MODEL 170 ULTRASONIC DISK CUTTER
INSTRUCTION MANUAL

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1. Introduction

Many of today's advanced materials are prepared for transmission electron microscopy (TEM) using a combination of ultrasonic disk cutting, dimpling, and ion milling. E.A. Fischione Instruments, Inc. currently produces instrumentation for all of these TEM specimen preparation phases.

When conducting TEM, optimum analytical results are achieved by preparing the highest quality specimens. With proper specimen preparation instrumentation and techniques, TEM performance and the corresponding analysis are greatly enhanced.

Ultrasonic disk cutting is an extremely successful method for producing TEM specimen disks from ceramic, semiconductor and geological materials. This is largely due to the significant time savings when compared to slurry type rotary coring devices. This rapid technique directly produces either disk specimens from materials as thin as 40 μm or cylindrical rods up to 10 mm in length from bulk materials.

The Model 170 Ultrasonic Disk Cutter has been designed and produced to the highest quality standards. Precision machining throughout insures peak performance.

In order to fully utilize all of the functions of the Model 170 Ultrasonic Disk Cutter, please read and understand this instruction manual prior to operating the instrument.

2. Instrument Description

2.1. General

The Model 170 Ultrasonic Disk Cutter employs an ultrasonic mechanical vibration to rapidly produce TEM disk specimens. Cutting tool excursion is achieved through the excitation of a lead zirconate titanate crystal at a nominal driving frequency of 26 kHz. The ultrasonic transducer has been specially designed to provide maximum energy at the tip of the cutting tool. Tool excursion is optimized to achieve the maximum cutting rate while minimizing thermal induced and mechanical specimen damage. A rare earth magnetic coupling rigidly attaches the specimen container to the force-applying specimen stage. The electrical continuity detector of the Model 170 ensures a positive, automatic process termination. An optional microscope attachment facilitates specimen positioning for the selection of a specific feature. Abrasive slurry compounds of either boron or silicon carbides are utilized as the cutting media.

2.2. Minimization of Specimen Damage

2.2.1. Optimized Tool Excursion

Due to the very aggressive nature of ultrasonic cutting, a certain degree of specimen edge damage and surface deformation may result. In order to minimize this damage, the amplitude of movement of the cutting tool has been optimized. In an ultrasonic transducer, the axial movement of the cutting tool is a function of the voltage applied to the lead zirconate titanate crystal. By selecting the proper driving voltage, specimen damage is significantly reduced. An amplitude of approximately 40 μm has been chosen to provide both minimal specimen damage and reasonable cutting rates (Figures 1a and 1b).

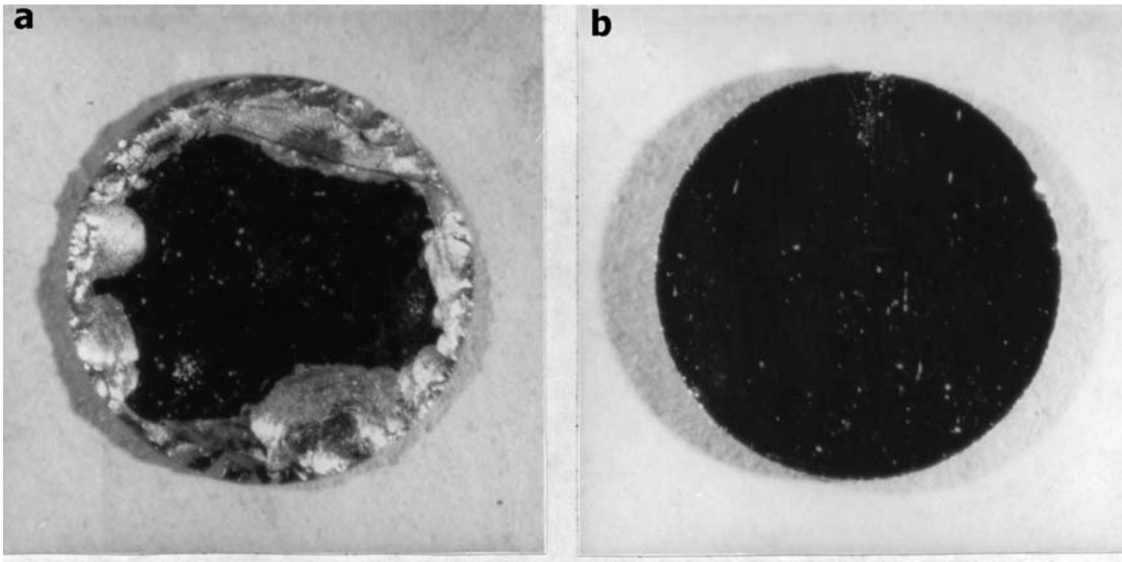


Figure 1. Specimens cut with a)maximum and b)optimized applied voltage.

2.2.2. Magnetic Mount

Specimen damage may be related to the lateral movement of the specimen in relation to the cutting tool with a great deal of the damage occurring during the first few seconds of cutting when the tool may be vibrating across the specimen surface. Once the tool achieves a cutting path and proceeds in the material, lateral movement of the specimen in relation to the tool is virtually eliminated and edge damage is significantly reduced.

Rigidly attaching the specimen container (Figure 2) to the force-applying specimen stage reduces this lateral motion. Samarium/cobalt rare earth magnets are utilized to attach the specimen container to the magnetic stainless steel specimen stage.

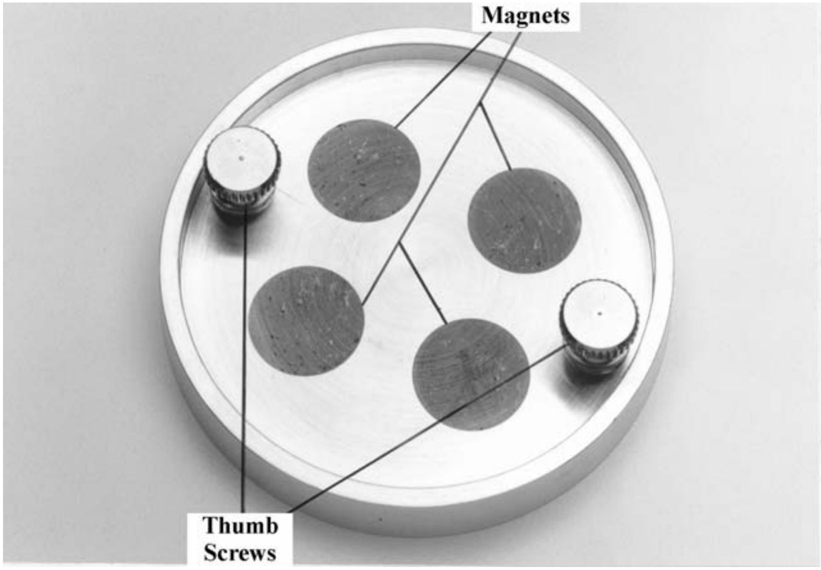


Figure 2. Specimen Container

2.2.3. Cylindrical Samples

In order to obtain cylindrical samples with consistent cross-sectional area for subsequent wafer cutting into 3 mm TEM specimen disks, the constant force applying specimen stage (Figure 3) of the Model 170 Ultrasonic Disk Cutter advances the sample material parallel to the cutting tool. Rods of up to 10 mm in length have been readily produced by this technique. A dial indicator, with a resolution of 10 mm, accurately displays the cutting depth of the tool.

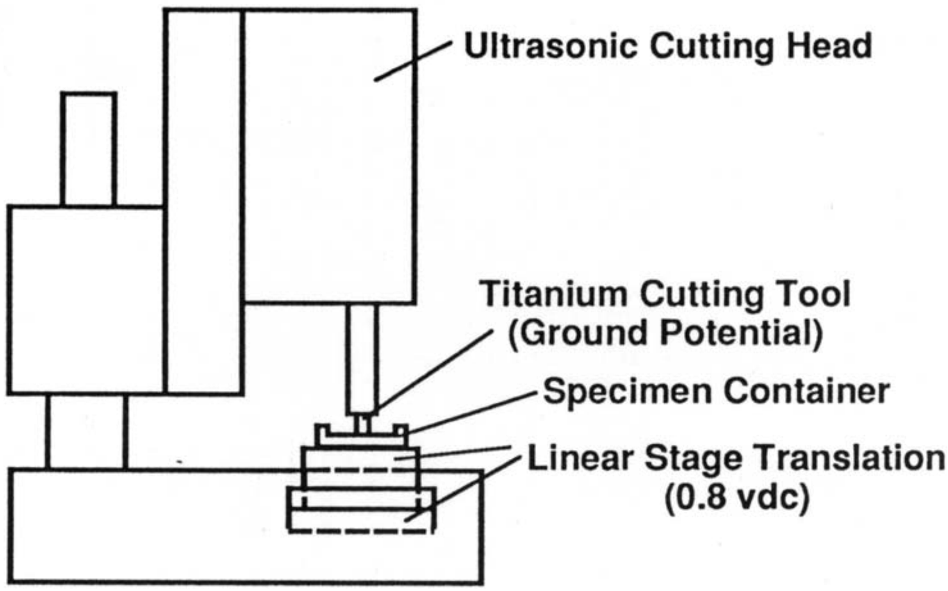


Figure 3. Auto-Termination Circuit

2.3. Auto Termination

The Model 170 utilizes an electrical continuity detector for determining the completion of the cutting process. The cutting tool and ultrasonic transducer assembly is maintained at ground potential. A +0.8 vdc signal is placed on the specimen stage (Figure 3).

The sample material is glued onto an aluminum specimen plate (Figure 4) using a low melting point polymer. Two thumb screws rigidly attach the specimen plate to the specimen container. Electrical continuity is maintained between the specimen container and the specimen stage. When contact is made between the tool and the aluminum specimen plate, continuity is sensed and the process is automatically terminated. An override switch is provided so that, if desired, cutting may be continued. When cutting conductive materials, an insulated specimen plate is utilized to isolate the specimen material from the +0.8 vdc signal.

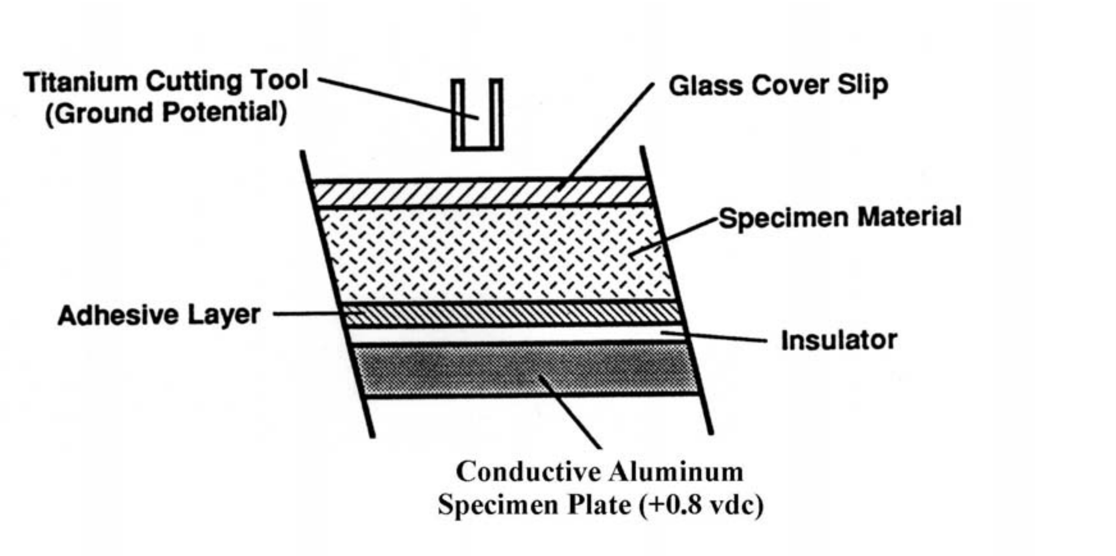


Figure 4. Specimen Mounting

2.4. Microscope Attachment (optional)

An important aspect of producing a 3 mm disk is capturing the specific area of interest. The Microscope Attachment (Figures 5 and 6) facilitates this procedure. The microscope is rigidly attached to the ultrasonic cutting head and is easily rotated into position for specimen observation and positioning. Once the region of the material to be cored is established in the microscope's field of view, the ultrasonic cutting head is rotated into position for subsequent specimen cutting.

An alignment and locking mechanism establishes precise angular positioning of the microscope and ultrasonic cutting head with a repeatability of better than 0.01 mm.

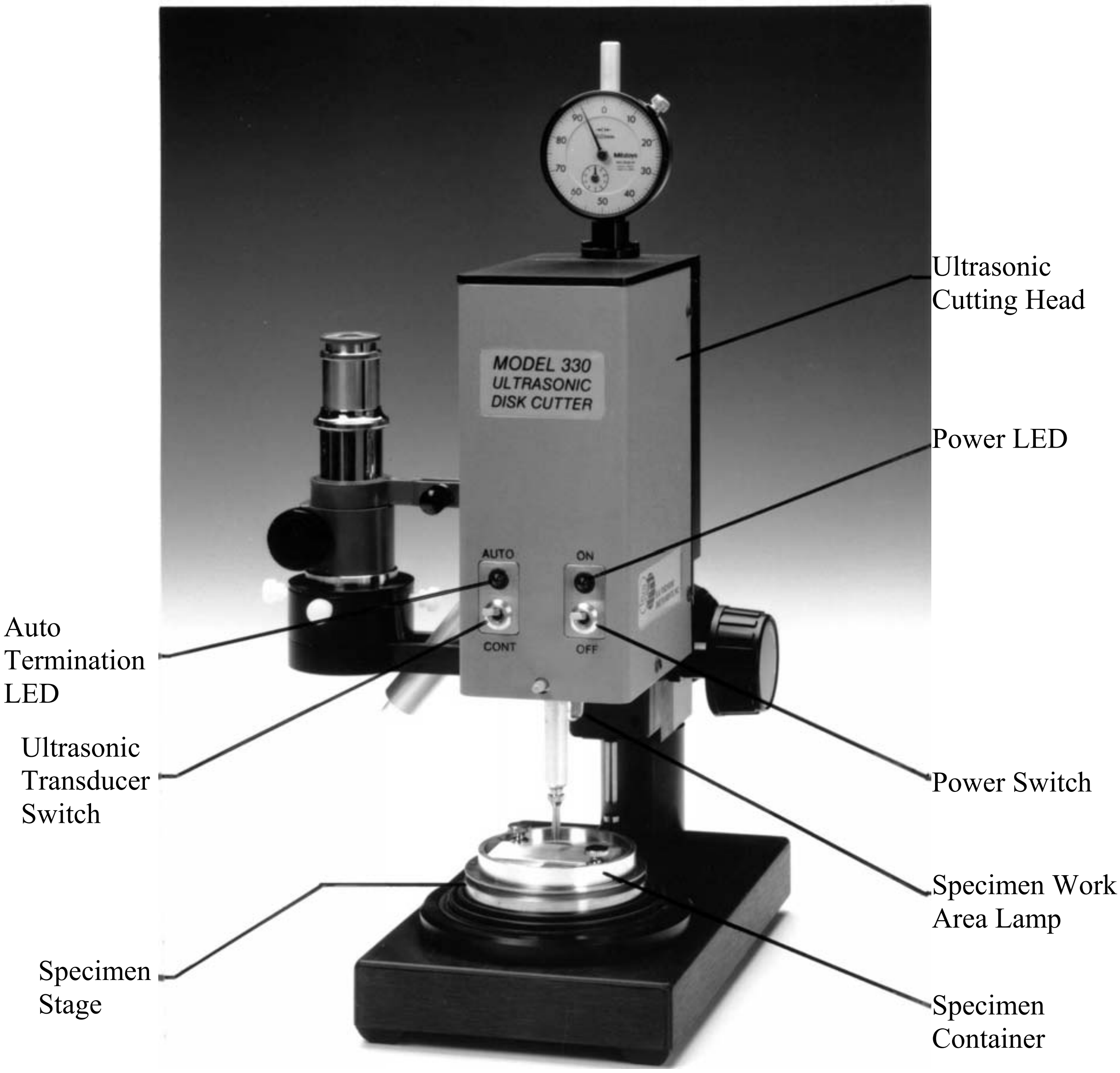


Figure 5. Model 170 with Ultrasonic Cutting Head in position.

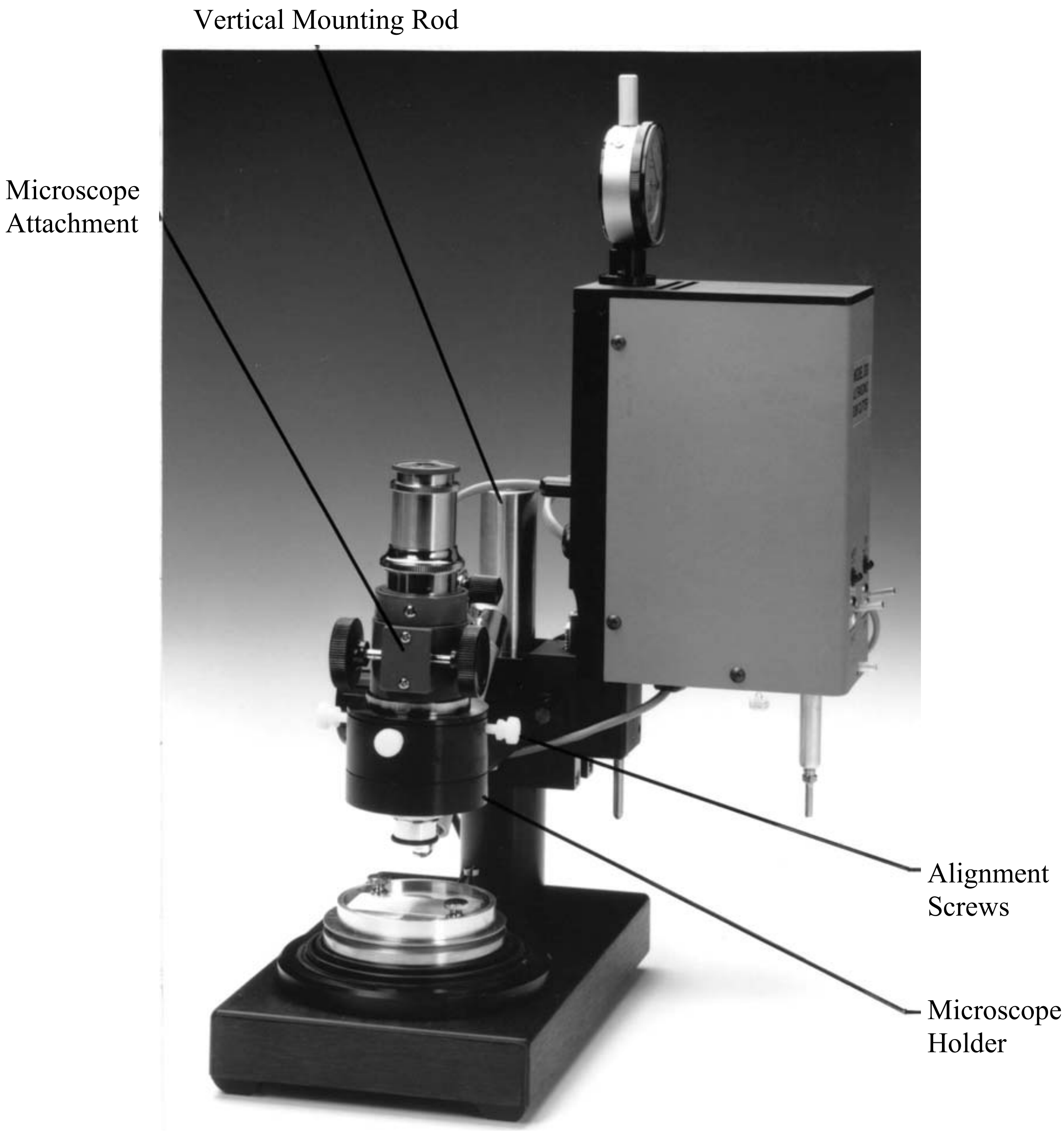


Figure 6. Model 170 with Optional Microscope Attachment (P/N 008-0086) in position.

3. Operation

3.1. Initial Set-up

3.1.1. Instrument Lab Location

The Model 170 Ultrasonic Disk Cutter should be placed on a rigid work surface in a location where the noise generated by the cutting process will not disturb other personnel working in the same area. Because of the abrasives associated with ultrasonic cutting, it is suggested that the Model 170 be positioned away from any type of precision instrumentation which requires a clean environment.

3.1.2. Installing the Cutting Tool

The cutting tool is machined with internal threads which correspond to the threads located on the ultrasonic transducer (Figure 7).

Figure 7. Specimen Stage

NOTE: When installing the cutting tool onto the transducer, it is first necessary to fit the Copper Washer (P/N 008-0026) between the cutting tool and the transducer. This washer facilitates the transmission of the energy from the transducer to the cutting tool and also provides a liquid tight seal which prevents abrasive slurry from eroding the transducer screw threads.

To install the cutting tool, simply thread the tool onto the ultrasonic transducer. The tool wrench (P/N 008-0068) should be utilized for tightening.

NOTE: Although the tool must be securely fastened to the transducer, DO NOT exert excessive force when tightening. Damage to the ultrasonic transducer assembly could result.

3.1.3. Verify Power-up

Turn the power switch (Figure 5) to the "ON" position. Both the power LED and the specimen work area lamp will become illuminated. The ultrasonic transducer switch has three positions, with the center position being "OFF". The transducer can be activated by placing the switch in either the "AUTO" or the "CONT" mode.

WARNING: When energized, never firmly grasp either the cutting tool of the tip of the ultrasonic transducer. Due to the rapid excursion of these components, burns could result.

NOTE: The LED associated with the ultrasonic transducer switch indicates the auto termination mode. When the LED is illuminated, the transducer/tool is in electrical contact with the specimen stage. With the switch in the "AUTO" position, the transducer is disabled when the LED becomes illuminated. With this switch in the "CONT" position, the transducer remains energized while the LED is illuminated.

3.1.4. Microscope Attachment Installation

NOTE: For instruments that are factory ordered with the optional Microscope Attachment (P/N 008-0086), please proceed to Section 3.1.5. For instruments where the attachment was ordered later: to assemble the Microscope Attachment onto the Model 170 (Figure 6), locate the two screws on the side of the block through which the vertical mounting rod fits. (**NOTE**: While looking at the front of the instrument, these screws are located on the left side.) Fasten the Microscope Holder Arm onto the block using the supplied screws.

3.1.5. Microscope Installation

Install the four (4) alignment screws (Figure 6) into the microscope holder. Place the microscope lamp into its corresponding holder located on the microscope assembly. Place the microscope into the microscope holder and secure it with the four (4) alignment screws. Plug the lamp electrical jack into the socket located on the rear panel of the instrument.

3.1.6. Microscope Alignment

Initially, it is required to adjust the microscope in relation to the cutting tool. To facilitate this procedure, mount a portion of a glass microscope slide to an aluminum specimen plate (P/N 008-0065) using a low melting point polymer. Place the specimen plate in the specimen container and rotate it until it is beneath the heads of the thumbscrews, then firmly tighten the thumbscrews (Figure 2).

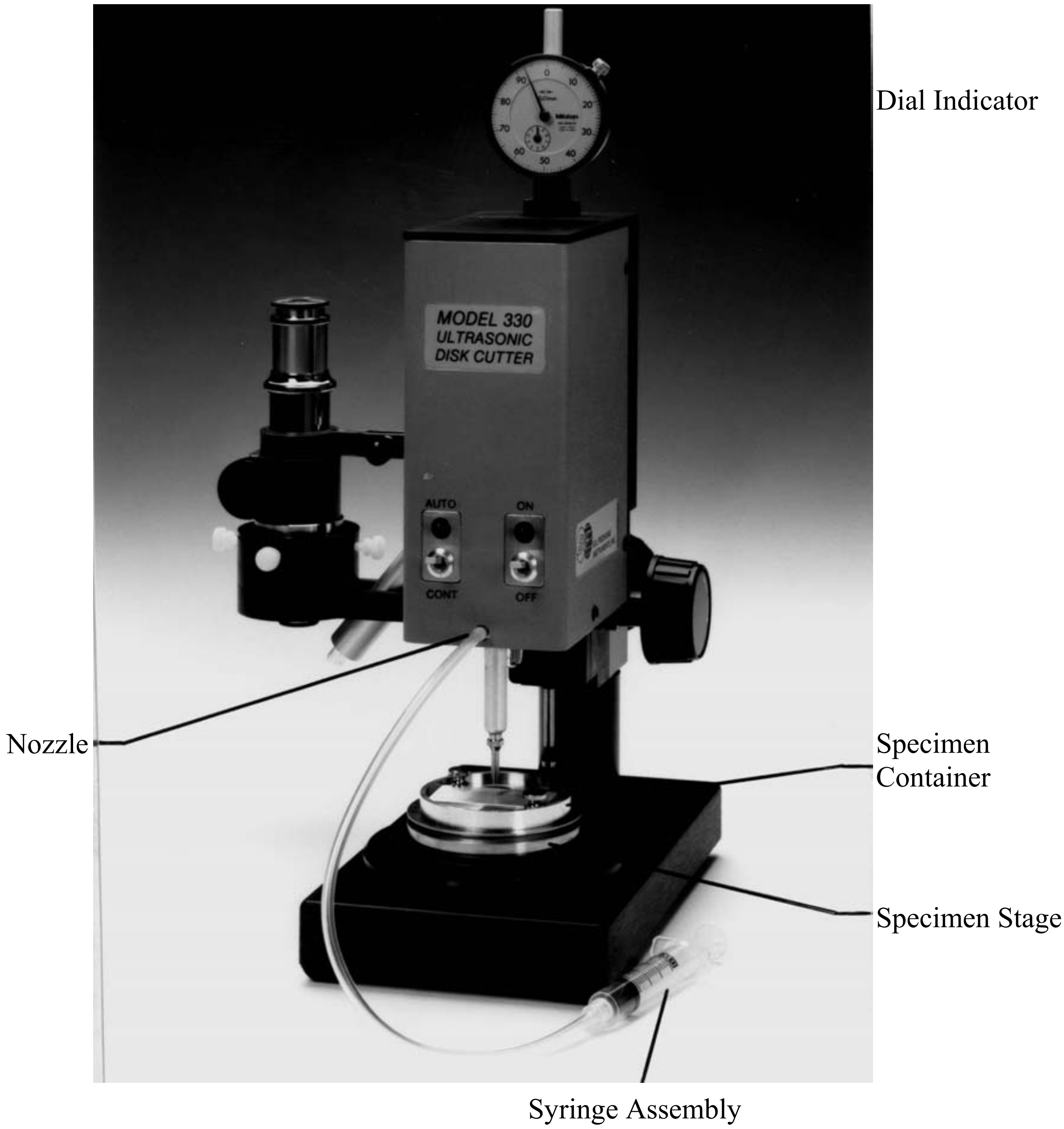


Figure 8. Model 170 front view.

Attach the syringe assembly (P/N 008-0090) (filled with water) to the nozzle (Figure 8) on the front of the instrument. Place the power switch in the "ON" position. Apply a small amount of abrasive powder to the glass slide directly beneath the cutting tool.

NOTE: The use of 1000 grit silicon or boron carbide abrasive powders as the cutting media is recommended for virtually all specimen materials.

To eliminate the undesirable movement of the ultrasonic cutting head, ensure that the locking knob (Figure 9) is firmly tightened. Lower the ultrasonic cutting head until the cutting tool contacts the glass slide. Continue lowering slightly to apply cutting pressure.

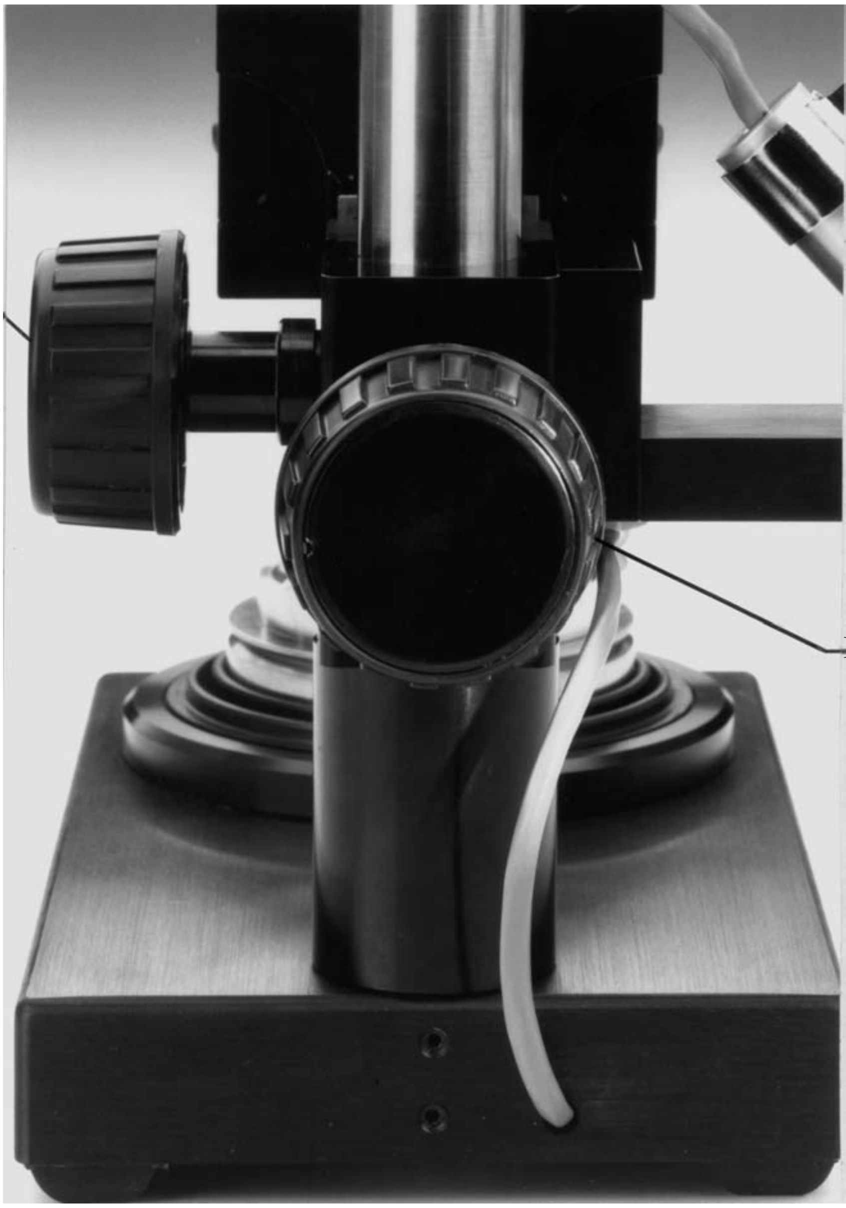


Figure 9. Model 170, rear view.

Inject water from the syringe until the abrasive powder begins to wet. To initiate the cutting process, place the transducer switch in either "AUTO" or "CONT". Allow cutting to continue for approximately 10 to 20 seconds. This should produce an indentation in the glass slide sufficient for the subsequent alignment operation.

Return the transducer switch to the center "OFF" position and raise the ultrasonic cutting head. Gently wipe the surface of the glass slide. DO NOT MOVE THE SPECIMEN CONTAINER.

Loosen the knob on the back of the instrument. This knob is an extension of a tapered pin which fits into a tapered groove in the vertical mounting post. The design of this coupling insured a positioning repeatability of better than 0.01 mm. For proper movement of the ultrasonic cutting head/microscope, it is necessary to rotate the knob until the pin is fully retracted from its corresponding groove.

Rotate the microscope into position above the specimen stage, then firmly tighten the knob. Adjust the four alignment screws until the circular depression cut into the glass slide is centered in the field of view of the microscope (Figure 10).

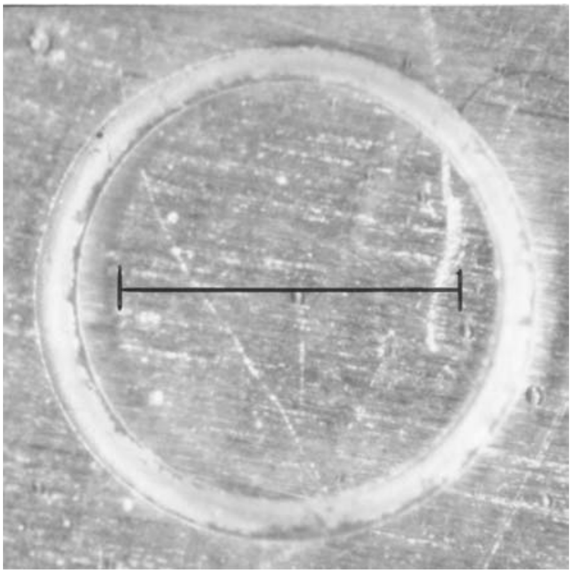


Figure 10. Properly Aligned Microscope Attachment.

Because of manufacturing tolerances in the entire apparatus and slight dimensional differences in the cutting tools, adjustment of the microscope from time to time may be required. Periodically check for microscope alignment, and when required, repeat Section 3.1.6. to adjust the microscope.

The Model 170 Ultrasonic Disk Cutter is now fully operational, and the cutting of actual specimens may commence.

3.2. Specimen Cutting

3.2.1. Sample Mounting

To utilize the effectiveness of the electrical continuity detector for determining process termination, it is necessary to mount the sample material to a conductive (aluminum) specimen plate (P/N 008-0065) (Figure 4).

For non-conductive materials, the specimen plate is quite acceptable. However, for conductive materials, it can not be assumed that the adhesive layer to be applied between the sample material and the specimen plate is sufficient to prevent conduction. Therefore, a non-conducting layer of epoxy is applied to the aluminum specimen plate surface.

Place the specimen plate on a hot plate and generously apply a layer of a low melting point polymer. Care should be taken to completely cover the specimen plate with adhesive in the area in which the sample material is to be secured. Voids or gaps in the adhesive layer will contribute to specimen breakage during the cutting process.

Place the sample material into the pool of molten adhesive. Move the material in a small circular motion and apply slight downward pressure to evenly distribute the adhesive.

For materials that are particularly prone to damage, a successful technique for minimizing both edge and surface damage involves mounting a microscope cover slip to the top of the sample material (Figure 4). The cover slip in essence provides a protective coating for the specimen.

NOTE: When the glass cover slip is employed, the cutting path is achieved while the tool proceeds into the glass, thus minimizing any lateral motion of the specimen in relation to the cutting tool.

The cover slip should be affixed to the sample material with the low melting point polymer.

Remove the aluminum specimen plate from the hot plate and allow it to cool.

3.2.2. Attachment to the Specimen Container

Place the specimen plate in the specimen container and rotate it until it is beneath the heads of the thumb screws. Firmly tighten the thumb screws (Figure 11). The thumbscrews provide electrical continuity from the specimen plate to the specimen container, thus enabling proper functioning of the automatic termination detector.

The specimen container is fitted with four Samarium/Cobalt rare earth magnets, which ensure secure attachment to the specimen stage (Figure 7). By rigidly attaching the specimen container to the specimen stage, lateral motion of the sample materials in relation to the cutting tool is reduced and specimen damage is minimized.

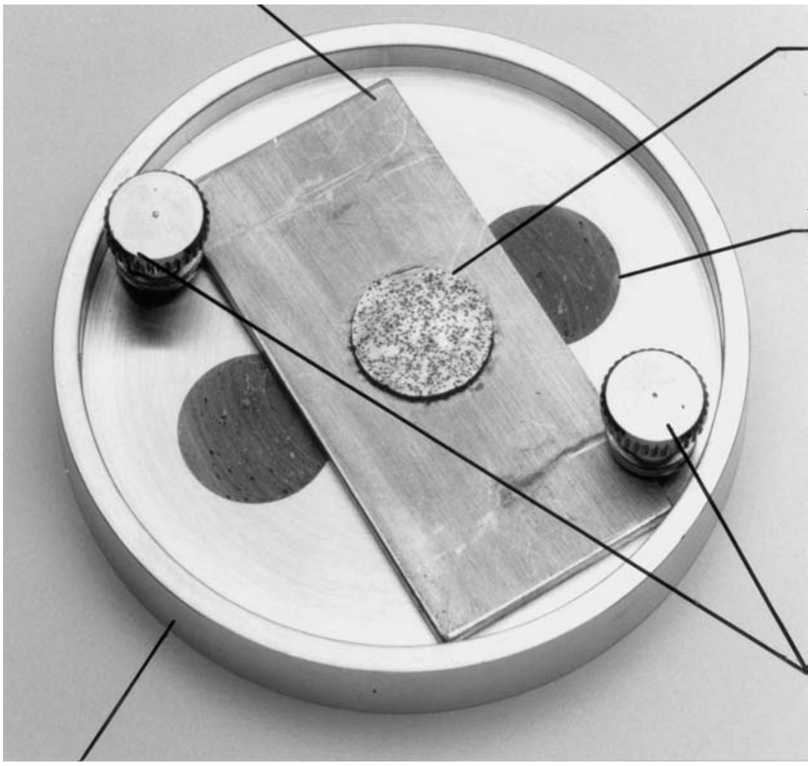


Figure 11. Specimen Container

3.2.3. Specimen Positioning

3.2.3.1. Introduction

The single most important aspect of going from a bulk state to a 3 mm disk is the ability to capture the specific area of interest, and to preserve it in an unaltered state. For electronic materials where analysis of a specific junction is required, that junction should be in the center of the disk. For composite materials (Figure 12), where the analysis of an interface is required, it is beneficial to obtain a disk whereby the interface is situated near the center.

By initially controlling the area to be thinned, a specimen with optimum structural integrity is achieved. A required result of dimpling is to have an electron transparent area in the center of the specimen combined with an outer rim of sufficient thickness to permit ease of handling (Figure 13). Properly selecting the area of the bulk materials for the specimen facilitates subsequent preparation operations.

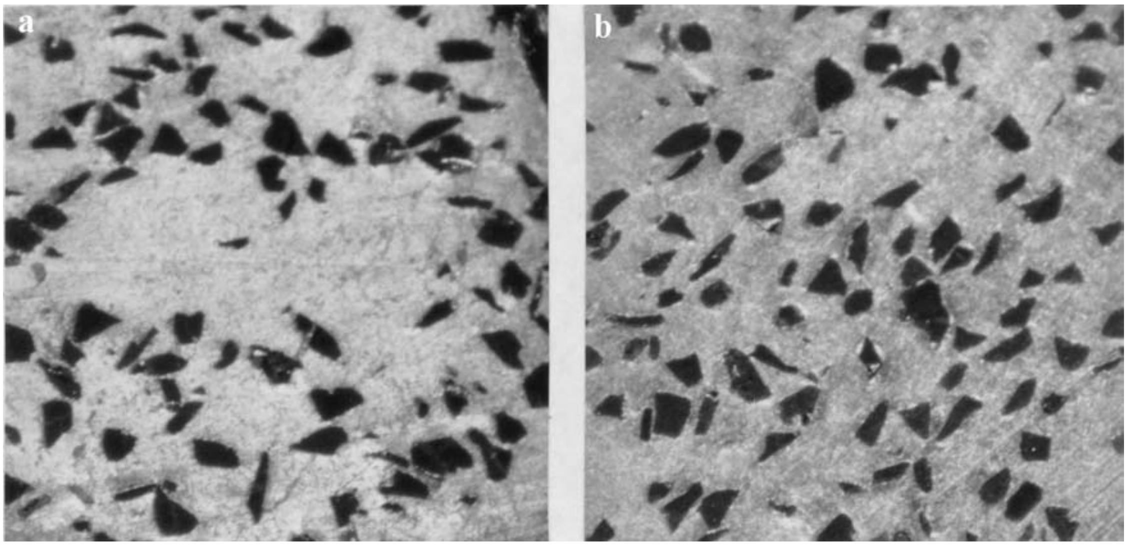


Figure 12. Al/SiC composite specimen a)incorrectly and b)ideally positioned for cutting a 3 mm specimen disk to include a number of SiC particles.

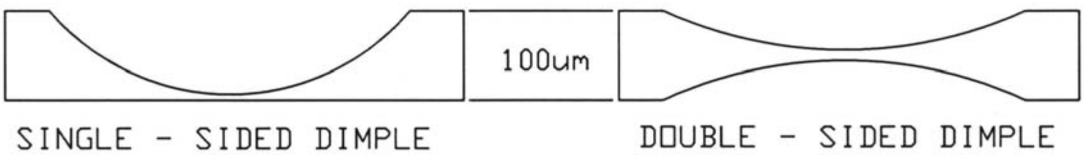


Figure 13. Cross-Section of a Dimpled Specimen.

3.2.3.2 Microscope Operation

The Model 170 Ultrasonic Disk Cutter incorporates an integral (optional) microscope which is used for both positioning and observation of the specimen (Figure 6). This 40X microscope is rigidly attached to the ultrasonic cutting tool head. Because the ultrasonic cutting head is mounted to a round post, either the microscope or the cutting head is easily rotated into position for subsequent specimen positioning and cutting. An alignment and locking mechanism establishes precise angular positioning of the ultrasonic cutting head/microscope. The locking knob (Figure 9), located on the back of the instrument, facilitates rotation and ensures angular repeatability.

3.2.3.3 Specimen Selection

To initially establish the specific area of the bulk material to be cored, fully loosen the locking knob by rotating it counterclockwise (Figure 9). Rotate the microscope into position over the specimen, then tighten the knob. While observing the specimen material through the microscope, select a specific area of interest by sliding the specimen container. Once the region of the bulk material to be cored is established, rotate the ultrasonic cutting head into the cutting position and firmly tighten the knob.

3.2.4 Cutting

Attach the syringe assembly (filled with water) to the nozzle on the front of the instrument (Figure 8). Place the power switch in the "ON" position. Apply a small amount of abrasive powder to the specimen surface directly beneath the cutting tool.

NOTE: The use of 1000 grit silicon or boron carbide abrasive powder as the cutting media is recommended for virtually all specimen materials.

Lower the cutting head until the cutting tool contacts the specimen. Continue lowering slightly to compress the specimen stage, thus applying the cutting pressure. The lineal travel of the specimen stage is approximately 5mm. For optimum performance, only compress the stage an amount slightly greater than the specimen material thickness.

NOTE: The Model 170 is equipped with a dial indicator (Figure 8) which indicates cutting depth. The resolution of the dial indicator is 10µm per minor division. The lower portion of the indicator contactor assembly (Figure 14) is directly coupled to the specimen stage assembly. Once the tool contacts the specimen surface, the indicator and the specimen stage travel at approximately the same rate while the stage is being compressed. During this compression, the dial indicator will show little or no movement.

Inject water from the syringe until the abrasive powder begins to wet. Place the transducer switch in "AUTO" to initiate the cutting process. Observe the dial indicator to insure that the specimen is being cut. Approximate cutting times for various materials are provided in Appendix A. If it is noticed that the cutting rate decreases, inject additional water. It is necessary to keep the tool both lubricated and cool during the cutting process. Should the injection of water fail to increase the cutting rate, additional abrasive powder should be added.

3.2.5 Process Termination

The cutting process will continue until the tool penetrates through the specimen material. When contact is made between the tool and the aluminum specimen plate, continuity is sensed, the cutting process is terminated, and the ultrasonic transducer LED will become illuminated. For cases whereby the tool has experienced uneven wear, it may be necessary to continue cutting for a brief period of time to ensure that the periphery of the disk has been completely cut. To accomplish this, place the ultrasonic transducer switch in the CONT position and allow cutting to continue for an additional 10 to 20 seconds then return the ultrasonic transducer switch to the center “OFF” position. If it is so desired, additional specimen disks can be produced by repeating Sections 3.2.3.3 through 3.2.5.

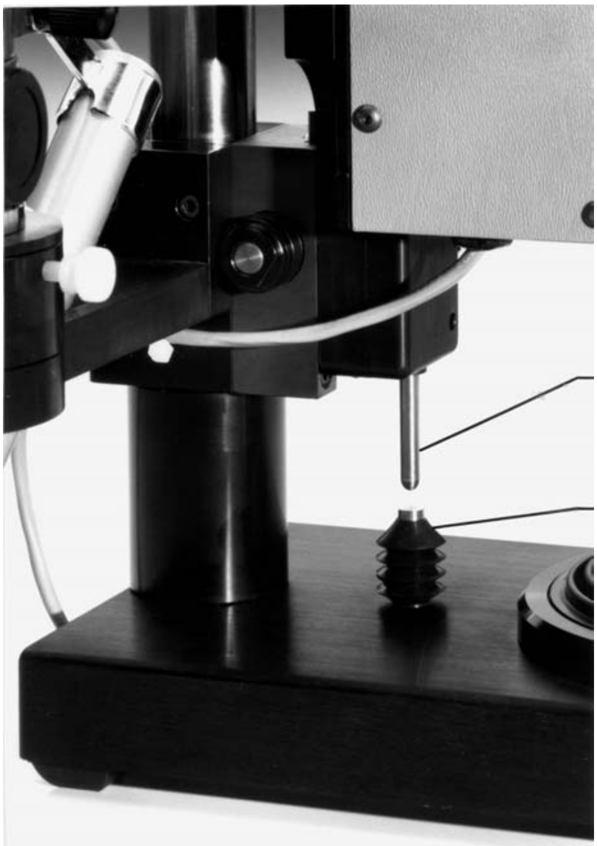


Figure 14. Lower Indicator Assembly

3.2.6 Specimen Removal

Place the main power switch in the “OFF” position then raise the ultrasonic cutting head. Remove the specimen container from the instrument. With an absorbent paper/cloth, carefully remove the abrasive slurry. An extreme amount of care should be taken during this process so as not to lose any of the disk(s) that may have broken free from the specimen plate during the cutting process.

NOTE: Occasionally, a specimen disk will become entrapped in the tool. To free the disk, energize the ultrasonic transducer and inject water from the syringe. It is advisable to place an absorbent material on the specimen stage when conducting this procedure.

Remove the specimen plate from the specimen container and thoroughly clean both of these components. Place the specimen plate on a hot plate to melt the low melting point polymer adhesive. Remove the specimen disks and allow them to cool. Place the specimen disks in a proper solvent (water or acetone, as recommended by the adhesive manufacturer) to remove all adhesive. Remove any bulk material fragments from the specimen plate, then clean the plate in the proper solvent.

3.2.7 Tool Wear

Due to the abrasive nature of the ultrasonic cutting process, the cutting tool is subject to wear. When preparing disks from homogeneous materials, tool wear is usually even around the circumference. When cutting composites or cross-sectional interface materials, the tool may experience uneven wear. Should the unevenness become excessive, remove the tool then polish the cutting surface until it is flat using any type of rotary grinding wheel. Care should be taken to avoid burrs on the cutting edge. Cutting tools can be utilized until their overall length becomes approximately 9mm.

3.2.8 Cleaning

Following usage, it is necessary to thoroughly clean the entire instrument. A damp wet cloth containing a mild detergent should be used to clean all surfaces.

WARNING: NEVER USE ANY TYPE OF SOLVENT ON THE ULTRASONIC CUTTING HEAD COVER. DAMAGE TO THE PLASTIC WILL OCCUR.

A cotton swab should be used to clean between the convolutions on the specimen stage seal.

4.0 Model 170 Electronics

4.1 Description

4.1.1 Transducer

The ultrasonic cutting force is generated by driving a pair of Lead Zirconate Titanate (PZT) disks with an oscillating voltage. The expansion and relaxation of these disks is in direct proportion to the applied voltage. The Model 170 Ultrasonic Disk Cutter uses a transformer coupled oscillator to drive the disks at a nominal 375 volts peak.

4.1.2 Electronics

Electronic drive for the transducer assembly is via a single printed circuit board mounted to the rear bracket of the Model 170. This PCB contains the oscillator, shutoff relay, latch circuitry, and regulators for the external incandescent lamps. Schematics, parts lists and wiring diagrams are included in Appendix B.

4.1.3 Controls

There are no PCB potentiometers, therefore, no calibration is required. In final assembly, the PCB and transducer are matched. The following external controls are provided:

A. Power Switch

Cycles the main power on and off.

B. Ultrasonic Transducer Switch

Enables or disables the auto-termination function. AUTO mode enables the shut-off feature. The Model 170 will terminate cutting whenever the tool has contacted the metal specimen slide. In the CONT mode, cutting will continue until the switch is placed into the center-off position.

4.2 Circuit Operation

Refer to schematic drawing B1241 and wiring diagram B1242.

4.2.1 Power Supply

A bridge rectifier and filter is formed with D1,2,3,4 and C1. The output of this rectifier is approximately 35VDC +5vdc and is applied to J1-5. This voltage is the power source for all of the Model 170 functions.

4.2.2 Oscillator

The 35VDC signal is applied to U2, a LM317 regulator, configured as a constant current source by R10. The constant current of U1 is switched on and off by Q3. The current in Q3 is also applied to the primary of T1. This switching current in T1's primary winding creates a larger (350volt) voltage swing in the secondary of T1. A second transformer T2 takes a portion of the signal (as determined by R8,R9,C6, and C7) and feeds it back into the base of Q3. This feedback control loop then allows this section of the circuit to self oscillate at a frequency determined by C3,C4,C5, and C6. Additional biasing is provided by R6 and R9 to assure start-up.

4.2.3 Lamp Driver

The 35VDC power is applied to U1, a LM7812 voltage regulator. This regulator output drives the two external incandescent lamps. The regulator is short-circuit proof and will self-limit in the case of an external short circuit.

4.2.4 Shut-off Circuit

The 35VDC power is also applied to the shut-off circuit. R2 and R10 serve as current limiting resistors for the power LED and the ultrasonic transducer LED. Transistors Q1, Q2, and relay K1 form the termination circuit. Transistor Q1 is normally on via R1. Capacitor C2 stabilizes this voltage from outside transients. When the cutting tool contacts the grounded specimen plate, Q1's base becomes grounded. Turning Q1 off in this manner causes Q2 to turn on via R3 and R5. Transistor Q2 turning on pulls in relay K1. K1 latches in the on position through Q2 via one of its contacts and R4. A second contact of K1 shuts off the 35VDC power to Q3 and terminates the tool oscillation. K1 becomes reset when the ultrasonic transducer switch is placed in the center- off position, which removes the 35VDC power from the relay.

5.0 Troubleshooting

5.1 Transducer Stalling

When cutting through thick materials (>1mm) or cutting under heavy pressure (dry tool), the transducer assembly may stall. This results in either a stop in the transducer oscillation or a shift in the operating frequency to a range where the cutting tool has no power. Stalling will occur when the force exerted on the cutting tool exceeds the available electrical power to the PZT disks. Should the tool stall, it is necessary to place the ultrasonic transducer switch in the center-off position, lift the tool from the sample material, add more abrasive media and water, then resume the cut using no more than 2mm of the stage travel.

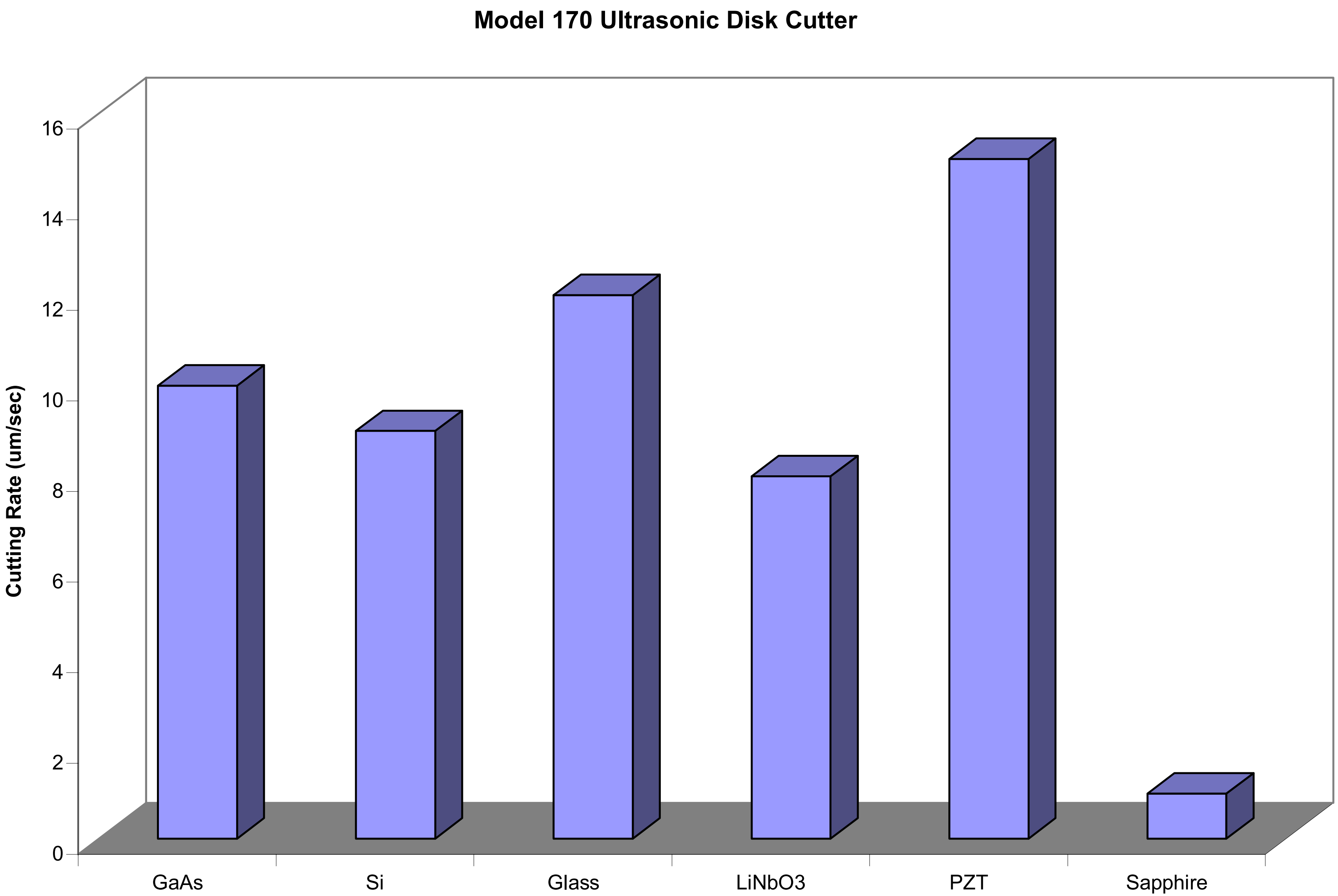
5.2 Stage Restricted

Remove the two screws on the bottom of the instrument. Remove the pin, spring and O-Ring. Thoroughly clean these components, then lubricate with a very light oil. Replace by reversing the disassembly sequence.

6.0 Parts List

Part No.	Qty. Supplied	Description
008-0086	1	Microscope Attachment (optional)
008-0002	3	Titanium Tool, 3mm
008-0026	5	Copper Washer
008-0065	5	Specimen Plate
008-0088	1	Specimen Container
008-0089	1	Lamp Holder
008-0090	1	Syringe Assembly
008-0068	1	Tool Wrench

APPENDIX A. Cutting Rates for Different Materials



APPENDIX B. Electronics Drawings

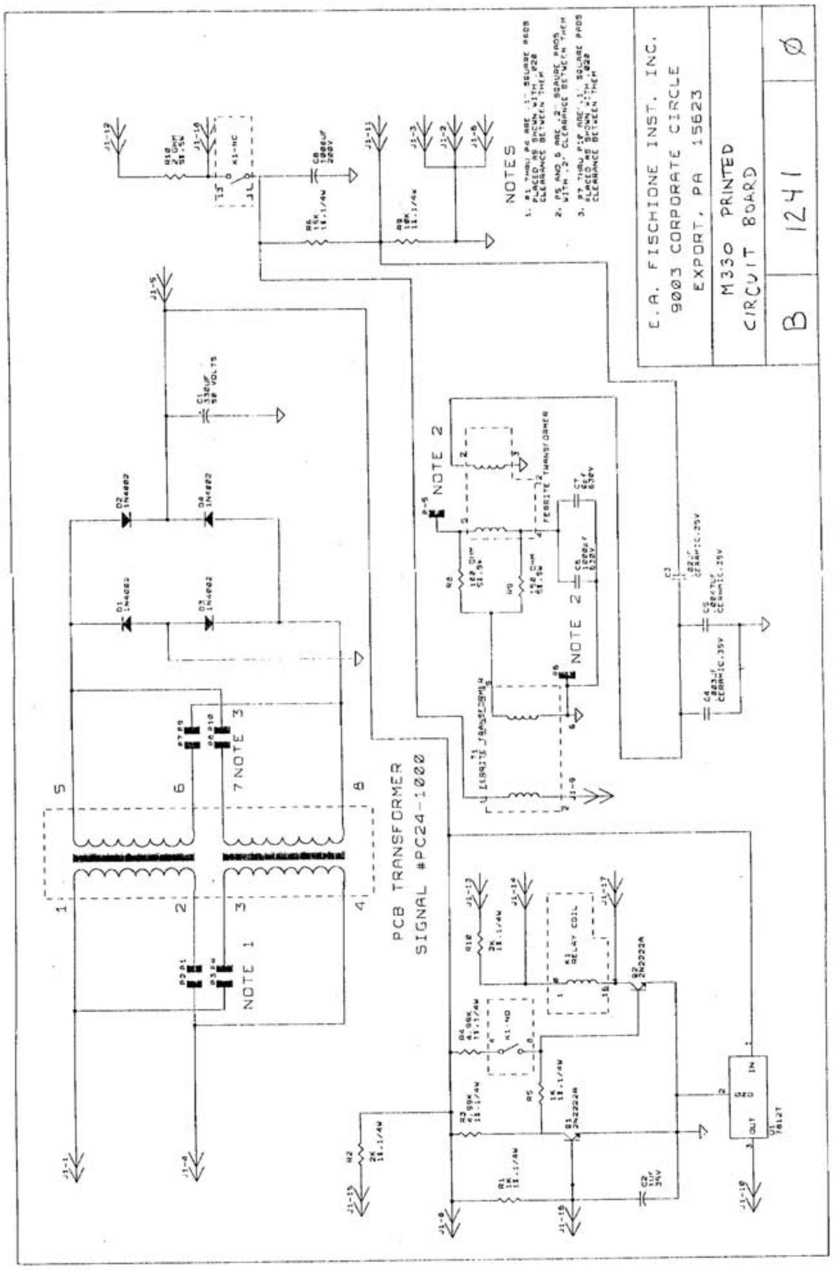


Figure B1. Model 170 Printed Circuit Board

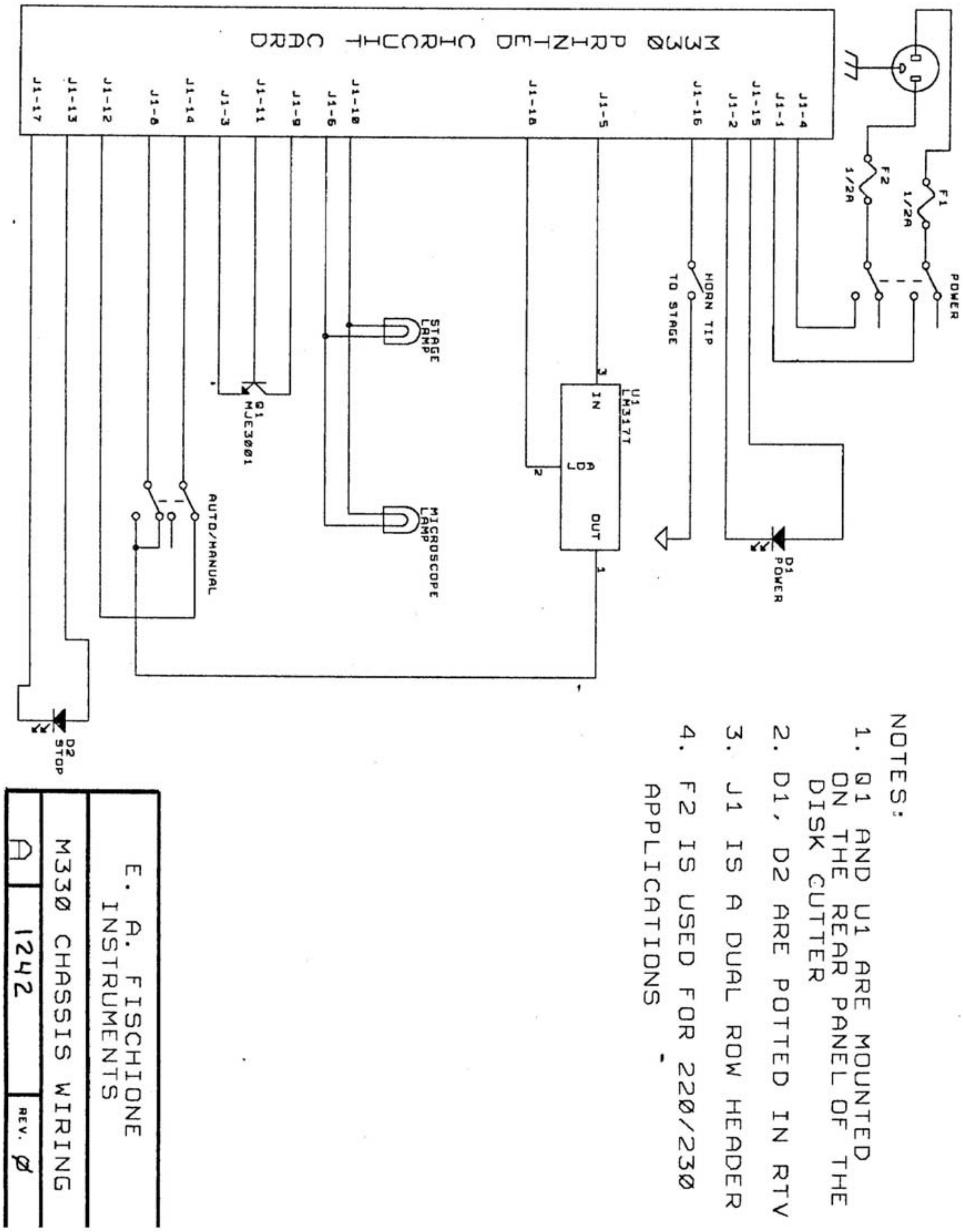


Figure B2. Model 170 Chassis Wiring.

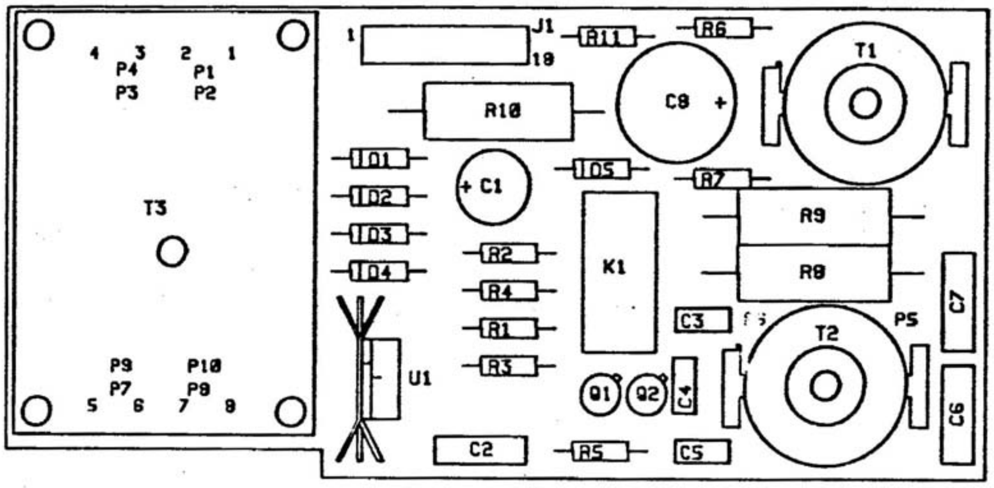


Figure B3. Model 170 PCB Assembly

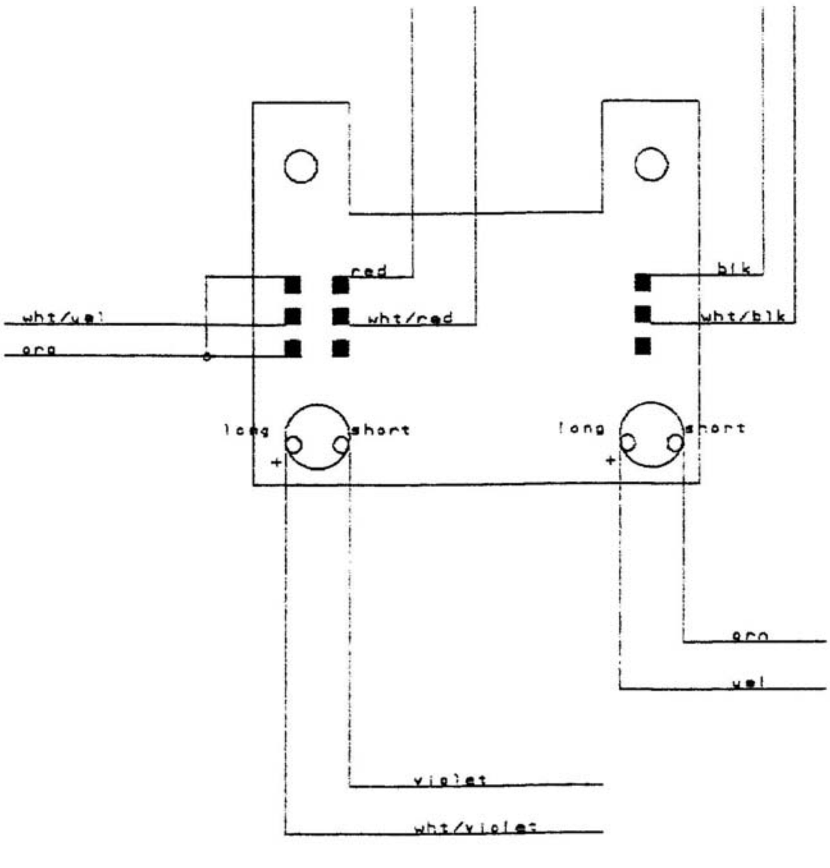


Figure B4. Rear View