Desk Top Engineering Project

W-EDM

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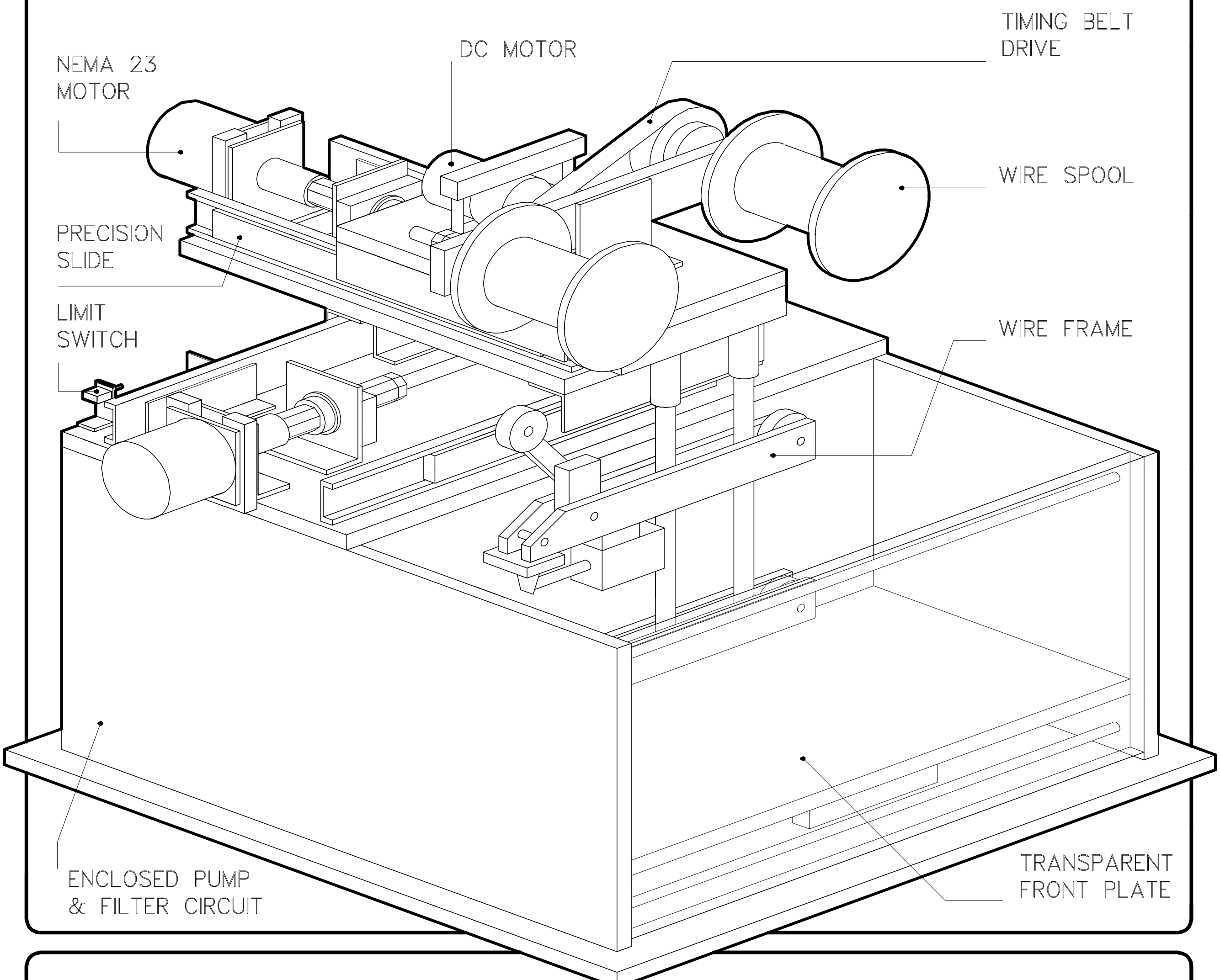

A Manual for the Creation of a Desk Top Sized CNC WEDM Unit

Version 1.0

Includes Software

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Please see the section titled "Safety Protocol".

Desk Top Engineering Project, W-EDM, Version 1.0 by B.J. Rao
W-EDM Testware for DOS Version 1.0 by B.J. Rao
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To the Home Engineer

Creating more with less

Introduction

Spark Erosion, or more commonly known as Electrical Discharge Machining (EDM), is a special type of machining technique. It's essentially based on the localized erosion of a work piece through repetitive electrical spark discharges. The tool, which delivers the discharges, slowly erodes into the work piece and its inverted profile is thereby formed into the material.

There are several variant EDM machine configurations in existence. One type that has endured much attention in recent years is Wire EDM. Here the tool is a very thin strand of electrically conductive wire. The wire has no cutting edges and mechanically it has little significance in comparison to a drill bit or saw. Yet coupled to an EDM circuit the wire can cut through just about any electrically conductive work piece regardless of hardness.

EDM has gone through an extensive amount of development and has proved to be a very useful machining technique. In this development Wire EDM, or W-EDM, has become a distinct class of spark eroding machining techniques. Today it can be found in most all high-tech workshop environments.

Interestingly, the EDM process is not a high speed machining technique, in fact it is very slow. Yet this has not caged its development and wide spread application. It carries other attributes like high precision machining capacity and the ability to work materials that are too hard or brittle to form using conventional mechanical techniques. This allows the machinist to create highly complex intricate precision parts. Parts which could sometimes not be produced efficiently by other means or not at all.

This manual describes the building of a W-EDM unit. It's a highly simplified, desktop sized version of its W-EDM industrial counterpart. The unit is a 2-axis computer controlled system, which uses the PC's parallel port as the communications channel. The EDM power supply is a 300+ Watt capacitor discharge chopper circuit. The unit can be used to cut through just about any electrically conductive material. Its application may be for simply making very thin cuts in a work piece but it can also create more complex design geometry.

The W-EDM unit described here has been designed in such a way that lathe/mill work is not required. Anybody with basic home machinery and tools, and naturally some good electrical/mechanical know-how, can create their own home made Wire EDM setup. Provided that certain materials can be purchased pre-sawed, to the required dimensions, the main manufacturing task is drilling holes. A good quality drill press and vise is the only real machine needed to complete the unit.

Software is also included in this publication. It's test software or “Testware”. This will control and test the unit’s workings and allow it to perform basic machining tasks. Explanations are also provided, which permit a general insight into the workings of PC controlled machinery.

The chosen design concept is based on various criteria. One of which is to bypass the severe economical constraints and electrical/mechanical complexities usually coupled with a machine of this type. Every aspect possible, from the design to the assembly, has been stepped down to the most basic and cost effective level. This has also been applied towards the complexities involved in operating a machine of this type. Like any machine operation there are certain aspects that must be understood through theory as well as experience. Machine operation requires the adjustment of many parameters. The design attempts to simplify these to a level that will yield effective and efficient machining results. This while allowing the unit to still incorporate an acceptable degree of precision and durability to create a useful home built Wire EDM system.

Hopefully builders will construct the setup as described in this manual first before attempting any major modifications of their own. It can be a complicated instrument. Naturally builders may still choose other ways to construct the unit or make modifications to the design and workings of the system. Yet the unit described here has proved its design in practice. Building it first will then form the basis and provide insight. This will allow more complex EDM projects to be constructed with a greater certainty of success. Home shop innovation, which strives to do the most with the least, will be more effectively applied. However, although every effort has been taken to choose a design plan that incorporates common and available components this may not be the case everywhere. Modifications may therefore still be necessary. Use the design (then) as a guideline. Yet try and keep the modifications as limited as possible. The explanations regarding the operation of the process and the workings of the unit strive to illustrate and allow the builder to understand what is and what is not possible.

The building of the unit requires some skill. It is also a fairly big project, which may make it seem a bit overwhelming. This despite the consistent design plan. Naturally, time, attention and patience to manufacture and assemble the unit are the most important tools required. The explanations and drawings should first be looked over thoroughly before starting. Working precisely and systematically will ensure that unnecessary obstacles and errors are avoided. A properly working unit will then become the result of the labor invested.

An important aspect, that demands attention, is safety. Every attempt has been carried out to integrate this in the manual explanations and unit design. EDMing can be very dangerous and even fatal when used incorrectly. Liquids, electricity, flammable substances and sparking can be a lethal combination. Be alert!

One other aspect that needs to be mentioned is that certain terms and techniques used in the manual may not always completely correspond to industrial norms and technology. The project was devised by a home engineer for home engineers.

CNC machining and other related modern manufacturing and engineering techniques are steadily entering the home shop. This as information and components become more accessible and less expensive. The home machinist/engineer can adapt new technology into his/her workshop. More easily can ideas now be translated into tangible, functional products or even artwork.

As with this first manual it is hoped that more manuals will follow. There are several other machining processes and techniques, some known and some less known that the home machinist can incorporate. Your purchase of this manual, and the building of this unit, will invite the incentive to carry on and provide more publications. Publications that regard relatively inexpensive and easy to build yet versatile and useful machining units and instruments for your home shop and desktop.

If you have any questions, suggestions or comments regarding this publication please write to:

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Your feedback will provide you and future builders of a better publication package.

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Amsterdam 2001

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Fig.1 Wire-EDM in Action

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1. The EDM Process

The EDM process is based on the repetitive sparking between two electrically conductive surfaces namely the tool and the work piece. The sparking cuts into the work piece. It chips or, more precisely, erodes pieces away in very specific areas thereby machining it, electrically, into a new form.

Two of the most frequently employed EDM configurations are the Sink EDM and the Wire EDM setups. However, although based on the same idea their workings have some differences and require different process handling. Yet before going into more detail about the WEDM setup it is probably best to start off by explaining the essential EDM process based on the more conventional Sink EDM configuration.

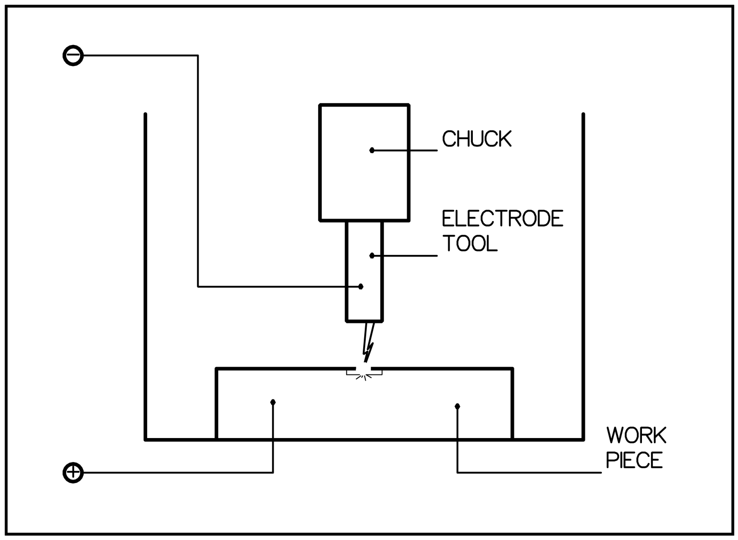


Fig.2 The Basic EDM Setup

1.1 Machining Basics

Short circuiting an electrical power source, by connecting its terminals together, via wires, will at the point of near contact cause a spark to jump the gap. An inspection of the surface of the sparked points will reveal that some of the material has been melted away. The spark has eroded a minute fragment of the material and left a small cavity.

Instead of wires, a metal plate (work piece) and a small diameter metal rod (electrode tool) can be used. The two are positioned closely adjacent to one another and placed in an electrical circuit. Bringing them closer together in a controlled fashion will at a certain distance cause a spark to jump the gap. This will result in the electrically induced erosion of the materials. Repeating the sparking over and over will cause the rod to slowly erode itself into the metal plate. The rod surface may be many times greater than the diameters of the sparks. Yet evenly distributed spark erosion will occur over the work piece. This is due to the fact that only the areas closest, between the electrode and the work piece, will more or less induce spark over. The reciprocal profile of the rod will slowly be eroded into the work piece. This is the basis of the EDM process.

A closer inspection of sparked surfaces may sometimes reveal that the cathode end (negatively charged part) displays less erosion than the anode (positive) end. Due to this characteristic the cathode is generally chosen as the tool (which is usually referred to as the electrode) in the EDM process. A more detailed explanation is as follows: The electrical tension between the adjacent electrode and work piece is at a maximum value before the spark exists. When these two surfaces are brought sufficiently closer together the electrical tension will cause the substance in between, for instance air, to breakdown, electrically. The air becomes ionized creating an electrical path for the current from the EDM power supply circuit to flow through. The effect is displayed as a spark, which jumps the gap. The current is made up of mobile charged particles called electrons. The electrons will travel from the cathode to the anode. This is because these particles are negatively charged and are attracted by the positively charged anode. The avalanche of electrons hit the anode surface very violently, generating enormous heat due to the mechanical impact of the electron bombardment. This is why the anode wears somewhat faster than the cathode. It's the target that the electrons are shot out at. The temperatures generated can reach levels of 6000-10000 degrees Celsius at the impact zone. This area is melted away, even partly evaporated, leaving a minute crater as the end result.

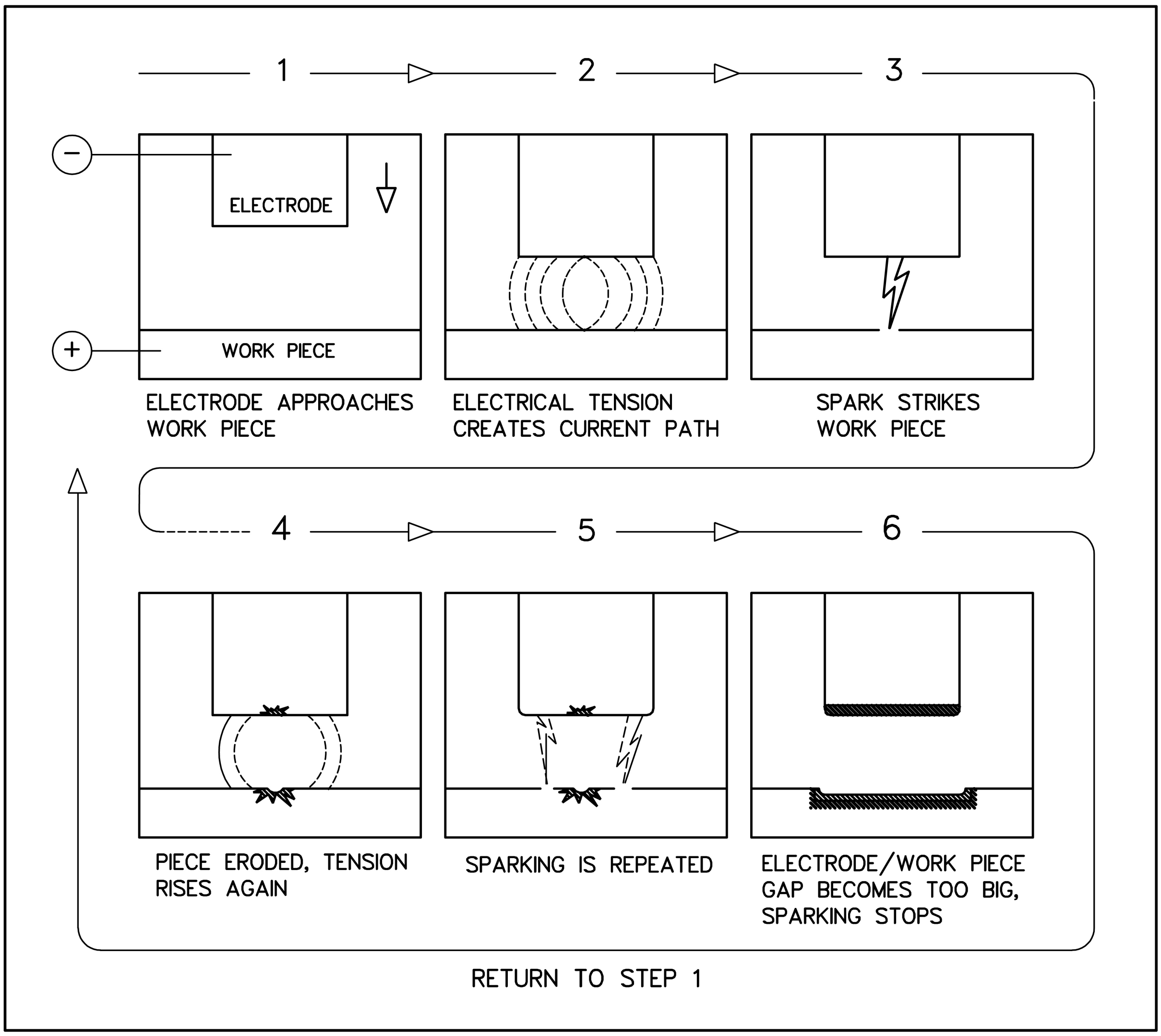


Fig.3 The EDM cycle

1.2 Spark Discharge Circuit

Creating the spark is achieved through an electrical discharge circuit. This can be based on an inductive circuit, capacitive circuit or a combination of the two. An inductive discharge circuit could be devised and would resemble that of a car ignition system. Yet it would operate at much greater current discharge values.

Capacitive discharge circuits are frequently used for EDMing. Capacitors offer simplicity and ruggedness and can release their electrostatic charge acutely. The immense power with which a capacitor can release its stored energy is similar to releasing a tightly compressed spring. When a spring is compressed and held in this state it has stored the energy used to compress it. Charging a capacitor is the same, only it stores electrical energy. If the spring is allowed to acutely unwind (the capacitor discharges) it will instantly release its energy at a very high power level. This high power level is achieved simply because the release time (or discharge time for a capacitor) is so short. Yet, if any resistance is encountered it will lengthen the time to release the stored energy. This will lead to the reduction of the power produced. Since the EDM unit described in this manual allows almost zero resistance discharges (practically short-circuited), the power level is consequentially high. The end result is that the sparking is like having many micro sized spring-loaded hammers slamming on the work piece, chipping pieces away bit by bit.

A basic capacitor discharge circuit would be comprised of the following:

- DC power source
- Capacitor
- Anode terminal (work piece)
- Cathode terminal (electrode)

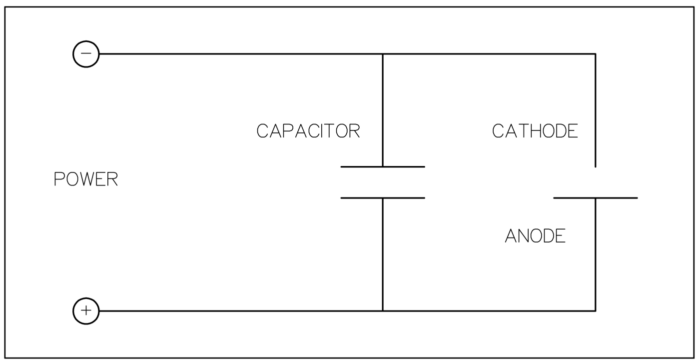


Fig.4 Basic Capacitor Discharge Circuit

The capacitor and anode/cathode gap are placed in parallel to the DC power source. The anode/cathode gap is in the “normally open” position. When the power source is activated the capacitor is almost instantly charged up. Closing the anode/cathode gap (bringing the electrode and work piece together) will, at a certain gap distance, allow a spark to jump the gap, instantly depleting the capacitor of its charge. Opening the gap would stop the electrical flow through the gap and allow the capacitor to charge up again. The sparking can then be repeated in the same fashion.

1.3 Spark Gap

The spark gap refers to the space between the electrode and the work piece. It represents the distance that is just about at the position necessary to allow a spark to jump the gap. This gap should be maintained throughout the erosion operation.

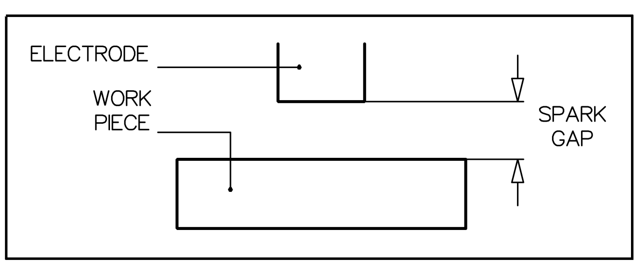
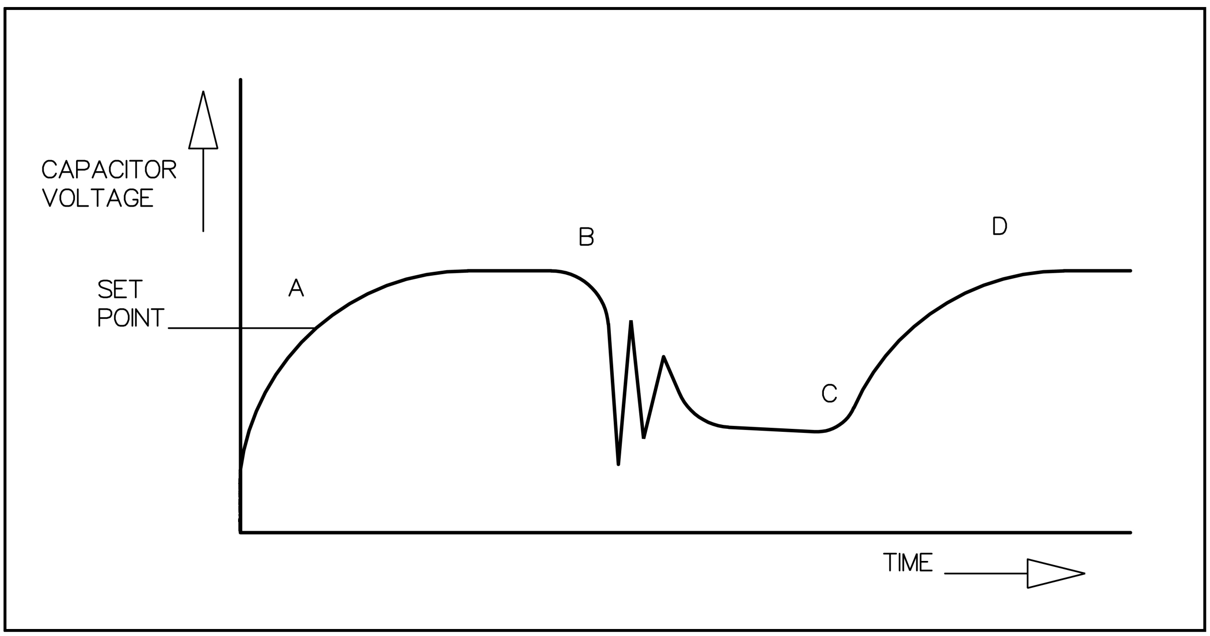


Fig.5 Spark-Gap

In practice, the tool almost lightly brushes against the work piece to yield a spark. The tool is then within the spark gap “strike zone”. Depending on certain parameters this can be as small as 100 um. However if the electrode makes more significant contact with the work piece it will constitute a short circuit and the process is disrupted or it may even crash. In this case, if the contact time is sufficient, the electrode will then have weakly welded itself to the work piece.

A feedback circuit attempts maintain the spark-gap distance. This circuit determines the state of the process over a certain parameter reference. This state is usually represented by the level of voltage over the EDM circuit capacitor. When the voltage is above a set reference point, the feedback circuit sends a signal to the PC and the motor feed is initiated. The electrode moves closer towards the work piece. As soon as sparks strike the work piece the capacitor voltage will quickly recede to under the set point. The feedback circuit immediately sends a signal to the controller (PC) and the motor feed is then "paused". The spark gap slowly increases as sparks erode the work piece surface. At one point the gap distance becomes too great for the sparks to strike. The capacitor now has a chance to fully recharge. The feed is then resumed as soon as the capacitor voltage is again above the set reference point.



A. Capacitor voltage is above set value, electrode moves towards work piece.
B. Electrode sparks work piece. Electrode feed is paused. Capacitor voltage recedes.
C. Gap becomes too big for strikes to continue due to erosion of work piece. Sparking stops.
D. Capacitor recharges and electrode feed is resumed as soon as the voltage again goes above set point.

Fig.6 EDM Capacitor Duty Plot

1.4 Electrode

Like any tool, the EDM electrode will start to wear the more its used. In comparison to normal cutting tools the EDM electrode wear can be very significant. As previously explained, the electrode (cathode) is the source of the discharge. The electrons are emitted from it and strike the work piece (anode). Although the work piece receives the greatest amount of mechanical/thermal punishment, the electrode is being attacked as well. Its profile will be reduced because of this. Sharp corners, for instance, will quickly become blunt.

Decreasing the amount of electrode wear can in part be achieved by using appropriate electrode materials. Relatively soft, low electrical resistance materials with high melting temperature appear to work best for most EDM applications. A soft material won't break away as easy as a hard material. The low resistance minimizes the amount of heat produced by the conducted electrical current. The high melting point of the material allows it to better withstand the thermal punishment.

Copper and its alloys are most frequently used for the EDM electrode. It's not always the best material but it scores "good" for most jobs. Copper is not that hard to machine. It's also sold in many different sizes and forms.

The type of material best suited for EDMing is dependent on the application. Graphite electrodes can be used for high removal rates. This can be for pre-working a desired profile. Graphite has a very high melting point. On the other hand for low removal rates where high precision is required, certain copper tungsten alloys may be best suited. These offer the best wear resistance.

1.5 Dielectric

Choosing the correct electrode material alone won't sufficiently retard its wear. In addition the discharges may tend to arc instead of spark, creating more of a messy oxidized melt of the electrode and work piece than a clean cut. Some other technique must be applied to reduce these adverse effects. This is best achieved by using a fluid to cool the electrode. The electrode and work piece are both submersed in a fluid or this is administered in the sparking zone.

Having the process perform in a liquid environment presents other benefits as well. One aspect is that the liquid serves as a flushing/rinsing agent. This by immediately carrying away eroded fragments from the strike zone, which may otherwise contaminate the workings of the process. Another aspect is that the liquid acutely cools the melted metal surface of the work piece after each spark, thereby promoting thermal shock. Micro cracks in the material are created by the shock and can cause fragments of the material to more easily break away (especially with hard materials). Hence, the thermal shock assists the erosion process and permits a more clean-cut surface.

However not all liquids will suffice for the EDM application. The conventional EDM process is an electrodynamic erosion process not an electrochemical erosion process based on electrolysis. What this means is that material is removed through localized spark discharges and not by the electrolytic break down of the work piece. The electrolysis process would eat up all the surface of the work piece (corrosion) and any other metal in the EDM circuit that is submersed in the liquid. It's the reverse of electroplating. To prevent this effect the fluid must posses sufficient electrical insulation. The level of electrical insulation is usually expressed as the dielectric value. High dielectric value equals out to high electrical insulation.

Fluids used for EDMing that have a sufficient dielectric value support the process in other ways as well. In particular with regard to the charging of the EDM capacitors and preventing arcing. When the fluid possesses a high enough dielectric value the capacitors have more frequent chances to charge up. This also occurs at a faster rate. This is because the current path from the electrode to the work piece, which is separated by the fluid, now takes more effort to be created and less effort to be extinguished (arc prevention).

As an EDM capacitor is loaded up with an electrical charge so does the voltage over it rise and consequentially over the spark gap as well. At a certain value the electrical tension (voltage) will break down the insulation of the fluid in the spark gap. The end result is a spark discharge. When the dielectric value of the EDM fluid is too low then the voltage over the capacitors will pre-maturely break down the fluid, electrically. This will create the current path too early. Little or weak sparking will occur since the capacitor did not have the chance to fully charge up prior to the subsequent spark strike. The surface of the work piece may also start to corrode.

There are several fluids on the market that are suited and even specially designed for EDMing. Most all of these fluids are hydrocarbon based. Some are in fact no more than low viscosity oils originally intended for lubrication of precision mechanisms. Apart from the fact that they are reasonably flammable, and most always corrosive, they can be quite toxic. Their use requires strict handling precautions (see Safety Protocol). In an attempt to try and avoid having to use commercial EDM fluids (which can also be costly) an investigation was carried out to find substitutes. Many different fluids were investigated, from anti-freeze to brake fluid to distilled water (under certain conditions pure water can be used). But the fluid that scored, on average, the "best" regarding its safety, cost and effectiveness was none other than house hold vegetable oil. The next best was lamp oil, also known as liquid paraffin. The ignition temperature of vegetable oil is relatively high, it's non-toxic and very inexpensive. Obviously it has its disadvantages (among other aspects, its messy) but it will perform well enough for most general jobs. Its foremost shortcoming is that it is not very thin (low viscosity). Hence, it’s wetting property is not that good. The importance of this is noticed when the surface of an EDM eroded work piece is inspected. The surface has somewhat of a bumpy melted appearance. This is in part due to the oil not being able to sufficiently wet the area being eroded (work piece material, capacitor settings and discharge output form also contribute heavily to this effect). Also, vegetable oil makes the workshop smell like fried chicken.

Vegetable oil is not easily ignited. Despite this, it is required, by established norm, that the sparking must occur at least 40mm under the surface of any oil used for EDMing (see Safety Protocol). Lamp oil is less thick in comparison to vegetable oil. It will perform better than vegetable oil but requires stricter handling as it is more easily ignited.

1.6 Work Piece

What types of work piece material can be used in an EDM process? Obviously the work piece must be electrically conductive. Besides metals, there are some technical ceramic materials that meet this requirement as well, like (Silicon Carbide) SiC. Some materials will be better suited for EDMing than others. This depends on several factors. Not surprisingly, harder materials usually work better than softer materials since the bombarded area in the strike zone can more easily be broken away. The choice of electrode material also has bearing on the EDM capability of a certain work piece material. For instance, a hard steel work piece using a copper electrode gives good results.

1.7 Wire Tool Setup

As explained in the previous sections, the EDM tool is an electrically conductive material and has a form or profile that can be reproduced in a work piece. This allows one to design and create a broad range of shapes that a work piece can be formed into using the Sink EDM process. WEDM is nothing more than a special variant with a specific type of EDM tool configuration. Yet in practice it also entails somewhat different process management and a more complex mechanical setup.

In a WEDM setup the electrode tool is a tightly tensioned strand of thin, electrically conductive wire. The wire is usually reeled through a framework of guides and pulleys. Unlike the Sink EDM tool, the wire tool is not clamped in. Instead the wire is continuously being replenished during the erosion process as it is slowly reeled off from one spool onto another. Here lies an important difference in the two techniques. In the SEDM setup more or less the same surface of the tool forms the spark interface throughout a machine task. With WEDM, the wire is moving and the work piece receives a new fresh segment of wire every other moment.

In practice the WEDM unit will require an EDM circuit with more precise control than that of the SEDM system. A SEDM spark circuit will usually be designed to provide relatively long duration, fat spark strikes. The WEDM circuit, however, requires high frequency, short duration spark strikes. One important reason for this is wire breakage. The wire can not withstand long duration spark strikes since the wire is thin and is under a certain degree of mechanical tension. Chances are that the extended electrical current time will cause the wire to melt through, pull apart and break, resulting in machine down time (the tedious task of having to reel the wire through again). High frequency pulsing, in which the mean power value is consequentially higher, can be tolerated without serious loss of the form integrity of the cut. This despite the surface damage to the wire profile. This is due to the fact that new wire is entering the strike zone and replacing the old almost immediately.

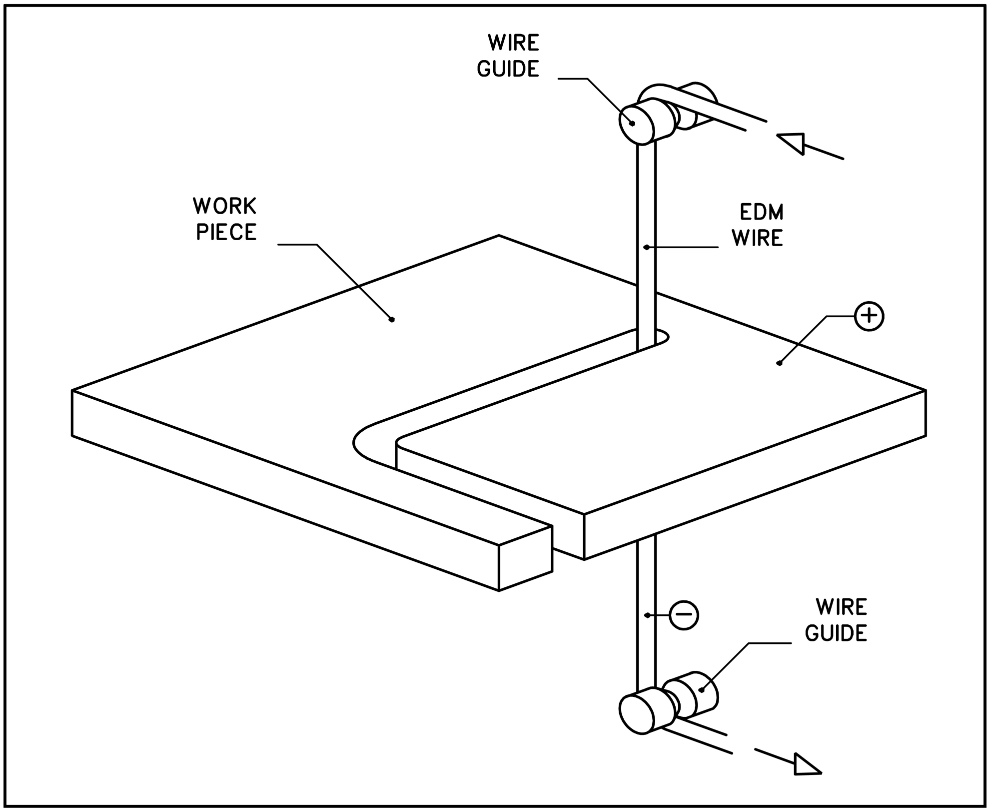


Fig.7 Basic Wire EDM Setup

2. EDM Background and Applications

The erosive nature of electrical discharges of high current between two terminals (cathode and anode) had been demonstrated many years ago. Benjamin Franklin was probably the first to document this. Years later it became a well know phenomena considered, by most, to have an impairing effect on the workings of electrical contacts and switches. That was until about the 30's when this phenomenon was applied to machine materials. Some time later someone had the bright idea to use a thin piece of wire as the electrode tool and the development of the W-EDM configuration was started.

Today several manufactures now produce precision machines that cut at relatively high rate with precision deep into the micrometer range. These machines incorporate multiple axis computer control with just about every feature applicable. Computer control has taken over much of the inherent complexities related to this type of machining process. This leaves more room for the machinist to create the desired parts quickly and with a greater degree of accuracy and certainty. Yet this all comes with a price tag. These units can cost many, many thousands of Dollars.

EDM is most traditionally and frequently applied towards the manufacturing of dies for producing injection-molded products. It is also applied for the fabrication of profiles that could not be produced by other means. For instance cooling holes in turbine engine blades (SEDM). To date a length to diameter ratio for boring holes is as much as 100 to 1.

There are essentially 3 distinct EDM setup's in existence, namely: Sink EDM, Wire EDM and Mill EDM. Mill EDM is a combination of Sink EDM and conventional milling. Two (sometimes more) additional axis have been integrated into the setup. Mill EDM requires, more or less, a greater degree of process control and regulation than W- or S- EDM. Mill EDM is generally applied towards small machining tasks in hard or brittle materials. The significance of EDM Milling has been lean in comparison to WEDM and SEDM, which endure widespread application. This may however change when very small work pieces with unconventional micro geometry become more required. This as industry steps into micro systems technology and subsequently into nanotechnology.

3. Previous Setups

The WEDM unit design described in this publication came about after several previous setup's had been built and tested. Development started at ground zero.

Initial EDM units were made using a small transformer. The output was rectified and connected over a capacitor bank. By taping the electrode on the surface of a work piece the circuit would be closed and sparks would be created, thereby eroding the surface. Each time the electrode was pulled up the circuit was opened permitting the capacitor to recharge. Using this setup, inscriptions could be made. But its cumbersome workings and limited performance left much to be desired.

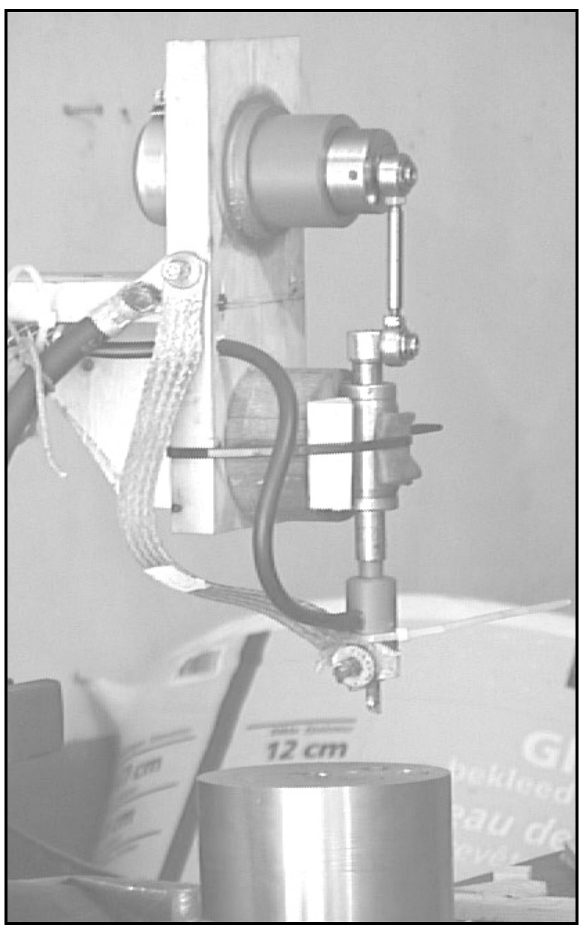


Fig.8 Experimental EDM unit

One of the first high power units built used an old electroplating transformer as the EDM power supply. The transformer was rated at 1000 watts. Its rectified pulsating output could supply in excess of 100 Amperes. This was an inductive system. A small diameter copper tube served as the electrode. The electrode was made to tap up and down with a stroke of about 3mm at around 200 RPM. This was realized using a simple self-made crank mechanism, which was driven by a variable speed power drill. Each time the electrode made contact with the work piece a current would flow through, heating the contact point. The electrode would then be retracted by the crank mechanism and sparks would fly. When an inductive system breaks contact the self-inductance wants to counter act the break in supply current. The result is high electrical tension, which produces a spark between the break point (just like an engine ignition system). The spark blasts the heated material away and eventually erodes a path for the electrode to sink in. To extinguish the spark and prevent arcs from forming, water was pumped at a high rate through the electrode. This also cooled the electrode and flushed the eroded material away. The water was pumped using an old washing machine pump in a closed circuit filtered system.

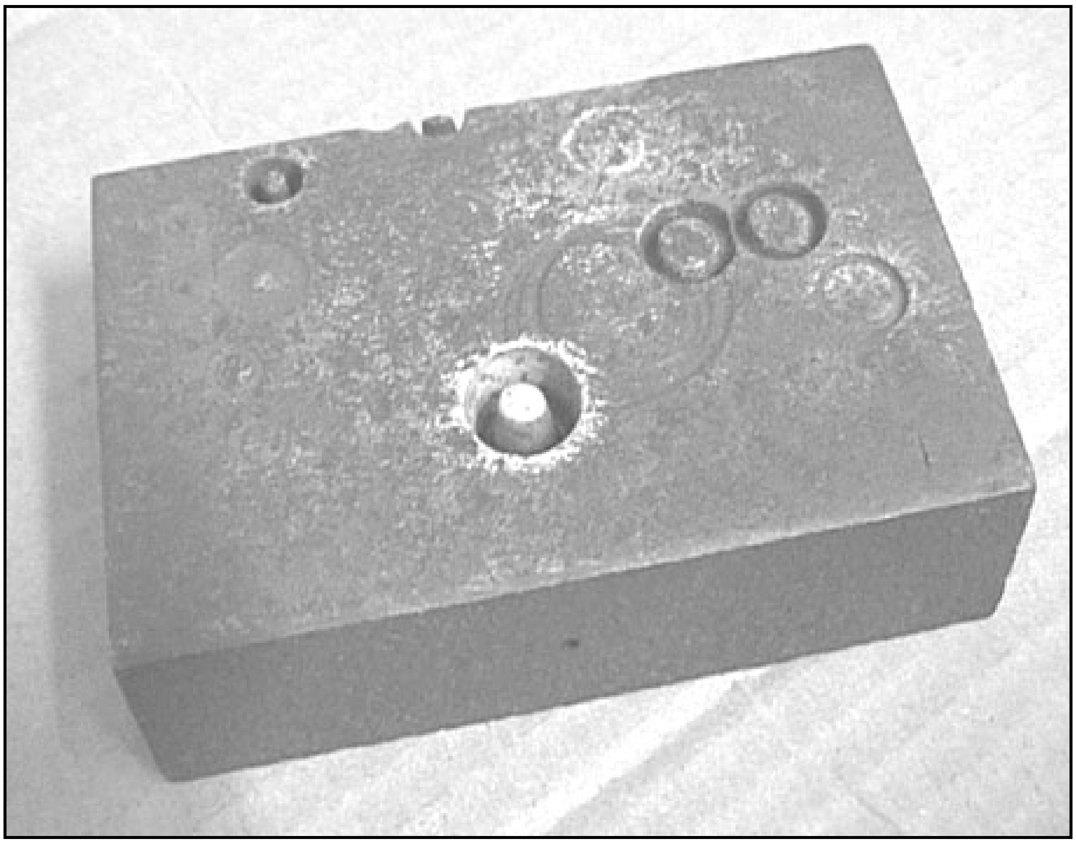


Fig.9 Test Piece

The unit was adapted to an old machine with a manual feed z-axis to move the electrode in a controlled fashion. Due to the high current, the electrode would quickly work its way through the work piece (the surface had a sand blasted appearance). However the system would overheat just as fast. The electrical spikes in the circuit where probably also polluting the mains. To remedy this, some current limiting electrical load would have to be placed within the circuit. Light bulbs proved adequate. They can dissipate the generated short circuit heat and also act as progressive current limiters.

Other tests where made using this setup. Eventually this led to the creation of the more docile Sink EDM described in the first manual and the Wire EDM setup described here.

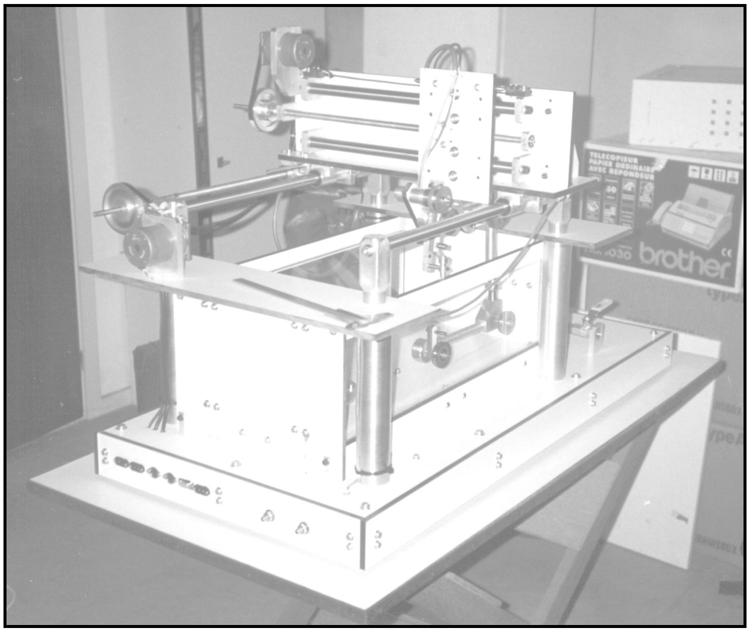


Fig.10 The Prototype W-EDM unit

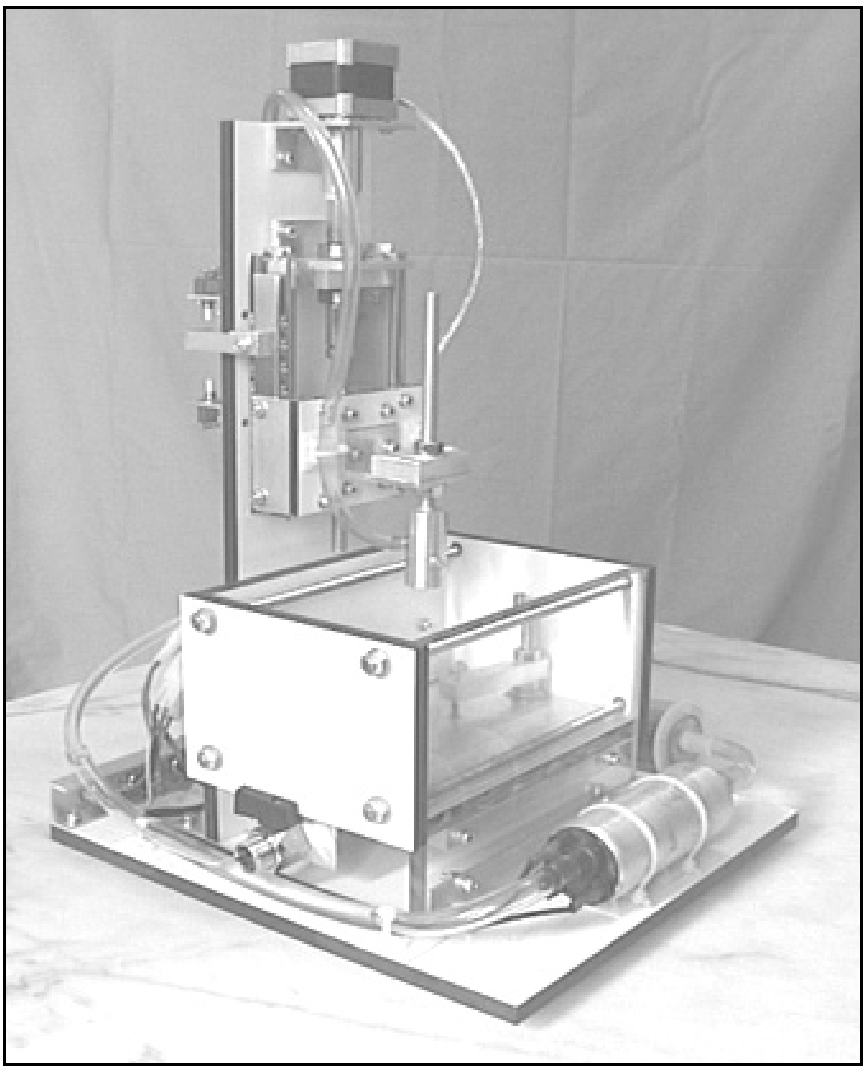


Fig.11 The S-EDM unit

4. The Wire EDM Setup

The Wire EDM design described in this manual is a PC controlled 2 axis (X,Y) unit. The entire setup is comprised of 3 main systems, namely:

1. The mechanical unit
2. The electrical units
3. The software (testware)

The mechanical unit has a footprint of about 0.5 by 0.5 meters and its height is about 0.4 meters. A work piece can be clamped in the tank at a level that allows it to be submerged in dielectric fluid. The clamp consists of two horizontally mounted aluminum strips, which can hold down flat work pieces. It can manage a maximum work piece size of about 140mm by 120mm by 5mm. The machine work area of the unit is about 100mm by 80mm. Depending on the area that needs to be worked and the shape of the work piece, larger dimensions can sometimes be clamped in as well. However the process requires finer control adjustments as work piece thickness is increased. The greater volume of material that needs to be eroded away means much slower machining. Built onto the tank construction are the Y-axis guide way and the X-axis guide way. A wire frame is connected to the X-axis. In its frame, the EDM wire is held in a vertical position perpendicular to a horizontally clamped in work piece surface. This configuration was chosen as it can take advantage of gravity flushing. Hence, the eroded debris naturally falls downward between the wire and work piece and away from the strike zone. Overhead the frame are wire spools which reel the wire through the frame and supply it at a slow, constant rate. The diameter of the spool drum is large to promote better reeling characteristics. The reeling is powered using a small DC motor with a stepped down gearbox. This is clamped onto the top of the X axis guideway. The clamping mechanism is best suited for a motor with a flat gearbox surface. The guideway travel for the assemblies are both based on precision ball bearing, limited stroke all metal drawer slides. Sled positioning is realized through simple lead screw assemblies, which are directly coupled to a designated stepper motor. Over travel is prevented using limit switches.

The electrical units include various circuits such as the stepper motor driver (Camtronics) and the pump and wire motor speed control systems. The most important system here is the EDM power supply circuit. Based on commonly available and inexpensive electrical components this circuit must supply the EDM erosion energy to the electrode/work piece interface as effectively and efficiently as possible. It must also output this in a controlled yet adjustable manner at all times during a machine task with a die-hard endurance. The EDM power supply is a capacitor discharge circuit with an additional circuit for chopped output. The system is also equipped with the feedback circuit that registers when sparking at the electrode/work piece interface occurs.

The parallel port on an IBM compatible Personal Computer is used to send signals out to the stepper motor drivers and receive signals from the limit switches and the feedback circuit. Based on the state of the process and pre-programmed settings, the software manages and controls the Wire EDM system to allow execution of a machine task. The supplied software will control and regulate all required functions of the system. Its function is as a means of testing the unit and allowing the user to become familiar with process. More advanced 3rd party software may become available in the near future.

There are many parameters that need to be analyzed before and during a machine task. The electrode and work piece material, the dielectric fluid type, capacitor settings, the state of the process, etc. all contribute to determine how well a machine task will perform. Even how the wire has been reeled onto the spool, which would seen trivial, is important criteria. The following chapters will address these aspects and provide an insight on what possible ways there are to best meet requirements.

Every part/component of the system has a certain function. If parts are modified, substituted or even omitted it may have repercussions for the workings of the unit. This, in particular, regards the mechanical setup. Development of the basic design concept is certainly encouraged. But is important to look over carefully what the precise function is of a component and if the modification or substitution will or will not impair this or simply make it more complex. For instance, the lead screw is carried by two bearings preloaded and secured by nuts. If conventional short length nuts are used, to save space, then the mechanism may not work well. This as the manufacturing process for a short length nut results in a different form quality than a long length nut.

Many components in this project are applied in ways that they were not directly designed or manufactured for. Their properties have been investigated and defined to determine if they can be successfully integrated and how best this can be accomplished. Besides meeting the technical demands, economic aspects and ease of use are greatly considered in the design decisions. The EDM circuit uses light bulbs as power resistors and, as stated, the guide ways are based on drawer slides, for example. Both are inexpensive items but were produced for other applications than for which they are used here. They may involve a bit more patience and time to be correctly implemented. Actually many important technologies are based on low tech principles (which can have a profound effect on industry), ask any home engineer.

The cost of the unit largely depends on where components are purchased. Also, it will become evident that a large portion of the cost is due to the required components and not necessarily the materials. In fact changing the design and limiting the use or using inferior construction materials may only reduce cost marginally, if at all. It would also probably lead to a lower precision and a less flexible-working unit. Costs should be kept to a minimum, for instance, by salvaging as many components as possible. Also, material distributors most always have a section in their establishment reserved for scrap material. These pieces are usually less than half the normal price tag or free.

The WEDM setup described in this manual was designed using the metric measuring system. The manual is also Metric system orientated as it is directed towards an international market. Most countries employ this system. In addition countries that don't are more or less familiar with it. The following applies:

Millimeters X (1/25.4) = Inches
Cubic Centimeters X (1/3785.4) = US gallons

5. The Mechanical Setup

Probably the most important system of this project is the mechanical unit. Even the best EDM circuit and software won't lead to positive results if this unit suffers from certain deficiencies.

The mechanical unit is largely comprised of composite plate, a small variety of aluminum profiles, basic components and fasteners. There are three main assemblies: the " X and Y guide way" assembly, the "tank" assembly and the wire frame assembly.

The X-axis and Y-axis guide way assemblies offer precision travel with a stroke of about 100mm for the X-axis and 125mm for the Y-axis. The X-axis is the guideway onto which the wire frame assembly is connected to. Both slides are based on commercial drawer slides. These slides are probably the most cost effective in terms of travel accuracy, low stick-slip, permissible load and size.

Ideally a slide should offer zero resistance and accurate travel under any load condition in only the intended travel plane. This while all other directions are infinitely rigid. In practice this is obviously not the case. Each slide always has some degree of error. The slides used here have been studied to determine how best they can be configured and modified to try and limit their inherent deficiencies and meet the set demands. They do the job reasonably well.

But it should be realized that they are being used at almost the maximum of their precision ability.

Slide actuation can be realized using NEMA 17 (should be 0.9 degree per step and have highest torque rating in this class) or (advised) NEMA 23 sized stepper motors in halfstep mode. The design permits both sizes to be adapted. Each motor is directly coupled to a lead screw. The lead screw is simply a length of M8 all-thread stud. It is carried by two, pre-lubed and sealed, radial ball bearings. These are clamped together and pre-loaded over a piece of aluminum angle profile using two opposing long length nuts. A stand off block is placed in between the bearings to reduce the slant angle error of the lead screw. Attention should be given to the choice of the all-thread stud lead screw diameter and pitch if other sizes are used than listed. The thread on basic all-thread studs is usually machine rolled (forced formed) and then galvanized. Machine cut threads with shorter pitch offer higher quality but can cost as much as 10 times more than the basic type. The pitch of the lead screw determines the resolution of the unit. Lowering the pitch increases resolution and system torque. But this is at the cost of maximum speed (not that important for this project). The M8 sized metric lead screw has a pitch of about 1.25mm (roughly 0.04 Inches). Choose the closest lead screw pitch that corresponds to this value. The diameter of the stud should, preferably, allow a snug fit within the inner diameter of the bearings that carry it.

The sled lead screw backlash is minimized using two nuts, which are screwed on adjacent to one and other over the lead screw. In-between the two nuts is a spring which forces the nuts apart. This is a "passive anti-backlash" set up meaning that backlash is canceled out by manual adjustment. To do this, one of the nut clamps is loosened causing thread play to be pushed out by the spring force. The nut is then secured again. Since the EDM unit will not meet any high speed/load guide way travel it is unlikely that the lead screw will show any significant wear during each operation. Also, the manufactured lead screw thread pitch is consistent enough over a relatively long length. Backlash needs then only to be canceled out by periodic adjustment.

The fluid tank has a capacity of about 11700cc or about 12 liters (4 gallons). The set up includes a closed circuit pumping unit, which delivers high pressure filtered dielectric flow over the sparking zone. This forced flushing induces better process characteristics and assists in the separation of eroded debris away from the sparking zone. Flushing away this debris prevents the process from being contaminated and also allows a faster more accurate cutting of the work piece. The tank also includes a dump valve to easily drain the fluid out when the unit is not in use.

The wire frame assembly constitutes the most critical aspect of the mechanical unit, it is the heart of the system. The wire frame is basically made up of two arm-like pairs of rectangular shaped plate material, which are clamped onto two M10 all-thread studs. The two studs are clamped to the X guide way assembly. Both studs include a nylon tube, which serves to increase the stiffness of the construction and dampen wire reeling induced vibrations. Attached to the X guide assembly are two, interchangeable, wire spools positioned overhead of the wire frame. These are both carried by a pair of clamped ball bearings like that of the lead screw assembly. Short length nuts may be used here, as required precision is less. The wire reel-on spool is driven by a small electric motor equipped with a highly stepped down transmission to deliver very low speed, constant torque. A timing belt type drive and pulleys translate this from the motor to the spool to ensure slip free rotation of the spool under relatively high torque conditions. The reel-off spool drags against a leaf spring when it is rotated. This is done in order to tension the wire being reeled off. The diameter of the spool drums is relatively large. More wire could be reeled on if the drum diameter were smaller. However this promotes possible entanglement of the wire when it is reeled off. It is advised not to significantly decrease the spool drum size. Between both of the frame plate arm pairs are various parts which guide and reel the EDM wire along a specific path from the reel-off spool onto the reel-on spool.

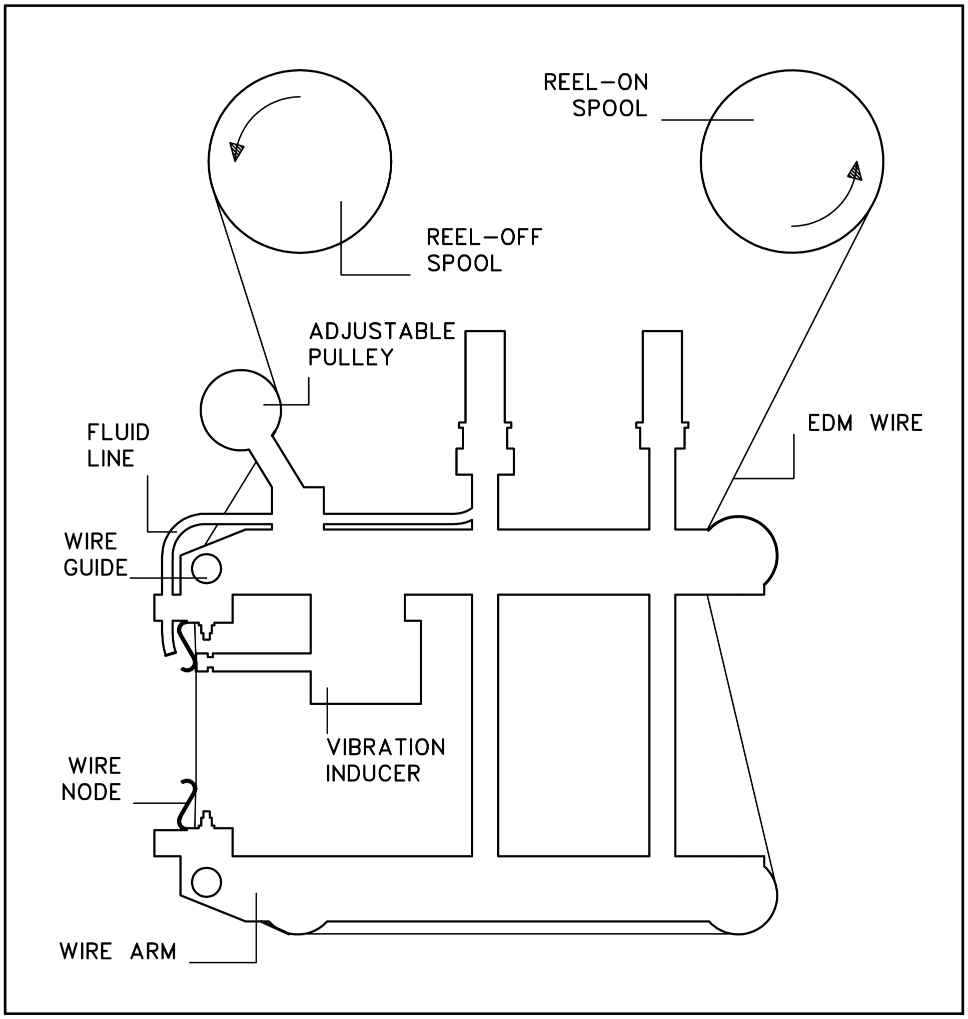


Fig. 12 Wire Frame

There are several demands that the wire frame assembly must meet to function correctly and supply a steady, constant jitter free segment of wire into and out of the strike zone. Firstly, the assembly must keep the wire under a certain degree of mechanical tension. This tension should be high enough to allow a nice straight and stable line of wire to enter and exit the strike zone. Yet the set tension should not cause the wire to break during sparking. Secondly, inconsistencies in the geometry of the pulleys and guides and jitter caused by the wire being reeled on and off should not be translated to the section of wire in the strike zone. Thirdly, the assembly must supply electrical energy to the wire efficiently without contacts being eroded in the process. Lastly, the wire must maintain a constant position and allow some adjustment to set this.

Industrial WEDM setups use a variety of techniques to guide and supply electrical energy to the wire. These systems can be complex and can resemble a mini wire production factory with integrated wire dies and annealing systems to meet demands. Usually the energy supply function and guide function are supported by two separate set of parts. For the home WEDM system several techniques had been investigated. This led to a very simple yet effective and efficient solution in which a piece of highly polished all thread stud is used. The thread serves to guide the wire accurately while at the same time supply the electrical energy to the wire as it slides through a valley of a thread section. The threaded stud allows two other aspects to be easily implemented. First, different wire diameters can be used easily and second, the wire can be easily positioned by simply moving it to another thread section or turning the stud (from this point on the term “wire guide” is used instead of “stud” for this part).

Tensioning the wire over the thread valley sections of two wire guides will allow the wire in-between the guides to be positioned. The relatively large contact surface of the wire/wire-guide interface insures a spark-free electrical supply contact. Yet for most cases this setup alone is not sufficient to permit the wire to enter and exit the spark zone in a steady and constant fashion. The tension in the wire may vary from time to time due to the inconstancies of certain parts, motor performance and jitter caused by the reeling of the wire. Also the wire guides position the wire more or less only in one plane. Consequentially the wire will tend to bounce a bit, which is unacceptable not only in terms of the resulting cutting precision but also the operation of the erosion process itself. To prevent jitter and other deficiencies from being translated to the wire in the spark zone, the design resorts to using a wire node gauge. A fancy term for a very simple part. There are two of these nodes in the design. One is placed after the top wire guide in the wire frame and the other is placed before the bottom guide. The wire node gauge is nothing more than a piece of thin, bent sheet metal, which is, positioned to very lightly drag, or rather brush, against the wire. The effect of this largely cancels out any bouncing of the wire caused by the previously stated. This is especially important when brass wire is used. Copper wire, the traditional WEDM choice, is very easily formed since it is so soft. It will cooperate well and follow a laid out reel path with little difficulty. Brass on the other hand is more rebellious and will want to bounce back. The effect of this can be seen when brass wire is reeled through the wire frame. The wire does not completely follow the path, even under relatively high tension. The wire node gauges largely solve this in a simple manner.

There are four wire pulleys used in the wire frame design. One of the pulleys is adjustable. Each pulley is fitted with a plastic plain bearing. The bearing ensures low friction easy rotation. Its length should also be a bit more than the thickness of the pulley (thrust) to prevent the pulley from running against the side of the frame plates. The adjustable pulley is used to set the amount of wire over the wire guide and wire tension. The wire tension is primarily set in using a leaf spring which drags along the reel-off spool and is also due to the resistance that the wire encounters as it is reeled over the pulleys and guides. The adjustable pulley provides a certain extra degree of tension to be tuned in based on the type and thickness of the wire used. This pulley is also used to direct a line of wire from a primary wire spool placed outside the main setup. The EDM process is slow and requires wire length to be very long even for simple machine tasks. This despite a low wire supply rate. For most small machine tasks the spool sizes used in this design will allow sufficient wire length to be reeled on. But for larger more complex jobs it may be better to directly reel wire from the primary spool itself during the machine task. In other words, directly from the spool on which the wire was purchased. The design setup includes drawings to make a simple construction that carries the primary spool. Modifications to this may be required based on the size of the primary spool. The only requirement when this configuration is chosen is that the rapid travel rate of the stepper motors and retract steps will not cause the wire to be significantly strained, break or jitter in the frame.

The required EDM wire thickness depends on the machine task application but for most jobs this lies between 0.25-0.45 mm. Thicker wire is less prone to break during sparking yet induces more strain to the wire framework. Surprisingly thicker wire can yield faster cutting. Although more material needs to be removed, thicker wire allows greater capacitor settings and hence increased current time and material removal per strike. The strike zone of the work piece reaches higher temperatures and cools down less quickly where upon the next spark strike more easily blasts the weakened material away. Thinner wire requires lower capacitor settings, this will allow a more fine cut but at a significantly lower cutting pace. It is important to note that the EDM process performance can also be impaired, to a degree, due to oxides forming on the wire surface. The wire must be protected from this by storing it in a plastic bag with pieces of dry paper (absorbs moisture in the air).

EDM technology has been in official development for several decades. Primary directives are to find ways to increase cutting speed and precision without sacrificing application range. One of the foremost areas of research and development, apart from EDM fluids, has been towards more sophisticated EDM power supply circuits. This in particular with regard to Wire-EDM systems. The main criteria here is finding better ways to initiate the sparking, turning it off at the right time for a certain duration and then repeating this all at high power and very high frequency. The process becomes more effective when the discharge is initiated by a higher voltage spike to strike a path to the work piece. The EDM capacitor discharges a portion of its charge and is then acutely turned off. Maintaining this with a broad range of adjustment, endurance and power sets some demand on the quality of the EDM circuit. In addition the EDM fluid must also be of sufficient quality to take advantage of the discharge form. A chopper circuit, which is included in this manual, attempts to meet some of this demand while still allowing the use of low grade oils, basic components and minimal troubleshooting (see Electrical Setup).

However several other industrial techniques have been devised to increase the cutting speed of the EDM process. One prominent tactic, which is finding renewed interests in industry, has been incorporated in the design described in this manual. This is a tool vibration inducer. Its application can result in an instant 25% increase in cutting speed. Equally important is that it also steps down and/or bypasses certain crucial parameters making the EDM setup and process less complex and less sensitive to operating conditions. The vibration inducer serves as a substitute to that of the voltage spike to initiate the spark and turn it off. It reproduces this effect mechanically by introducing high frequency, low amplitude vibration to the tool (wire).

There are several significant advantages to the mechanical approach. For starters, as previously stated, this will increase the cutting speed since the vibrating wire will result in more strikes per second to occur. The wire almost lightly brushes against the work piece as it vibrates forward into the spark zone. It thereby strikes the spark path and the capacitors unload their electro-static charge in clusters due to the chopper circuit. Almost immediately afterward the wire is pulled out of the strike zone cutting the path off. Since the discharge duration time is very short, in part due to the wire physically being pulled out of the strike zone, it is now possible to use higher capacitor settings, reach higher mean power levels with less chance of the wire burning through or welding itself to the work piece. This leads to a further increase in cutting speed. At the same time the flushing away of sparked debris is enhanced by the induced vibration, which again leads to better process performance and even surface quality of the cut. In all, the setup has become less critical to exact parameter adjustment. In other words parts can be machined faster and with more ease.

It is interesting to conclude how well related the electrical and mechanical approaches actually are. The electrical tactic relies on an initial, very short voltage spike to ionize a spark strike path. Mechanically, this is accomplished by the wire being vibrated forward into the strike zone, decreasing the distance and making it easier for the spark to jump the gap. The capacitor discharges and a spark is produced which is then quickly extinguished. The electrical setup does this by switching the discharge off while the mechanical setup more or less vibrates the tool out of the spark zone to accomplish the same (in addition to the chopper circuit).

A possible shortcoming of the mechanical approach is the obtainable cutting precision (not surface quality). In case the vibration amplitude exceeds the set tolerance factor then parts will not measure out to the demanded specs. Hence the vibration amplitude must be kept significantly lower than the required tolerance. Fortunately this adjustment will, for most cases, not severely reduce cutting performance. The reason is that the required vibration amplitude is not in the millimeters but rather in the micrometer range. In other words the distance to strike the spark "on" and then "off" only takes a gap distance of a few hundred micrometers.

Interestingly, during the past several years more research has been directed towards this mechanical tactic. Certain companies have already applied it for some time successfully. Traditionally it has been considered the crude approach to EDMing. Yet it appears that it is slowly regaining more popularity in the rest of the EDM industry as an accredited technique for certain applications. Research has extended from using moderate vibration frequency ranges all the way into the ultrasonic frequency ranges. Here the wire is made to not just move back and forth but resonate like a guitar string at several multiples higher than, its natural frequency. Amplitude of the vibration is in the micrometers. Introducing high intensity vibration such as ultrasonics into the scenario appears to lead to some intriguing advancements of the EDM process. Fig. 10. of the Wire EDM setup, built several years ago, was constructed for this investigation. Explanations of this study are beyond the composition margin of this manual. However certain mechanisms fall into play, which significantly assist the EDM erosion process when high intensity ultrasonics is employed. Studies have concluded that the injection of low amplitude ultrasonic vibration can result in enhanced process performance requiring less complex EDM circuits and adjustments for most machine tasks.

The setup described in this manual uses a small electro-magnet or solenoid as the vibration inducer. The armature or plunger is a rod of soft steel that nicely fits in the solenoid. Preceding the plunger is a short soft spring. The solenoid is secured in the wire frame with the plunger lightly held against the top wire node gauge. The solenoid is supplied with a pulsating DC current. When the pulse goes high the solenoid will retract the plunger and compress the spring. Immediately after the pulse goes low the plunger will be pushed back out by the spring and tap against the node gauge. Hence, pulse frequency dictates the vibration frequency. As stated above the amplitude of the vibration needs only to be very small. This can be adjusted by moving the solenoid and plunger closer or farther from the node gauge or using a different spring.

5.1 Construction Overview

The construction of the mechanical setup involves the manufacturing of parts and assembling the unit. The total mechanical setup is comprised of 7 different assemblies, namely:

- Assembly A, (Wire Spool)
- Assembly B, (X Axis)
- Assembly C, (Lead Screws)
- Assembly D, (Y Axis)
- Assembly E, (Wire Frame)
- Assembly F, (Tank, Fluid Circuit)
- Assembly G, (Primary Spool Stand)

Each assembly is made up of parts and components. Parts are defined as modified materials/components. Components are pre-manufactured materials, like a pump or a bearing.

Drawings of the parts can be found in the last section of this manual. Depending on the complexity of the shape, some parts are drawn from a 3D perspective. All other parts give a 2 dimensional perspective based on the American projection system. The drawings are not to scale. Scale may also differ between drawn parts on the same page. A description of each part regarding type of material etc. can be found in the "Drawings & Tables" section of this manual. Also included in this section is a list of all “Mechanical Setup” components and the material profiles and sizes required for the unit. This makes it easy to gather the material quickly. The lengths of the materials listed are always a bit longer than required so builders don't come up short.

The drawings do not list a tolerance on the part dimensions and hole positions. However, it is best to keep a general tolerance of 1mm (0.04”) on all measurements. This can be somewhat tight. Yet, to a degree, reservation has been made for measurement errors by over-sizing the holes in parts. Obviously this does not apply to parts that must precisely fit into or over another part.

The explanations provided with regard to the manufacturing and assembly of the unit serve only as a basic guideline and insight. Make sure that drawings and pictures of the unit are looked over carefully to assist in this.

To determine and label where holes must be drilled, based on the drawings, it's always best to measure out from a single origin point. This is done to cancel out any error made in the sawed length of parts. For example, in a flat strip of aluminum that was sawed 2mm too long, 2 holes are needed. The holes are both 6mm from each side of the part and must be 38mm apart to fit correctly. Measure from one side the 6mm distance for the first hole and mark this. Then from this same side measure out and mark the next hole at 6mm + 38mm. This will compensate for the length error. If the second hole were marked by measuring 6mm from its own side then the length error would be entered in the 38mm distance. This would mean that the 38mm distance is now 40mm. The part would have to be discarded as it is out of the specified tolerance.

The positions where holes need to be drilled can be determined using a measuring caliper. Using the caliper measure the correct position and mark this by lightly scratching cross hairs in the material that represents the hole position. Mark a dot at the intersection of the cross hairs using a small point tip magic marker. Then use a center punch to punch in a small notch on the marked spot. This will assist the drill bit in finding the correct position to drill. After drilling, counter sink the holes on both sides of the part and deburr. Deburring parts can mean the difference between the unit working right or not.

As stated, the guide ways for the WEDM unit are drawer slides. These are widely available. The type used for this unit is made of steel, including the ball bearings. They offer the highest precision and load rating in relation to cost of most all other types of guide ways.

There are a number of drawer slide suppliers. For this unit drawer slides produced by Thomas Regout were chosen (see Suppliers section). Slides of a different manufacturer with equivalent dimensions and similar quality can also be used. However more modifications to the alternative slide, and maybe other parts, may be required to properly integrate them into the unit.

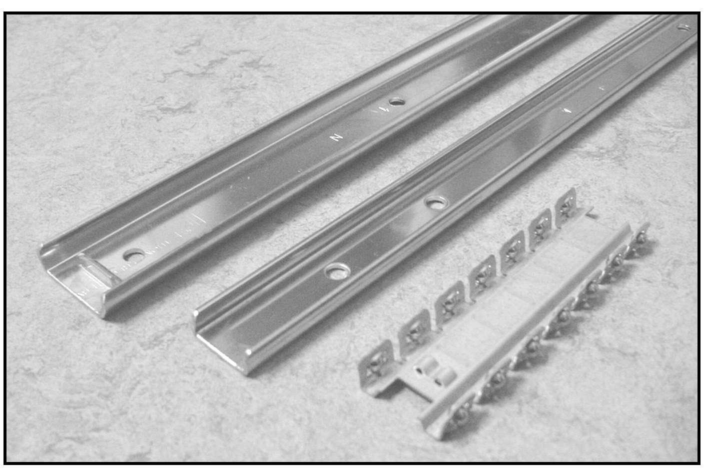


Fig.13 Dismantled Drawer Slides

The slides have been defined as parts since they require some modification. The standard slide length, and thereby its travel, need to be reduced before they can be integrated into the unit.

Most all hole sizes that need to be drilled are about 6mm, yet some are as much as 12mm. Certain parts may require even larger sizes yet the chuck of most power drills may not be able to accommodate this. However large drills can sometimes be purchased with the clamping end (shank) grounded down to a smaller size. Another alternative is to grind the hole to size using a power drill with a grinding bit. This is, however, cumbersome work.

5.2 Manufacturing

This section provides some general information on the manufacturing techniques involved to create parts. Explanations are also given towards certain parts that require some special attention to manufacture.

The drawer slides are the first to be modified. Each slide is made up of 3 parts:

- outer rail
- inner rail
- bearing cage

The lengths of both the inner and outer slides need to be reduced according to drawing DR.6. Before this can be done, the slides need to be disassembled. The outer slide has a lip on one end that serves to stop the travel of the inner rail. This needs to be bent back or grounded off. This lip can be found on the side that has its first installation hole at 27 mm from one end of the slide (this is depicted on DR.6 for orientation purposes). When bending make sure the slide is on a flat surface and held firmly. This must be done with care so that the rest of the slide does not become deformed. If the lip is to be grounded off then make sure that the slide does not become too hot. The slides are made of soft steel. But they can lose some springiness (induced by cold working manufacturing) when heated.

After the lip is bent back or removed, the inner rail and bearing cage can now be extracted. The length of the outer and inner rail is reduced according to DR.6. Place one of the rails in a workbench vise. The clamp force should not damage or bend the rail (small strips of soft wood between the clamps can be helpful). Cut the rails using a good hand saw. Work easy and prevent any excess bending of the rail while sawing. Repeat this for the other rails. After the rails are cut to length deburr them using a power drill with a small grinding head bit and/or use a low course file.

The bearing cages also have a small stop notch. This should be removed by carefully grinding it off.

Clean the rails and bearing cage using a de-greasing agent. Most automotive stores carry these kinds of products. All the grease and fragments from the sawing/de-burring process must be removed. Inspect that this is done well. Very lightly re-grease the cage. Do not over grease, this will attract dirt. The re-installation of the rails will be carried out later.

For the most part the mechanical unit uses a composite material called Trespa as the main construction material. Other materials could also be used but may be inferior to Trespa. Lexan (polycarbonat), aluminum and steel are also used for this unit. Working these materials properly requires different techniques and handling. The manufacturing is largely drilling and some sawing. Most builders will have no problem doing this. However to be thorough, explanations will follow as to how best to work the materials and what precautions must be taken.

Trespa is a composite material made up of a paper-reinforced thermoset. Nowadays it's used for everything from building panels to laboratory instrument constructions. The material has a special, usually white colored, hard surface. This surface is scratch resistant and has a professional appearance. The base material won't decay or swell over time. It's strong, ridged and resistant to most chemicals. Trespa allows grinding to shape without threading like most plastics normally do. However it has no mercy when worked incorrectly. This aspect applies to the material Lexan (poly carbonate) as well, which is used for the front tank plate.

Sawing Trespa does not present any special problems. But drilling the material is a different story. The material is somewhat brittle. When drilling, the drill can sometimes take a bite bigger than it can chew. This can cause the drill to be forcefully pulled in. Apart from the drill probably breaking, this situation can be dangerous if the part is not held down firmly enough (clamp work piece down whenever possible). Some guidelines are required to reduce the chances of this situation from occurring. First of all the rotation speed of the drill is very important. Large holes should be drilled at slow speed while small holes at a higher speed. Drill speed should not be higher, at any drill size, than about 500 RPM and about 200 RPM for drills larger than 8 mm. An indication of a correct drill speed can be seen by the type of chips produced. Long curled chips represent the correct speed. Powder sized chips along with a burning odor and a darkened drill head obviously indicates that the drill speed is too high. When first drilling a hole in Trespa, the hard top layer must be broken through by feeding the drill somewhat hard yet in a docile manner. When the base material is entered the feed must proceed in a steady easy manner (this takes some practice). Take into account that the drill must also punch through the hard layer on the underside as well. Do this with a very docile feed.

The type of drill used must be appropriate for the job and of good quality when drilling Trespa. HSS (High Speed Steel) drills for steel will suffice for holes up to about 4 mm. Larger holes should be drilled with drill bits meant for drilling holes in brass. These are also HSS drills. Yet this type has crown cutting edges which are at and angle of 0 degrees (opposed to the 15 degrees cutting angle for working steel). Drills meant for brass appear to almost work through the material in a scrapping fashion instead of directly cutting through it. They are less prone to biting and latching into the material than drills meant for steel. Also they have less tendency to chip off pieces of the top layer.

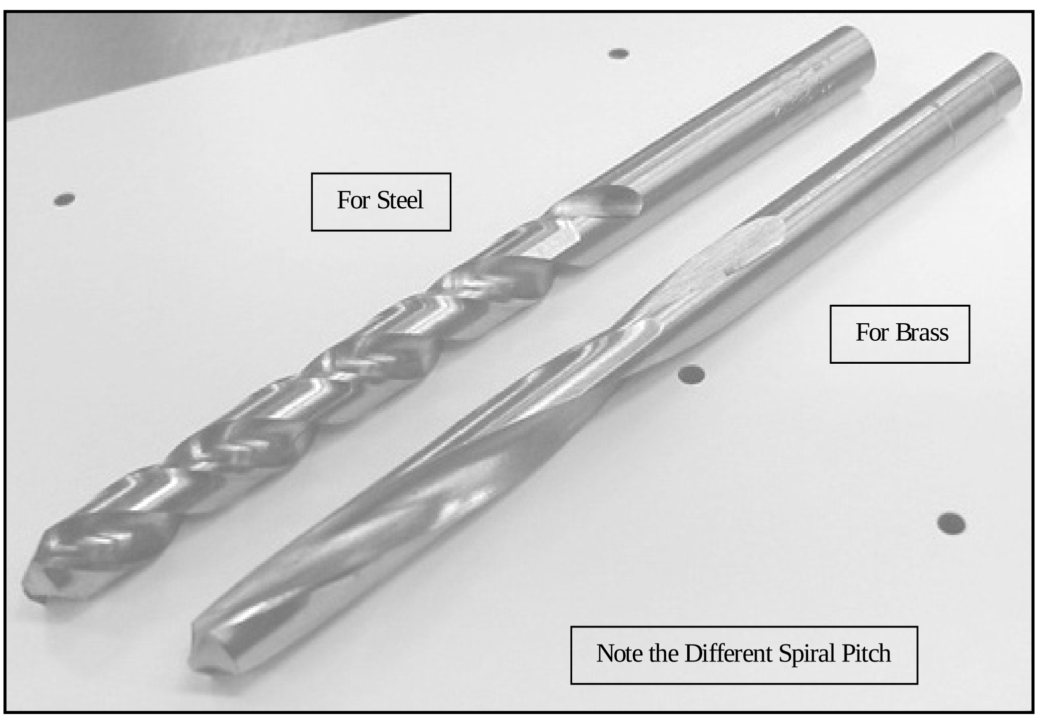


Fig.14 HSS Drills

However drills meant for brass can be expensive. An alternative is to modify standard drills meant for steel. This is done using a flat, fine grain stone type material normally used for sharpening knives called a whetstone. While holding a drill bit in one hand position the side of the stone parallel to the axis of the drill. Move the drill in an "up and down" manner and slightly grind flat a facet on both cutting edges of the drill crown. The flat stone surface must remain parallel to the drill while this is done or the angle will not be correct.

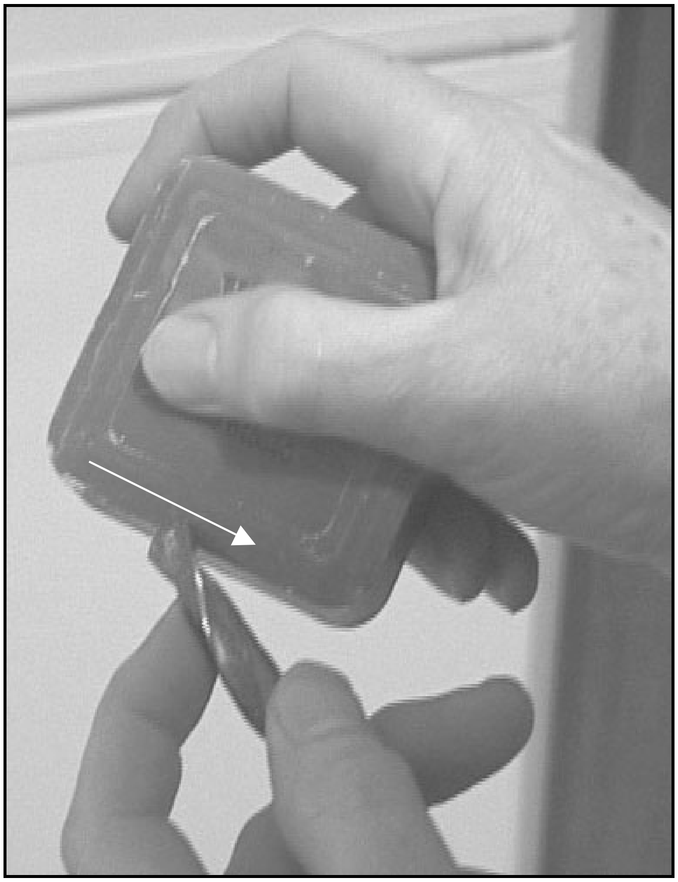


Fig.15 Modifying the Drill

When large holes need to be made it is best to first pre drill a hole with a smaller diameter drill. This will accommodate the drilling process. With aluminum or steel the pre drill size is not that critical. Trespa however will more easily cause the drill to bite if the pre-bored hole is too big in relation to the desired end hole size. For instance, a hole that needs to be bored to 8 mm should first be pre-bored to about 3mm and no bigger.

When drilling holes in Trespa (or any other material for that matter), use plenty of cooling fluid. This is an emulsion of special cutting oil and water. Trespa has a high coefficient of friction and will blunt tools rapidly when dry drilling is performed. Dry drilling may also promote drill biting as well. Lastly, an electric hand drill is sometimes easier to use than using a drill press for certain tasks. However it is most always less precise.

The wire guides (part 3E) must allow the wire to easily slide over its surface. It is imperative that the threads of the wire guide be highly polished using a good polish wax and an electric polishing machine. If rough surface is encountered then this may lead to sparking which would quickly lead to making the surface worse, resulting in possible wire breakage.

Copper pipe is used to supply the EDM fluid. The pipe can be easily bent into a desired form using pliers to carefully do this.

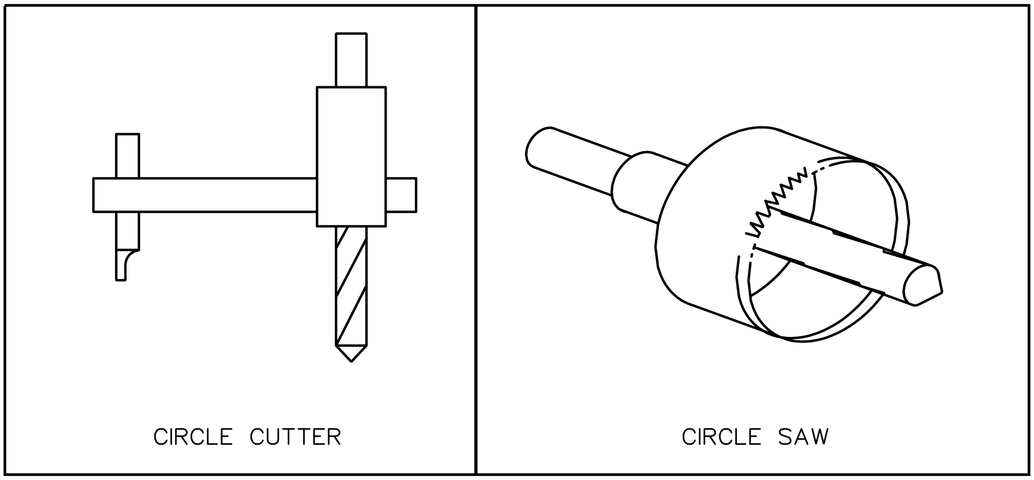


Fig.16 Circle Cutter & Circle Saw

The spool discs (part 6A) are made using a circle cutter. This is a simple handy unit, which can cut discs out of plate material. It is fitted into the chuck of a drill press. It uses only one tool bit and it is usually adjustable to allow different circle sizes to be cut out. The pulleys (4E) could also be cut out using this device. However it is probably best to use a circle saw attachment for a drill press. A more equal cutting force will result. Feed should be slow and drilling should be accompanied by a steady amount of cooling fluid. Drill the center hole up to the required size before cutting out the pulley. After the pulleys have been cut out remove any burr type chips that may still reside on the pulley circumference. Careful, the material may have very sharp edges. Take a short piece of all thread stud and attach it into an electric hand drill chuck. Using nuts clamp the pulleys over the stud. Carefully sand the pulleys using the drill to rotate them over a sheet of taped down sandpaper until they are nice and round and free of burrs. Then remove the pulleys except for one and clamp this on the stud as before. With the pulley in the drill, grind a 90-degree grove into the pulley using the corner of a tool bit grinding disc. This should be done with minimal force and with precision. Wavy groves will otherwise cause the EDM wire to move back and forth or even ride off the pulley. Also, allow plenty of ventilation during grinding. Take care not to let the pulleys become too hot during grinding.

5.3 Assembly

Before starting assembly make sure that the parts have been properly de-burred. This is very important. As a final precaution lightly sand the mounting sides of all the aluminum parts. Do this by taping down a sheet of course sandpaper (normally intended for wood) onto a flat clean surface. Holding a part firmly down on the paper slide it over in a steady controlled fashion once or twice. Do not sand too much or unevenness will result. File away any excess burrs and lightly sand down. Clean all parts in soap and water and dry them. In particular make sure that the Trespa parts are cleaned thoroughly of oil, grease and dirt as some of these will be sealed using adhesive.

Each part is identified by a number followed by an assembly letter. Unless otherwise specified, the numbers more or less refer to the assembly step procedure. They give an indication of the order in which parts could be assembled. For example, part 1A is related to part 2A and is intended to be assembled in that order.

The lead screw, assembly C, is held in position by a set of radial bearings that are clamped together using two nuts listed as components C17 (see DR.5). It is important that the C17 nut is only in contact with the inner race side of the radial bearing. If the nut contact diameter is too large it will drag over the bearing seal making it harder to turn the lead screw. Another aspect that must be taken into account is the length of the nuts. As previously explained, normal short length nuts tend to wobble when screwed on the lead screw. This wobble cannot be tolerated for this application. Long length nuts wobble much less and are usually acceptable.

The lead screw should turn easy and not require the use of a lubricant. Lubricants tend to attract dirt and debris. At most only a small amount of lubricant may be applied. Better yet, brass nuts should be employed. This provided that they incorporate equal or higher form and dimension quality.

With regard to the tank assembly, it is important that nylon or hard rubber washers be used. These should be sandwiched between steel washers. This pertains to all fasteners for the tank assembly that could lead to a potential leak. To further ensure sealing integrity of the tank it is advised to apply a small amount of silicon sealant to these washers and their bolts. A better leak-preventing offensive is to seal the fasteners with a bit of superglue. Superglue is so thin that it can easily pull itself into small cracks between a nut and bolt interface. It is no fun having a completed unit that leaks, take every precaution to prevent this. Leaks can occur in the strangest places.

The unit requires different hose diameters as plumbing parts, pump and the filter may have different nozzle sizes. Use connectors to interconnect these hoses. It is sometimes possible to fit a smaller hose into a larger one. Also, the non re-enforced transparent type hose can be heated using a hair-dryer. The material will then soften and be less difficult to force over a nozzle. Make sure, even when the sealing integrity of a hose/nozzle connection appears acceptable that a tie-wrap or other type of clamping element is applied. The pump used for this project delivers low flow but it can produce high pressures.

Be careful not to over tighten bolts that clamp the composite plate material. Over tightening can cause the material to deform and/or induced stress on other parts and components.

5.3.1 Wire Spool

This is the first assembly and is listed as Assembly A. Attach the angle bracket (1A) to the support arm (2A) and secure. Secure the leaf spring (3A) onto (2A). The leaf spring can be adjusted during use by screwing a bolt into part (2A), which can be set to push on the spring backside and increase the spring tension against the spool.

Parts (4A) serve as the spool shafts. Each are carried by a pair of radial bearings, which are pre-loaded and clamped on the support arm. In between the support arm and bearing is a thin stand-off ring (C4). The bearing rests on this. It prevents the bearing from running against the surface of the support arm. Screw on two short length nuts onto one of the shafts (4A) until about 20mm of thread extends from one end. Slide a bearing over on the other end of the shaft until it rests against a nut. If the bearing shaft clearance seems too much then neatly apply a thin brass foil (C28) layer in between the shaft and bearing. This type of foil can be found at hobby stores, bearing specialists and shops that rebuild machines. It is commonly used to cancel the clearance between bearing and housings that have been oversized after being rebuilt. The foil should allow no more than a snug fit of the bearing on the shaft. Run this same shaft side through one of the shaft holes of the support arm from the backside. A stand-off ring (C4) should be placed in between. On the other side of the support arm at least 100mm of shaft should extend out. Place a stand-off ring on this side as well and then slide a bearing over the shaft. Screw two nuts over the shaft and now clamp in the bearings by tightening the nuts by hand. The tightening of the nuts should pre-load the bearings only. In other words the shaft should turn easy and more or less true without feeling loose. This may take some adjustment. When the proper setting is achieved use the secondary nuts on each side to secure position by tightening them against their adjacent nut. Repeat the same procedure for the other shaft on the other end of the support arm. Take into account that one side is the wire reel motor side and that this side has a timing gear pulley instead of a nut. Hence, only three nuts are used here to clamp in the bearings.

The spools are interchangeable and can be equipped with thin circular metal plates (5A) on the surface of both sides of each spool disc (6A). This is optional (was not used for this project) and it is to ensure that the leaf spring, which drags along a spool functioning as the reel-off spool, does not eat into the disc material as it turns. To assemble each spool, slide a spool disc (6A) over one of the shafts then a drum, part (7A), and then another (6A) to enclose it. Clamp the spool assembly together by screwing on two nuts onto the shaft. Turn the shaft and adjust (7A) until it rotates concentrically between the two spool discs. Extend M3 bolts through the discs of the spool and secure using nuts (use washers in between). Carefully apply a small amount of super glue between the (6A) and (7A) interfaces. Repeat this procedure for the other spool. To ensure that the spools do not cause the shaft nuts to become loose during the reeling of the wire, use toothed washers in between the discs and their adjacent nuts.

The wire spool assembly is attached to part (7B) only after assembly D is completed. Parts (8A) and (9A) represent the motor clamp and should already be applied to part (7B). Screw in both clamp studs (9A) into (7B). Slide a clamp block (8A) over the studs. Secure the clamp block using nuts.

5.3.2 X-axis

The X-axis guideway assembly is listed in the drawings as Assembly B. The guide bed, part (1B), is the first part to start with. Mount the angle brackets (2B) on using appropriate length nuts and bolts and tighten only enough to still allow repositioning. Try to position the parts as parallel as possible to the sides of the guide bed. Measuring from the top inside surfaces, parts (2B) should be about 88 mm apart. The angle brackets closest to the side of the guide bed should be about 12mm from the edge.

Mount and secure the outer rails of parts (3B) onto the brackets (2B). The rails should be offset about 3mm from the surface of the guide bed (1B). Install the bolts from the outer rail side. Use bolts with low height heads so the surface of the inner rail, which will be installed later, will not run against them and obstruct travel.

Before re-installing the bearing cages and inner rails, first mount and secure part (4B) on the inner rail (home switch side). Use low height headed bolts. Mount and secure part (5B) to the same inner rail and part (6B) to the other. Make sure that the sides of the rails run parallel to the sides of the brackets (5B) and (6B). Mount the other side of parts (5B) and (6B) to the slide plate (7B). Position parts (5B) and (6B) for now, do not secure them yet. Each inner rail can now be installed into the corresponding outer rail. First place bearing cages about one-third length into the outer rail races. Holding the cages in place slide the inner rail sub-assembly, that was constructed previously, into the cages. When it reaches the outer rail it will feel a bit locked in as the ball bearings are pushed into the rail races. Release pressure on the cage and gently feed the inner rail further into the outer rail. The cage should invite more of the inner rail to slide in while it is being fed into the outer rail. Since the brackets are not secured, some adjustment is permitted to allow the slides to be installed correctly. Move the slide assembly back and forth. It should not run too loose and in fact feel a bit pre-loaded. Pre-load force should feel the same over the entire slide travel length and certainly not cause the bending of the rails. If it does, then some or other part is not in alignment. When correct travel is accomplished and all seems straight and parallel secure the rest of the bolts. Using two pliers, bend the copper pipe (8B) into form as illustrated in the drawings. Using tie wraps and mounts lay it in position.

Parts (9B), which hold the limit switches, should be installed only after both guideways are completed and correctly adjusted.

5.3.3 Lead Screws

Both the X-axis and the Y-axis use the same lead screw parts. Installing the lead screws and adjusting them correctly is probably the most difficult assembly to realize. It can take several minutes to several hours to get it right. The reason for this is that the lead screw has to be correctly aligned in two different translatable planes. Before starting the assembly it is very important to check that the all-thread studs, which act as the lead screws, are not bent and that the threads are not damaged nor have burrs. A nut should screw on easy and not encounter resistance over the entire length.

Extract the inner rail sub-assembly from the outer rails. Parts (5C) act as stand-off's and to clamp in the slide nuts of the lead screw. Glue (using a very small drop of super glue) two (5C) parts onto the underside of part (7B) according to the drawings. Check that they are glued on flat and that their holes are aligned with the corresponding holes of part (7B). The gluing of parts (5C) to (7B) is only to hold them in position to permit easier installation of the lead screw assembly. Also glue down the stand-off (2C) to the bearing bracket (1C). Again, this is just position the parts together and ease installation.

Screw a long length nut onto the lead screw (3C) until about 50mm of thread extends. Place the spring (C5) over this end and screw on a second long length nut. While holding the first nut and lead screw and holding back the spring, turn the second nut until it is about 15mm from the first nut. Release the spring. The two nuts should feel a bit pushed apart. Holding the nuts in place turn the lead screw. It should turn with only a bit of resistance due to the spring tensioned nuts. If it feels too tight or loose then adjust the distance between the nut accordingly to set the spring at another tension level. If this still does not help, use another spring length. Continue turning the spring-loaded nuts onto the lead screw by holding them as one until about 80 mm of thread extends. On the other end of (3C), screw on a normal length nut until about 100mm extends and then screw on a long length nut. Tighten these two nuts together to ensure that they maintain this position. Slide a bearing on. It should have a nice snug fit and not feel loose. If this is not the case then remove the bearing and very neatly insert thin copper foil (C28) between the bearing and lead screw. The amount of foil should only allow the correct fit and not require the bearing to be forced on. The function of the foil is to position the bearing correctly, not secure it in place. Place a stand-off ring (C4) over the lead screw and also parts (2C) and (1C). Place another stand-off ring, slide a bearing on (apply foil as before if necessary) and then a long length nut. Lightly clamp the bearings on by tightening the nut by hand.

Place the lead screw end that has the spring loaded nuts on the surface of the previously glued parts (5C). Use another two (5C) parts and nuts and bolts to clamp in the assembly. This should remain somewhat loose for now, as it will require adjustment. Re-install the inner rail sub-assembly, with the lead screw assembly now loosely attached, in the outer rail sub-assembly as previously described. Mount the angle bracket (1C) to the guide bed (1B). Position as accurately as possible and secure (careful not to bend the lead screw in case it is in a wrong alignment).

The final adjustments can now begin. This can be a difficult task, as explained before. Be prepared to provide the time, attention and patience. Unscrew the bearing nuts a bit so that any tension induced by misalignment can be relieved. There are two areas, which will allow adjustment and permit an approach of the correct alignment of the system. These areas are at the bearing end of the lead screw and at the spring-loaded nuts end (Note: check again that the slide alignments are correct). The spring-loaded nuts can only be adjusted in one plane. Try to position them in parts (5C) such that the lead screw runs as parallel to the slides as possibly. Loosen the bearing nuts, allow the lead screw at this side to set itself at a relieved position and then retighten by hand. Turn the lead screw one turn. It should turn easy. If not then adjust the (5C) clamps that hold the spring loaded nuts. Turn the lead screw and thereby have the slide assembly come towards the bearings as close as possible. If it starts to become difficult to turn then loosen the clamping of the spring loaded nuts enough to allow the lead screw to be re-position a bit. Turn the lead screw again but now in the opposite direction so that the slide assembly extends all the way out. Do this until the spring loaded nuts are just about at the end of the lead screw. Loosen the bearing nuts and relieve the lead screw from any tension. Repeat the procedure and continue to make adjustments until the lead screw turns easy over the entire travel length. After this make sure that the slide is not waving from side to side while turning. This is due to the lead screw not correctly being carried in its bearings and/or its bent. Adjust accordingly.

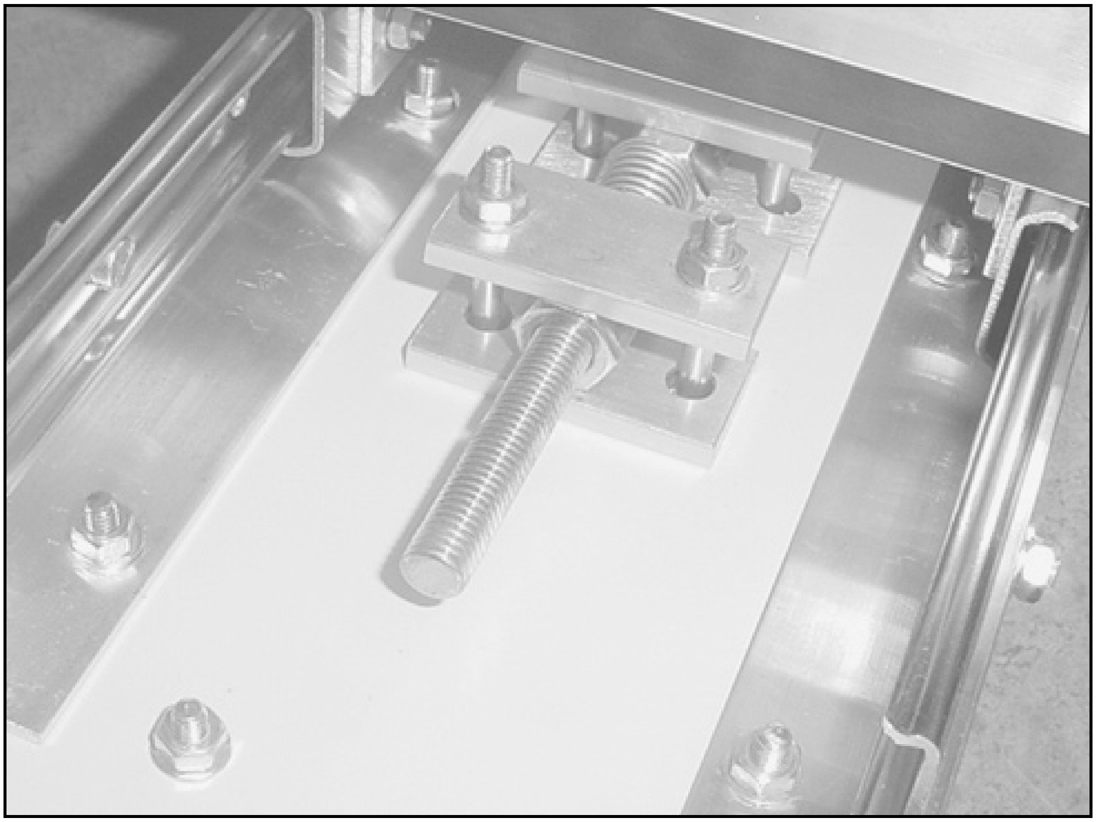


Fig.17 Anti-Backlash Assembly

The spring loaded nuts comprise the anti-backlash setup. By loosening one of the nuts in its (5C) clamps a bit the spring will push out the play between threads. Tighten after doing this. In practice, backlash is concluded to be virtually zero using this simple setup.

The lead screw is attached to the motor shaft (C1) via part (4C). This is a hard link and any misalignment between the shaft and the lead screw can not be compensated for. The result is that the lead screw may periodically turn hard. The misalignment may be due to 3 things:

- Motor shaft hole and lead screw hole in part 4C are not concentric
- Shaft and/or lead screw holes in 4C have too much clearance
- A combination of the first two aspects

The clearance can be canceled by applying a layer of foil to the lead screw and/or motor shaft. The amount of foil should be just enough to cancel the clearance and no more than that. The sets crews will also allow the parts to be adjusted a bit.

Add part (4C) on to the lead screw. The advised motor type is the NEMA 23 size. Parts (7C) will allow this motor type to be installed. The motor shaft is usually only about 15mm

(NEMA 23). Since the motor shaft must extend through (6C) and (7C), only about 6mm of the shaft will extend out. The shaft should extend into part (4C) as much as possible. This without (4C) touching the surface of the bracket (6C). This can be accomplished by adding thick washer rings to act as shims between part (4C) and the adjacent long length nut until a proper clearance is obtained. Apply an adhesive to the set screw to ensure that part (4C) and the motor shaft do not loosen during machine operation. Position part (6C) on to the guide bed. Install the stepper motor, (C1). Have it only lightly held in position by bolts. Insert the headless set screw bolts into part (4C) and secure the shaft of the motor. Make sure that the lead screw and motor shaft line up correctly by turning the lead screw to feel the drag. It must turn true. The remnant torque of the motor is minimal. The lead screw drag should feel the about the same as when the motor was not installed. Inspect and make sure that everything is aligned correctly and then secure the parts by tightening the bolts.

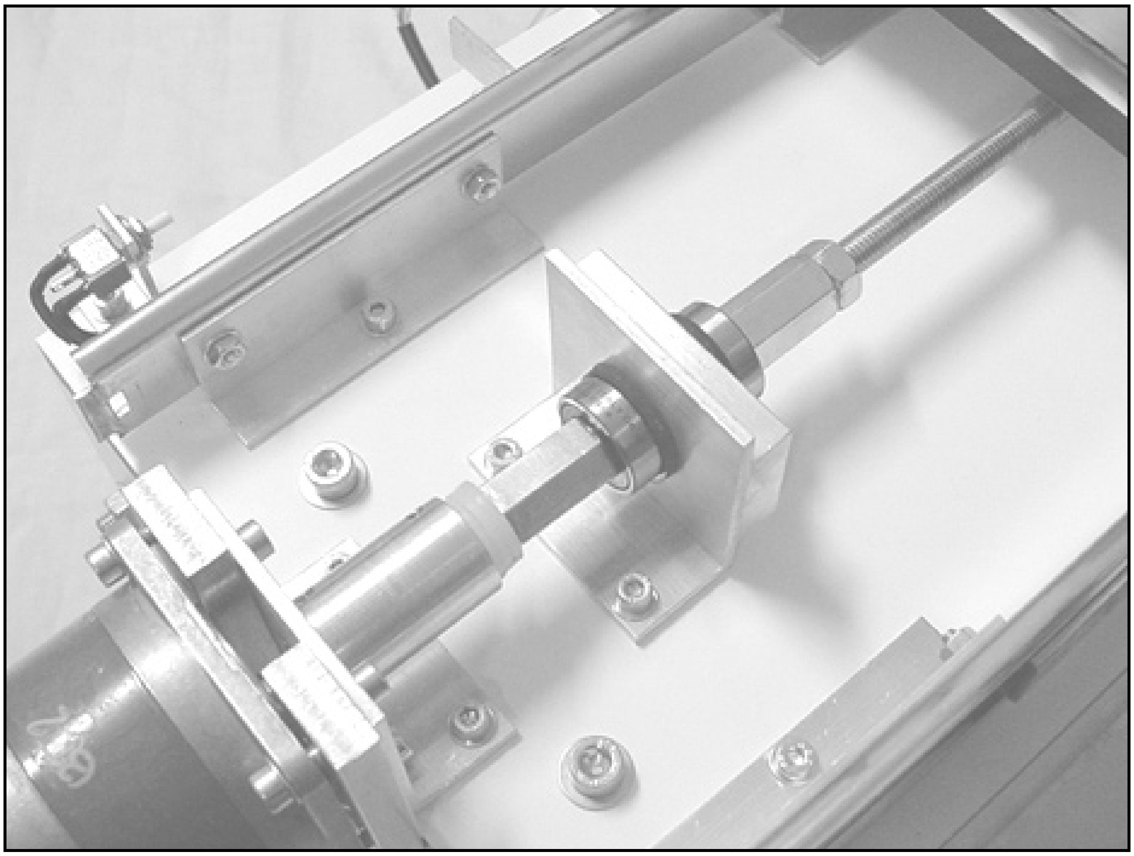


Fig.18 Lead Screw Assembly

5.3.4 Y-Axis

The assembly of the Y-axis is almost completely the same as the X-axis. However, since the slides are wider apart, to increase stability and support the X-axis, they may be a bit more difficult to adjust correctly. Errors in the alignment of the lead screw have more influence on the motion integrity of the guideway.

After both guideways have been assembled together, install the wire spool assembly onto the X-axis and then the wire reel motor and its drive (pulley and timing belt). Adjust the position of the motor to tension the pulley belt.

The X-axis has several drilled holes in (7B). These allow wiring and fluid hose to be fitted through. There are also four 8mm sized holes in the bed plate (1D). These are used to clamp the entire guide way assembly, using parts (15F), to the tank assembly. This will be explained later.

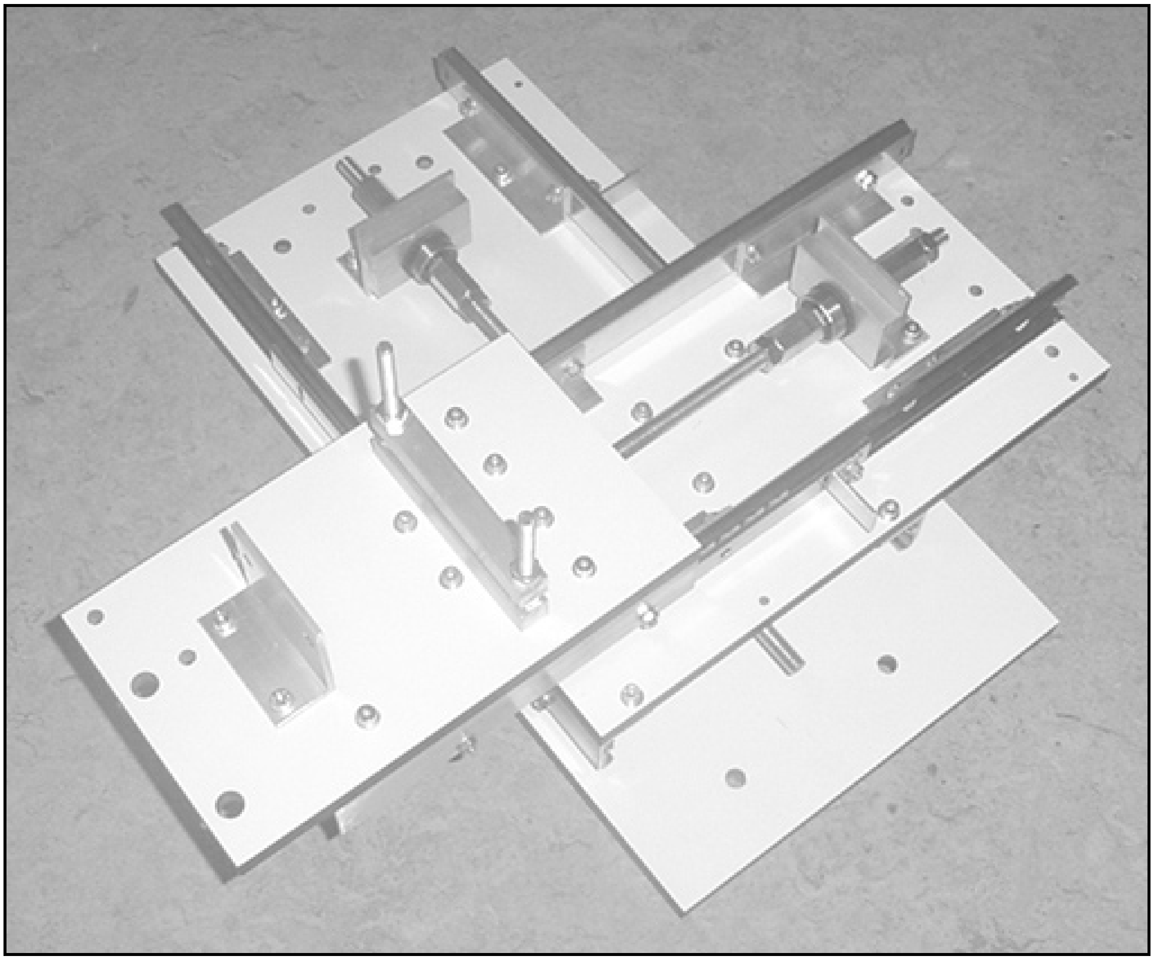


Fig.19 X & Y Axis Sub-Assembly

5.3.5 Wire Frame

The wire frame assembly is defined as Assembly E. although it serves a crucial function, the assembly and adjustment are not that difficult. The plain bearings (C25) should be inserted in the pulleys, parts (4E). After making sure that the bearings are correctly positioned within the pulleys add a small drop of super glue to secure.

The first sub-assemblies to construct are the top and bottom wire frame arms. Insert a wire guide (3E) and pulley shafts (2E) into one of the arm frame plates (1E). Slide a pulley over the rear shaft. The adjustable pulley is made up of two parts: (5E) and (6E). Slide part (5E) over the front shaft. Then secure part (6E) to part (5E) using a nut and bolt. Slide a shaft into part (6E) and then secure it with a set screw. Slide a pulley over this and then a shaft retaining collar (C21). Add another plate (1E) over this sub-assembly. Check that the two plates line up parallel, adjust if necessary. The pulleys should rotate easy and not run against the sides of the plates. This sub-assembly is the top wire frame arm. The bottom frame arm is assembled the same with exception that it does not have the adjustable pulley arrangement.

Insert parts (7E) between the frame plates of both wire frame arms. This may require that the plates be moved apart a bit to permit enough clearance. Lightly tighten the plate's together using nuts and bolts and clamp the plates over the studs (7E). Do not secure yet. Insert and secure the (7E) studs of this sub-assembly into part (7B) of the X axis assembly using nuts. Adjust the position of the wire frame arms. The arms should be about 80 mm apart. The two studs should not extend all the way out of the bottom arm. This will otherwise obstruct the wire reeling. Tighten the nuts and bolts that clamp the plates over the studs. Remove this sub-assembly from the X-axis. Screw in the threaded studs (8E) into the plates of both arms until they secure the position of the wire guides in the frame plates. It is important that the (8E) studs make good contact with the wire guide as this serves as part of the electrical current supply line. Slide parts (9E) over each stud pair and then the wire node gauges (10E). Secure with nuts. Slide part (11E) over the first stud (7E) and secure. Using two pliers carefully bend the copper pipe (12E) in shape. The tube supplies the fluid to the strike zone area. It is also part of the electrical current line. Insert the bent pipe into (9E) and secure. The other end of the pipe is secured in (11E).

Screw nuts on the (7E) studs until about 80 mm extends. Slide a nylon bushing (C27) over both studs. Then slide part (13E) over the studs. Slide a piece over hose over the copper pipe on the end that extends out of (11E). The length of the hose should be long enough to also slide over the copper pipe of assembly B. Use tie wraps to ensure that no fluid leaks can occur. Again insert the sub-assembly into (7B). Add part (14E) over the studs, then screw on the nuts and clamp the entire assembly together until it is secure.

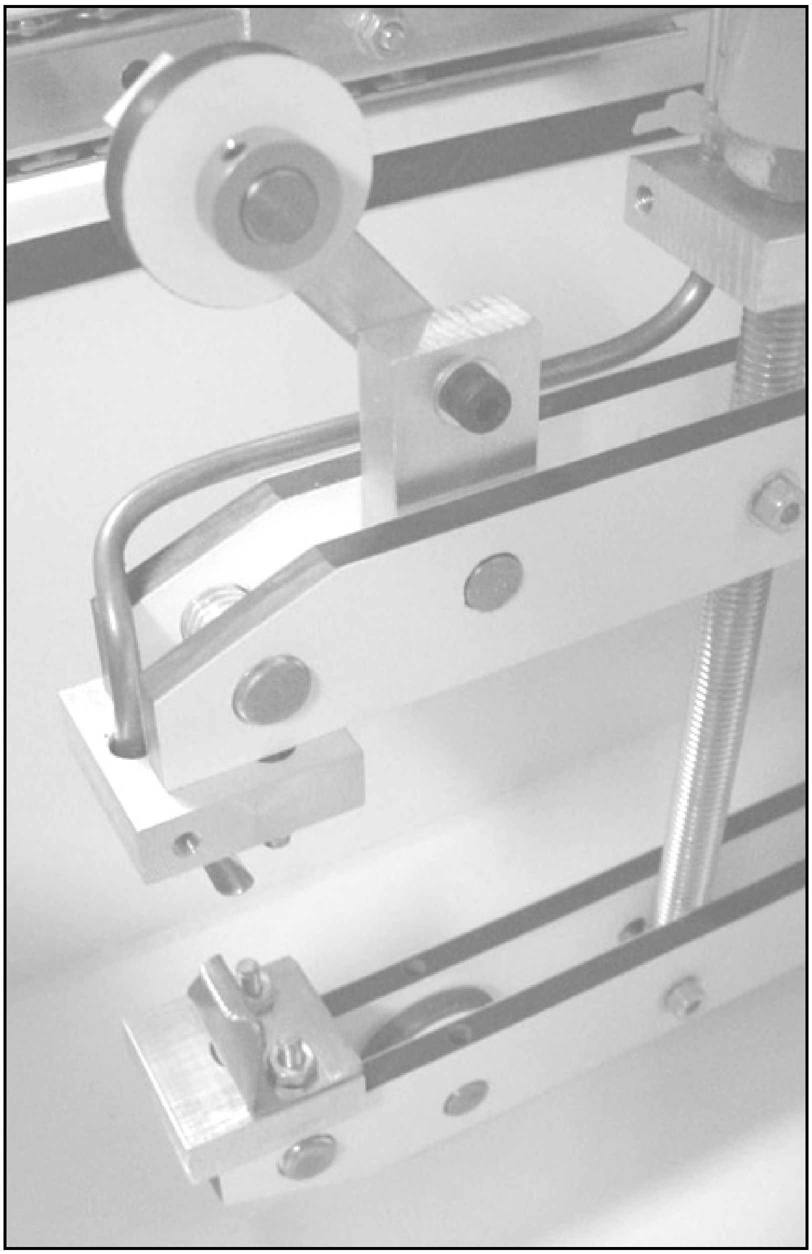


Fig.20 Wire Frame

The assembly is now completed. Final adjustments will be made later. The electrical current line (EDM GND) is connected to part (14E). Since this part is in contact with the studs (7E) the current will flow through it, proceed to part (11E) and make its way to the wire guide and wire node gauge via the copper pipe (12E). Make sure this is the case by using a multi meter.

The assembly drawings do not include parts for the vibration inducer, which is attached to the underside of the top wire frame arm assembly. This as solenoid design differs. However a schematic of the setup is provided. The vibration inducer should only be incorporated after the wire reel testing is completed. The solenoid is nothing more than a coil of enamel insulted copper wire. However EDM fluids and other oils can sometimes be chemically aggressive. As it is unclear how the wire insulation will react to the fluid it is best to seal in the solenoid and protect it by applying a layer of contact adhesive around it.

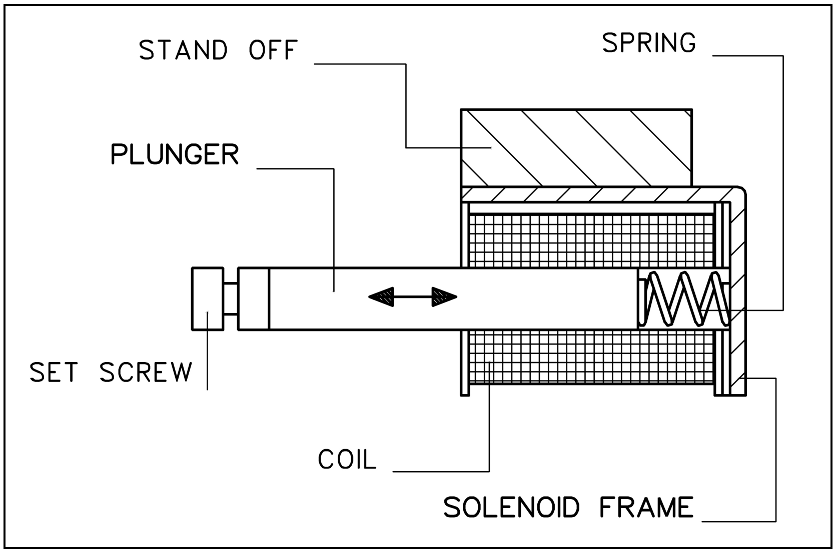


Fig.21 Vibration Inducer

5.3.6 Tank

It is important that all assembly F parts be washed. This is to insure a good bonding surface, as gluing at certain plate sections is required. The adhesive is used to seal the cracks at the intersections of the plates to prevent the EDM fluid from leaking out. It also adds to the strength of the assembly. Make every attempt to ensure that the sealing of the tank is done neatly.

Part (1F) is the drain block. It should first be equipped with a nozzle (C24) onto which EDM fluid hose can be attached to. Make sure that the nozzle fits in tight and will not leak. Apply adhesive around it as well. The drain block is attached to the underside of part (2F). To ensure that no leaks occur make a gasket out of the thick paper that fits over part (1F). Apply an all purpose contact glue to the gasket. Secure the two parts together tightly with the gasket in-between using nuts and bolts. Apply adhesive around the nuts and bolts to ensure sealing integrity. Allow the adhesive to cure.

Mount and secure the mount blocks (3F) to side plate (4F) and the support block (5F) as well. The support blocks are used on other plates as well and function to support the floor plate (2F). They made need to be adjusted to the correct height later. Screw a nut on each of the 6 studs (6F) until about 20mm extends. Add a nylon or rubber washer over the studs and insert each stud into the side plate (4F). Add washers and screw on nuts to each stud to secure it in the side plate. Mount and secure parts (3F) and (5F) to the other side plate part (7F). Slide the plate over the studs and secure in the same fashion as (4F). Slide the floor plate (2F) in-between the side plates. Mount part (5F) to the front plate (8F). Slide (8F) in-between the side plates. Mount part (5F) to middle plate (9F) and slide it in-between the side plates. Slide back plate (10F) in-between the side plates.

Adjust the position of the plates until they are all neatly together. The floor plate should nicely rest on the support blocks (5F). Make sure that the surface worked on is flat and free of debris. In a distributed fashion, tighten each outside nut of parts (6F). The inside nuts should be a bit loose to permit the tightening of the outside nuts. Unless sawing errors have been made, the plates should not extend material from the sides, be slanted or bent. Check that the unit does not rock on the flat surface and that there is no excessive clearance between plates. Note: only the side plates touch the ground. The three inner plates (front, middle and back plates) are all offset from the ground. Tighten the inside nuts.

After the tank plates have been checked that they are in proper position, carefully apply super glue to all possible intersection corners points. This is done to fix the plates in position prior to the sealing procedure. Do not to apply too much to fast, especially around the transparent front plate (8F). Super glue crystallizes and displays a frost like appearance, which can look sloppy when too much is added. Apply some more super glue later at the intersections to reinforce the bond. However, this time allow the glue to seep through into the cracks of the plate intersections a bit. Super glue is thin and will easily flow into cracks. It is also resistant to most types of chemical attack. Carefully check that the nuts of the studs are still screwed on tight.

When the adhesive is fully cured, tilt the tank at a 45-degree angle and support this position using a small object. One of the plate intersections is now positioned as a valley. Very carefully, at a slow even pace, administer semi-thick flowing contact glue in this intersection valley. The glue is used to seal the intersection. It must not be too thin or it may seep through the intersection crack and flow out. It should not be too thick either or it won't creep into and seal the crack. Allow the adhesive to fully cure. Do this same procedure for all the other inner intersections of the tank including the outside and the underside. Make sure that all intersection areas are sealed. Do not apply too much adhesive at once. This may promote the adhesive to peel of due the stress induced by the curing. Repeat the procedure using a chemically resistant two component epoxy.

Silicon sealant is not used to seal the intersection cracks. Administering it correctly requires a lot of attention, as it is too thick to creep into cracks by itself. Model shops do however carry silicon sealant that is less thick. Yet these do not seem to poses enough adhesive strength and peel easy.

When the adhesive in nearly fully cured check that the stud (4F) outside and inside nuts are still tight. If a cracking sound is heard when tightening, this may be the adhesive acutely losing its bond. Check to make sure that the adhesive has not come lose at one or more intersections.

The work piece clamp is made of two parts: (11F) (clamp bed) and (12F) (clamp block). Mount part (11F) onto the inside of side plate (4F) (cut a gasket out of thick paper and apply in-between to insure sealing). One of the bolts used to secure (11F) to (4F) must be attached to the EDM Pos. line using a connector terminal (C15). Screw in, in the inner most holes of part (12F), two bolts. At least 10 mm of each bolt should extend out. Insert bolts through the outer holes of (12F) and clamp this using nuts onto the clamp bed (11F).

Close off all open holes in the tank and slowly fill the tank with water. Check to see if any areas leak. If so, find the source, drain the tank dry and seal off the leak with the adhesive. Repeat this procedure until no more leaks are detected.

Test the sealing integrity of the tank again using water by blocking off any drain holes. Allow the water filled tank to remain that way for about 3 hours. Afterwards check if any of the water has leaked out. Remedy any leaks. Try and find the source and seal it off as close as possible. Drain the water completely. Install the pump, filter, valve and other plumbing

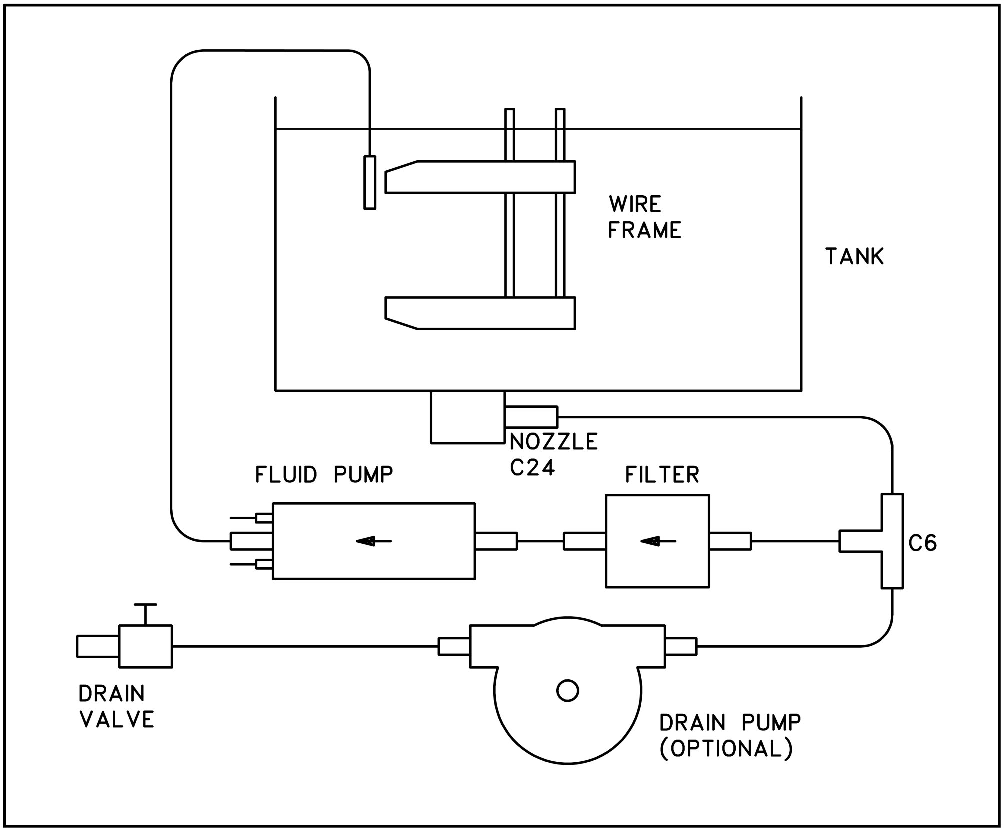


Fig.22 Fluid Circuit

components based on the fluid circuit schematic. Make sure that all connections are tightly tie-wrapped and/or sealed and that no leak is possible anywhere in the circuit.

The connector rack (13F) holds all of the chassis connectors. Drill appropriate size holes to allow these connectors to be fitted in including the EDM terminals. The EDM connections require an electrically insulated heat resistant standoff (Trespa or nylon ring) so that no short circuit is possible. Mount and secure the connector rack (13F) to the foot plate (14F). Mount the tank assembly to the foot plate via the mount blocks (3F), which were attached to the side panels. Add foot pegs (C12) on the underside of the foot plate. Hold components such as the pump in place using tie-wraps and mounts.

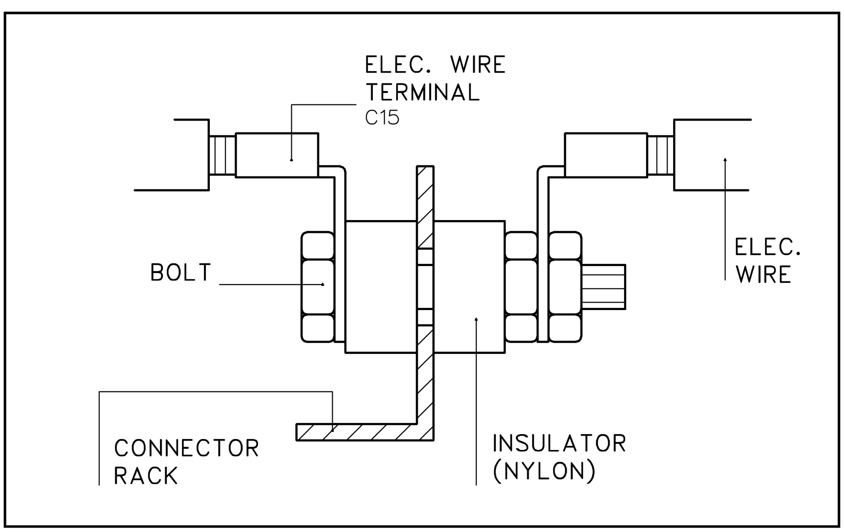


Fig.23 EDM Terminal Setup

When it’s ABSOLUTLY certain that the tank and plumbing does not leak, administer vegetable oil in the tank. Use enough to fill the tank to just above the floor plate (2F). Apply 12 volts to the pump motor and test the pump circuit for leaks. The pump must first prime the circuit since there may be air in it. Run the pump for about 5 minutes (the motor should not overheat). There is always some fuel left in the pump. The odor will be evident (keep away from sources that may ignite this). Discard the oil appropriately and repeat the procedure using fresh oil. Repeat this procedure until the scent of fuel is no more. Do not use this oil for EDMing, it may now be much more flammable.

Position and secure the completed guideway assembly (ABCDE) to the completed tank assembly F. Using the two mount bars (15F) to clamp the guideway assembly onto the studs (4F). Do not over tighten! The guidway assembly rests on the tank. It only requires a light pre-load to secure its position. Since it will not meet any significant machine cutting forces it does not even need to be tightly clamped down.

Install the limit switch holders onto the guideways. Place all wiring and cable. Use tie wraps to neatly hold the plumbing and cables in place. Attach the appropriate connectors to the connector rack, part (13F). Connect the wiring. When the system is in use an air pocket may start to reside in the filter. Try to avoid this.

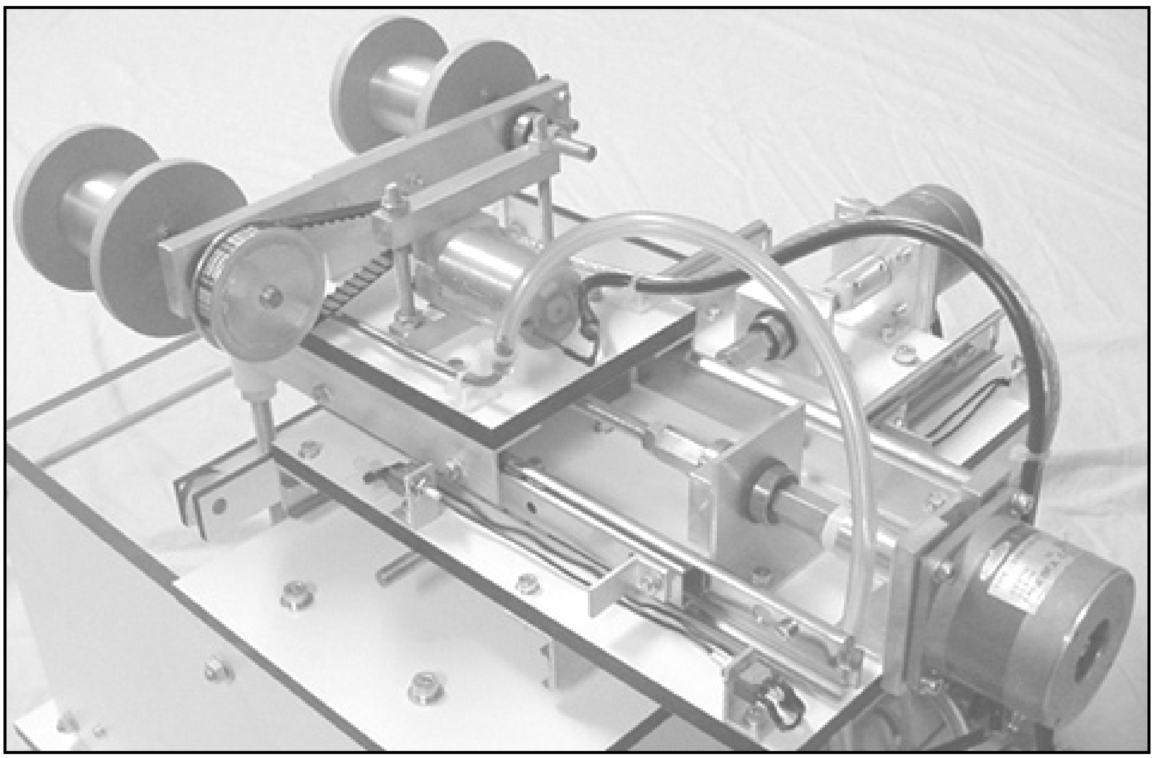


Fig.24 Guideway Assemblies

5.3.7 Primary Spool Stand

The primary spool stand is the last assembly. Its function is to simply allow the wire on the spool, onto which the EDM wire was purchased, to be reeled off and onto the one of the wire frame spools. The stand uses a round steel rod to carry the spool. The ends of the rod are each carried by two bolts. The spool is does not use bearings; it simply slides around over the rod. The size of the stand will accommodate small size EDM spools.

Mount and secure the studs (1G) into side plate (2G). Mount and secure the other side plate. Make sure that the side’s plates are nice and parallel to one and other (work on a flat surface). Screw in the plate’s bolts (carries the spool shaft 6G) with the pulley arms (3G). Slide the pulley shaft (4G) into one of the pulley arms. Slide a (C21) then a pulley (5G), another (C21) and then the rest of the pulley shaft into the other pulley arm. Secure position of the shaft in the arms using two more (C21). Place the spool shaft (6G) through the primary spool. The shaft ends extend out of the spool, rest these ends on the extending bolts. Rotate the spool by hand. It must turn easy and not encounter any significant fluctuating resistance.

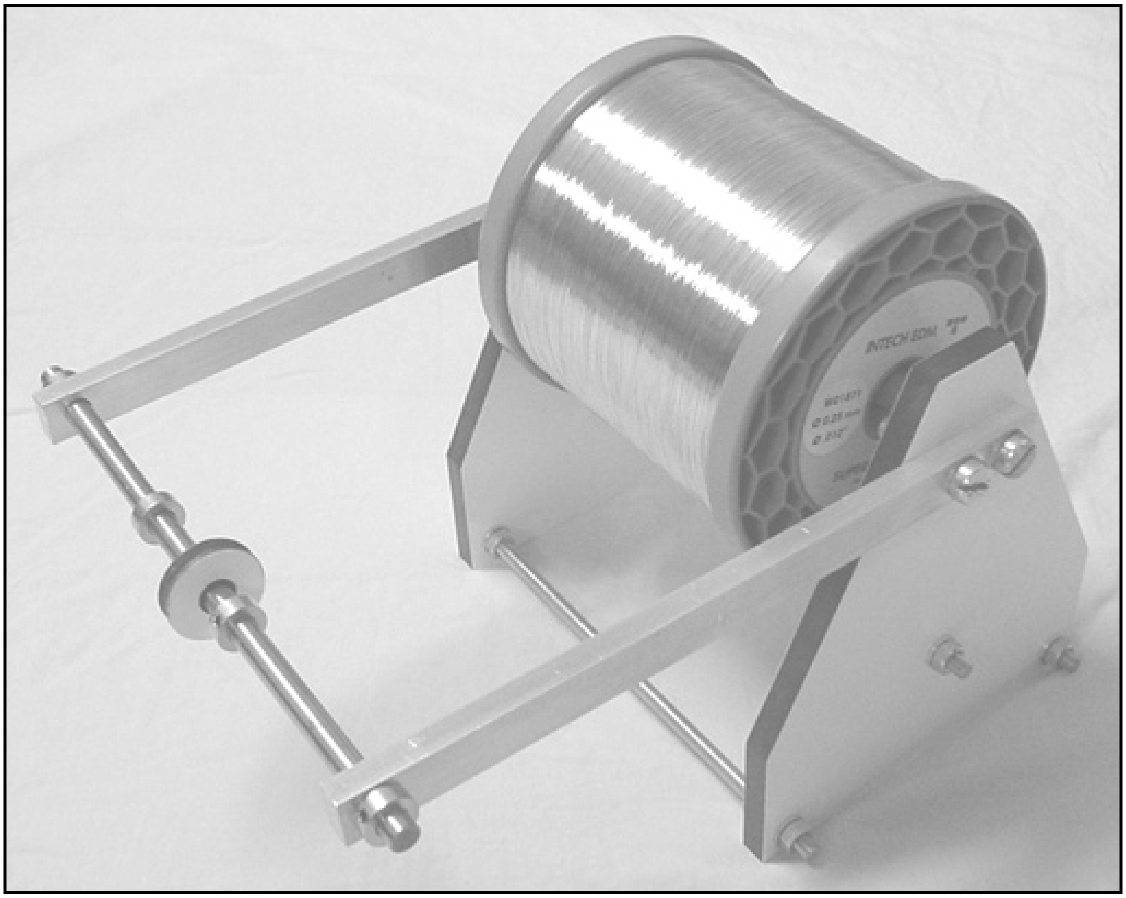


Fig.25 Primary Spool Stand

5.3.8 Configuring the Wire Frame

The assembly testing pertains to the adjustment of the wire frame. The reeling of the wire through the frame must proceed accurately and vibration free between the wire frame arms. It must be adjusted to a point that it is virtually insensitive to outside mechanical disturbances.

The reeling of wire from the primary spool onto one of the wire frame spools is a seemingly easy task. This is true, yet it must be done in a certain way otherwise it will cause problems later during reel-off. When the wire is reeled off during a machine task it has the tendency to become entangled in the remaining wire segments on the spool. The wire jerks and may even run under another segment of wire on the spool. This may cause the wire to lock and possibly break. The reason for this situation is that during the reeling on of the wire, from the primary spool, the reel forces may tend to fluctuate. This causes the wire to tighten and loosen which promotes the wire to sometimes unwind a bit, then tighten and overlap other segments. There are several approaches to retard this situation from occurring:

- During reeling apply small drops of candle wax onto the wire to hold it in place.
- Spool drum diameter size should not be too small.
- Make sure that the wire is nicely reeled from one side of the drum to the other. Since the primary spool is usually much wider than the wire frame spools, the wire may tend to reel onto only one side of the drum.

- Make sure that the primary spool does not become periodically obstructed and then relieved during reeling.
- Make sure that wire reel tension is sufficient.
- Keep the primary wire spool stand at a significant distance from the wire frame spool during reeling.
- After the wire is reeled on use a piece of tape to hold the wire in place. The wire may easily unwind otherwise. The result is an entangled mess, especially with brass wire.

Other ways to allow proper reeling is to directly reel the wire from the primary spool itself during a machine task. The adjustable pulley on the wire frame will assist to allow this. Note: the wire frame travel (X and Y-axis motors) should not be set to a high feed rate when this configuration is employed. Also, if the wire breaks during a machine task it may cause the rest of the wire on the spool to release and unwind. One last approach is to make a seperate wire spool stand with a strong motor that runs at much higher speed. The wire is reeled on at a much higher rate. The result is that wire tension is more stable during reeling and the wire can more easily be evenly spread out over the spool drum. This is accomplished by holding the wire with a piece of cloth, allowing it to slide and directing it in a side to side motion over the drum.

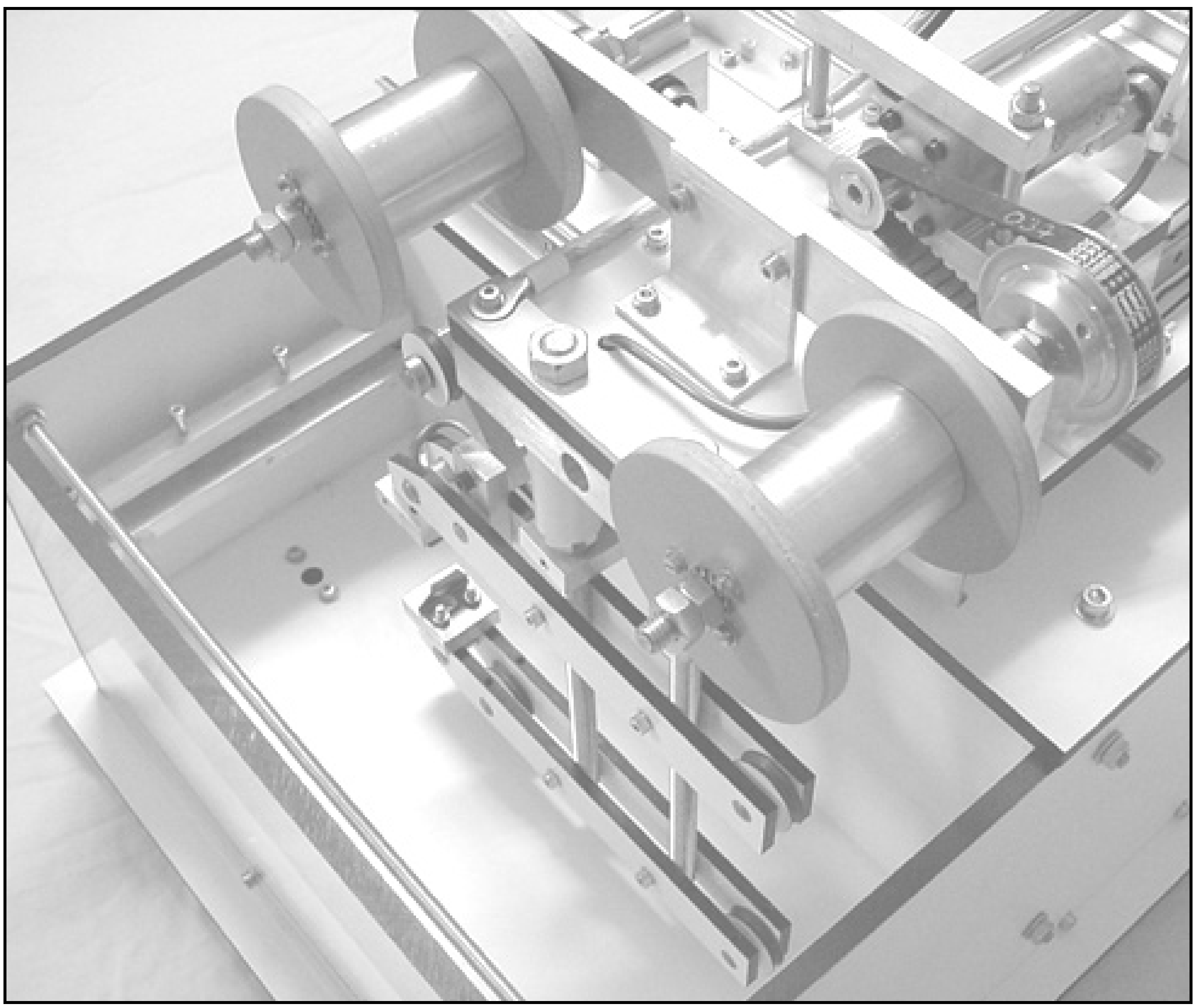


Fig.26 Wire Reel System

Reel about 20 meters of thin wire (+/-0.3mm) onto the wire frame spool. Use a 12-volt power supply for the wire reel motor. After reeling apply tape to prevent the wire from unwinding. Exchange the wire frame spools. Rotate the spool with the new wire and adjust the leaf spring until lightly drags against the spool. Remove the tape and direct the wire through the wire frame. Be careful that the wire does not unwind. Wrap the wire around the other spool (reel-on spool) a couple of times. Use a piece of tape to hold the wire in position. Make sure that the wire runs in the valleys of the pulleys and guides. Loosen the nuts that secure the wire node gauges a bit so these can be repositioned. Position the gauges to lightly brush against the wire and re-secure the nuts. Check to see that the wire is in a vertical position between the wire frame arms. Activate the wire reel motor. If the wire breaks then the tension was set too high. Adjust the adjustable pulley and/or leaf spring accordingly. Look for any reel obstructions that may have contributed to the wire breaking. Activate the motor again and check that all pulleys rotate during reeling of the wire. Make sure that the wire segment in-between the wire frame arms runs steady and jitter free. Adjust the wire node gauges and/or adjustable pulley if necessary. Getting this to work right may take some practice. Tap on the reel-off spool to simulate external mechanical disturbance. The wire segment in-between the wire frame arms should be virtually insensitive to this. If not, adjust the wire nodes and/or wire tension.

After completing the above, attach the vibration inducer. Position it in such a way that the plunger rests against the wire node. The spring inside the solenoid should be lightly pre-loaded by this. During a machine task the vibration inducer must supply only low amplitude vibration to the wire. The plunger should preferably only tap against the wire node and not clap against it. This can be adjusted by moving the solenoid forward or backward. The vibration inducer supplies vibration in only one translation plane. However, inaccuracies in the plunger dimensions and other parts will promote the wire to vibrate in other planes as well. This is of value as vibration should ideally be present in both the X as well as Y directions.

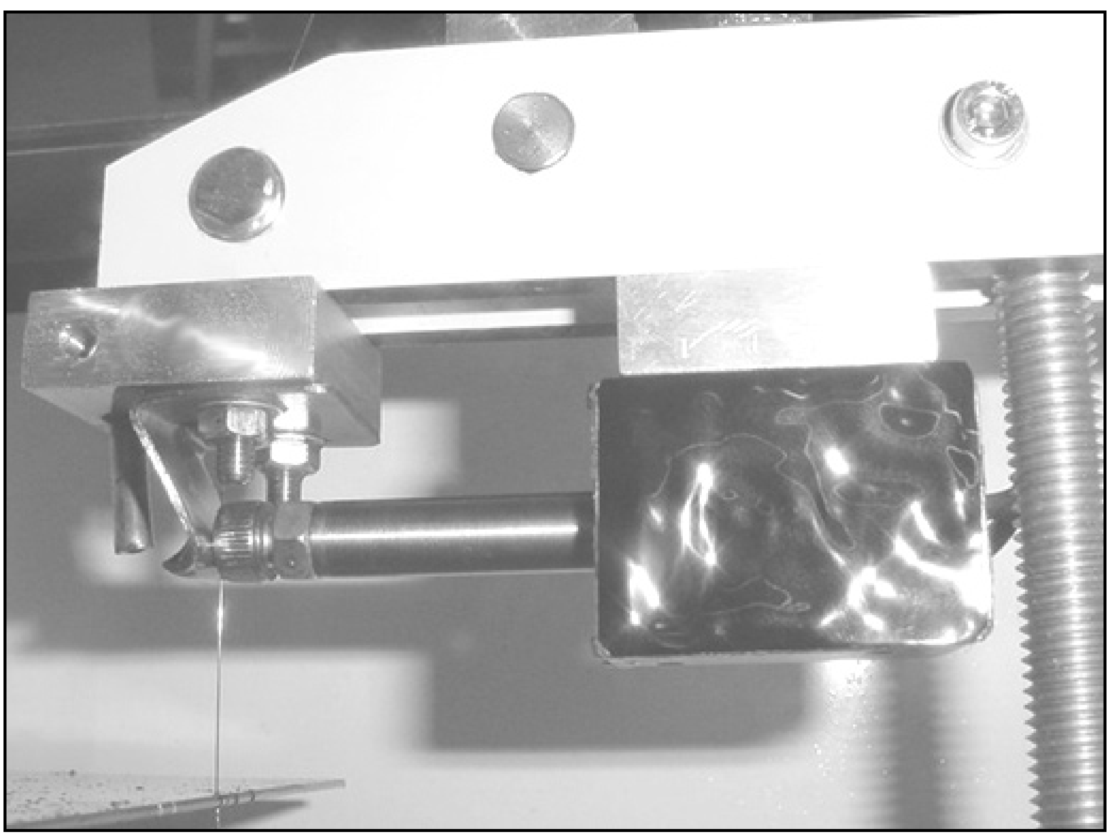


Fig.27 Vibration Inducer

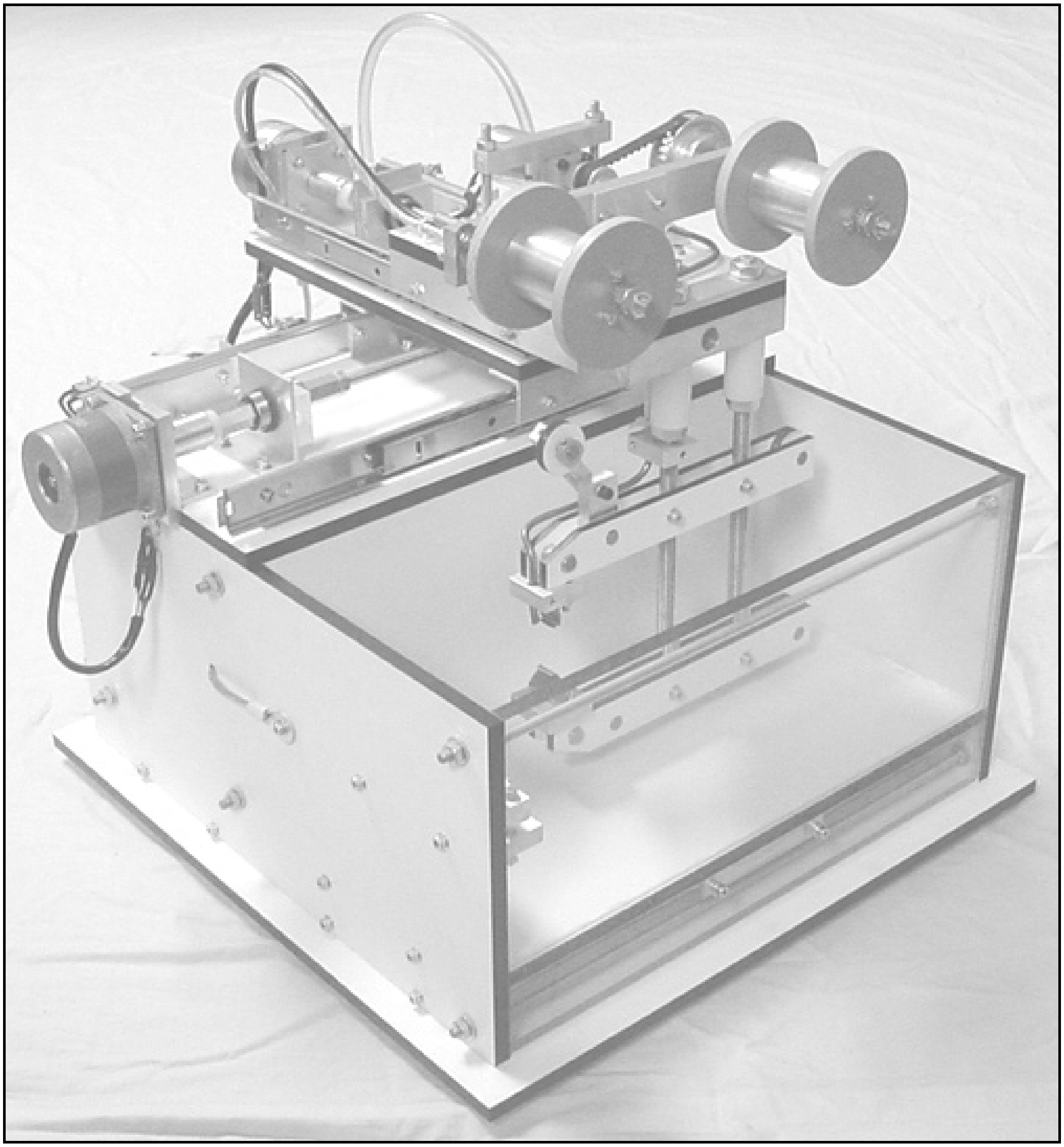


Fig.28 Completed Mechanical Assembly

6. The Electrical Setup

WARNING
The EDM power circuit can be very dangerous if used incorrectly. Output can be lethal (see Safety Protocol).

The electrical setup is comprised of 8 different units, namely:

1. EDM power circuit
2. Feedback circuit
3. Chopper circuit
4. Pump speed control circuits
5. Wire motor speed control circuit
6. Vibration inducer circuit
7. Stepper motor driver circuit
8. Stepper motor power supply circuit

These 8 units should be integrated into two separate housings. One case would include the first 6 units and the other would include the last two. Computer cases may suffice best for this. They are already equipped with many of the connectors brackets needed for the unit. However housings can also be built which would permit a more desired layout of the circuits. A simple design is to use aluminum plates and angle profiles which are bolted together to form the housing. A basic example for constructing a suitable housing is depicted in the drawings.

The circuit drawing schematics can be found at the end of this manual. The drawings are largely self-explanatory and should be easy to follow. Yet some explanations are given as to the workings of the circuits and tips to assist in the installation.

The EDM power supply is a capacitive discharge system. The unit can be very dangerous. A charge becomes present in the EDM circuit capacitors when the unit is turned "on". Yet this charge remains present after the unit is turned “off”. The capacitors may still be loaded. This charge must immediately discharge after the unit is turned "off". As a precaution, always short the EDM terminals using a screwdriver with an insulated handle to make sure that their is no electrical charge present. A spark may result when the terminals are shorted. This procedure protects the operator from accidental electric shock due to the capacitor charge. This is especially important when making adjustments to the unit after the unit is turned “off”. However the circuit design includes a chopper circuit that shuts off the EDM terminal connection when the unit is off. It also includes a warning LED to be placed in the front panel of the EDM power supply housing. This provides an indication regarding the capacitors charge when “on”. When “off” however it should not be concluded that the capacitors have been completely discharge since the LED may have somehow been damaged. Another aspect is that the EDM circuit uses the mains for power. When opening the EDM circuit housing be alert that mains voltages are present. ALWAYS unplug the unit from the mains, short the terminals of the unit and flip all capacitor switches once before opening the housing. Again, be alert!

Mains voltage for the components listed in the “Electrical Setup” section are for 220V. For countries that have 110V simply use this value when selecting components. However, output should more or less conform to the values listed. Example, a transformer with 40V, 6 Amp. out is required. Find a transformer with a 110 V (or which corresponds with the mains voltage used) that delivers the 40V, 6 Amp output. The rectifiers used for this circuit are bridge rectifiers normally used for full rectifying of AC to DC. Only one of the internal rectifiers of each bridge is used.

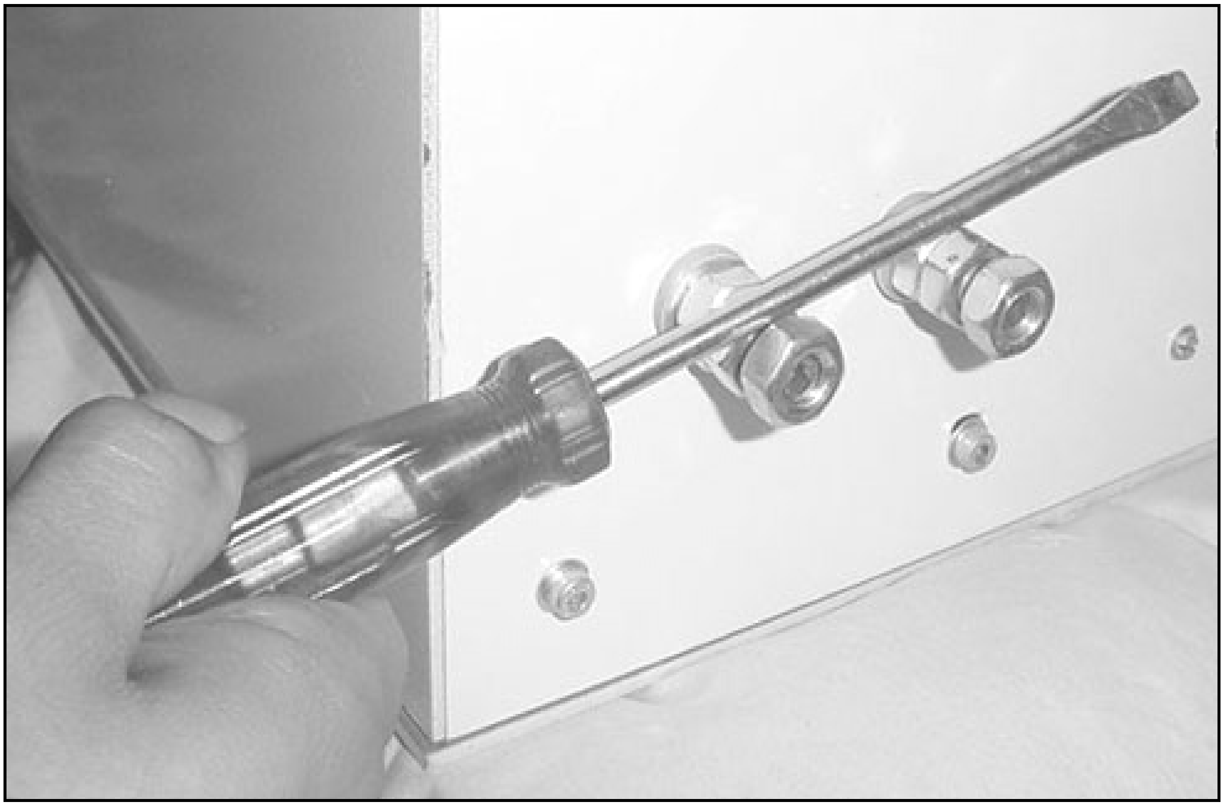


Fig.29 Discharging the EDM circuit

This can be a less expensive solution than buying single high current diodes. The bridge rectifiers should be bolted to the housing for proper heat transfer.

To maintain gap clearance between the electrode and work piece during operation, the unit resorts to a feedback circuit. The circuit is based on a conventional reed relay circuit with an adjustable set point.

A MOSFET switched chopper circuit is included in the design to enhance sparking process control.

The W-EDM unit is designed to use a 3 axis 2 Amp Camtronics Inc. driver for the stepper motor. This 2 Amp, 12-volt driver offers very good performance at low price (see Suppliers Section).

Two “speed control” circuits are used. One is for regulating the wire speed, this is essential. The second is for the fluid pump. Speed control circuits are very common. There are a number of companies which sell inexpensive and completed circuits (see suppliers section). Since the motors are not of a specific model, it is necessary to find the best suited control circuit based on the specifications of the acquired motors. The motor for the wire reel is also required to be greatly geared down. Motor specifications can be found in the component list.

Certain components (resistors, diodes, LED’s) are to be spliced in between lines sometimes. These should be solder connected and insulated using shrink tube. This is a special material in tube form. It is placed over the soldered wire connection and then momentarily heated. It then shrinks over the connection. Use this on every possible connection.

The EDM circuit case includes three transformers. T1 is for the EDM power supply, T2 is for the speed control circuits, feedback circuit and chopper circuit and T3 is for the vibration inducer. Make sure that T2 and T3 have sufficient power to support the demand of the connected circuits.

6.1 Building Tips

- Try to avoid that the high current EDM lines cross over or are laid in the direct vicinity of other circuitry. This could otherwise induce cross talk and may cause the circuitry to perform improperly.
- Install passive components like resistors and capacitors first. Active components, like ICs, are the most sensitive and should be installed last. Observe anti-static precautions and use IC sockets. If an IC fails it can then be replaced easily. Try not to touch the pins.
- Whenever possible test component values using a multimeter. This not only determines if the component functions but also if it’s the right one.
- Make sure that electrolyte capacitor pins, and other polarized components, are fitted correctly. If installed incorrectly they may burn out or even explode. Usually the side of the capacitor will have markings that indicate which pin is the anode or cathode.
- Use thick stranded cable (audio speaker cable) for the EDM wiring. Try and keep all cables as short as possible.
- Use a solder iron that has sufficient power to work fast. Use only solder that was specified specifically for electronics use. After soldering clean the circuit using an appropriate PCB cleaner.
- Use cable strap mountings (tie-wraps) to neatly hold down cables. Work as systematically as possible. After all is done check that lead clippings and other material are not laying around in the housing. This type of debris can cause shorts.
- Check if the main transformer (T1) works by measuring the output voltage with a multimeter. The primary side of a transformer usually has thin coil wire while the secondary side has thick coil wire. Be careful, the primary is connected to the mains.
- Bad solder connections on the circuit board and at connectors are most frequently the source of problems. Check using a multimter. Purchase pre-made connector cable if possible.

6.1.1 The Housing

The housing depicted in the drawing uses a relatively thick aluminum plate as the base and less thick plates, of the same material, function as the panels. The thin plates are bolted onto angle profiles. Since the case is all metal it acts as a heat-sink for the components. To improve cooling performance the side panels have a number of vent holes drilled in.

The size of the housing can be determined by placing all the components in a desired configuration (drawings give the suggested placement of components). The dimension is then measured and oversized about 15% to allow for placement of wiring, panel switches etc.

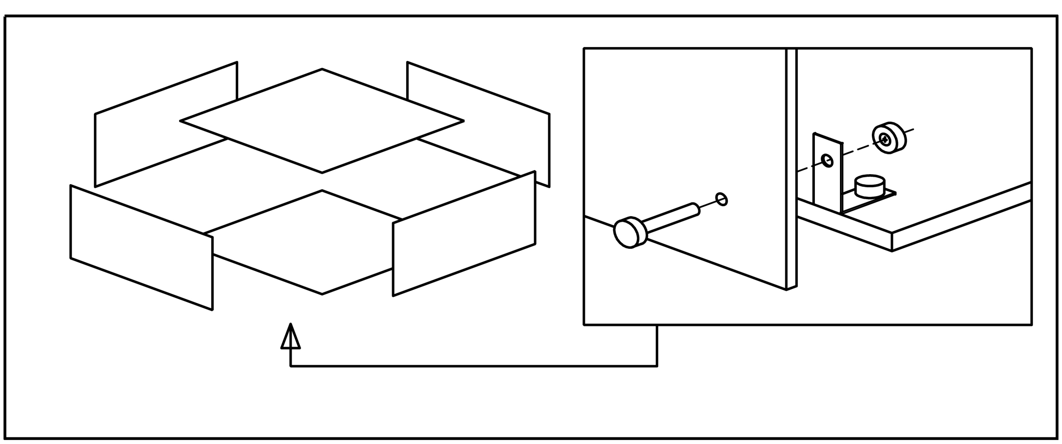


Fig.30 Housing Design

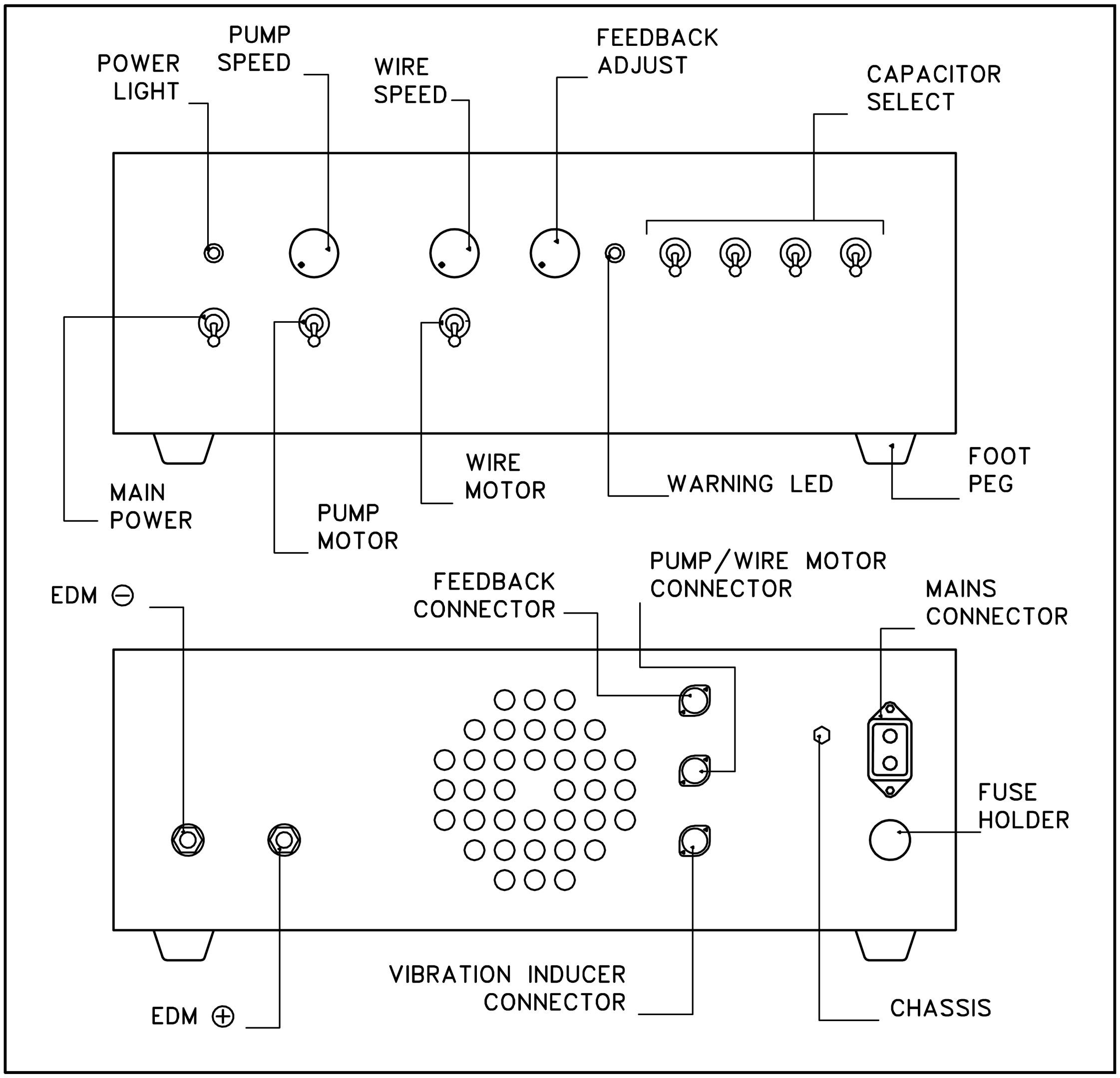


Fig.31 Front and Rear Panels

6.2 The EDM circuit

Just like a mechanical assembly the components of the EDM circuit need to be made to fit together correctly, electrically that is. The following elementary calculations show how to do this. They provide ball-park figures. However, the calculations are not necessary to build the circuit. Gathering the listed components and following the schematics of the circuit will allow the completion of the unit just as well. The calculations simply give an insight for builders interested in better understanding how certain aspects of the unit have been designed and work. This can be important when selecting components that do not exactly conform to the component list. In addition, if components fail the cause may be more easily located. And lastly the calculations may be useful when making modifications to the circuit.

6.2.1 Calculations

The EDM power circuit described here is a 300-Watt capacitive discharge chopper circuit. The unit is made up of very common and inexpensive electrical components and will perform most adequately for this project.

The basic workings of the circuit are simple. It uses a large high current output transformer to separate the circuit from the mains and step down the voltage. A rectifier then converts the AC voltage into DC. The output from the rectifier is directed to a low resistance resistor that can handle high current. The function of the resistor is to limit the short circuit current to a value that is under the maximum tolerable current of the transformer. This protects the transformer from burning out. The resistor needs to dissipate the short circuit power that is developed.

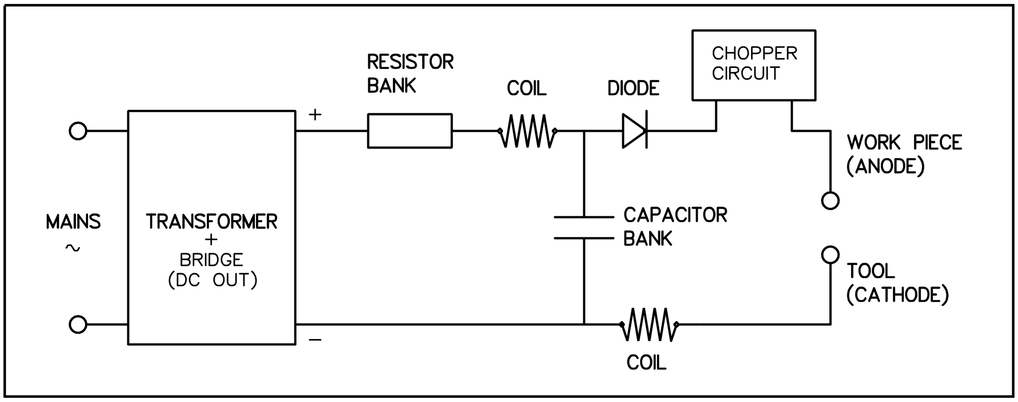


Fig.32 EDM Circuit

The output of the resistor is directed towards a bank of capacitors ranging from a low to a high capacitance value. Each capacitor can be selected individually, using toggle switches, to provide the desired capacitance. Discharge capacity of the EDM circuit results in 16 different capacitor combinations. The minimum capacitor setting is about 50 uF and maximum setting is around 1000 uF. In between the short circuit resistor and the capacitor bank is a small coil. This component reduces the possibility of surge currents from semi welding the toggle switch contacts during switching. The workings of the coil are similar to the inertia experienced when trying to push a mass that is at rest. Initially it takes some effort to push the mass and get it to move. This is the same in the case of the coil. The electrical tension (voltage) needs a moment to get the current up to speed. Parallel connected to the capacitors is a bleed resistor setup and “Warning” LED. The function is to drain the capacitor charge as soon as the circuit is turned off.

The positive line (anode) from the capacitors is connected to a terminal located in the back of the housing. From here a line is directed to the work piece via the tank assembly clamp (see DR.3 at the end of this manual). The negative line from the capacitors is first attached to another coil. The coil serves to produce the same effect as that of the previous coil. However, here the coil is used to protect the EDM wire from surge currents. This line also has its own terminal and from here a line is directed to the tool (wire), representing the cathode.

With the EDM circuit turned "on" the transformer will load a base capacitor (C1) and any switch-selected capacitors almost immediately. A voltage will be present over the electrode and the adjacent work piece. When these two come sufficiently close together the electrical tension will cause a spark, generated from the electrostatic charge of the capacitors, to jump the gap and strike the work piece. After the spark, the gap resistance will then rise again allowing the selected capacitors to recharge (This is the reason that fluid with a sufficient dielectric value is required. If the insulation properties of the fluid are poor then the recharging process of the capacitors may be impaired). The capacitors will then again cause a spark to strike the work piece once their voltage breaks down the resistance of the gap.

However an electrical effect takes place after each spark which, if not canceled out, could lead to the capacitors being reversed charged. This effect would also start to erode the electrode more rapidly. After each spark discharge the current will start to ring back and forth in the EDM circuit until it dampens out. The current is changing direction periodically. This scenario can be better illustrated using the mechanical analogue of the effect. When a metal rod is secured at one end and is tapped with a hammer on its other end (tuning fork, for example) it will cause the rod to vibrate or ring back and forth at its natural frequency. This same effect applies to the electrical circuit. The hammer is represented by the spark discharge and the rod is represented by the electrical circuit. The ringing can have a detrimental effect on the electrode (the wire) since the current periodically changes direction. In other words the electrode becomes the anode for a moment and receives, during this period, the incoming spark discharge. Hence, the electrode will start to prematurely erode since its also taking the punches. To prevent this ringing effect, a rectifier is place between the work piece line and the output from the capacitors. The spark discharge can now only jump the gap from the electrode to the work piece and not the other way around, protecting the electrode and the capacitors.

6.2.2 Short Circuit Resistance

The transformer used in this project is a single unit. Although smaller transformers set in parallel could be used, to increase the maximum current, it is not advised to do this. Outlets, which sell salvaged electrical components, are common in most places. Most always a good-sized transformer can be found. Large sized transformers are preferred due to their high heat sink capacity.

As previously explained the required transformer should step down the mains voltage to about 40 volts and allow 4 to 6 amps maximum current. Naturally, if the transformer output is shorted the current will rise above this level, and may cause it to burn out. A resistive load is therefore required to limit this value to under the maximum value. The equation to determine the resistor value is as follows:

U 1.4 / I = R

U = Voltage (Volts)
I = Current (Amps)
R = Resistance (Ohm)

For a 40 Volt, 6 Amps transformer:

40 X 1.4 / 6 = 9.3

Hence, a resistance value of 9.3 Ohm is required to safeguard the transformer by keeping maximum current to under 6 Amps. This resistance value is low with respect to the current that will be passing through it. A lot of heat will be produced and the resistor must be able to dissipate this. The amount of heat can be represented by the power developed. The calculation is as follows:

U X 1.4 X I = P

P = Power (Watts)

40 X 1.4 X 6 = 336

The resistor must be able to dissipate 336 Watts of power.
There are a number of different types of resistors that can meet the value of 9.3 Ohms and dissipate 336 watts of thermal power. Take into account that these are ballpark figures. The components chosen do not have to meet these calculated values exactly. However they must not be much less than these values.

Probably the most inexpensive type of high power resistor available is the common light bulb. This type of resistor performs as an active current limiter. The resistance increases as voltage over the bulb increases. This attribute can be helpful in preventing voltage spikes from the EDM circuit passing through the transformer and polluting the mains. The light from the bulbs also acts as a diagnostics indicator of the circuit. Hence, it can be used to isolate problems or failures in the circuit. Apart from light bulbs, high power carbon resistors in anodized heat sink housings could be used. This type of resistor permits a tight high-tech looking package with high tolerance values. But they offer little extra advantage over the common light bulb for this application. They are also about 10 to 15 times more expensive than bulbs.

A common 100-watt light bulb offers about 50 to 70 Ohms of resistance. This is 5 times more resistance than needed and 3 times less power than required. However placing a number of these bulbs in parallel can reduce the total resistance value. The sum resistance of a parallel resistor circuit is always lower than the smallest resistor value. Since the bulbs all have the same resistance value, the following calculation applies:

R / LBn = Rt

LBn = Amount of light bulbs
Rt = Total resistance (Ohms)

50 / 4 = 12.5

Again, this equation only applies when each resistor has the same resistance. 12.5 Ohms is above the minimum value. This is okay. However, the resistance also limits how fast the connected capacitors will charge up. If the resistance value is much greater then 9.3 Ohms it will cause the capacitors to charge up slower. As explained, light bulbs do not have a constant resistance value. The greater the voltage over them the higher their resistance becomes. In practice this effect has proved not be of that much influence. The reason is explained later. But it's good to keep the total nominal resistance no more than about 50 % greater than the calculated value. For builders that wish to get a bit more out of the circuit, 5 bulbs of 100 watts each in parallel could be used. This will amount to 10 Ohms total resistance. This is just above the 9.3 value.

Since each bulb is a 100-watt resistor the 4 bulbs will have a combined power of:

P X 4 = Pt

Pt = Total power (watts)

400 watts

This is about 15% above the 336 watts calculated. That's good. The more the better. All it means is that it can handle the minimal required thermal power dissipation value. If 5 bulbs are used then the total power dissipation will jump to 500 watts.

6.2.3 Discharge Power

The total time that a capacitor requires to fully charge depends on its capacitance and the resistance that the current meets. This can be calculated as follows:

Rt X Ct = t

Ct = Total Capacitance (Farads)
t = tao (time factor)

Lets say that Ct = 500 microF

12.5 X 0.0005 = 0.00625

The t represents a time factor. Normally when this t value is multiplied by 5 it depicts the total time needed to charge the capacitor to more than 95 % of its capacity.

0.00625 X 5 = 0.03125 sec

It is evident from the equation that increasing either the resistance or the capacitance will increase the charge time as well. However take into account that we are working with milliseconds.

The amount of power that the capacitor will develop when it discharges can be calculated as follows:

5 X (R X Ct) = T

Rd = Discharge resistance
T = Time (milliseconds)

Lets say that Rd = 0.5 Ohm and Ct = 500mF

5 X (0.5 X 0.0005) = 0.00125 sec

Encountered resistance for the discharge is different from the charge resistance. This is because the discharge occurs over the electrode (wire) and work piece and not over the bulb resistors. Hence, the resistance is very low and consequentially the discharge time is as well. The discharge energy is:

0.5 X Ct X U X U = E

U = Volts
E = Energy (Joule)

0.5 X 0.0005 X 58 X 58 = 0.841 Joule

The duration time at which this energy is released, the power, is 0.00125 sec.

E / t = P

0.841 / 0.00125 = 680 watts!

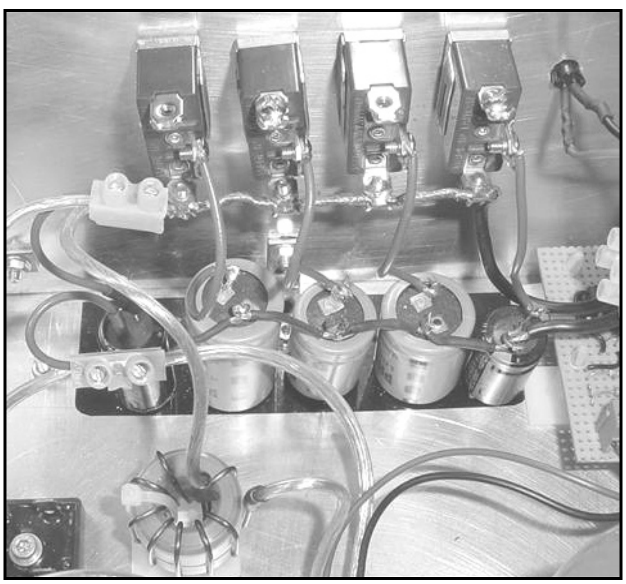


Fig.33 EDM Capacitors

The equation reveals that increasing the voltage and/or decreasing the resistance, thus discharge time, will proportionately increase the power of the spark. Since the voltage is squared in the equation it has the most effect.

High power discharges result in a high material removal rate. But this is done at the cost of precision and surface quality and can lead to the wire breaking. The wire and work piece will display a more beaten surface. Hence high power discharges may serve to pre-erode a desired profile in a relatively short time. Selecting a lower value capacitance has a more docile effect. Discharge power is less and the erosion rate decreases but surface quality of the work piece is better.

6.2.4 Testing the EDM Circuit

After all EDM circuit components have been installed in the housing check for any possible shorts or incorrect wiring connections. Also to make sure that loose wiring or connections can NEVER make electrical contact with the panels of the housing. Use PCB stand-off's, tie wraps, mounts and connector blocks to neatly integrate the wiring. When all is complete and double checked for shorts and/or incorrectly connected components switch all capacitor toggle switches to "off", including the main switch. Plug the unit in the mains and then turn the main switch "on". The fan should run and the "power" and "warning" lights should light up. Holding the insulated portion of a screwdriver, tap the EDM terminals with the metal end and short them. A nice small spark should occur. Tap the circuit a couple of times more. Now do the same again and one by one increase the capacitor setting from small to big. (Note: the toggle switch contacts may have the tendency to percussion weld despite their amp rating, the application of the coil (Coil1) in the circuit and the step wise switching from low settings to high. If welding occurs use a higher inductance rated coil or only switch when the unit is off.) The spark size and cracking sound should progressively increase as higher capacity capacitors are selected.

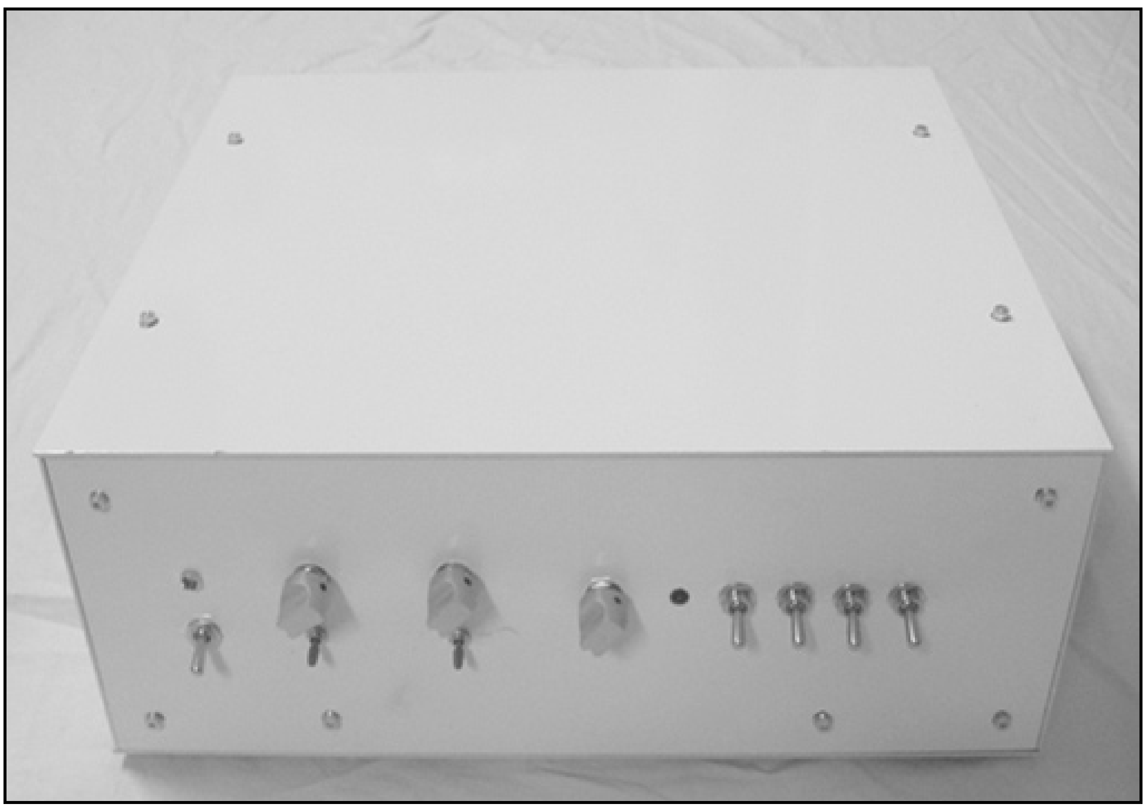


Fig.34 The Completed EDM Circuit Housing

Turn off the main switch. The warning LED should quickly fade out. Short the terminals to make sure that the capacitors have been fully discharged. Each capacitor could also be fitted with its own bleed resistor (100K). However it is still good practice to short the EDM terminals. Unplug the unit from the mains and wait 30 seconds. Check for components and wiring that may seem to have become very warm. No component should become so warm that you can't touch it. If this is the case then this needs to be replaced with a higher rated substitute.

6.3 Feedback Circuit

The function of the feedback (FB) circuit is to maintain a certain spark gap distance throughout an EDM operation. This is necessary for the process to function correctly. Also, if the wire and work piece touch, no sparking will occur. The process may crash and/or the wire may burn through and break.

The feedback circuit uses a reed relay to insure circuit separation. The relay is transistor switched. The FB circuit senses the EDM circuit voltage by connecting a line from the EDM capacitors (anode) to the transistor. The voltage from the capacitor is first divided between 2 resistors (R1 plus VR1 and R2). Due to the high value of the first resistor and the input resistor of the transistor, reduced voltage is present and only low current will pass. The sensitivity of the FB circuit can be adjusted by the variable resistor VR1 (sense adjust).

To maintain the correct spark gap distance, a signal is provided to the computer by the FB circuit based on the state of the capacitor charge. Capacitor charge is high when no sparking occurs and low when it does occur. It goes to zero when the electrode and work piece are short-circuited. The level of voltage over the terminals of a capacitor is directly related to its level of charge. If this level is above a certain set value, the feedback circuit sends a signal to the PC. This signal is interpreted by the software, which in turn instructs the stepper motor to continue running the task. Consequentially the tool is fed towards the work piece. At one point sparks will strike and the mean voltage over the capacitor will decrease as its charge is being depleted. When the voltage goes under the set point, the feedback circuit senses this and cancels the signal to the PC. The software then, almost immediately, instructs the stepper motor to automatically "pause" motion. After a moment of spark strikes the software then gives instructions to "retract" the wire from the work piece a bit and then "reset" to the original position. The "pause" time can be pre-set in the software as well as the degree of "retraction" steps (larger work piece strike area requires longer pause time). The retraction of the tool creates a larger spark gap distance and allows the eroded material to be more easily flushed from the strike zone. This prevents shorts and promotes better process workings. However it is more of a fail-safe feature to limit the chances of the process crashing. When the capacitors are charged up again, and above the set point, the circuit will resume sending the signal to the PC and the process continues.

The feedback circuit is comprised of only few basic parts. Taking the time and effort to specially make a print for this circuit would not present that much advantage. Using a test board and connecting the components based on the circuit drawing would work just as well. The test board is made of many equally spaced copper islands on a resin plate. Each island has 3 holes to solder component pins and wiring in.

The feedback circuit and the EDM circuit ground (EMGND) must be connected. After soldering inspect the circuit for shorts.

6.3.1 Testing the Feedback Circuit

After the feedback circuit is installed verify that all connections are correct. The feedback output line should be as far away as possible from any high current EDM lines. Connect a multimeter (set to lowest Ohm reading) to the output line (FBGND and FB). The multimeter must read an open circuit since the reed relay of the feedback circuit is "normally open" when the EDM unit is “off”. Connect the mains to the EDM circuit and check the reading again it must read the same. Turn the EDM circuit “on”. Turn the feedback adjust (VR1) from one side to the other and back slowly. At the same time view the reading on the multimeter. At some point the reading will indicate a closed circuit (very low Ohm value). Keep the feedback adjust at just about this point. (Note: It has occurred more than once that the relay of the FB circuit does not become active when the EDM circuit is initially turned “on”. By tapping the EDM terminals with a screwdriver the relay should become active). Short the EDM terminals. The reading on the multimeter should switch over to an open circuit reading (infinite resistance or no reading). Now tap on the terminals and produce some sparks. The reading should jump in relation to the tapping. If this does not occur then slightly adjust the feedback adjust. If still no reading then check all lines, connections (including solder) and components. After testing turn off the unit and short the terminals.

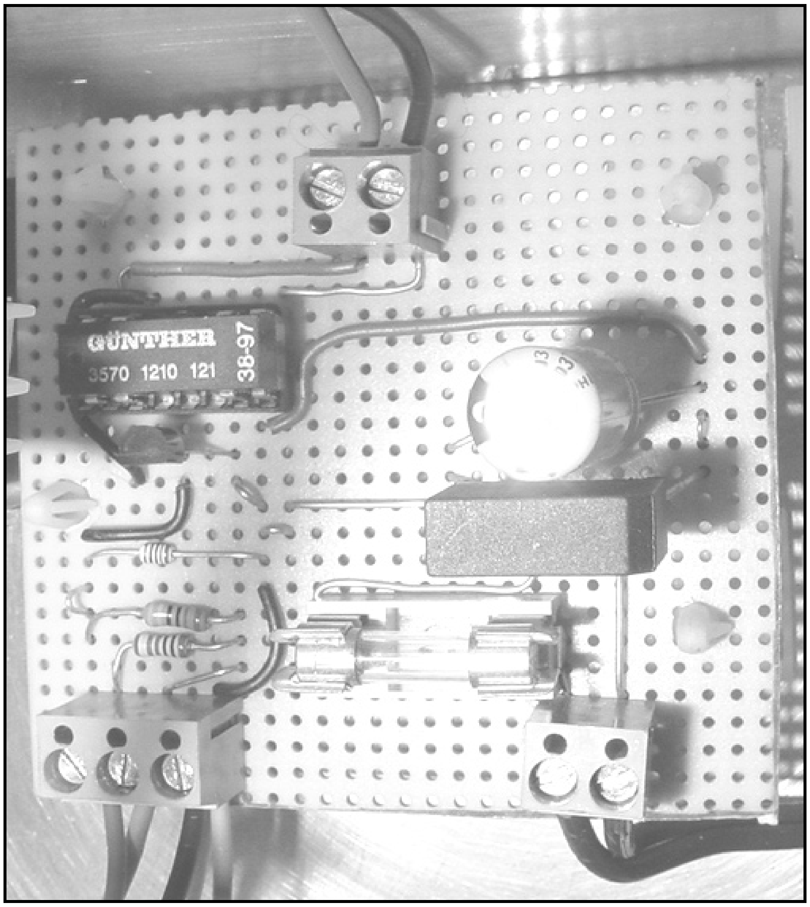


Fig.35 Completed FB Circuit

6.4 Chopper Circuit

The chopper circuit adds an extra degree of control to the EDM process. It does this by repeatable switching the EDM capacitor discharge on and then off. Normally the selected EDM capacitors almost fully discharge until the EDM fluid electrically recovers. Yet a large portion of this charge has relatively little effect on the erosion process (voltage drop). Most of the punch has already occurred during the initial discharge. The chopper circuit allows the EDM capacitors to briefly recharge (voltage is somewhat recovered) by switching the discharge off shortly after it started. After a small duration it is then switched on again. This consequentially results in a higher nominal power output (voltage and current are more stable) and output is at greater erosion efficiency. Hence, stronger and more frequent spark strikes.

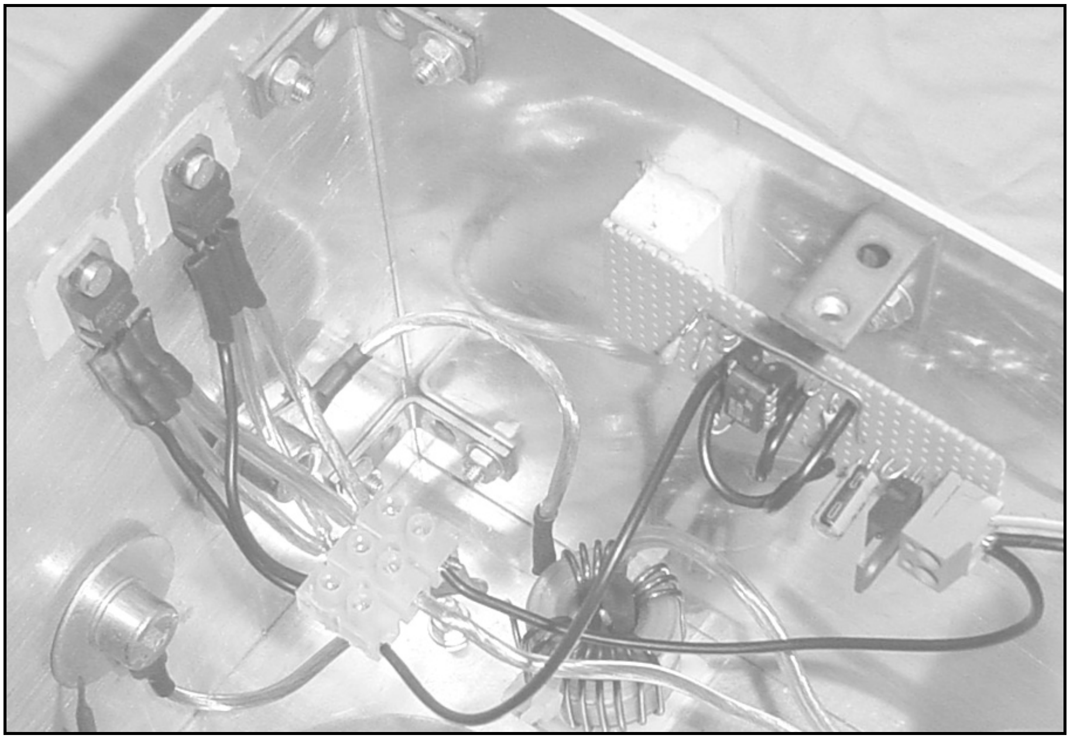


Fig.36 Chopper Circuit

In practice the chopper circuit can, for the most part, offer higher machining surface quality and precision for certain machine tasks. In particular with regard to easily corroded metals. However it will be much less significant with regard to cutting speed in comparison to the effect of the vibration inducer.

The chopper switching frequency and off time duration has been set to values based on empirical information and the power and design criteria of the EDM power supply. Pulse frequency and duty cycle are about 600Hz and 65% respectively.

The circuit is made up of only a few basic components. A 555 timer chip controls the Gate of a MOSFET. MOSFET's act as solid state switches which can handle high current switching at high frequency. The basic FET package includes three pins: Gate, Drain and Source. The Gate is the key to opening and closing the solid state switch which is represented between Drain and Source. It is voltage activated meaning that supplying a small voltage over the Gate will cause the switch to close (current may flow through Drain and Source).

When fully open, MOSFETs have very high resistance and virtually no current flows. When closed the resistance is very low and current flows almost unrestricted. Much of the heat generated by the current flow through the MOSFET occurs between switching. This is because the switch is not completely open nor closed, its in-between states. The effect of the resistance is highest here. The 555 which controls the switching of the MOSFET does this very fast and at sufficient voltage. The result is a very basic, small yet high power switch setup.

The circuit includes two MOSFETS set up in parallel. The Drain and Source connections of the FET's are spliced in the anode line (EDM+) of the EDM circuit. The 555 timer IC receives 12V DC power from the Speed Control Power Supply Circuit.

The type of FET used here can handle currents up to 27 Amps and has a breakdown voltage of 100V. Two are employed to be on the safe side since the power rating for continuous use is about 100 watts per FET. In practice the FET's hardly warm up even after hours of use.

6.4.1 Testing the Chopper Circuit

The testing of the chopper circuit should be carried out after the testing of the EMD circuit power supply and feedback circuit have been completed.

After the chopper circuit has been completed check for shorts. Connect 12 to 18 Volts DC to the timer circuit. The output after the voltage regulator (IC1) at pins 2 and 3 should read 12Volts. If a scope is available check that the output from the 555 is about 10 Volts and that frequency and duty cycle are within set values.

Install and connect the chopper circuit in the EDM case including the FET's. Check that all lines are correctly connected. Using a multimeter measure the resistance at the EDM terminals. This should be infinitely high. If not, then there is a short somewhere in the circuit connections. Locate and remedy. Remove the multimeter. Set all the EDM capacitors switches off. Turn on the EDM power supply. Using a screwdriver, with plastic insulated handle, short the EDM terminals. Sparking should occur. Turn off the power supply. Short the terminals. No sparking should occur since the chopper circuit is off and the FET's are no longer closed. Although selected capacitors can now no longer be discharged at the EDM terminals, due to the chopper circuit, it is still a good habit to short the terminals each time the unit is turned off to make sure no voltage is present.

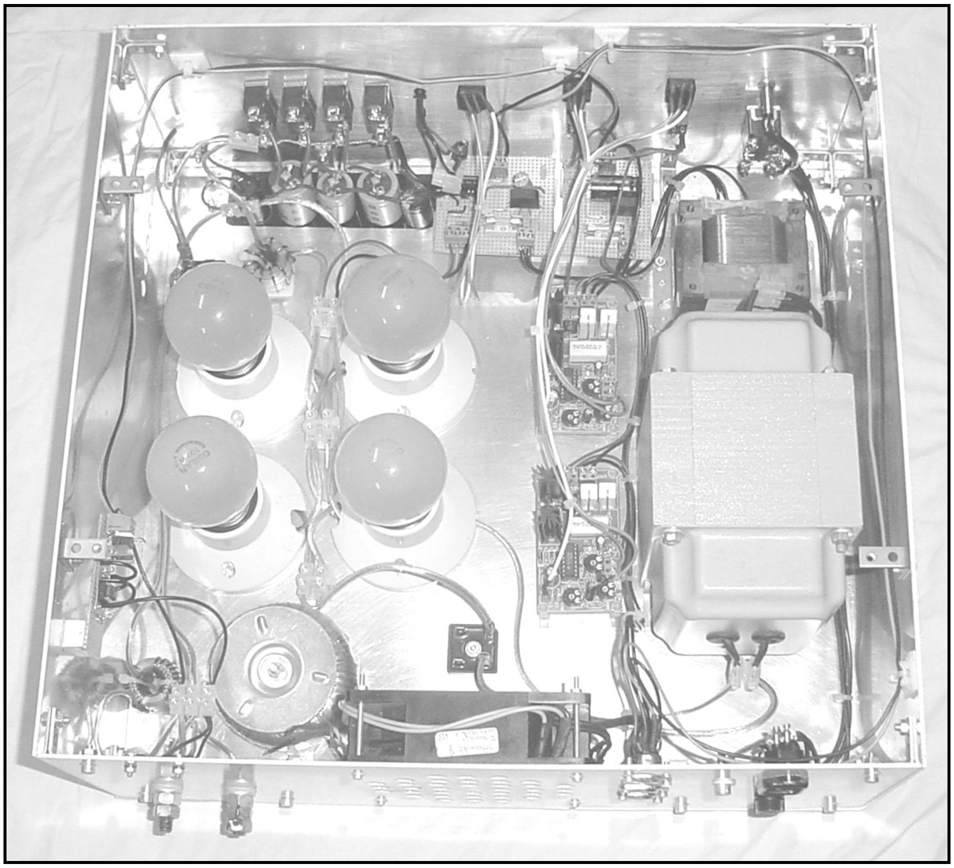


Fig.37 Completed EDM Circuit

6.5 Speed Control Circuits

The fluid delivery of for the EDM unit is realized using a pump. Controlling the amount of fluid flow delivery may not be needed for most jobs yet it may be sometimes useful. This may arise when delicate machining must be carried out and/or if the nominal flow of the pump is too high and is causing the fluid to splash out. Industrial type machines actually use very high fluid pressure to promote better flushing of debris, yet these are more rigid setups with larger fluid containment design.

The speed circuit should coincide with requirements of the pump. The type of pump used must allow constant operation without overheating. Many DC pumps will not always allow this. However an automobile fuel pump intended for fuel injection delivery uses a cooled motor. These are very high quality positive displacement pumps. They produce low flow but can attain high pressure, which is of more interest to this project. The fuel normally surrounds and flows through the motor while it is being pumped through. This cools the motor and thereby allows constant operation. One aspect that must not be overlooked are the types of fluid that may flow through the motor. Water may cause it to rust while other more aggressive EDM fluids may cause any internal pump seals or other rubber components to lose cohesion. Be prepared to replace the pump if this occurs or, better yet, test it before integrating it. The fluids used for this project have not caused the acquired pump any damage (vegetable oil, liquid paraffin).

An induction motor pump could also suffice for this project. These are fan or centrifugal type pumps, which use the mains voltage for power. They produce high delivery at low pressure, are rugged and can withstand constant use. Usually they can be found in washing machines. However this type of pump must be used with caution as it directly uses the mains voltage. It should at least be inclosed in a housing that protects the operator from accidental shock. It also has the more tendency to leak.

Fuel pump motors usually require 12 volts and 1-2 Amps. The speed control circuit should be rated to supply at least 25% more current at this voltage. Obtaining an inexpensive speed control circuit to handle this should not be a problem. "Pulse Width Modulated" circuits are the most efficient.

The requirements for the wire spool motor speed controller are more or less the same as that for the pump motor. The motor must be severely stepped down (mechanically) and provide sufficient torque to rotate the spools and reel the wire through. Take note that the reel motor is in constant use yet it is not receiving any cooling. The temperature should be monitored. A PWM speed control circuit is a must here.

6.6 Vibration Inducer Circuit

This is the simplest circuit used for this project. It requires only a transformer and a diode. The function is to provide pulsating DC output to the vibration inducer by having the diode pass only one half of the AC input. Most small solenoids operate at about 12 Volts and 0.35 Amps. The coil resistance is usually between 20 and 200 Ohm. A 30-Volt transformer may suffice. To determine the diode and transformer current rating measure the coil resistance using a multimeter. The following applies:

(Ut X 1.4) / Rc = Ic

Ut = transformer output (Volt)
Rc = coil resistance (Ohm)
Ic = coil current (Amps)

The current should be about the same as previously listed. If it differs too greatly then choose another transformer output. The transformer and selected diode ratings must be more than Ic.

6.7 Driver Circuit

The 3 axis Camtronics Inc. stepper motor driver circuit used for this project is a low-cost high quality unit. The components used are tried and true, and have served the industry for many years. The driver incorporates all the required features for its application in the EDM unit. The Camtronics manual, which accompanies the purchase of the driver, provides complete information on the installation procedure and testing. The driver can be purchased as a kit (see the Suppliers Section). The unit inputs step & direction signals to operate the attached stepper motor. This is an industry standard. The "step" signal determines the amount of steps per second that the driver will instruct the motor to make. The "direction" signal simply determines the direction that the motor shaft must rotate when making steps. The Camtronics unit also includes a feature, which is of much use for this project, namely the idle current setting of the motors. This will be explained in the next section.

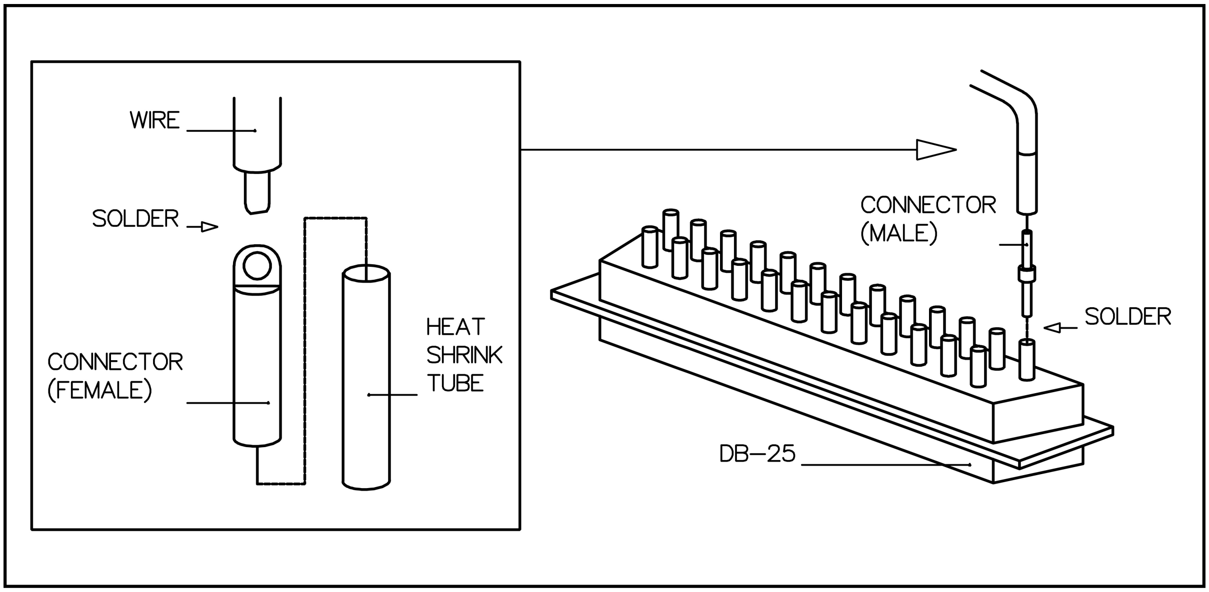


Fig.38 Parallel Port Connections

Be very careful never to cross and short the output lines of the driver. It is not short circuit protected. Also, do not detach motor leads while the driver is "on". This will induce voltage spikes, which may damage it and other connected circuits. Note: bad connector pin connections may also cause the same effect. Pay ample attention to prevent these errors.

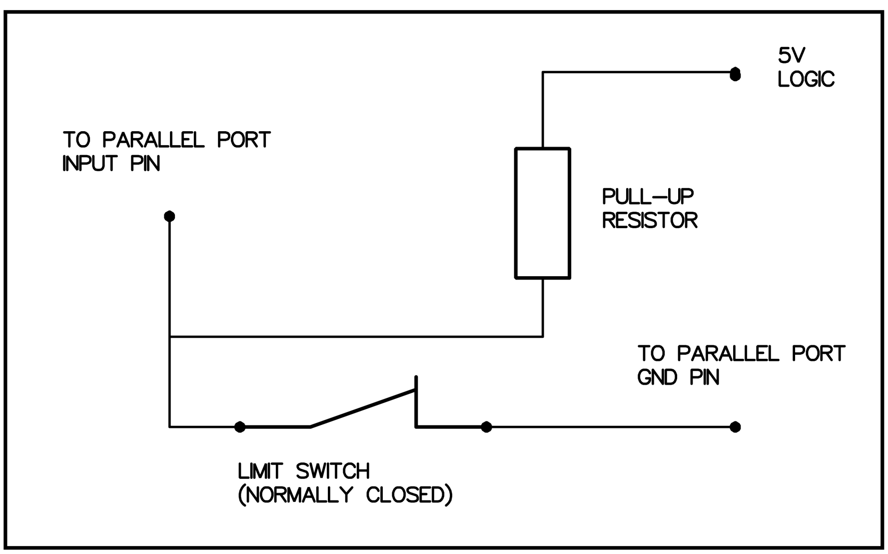


Fig.39 Limit Switch Schematic

The driver requires a 12-volt power supply. This is realized using a transformer to step down the mains voltage to 12 Volts. The output from the transformer is rectified and then filtered using a capacitor. The capacitor flattens out the DC voltage into a more stable DC component. Apart from the 12 Volt supply, the driver also requires 5-volt logic for the parallel port input connections. This is realized using a voltage regulator, which is placed parallel with the 12 volt (fit a small heat-sink on the voltage regulator). The circuit diagram shows how the components are setup. The diagram also includes the home switch and FB circuit resistors.

The amount of current that the driver should supply each stepper motor is around 0.5 Amp. The driver manual will provide information on how to set this. Current usually does not need to be higher than this for the NEMA 23 sized stepper motors since only low speeds are required for the unit.

The wiring scheme for attaching different types of stepper motors is given in the Camtronics driver manual. A procedure to determine this is also briefly explained in the next section.

6.7.1 Testing the Driver Circuit Power Supply

After the power supply circuit is completed connect it to a 12 to 18 Volt transformer. Set a multimeter to read up to 20 volts DC. Connect the ground lead of the multi meter to the output GND of the power supply and the other lead to the 5 Volt logic out. It should read 5 volts. One by one check that all pull-up resistors output 5 Volts as well. Then check, one by one that 12 to 18 Volts is present on the output lines designated for the fan and X, Y, and Z axis.

6.7.2 Stepper Motor

The stepper motors intended for this unit are either NEMA 17 or NEMA 23 (advised) sized motors. The NEMA 17 must be a 0.9 degrees per step motor that has the highest holding torque rating in its class. Only 4,6 & 8 lead motors can be used for this unit.

Several different types of stepper motors exist. The hybrid type is frequently used and pertains to this project. Stepper motors are the answer to low cost motion control. However they usually are not equipped with a feedback system to monitor and correct any positioning errors.

The workings of a hybrid type stepper motor is basically the same as a that of a solenoid or electro-magnet. When a voltage is applied to its terminals it causes a magnetic field to be set in its winding. Consequentially it causes the armature or plunger to be forcefully pulled inward. A stepper motor basically does the same. The difference is that the configuration allows for infinite rotational motion of the armature instead of finite or limited stroke linear motion.

The stepper motor is comprised of multiple windings (stator) that surround the armature (rotor). The rotor is equipped with many small teeth or notches in a permanent magnet package. When the windings are provided with a voltage the resulting field attracts certain teeth and repels others depending on their magnetic polarity. The shaft, which carries the rotor, will then move a step. As long as current flows through the windings the motor will forcefully hold that position. This is commonly referred to as the "holding torque" of the motor. The motor should always provide much more holding torque than the application requires. If this is not done then steps may be lost and motion accuracy will recede. (Note: stepper motor torque recedes rapidly as RPM increases). If the polarity of the windings are reversed in a “take over” fashion it will cause the rotor to again take a step based on the same principal as explained. The direction that the shaft rotates depends on the polarity of the windings and when this changes in relation to other windings.

As explained, the driver will hold the position of a stepper motor when it’s idle. To accomplish this the driver supplies the motor with a holding current. Since this project will require only low motor speeds most of the time it is important to keep the idle current low. High holding torque current will unnecessarily heat the motors.

The stepper motor lead connection can be determined using a multimeter. The resistance is measured at its wires. If the value is infinitely high then this constitutes that the wires are not related to the same coil winding. If the value is low then they are related. This is for stepper motors with 4 wires. Related wire pairs are connected to the related driver outputs. This is commonly labeled as (A and a) for one pair and (B and b) for the other pair. For 6 wire motors it gets a bit more difficult. This is because 3 wires are related. Yet one is not of use here. When the 3 related wires, using the previously explained procedure, are found it is necessary to determine which wire pair results in the highest resistance value. This wire pair is connected. Repeat the same for the other 3 wires. For 8 wire motors the procedure is the same only now there are 4 related wires of which two need not be connected.

Fig.40 Completed Driver Circuit & Power Supply

7. Interfacing

Traditionally, the PC's parallel port has always been labeled as the printer port. But for the home engineer it has become to represent one of the most popular ports used to communicate between the digital and the outside world. In particular with regard to motion control systems and robotics. The port usually has a 25 or 32 pin connector. 8 of these pins are for output while 5 are for input and 4 are bi-directional. The other pins are GND pins. For this unit 4 output pins will be used and 5 of its input pins.

Each output and input pin can represent a single “bit” of information. The parallel port can output 8 bits simultaneously. In other words, in parallel. This makes it inherently fast in comparison to other ports. However it's also probably the most sensitive ports and requires careful use to protect from damage. For this reason it is highly recommended that the PC used for this project be equipped with a parallel port that is not part of the motherboard.

Otherwise, in case the port shorts out, it could have repercussions for the motherboard as well.

The parallel port pumps out information in binary code. Binary code represents characters as bits (1 or 0). A 1 would mean “on” (high) and a 0 would mean “off” (low). 8 bits in a row are known as one byte and allow 256 different combinations of high and/or low bit states to be made. Each byte combination has been appointed to represent a certain symbol. For example: the number "3" is represented as 00000011. Each of the 8 bits is represented by an output pin at the port. Take into account that the binary number must be read from right to left. The most right digit represents the "Least Significant Digit". If the number 3 is output to the port then the first 2 pins will change to 1 while the remaining 6 pins will go to 0.

A few examples of decimal digit to binary translation:

Decimal		Binary
0	=	00000000
1	=	00000001
2	=	00000010
3	=	00000011
4	=	00000100

The LSD represents a binary number with the decimal value of 1. This is because 2 to the power of 0 is 1. The next bit to the left represents a value of 2. This is because 2 to the power of 1 is 2. The next bit represents a value of 4 since 2 to the power of 2 is 4, and so on. As explained, the decimal number 3 is represented by the binary number 00000011. This binary number can be read as follows: start at the LSD, which is a binary 1 and hence, is a decimal 1 as well. The next binary digit is also a 1 which represents a decimal value of 2. The rest of the 6 digits are all 0 so they can be ignored since these are low. The result, 1 + 2 = 3. It's that simple.

As previously explained, the driver has two inputs namely, “step” and “direction”. An example now follows which will illustrate how the driver receives instructions from the parallel port: The step line of the driver is connected to the first output bit of the parallel port which is the LSD. The direction line is connected to the following bit. When the software pumps out the decimal number 2 (00000010), to the parallel port, then the driver step line receives a 0 and the direction line of the driver receives a 1. If the number 3 is pumped out then the output will be 00000011. Consequentially the motor shaft will turn one step in a particular direction. This is because the first bit (LSD) went high and since this is the “step” line the motor driver was instructed to move the motor one step. The output is then changed again to 2. Nothing happens, the motion is paused for a moment. After that the output is set to 3 again and the motor takes another step in the same direction because the step line went high again. However, if the number 1 (hence, a 00000001) is then pumped out, the shaft will turn one step in the opposite direction. It turns in the opposite direction because the second digit is now a zero. The direction line is now low. The signals from the feedback circuit and the home switches follow a similar idea. Only these are input signals to the port.

The speed at which the shaft rotates is set by first looping the output. What this means is that the program instructs the computer to pump out, for example, the number 3 over and over again. In-between this are instructions to pump out the number 2 and then wait or delay for a moment. Hence, 3 then 2, pause then again 3 and so on. The delay sets the speed of the motor. Lowering the value of the delay will result in faster steps and hence higher motor RPM. Naturally the amount of steps that the motor can make per second is restricted. If the speed is too high the motor will simply not run or at most, it will just sit there and rattle.

7.1 Software

The software included with this manual is called testware. Weighing in at about 50 Kbytes its purpose is to allow the user to test the workings of the constructed setup and the EDM process. Using g-code, a machine task file can be written and desired profiles produced. The essential workings of the testware program can be summarized as follows: the program manages and controls the WEDM process based on machine and process settings that the user has entered. It reads this information and also registers input signals from the home switches and the EDM feedback circuit. Based on this and the pre-programmed g-code it writes (outputs) information to the stepper motor drivers accordingly. During the execution of the code it continuously monitors the state of the process and takes pre-defined action when required.

As testware, the software only includes what is absolutely necessary to configure the setup and run simple machine tasks. Features such as its own editor, syntax checking, graphical and/or numerical code simulation are not part of the curriculum. The directive here is to keep it simple. This to permit installation and efficient use on different systems with minimal chance of lock-up and incompatibility problems.

The software is made for use on a DOS platform. This is to reduce software production cost, development time, incompatibility problems and also since most users will apply older type computers for this project. In addition, exclusion of user interface luxuries and graphics reduce the amount of memory required to use the software. More attention has been directed towards what the software was made to do, namely control and regulate the EDM process. Note: do not run this program to perform a machine task in Windows. Although possible, under certain conditions, it may lead to unpredictable results and problems. More advanced 3rd party software may however become available that includes more features. This will allow more functionality and be easier to use.

The software package includes two executables and several files. The ReadMe.txt file will explain how to install, configure and use the program. One of the executables is called 4FastPC.exe. This is the same program as the other (WEDMTWV1.exe) but it was compiled differently. Its use is for faster type systems in case the primary executable does not run properly. Other files in the package with the .dat extension should be left alone as any modification to them may result in the program malfunctioning.

Machine tasks can be written in g-code using only the symbols supported by the software. Files can be written in most any text editor that can produce text files. A file can then be linked to the program for subsequent machine task operation. However, as testware it is important to note that if wrong values for certain parameters are entered, the software may not inform the user that this may be the case (no syntax checking). The program will simply follow orders as they are requested, nothing more or less. This is especially important to take note of when writing the g-code.

8. Machine Operation

There are a several general precautions and guidelines that should be taken into account before using the WEDM unit:

- Turn the driver "on" only after the PC has started up. The PC may perform procedures, which activate port output pins and thereby move motors.
- Always turn "off" the PC before hooking up or removing the parallel port connector, or for that matter any connection.
- Long cables to the port should be avoided as the port uses 5-volt logic to communicate. Long cables provide more resistance and can thereby degrade the voltage.
- The printer port interface for the WEDM unit is not optically isolated. This means that the port is not protected from the outside world. In practice this has not proved to be a

problem unless wrong connections are made. Double check that the connections to the port are correct, careful not to make cross connections.

- Do not detached motor leads while the driver is powered. This may induce voltage spikes, which may run back into the port and destroy it and the driver.
- Most problems encountered are due to faulty connections. Connections that break because of a bad soldered pin, for instance.

The orientation of the machine is as follows: Looking into the tank, the work piece clamp side is defined as “up” or positive Y-axis travel and the side opposite to this is Y axis down. To the right and left is the X-axis. Travel to the right is positive X-axis motion. Hence, motion to the left is negative.

8.1 Configuring the System

With all hardware completed begin by connecting the driver, limit switches and feedback line to the PC and the motors to the driver. The EDM power, motors and vibration inducer connections should not be connected to the unit at this time. Note: driver settings and adjustments should have already been completed using the Camtronics manual. Check that all connections are correct. Start up the PC and go to the W-EDM TestWare program. Select “Machine Setup” and configure the system. Afterwards go to “Input Test”. Press each limit switch one by one to test that it is sensed and is connected to the correct pin. Turn the EDM power supply on (again, do not connect EDM power lines to the mechanical setup yet). The screen should display that the feedback signal was sensed. If not, slowly adjust the feedback adjust until it does. Turn off the EDM power supply and short the terminals.

Go to “Machine Task” and choose “Jog Tool”. Jog the tool up and down and left and right. In case the tool moves in the opposite direction than requested then reverse a stepper wire pair for that axis. When both the X and Y-axis move in the correct directions jog each axis to their limit switches. When a limit switch is reached travel must automatically stop. Test this. If not, then there is a wrong connection somewhere or an electronic malfunction. Correct by visual inspection of the connections. If still nothing seems wrong use a multimeter to locate the error. Beware of the mains voltages. Remember that all limit switches must be in the normally closed state. If any are open then “Jog Tool” will not work for that corresponding axis travel direction.

After completing the above it is now time to write a simple g-code file to test the system and process. In “Machine Task File” choose “Go to Editor” or use another editor that can produce text files. Write only the following:

```
N10 G01 Y4
N20 G01 X4
M02
```

The above is Metric. If the setup was configured for the English system then simply replace the X and Y values with 0.15. Next, save the file in the editor using a desired name. Link the g-code file to the program by going to “Link Task File” and entering the full name plus the extension of the file. Make sure that the path is correct. This can be configured in “Change Path”. The file is now linked to the program. It will remain that way even if the software is closed.

8.2 Run A Machine Task

The wire reeling procedure should already have been completed as explained in the Assembly section. Go to “Jog Tool”, turn the stepper motor driver “on” and position the tool completely down and to the right until the limit switches stop the travel. Clamp in a thin piece of steel plate (1 or 2 mm thick) to function as the work piece. Jog the tool (wire) to a start position in which the wire is just adjacent to the work piece but not touching it. Turn “off” the driver so that the motors do not get warm from idle current. Connect the pump motor, wire reel motor cables from the EDM case to the mechanical setup. Carefully administer the fluid into the tank until the level is at least above that of the work piece. The norm dictates that this should be at least 40mm. However using vegetable oil has, as yet, not given any indication of a fire hazard at all. Still take precaution, have a fire extinguisher present. Contents should be powder based to smother a fire. Liquid based will cause bigger problems, as burning oil and water don’t mix. Go to “Process Control” and select “Cut Feed Rate”. Choose a feed of about 5 steps per second. “Pause Time” should be set at about 10 seconds and “Retract Steps” at about 25 steps. Connect the EDM power lines to the mechanical setup. From now on the mechanical setup may only be touched after the EDM power supply capacitors have been shorted and discharged.

Turn the main EDM switch “on” and also turn “on” the pump and wire reel motors. Turn the driver “on”. Set the wire reel motor to a low speed. Go to “Start Machine Task” and then “Run Machine Task”. The machine task is now in progress and the tool will start to advance towards the work piece. The process can be paused at any time by pressing the keyboard “space bar”. This will lead to the “Pause Task” menu. The task can be resumed, aborted, tool jogged or process control parameters changed. After the task is completed or aborted turn “off” the EDM power supply, short the terminals and then turn “off” the stepper motor driver.

8.3 Machine Task Process

As the previous chapters have disclosed, the EDM process involves the setting of many parameters, which can influence how well and how fast a task is realized. Since the process is slow the object is to find ways to increase cutting speed with minimal sacrifice to precision and without having the process crash. The “vibration inducer” provides much assistance but it will become evident that a good understanding of the process and experience are just as important. Initially the vibration inducer should not even be used. Only once adjustments result in a good steady sparking should the vibration inducer be activated. Its employment will then be more effective.

During a machine task the wire will advance towards the work piece and at a certain distance sparks will strike. The feedback signal will then go low and the software will automatically pause the task. Ideally, the duration of the pause should only be enough to allow the zone to be completely sparked away. The wire should then advance again until its close enough to repeat the sparking. Hence, the operator should strive to choose “Pause Time”, “Cut Feed Rate” and “Feedback Adjust” settings that cause an almost uninterrupted cluster of sparking to progress. Any time that no sparks strike is simply wasted time.

In practice, shorter “Pause Time, higher “Cut Feed Rate”, thicker work pieces and thinner wire all contribute to making the process more critical and increase the chances of it crashing. In the event of crashing, the tool will run against the work piece. Since the feedback signal would remain low, the tool will just sit there, pause and every now and then maybe advance more against the work piece without sparking. The vibration inducer reduces the chances of this scenario occurring. However the retraction of the tool provides an extra line of defense. If after automatic pausing the feedback signal is still low then the software will instruct the motors to move back or retract a set number of steps along the same path that the wire entered. It will retract at maximum feed rate. Directly after that it will return or reset back to the original position where the retraction started. Yet it will do this at cut feed rate. It will repeat this cycle until the feedback signal goes high again. Apart from minimizing the chances of the process crashing retraction also promotes better debris flushing. However the retraction feature should be considered somewhat of a “fail safe” mechanism, only there to try and bail out the process when in trouble. Its activation should be limited as much as possible by setting other parameters such as the "Pause Time" and "Cut Feed Rate" to more precise settings. This is easier said than done and will require practice to understand better.

Another influential parameter is the capacitor settings and wire reel speed. Higher capacitor settings result in higher current discharges. Capacitor setting should be chosen as high as possible but with enough margin to minimize the chances of the wire breaking. As calculated in previous sections, the load and discharge time for the capacitors time is relatively fast. Hence, higher capacitor settings will increase the mean power level as well since the charge contained in higher capacity capacitors is being depleted less quickly. Output current and voltage is more stable. The wire reel speed is usually low. It should be set at a speed that results in each segment of the wire to be used. Long unsparked segments of wire during successive spark strikes is wasted wire and an indication that wire reel speed should be reduced and/or other process settings need adjustment. Wire spool speed is usually 1-3 RPM.

Wire Spark your Imagination

Safety Protocol

The following information advises on some areas that may help prevent accidents. It is in no way complete, as it is not possible to foresee all scenarios that the operator may encounter and/or create. When working with the WEDM equipment:

- Try not to use both hands at the same time while touching different equipment. If the operator becomes part of the circuit the current may flow through the heart.
- Try to use only your right hand to touch equipment.
- Work in well-ventilated area.
- Minimize ventilation directly over the fluid tank, this can lead to greater oxygen pick-up.
- Drain fluid after use. Clean the tank with a towel. Do not leave towel fibers in the tank. Debris can burn like a candlewick.
- Do not use old dirty fluid. Fluid can certainly be used many times over but if it becomes less thin more sticky then it must be replaced.
- Seal fluid in airtight container after use. If this is not done fluid will pick up oxygen over a period of time. It will polymerize like glue, become more flammable.
- Have a fire extinguisher present. Use appropriate type. Remember oil and water don’t mix! A box of sand may also work to smother any fire that may occur.
- Use shoes with rubber soles on dry ground.
- Remember that dirty oil is much more easily ignited.
- Flammable substances should not mix with fluid.
- Always use a screwdriver with an insulated handle to short the EDM terminals after it is turned off.
- Sparking must occur at least 40mm (1(1/4) Inch) under the fluid level by established norm.
- If other fluids are used, consult safety data sheets. Any company that produces fluids for EDMing has this information.
- Attach appropriate warning labels to the units, which informs of their danger and use.
- Disconnect EDM power supply mains after use.
- Keep unit away from children.

Suppliers

The project requires many different components and materials, most of which can be found at a local hardware store and on the Internet. Some of the more important suppliers have been listed below.

- Camtronics, WWW.SEANET.COM/~dmauch Supplies stepper motor drivers and other related equipment. High quality and performance at very low cost.
- Velleman, WWW.VELLEMAN.BE Supplies electronics kits. Very well designed.
- Trespa, WWW.TRESPANORTHAMERICA.COM Find a distributor near you (sign-making stores use Trespa a lot).
- Thomas Regout, WWW.THOMASREGOUT.COM Supplies high precision slides at low cost.

Copper and brass wire can be obtained from several different suppliers. Much of the wire sold on the market is used for electrical products such as solenoids and transformers. This type of wire has an enamel insulation layer and cannot be used for this project. Hardware stores sell bare, short length (+/- 20 meters) wire with a diameter of about 0.4 mm. This wire is too short for most all tasks yet it is ideal choice for the initial testing of the unit.

Smaller diameter, long length, bare, brass and copper wire can be found at EDM product suppliers. Brass wire dominates most of the wire product selection but copper wire is usually also sold (advised for this project). However, most suppliers will only sell copper or brass wire in batch amounts which can be costly. Try looking around for the best deal. Also, companies that specialize in Wire EDM may stock wire and sometimes sell it in smaller quantities.

Drawings & Tables

Tools	Table 1
Tool	Remark
Drill press (variable speed) and vise	Drill chuck must accommodate drill sizes up to 12mm. Note: For this project larger sized drills are necessary (especially for the electrical connectors). However some hardware stores provide larger sized drills that have been grounded down on the clamping side to accommodate smaller size chucks.
Hand-held power drill	Drill chuck must accommodate sizes up to at least 10mm. Note: this tool is used to complement the drill press.
Power saw with table	This is an optional tool for cutting the plate material. Most distributors of the plate material will saw the material to size.
Bench grinder	Grind wheel and polish wheel
Hand saw	For cutting metal.
Band saw	For cutting metal. This is optional since most parts are small and easily cut using a handsaw.
Fret saw	For metal cutting.
Center punch	
Hammer	Small
Bench vise	
Drill 2mm	Metal cutting HSS drills are required. Note: larger drills are required but depend on certain component dimensions.
Drill 3.2mm (For M4 Thread)	
Drill 4.8mm (For M6 Thread)	
Drill 6mm	
Drill 8mm	
Drill 10mm	
M4 tapping set for internal thread cutting	Preferably use the 3 part set, not the single machine tap. Use cutting fluid.
M6 tapping set for internal thread cutting	Preferably use the 3 part set, not the single machine tap. Use cutting fluid.
Allen key set	
Flat screw drivers	
Lead clippers	For electronic componants
Precision calipers	
Band ruler	
Cable insulation remover	Very handy
Pliers	
Counter sink drill	
Small course grinding head	For power drill.
Paper tape	
Epoxy	Two component type (transparent)
Super glue	cyanoacrylate
contact glue	High strength “all purpose” that is water/oil resistant. Note: glue is used to seal off areas in the tank. It must be a bit viscous like syrup.
Wrench set	

Soldering iron	High power (25W)
Lead clipper	
Multimeter	
Double sided tape	High strength
Course file	
Medium course file	
Solder	For electronics!
Scissors	
Phillips screw driver set	
Pin set	
De-greasing agent	Automotive.

Mechanical Setup					
Part Description List					Table 2
Part	Qty.	Material	Name	Reserved	Remarks
1A	1	Aluminum	Angle Bracket		
2A	1	Aluminum	Support Arm		
3A	1	Steel	Leaf Spring		
4A	2	Steel	Spool Shaft		***
5A	4	Steel	Slide Disc		
6A	4	PVC/Plastic	Spool Disc		
7A	2	Aluminum	Spool Drum		
8A	2	Aluminum	Clamp Bar		
9A	2	Aluminum	Clamp Shaft		
1B	1	Trespa	Guide Bed		******
2B	4	Aluminum	Angle Bracket		Same as 2D
3B	2	Steel	Drawer Slide		Same as 3D *
4B	1	Aluminum	Stop Bracket		Same as 4D
5B	1	Aluminum	Angle Bracket		
6B	1	Aluminum	Angle Bracket		
7B	1	Trespa	Slide Plate		******
8B	1	Copper	Pipe		
9B	2	Aluminum	Limit Switch Bracket		Same as 7D
1C	2	Aluminum	Bearing Bracket		
2C	2	Aluminum	Stand-off Block		
3C	2	Steel	Lead Screw		***
4C	2	Aluminum	Coupling		
5C	8	Aluminum	Offset Strip		
6C	2	Aluminum	Motor Bracket		
7C	4	Aluminum	Motor Mount		
1D	1	Trespa	Guide Plate		******
2D	4	Aluminum	Angle Bracket		Same as 2B
3D	2	Steel	Drawer Slide		Same as 3B *
4D	1	Aluminum	Stop Bracket		Same as 4B
5D	1	Aluminum	Angle Bracket		
6D	1	Aluminum	Angle Bracket		
7D	2	Aluminum	Limit Switch Bracket		Same as 9B
1E	4	Trespa	Arm Frame Plate		******
2E	5	Steel	Bearing Shaft		
3E	2	Steel	Wire Guide		
4E	5	Trespa	Pulley		Same as 5G ******
5E	1	Aluminum	Link Block		
6E	1	Aluminum	Pulley Arm		
7E	2	Steel	Frame Stud		**
8E	4	Steel	Stud		*****
9E	2	Aluminum	Frame Block		

10E	2	Steel	Wire Node Gauge		
11E	1	Aluminum	Pipe Clamp		
12E	1	Copper	Pipe		
13E	1	Aluminum	Stand-off Block		
14E	1	Aluminum	Contact Strip		
1F	1	Aluminum	Drain Block		
2F	1	Trespa	Floor Plate		******
3F	4	Aluminum	Mount Block		
4F	1	Trespa	Side Plate		******
5F	4	Aluminum	Support Block		
6F	6	Steel	Stud		****
7F	1	Trespa	Side Plate		******
8F	1	Lexan	Front Plate		******
9F	1	Trespa	Middle Plate		******
10F	1	Trespa	Back Plate		******
11F	1	Aluminum	Clamp Bed		
12F	1	Aluminum	Clamp Block		
13F	1	Aluminum	Connector Rack		
14F	1	Trespa	Foot Plate		******
15F	2	Aluminum	Mount Bar		
1G	3	Steel	Stud		****
2G	2	Trespa	Side Plate		******
3G	2	Aluminum	Pulley Arm		
4G	1	Steel	Pulley Shaft		
5G	1	Trespa	Pulley		Same as 4E ******
6G	1	Steel	Spool Shaft		
*	Thomas Regout Drawer Slide. See Material Description List + Suppliers Section.				
**	M10 All thread stud. See Material Description List.				
***	M8 All thread stud. See Material Description List.				
****	M6 All Thread Stud. See Material Description List.				
*****	M4 All Tread Stud. .See Material Description List.				
******	See Suppliers Section.				

Mechanical Setup				
Fastener Component List (General guideline)				Table 3
Qty	Description	Size	Material	Type/Remark
4	Nut	M10	Steel	Round
8	Washer	M8	Steel	Round
8	Washer	M8	Nylon/rubber	Round
17	Nut	M8	Steel	Hex
1	Bolt	M8; L20	Steel	Internal hex, cyl.
32	Nut	M6	Steel	Hex
40	Washer	M6	Steel	Round
4	Washer	M6	Steel	Toothed
4	Washer	M6	Nylon/rubber	Round
2	Bolt	M6; L15	Steel	Internal hex, cyl.
1	Bolt	M6; L20	Steel	Internal hex, cyl.
4	Bolt	M6; L10	Steel	Internal hex, cyl.
24	Set Screw	M4; L5	Steel	Internal hex, headless bolt
4	Bolt	M4; L5	Steel	Hex, low head height
18	Bolt	M4; L10	Steel	Hex, low head height
4	Bolt	M4; L 20	Steel	Hex, low head height
14	Bolt	M4; L 10	Steel	Internal hex, cyl.
8	Bolt	M4; L 15	Steel	Internal hex, cyl.
34	Bolt	M4; L 20	Steel	Internal hex, cyl.
5	Bolt	M4; L 25	Steel	Internal hex, cyl.

20	Bolt	M4; L 30	Steel	Internal hex, cyl.
10	Bolt	M4; L 35	Steel	Internal hex, cyl.
2	Bolt	M4; L40	Steel	Internal hex, cyl.
125	Nut	M4	Steel	Hex
250	Washer	M4	Steel	Round
6	Washer	M4	Nylon/rubber	Round
12	Washer	M3	Steel	Round
6	Bolt	M3; L80	Steel	Hex
L = Length				
Unit = mm				

Mechanical Setup			
Component Description List			Table 4
Component	Qty	Description	Source
C1	2	NEMA 23 Bipolar Stepper Motor, 50 ozin holding torque	Camtronics
C2	4	Switch, normally closed, momentary type, small	Electronics
C3	8	Radial bearing, rubber sealed, OD 22; ID 8; T7, pre-lubed	Hobby
C4	8	Fiber washer/gasket, used in plumbing, OD 24; ID 20; T2	Hardware
C5	2	Coil spring, OD 20; ID 18; L50	Hardware
C6	1	3-way plumbing section (T-section), PVC or brass, small	Hardware
C7	1	Fuel filter, axial flow	Automotive
C8	1	Valve, teflon sealed, ball type, small	Hardware
C9	3	2-way plumbing section (L-section), PVC or brass, small	Hardware
C10	1	Fuel injection pump with integrated DC motor, 12Volt	Junkyard
C11	-	Plumbing, should match pump + filter etc., transparent type	Hardware
C12	4	Foot pegs (use door stops)	Hardware
C13	20>	Tie wrap mount, small	Electronics
C14	50>	Tie wraps, short	Electronics
C15	15	Cable terminal connector, ring type	Electronics
C16	3Mtr.	Elec. Speaker wire, thick, highly stranded	Electronics
C17	8	Hex nut, M8, L24	Hardware
C18			Reserved
C19	1	12V DC Motor, step down trans 1:200	Hobby
C20	1	12V Solenoid	Electronics
C21	5	Shaft Retaining Collar	Hobby
C22	1	Toothed belt L250; W10	Hobby
C23	1	Toothed pulley set, 3:1 ratio	Hobby
C24		Nozzle for plumbing (drain)	Hardware
C25	5	Nylon plain bearing for pulley OD10; ID8; L8	Hobby
C26	2 Mtr.	Elec. wire, standard	Hardware
C27	2	Nylon tube, OD20; ID10: L40	Hardware
C28		Copper foil (used to remove bearing/housing clearance)	Hobby/Bearing distr.
OD = Outer Diameter; ID = Inner Diameter; T = Thickness; L = Length; W = Width			
Unit: mm			

Mechanical Setup					
Material Description List					Table 5
Material	Qty.	Profile	Size	Source	Remarks
Aluminum	1	Square Solid	(10 x 10) L80	Hardware	
Aluminum	1	Square Solid	(12 x 12) L1150	Hardware	
Aluminum	1	Square Solid	(20 x 20) L150	Hardware	
Aluminum	1	Square Solid	(25 x 25) L40	Hardware	
Aluminum	1	Angle	(50 x 25) T3; L300	Hardware	

Aluminum	1	Angle	(25 x 25) T2; L650	Hardware	
Aluminum	1	Angle	(25 x 15) T2; L1100	Hardware	
Aluminum	1	Flat Solid	(20 x 8) L800	Hardware	
Aluminum	1	Flat Solid	(30 X 10) L600	Hardware	
Aluminum	1	Strip	(20 x 4) L500	Hardware	
Aluminum	1	Pipe	OD40; ID>35; L58	Hardware	
Aluminum	1	Round Solid	D20; L100	Hardware	
Steel	1	Plate	L300; W100; T0.5	Hardware	
Steel	1	Strip	(10 x 0.5) L 40	Hardware	
Steel	1	Strip	(28 x 1) L100	Hardware	
Steel	1	Round Solid	D8; L330	Hardware	
Steel	1	Round Solid	D12: L150	Hardware	
Copper	1	Pipe	OD4; ID2; L1000	Hardware	
PVC/Plastic	1	Plate	L450; W100; T8		**
Trespa	1	Plate	L360; W180; T10		* **
Lexan	1	Plate	L360; W195; T10		* **
Trespa	1	Plate	L360: W195: T10		**
Trespa	2	Plate	L160; W140; T10		**
Trespa	1	Plate	L360; W80; T10		* **
Trespa	2	Plate	L390; W200; T10		**
Trespa	1	Plate	L270; W140; T10		**
Trespa	1	Plate	L200; W116; T10		**
Trespa	4	Plate	L200; W25; T6		**
Trespa	5	Plate	L250: W50; T6		**
Trespa	1	Plate	L380; W200; T10		**
Trespa	1	Plate	L430; W420; T10		**
Steel	1	Stud	M10 All Thread L600	Hardware	
Steel	1	Stud	M8 All Thread L1000	Hardware	
Steel	1	Stud	M6 All Thread L3000	Hardware	
Steel	1	Stud	M4 All Thread L200	Hardware	
Steel	2 Pairs	Drawer Slide	L300; W27; S185	Hardware	Without Bracket
OD = Outer Diameter; ID = Inner Diameter D = Diameter; L = Length; W = Width; T = Thickness; S = Stroke					
* L360 must correspond exactly for each part					
** See Suppliers Section					
Note: Unit = mm					

Electrical Setup					
EDM Circuit					Table 6
Component	Qty.	Name	Description	Source	Remarks
T1	1	Transformer	40V; 6-8Amp	Electronics	Salvage
T2	1	Transformer	12V; 2.5Amp	Electronics	Salvage
T3	1	Transformer	30V; 1Amp	Electronics	Salvage
R1	2	Resistor	680Ohm; ½ W	Electronics	
R2	3	Resistor	10Kohm; ½ W	Electronics	
C1	1	Capacitor	50uF; 150V; Elco; Radial	Electronics	
C2	1	Capacitor	100uF; 150V; Elco; Radial	Electronics	
C3	1	Capacitor	200uF; 150V; Elco; Radial	Electronics	
C4	1	Capacitor	300uF; 150V; Elco; Radial	Electronics	
C5	1	Capacitor	500uF; 150V; Elco; Radial	Electronics	
L1	1	Power Light	Mains voltage	Electronics	
L2	4	Light Bulb	Mains Voltage; 100W	Electronics	
LF	4	Bulb Foot	Bulb Foot for L2	Electronics	Surface Mount
BR1	2	Bridge Rectifier	250V; 25Amp	Electronics	
D1	1	Diode	60V: 2Amp	Electronics	
COIL1	2	Coil+Core	1mH; 10Amp	Electronics	
F1	1	Fuse + Holder	Mains Voltage; 3 Amp; Fast	Electronics	Chassis Mount

S1	1	Toggle Switch	Mains Voltage; 5Amp	Electronics	Chassis Mount
S2	4	Toggle Switch	100V; 10 Amp	Electronics	Chassis Mount
S3	2	Toggle Switch	40V; 3 Amp	Electronics	Chassis Mount
X1	1	Connector	Female; 2 pins; 0.5 Amp	Electronics	Chassis Mount
X2	1	Connector	Mains	Electronics	Chassis Mount
X3	1	Connector	Female; 4 pin; 1Amp	Electronics	Chassis Mount
X4	1	Connector	Female; 2 pin; 1Amp	Electronics	Chassis Mount
V1	1	Ventilator	Mains Voltage; Large	Electronics	
CT	4	Crimp Terminal	Ring Type	Electronics	Fit W1
Other		Cable+Connector		Electronics	For X1-X4

Electrical Setup					
Feed Back Circuit					Table 7
Component	Qty.	Name	Description	Source	Remarks
R1	1	Resistor	10Kohm; 0.25W	Electronics	
R2	1	Resistor	330 Ohm; 0.25W	Electronics	
R3	1	Resistor	100Kohm; 0.25W	Electronics	
TR1	1	Transistor	BC 237	Electronics	
RR1	1	Reed Relay	12V; 0.1 Amp	Electronics	Normally Open*
C1	1	Capacitor	500uF; 30V; Elco; Radial	Electronics	
BR1	1	Bridge Rectifier	30V; 1Amp	Electronics	
F1	1	Fuse + Holder	30V; 0.5Amp	Electronics	PCB Mount
VR1	1	Variable Resistor	1Kohm	Electronics	Chassis Mount
X1	1	Connector Block	2 Pins; 1Amp	Electronics	PCB Mount
X2	1	Connector Block	3 Pins: 1Amp	Electronics	PCB Mount
X3	1	Connector Block	2 Pins; 0.5Amp	Electronics	PCB Mount
ICS	1	IC Socket	14 pin DIL	Electronics	PCB Mount**
B1	1x	Board	Board; 3 Island solder trace	Electronics	
* Circuit connections for the reed relay may differ from drawing. Consult data sheet for reed relay used					
** Reed relay is a 12 pin DIL. Take this into account when making board connections					

Electrical Setup					
EDM Chopper Circuit					Table 8
Component	Qty.	Name	Description	Source	Remarks
R1	1	Resistor	8Kohm; 0.25W	Electronics	
C1	1	Capacitor	22uF; 30V; Elco; Radial	Electronics	
C2	1	Capacitor	0.1uF; 30V; Elco; Radial	Electronics	
IC1	1	Voltage Regulator	7812	Electronics	
IC2	1	Timer	555	Electronics	
IC3	2	Mosfet	IRF540	Electronics	
CI	2	Ceramic Insulator		Electronics	For IC3
ICS	1	IC Socket	14 pin DIL	Electronics	PCB Mount
B1	1x	Board	Board; 3 Island solder trace	Electronics	

Electrical Setup					
Speed Controller Power Supply Circuit					Table 9
Component	Qty.	Name	Description	Source	Remarks
R1	1	Resistor	10KOhm; 0.5W	Electronics	
C1	1	Capacitor	1000uF; 30V; Elco; Axial	Electronics	
BR1	1	Bridge Rectifier	30V; 4 Amp	Electronics	

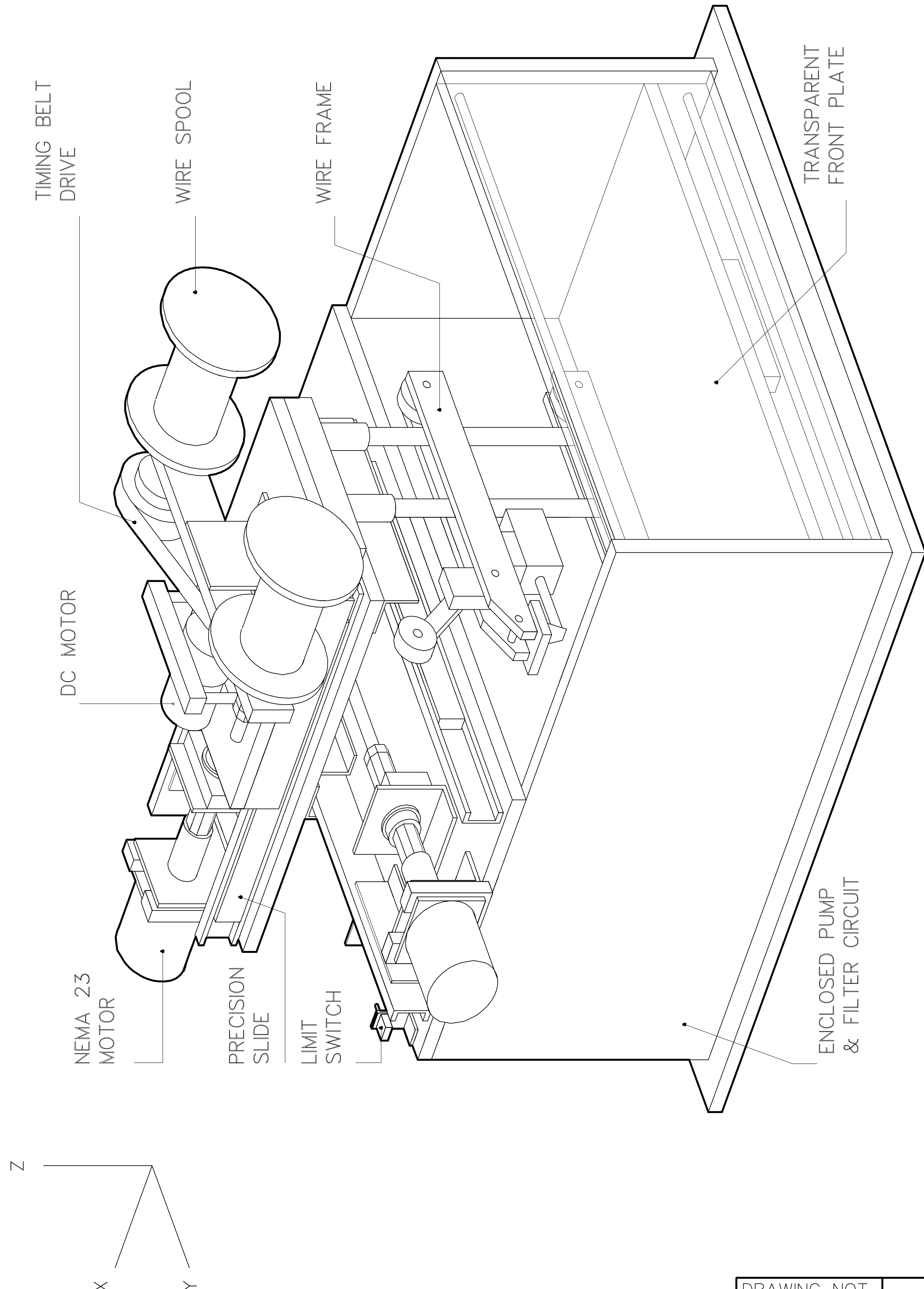
F1	1	Fuse + Holder	2 Amp; Fast	Electronics	PCB Mount
X1	1	Connector Block	2 Pins; 2 Amp	Electronics	PCB Mount
X2	1	Connector Block	2 Pins; 2 Amp	Electronics	PCB Mount
B1	1	Board	Board 3 Island trace	Electronics	PCB Mount

Electrical Setup					
Stepper Motor Driver Power Supply + Related Components					Table 10
Component	Qty.	Name	Description	Source	Remarks
T1	1	Transformer	12Volt; 3 Amp	Electronics	
R1	1	Resistor	10KOhm; 0.5W	Electronics	
R2	5	Resistor	2K2; 0.25W	Electronics	
C1	1	Capacitor	1000uF; 30V; Elco; Axial	Electronics	
C2	1	Capacitor	22uF:30V: Elco: Radial	Electronics	
BR1	1	Bridge Rectifier	30V; 4 Amp	Electronics	
IC1	1	Voltage Regulator	7805	Electronics	
F2	1	Fuse + Holder	250V; 2 Amp; Fast	Electronics	PCB Mount
S1	1	Switch	250V; 2Amp	Electronics	Chassis Mount
V1	1	Ventilator	12Volt DC; Medium size	Electronics	
X1; X2; X3	3	Connector	Female; 4 pins; 2Amp	Electronics	Chassis Mount
X4	1	Connector	Female; DB-25 Parallel Port	Electronics	Chassis Mount
X5	1	Connector	Female; 5 pins; 0.5Amp	Electronics	Chassis Mount
X6	1	Connector	Female; 2 pins; 0.5Amp	Electronics	Chassis Mount
X7	1	Connector	Mains Voltage; Female	Electronics	Chassis Mount
X8	1	Connector Block	2 Pins; 2 Amp	Electronics	PCB Mount
X9	1	Connector Block	6 Pins; 0.5 Amp	Electronics	PCB Mount
X10	1	Connector Block	2 Pins; 2 Amp	Electronics	PCB Mount
X11	1	Connector Block	4 Pins; 2 Amp	Electronics	PCB Mount
CC	1	Computer Case	Desk Top (Horizontal)	Electronics	Salvage
MC	1 Mtr.	Mains Cable		Electronics	For X7
B1	1	Board	Board 3 Island trace	Electronics	
Other			Connector + cable	Electronics	For X1-X6

Electrical Setup			
General			Table 11
Qty.	Description	Source	Remark
2Mtr.	Shrink Tube (shrinks when heated)	Electronics	Insulates wire connections
24	PCB Stand Off Plugs	Electronics	
>30	Tie Wrap	Electronics	Small, short length
>15	Tie Wrap Mount	Electronics	
2Mtr.	Bare Wire, Thin and Tinned	Electronics	For circuit board connections
4	Crimp Terminal	Electronics	For EDM connections
10	PCB Pin Connections; Male + Female	Electronics	For DB-25 connector
4 Mtr.	Elec. Wire, High Current, Highly Stranded	Electronics	Type used as audio speaker wire
5 Mtr.	Elec. Wire, Standard Mains, 2 lead	Electronics	
5 Mtr.	Elec. Wire, 1 Amp, Highly Stranded	Electronics	(Black)
5 Mtr.	Elec. Wire, 1 Amp, Highly Stranded	Electronics	(Red)
4 Mtr.	Elec. Wire, 1 Amp, Highly Stranded	Electronics	(Blue)
2 Mtr.	Elec. Wire, 1 Amp, Highly Stranded	Electronics	(Yellow)
2 Mtr.	Elec. Wire, 1 Amp, Highly Stranded	Electronics	(White)
2 Mtr.	Elec. Wire, 1 Amp, Highly Stranded	Electronics	(Orange)

DESK TOP ENGINEERING PROJECT
W—EDM

MECHANICAL SETUP

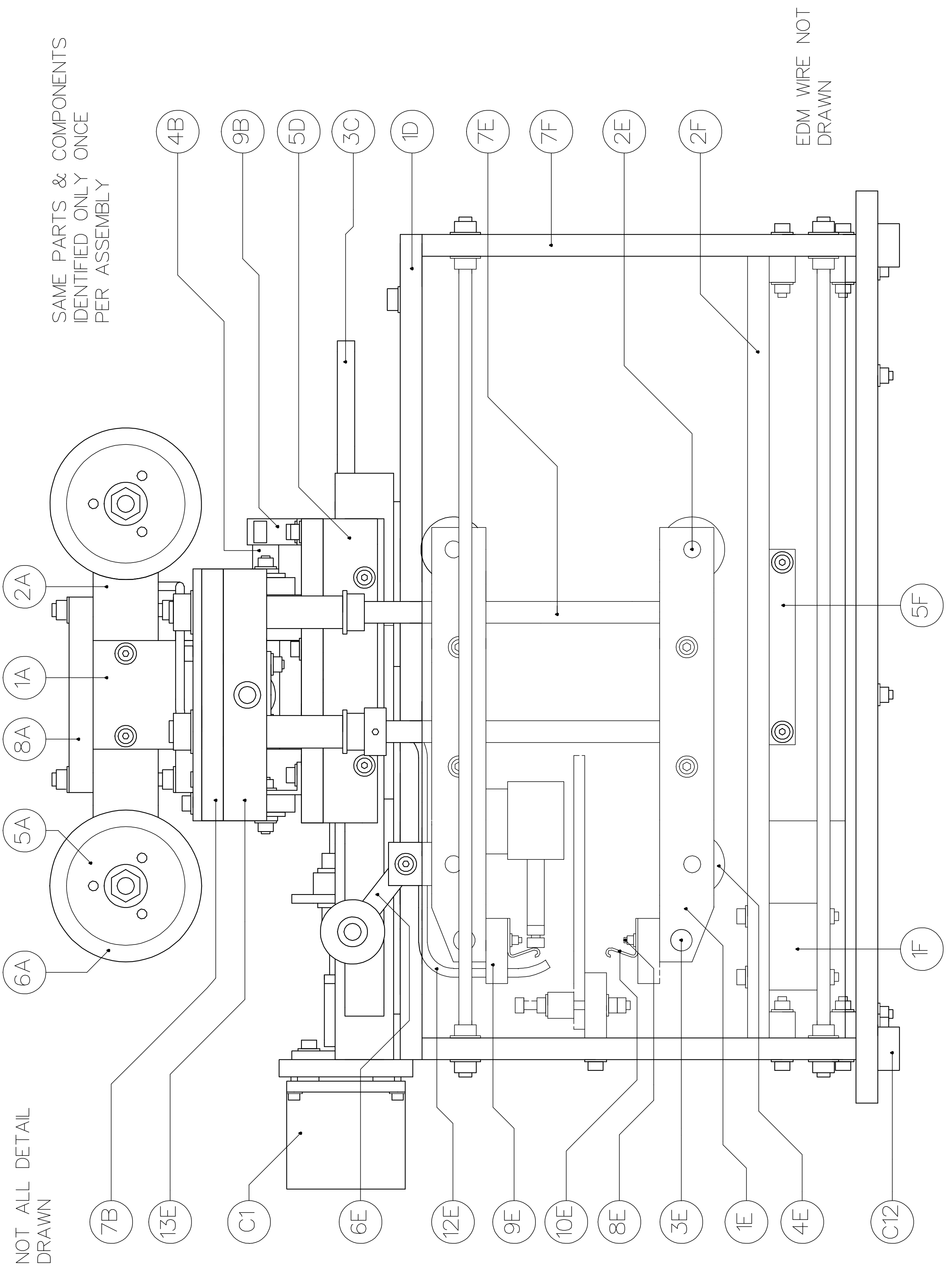


DRAWING NOT TO SCALE

DR. 1

DESK TOP ENGINEERING PROJECT
W-EDM

MECHANICAL SETUP



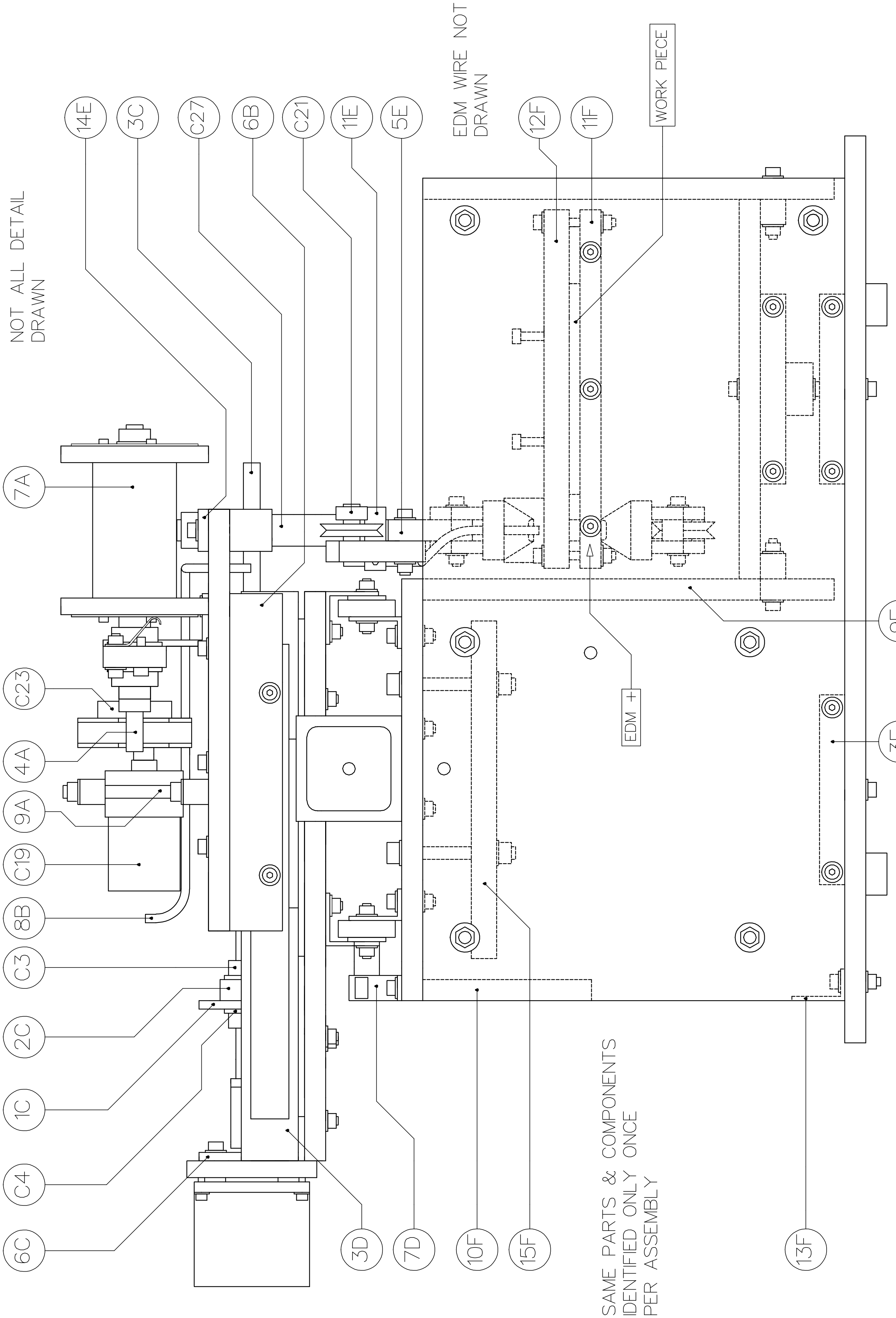
FRONT VIEW

DRAWING NOT
TO SCALE

DR.2

DESK TOP ENGINEERING PROJECT
W-EDM

MECHANICAL SETUP



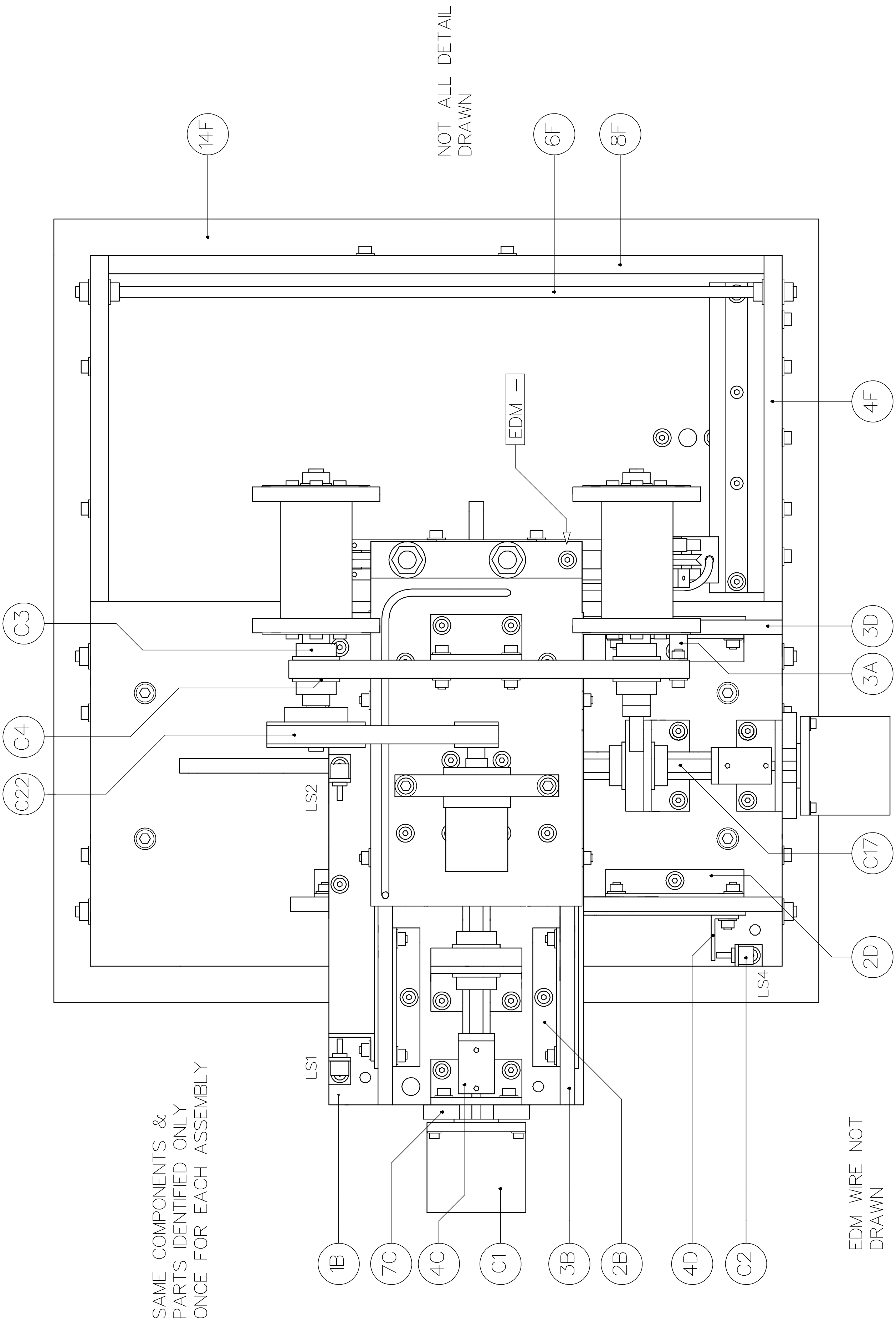
LEFT VIEW

DRAWING NOT TO SCALE

DR.3

DESK TOP ENGINEERING PROJECT
W—EDM

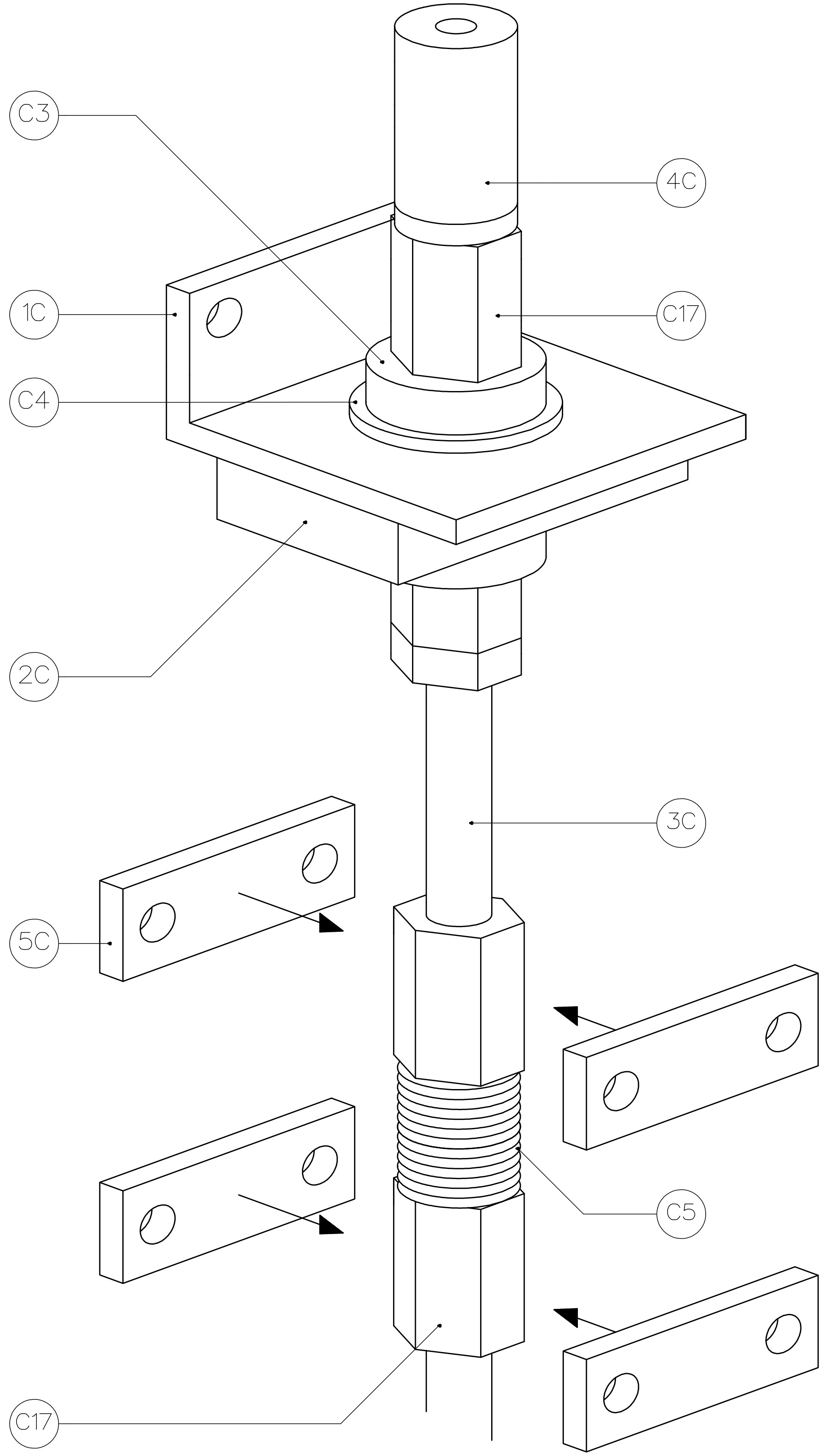
MECHANICAL SETUP



TOP VIEW

DRAWING NOT TO SCALE

DR. 4



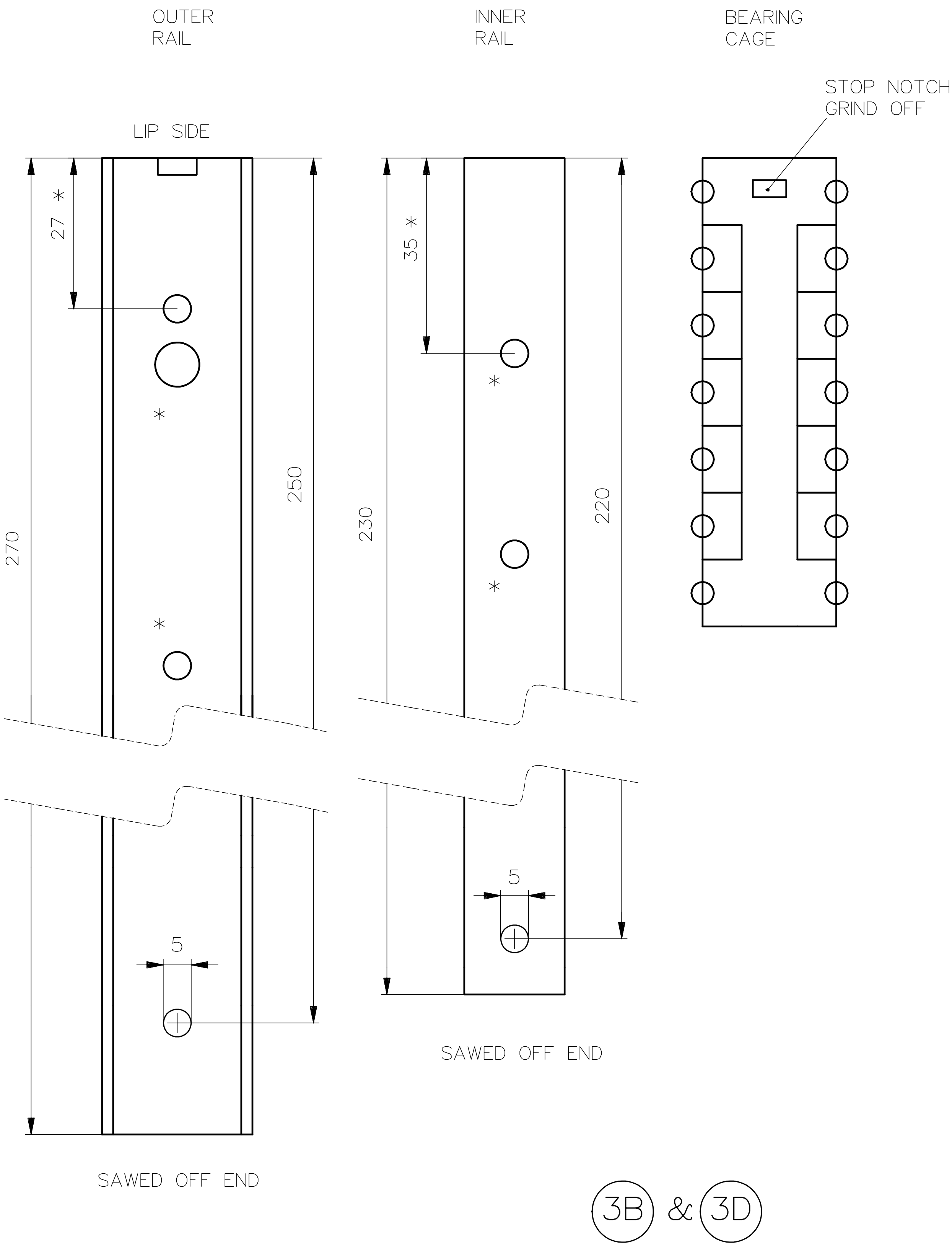
SAME PARTS & COMPONENTS
IDENTIFIED ONLY ONCE
PER ASSEMBLY

CLOSE UP ASSEMBLY C

DRAWING NOT
TO SCALE

DESK TOP ENGINEERING PROJECT
W–EDM

MECHANICAL SETUP



* LISTED FOR ORIENTATION
PURPOSES

2D PROJECTION

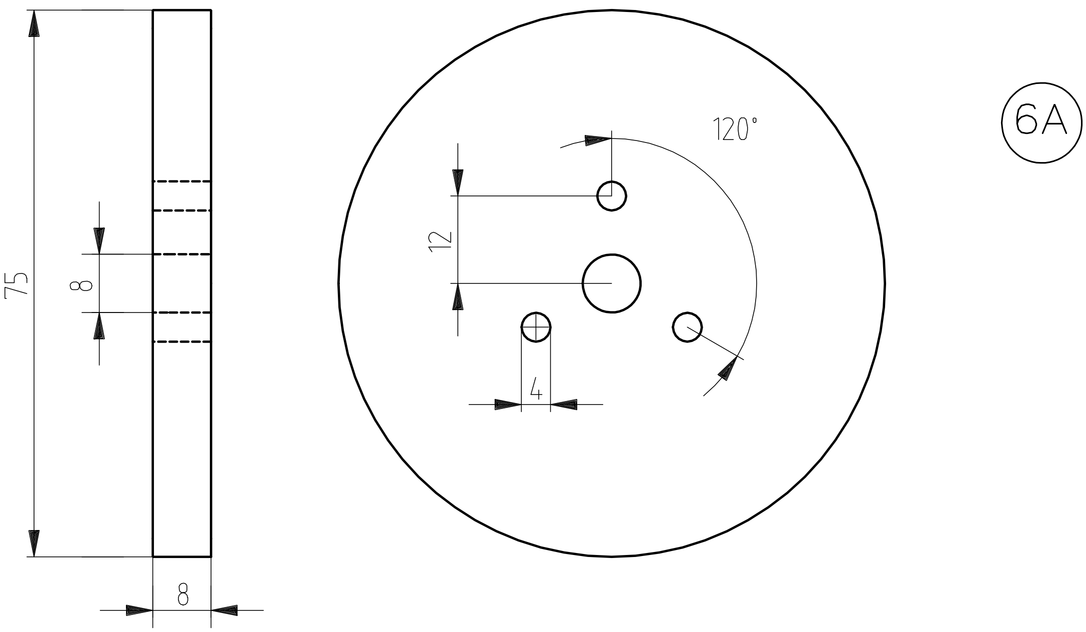
UNIT: mm

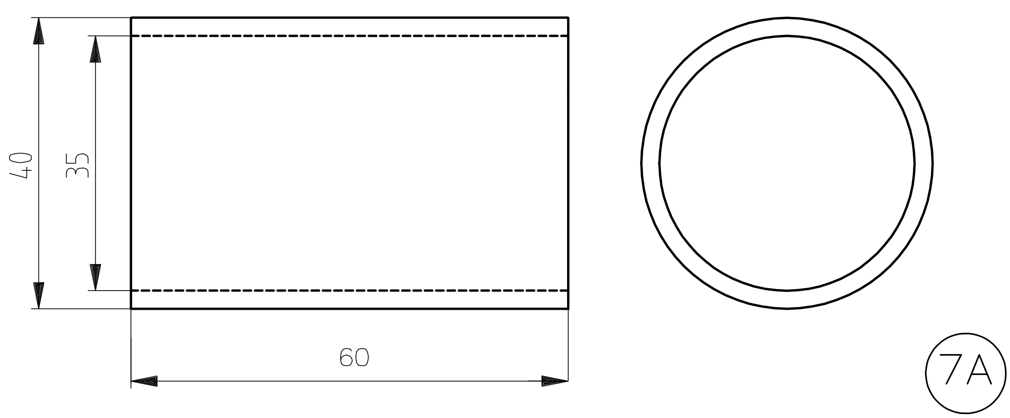
DRAWING NOT
TO SCALE

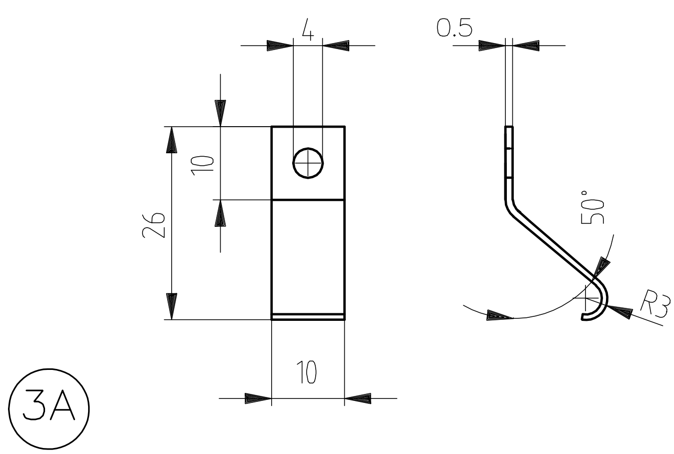
DR. 6

DESK TOP ENGINEERING PROJECT
W–EDM

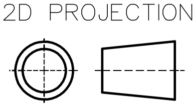
ASSEMBLY A







2D PROJECTION



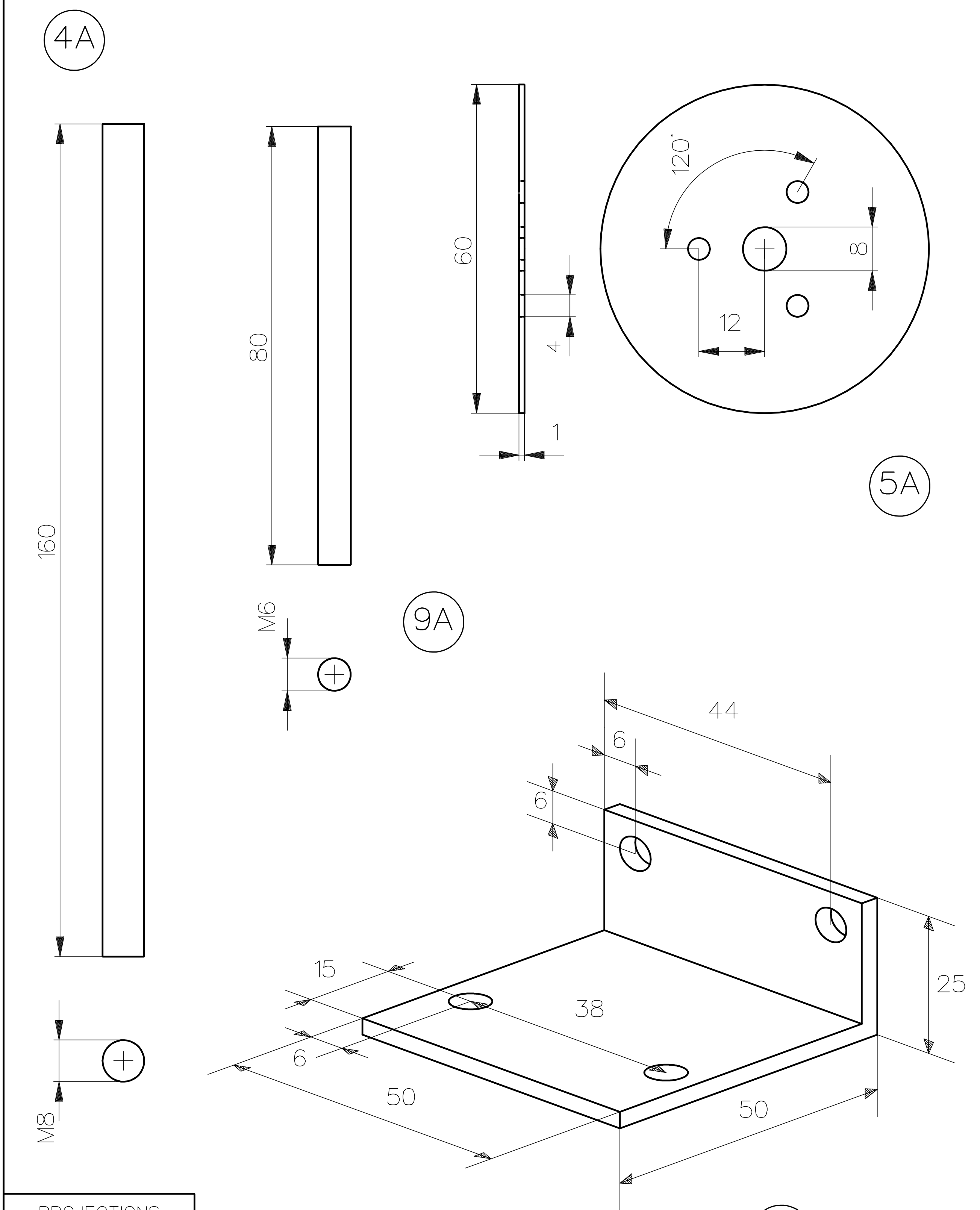
UNIT: mm

DRAWING NOT TO SCALE

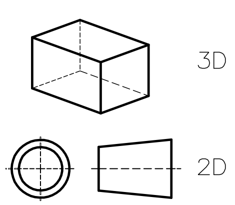
DR. 7

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY A



PROJECTIONS



UNIT: mm

ALL HOLES 6mm
UNLESS SPECIFIED

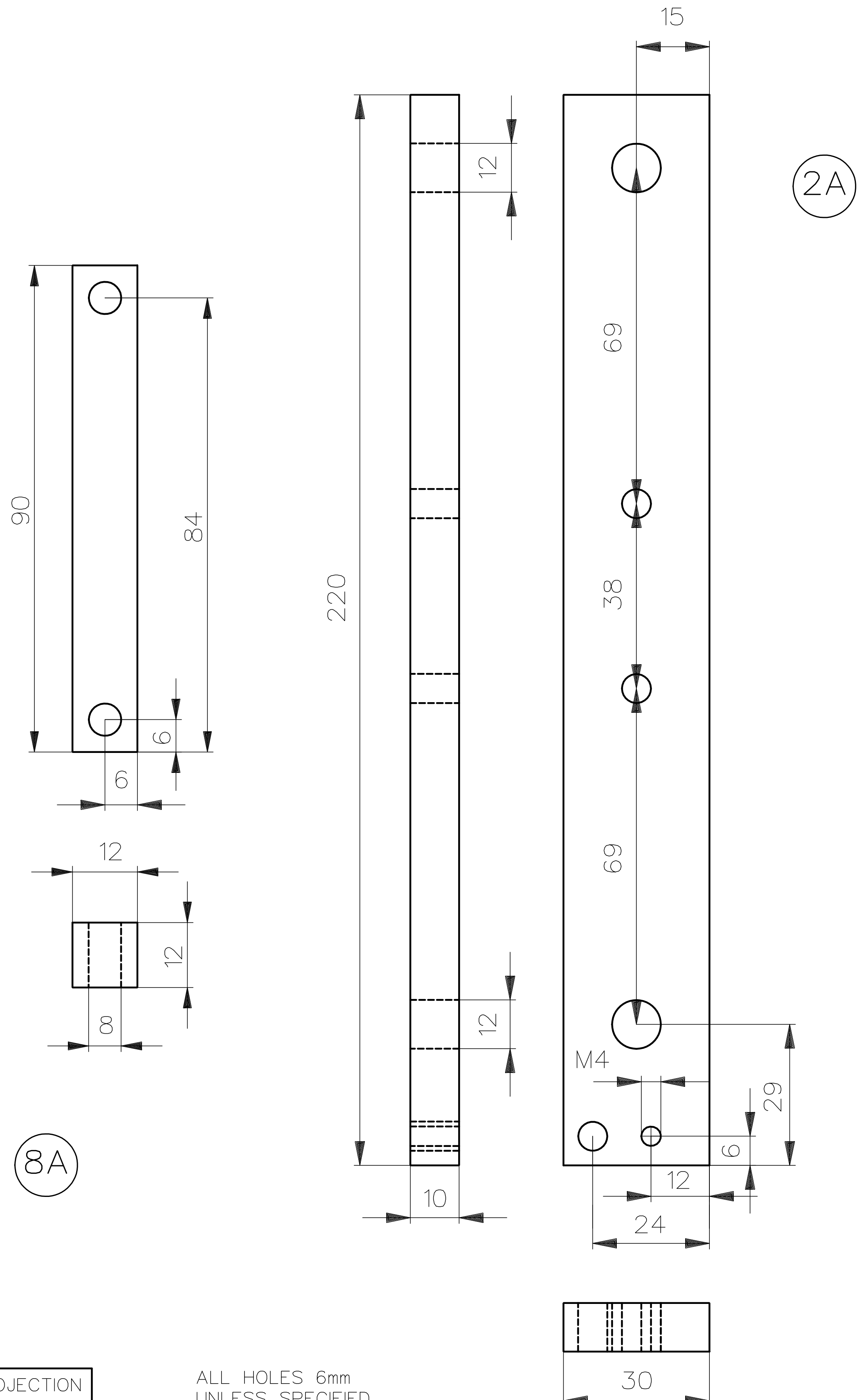
THICKNESS 3mm

DRAWING NOT
TO SCALE

DR.8

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY A



ALL HOLES 6mm
UNLESS SPECIFIED

2D PROJECTION

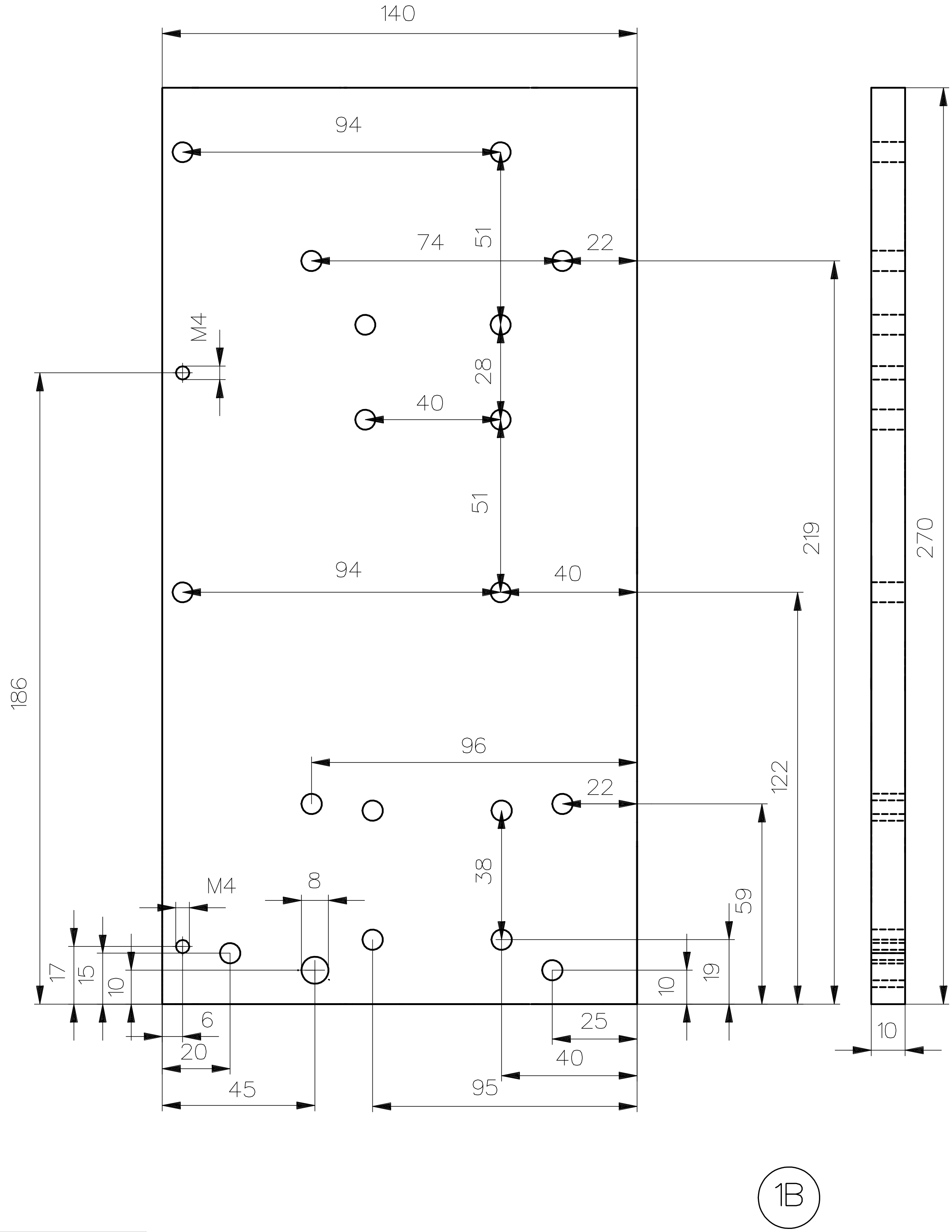
UNIT: mm

DRAWING NOT
TO SCALE

DR.9

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY B



2D PROJECTION

UNIT: mm

ALL HOLES 6mm
UNLESS SPECIFIED

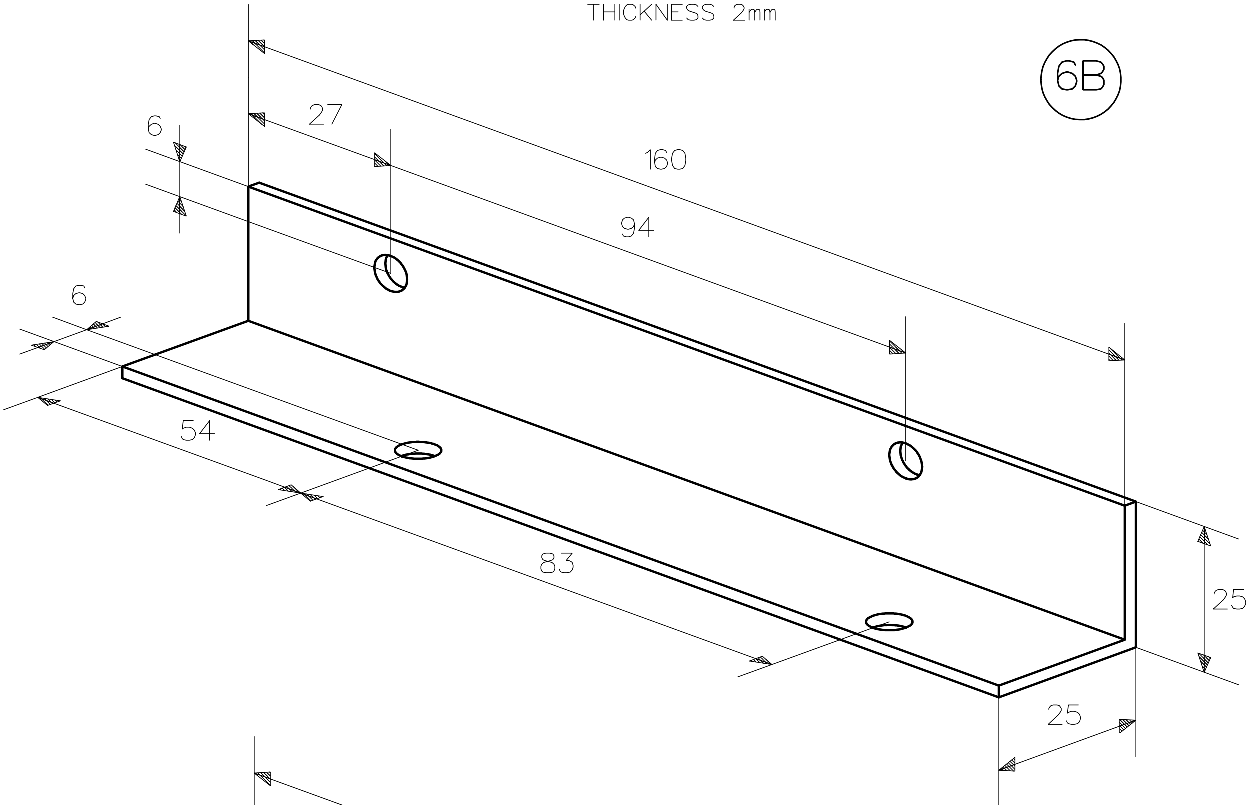
DRAWING NOT TO SCALE

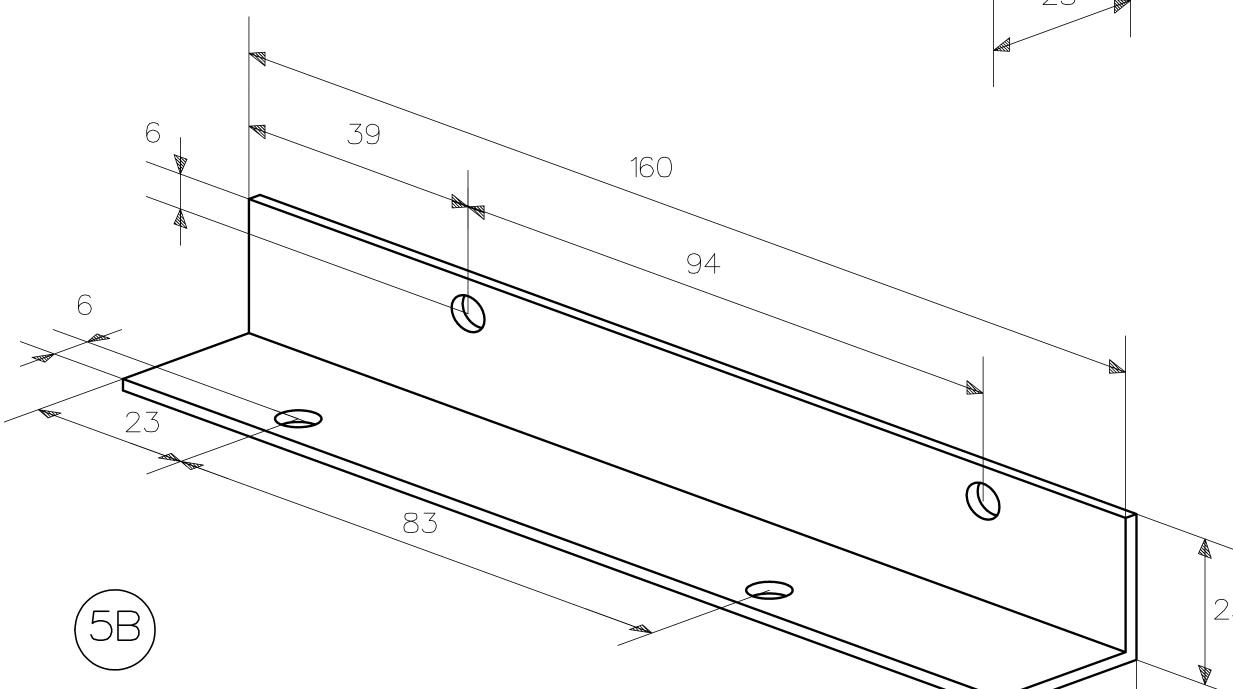
DR.10

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY B

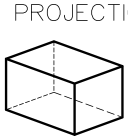
THICKNESS 2mm





THICKNESS 2mm

3D PROJECTION



ALL HOLES 6mm
UNLESS SPECIFIED

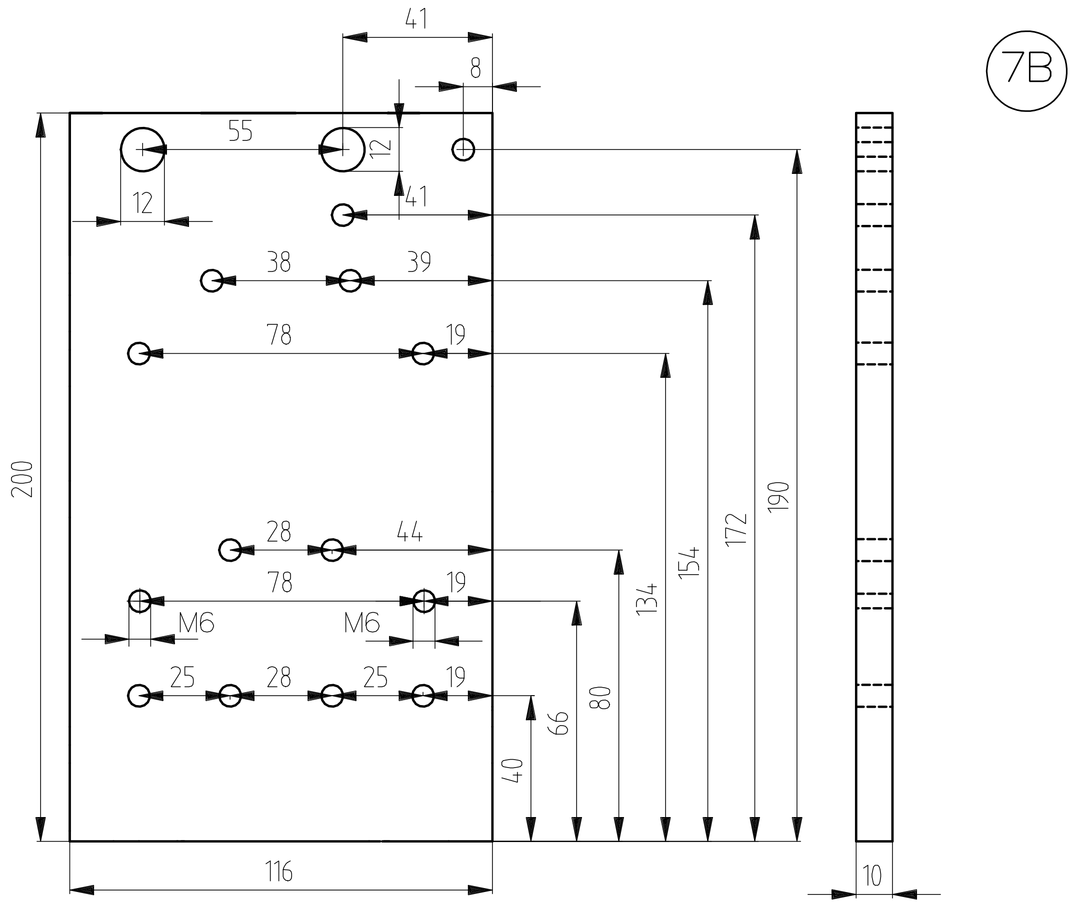
UNIT: mm

DRAWING NOT
TO SCALE

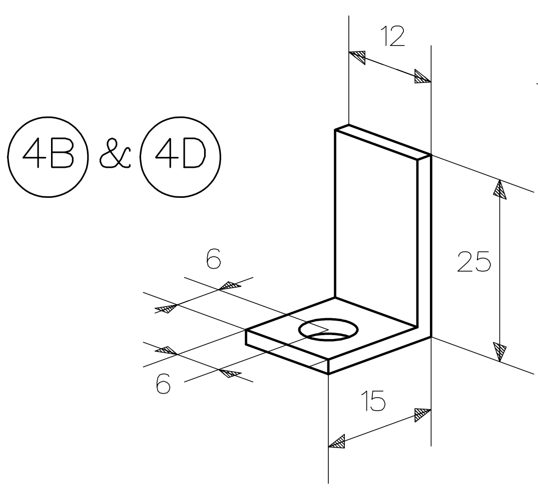
DR.11

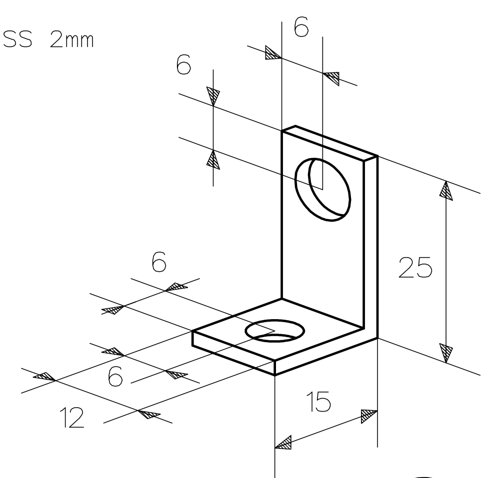
DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY B



THICKNESS 2mm



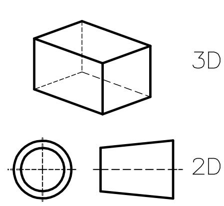


9B & 7D

ALL HOLES 6mm
UNLESS SPECIFIED

THICKNESS 2mm

PROJECTIONS



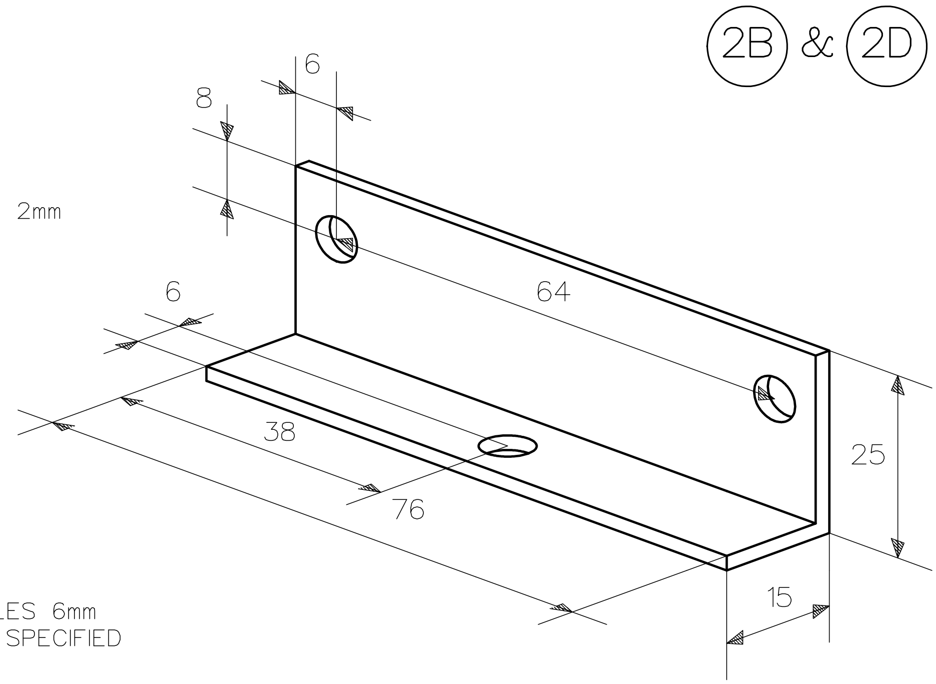
UNIT: mm

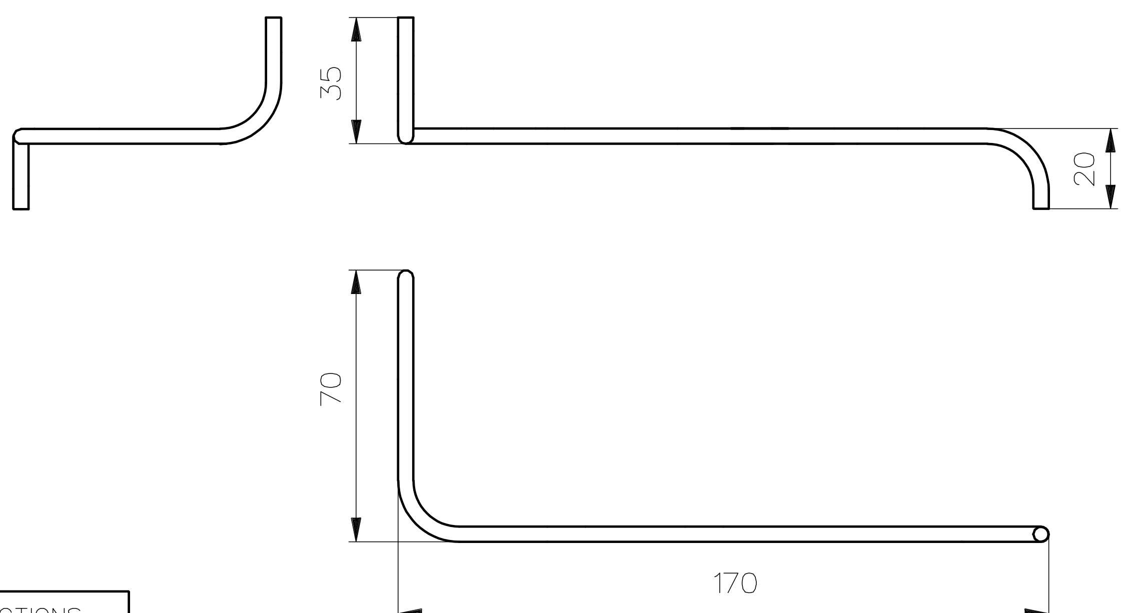
DRAWING NOT
TO SCALE

DR.12

DESK TOP ENGINEERING PROJECT
W–EDM

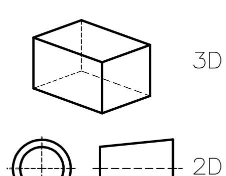
ASSEMBLY B





8B

PROJECTIONS



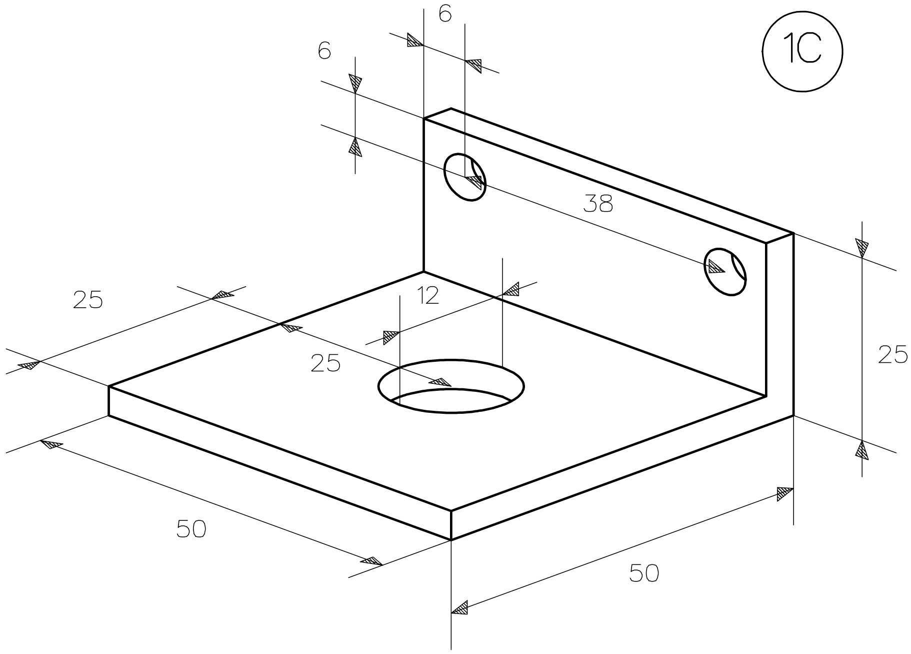
UNIT: mm

DRAWING NOT
TO SCALE

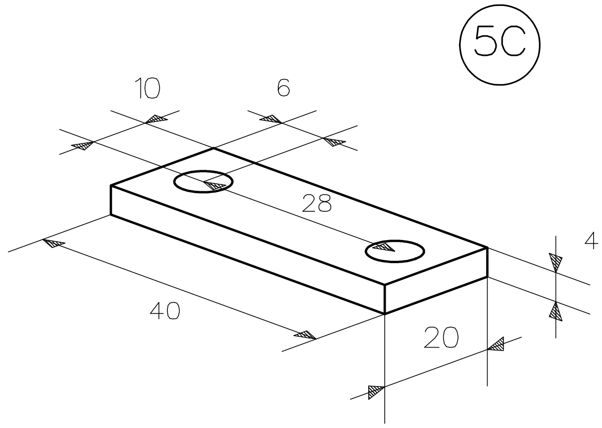
DR.13

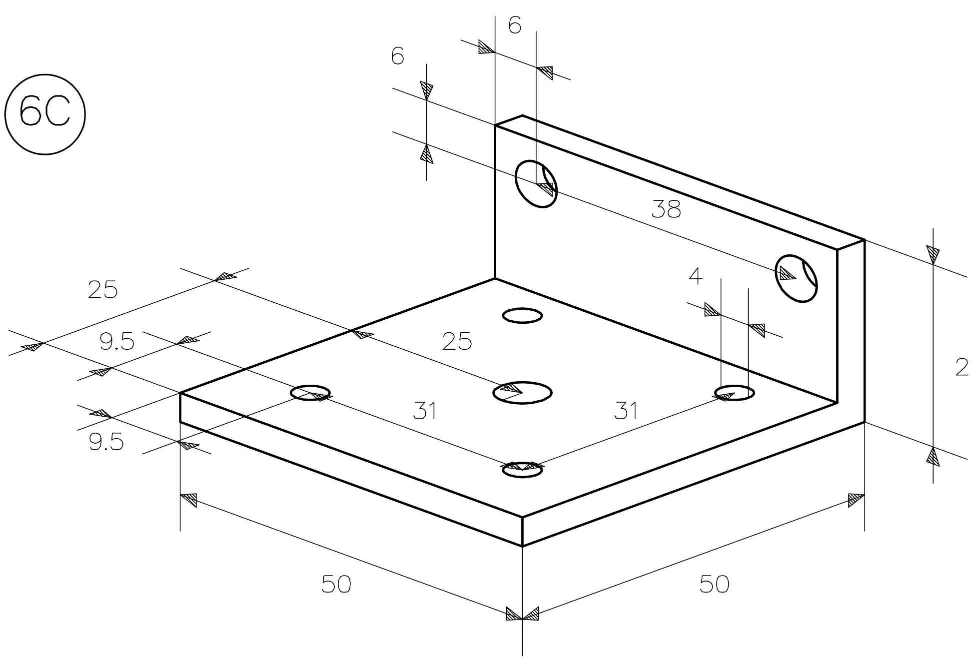
DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY C



THICKNESS 3mm

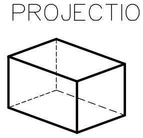




THICKNESS 3mm

ALL HOLES 6mm
UNLESS SPECIFIED

3D PROJECTION



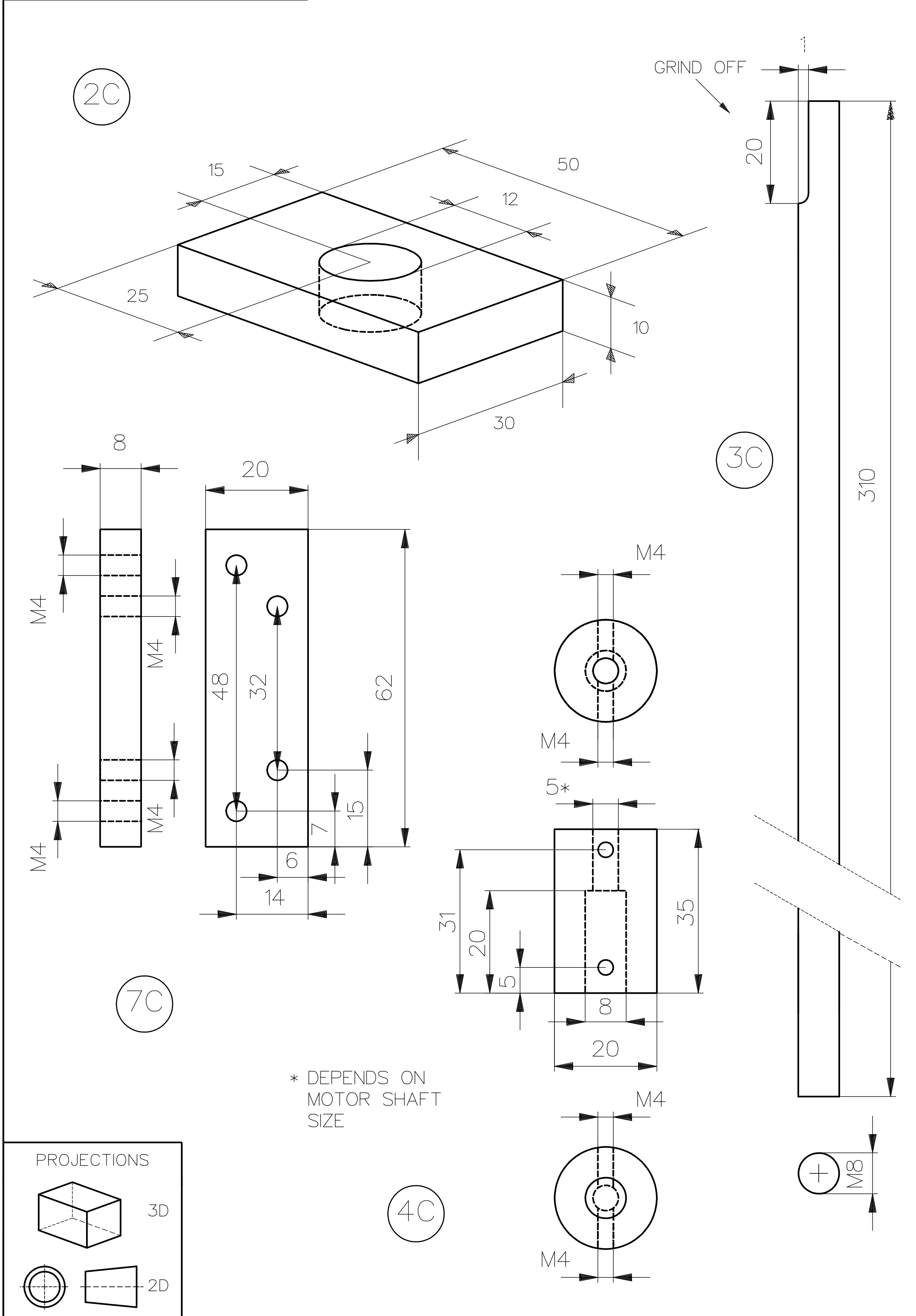
UNIT: mm

DRAWING NOT
TO SCALE

DR.14

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY C



UNIT: mm

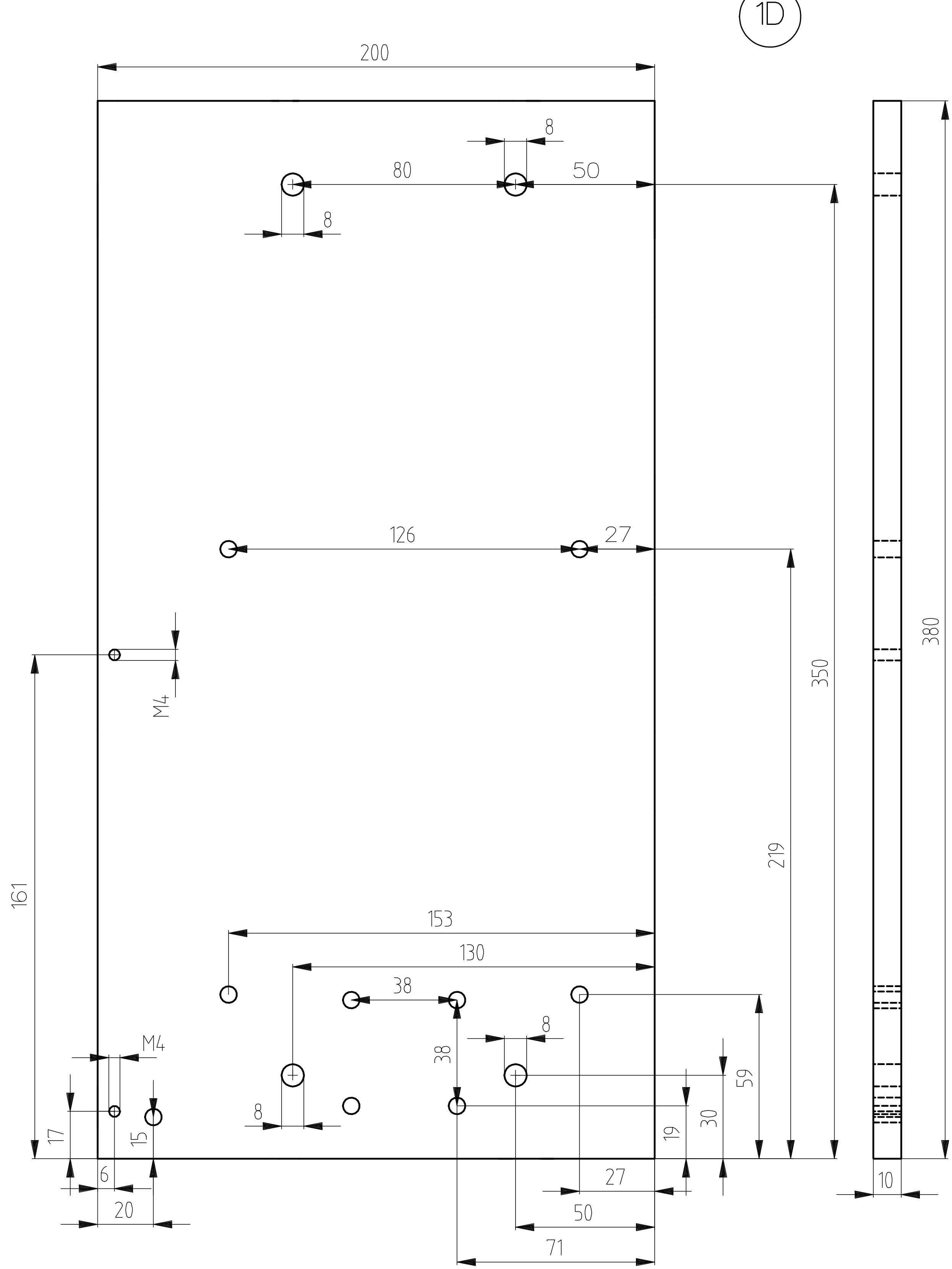
DRAWING NOT TO SCALE

DR.15

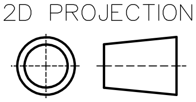
DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY D

SEE ASSEMBLY B
FOR ADDITIONAL
PARTS



2D PROJECTION



UNIT: mm

ALL HOLES 6mm
UNLESS SPECIFIED

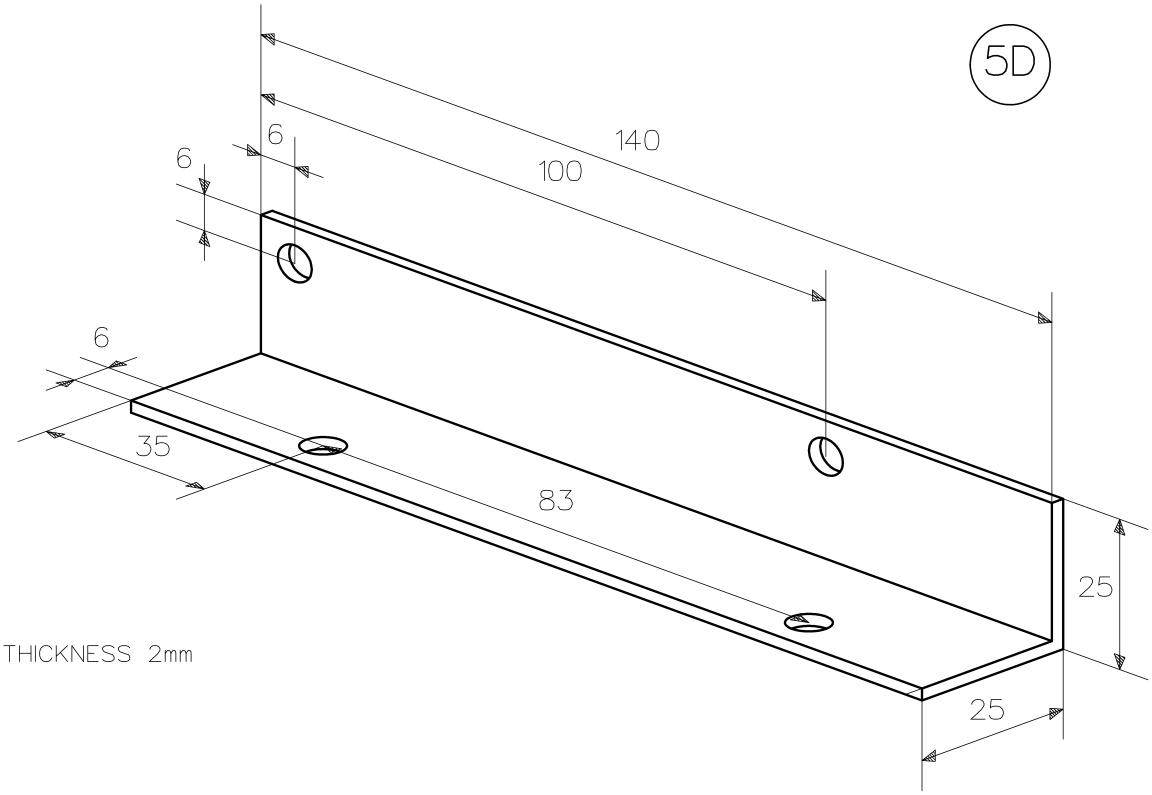
DRAWING NOT
TO SCALE

DR.16

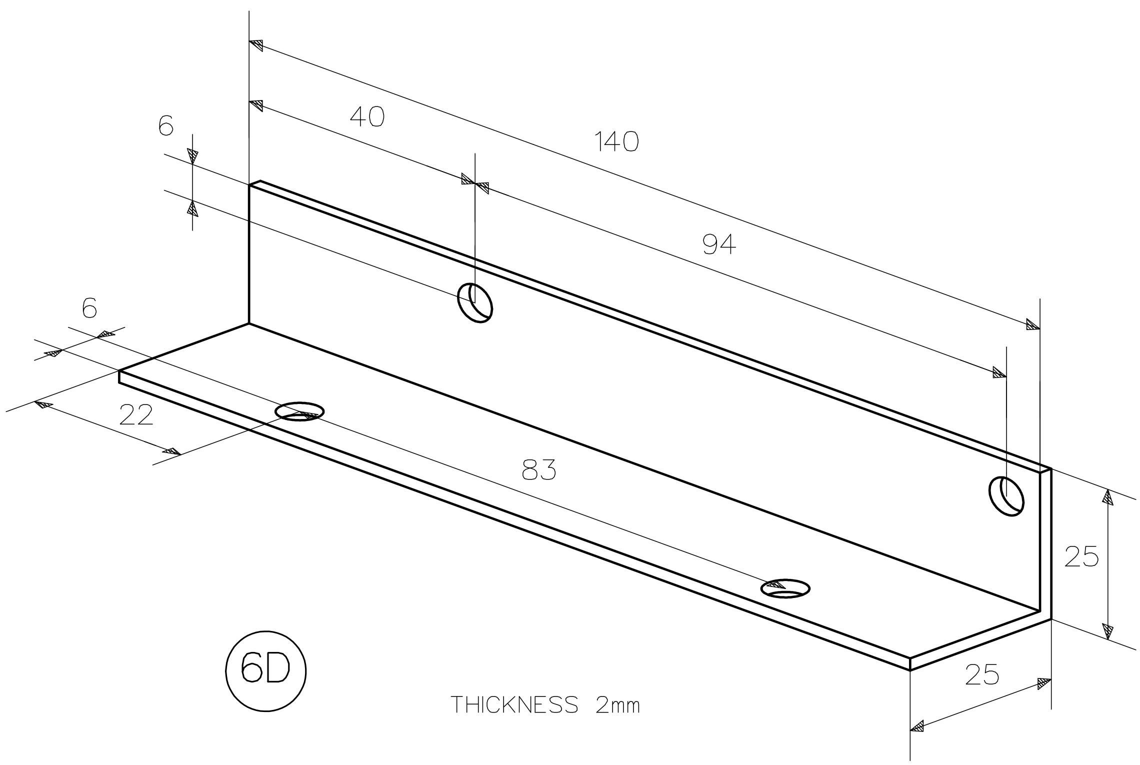
DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY D

SEE ASSEMBLY B
FOR ADDITIONAL
PARTS



THICKNESS 2mm



THICKNESS 2mm

3D PROJECTION

UNIT: mm

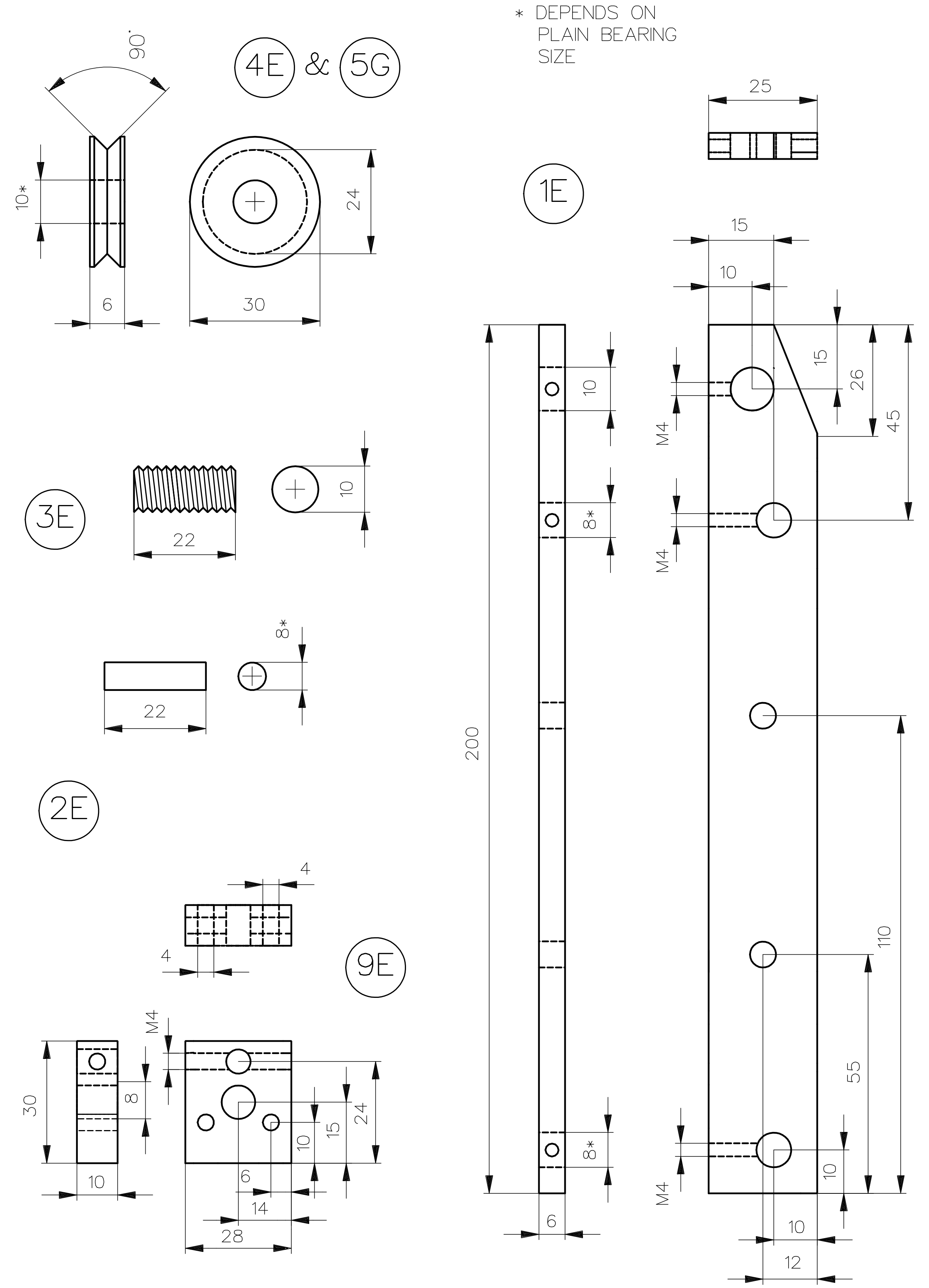
ALL HOLES 6mm
UNLESS SPECIFIED

DRAWING NOT
TO SCALE

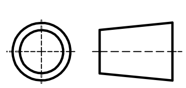
DR.17

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY E



2D PROJECTION



UNIT: mm

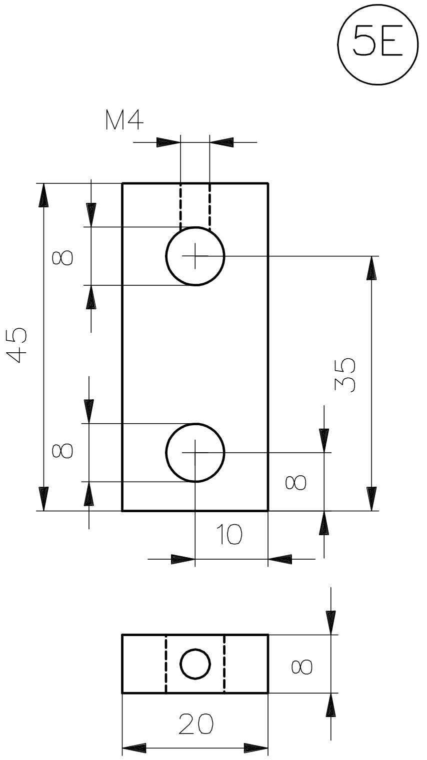
ALL HOLES 6mm
UNLESS SPECIFIED

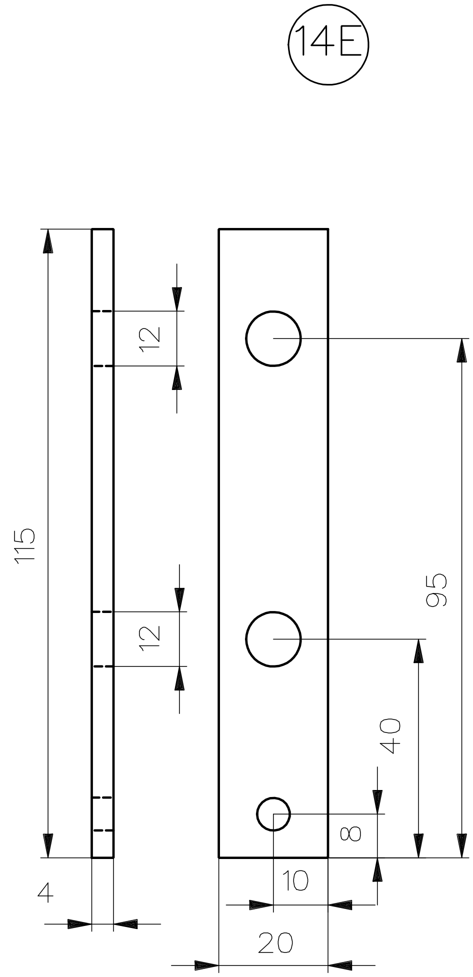
DRAWING NOT
TO SCALE

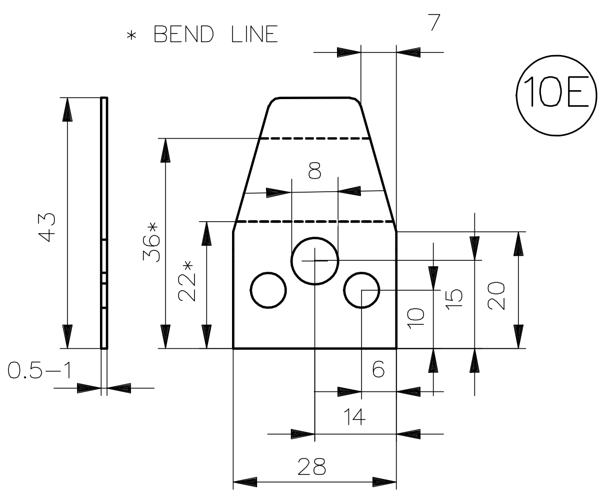
DR.18

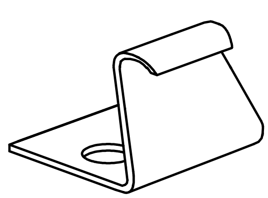
DESK TOP ENGINEERING PROJECT
W–EDM

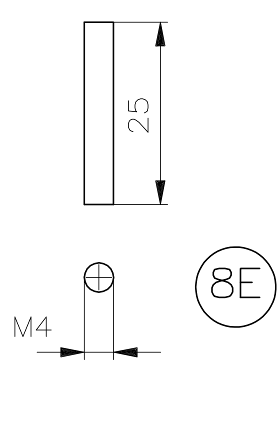
ASSEMBLY E





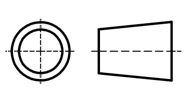






ALL HOLES 6mm
UNLESS SPECIFIED

2D PROJECTION



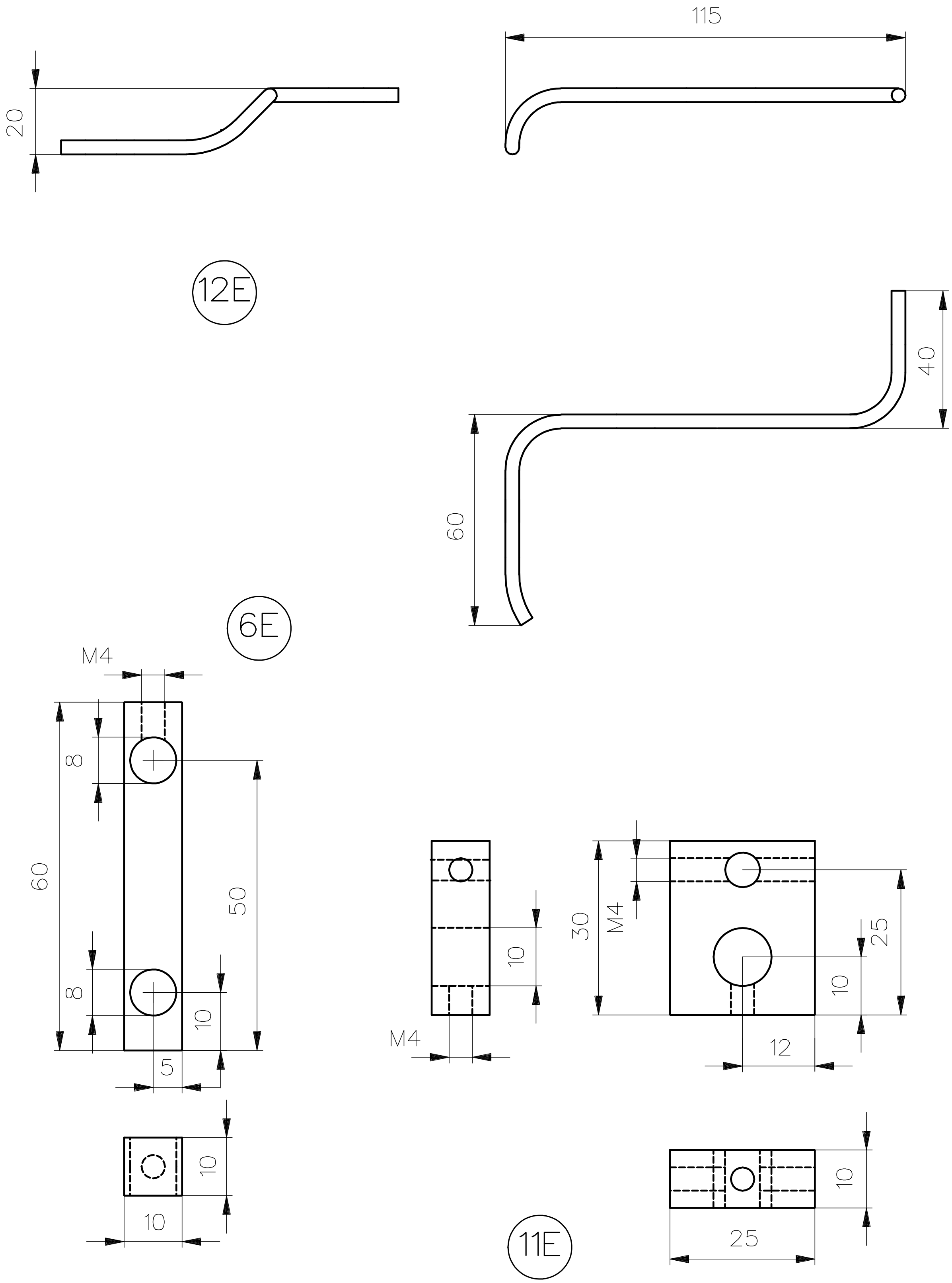
UNIT: mm

DRAWING NOT
TO SCALE

DR.19

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY E



2D PROJECTION

UNIT: mm

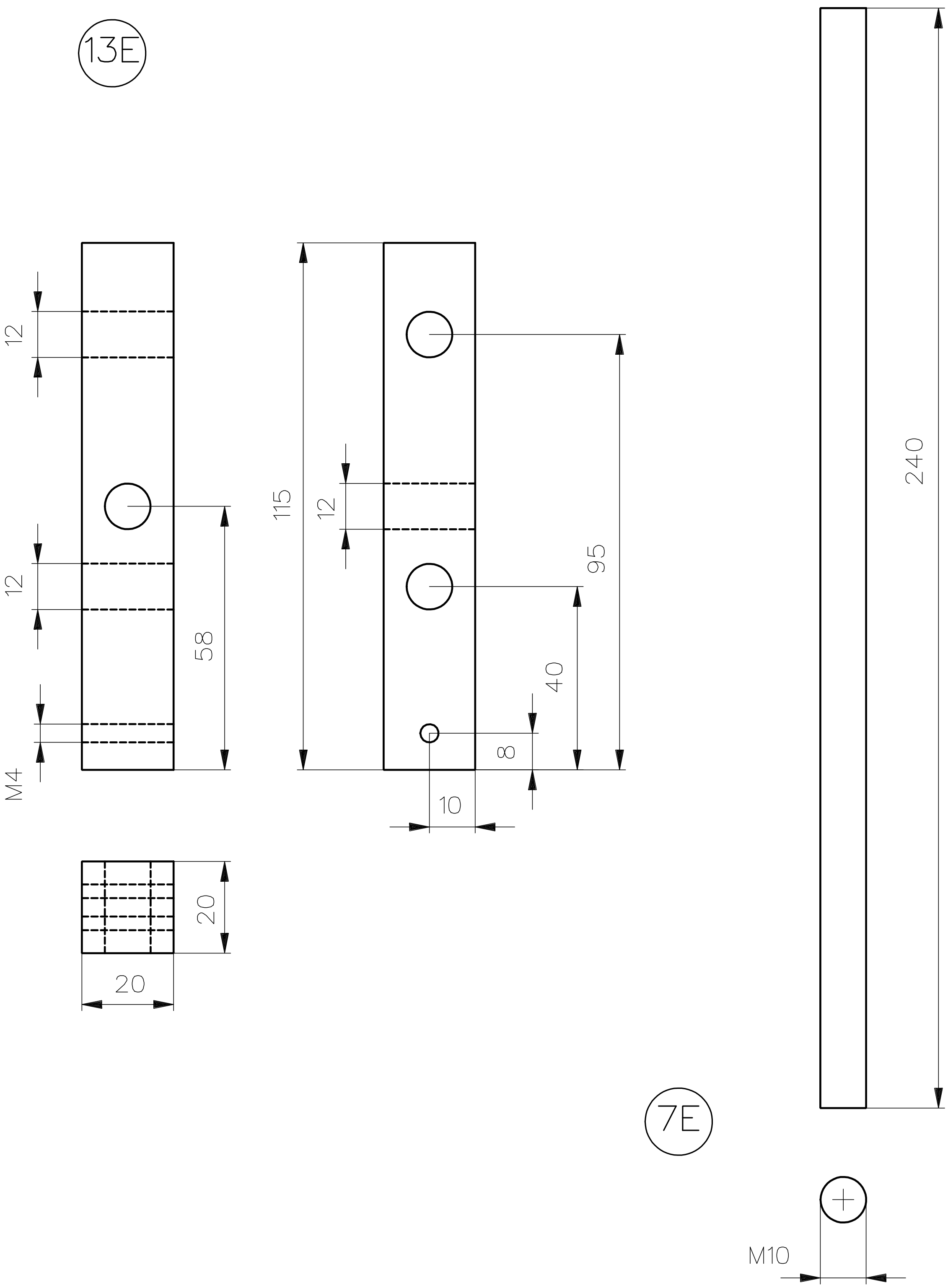
ALL HOLES 6mm
UNLESS SPECIFIED

DRAWING NOT TO SCALE

DR.20

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY E



2D PROJECTION

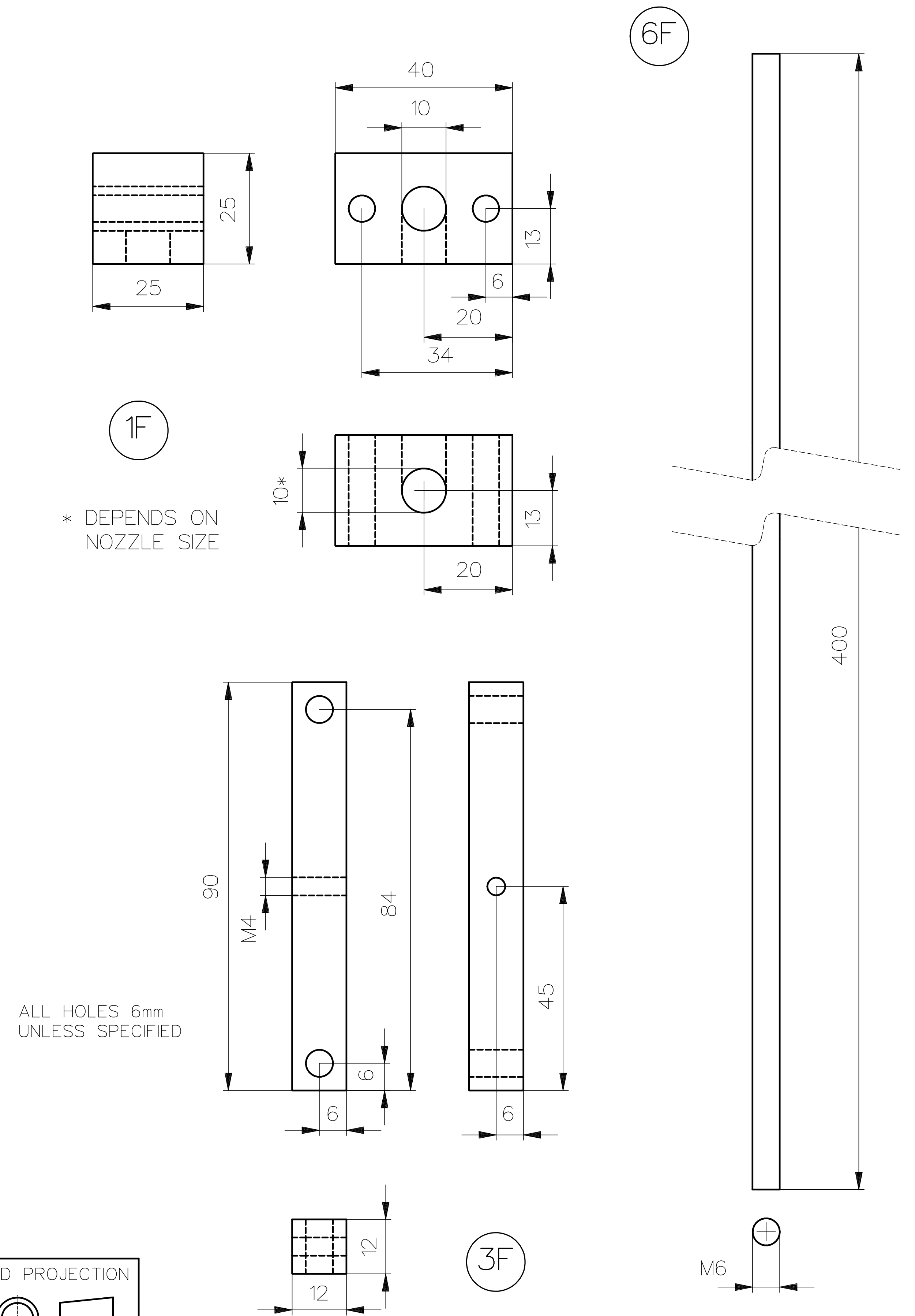
UNIT: mm

DRAWING NOT TO SCALE

DR.21

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY F



2D PROJECTION

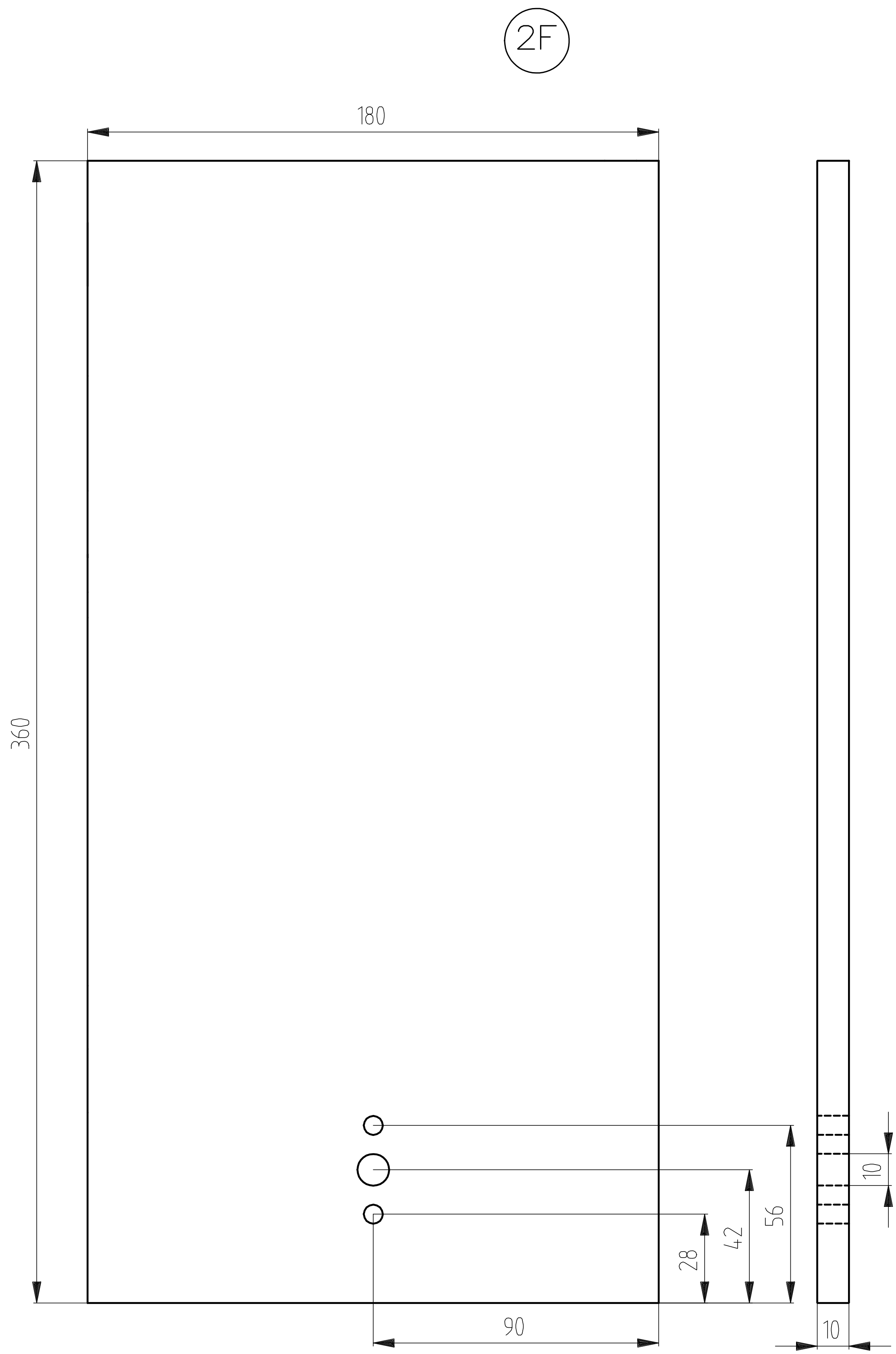
UNIT: mm

DRAWING NOT
TO SCALE

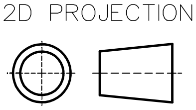
DR.22

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY F



2D PROJECTION



UNIT: mm

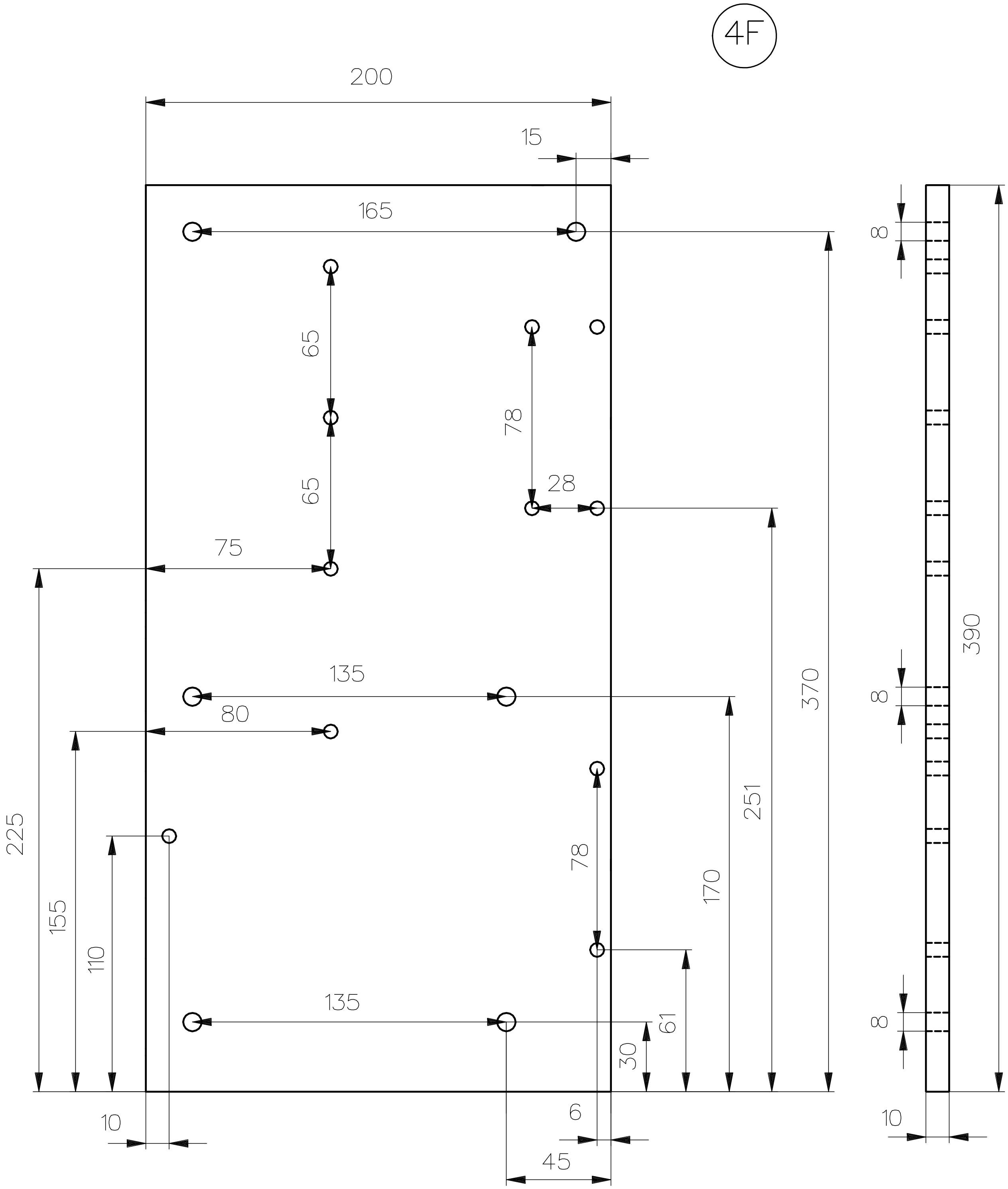
ALL HOLES 6mm
UNLESS SPECIFIED

DRAWING NOT TO SCALE

DR.23

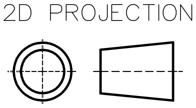
DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY F



ALL HOLES 6mm
UNLESS SPECIFIED

2D PROJECTION



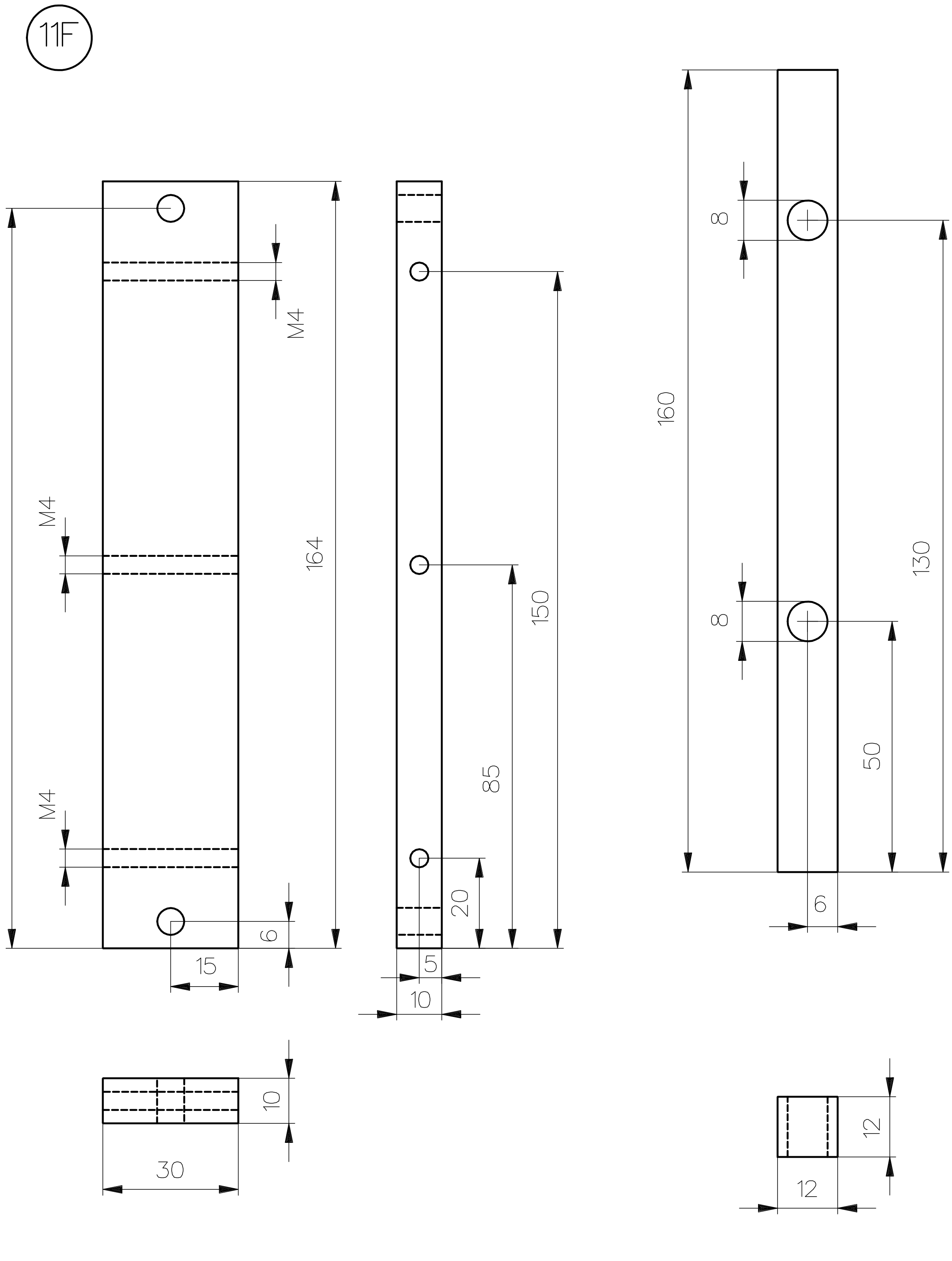
UNIT: mm

DRAWING NOT TO SCALE

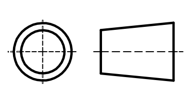
DR.24

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY F



2D PROJECTION

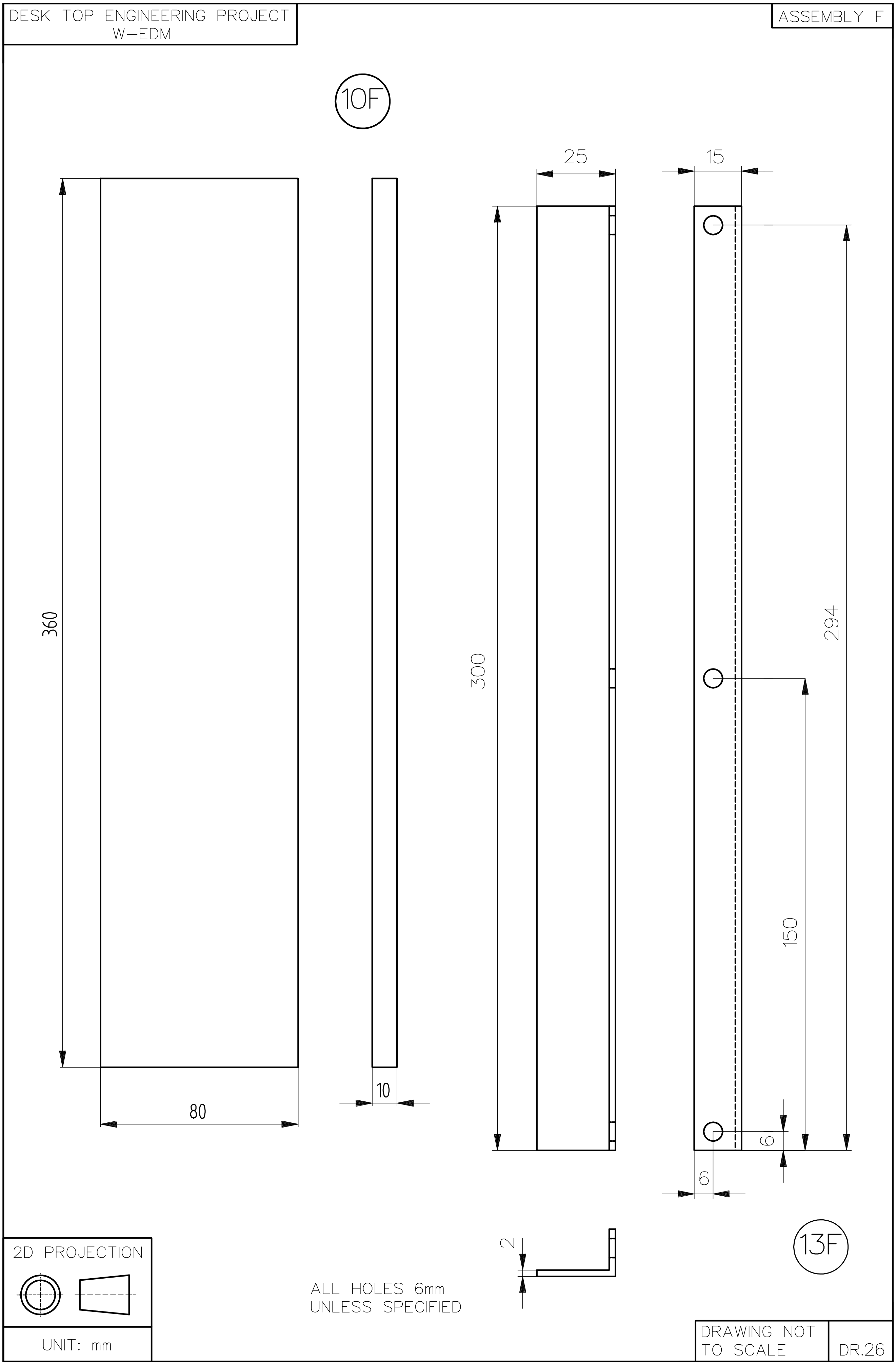


UNIT: mm

ALL HOLES 6mm
UNLESS SPECIFIED

DRAWING NOT TO SCALE

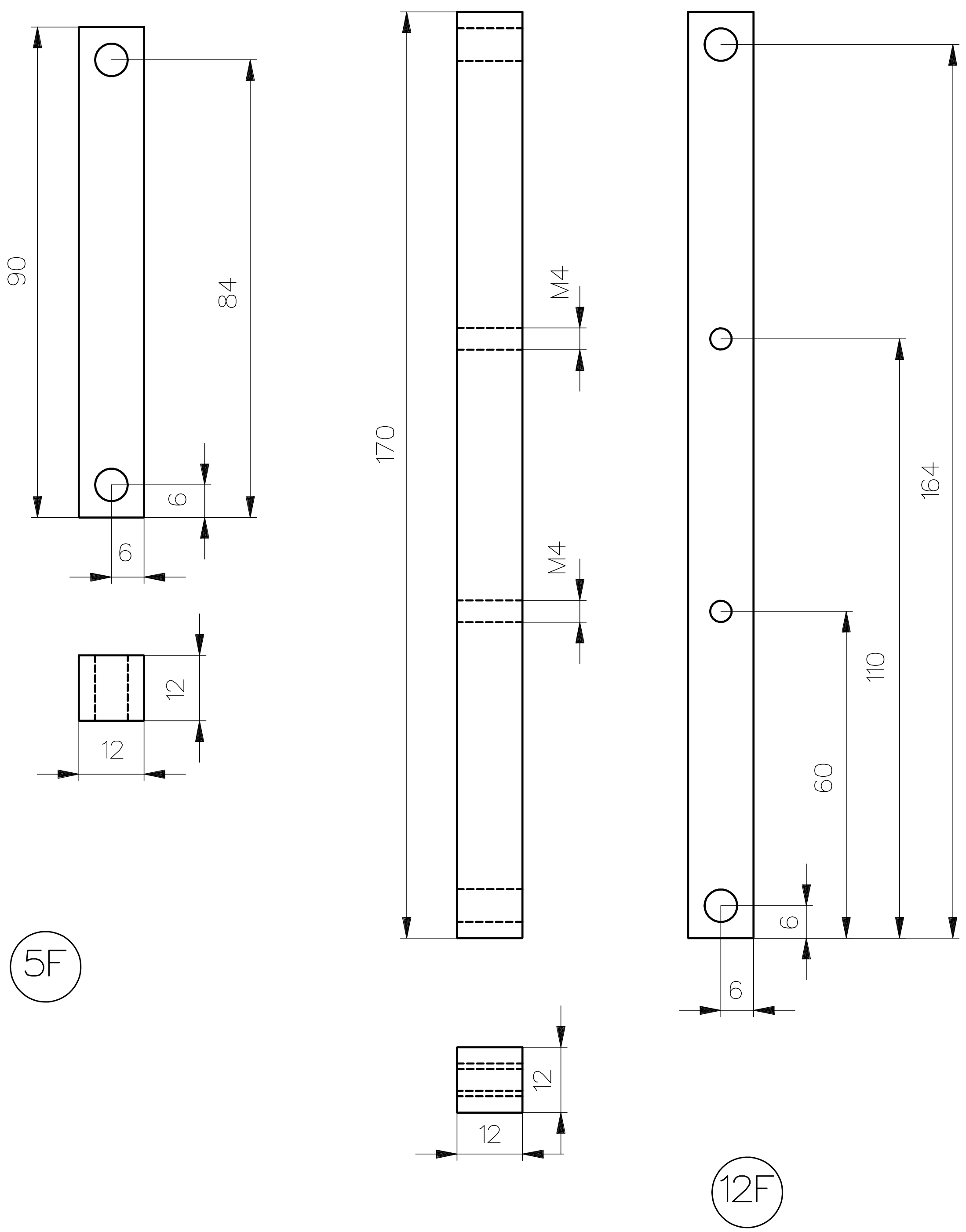
DR.25



DESK TOP ENGINEERING PROJECT
W-EDM
ASSEMBLY F
10F
360
80
10
25
300
15
294
150
6
6
2
13F
2D PROJECTION
UNIT: mm
ALL HOLES 6mm
UNLESS SPECIFIED
DRAWING NOT
TO SCALE
DR.26

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY F



ALL HOLES 6mm
UNLESS SPECIFIED

2D PROJECTION

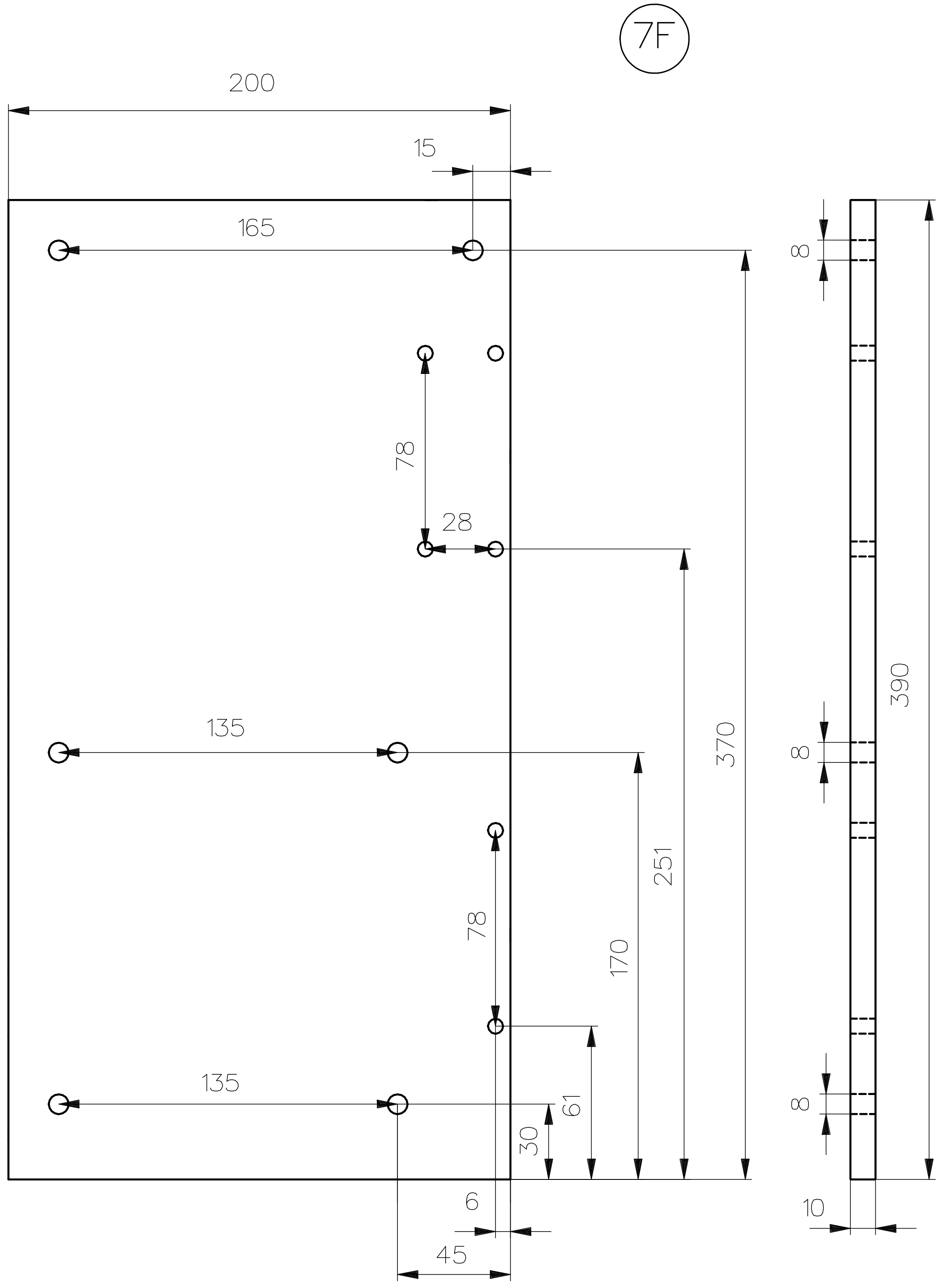
UNIT: mm

DRAWING NOT TO SCALE

DR.27

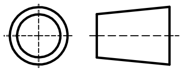
DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY F



ALL HOLES 6mm
UNLESS SPECIFIED

2D PROJECTION



UNIT: mm

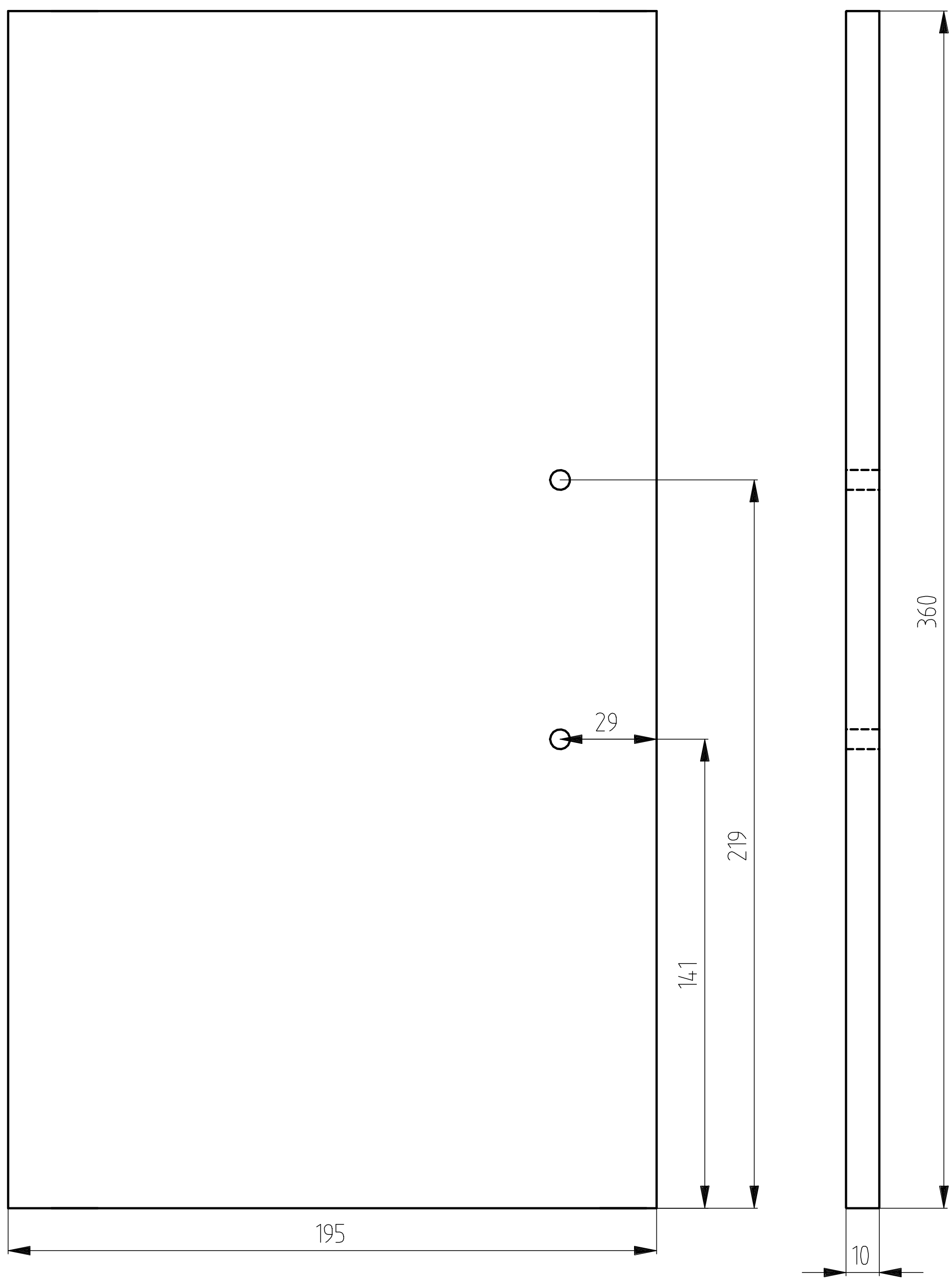
DRAWING NOT
TO SCALE

DR.28

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY F

8F



2D PROJECTION

ALL HOLES 6mm
UNLESS SPECIFIED

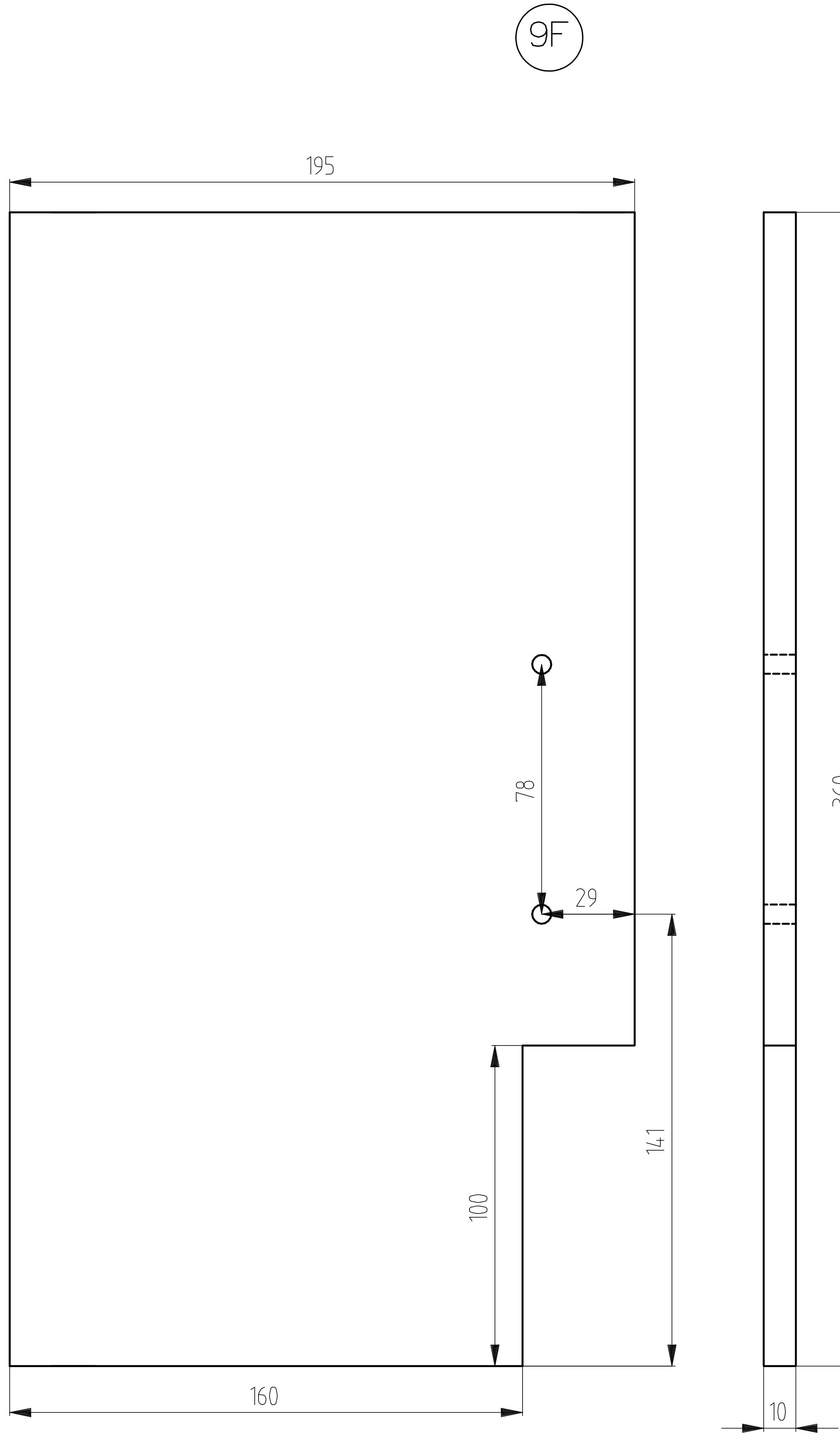
UNIT: mm

DRAWING NOT
TO SCALE

DR. 29

DESK TOP ENGINEERING PROJECT
W—EDM

ASSEMBLY F



2D PROJECTION

UNIT: mm

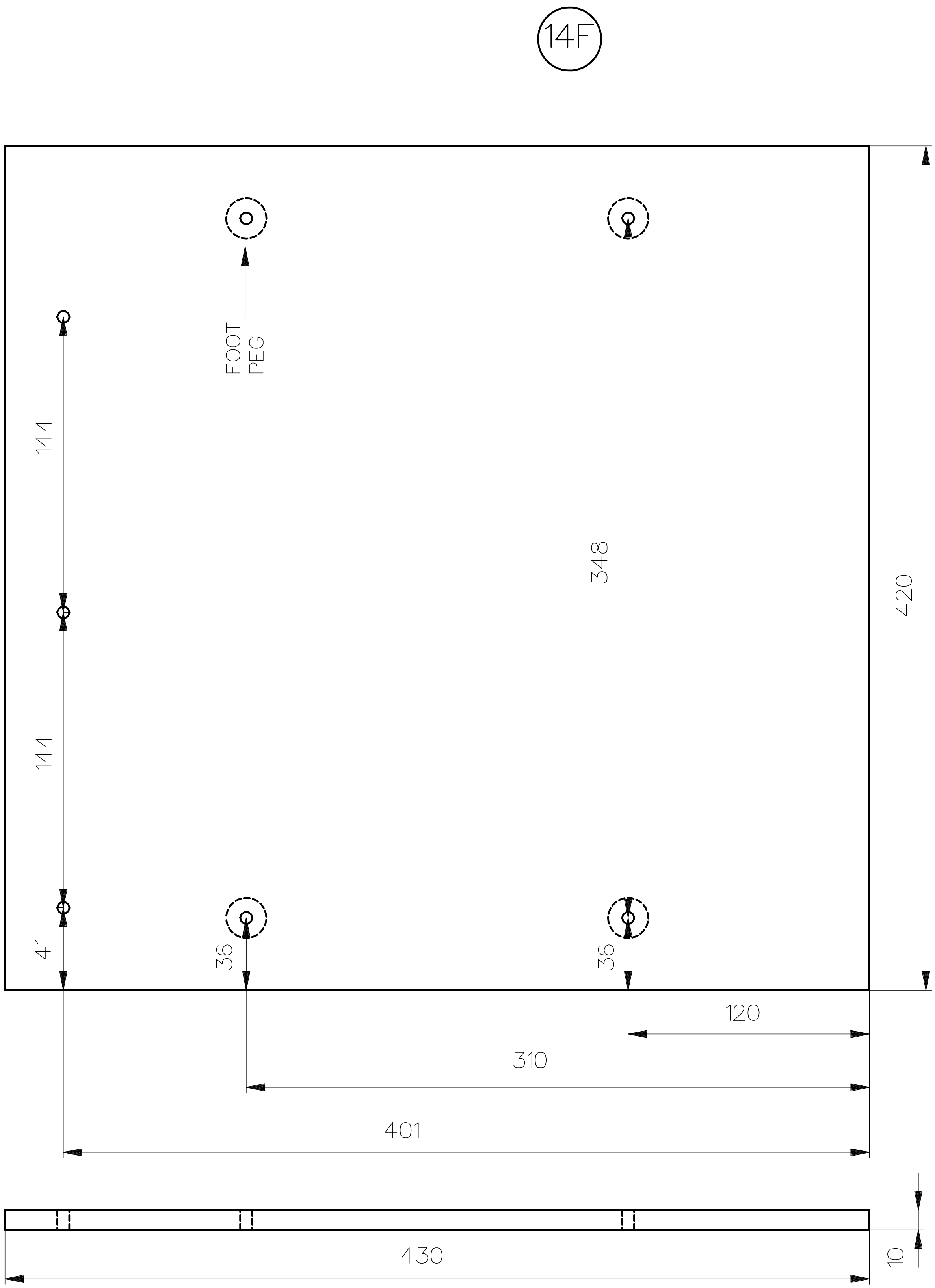
ALL HOLES 6mm
UNLESS SPECIFIED

DRAWING NOT
TO SCALE

DR.30

DESK TOP ENGINEERING PROJECT
W-EDM

ASSEMBLY F



ALL HOLES 6mm
UNLESS SPECIFIED

2D PROJECTION

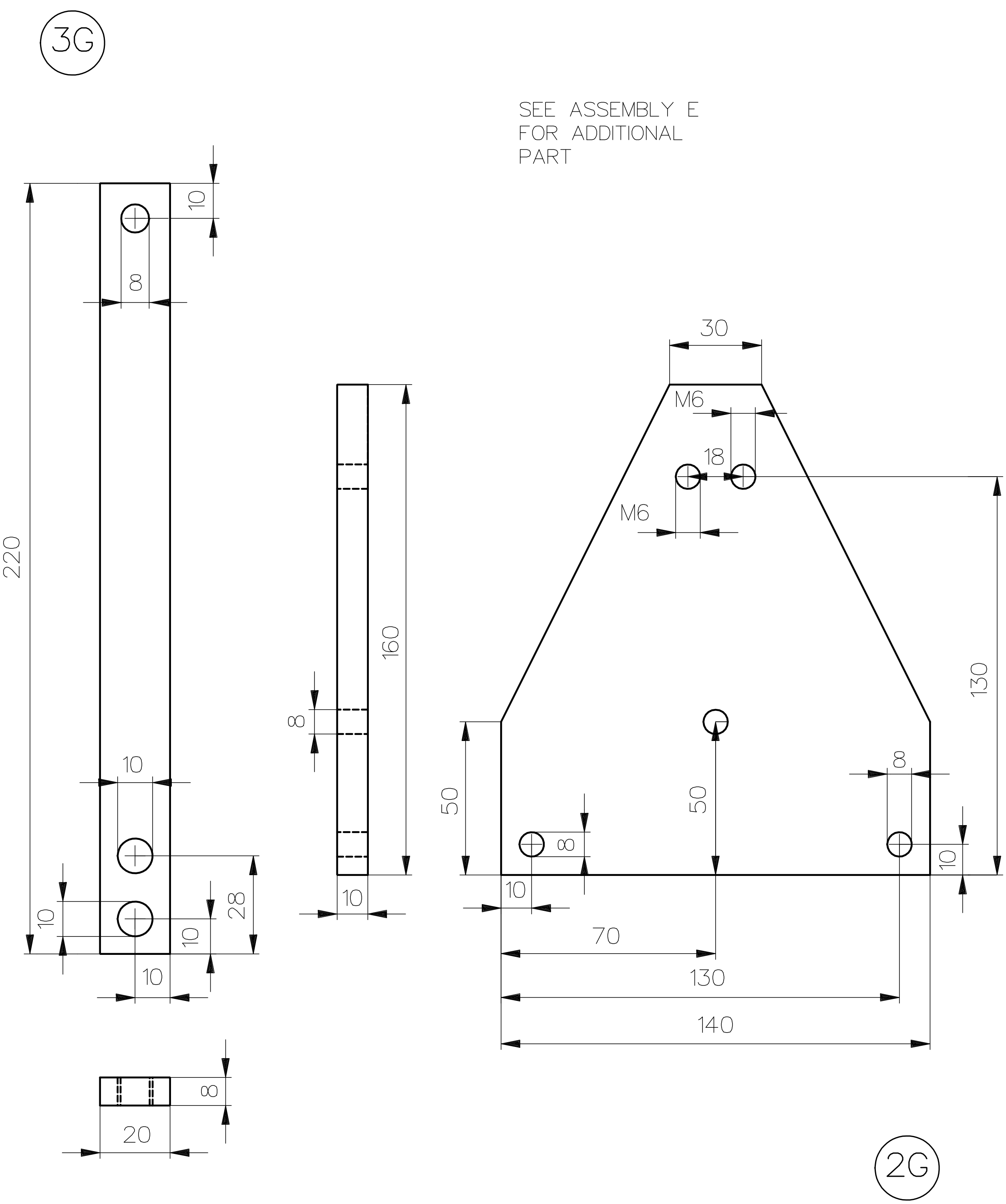
UNIT: mm

DRAWING NOT TO SCALE

DR.31

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY G



SEE ASSEMBLY E
FOR ADDITIONAL
PART

2D PROJECTION

UNIT: mm

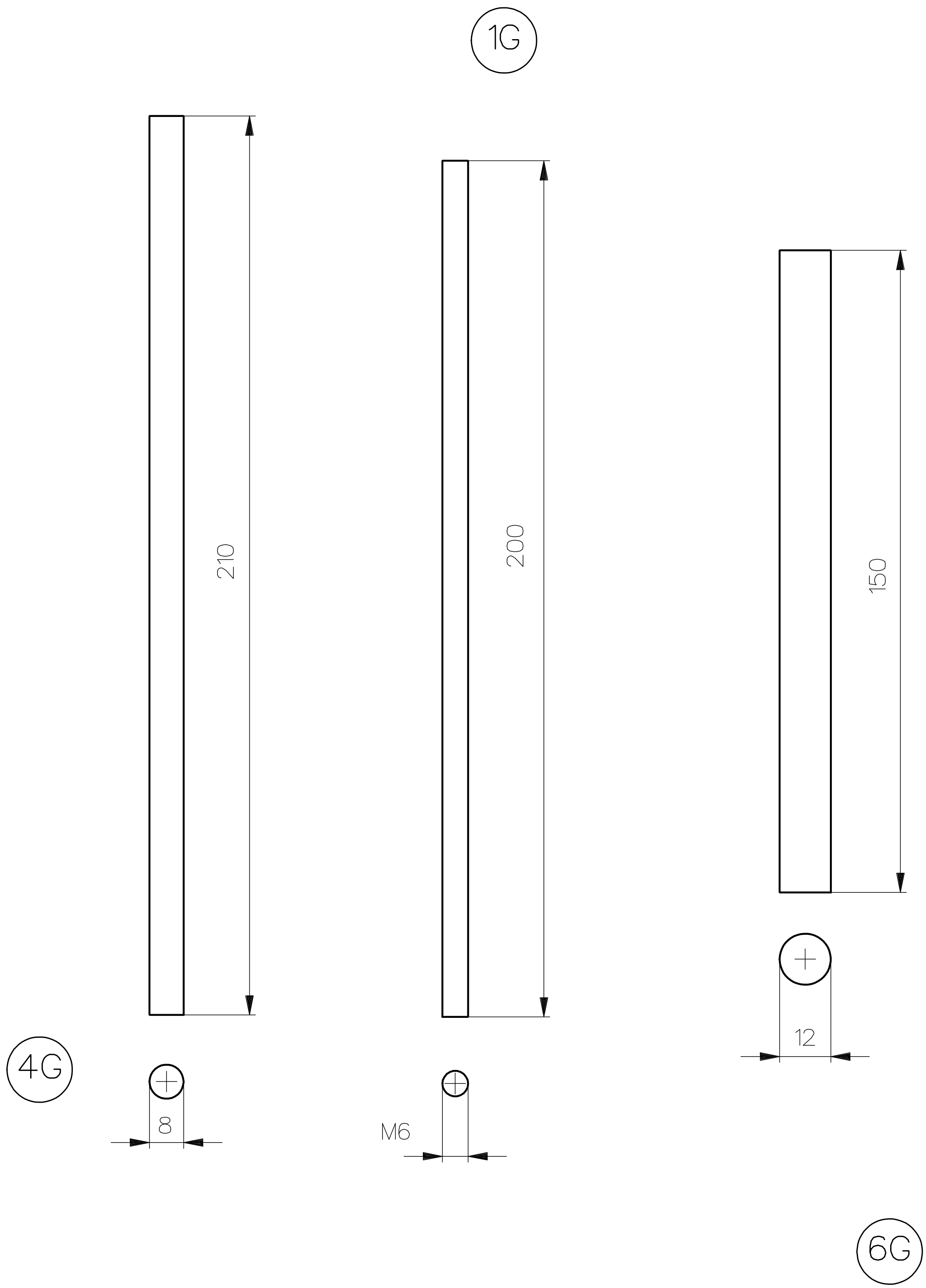
ALL HOLES 6mm
UNLESS SPECIFIED

DRAWING NOT
TO SCALE

DR.32

DESK TOP ENGINEERING PROJECT
W–EDM

ASSEMBLY G



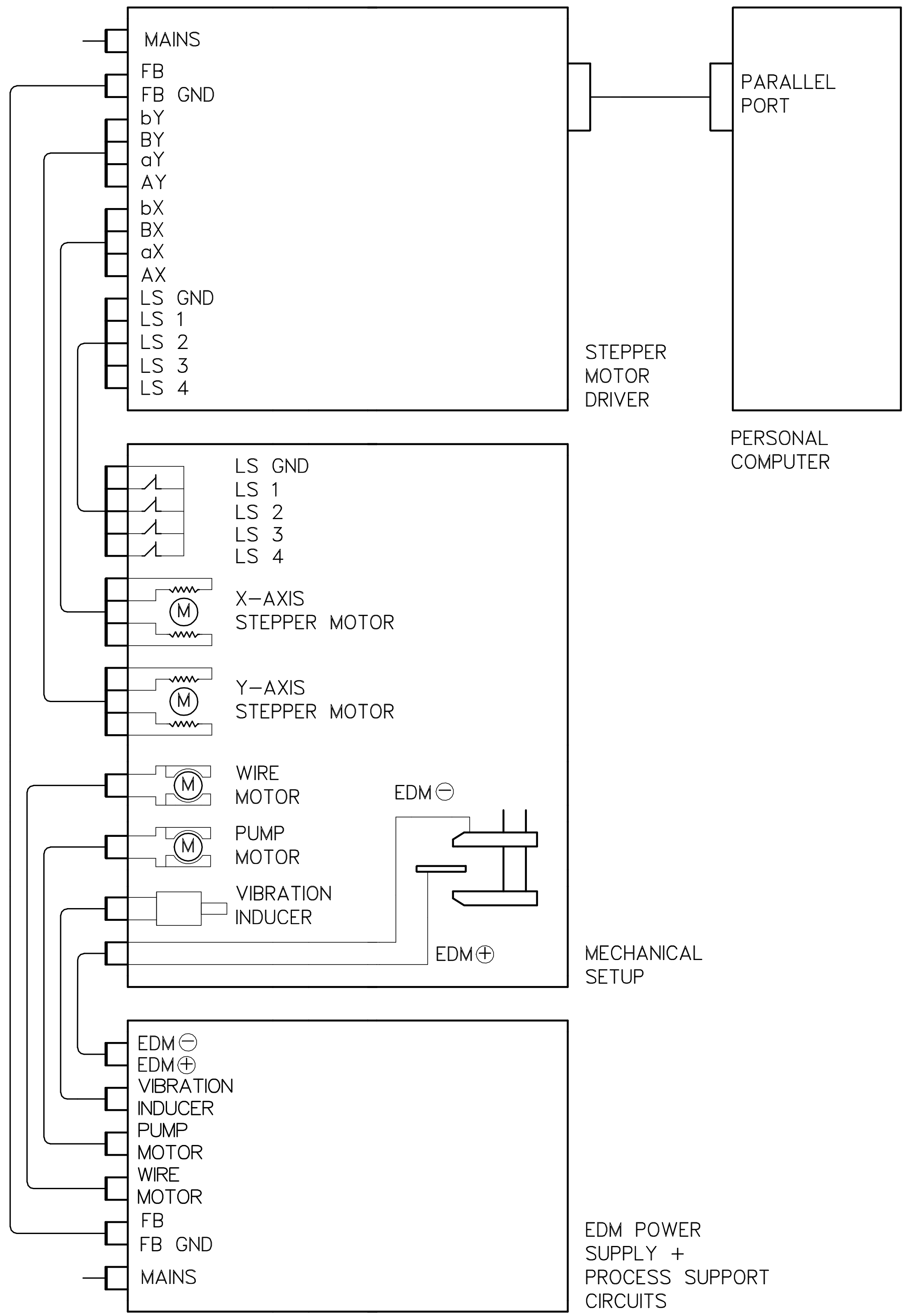
2D PROJECTION
UNIT: mm

DRAWING NOT TO SCALE

DR.33

DESK TOP ENGINEERING PROJECT
W-EDM

ELECTRICAL SETUP



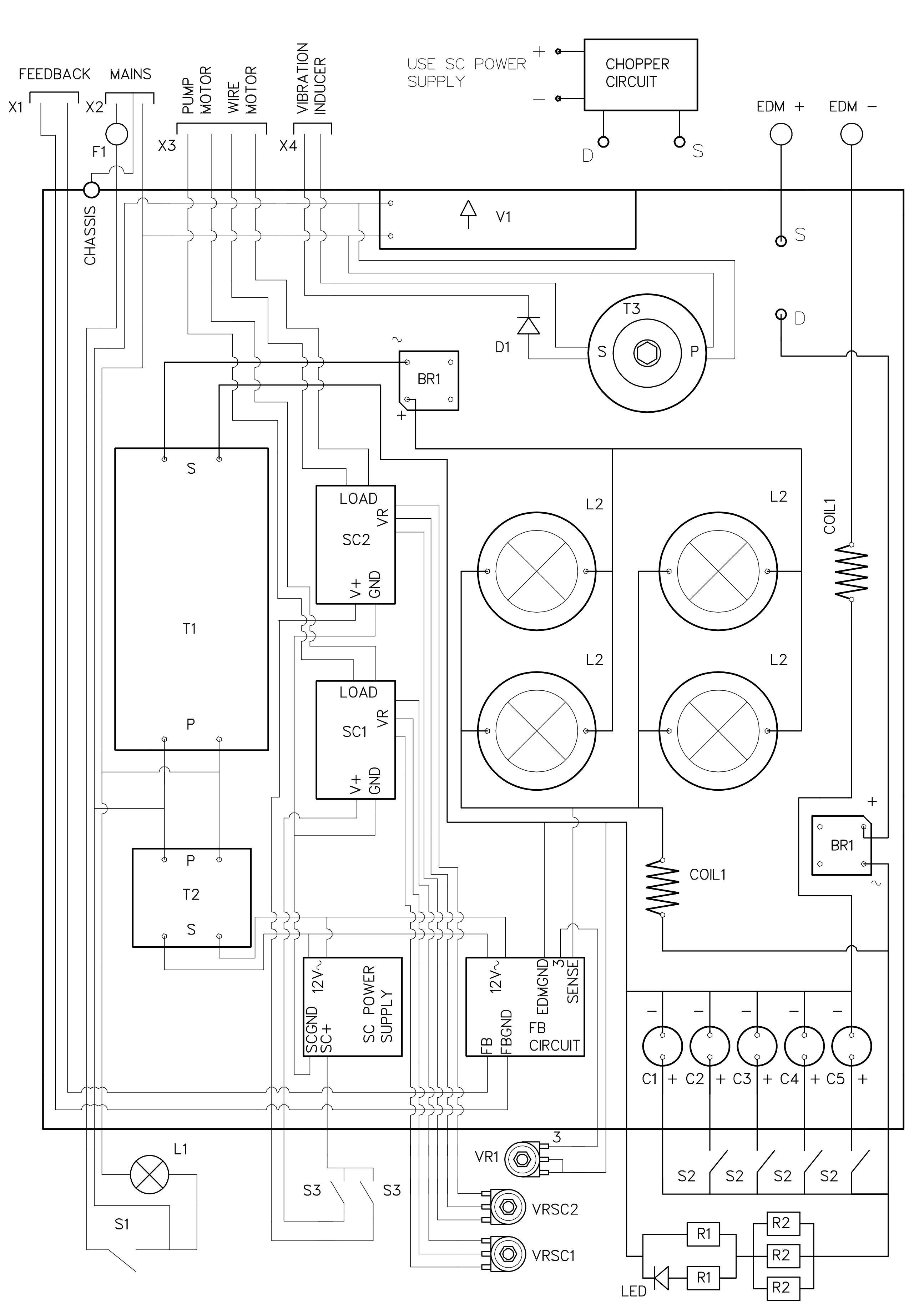
GLOBAL CONNECTIONS

DRAWING NOT
TO SCALE

DR. 1

DESK TOP ENGINEERING PROJECT
W–EDM

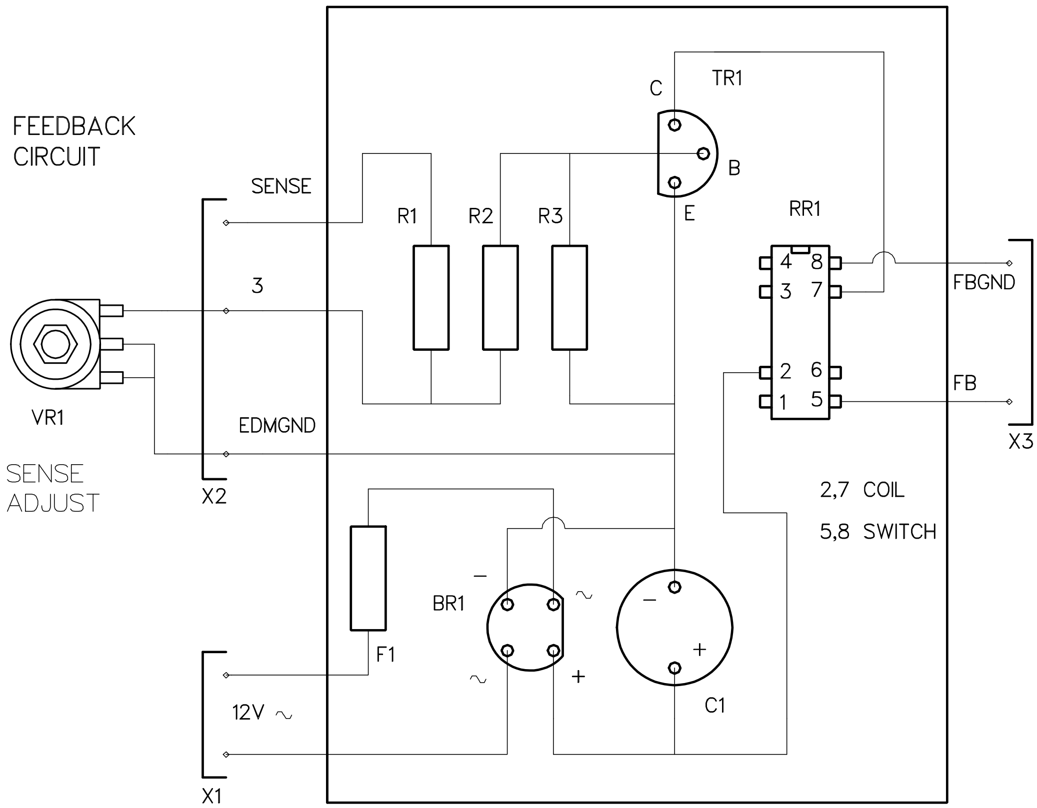
ELECTRICAL SETUP

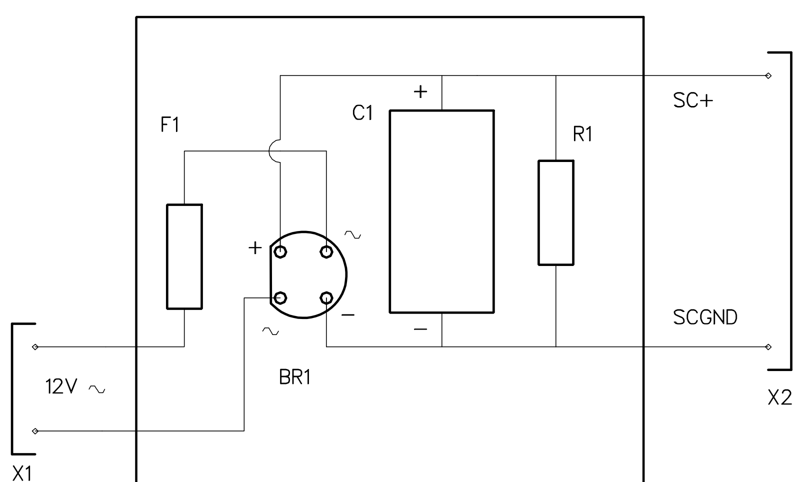


EDM POWER SUPPLY +
PROCESS SUPPORT CIRCUITS

DRAWING NOT TO SCALE

DR.2

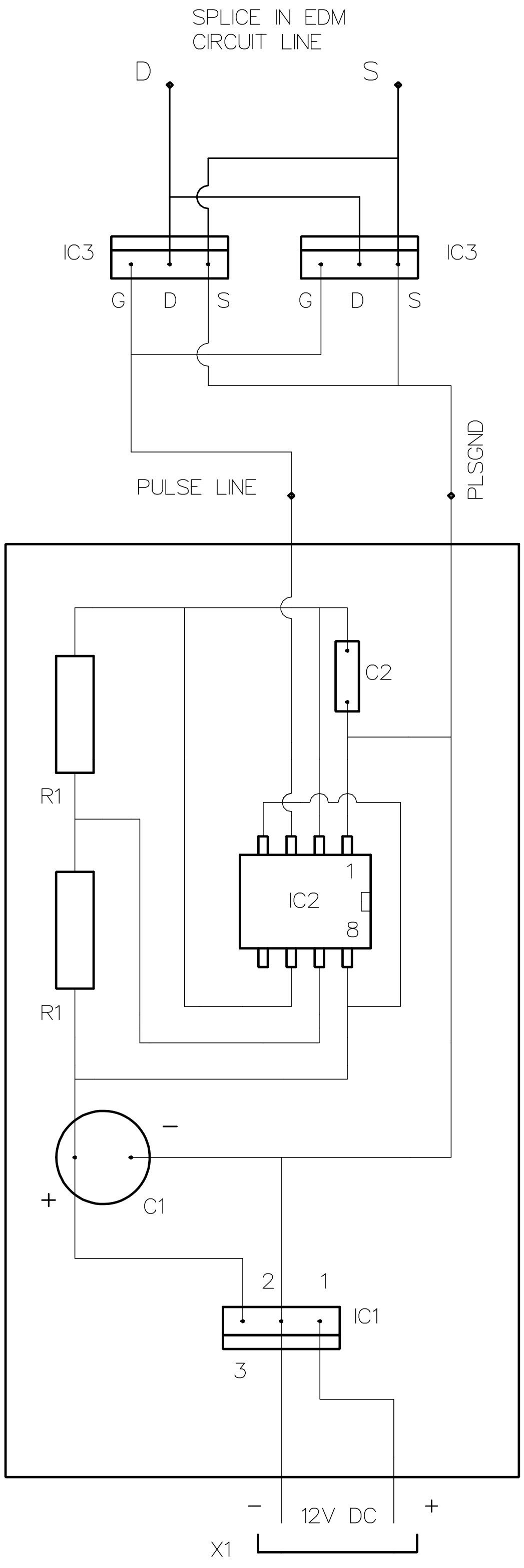


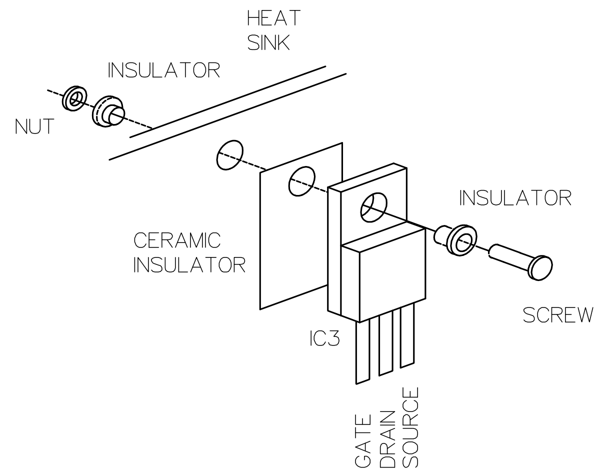


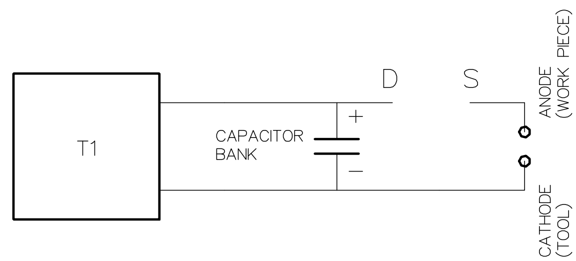
SPEED CONTROLLER
POWER SUPPLY CIRCUIT

DESK TOP ENGINEERING PROJECT
W-EDM

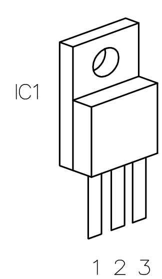
ELECTRICAL SETUP







EDM CIRCUIT



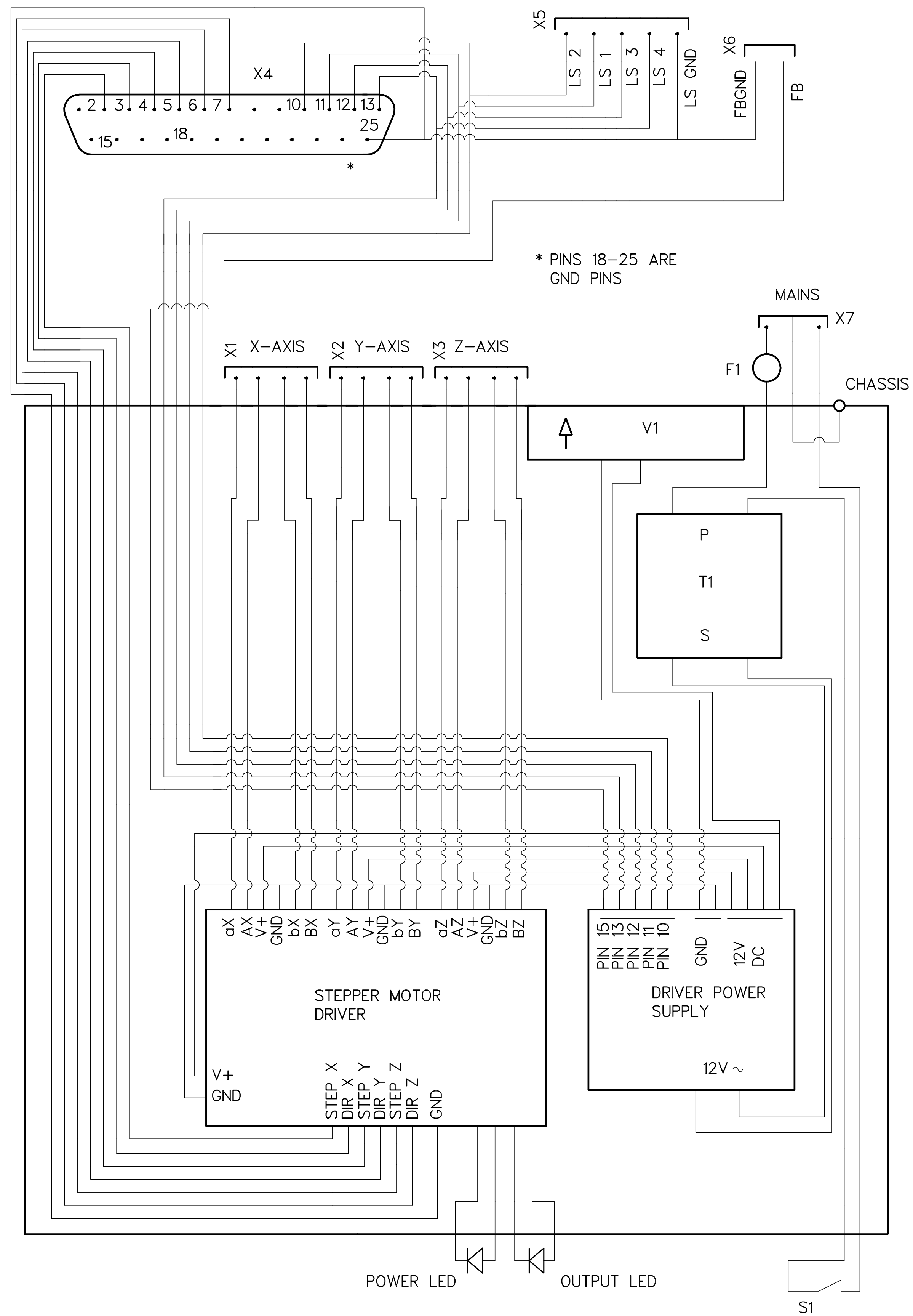
CHOPPER CIRCUIT

DRAWING NOT TO SCALE

DR. 4

DESK TOP ENGINEERING PROJECT
W-EDM

ELECTRICAL SETUP



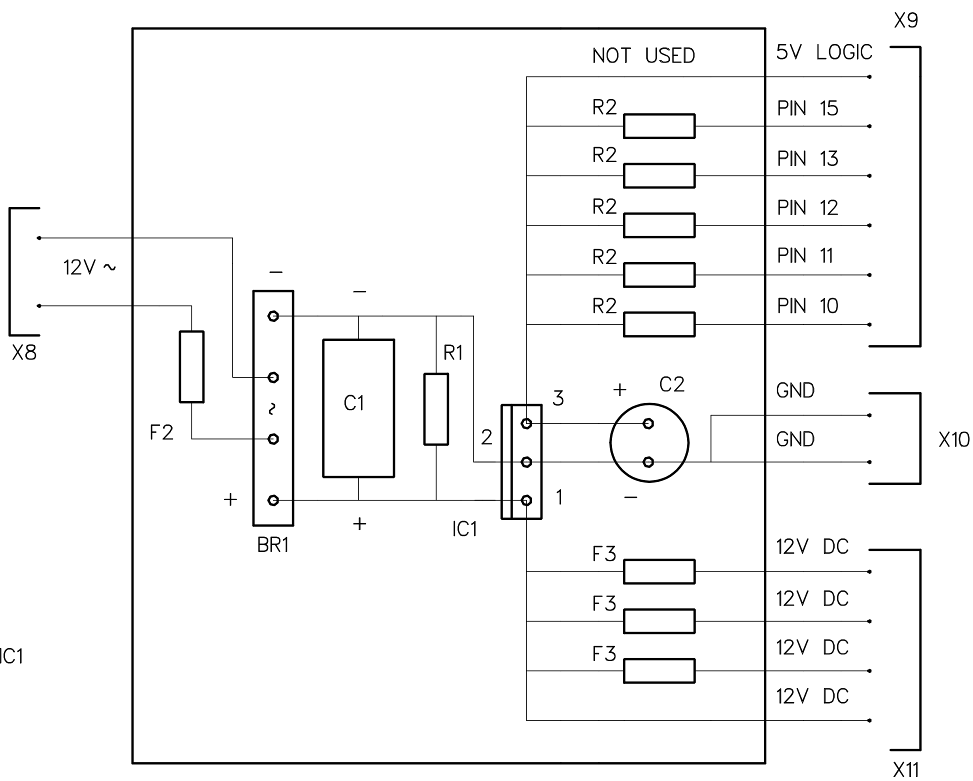
STEPPER MOTOR
DRIVER CIRCUIT

DRAWING NOT TO SCALE

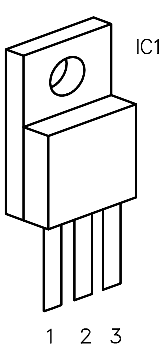
DR.5

DESK TOP ENGINEERING PROJECT
W–EDM

ELECTRICAL SETUP



ADD SMALL
HEAT–SINK



STEPPER MOTOR DRIVER
POWER SUPPLY

DRAWING NOT TO SCALE

DR.6