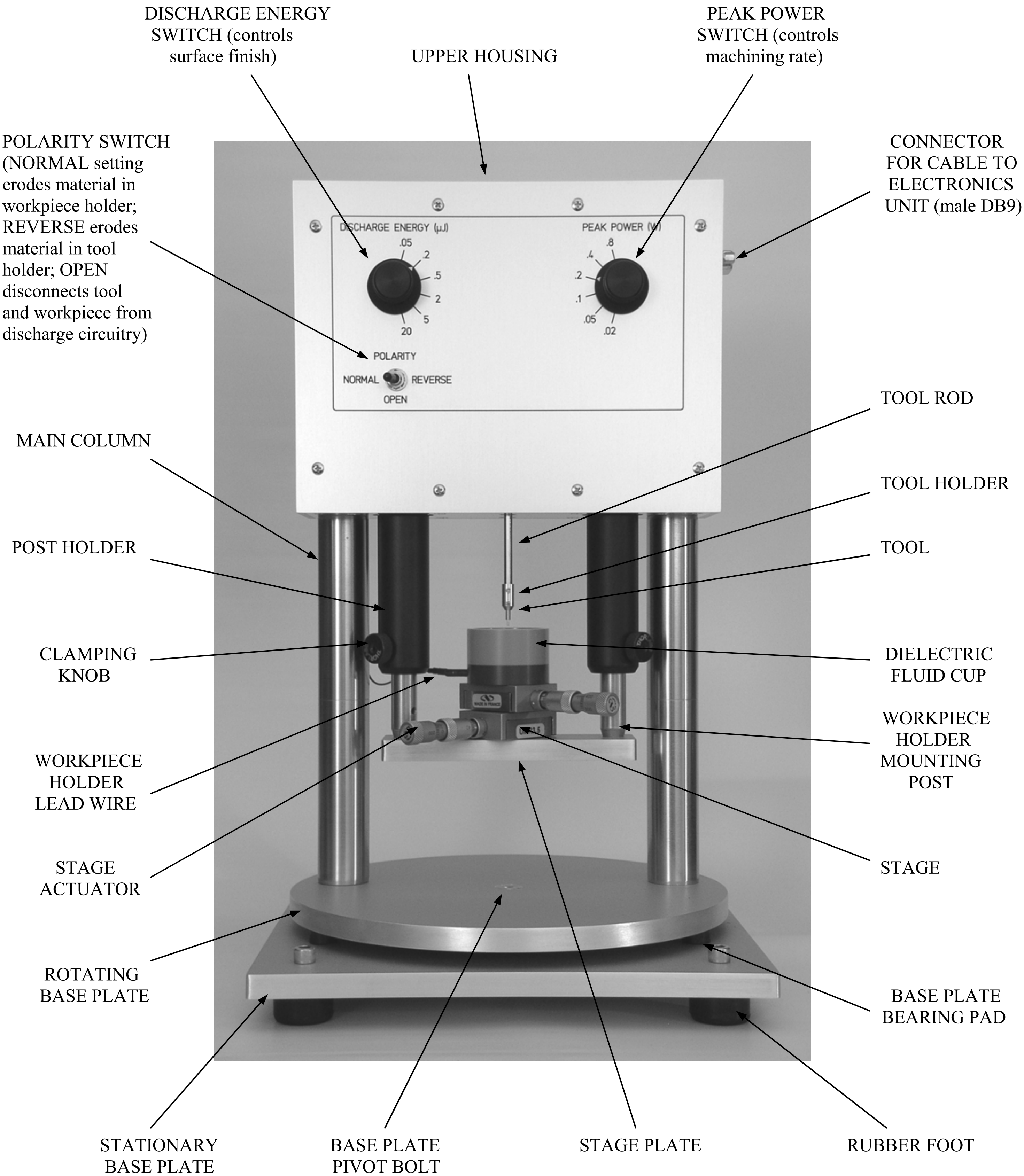
HYLOZOIC PRODUCTS MICRO EDM SYSTEM – MACHINING UNIT



DIMENSIONS: 14.8 IN. (37.3 CM) HIGH x 8.8 IN. (22.4 CM) WIDE x 8.8 IN. (22.4 CM) DEEP

HYLOZOIC PRODUCTS MICRO EDM SYSTEM

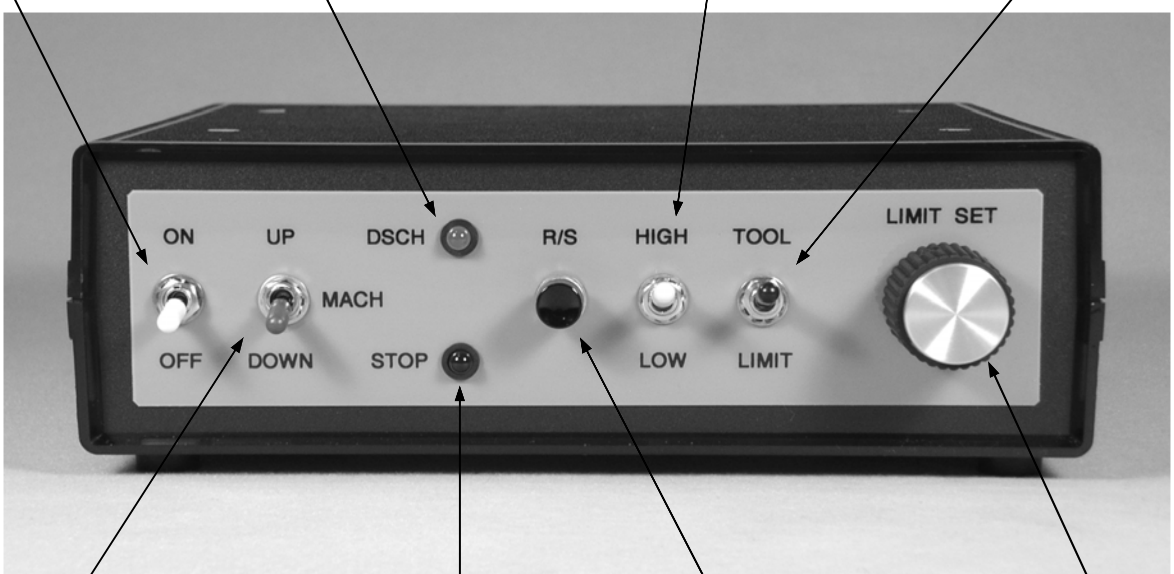
FRONT PANEL OF ELECTRONICS UNIT

POWER SWITCH

DISCHARGE LED
Indicates discharge intensity relative to peak power setting.

THRESHOLD SWITCH
Set HIGH for rapid machining, LOW to avoid irregular tool wear when machining refractory materials.

DISPLAY SWITCH
Allows either tool position or lower limit setting to be displayed on meter.



MODE SWITCH
Select UP to raise tool to upper travel limit; DOWN to lower tool until it contacts work-piece; MACH to machine workpiece.

STOP LED
Lights when system is in standby state.

RUN/STOP BUTTON
Toggles operation of system on and off.

LIMIT SET KNOB
Sets lower travel limit to shut down system when machining is completed.

DIMENSIONS: 2.5 IN. (7 CM) HIGH x 8 IN. (20 CM) WIDE x 7.5 IN. (19 CM) DEEP

FEATURES AND CAPABILITIES OF HYLOZOIC PRODUCTS MICRO ELECTRIC DISCHARGE MACHINING SYSTEM

Introduction

Hylozoic Products' Micro EDM System is a tabletop single-axis electric discharge machining system developed to drill pre-indented gaskets for diamond-anvil high-pressure cells. It is also well suited for many other specialized micro-machining operations in a laboratory setting, such as machining slits and apertures to collimate light or x-rays, and cutting small disks or slabs from metal foils, wires, or crystals.

The Micro EDM System offers many advantages over conventional mechanical machining:

- Metal is removed from the workpiece by localized melting rather than by cutting. Edges of holes are sharp and free of burrs, and the mechanical and thermal effects of machining extend only a few micrometers into the material. Surfaces machined at the lowest discharge energies can be extremely smooth, appearing specular or showing a fine matte texture when viewed with a microscope.

- The system can machine extremely hard or refractory metals, including hardened stainless steel or Inconel, rhenium, tungsten, tungsten carbide, and even some types of metal-bonded poly-crystalline diamond.

- Holes need not be axially symmetric; slits, rectangular or pyramidal holes, and other more complex shapes can be produced.

- Tool tips will not wander over the surface of the workpiece at the start of drilling, and holes can be drilled at any desired angle to a surface.

- Expensive drill bits are unnecessary; gaskets are drilled using copper or tungsten wire mounted in a reusable wire holder. A single tool wire can typically drill from 10 to 100 holes, and tool cost can be as low as a few cents per hole.

The system is very simple to set up and operate, and has been carefully designed to minimize potential hazards to the user. Its ease of use, low operating cost and reliability have made it very popular; as of March 2009, 90 Micro EDM systems have been purchased by high-pressure research groups around the world.

General Description and Operation

The machining unit is approximately 15 in. (38 cm) high x 9 in. (23 cm) wide x 9 in. (23 cm) deep. A housing the top of the unit contains the tool drive mechanism and discharge circuitry. Rotary switches on its front panel select the discharge energy and machining power, and a separate three-way toggle switch selects the tool polarity. The center position of the toggle switch disconnects the tool and workpiece from the discharge circuitry, allowing the tool to contact the workpiece without eroding it when setting up a machining operation. The upper housing sits atop a pair of columns mounted on a rotating base plate, making it easy to examine the alignment of the tool and workpiece from various directions with a microscope placed in front of the unit.

The tool is secured by a setscrew in a double-bored holder at the lower end of a stainless steel rod that extends vertically downward from the upper housing. This tool rod is driven up and down by a servo-mechanism inside the housing, and its position is measured by an optical transducer.

The workpiece is clamped to an aluminum plate in the bottom of a cup containing the dielectric fluid. This cup is mounted on a two-axis stage, which is bolted to a heavy aluminum base (the stage plate). Several standard stage and actuator options are available, and custom stages can also be provided to meet specialized requirements.

To mount the workpiece holder on the machining unit, the user inserts two standard ½-in.-diameter optical posts extending upward from the ends of the stage plate into a pair of optical post holders extending downward from the tool drive mechanism in the upper housing. This arrangement makes it easy to remove the workpiece holder assembly from the machining unit to install or remove the tool and workpiece. Also, by sliding the posts up or down in the post holders, the user can quickly adjust the height of the workpiece holder to accommodate variations in tool length or workpiece thickness.

The upper housing and base plate assembly are made of anodized aluminum, and the main columns that support the housing are stainless steel. All critical parts of the drive mechanism and workpiece holder assembly are made of aluminum or stainless steel, forming a stiff, dimensionally stable frame that is connected to the lower plate of the housing by three elastomeric supports. This design ensures that the alignment of the tool and workpiece is not disturbed by forces applied to the housing when handling the unit or operating the controls.

The separate electronics unit, which is approximately 2.5 in. (7 cm) high x 8 in. (20 cm) wide x 7.5 in. (19 cm) deep, sits alongside the machining unit and is connected to it by a short cable. It contains additional controls and most of the circuitry for the system. The tool position and limit setting are displayed directly in millimeters, with 1-micrometer resolution, by a separate 3-1/2 digit meter on a tilt stand. The system is powered by 12 V DC from an AC adapter; adapters are available for AC line voltages from 100 V to 240 V and line frequencies of 50 or 60 Hz.

The mode switch on the electronics unit selects one of three functions: UP, DOWN, or MACH (Machine).

- In the UP mode the tool rod moves upward until it reaches its upper travel limit.
- In the DOWN mode the tool rod moves downward until the tool touches the workpiece.
- In the MACH mode the system begins machining, and continues until the tool rod reaches the position set with the LIMIT knob.

In each mode, operation of the system can be stopped or started at any time by pressing the R/S (Run/Stop) button, which toggles the system back and forth between the operating and standby states.

Machining is fully automatic once the limit and discharge parameters are set. The tool drive servo-mechanism controls the distance between the tool and workpiece to maintain proper discharge action, and an LED provides a visual indication of discharge intensity.

Hole Diameters and Machining Rates

The system can drill circular holes with diameters ranging from 10-15 µm up to at least 1.5 mm, and narrow slots up to several millimeters long. The minimum hole diameter is limited by the minimum width of the gap between the tool and workpiece (1-2 µm) and by the difficulty of preparing and handling very small tools. The maximum practical hole diameter depends upon the workpiece thickness, the required surface finish, and the patience of the user.

Typical drilling times for pre-indented diamond-cell gaskets range from 1-3 minutes for holes less than 50 µm in diameter to 15-30 minutes for holes 300-400 µm in diameter. Machining times for larger holes can be estimated from the hole volume and the maximum machining rate of the system, which is approximately 0.3 $mm^3\ hr^{-1}$ in steel and 0.1-0.2 $mm^3\ hr^{-1}$ in more refractory metals.

Wear Ratio

Tool wear in electric discharge machining is measured by the wear ratio, defined as the volumetric ratio of material removed from the tool to that removed from the workpiece. Using a copper tool at discharge energies of 0.5 µJ or lower, typical wear ratios for the Micro EDM System are 3-4% when machining stainless steel, and 8-13% when machining rhenium. These low wear ratios allow a single tool wire to drill many holes, and make possible a number of specialized applications (such as EDM fabrication of EDM tools) which would not be practical with higher-wear systems.

Additional Specifications

Discharge energy: 0.05 µJ to 20 µJ in 6 steps

Peak machining power: 0.02 W to 0.8 W in 6 steps

Maximum tool travel: 3 mm (height of workpiece holder can be adjusted to accommodate variations in workpiece thickness and tool length)

Workpiece cup inside diameter: 33 mm (four #2-56 tapped holes are provided in mounting plate for clamping workpieces up to 25 mm wide)

Maximum travel of workpiece positioning stage: 5-6 mm on each axis

Power consumption: 5 W max. (12V DC, 0.4 A)

Electrical Safety Features

The tool rod and workpiece holder are not enclosed, but are left accessible to facilitate installation and alignment of the tool and workpiece and visual monitoring of the machining process. For this reason the output voltage and machining power of the system have been limited to protect the user.

The double-insulated Class 2 AC adapter (CSA certified/UL listed) isolates the system from the AC power line. The high-voltage supply for the discharge circuitry (130 V peak) is pulsed on and off at approximately 1.8 kHz with a low duty cycle, limiting the average voltage between the tool and workpiece to approximately 22 V. Because the average voltage is low and the high-voltage pulses are very short (100 µs), the shock hazard from contact with the tool and workpiece is minimal (comparable to that presented by a 22 V DC supply). Should a malfunction ever cause the average output voltage to exceed 28 V, a high-voltage protection circuit will prevent the system from operating by returning it to the standby state. A second independent high-voltage protection circuit will block the high voltage from reaching the machining unit should the primary circuit fail to activate.

An increase in the duration of the high-voltage pulses could conceivably create a hazard, even if the average output voltage remained low. There is no physically plausible way that failure of a single component could increase the pulse duration without also raising the average output voltage, but as an added precaution the primary protection circuit is also designed to shut down the system if the pulse duration should ever increase significantly.

To minimize the possibility that the user might contact the tool and workpiece simultaneously, the dielectric fluid cup containing the workpiece mounting plate is made of PVC, and the lead connecting the plate to the discharge circuitry is fully insulated.

With the exception of the tool rod and workpiece mounting plate, all exposed metal parts including the machining unit housing are electrically isolated from the circuitry. In addition, the voltage to the discharge circuitry is pulsed by turning the high voltage generator off and on, not by allowing it to run continuously and chopping its output. Consequently, at no place inside the system does the average potential difference between any two points exceed that between the tool and workpiece, so there is no risk of contacting dangerously high voltages by simultaneously touching the tool or workpiece and one of the other metal parts, even if that part were to come in contact with the circuitry because of a fault condition.

The maximum r.m.s. output voltage of the system is approximately 50 V, and the minimum output resistance of the discharge circuitry is approximately 800 Ω. This limits the maximum dissipation to 800 mW, so there is no danger that accidental contact with the tool and workpiece could cause a burn.

Protection from Accidental Ignition of Dielectric Fluid or Gases

The dielectric fluids recommended for use with the Micro EDM System have flash points of 140 °F (60 °C) or higher. The fluid (maximum volume 10 ml) is contained in a small cup surrounding the workpiece mounting plate. This cup is not enclosed, but is suspended beneath the upper housing of the machining unit where it can be convectively cooled by the surrounding air.

Even under optimum machining conditions at the highest peak power setting the maximum power dissipated in the fluid is only about 300 mW. The resulting temperature rise is barely noticeable (less than 10 °C), so there is little chance that the fluid could be heated to its flash point so long as the system is operated at normal ambient temperature. For added protection the dielectric fluid cup is made of non-flammable PVC; the machining unit base and housing, and all other exposed parts of the drive mechanism and workpiece holder assembly, are made of aluminum, brass, or stainless steel.

EDM discharges do produce some flammable gases such as acetylene, which could create an explosion hazard if they accumulated in an enclosed space. Because of its very low power, however, the Micro EDM System produces negligible quantities of gas (a few milliliters per minute or less). Because the workpiece holder assembly and fluid cup are not enclosed, any gases produced are quickly dissipated into the surrounding air and cannot build up to explosive concentrations.

Stage Options

When ordering a Micro EDM System, the purchaser should select one of the following options for the X-Y stage that positions the workpiece holder (custom stage options can also be provided):

Standard Stage — an aluminum ball-bearing stage assembled from two Thorlabs MS1 single-axis stages, equipped with M3-0.25 fine adjusting screws which advance the stage by 250 μm/turn; total stage travel is 6.4 mm (this replaces the Newport MT-XY dovetail stage previously offered as the least expensive stage option).

Micrometer Stage — a steel stage with dual-row ball bearings assembled from two Newport UMR3.5 single-axis stages, equipped with Newport BM11.5 metric micrometer actuators which advance the stage by 500 μm/turn; total stage travel is 5 mm.

Precision Stage — the same stage offered with the micrometer stage option above, but equipped with Newport DM11-5 differential micrometer actuators which provide a 500 μm/turn coarse adjustment and a 50 μm/turn fine adjustment; total stage travel is 5 mm.

The standard stage is a good choice if the system will mainly be used to drill 50 μm or larger holes in diamond-cell gaskets and position measurement is not required. The micrometer stage is recommended if the user will rarely drill gasket holes smaller than about 50 μm but needs position measurement capability with a precision of a few μm. The precision stage is the best choice for users who will frequently drill gasket holes smaller than 50 μm or who require position measurement capability with 1 μm precision.

Drilling Tools and Accessories for the System

Small circular holes are most easily drilled using tools made from copper or tungsten wire. Users can make their own tools, but they can save considerable time and effort by using the tool wires, reusable V-grooved wire holders, and wire mounting kit available from Hylozoic Products. The tool wires are precut to the proper length. The user need only straighten each wire by rolling it between two glass plates, glue it into the V-groove of a wire holder with conductive cement, and mount the wire holder in the tool holder of the machining unit.

A single tool wire can typically drill 10 to 100 diamond-anvil gaskets, depending upon the wire diameter and the thickness and composition of the gasket. A worn tool wire can be removed from a wire holder by soaking it in acetone for a few minutes, and a new tool wire can quickly be installed using the wire mounting kit.

Tool wires are available to drill holes of the following diameters in micrometers:

20	35	40	50	65	80	90	100	120	130	150	165
190	210	235	260	295	325	410	460	515	600	650	730

Wire holders are available in three different sizes:

- Micro -- for mounting tool wires 90 µm in diameter or smaller
- Small -- for mounting tool wires 75 to 300 µm in diameter
- Large -- for mounting tool wires 200 to 750 µm in diameter

Specialized Tools for other Machining Operations

The Micro EDM System's uses are not limited to drilling circular holes. Users have found it suitable for a variety of other tasks, such as:

- slicing disks from wires or cutting slabs from metallic crystals;
- cutting disks from metal foils;
- cutting grooves in metallic crystals to accommodate thermocouple wires;
- sharpening metallic rods to points with tip radii of a few microns;
- generating razor-sharp edges on small carbide cutting tool inserts.

Several steps in the manufacture of the V-grooved wire holders described in the Drilling Tool section above are also carried out using a Micro EDM System.

Hylozoic Products does not currently sell standardized tools for such specialized tasks, but is happy to provide users with free advice on preparing their own tools, and can also custom-fabricate special-purpose tooling on request.

Recommended Dielectric Fluid

Electric discharge machining requires that the tool and workpiece be immersed in a dielectric fluid, typically a highly refined low-viscosity mineral oil. The dielectric fluid recommended for use with the Micro EDM System is a commercial petroleum-based EDM fluid with a flash point of 170-185 °F (77-85 °C). Fluids of this type have lower viscosities than general-purpose EDM fluids, and were developed to provide superior flushing action in narrow gaps during fine machining and finishing operations.

Two specific products that meet the requirements are Commonwealth Oil's EDM 185 and British Petroleum's BP 180. Both fluids can be purchased in 5-gallon pails (other fluids such as Grade 25W may be suitable, but may only be available in 55-gallon drums). Commonwealth's EDM 185 is probably the better choice, as it is less expensive than BP 180 and seems to be more readily available. Both fluids can be ordered from TriGemini LLC in Broadview, Illinois (www.tri-gemini.com; phone: 800-561-6250).

Odorless paint thinner (odorless mineral spirits) will also give excellent machining performance, but its composition and properties are highly variable. Some odorless thinners have flash points as low as 100 °F (38 °C), which could pose a fire hazard if the system is operated at high ambient temperatures. If odorless thinner is used it should have a flash point of at least 140 °F (60 °C). Gamblin Artists Colors Co. in Portland, Oregon (www.gamblincolors.com; phone: 503-235-1945) sells an odorless thinner called Gamsol with a flash point of 145 °F (63 °C) which can be purchased from some art supply dealers.

Microscope Requirements

Most applications of the system require a microscope to precisely align the tool with the workpiece. The type of microscope needed will depend upon the specific applications and personal preferences of each user, and many users will already have a suitable microscope in their laboratory. For these reasons a microscope is not included as part of the system.

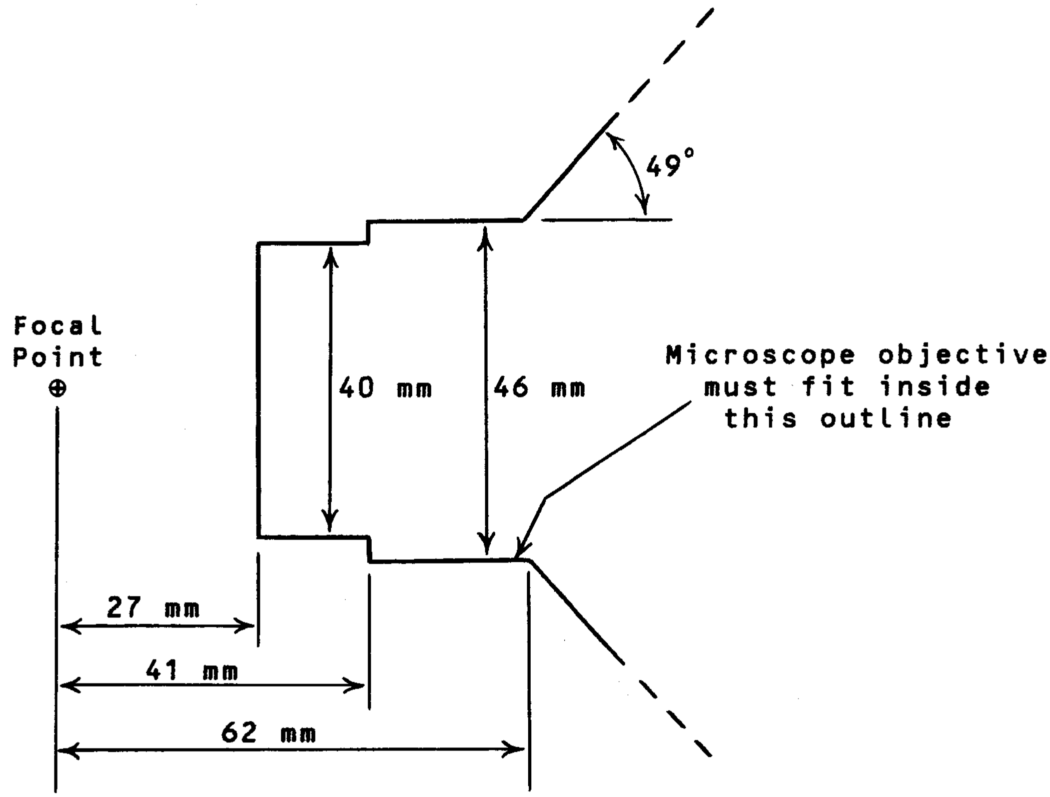
The microscope should be mounted on a boom or pillar stand and placed directly in front of the machining unit, looking downward into the workpiece holder cup at an angle of approximately 35º below the horizontal. A pivot in the machining unit base allows the user to rotate the unit and examine the alignment of the tool and workpiece perpendicular to both axes of the workpiece holder stage without moving the microscope.

To mount a small microscope directly on the machining unit, the user can remove one of the ¼-20 capscrews that secure the rubber feet at the front of the stationary base plate, insert a longer capscrew through the rubber foot from below, and use it to mount an optical post holder on the corner of the base plate. The user can then mount the microscope in the post holder using a combination of standard optical posts and other components available from suppliers like Newport or Thorlabs. When mounted in this way, the microscope can easily be swung out of the way to install or remove the tool and workpiece, and to protect its objective lens from the small droplets of dielectric fluid ejected by breaking bubbles during machining.

The working distance of the microscope should be at least 27 mm so that it can focus on the tool tip without touching the edge of the dielectric fluid cup. Its objective end must also be small enough to clear the workpiece holder support columns and the lower edge of the machining unit housing. The complete dimensional requirements are indicated in the diagram below.

When drilling pre-indented diamond-anvil gaskets, a magnification of about 2500/d is recommended, where d is the hole diameter in micrometers.

Many users will already have a long-working-distance stereo zoom microscope that meets the above requirements. If not, a small monocular zoom microscope with straight-through optics is recommended. One reasonably priced option is the Model ZMM-1 Zoom Observation Microscope sold by the Titan Tool Supply Co. of Buffalo, N.Y., U.S.A. (www.titantoolsupply.com; phone: 716-873-9907; fax: 716-873-9998). The ZMM-1 includes a versatile pillar stand and rack-and-pinion focuser, and provides a magnification range of 15X to 60X with its standard 10X eyepiece, or 30X to 120X with the optional 20X eyepiece. With its small objective and 63 mm working distance the ZMM-1 easily meets the dimensional requirements for use with the Micro EDM System. Its price (as of March 2008) is $1,190; the optional 20X eyepiece costs an additional $169.



View Perpendicular to Optic Axis of Microscope, Showing Maximum Dimensions of Objective and Minimum Working Distances Required for Use with Micro EDM System

Components and Accessories Included with System

The Micro EDM System includes all of the following items:

- machining unit
- electronics unit
- workpiece holder assembly
- digital voltmeter with stand
- AC adapter
- all necessary cables, leads, wrenches, hardware, spare fuses, etc.
- tool storage case (holds up to 12 wire holders or other tools, and protects them from dust or damage)
- 50-page User's Manual

PLEASE NOTE: Drilling tools (tool wires, wire holders, and wire mounting kit) are not included with the system and must be ordered separately (special discounted tool packages are available for customers purchasing a Micro EDM System). See the separate tool flier for details and current prices.

User's Manual

The 50-page User's Manual provides extensive information on the features and operation of the Micro EDM System. It is divided into five chapters:

- Chapter 1 describes the design philosophy, capabilities, specifications, and safety features of the system, and covers precautions to minimize hazards to the user and protect the system from damage.

- Chapter 2 provides complete instructions for assembling and testing the system.

- Chapter 3 explains the general principles of electric discharge machining, describes the system's components and operating principles, and provides information on obtaining and handling dielectric fluid.

- Chapter 4 describes how to mount workpieces, prepare standard drilling tools using wire holders and tool wires, fabricate other types of tools for specialized applications, and measure and compensate for tool wear.

- Chapter 5 provides detailed step-by-step operating instructions. It explains how to install and position the tool and workpiece, select and set the discharge parameters and travel limit, monitor machining performance and make adjustments, avoid or correct machining problems, optimize surface finish and tool wear, and clean workpieces after machining.

Please be advised that the User's Manual for the Micro EDM System is only available in English. The Micro EDM System is very easy to use and incorporates numerous safety features. However, to operate the system safely and effectively, users must be able to read and understand technical information in English.