dielectric from draining back into the storage tank.

Work plate selection and mounting

[ ] Decide on the size work plate you want. I chose a 12" x 15" x 3/8" aluminum plate (steel is also acceptable).

[ ] I recommend drilling and tap a series of 1/2-13 holes (on 2 ½" centers) in the work plate. These holes provide a means of holding common fixture/hold down devices.

[ ] Completely debur all holes and edges, particularly on the surface of the plate that will contact the tank's bottom. When glued in place, the plate must be as parallel to the tank bottom as possible in order to accomplish accurate EDM work.

[ ] Mark exactly where the plate is to be positioned in the tank.

[ ] Rough up the bottom of the tank and the work plate with coarse sandpaper.

[ ] Make sure all traces of dust are removed, then wipe both the tank bottom and the plate with a solvent such as acetone, to remove any oil/grease.

A glue that is known to work well for attaching the work plate is a 5 minute epoxy Plastic Welder # 14300 made by the Devcon Corporation (see Appendix) This glue is used because it has very good resistance to the hydrocarbons found in the dielectric fluid. No matter what glue is used, make sure it is resistant to solvents.

[ ] Place the fiberglass tank on a flat surface.

[ ] Apply a uniform bead of glue on the backside of the **work plate,** leaving a glue free space around each threaded hole in the plate. This will minimize the amount of glue that "squishes" into the holes when the plate is set in the tank.

[ ] With a wooden paddle, mix both parts of the glue together. I suggest doing the mixing right on the work plate. This is a time when two people are better than one; the glue has only a **2-3 minute** working life.

[ ] Position the plate in the work tank. Once in position, use a "Q" tip to remove any glue in the threaded holes. Full bond strength of this particular glue occurs in 8 hours.

I have used this glue on quite a few tanks and have never had a problem with the work plate releasing from the tank, even when left for extended periods with dielectric in the tank.

Dielectric pump and filters overview

If the EDM operations last for more than a few minutes, it is necessary to supply a clean flow of dielectric fluid to the gap area. This will promote an efficient stable burn under most conditions. A brushless 120VAC submergible pump is used to circulate fluid through a set of automotive (spin on) oil filters for cleaning.

The submergible pump **must contain Viton seals**. Various industrial suppliers such as Grainger, Beckett, and Teel sell these pumps (see Appendix). I used a Grainger model #2P407, (Grainger does not sell direct to the public). The Beckett model is G600AVS. The pump is rather expensive costing about $85 (2005). This pump is a good choice for the application, it flows a respectable volume of fluid at a relatively high head pressure for a small pump. I have had this pump in operation for about 8 years with no problem.

There are some solvent tank pumps, which are less expensive, but in most cases develop less head pressure. Make sure the pump is **brushless** with Viton seals.

Filter mounts and filters

Remote oil filter mounts are used in the automotive industry. Dual and single oil filter mounts are available, see photos.

These remote oil filters mounts may be purchased from
Jegs High Performance.
http://www.jegs.com
They are also available from
http://www.holleyreman.com
(see Appendix for both items).

[ ] Purchase a spin-on oil filter to fit your particular mount.

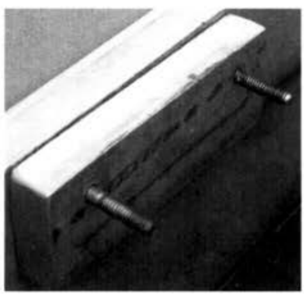
Filter mounting and plumbing

To mount the two-filter system, a spacer block, (as shown on page 84 bottom photo) 5 1/2 x 2 x 3/4" is need. The block may be made of metal, plastic, or wood. This block will correctly position the filter mount above the drain/fill hole.

[ ] Next, locate the centerline of the thru-hull connector drain hole. On this centerline, a 1/2" hole is drilled through the

the filter mount. This hole should fall close to the location seen in the photo below.

[ ] Drill holes in the tank and spacer block to match the filter mount. Mount the spacer block, and filters, see photos



The drain valve

The drain valve consist of a ping-pong ball, a 9 1/2" length of 1/4-20 threaded rod, four 1/4-20 nuts, one 5/16-18 nut, and a 2" length of 1/2 diameter aluminum rod with a thru hole (optional).

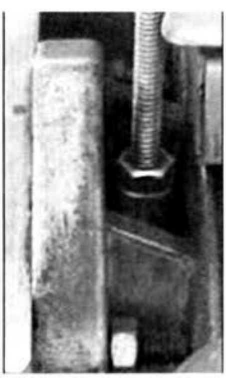
Note: In the photo on page 85, there is a short bolt glued to the right hand side of the ping-pong ball; disregard, as that was part of a design that did not work out well, but was never removed. The parts of the drain valve are glued together using the same glue as used for the work plate.

[ ] On the top of the ping-pong ball, glue the 5/16-18 nut. Do not let glue "squish" into the threaded area of the nut. Permit the glue to reach full cure strength.

[ ] Thread two 1/4-20 nuts on one end of the threaded rod, leaving 1/4" of the rod extended through the bottom nut. Run one nut against the other in jam nut fashion.

[ ] Mix a small amount of glue and fill the hole of the 5/16" nut, then insert the short end of the threaded rod into the nut and rotate the rod. This causes the glue to attach to the thread rod and to squeeze between the two nuts for a strong bond.

[ ] The 1/2" aluminum sleeve on the threaded rod gives a smooth slip fit through the filter mount base, see photo.



In operation, compressed air (approximately 3#) is applied to the storage tank, forcing dielectric fluid past the ping-pong ball valve. When the work tank is full, the air pressure is cut off. As the dielectric starts to flow back to the storage tank, it pulls the ping-pong ball against the thru-hull connector thus closing the valve. To drain the tank, lift the ping-pong ball valve stem.

Final tank plumbing

[ ] To finish the tank plumbing, purchase the following 3/4" PVC items from a hardware store. Two 90° elbows, three male and one female threaded couplers (to match the oil filter mounts and pump, usually 3/4" NPT), as well as an end cap, and enough (approximately 3 feet) 3/4" schedule 40 PVC pipe to plumb the system (see Appendix).

If a portable system is being built, or if the storage tank for the dielectric fluid will be higher than the work tank, a valving system is needed to control the flow of the dielectric fluid to and from an elevated storage tank. The valving is a good idea, even if a portable tank is not being built. The valving consist of an adapter to go from a 3/4" NPT (pipe thread) to a garden hose thread, as well as a garden hose "Y" and straight shut off valve; see photo below. Also, purchase a male brass 1/2" garden hose replacement end (remove the steel crimp teeth), a 3" length of 1/2" copper tubing, and a 45 deg elbow to match.

[ ] To one side of the elbow, solder the tubing. To the other side of the elbow, solder the brass replacement end, as shown. By opening and closing the appropriate valves, it is possible to permit the fluid in the tank to be circulated for filtering, or be discharged to a storage tank higher than the work tank.

Dielectric cleaning tips

Filter life may be extended by placing bar magnets at random locations in the dielectric tank. Metal swarf particles floating in the dielectric are attracted to the magnets. To clean remove the magnets and wipe the residue off with a cloth. Letting the swarf settle out in the storage tank after a burn extends filter life also. If the EDM is used often it is a good idea every week or so to remove all dielectric from the storage tank and properly dispose of the settled swarf. If not removed, over a period of time it tends to pack in the storage container and is almost impossible to remove.

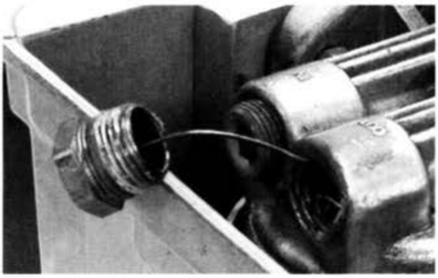
Static discharge dissipater and AC switch

[ ] Drill a 1/16" hole through the center of a brass plug that threads in the **discharge side** of the oil filter mount.

[ ] Solder an 18 gauge copper wire in the hole, see left hand photo page 88, which is long enough to extend the full length of the PVC plumbing. This wire discharges most of the static charge (to ground), which is naturally developed as the dielectric is pumped through the fiberglass tank and plastic tubing.

[ ] The on/off switch for the motor is a standard 120VAC household light switch installed in a **metal** switchbox; no plastic boxes, see right hand photo page 88.

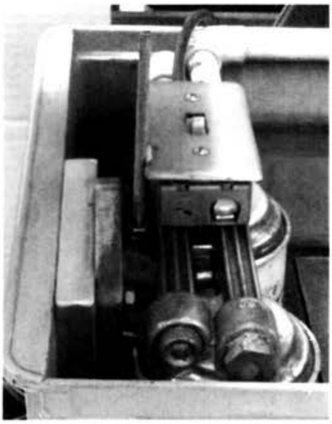
[ ] Drill and tap 10-32 holes between the inlet and outlet tubing on the filter mount. Using a long 10-32 screws, attach the switchbox to the oil filter mount. The switch box needs good physical/electrical contact with the filter mounts. The static discharge passes through this connection.

[ ] When wiring the switch, use a three conductor AC power cord (Radio Shack #61-2859) or similar. Strip the covering back about five inches, exposing the three inner wires.

[ ] Strip the black and white (some are blue and brown) wire ends back 1/2" exposing the bare wire. Strip the green wire back 1".

[ ] Thread the cord through the switch box and clamp the strain relief snuggly against the AC cord.



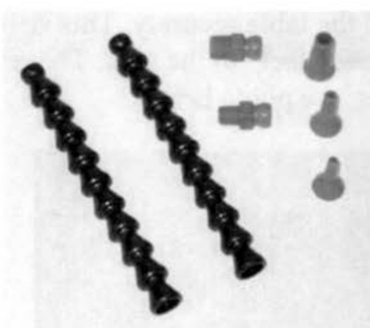
[ ] The switch and motor are wired in series, secure the connections inside the switch box with wire nuts (Radio Shack 64-3057)

[ ] **This is very important** the green wire from the plug and the ground wire from the motor must have good electrical contact with the oil filter mount. The static charges collected by the wire are discharged to ground through these connections.

Flexible flushing line

To direct the clean dielectric fluid to the area of the gap, use a great product called Loc-Line, see photos below. A similar product by other manufacturers is called Snap Flow, Snap-Loc etc. These products are available with various valves, nozzles, connectors, etc., (see Appendix)

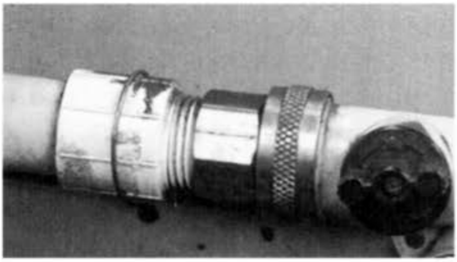
[ ] Purchase at least one male 1/8" NPT valve, a round 1/8" nozzle, and a foot of the Loc-Line. Many industrial suppliers sell a kit with these basic items for less than $10 (2005). Should your flushing methods include through electrode flushing, pot flushing, etc. (see the EDM techniques and methods section), purchase at least two of each item listed.



[ ] In the filter (PVC) discharge line, which runs along the back side of the tank, drill and tap a 1/8" NPT hole for the Loc-Line male valves to thread into. In the right hand photo above of the loc-line valve, note the placement of a PVC coupling. This coupling provides a little more thickness of PVC material to thread into. Install as many flush lines and valves as needed on this PVC discharge line.

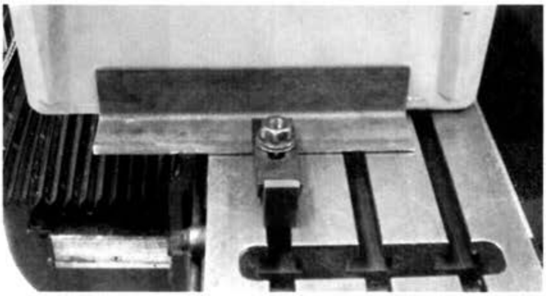
[ ] Along the backside of the tank, drill several 3/32" holes.

Through these holes, zip ties or wire are used to hold the PVC pipe in place, see photo below.



Portable applications

The dielectric work tank may be set up temporarily on a milling or drill press table. For such an application, the tank should be attached to the table securely. This is accomplished by adding two "feet" to the tank. These feet are glued to the tanks ends, see photo below.



[ ] The feet are 11" long (or as dictated by your tank size) and cut from a piece of 2" angle iron. Center the feet on the tank ends and mark the location.

[ ] Sand the tank to rough the surface so the glue will adhere in the contact area. With acetone, or similar solvent, degrease the angle iron and tank.

[ ] Position the tank on the milling/drill press table. Clamp one angle iron piece in place. Use the same glue used to glue the plate in the tank bottom. Apply this glue to the angle iron. Slide the tank against the angle iron.

[ ] Repeat the same process on the other end of the tank and let the glue fully cure.

Stationary applications

Building a stationary EDM machine is really beyond the scope of this book. But, if you are building such a machine the tank may be placed on a drill press table, or you could build a column with an over reach arm that the servo ram is attached to. Either way, a low cost "X" "Y" table (also called mill and drill table, or some times called compound slide milling drill table) as seen in the photo below, will serve well for moving the tank in the "X" "Y" axis. Depending on size and travel, these tables cost between

$75 and $200 (2005); most industrial suppliers carry them.

In my application, I cut, from a piece of particle board, a section large enough to fit under the dielectric tank (particle board is very precise in thickness) It is a good idea to water proof the board or put some kind of sealer on it to minimize moisture absorption by the wood. Secure the board to the "X" "Y" table with "T" nuts and flat counter sunk screws. The tank maybe glued directly to the particle board.

If you choose this method, it will be almost impossible to remove it from the table without destroying the setup.

If you have feet on the tank (as described in the previous section), holes maybe drilled through the feet and screws or bolts used to hold the tank in place on the particle board. The dielectric tank is now complete, except for the storage tank.

Chapter 13

Storage tank options and construction

The simplest storage system is one where the dielectric is kept in a covered container, such as a five-gallon bucket. The work tank would have a flexible drain tube on the bottom or side of the tank. The end of the drain tube attaches to the tank side, above the dielectric level in the tank. Dielectric is manually poured from the storage container into the work tank. When the EDM job is finished, or when the dielectric level needs to be lowered to facilitate working in the tank, simply drain the tank into the storage container. It's a bit messy, but is low cost and works well.

Storage above the work tank

Having the storage above the work tank may be used for both portable and stationary applications. This storage method requires a stand on which to place the tank. A covered, and vented, five-gallon plastic bucket works well for storage. Cut a hole in the bottom, or through the side, and place a through-hull connector in it; see page 79. In this case a 3/4" size bilge drain hose will work well with the garden hose "Y" valve used on the work tank; see page 86.

By turning the pump on and opening and closing the correct garden hose "Y" valve, it is possible to direct the dielectric flow into the storage tank, or vice versa. One of the real advantages of this method, is that it does not require holes in the work tank below the operations level of the dielectric. This is a very clean storage method. The disadvantage is that the filling and draining of the system is much slow than using the previously described pour method, or the air lift method described in the next section.

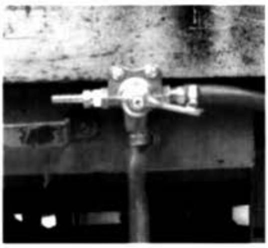
Storage below the work tank

For those that wish to have the most advanced work tank filling and storage system, the following will serve you well. I used this method on my stationary EDM. It is very similar to the systems used on many commercial EDM machines. This method can be used, even in portable applications where air pressure is available. All that is needed, is a sealed tank and a three-way valve, to admit and vent the tank.

For the most part, the storage tank is simple, yet it poses some difficult problems. Assuming the previously described work tank is being used, a minimum of five gallons of storage is needed (six or more is preferable) The storage tank must be completely sealed and capable of withstanding at least three to five pounds of pressure. Most of the plastic kerosene and water storage containers, as well as some plastic gas cans, meet these specifications

The tank must have two openings, one through which air pressure is applied, and a larger hole to discharge the dielectric through. I have noticed recently, that many of the plastic gas cans no longer have a separate vent in them; instead they are vented via the pour spout. This new type of venting system creates a problem in our application, as there is no readily accessible vent hole to apply air pressure (above the dielectric) thorough. Use your creative juices here to overcome this problem.

The tank seen in the photo below, (left) had a vent hole with a thread-on cap to seal it. I removed the vent cap and connected the inlet airline using a hose clamp to seal it. How the inlet air pressure is applied to the storage will be determined by the design of the storage tank selected

Some kind of valve is need to turn the air pressure on and off to the storage tank and permit the air to escape when refilling the tank. I had a difficult time locating a reasonably priced, three-way air valve, so a three-way fuel valve was used. These valves are readily available via most auto parts stores. They are used to switch from one fuel tank to another, on a vehicle. The one I have been using, has worked well for this purpose for the last 8 years; see the photo above on the right.

Since you will be purchasing a tank from a local source that may vary in design from mine, it is difficult to give hard info as how best to seal your tank. No matter what kind or style of the tank, there are three basic rules to follow:

1. The tank must be sealed.
2. The discharge pipe must extend from the opening of the storage tank to the bottom.
3. There must be a means of applying air pressure above the top of the dielectric.

The description that follows, pertains to how I sealed the particular tank chosen. The discharge pipe passes through the tank pour spout hole, and the (threaded) tank cap. In most cases, it will be necessary to enlarged both to accept the 1" schedule 40 PVC discharge pipe. This pipe is about two feet long for a 6 gallon tank. The tricky part is getting a good seal, where the PVC pipe passes through the storage container opening. Having access to a machine shop, of coarse, made the job a simple affair.

[ ] Enlarge the pour spout and cap, to accept the discharge pipe.

[ ] Slide the pipe through the snug tank opening all the way to the bottom on the opposite side of the storage tank.

[ ] Using a marking pen, draw a circle around the pipe where it comes through the tank.

[ ] Machine a standard 1" PVC coupling to have a very snug fit over the pipe.

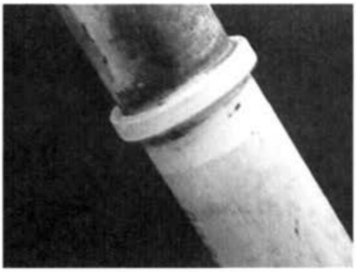
[ ] From the machined coupling, cut a 3/16" wide (or wider) ring; see left hand photo on page 96.

[ ] The ring is placed over the PVC pipe and glued in place by the previous pen marking. Use regular PVC glue to join the pipe and ring.

[ ] At a hardware store, I found a rubber gasket, used to seal sink drains, that was large enough to slide over the 1" PVC.

[ ] The complete assembly with rubber gasket between the tank, and the PVC lip pipe is shown on page 96, right photo.

[ ] The existing tank cap was then placed over the pipe and threaded tight. This seals the discharge side of the tank.

It is not necessary to make and glue the PVC ring to the pipe, though in my opinion, it is best to ensure a good seal. I have, on some tanks, used just an "O" ring around the pipe and placed the cap over the tube, and tightened in place. Other materials that may be used for sealing are pump packing, cutting rubber gaskets from inter tubes, etc. The bottom line is that the tank needs to be as airtight as possible.

[ ] I used bilge pump line and stainless steel automotive type clamps to make the drain/fill connection (left hand side of photo above) to the through-hull connector on the work tank and the storage tank.

Chapter 14

EDM techniques and methods

The following section, as far as I know, is unique to all EDM plans I have seen. Most plans for EDM machines tell you how to build a very complicated machine, and never give any real hands on application information. What good is an EDM machine if you really don't know how to use it? In the next few pages, I hope to give you some insight into ways to use your EDM for fun and to actually make money.

Electrode materials

The most commonly used electrode materials are graphite and copper. In the U.S. the primary material is graphite, in Europe I understand copper is widely used. The EDM machine described in this book burns with graphite, copper, and brass electrodes. The wide availability of these materials make them an excellent choice for everyday applications. About 90% of my work is with graphite as the electrode material. When graphite is used, it must be of the type manufactured specifically for EDM applications. Carbon welding rods, carbon rods from batteries as well as motor brush material, and other forms of carbon and graphite are very poor choices; their use will be disappointing at best.

A good source for graphite in small quantities is the on line auction sites that often sell short pieces that are no longer useful for large commercial machines. Some retailers sell these "drops" as well.

The largest manufacturer and supplier of commercial grade EDM graphite is POCO. A good general-purpose grade of Poco graphite to start with is sold under the name Poco **EDM-2. and EDM-1.** The Poco website is

WWW.Poco.com

As mentioned earlier the generator used in this machine is not a state of the art design. Some specifications quoted for electrode performance may not apply to this machine.

Other suppliers of EDM consumables are listed below; most sell POCO graphite as well as less expensive EDM grade graphite.

Intech EDM
Broadview Il 1-
800-3257584
http://www.intech-edm.com/

Saturn Industries Inc
Hudson N.Y.
1-8007751651
http://www.saturnedm.com/home.html

An industrial supplier that carriers EDM electrode material, as well as a fair selection of EDM consumables is

Manhattan Supply Company or MSC
1-800-645-7270
http://www1.mscdirect.com/cgi/nnsrhm

Machining electrode material

Graphite is most commonly used to EDM steel; it is not normally a good choice to EDM carbide. Graphite is manufactured in bulk form and is machined with cutting tools to the desired shape. It has good machine ability, although most grades are brittle and machining sharp corners should be done with care.

Graphite machining tips

If possible, use carbide tools for machining and keep the spindle speeds up; graphite loves to be cut at high speeds. High-speed steel tools may be used, but expect high tool wear. To reduce chipping, climb mill and reduce feed rate when about to exit a cut. When turning, typical roughing feed rates are .015, finishing should be around .005. Cut depths of. 015-.020 are better than light .005 cuts. Use positive rake tools with a nose radius of at least 1/64".

Graphite is very dusty and messy. Some people like to machine wet to reduce the dust problem, but then you end up with a black abrasive slurry. I often us WD-40 when cutting and wipe the residue with a shop towel. If machined dry, use a respirator and a vacuum to collect the dust.

Roughing and finishing electrodes

In some applications, two electrodes are needed to finish a hole to a precise size. The first electrode is for roughing, the second electrode is the finishing electrode.

The roughing (or coarse) cut is usually made at a lower frequency, but with higher electrical energy being dissipated per discharge (higher capacitance). The higher discharge energy erodes not only the workpiece, but also the electrode (but to a much lesser degree), in particular, the sharp corners of the electrode. Once the hole is roughed out, a finishing electrode is used to bring the hole to size. I usually make the roughing electrode about .010-.015 smaller than the finishing electrode

The high quality dense graphite manufactured today significantly reduces the electrode erosion problem on RC generators. Diodes D4-D5, see schematic diagrams on page 7 and 23, are also used to reduce electrode wear on RC generators. These diodes block the "electrical ringing" that occurs after each discharge. This greatly reduces the electrode wear in RC generators. With the newer pulse EDM power supplies, the wear problem is virtually non existent under certain machining parameters.

Indexing electrodes

In applications where two (or more) electrodes are needed to bring the hole to the correct size, the electrode holder on the servo ram should have a means for indexing (or aligning) the electrodes, to ensure that all the electrodes are properly positioned. In one-off jobs and temporary set up's, a dial indicator may be used to check the positioning.

It is beyond the scope of this book to outline the details for building the complex tooling necessary to accomplish this indexing task. I will suggest that perhaps, the simplest method I have seen that gives predictable results, is a "V" block and associated clamps for holding the electrodes. By using "V" blocks and square shank electrodes (or a round electrode with a flat cut on at least one side) good repeatability is possible.

In most cases, two "V" blocks are used. One of the "V" blocks is used off the ram to properly set up the electrode. The second "V" block mounts on the ram in place of the drill chuck. The "V" block and a clamp are used to hold the electrode. One of the leading companies in the EDM industry that builds indexing tooling is System 3R.

http://www.system3r.com/
40-D Commerce Way
Totowa, N.J. 07512
973-785-8200

The 3R system of most interest is the Mini system. In the most basic design, they use a cylindrical arbor with a pin through the arbor that rotates against a stop on the ram. The following photos show examples of their Mini electrode holders. The one on the left is a holder with a copper electrode attached. The holder on the right does not have an electrode attached to it; instead it has a large area for attaching electrodes. By reviewing their literature and web site, those that are machinists should be able to develop a simpler version of tooling for home shop use.

Stepped electrodes

If the EDM ram has enough travel and the cut is a through hole, a stepped electrode provides for roughing and finishing in a single electrode i.e. no electrode indexing is necessary. The first part of the electrode does the roughing and the second step (mirror image of the small section) on the electrode is sized for the finishing cut.

Since the EDM process is a slow metal removal process, it is advantageous to remove the bulk of the metal via conventional machining processes, if possible. An example of this would be when a 1/2" square hole is required. By drilling a 7/16" through hole, most of the metal is removed. The electrode would only need to square up the hole, not remove all the material. Of course, if the workpiece is hardened, EDM may be the only choice for all of the metal removal.

Overcut

Because the EDM process always produces a cavity larger than the electrode, the electrode must be slightly smaller than the specified cavity dimension. This size difference is called overcut. The overcut can vary from a few ten thousandths to a few mils, depending on the gap voltage, the power level (discharge energy), and the dielectric condition. As the gap voltage or power level increases, so will the overcut. The number to know is the amount of the overcut. Once known, overcut is predictable, assuming the dielectric conductivity does not change a large amount.

To determine the overcut, make an electrode and perform a burn. Then measure the difference between the electrode diameter and the actual hole diameter. With this information, it is possible to calculate the undersize of future electrodes. My experience indicates, with the EDM generator outlined in this book, the overcut is generally .004-.008.

Recast layer

In the EDM process, material is removed from the workpiece by thermal action. This results in a layer of melted and solidified material on all cavity surfaces, known as recast. The recast is brittle and forms because the metal is heated to the melting point and then quickly quenched; cracks may develop in this recast surface.

The recast surface may be in excess of 65 Rockwell (Rc) hardness. The recast is usually between .00001" and .002" thickness. Higher energy-per-pulse (i.e. coarse burns) will generally leave a thicker recast layer. If machining of the EDM surface is required by conventional methods, be aware of the hardened surface.

Electrode polarity

Ram , also know as sinker machines, use both positive and negative polarity, depending upon the application. The **electrode polarity** describes the polarity of the burn. Polarity can affect speed, finish, wear, and stability. In most cases, positive polarity (electrode positive) will machine slower than negative polarity. Despite this disadvantage, positive polarity is often used to protect the electrode from excessive wear.

When a significant amount of time has been invested in the fabrication of the electrode a bit of instability and reduced cutting speed can be tolerated, to conserve the electrode. Some electrode workpiece polarity combinations work better than others. In some cases, only one workpiece electrode polarity combination will give a stable burn.

Metal removal rates

The rate which metal is removed is determined by several factors. Generally speaking, the larger the capacitance being discharged, the faster the removal rate. Other factors are flushing (gap contamination), the type of electrode material used, the composition of the workpiece, as well as the electrode polarity. Materials such as nickel, chrome, molybdenum, and other alloys sometimes slow down EDM metal removal rates. A typical burn rate for the EDM generator described in this book is about .006 per minute for a 3/8" round electrode.

Dielectric fluids

For the small shop, I suggest using common kerosene as a dielectric; it is easy to obtain and low in cost. If you insist on using a commercial dielectric fluid, purchase is possible in small quantities (1-5 gallons) from many industrial suppliers. When purchasing commercial fluids, I recommend getting the dielectric designed for fine and/or finishing work, such as Rustlick EDM-30, or similar. Dielectric fluid generally cost about $20-23 per gallon (2005). The fluid is available from most of the listed EDM suppliers as well as MSC.

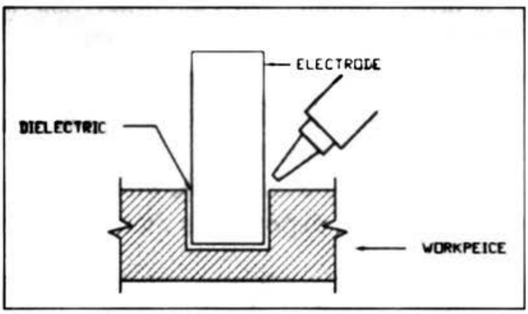
Flushing

A critical factor in successful EDM work is the removal of particles from the gap between the electrode and the workpiece. **Good flushing is key** to good machining and surface finishes. There are three rules for good EDM work: 1. flush 2. flush 3. flush

Poor flushing will result in erratic metal removal, rough surfaces finishes, and increased machining time. Of all the functions performed by the cutting fluid, the removal of particles, or swarf, is the most important. If the swarf is not properly flushed from the gap, the gap becomes overly conductive. Efficiency drops off sharply, surface finish is poor, and shorting conditions occur more frequently. Basically, the flushing operation is as follows: (1) the dielectric is removed from the work tank and filtered, (2) the cleaned dielectric is forced, either around the area where the electrode enters the workpiece (known as jet flushing), or through a hole drilled in the electrode (known as pressure flushing) that exits in the arc gap.

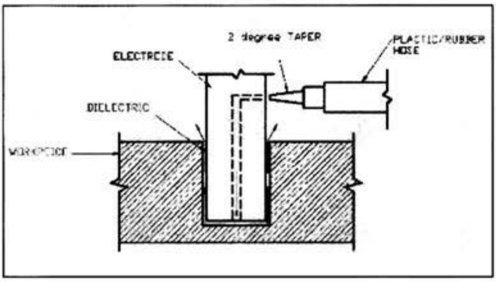
Jet flushing

The most simple and least effective (though most often used by homebuilders) flushing method is jet flushing. If a shallow through, or blind hole, is burned in the workpiece, jet flushing may be used. It is flushed by forcing dielectric from a nozzle into the area around the electrode workpiece interface; see drawing below. It's advantageous to extract the electrode occasionally to permit clearing of dirty dielectric fluid, this improves stability, speed and finish.



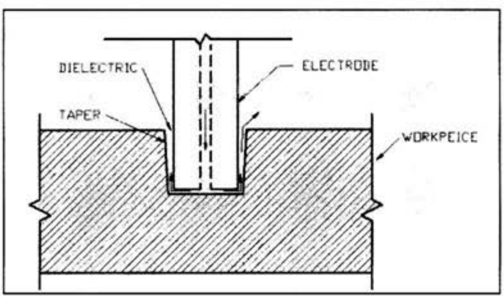
Through electrode pressure flushing

One of the most common efficient flushing methods is through electrode flushing. In pressure flushing, the dielectric pump forces clean dielectric fluid through a hole in the electrode The drawing page 106 suggests a method that facilitates this technique. The end adapter with the small (2-5 deg) taper, is inserted into a side hole which intersects with the flush hole/s drilled in the electrode. The other end of the adapter is inserted into the flexible flush line that slides over a 1/8" plastic Loc Line nozzle. At one time the tapered adapters were sold by EDM suppliers but recently they no longer appear to be available. One possible options is to use

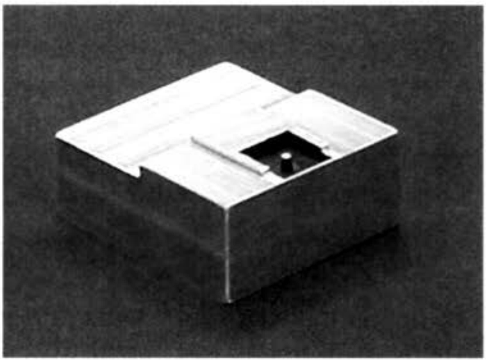


plastic vacuum line connectors sold in automotive supply stores. File or machine a taper on these connectors to fit into the small hole drilled in the electrode, otherwise it's necessary to manufacture your own adapters.

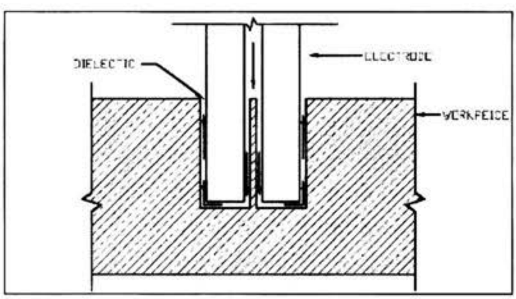
The hose used to carry dielectric fluid to the electrode should be flexible to avoid deflecting the electrode. Often I use rubber automotive vacuum line tubing. It is low in cost, readily available, very flexible, the down side is it tends to degrade after continuous exposure to most dielectric oil.



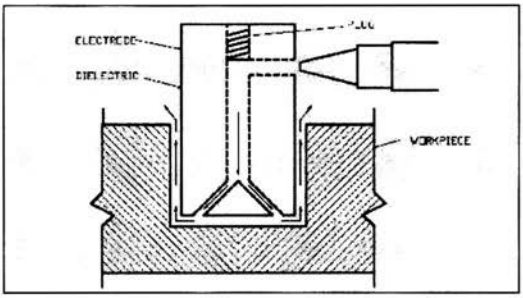
The pressure flushing method is easy to accomplish and supplies clean fluid to the arc gap. The correct pressure and flow of dielectric through the gap **is critical** for burn stability. To high a pressure or to much volume can cause an unstable burn. Often I start with jet flushing then switch to pressure flushing after a few minutes. Pressure flushing has several problems associated with it. One problem is that it causes taper to develop in the burned hole. As the dielectric leaves the arc gap area, it is swarf laden. The dielectric and swarf are forced between the electrode and the workpiece (in the overcut area). This creates sparking along the side of the electrode as it exits, and will create slight tapers as shown in the second drawing (exaggerated) on page 106.



Thru-electrode flushing leaves a core of metal extending into the flush hole, in the electrode, as shown in the photo and drawing on this page. The problem with the core is it restricts dielectric flow. With deep holes, it's necessary to extract the electrode and break the metal core off.



One way to reduce the core problem is to drill flush holes in the bottom of the electrode at an angle to the main feedhole. This is show in the drawing below. By doing this, the cores are mostly burned away as the cavity is formed.



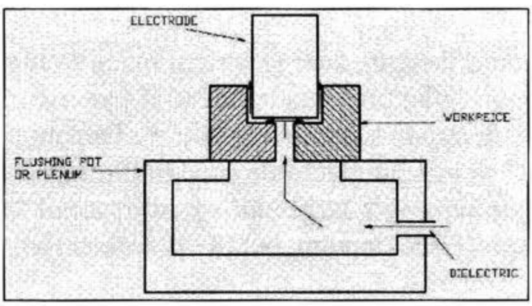
The best conditions for pressure flushing are when a sealed flushing condition exists. Sealed flushing is when the whole face (end) of the electrode is in a closed burn cavity. This condition forces the dielectric to flow completely across the face of the electrode as it removes swarf. When burning a thru hole, the whole electrode face is initially in the burn pocket. As the electrode starts to break through, the sealed flush condition is lost, the burn becomes unstable, and the dielectric quickly escapes thru the hole which is being burned

The simplest solution to this problem is to mount the workpiece on top of a sacrificial metal block and clamp it in place. As the electrode burns thru the workpiece, the sacrificial metal block maintains the sealed flush condition. This method will result in the best surface finish and the lowest most stable burn time.

Another common case where sealed flushing does not exist, is when doing a finished burn on a thru hole that has already been roughed out. One solution to this problem is to place the workpiece over a piece of metal that has a pocket drilled or milled into it. The electrode will exit into the drilled hole. Using this method, the pocket should be completely filled with dielectric fluid prior to placing the workpiece over it. Remember the workpiece must completely cover the hole in order to seal it off.

Pot flushing

A second means of pressure flushing is shown below; it is pot flushing. A pot or plenum is provided below the workpiece. Dielectric fluid, under pressure is forced into the

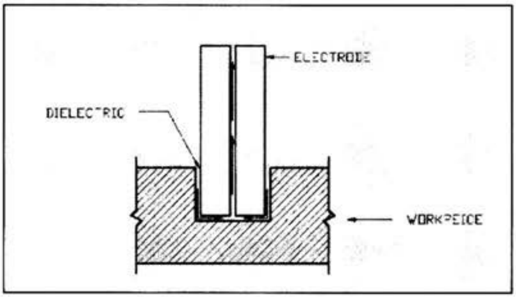


pot and through the gap via a hole drilled in the workpiece. This method is especially convenient in mold making, where drilled ejector and/or core pin holes are already in the workpiece. Pot flushing is excellent to use with long or thin electrodes, that are difficult to drill flush holes in.

Suction flushing

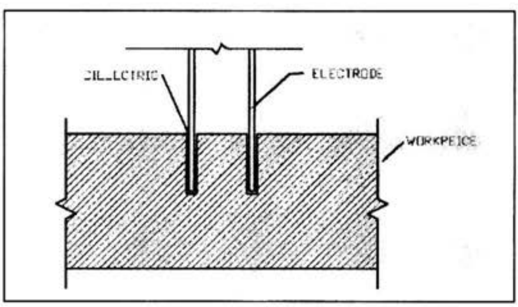
If flushing is accomplished by suction, as shown in drawing on page 110, the tapered electrode and workpiece problem is virtually removed. Although this is the preferred flushing method, it is more difficult since it requires a means of drawing (sucking) the fluid through the electrode.

Unfortunately, the dielectric tank/pump described earlier in this book does not lend itself well to this method of flushing.



Trepanning

Should there be a large area of metal to remove, and it is a through-hole, time can be saved if you use a trepanning electrode see drawing below. Trepanning is a "holed out" or tubular electrode used in through-hole machining to remove a large amount of material from the solid workpiece see drawing below. A core is formed during



the cut, and drops out when the electrode penetrates the workpiece. Trepanning is always the fastest method for creating large thru-holes.

Remember a good flushing system will make a poor EDM generator look good, a poor flushing system will make a good EDM generator look bad, Flush Flush Flush.

Tips and tricks

In some applications, it is beneficial to mount the electrode on the work plate and attach the workpiece to the platen (the insulator block on the servo slide) assuming the workpiece is small enough. This arrangement simplifies the flushing process, as the swarf naturally falls out of the gap.

Pressed arbor

Many times, it possible to use small, lightweight thin electrodes to do the operation, see photo above. The graphite electrode has a reamed hole in the center, and the brass (note the knurl) arbor is pressed into the hole, a round piece of graphite may be used in place of the brass. The brass piece has a hole through the center for flushing.

The electrode itself need not be large or thick to cut a pocket much deeper than its thickness. This design also minimizes hole taper. This 1/8" thick electrode was used to burn the gear shape 1/4" deep into a hardened workpiece, for a plastic injection-molding project.

Glued arbor

Another technique for holding electrodes is to glue them to an arbor, versus pressing them. Use superglue for the adhesive and mix graphite dust with the glue. The graphite dust provides a conductive path for the current to flow through. The glue bond needs to be electrically conductive with less than 1 ohm resistance, check with ohm meter. Incase you are glued together acetone is the solvent for super glue

Glued together electrodes

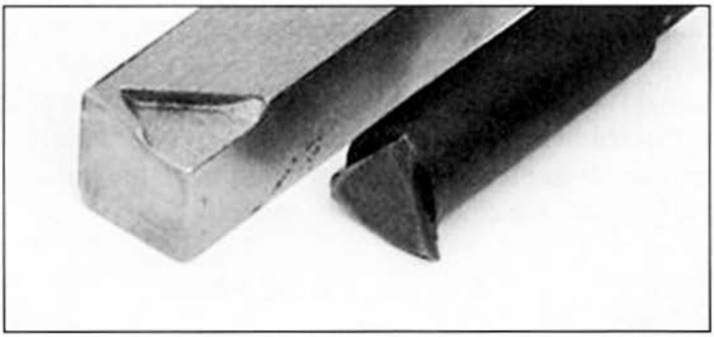
Sometimes it is faster and more cost effective to make electrodes in parts and then glue them together. Use the super glue and graphite dust combination described above for glued electrodes.

Carbide insert tool holder

Another very useful application of the EDM process is burning the pockets needed to hold carbide tool inserts. Often carbide inserts may be found on the internet auction sites for very reasonable prices. Many times, these are discontinued inserts so the inserts are sold cheap. The problem is holders for these inserts often are difficult to locate and expensive. With an EDM machine this becomes a mute point, in fact, it has the potential for being a real moneymaking side line.

Attach the actual carbide insert to the end of an arbor, via the described glue method, and use the actual insert as the electrode material, as seen on the right in the photo below!! This will give a perfect match to the inserts. It takes about 15-20 minutes to burn an insert pocket.

All that is needed to finish the holder is to machine a finger to hold the insert in place. Of course, it is possible to make a graphite electrode of the required shape and burn the pocket. The graphite electrode will give a slightly better surface finish than will the carbide electrode.



Multiple electrode burns

It is also possible to burn multiple holes at the same time with an EDM. Let's assume five, 3/16" holes are needed in a part. Instead of burning each hole individually, make an arbor with five electrodes attached. The electrodes may be machined from one piece of electrode material or individual electrodes can be glued or pressed into an arbor. There is no increase in burn speed using this method. It will take five times longer to burn than with a single electrode. However, you will save set up time and minimize the chance of loosing position, by accomplishing the task with one set up.

During the burn, if any of the electrodes short, all five will be retracted, as they are all attached to the same arbor. Remember, the generator only generates one spark at a time; it will spark at whichever electrode's gap ionizes first. In the end, things average out to equal burn depths, assuming good flushing.

Broken screw and bolt removal techniques

To remove broken screws, bolts, studs, etc. (in many cases), it is not necessary to burn the complete broken item out. I have, on occasions, made a six-sided hex electrode and then burned a hex shape in the broken part. Once deep enough, insert a standard hex key and remove the part. Screw driver slots may also be burned into broken parts to assist in removal. When removing a broken tap, make a trepanning type electrode and just cut through the flutes in the area where the chips normally collect.

A money making job

One money making job I did for a customer was burning blind 1/4" keyways in 48 (existing) commercial tool holders with 3/4" bores. The holders were hardened and the blind keyways made conventional machining extremely difficult. I made an electrode of the required size and length. The parts were positioned horizontally and the electrode (which was horizontal) was extended into the tool holder's bore. Instead of making the cut down to the 6 o'clock position, I chose to move the servo up toward the 12 o'clock position. This made flushing much easier, as the swarf fell out of the cut area. To accomplish this, I rewired the servo to cut going up, instead of down. It is nice to understand the design of the machine so that these kinds of changes are made with ease.

Non-conventional EDM work

The following example is a case where the best EDM conditions are not possible, but it was the only option. A 24-cylinder diesel engine shipboard was down with a broken head bolt. The service person tried to remove the bolt, he ended up with an easy-out broken off, then he attempted to drill it out. Yes, a broken drill bit was also in the mix. With a EDM and small servo heads, such as you have built, it is possible to perform the operation in a remote location.

Make a temporary fixture ("C" clamps, magnetic bases, weldment, etc.) to hold the servo head in the proper position. Around the location needing the EDM work, build a dam using putty (clay) designed for sealing ducts in HVAC systems (shipboard, it is called monkey poop). Fill the dammed area with dielectric and start the cut. The cutting area is flushed with a turkey baster to pump fluid in around and through the gap.

After a period, the swarf laden dielectric should be replaced with fresh dielectric. In some situations, I have actually supplied clean dielectric to the gap by running small plastic tubing from a pump in a storage tank and collected the dirty dielectric in another tank. Let the dielectric sit over night and most of the swarf will settle out.

Another dielectric that maybe used with some success is distilled water. Use it only where there is good ventilation, as the possibility of (explosive burnable) hydrogen generation is ever present. Use the distilled water as a single pass waste water system; it will quickly become contaminated and not work. The nice thing about water is it can be wasted. Only the gap needs to be submerged to perform a successful EDM burn. Performing such an EDM operation means no dielectric tank or dam is required. Use your imagination, there are a lot of ways to skin this cat.

Chapter 15

Your first burn

It is time for the first test burn.

[ ] Securely attach a steel workpiece to the plate in the work tank, via clamps, vice, etc.

[ ] Secure the EDM head on the holding device, if it is attached to drill press or milling machine secure the spindle so that it will not rotate or move.

[ ] Turn off all electrical power to the drill press or milling machine. I have found myself wanting to turn the spindle on when performing any work on these machines, habits are hard to break, at least for me, I guess! It is not fun playing helicopter with the EDM head.

[ ] For the first burn, use a 3/8" (or larger) piece of round graphite for the electrode. Make a hacksaw cut through the center to make the EDM cut interesting.

[ ] Insert the electrode into the electrode holder (i.e. the drill chuck).

[ ] Attach the generator lead clips, positive to the electrode, or the arbor holding the electrode, and negative to the workpiece. Plug these leads into the generator.

[ ] Position the electrode approximately 3/16" above the workpiece.

Caution: should you come in contact with the electrode and the workpiece when the generator is turned on an electrical shock is guaranteed !!

[ ] Use jet flushing to keep things simple. Position the flush nozzle to flush across the workpiece surface.

[ ] Fill the dielectric tank with fluid. **The workpiece should be submerged at least 1" or more under the dielectric to prevent a fire hazard.** Make sure the filter pump (assuming it is submergible) is completely covered with fluid for cooling purposes.

[ ] Turn on the circulating pump

[ ] If, in the unlikely event there is a fire, have a fire extinguisher ready at hand that is recommended for oil fires. I have never had to use an extinguisher on an EDM fire. My experience has been that as soon as the generator is switched off, the fire extinguishes itself; your experience may differ. You have been warned and I am not responsible for any disaster because of fire or electrical shock.

[ ] Turn the finish and coarse capacitor switches on to apply the full capacitance across the gap for this first burn.

Capacitor switch operation

There are three cutting capacitors in the generator, of which two maybe switched in and out of the circuit. For the finest workpiece surface finish (and the slowest least stable burn), both capacitor switches are turned off. With the "finish capacitor" switch (SW2) turned on, the C1 capacitor is connected in parallel with the non switched C2 capacitor. The cut will be a little faster and the surface finish will degrade slightly. When the "coarse capacitor" switch (SW3) on, the photo flash capacitor is switched in the circuit. The cutting speed significantly increases and the surface finish is much coarser.

The capacitor switches should never be switched in and out when an actual burn is taking place. If the capacitor switches are switched on and off during a burn, expect the life of the switches to be greatly decreased. The switches may actually weld themselves together or be disintegrated in a way similar to the workpiece. Always withdraw the electrode and/or extinguish the arc, and then toggle the switch on or off. The arc maybe extinguished by turning the AC power switch off.

Servo switch and reference potentiometer operations

When the servo switch (SW4) is turned on, power is applied to the servomotor. The bicolor LED (D3) connects in parallel with this circuit. The LED will switch from red to green depending on the polarity of the current supplied to the servomotor.

[ ] Turn the generator on

[ ] Turn the servo switch on

[ ] Rotate the reference potentiometer to a position so the LED is off.

[ ] If you have not previously set up your motor, go to page 58 and 74 and follow instructions on setup and testing of the servomotor.

[ ] Plug the servomotor into the generator; the motor should not move.

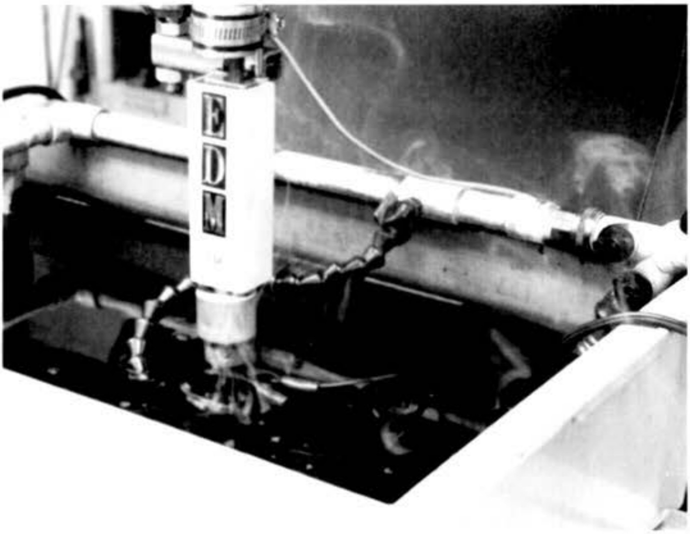
[ ] Rotate the reference control left and/or right to get the servomotor to drive the electrode toward the workpiece. If wired properly, the LED will display a green glow. If it is glowing red, no problem, it will not effect the burning. Just remember which direction is down for your generator.

[ ] Let the servomotor drive the electrode down. When it comes within one thousands (.001) or so of the workpiece. an electrical arc should automatically be established,

[ ] Adjust the reference control until a stable burn is obtained, i.e. you hear a sound similar to frying bacon. The object is to keep the electrode very close to the part and still obtain a stable burn. The LED will be a yellowish color at this condition. Should the servo start oscillating, rotate the reference control to increase the gap voltage until the servo stabilizes. As the burn progresses from time to time, a shorted condition will occur, the servo will automatically retract the electrode to break the short. The servo will then reestablish the burn at the preset gap voltage.

The photo on page 120 shows a burn-taking place. It is very common to see smoke hanging above the dielectric during the burn and bubbles forming in the fluid. Also, you will be able to see the submerged arc in the dielectric fluid.

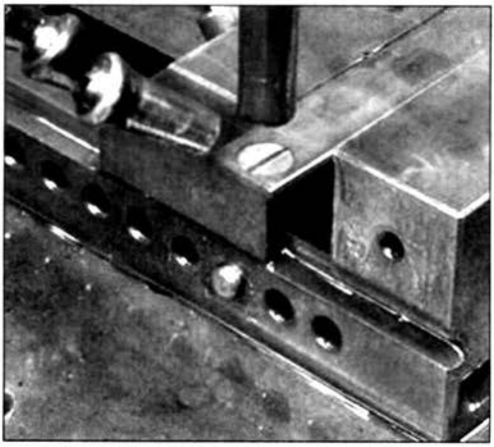
The gearmotor on my head has the motor shaft visible. I find it fascinating to watch the shaft "twitch" back and forth during a stable burn; imagine manually adjusting that gap! It can be done, but is not fun for very long.



[ ] Let the burn continue for about 5-10 min. Turn the generator off and make sure the capacitors are fully discharged at the end of a burn, or before changing electrodes. Use an insulated wire to short from the electrode to the workpiece after the generator is turned off. Drain the fluid, remove the workpiece, and observe the cut. The photo on page 121 shows the suggested first burn, just before removing it from the dielectric tank.

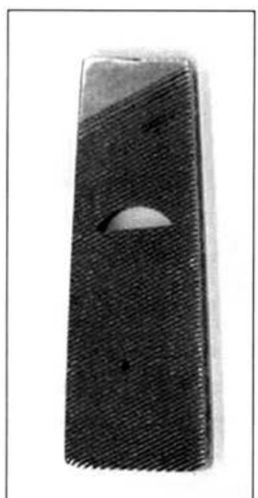
[ ] You may want to experiment with different surface finishes by doing another burn with different capacitor switch combinations. Remember to turn the generator off or retract the electrode before changing the capacitor switches.

From here on, you are an official EDMer!! Be creative and try different electrode sizes and materials. Try different workpiece materials: hard stuff as well as soft stuff. Don't forget to try reversing polarity if the burn is unstable. Just experiment have fun and make some money as well!



Sample of EDM parts

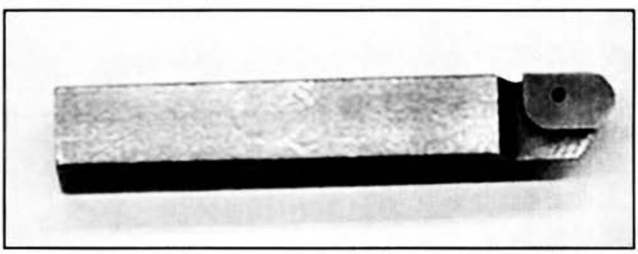
All of the examples shown in this book use the EDM system outlined in the book, unless otherwise noted. The photos below show part of a file with several sample burns made in it, along with the electrodes which were used. The



cuts made in the file serve no purpose, other than to illustrate the capabilities of this small machine. The burn on the left is a 1/2 "blind hole with protrusions into the circle.

The specifications are (CCW) 3/16" square, 1/64" square, and a 1/8" square with a radius end. The latter has a.043 diameter. hole cut through. The small hole took about 4 minutes using only the 20 mfd finishing capacitor. The electrode for the small hole was tungsten carbide. The burn with the tungsten Carbide was not extremely stable, but the mission was accomplished. The second burn is a blind hole and a through hole made with a single electrode. The "D" shape is 17/32" across the flat side. The off center boss is 5/16" diameter. The file is a little over 1/8" thick. Both burns were extremely stable with the noted exceptions. Each burn took approximately 12 minutes each. The photo to the right on page 221 shows the back side of the same file.

The photo below is a standard C-6 cemented carbide, with a hole through the carbide. The burn of the carbide was not very stable and the progress is rather slow.



Remember, carbide is a semi conductor, which makes cutting it difficult. I find that a copper or brass electrode burns very nicely into carbide with this machine, but expect considerable electrode wear. If, for some reason cuts are need in carbide, you now have limited capabilities to do so with this EDM machine.

Appendix

The complete EDM system parts list.

Generator items available from Radio Shack

www.Radioshack.com
1-800-843 74225

Radio Shack (276-1712) LM339 Quad Comparator
Radio Shack (276-168) Component P C Board
Radio Shack (276-1381) 10 mm standoffs, **four req**.
Radio Shack (276-1999) 14 Pin DIP socket
Radio Shack (276-1998) 16 Pin DIP socket
Radio Shack (276-1771) 7812 fix (12 volts) regulator
Radio Shack (272-1030) 470 mfd 35VDC capacitor
Radio Shack (276-1388) PC board terminals **two pkgs.**
Radio Shack (271-1321) 1K ohm resistor
Radio Shack (271-1335) 10K-ohm resistors
Radio Shack (271-1341) 33K ohm resistor
Radio Shack (900-0558) 47K 2-watt bleeder resistor
Radio Shack (271-1347) 100K ohm resistor
Radio Shack (271-1716) 50K potentiometer
Radio Shack (274-402) knob
Radio Shack (61-2859) AC power cord
Radio Shack (270-362) panel mounted fuse holder
Radio Shack (270-1066) 4-amp fuse
Radio Shack (64-3025) vinyl grommet
Radio Shack (276-1152) 1.4 amp rectifier
Radio Shack (276-1181) 6-amp rectifier
Radio Shack (273-1512) 25VAC transformers, **two req.**
Radio Shack (273-1365) 12VAC transformer
Radio Shack (275-603) 115V SPDT on off switch
Radio Shack (275-324) mini toggle switches, **two req.**
Radio Shack (275-1547) push switch, **two req.**

Radio Shack (276-012) bicolor Led
Radio Shack (276-079) LED holder
Radio Shack (274-246) (stereo) 1/8" jack
Radio Shack (274-284) (stereo) 1/8" plug
Radio Shack (276-1144) 3-amp rectifier **two req.**
Radio Shack (274-730) banana plugs.
Radio Shack (274-725) banana jacks
Radio Shack (78-1221) hook-up wire
Radio Shack (270-343) and (270-344) charger clips
Radio shack (278-1627) heat shrink
Radio Shack (273-242) cooling fan 3"
Radio Shack (276-1372) heat sink grease
Radio Shack (64-2346) self-sticking rubber feet
Radio Shack (278-001) alligator clips optional
Radio Shack (64-3057) wire nut optional
Radio Shack (22-410) DC panel meter optional

Generator items not available from Radio Shack

The following items are from
Parts Express
1-800-338-0531
http://www.partsexpress.com/
20 mfd polypropylene capacitor
part number 027-436 **two required**
****
The following items are from
All Electronics Corp.
1-888-826-5432
http://www.allelectronics.com
All Electronics frequently have photo flash capacitors in stock, the minimum spec. are 100 mfd @ 125VDC.

Another option is to recycle the photo flash capacitor from a disposable camera. Most are rated for 120 mfd @ 330VDC

The following items are from
Allied Electronics
1-800-433-5700
WWW.alliedelec.com
Servomotor driver chip
Stock number 7354048
Manufacturer type SN754410NE
****
Heat sink for servo driver chip
Stock number 619-6047
****
Electronic project box (3 1/2 x 6 x 10")
Part number 736-3643
****
20-ohm 50-watt power resistor
Stock number 895-1221
Manufacture type HL50-06Z **two req.**
****
Hardware kit to mount resistors
Stock number 895-1091
Manufacture type 101 **two req.**
****
The filter capacitor is a 25X40 mm
(160VDC 1000 mfd)
Stock number is 613-0408
*****
6.8 mfd capacitor
Stock number 881-7177

Parts list for servo head

Assuming you are not building the servo head, an alternative is to buy an aircraft trim servo. They may be purchased directly from the manufacturer.

The Ray Allen Company
2525-8 Pioneer Ave.
Vista CA 92081
Ph# 760-599-4720
http://www.rayallencompany.com/products/servos.html
There are two versions that I have used successfully,
T2-10A has 1" travel $119 (2005)
T2-12A has 1.2" travel $139 (2005)
****
The above head is mounted on a piece of angle (see text)
1 1/2" x 3" x 1/8"
****

The following items are needed to build the servo ram

Small replacement 3/8" hand drill chuck
****
1" length of 1/2" square steel (brass preferred) key stock
****
3/8" diameter cold roll steel 4 3/4" long
****
Two part epoxy glue, such as JB weld
****
Nylon washer and wavy washer
3/4" square x 1 1/4" long delrin, nylon or similar plastic
****
3/4" square steel tubing 3 1/4- -to 4 1/4" long (not critical)
3/8" bolt 3" long
1 1/2" diameter stainless steel hose clamp

The mechanical slide is made from a modified drawer slide.
Knape &Vogt KV1129PZC16 rated for 35 pounds.
*****
Pittman 12VDC gearmotor or similar (see text) are available from surplus suppliers listed later in the Appendix.
The following companies carry miscellaneous hardware

Small parts
http://www.smallparts.com

Pic Design
http://www.pic-design.com/

Parts list for dielectric tank

The Molded Fiber company model 814-308 (Toteline) fiberglass container is available from U.S Plastic corp.
www.usplastic.com
The US plastic stock number is 51005

A smaller tank 17 7/8 x 11 1/4 x 6 (which works nicely with a single filter but requires custom design work) of similar design is also available. U.S Plastics, stock number 51083
*****
Thru-Hull large diameter, connectors called cockpit drains are sold by the Attwood company. I do not have a physical address or phone number for the Attwood company.
http://www.attwoodmarine.com

Plastic Welder 5 minute epoxy made by
Devcon
Ph# 508-7771100
http://www.devcon.com
****
The dielectric pump is available from
Grainger Industrial supply
www.grainger.com
Grainger pump model #2P407

This same pump is available from the Beckett Corp.
www.888beckett.com
Beckett's pump number is G600AVS

aluminum plate 12" X 15" X 3/8"
****
Dual and Single filter mounts maybe purchased directly from
Jegs High Performance
http://www.jegs.com

The single filter part # is 771-111
The dual filter part # is 771-1221

They are also available from
http://www.holleyreman.com
The single filter part # is 2277ERL
The dual filter part # is 2377ERL
***
Spacer block measuring 5 1/2 X 2 X 3/4"
****
Ping-pong ball
****
Threaded rod 1/4-20, a length of 9 1/2" required
****
Four 1/4-20 nuts
*****
One 5/16-18 nut
****
A 2" length of 1/2-diameter aluminum rod with a thru hole
****
The following 3/4" PVC items are needed
Three feet of 3/4" schedule 40 PVC pipe
****
Two 90° elbows
****
An end cap to fit the PVC pipe
****
Three male and one female-PVC threaded couplers to match the oil filter mounts and pump, most likely 3/4" NPT

At least one straight PVC coupler 3/4"
****
An adapter 3/4" NPT (pipe thread) to a garden hose thread.
****
A garden hose "Y" and straight shut off valve
****
Male brass 1/2" garden hose replacement end
****
A 3" length of 1/2" copper tubing and a 45 deg elbow
****
Two feet of 18 gauge solid copper wire
****
Household light switch, 120VAC
Only use a **metal** switchbox
****
From the **Loc-Line** company
http://www.loc-line.com
Purchase at least one male 1/8" NPT valve, and one round 1/8" nozzle, and a foot of the Loc-Line.
****
Angle iron 22"X 2X 1/8"

List of surplus houses

Surplus Center
1015 West "O" St
Lincoln Nebraska 68501
1-800-488-3407
http://www.surpluscenter.com

C and H Sales Company
2176 E. Colorado Blvd.
Pasadena. California 91107
1-800-325-9456
Http://www.candhsales.com

Fair Radio Sales:
2395 St Johns RD
PO Box 1105
Lima, Ohio 45802
419-227-6573
419-223-2196
http://www.fairradio.com

All Electronics Corp.
P.O. Box 567
Van Nuys CA 91408
1-888-826-5432
http://www.allcorp.com

Glossary

Ammeter - An instrument for measuring electrical current in amps.
Amperage - The amount of average current measured while cutting is taking place.
Ampere - The unit of electric current produced by 1 volt across 1 ohm of resistance.
Anode - The positive terminal of a cell. Often applied incorrectly to the EDM electrode.
Arc - A continuous flow of electrical current (also known as D.C. arcing) between the electrode and workpiece. It is an undesirable condition and is normally recognized by a yellow flash.
Arc suppressor - A circuit in the control section of an EDM machine that reduces the possibility of arcing.
Automatic depth finder – An electrical device that stops the EDM ram slightly above the workpiece and maintains that position.
Average current - The average value of all the minimum and maximum peaks of amps flowing in the gap.
Burning - A slang term for the EDM process.
Capacitor - An electrical device that stores a charge. It is used in some power supplies (mostly older) designs. It is also used occasionally in newer supplies to intensify the spark with increased electrode wear.
Carbon - A natural occurring material used to make graphite. Many times it's used (slang) to describe the electrode material made of graphite.
Cathode - The negative terminal of a cell. Often applied incorrectly to the workpiece.
Circuit - A continuous path for the flow of electric current.
Condenser/condenser - An outdated term used to describe a capacitor.

Conductor - A material which will carry electric current.
Contamination - The accumulation of debris in the dielectric fluid which results in a decrease in the fluid's dielectric strength.
Coolant - See dielectric.
Copper graphite - A graphite electrode material infiltrated with copper.
Copper tungsten - A porous tungsten material infiltrated with copper.
Core - The slug that remains after EDMing with an electrode that has a flush hole in it.
Corner wear - The wear which occurs on the corners of an electrode (the highest wear area).
Crater - The small cavities (pits) left on the surface of the workpiece by the EDM sparks.
Cubic inches per hour - The unit of measure used to describe the rate of metal removal from the workpiece.
Cut - To machine with the EDM process.
Cutting rate - Same as machining rate.
DC arcing - See Arc.
DC/Direct Current - Constant polarity current, as opposed to Alternating Current (A/C) which changes polarity from negative to positive in cycles.
Deionization – A return of the dielectric to a nonconductive state. Failure to reach this state is a major cause of DC arcing.
Depth of crater - The distance from the peaks to valleys on the workpiece.
Depth to diameter ratio - The ratio of the depth of a blind hole compared to the diameter of the electrode used to make the hole.
Diameter (dia) - The straight line distance through the center of a round object.
Diametral sparking distance - The difference between the electrode dimension and the dimension of the hole produced.

Dielectric fluid - A light oil which insulates the spark gap between the electrode and the workpiece until a high voltage ionizes the spark gap and causes it to become an electrical conductor. This ionization permits an electrical current to flow through the dielectric to the workpiece. The dielectric also serves to cool the work and to flush away the particles removed from the workpiece.
Dielectric strength - The voltage at which the insulating qualities of a material break down.
Discharge - The EDM spark.
Discharge channel - The conductive path formed by the ionized dielectric and vapor between the electrode and workpiece.
Dither - A vibrator motion of the electrode used to improve cutting stability.
Down feed - A control circuit to advance or retract the electrode.
Duty cycle - The percentage of the on-time relative to the sum of the on-time and off-time setting for a particular cut.
Edge finder - An electrically activated device to aid in the accurate location of the workpiece with respect to the electrode.
EDM - Electrical Discharge Machine or Electrical Discharge Machining. A metal removal process using a series of electric sparks to erode material from a workpiece.
EDG - Electrical Discharge Grinding.
Electrical resistively - The resistance of the flow of electricity measured in ohms.
Electrode - A tool used in the EDM process most commonly made of copper or graphite.
Electrode growth - A plating action occurring at certain low wear settings, which causes workpiece material to build up on the electrode, causing it to increase in size.
End ware - A reduction in the length of an EDM electrode during EDMing.

Eroding - Material removal by the EDM process.
Farad - The unit of electrical capacitance. One farad= a potential of one volt when charged by one coulomb.
Filtering - The removing of debris from the dielectric fluid before being pumped back to the work tank or through flushing holes in the electrode or workpiece.
Finish - the surface texture produced by EDMing.
Finish cut - The final cut made with EDM on the workpiece. The finer the finish the longer it will take for the finish cut.
Flashpoint - The temperature at which any flammable material will burst into flame.
Flush pot - A multipurpose box- like fixture, which is clamped to the machine worktable. It is primarily used when EDMing through-holes. The workpiece is clamped to the box top, (over a predrilled hole or opening) that will permit an electrode to pass through the workpiece with out interference from the tank's top plate. When connected to the dielectric system it can be used for either suction or pressure flushing.
Flushing - Flowing dielectric through the gap to remove the debris caused by machining with EDM.
Flush hole - A hole through the workpiece or electrode used to introduce dielectric fluid to the gap for flushing away debris.
Frequency - The number of cycles (on/off)completed per unit of time. Usually expressed in Hertz.
Gap - The distance between the electrode and workpiece. Also referred to as spark gap.
Gap voltage - This can be measured as two different values during one complete cycle. The voltage that can be read across the electrode/workpiece gap before the spark current begins to flow is called the open gap voltage. The voltage which can be read across the gap during the spark current discharge is the working gap voltage.
Generator - An old term for EDM power supply.
Graphite - The most commonly used material for EDM

electrode in the U.S.. It has very high heat resistance and transfers electric current very efficiently. In Europe copper is the most common electrode material

Head - The part of and EDM machine which houses the ram or quill.

Heat Affected Zone (HAZ) - Also called the "recast layer". The depth of heat penetration altering the parent materials metallurgical structure due to the EDM process. The depth ranges from .0002 to .008 depending on material and energy per pulse.

Hertz (Hz) - The international term for one complete electrical wave cycle. In EDM, the unit of frequency.

Hunting - An erratic bouncing movement of the ram during a cut caused by poor flushing conditions.

Injection flushing - An external flushing method also known as jet flushing.

Initiation voltage - Same as open gap voltage.

Insulator – A material (such as rubber) which blocks the flow of electric current.

Ionization - Generally accepted as a phenomenon by which the dielectric between two points on the electrode and workpiece become electrically conductive.

Ionization voltage - The voltage at which current flow begins across the gap.

Ionized path - The path of electrically conductive dielectric molecules (between the electrode and workpiece) through which the spark current will flow.

Lateral flushing - Same as surface, splash, jet flushing.

Low wear - Settings for EDM machining which produces a very low degree of wear on the electrode. In some cases less than 1% wear is possible.

Machining rate - Same as metal removal rate. The rate at which material is removed.

Metal Removal Rate (MRR) - The rate at which material is removed from the workpiece by EDM, in cubic inches/hour.

Microfarad - One-millionth of a farad.
Micron micrometer - A unit of length equal to one-millionth of a meter.
Micro inch - One-millionth of an inch (.000001).
Microprocessor - A computer-on-a-chip. Found in all advanced EDM systems. The microprocessors provide many control functions.
Microsecond - One-millionth of a second (.000001).
Millisecond (ME) - One thousandth of a second (.001 sec.).
Miss - A pulse that does not produce metal removal.
Modular construction - In EDM a type of power supply where entire circuits are integrated on boards or modules. This makes possible rapid servicing and replacing.
Monitor - In EDM work, any mechanical or electrical device that is used to indicate various operating conditions.
Multiple electrode - The simultaneous use of two or more electrodes to produce cavities in workpiece/s.
Multiple lead power supply - One power supply with multiple independent power leads.
Nanosecond - One millionth of a second (.000001 sec.).
Non-directional finish – A finish having no specific direction to its surface pattern. An EDM finish is non-directional.
Normal polarity - Negative polarity to the electrode.
Off time - The time between sparks, measured in microseconds. To short an off-time may result in DC arcing.
Ohm - A unit of electrical resistance. Current flowing in a conductor of one ampere produced by a potential of one volt.
Oil through chuck - A sealed holder for tubular electrode through which dielectric fluid can be pumped or drawn.
On time - The duration time of the EDM spark measured in microseconds.
Open circuit - An electrical circuit that is not complete.
Open gap voltage - The voltage between the electrode/workpiece before current begins to flow.

Output - The voltage and current of an EDM power supply.
Overcut - An EDM cavity is always larger than the electrode used to machine it. The difference is called the overcut. Diametral over cut is most often used.
Pause - Same as off time.
Peak current - The maximum current available from each pulse from the power supply.
Percent electrode wear - The volume of electrode worn away as compared to the volume of workpiece worn away.
Platen - A large flat mounting surface affixed to the end of the ram of an EDM machine.
Polarity - In EDM, the designation of positive or negative electrical potential to the electrode.
Potential - The difference in voltage between two points of an electrical circuit.
Power supply - The part of the EDM system that supplies the voltage and current that causes the sparks or discharges between the electrode and workpiece.
Pressure flush - The forcing of dielectric through flush holes in the workpiece or in the electrode.
Pulse - The discharge of a quantity of electrical energy having preset voltage and amperage and expended over a preset time.
Pulse duration - Same as on-time.
Quench - The rapid cooling of the EDMed surface by the dielectric fluid.
Quill - See Ram.
Ram - The moving member of and EDM machine on which the electrode or electrode holder is mounted.
RC (relaxation) circuit - An outmoded EDM power supply circuit that uses capacitors to store the charge that produces the spark at the gap.
Recast layer - A layer created by molten metal solidifying on the work surface.

Rectifier - An electrical device that converts alternating current to direct current.
Relaxation circuit - See RC circuit.
Reverse burning - The technique of mounting the electrode on the machine table and the workpiece on the ram.
Reverse polarity - A term used to indicate positive polarity to the electrode.
RMS (Root Mean Square) - An obsolete term used in surface finish measurement.
Rotating spindle - A device used on EDM machine used to rotate the electrode to achieve more uniform wear and to improve flushing conditions.
Roughing - The mode of EDM that removes the most material in the shortest time.
Secondary discharge - A discharge that occurs as conductive particles are carried up the side of the electrode by the dielectric fluid.
Servo- mechanism - The device that drives and controls the movement of the ram.
Side wear - The wear along the sidewalls of the electrode.
Silicone - A dielectric fluid for special situations consisting mostly of the chemical polymer silicone.
Solid-state power supply - A power supply that uses transistors in the circuitry.
Spark - An electrical discharge of very short duration between two conductors.
Spark erosion - Another name for EDM. Used primarily outside of the U.S.
Spark gap - The distance between the electrode and the workpiece when discharges are occurring.
Spark intensity - The amount of energy in the spark.
Split electrode - Multiple electrodes on a single machine electrically insulated from each other.
Square wave - A term for an electrical wave shape generated by a solid-state power supply.

Stability - The steadiness of an EDM cut.
Stepped electrode - An electrode constructed in such a manner s to allow the roughing and finishing of a through-hole cavity in a single set up.
Stroke - The distance the ram travels under servo control.
Suction flushing - Using a vacuum to draw the contaminated dielectric away from the gap.
Surface finish - The relative roughness or smoothness of a machined surface.
Surface integrity - The quality of the machined surface and subsurface.
Surface flushing - The use of nozzles to direct jets of dielectric at the cutting area to flush away debris.
Surface roughness - Surface irregularities on a machined surface.
Taper - The dimensional difference between the entrance and exit opening of a through-hole cavity.
Through hole flushing - The use of a pre-drilled hole in the workpiece to inject dielectric fluid up toward the gap by injection flushing or down from the gap by suction flushing.
Timer - A control unit that controls spark on and off time.
Transistor - An electronic component used as a switch to turn electrical current on and off.
Trepanning electrode - A hollowed out or tubular electrode which is used in through-hole machining to remove a large amount of material from the solid to avoid pre-machining by conventional means.
Unstable - Erratic or intermittent EDMing.
Vacuum flushing - see suction flushing.
Vacuum tube power supply - An old power supply design which used vacuum tubes to switch the machine pulses on and off.
Vibrator - An accessory used to move the electrode back and forth rapidly primarily for improving flushing.
Viscosity - The tendency of a fluid to resist flow.

Voltmeter - An instrument that measures voltage.
Volumetric Wear - The total wear of the electrode expressed in cubic inches.
Waveform - A geometric display of the output of a power supply as seen on an oscilloscope.
Wear - The erosion of the electrode during the EDM process.
Wear ratio - The volume of electrode worn away as compared to the volume of workpiece material removed by EDM.
Wire EDM, WEDM - An EDM process where the electrode is a continuously moving conductive wire that moves in preset patterns around he workpiece.
Working gap voltage - See gap voltage.
Workpiece - Any part on which EDM is being used to cut holes or cavities.