1. INTRODUCTION

The Gatan Model 656 Dimple Grinder is a precision instrument used for grinding circular dimples, of spherical or flat bottomed profile, in the surface of materials such as ceramics, semiconductors and metals. The principle application is the preparation of TEM specimens. If specimen blanks are mechanically dimpled prior to final thinning, then the finished specimen has a larger than usual electron transparent area of a more uniform thickness and, in the case ion or neutral particle beam thinning systems, the time required for final thinning is significantly reduced. Moreover, the specimen has a relatively thick rim surrounding the thin region and is thus very robust.

A careful operator can routinely produce thicknesses less than 5 μm, although in the case of most metals a final thickness between 20 μm and 50 μm is more normal since mechanical damage introduced into the specimen surface by the action of grinding must be removed. The preparation of such specimens is completed by electopolishing, ion beam thinning, etc. However, the Dimple Grinder is gentle enough and provides sufficient control over the process of dimpling that many materials, such as ceramics and semiconductors, can be thinned below 5 μm with practically no mechanical damage and viewed subsequently in intermediate and high voltage TEMS without further thinning. The electron transparent area is precisely locatable in the specimen, both laterally to within a few tens of microns and vertically to within a few microns, not always possible with other thinning techniques.

Other applications of the Gatan Model 656 Dimple Grinder include the production of accurate, precisely located taper sections through the surface of specimens, which may then be subjected to analytical techniques such as EDX, SIMS, Auger, etc. In this way compositional profiles of segregated surface layers, coatings and platings can be obtained rapidly and with excellent 'depth resolution'.

2. INSTALLATION

The Dimple Grinder operates from the standard mains voltage. **Caution**: check the power socket module at the rear before connecting to the mains to confirm that your unit is compatible with the local mains voltage. Connection to the wrong voltage may damage your Dimple Grinder. No other external services or utilities are necessary. However, for reproducible, high quality results, the Dimple Grinder must sit on a flat, vibration-free and rigid surface and the local environment must be clean. The platform counterweight is packed separately and is attached by screwing into place. After installation, the scale zero should be checked (see section 5.2).

3. DESCRIPTION (see figure 1)

3.1. External

The base of the Dimple Grinder contains the a control systems, the micrometer drive and a magnetic turntable with motor drive and transmission illumination system. On top of the base unit sits a pivoted platform (arm) containing the grinding wheel assembly and a dial indicator. The arm is held in a vertical position by a magnetic latch at the rear of the base.

The **Raise / Lower Cam** allows the grinding wheel to be very gently lowered the last few millimeters onto the specimen and must **always** be used to raise or lower the arm through the final part of its movement.
Caution: dropping of the pivoted arm may cause considerable damage to the measuring systems. This will void the warranty.

The **Counterweight** varies the load applied to the specimen between 0 and 50 g. The black load scale is adjustable, by sliding and rotating, to permit zeroing. For this reason, during operation the load must be changed by holding the metal counterweight.

The analog **Dial Indicator** shows the progress of grinding and normally displays the thickness of specimen still to be removed. A housing protects the dial indicator stylus which is spring loaded to press downwards against the end face of the micrometer drive. The zero stop set screw is insulated and forms the live contact for the autotermination circuit. On connecting with dial indicator stylus and micrometer drive end face, it is earthed and, if the autotermination has been armed, will result in the grinding wheel and specimen turntable motors being automatically switched off.

3.2. Light Microscope

The X40 magnification light microscope has a precisely machined base which accurately fits the specimen turntable housing. The center mark within the eyepiece (projected diameter on the specimen about 80 μm) shows the position of the specimen turntable rotation axis thus allowing the center of the dimple to be located precisely at a specific feature. The light microscope base contains a lamp for observing specimens in reflected light. Certain materials which become transparent during final thinning may also be observed in transmitted light, when on the glass specimen mounts, by pressing the lamp switch. This will turn off the lamp in the microscope base and turn on a lamp beneath the turntable which shines up through the hole in the center of the turntable to illuminate the mount and specimen from below.

3.3. Grinding and Polishing Wheels (see figure 2)

The grinding and polishing wheels are available in 10 mm, the standard 15 mm or 20 mm diameters and are all interchangeable. The small wheel preserves a wide, thick rim around the thin area for fragile specimens and produces steep profiles for analysis. The large wheel prepares bulk specimens for analysis. **Note:** the grinding wheels wear and should be considered as consumables.

The grinding wheels are phosphor bronze, available with spherical or flat edges. The spherical edged wheels permit more accurate positioning of dimples and produce a spherical profile with a smaller thin area and are suited to fragile or brittle specimens, such as ceramics and semiconductors. The flat edged wheel produces flat bottomed dimples with larger thin regions and are better suited to tougher specimens, particularly metals.

The polishing wheels have a recessed rim which holds a felt strip . The felt strips have a limited lifetime and should be replaced regularly. **Note** : take care not to get the felt dirty and do not mix different compounds on the same strip.

Be careful to ensure that the male and female surfaces of the wheels and axle assembly are kept clean. **Caution:** do not use flooding with solvents to clean the male taper of the axle, as this may wash dirt into the axle assembly, leading to wear and impaired performance. Clean with a lens tissue, lightly moistened with solvent (e.g. freon) if the dirt is difficult to move.

3.4. Specimen Mounts (see figure 3)

The specimen mounts are magnetically held to the specimen turntable. In order to accomodate the different diameter grinding and polishing wheels, there are three different, appropriately sized mounts, so that the grinding wheel axis always remains horizontal.

The standard mount, for use with the standard 15 mm diameter wheels, consists of a cylinder and centering ring. For transparent specimens or for materials which become transparent when very thin, such as silicon, a glass cylinder allows the progress of thinning to be monitored in transmitted light with the light microscope and sub-specimen illuminator. Opaque specimens are normally mounted on a steel cylinder. Both the glass and steel cylinders adapt to the Gatan Model 623 Disc Grinder and the Gatan Model 601 Ultrasonic Disc Cutter, making it possible to carry out the whole process of grinding, cutting and dimpling up to 7 discs without remounting the specimen. The mount for use in conjunction with the small, 10 mm diameter wheels has a conical shape to prevent fouling of the grinding wheel axle assembly. The mount for the large, 20 mm diameter wheel is a simple disc. **Note:** The specimen mounts should be periodically checked for smoothness and flatness. This may be done either with a light microscope or a free-standing dial indicator.

3.5 Electrical Control System (see figures 4a and 4b)

The circuit diagram of the electrical system is shown in Figure 4a. The system consists of:

a) Power transformer T1 with dual windings for 115VAC and 230VAC inputs.
b) Unregulated 24VDC 12-Watt power suppply T1, CR4, C3 for the upper lamp DS5 or the lower lamp DS4.
c) Regulated 1.2VDC supply U2, C1 for the specimen table motor B1.
d) Regulated variable 1.2 to 13.9 VDC supply U1, R2, R5 for the grinding wheel (arm) motor B2.
e) Regulated 1.5VDC supply CR6, R10, R11, C5 for the digital micrometer.
f) Autostop circuit C2, K1, R1, S6 to switch off motors at preset specimen thickness.
g) Digital micrometer M1 with LCD display and Zero switch S5.

The (Corcom) power connector module is fixed to the Dimple Grinder casting and contains the input ac power connector, power switch, 120/240V line voltage selector card, and a 3AG-size, 1/4-ampere, 250-volt fuse. When the casting is set in place over the baseplate assembly all electrical connections are made to the main PC board via a pressure connector, eliminating the need for a cable.

The main PC board is fixed to the Dimple Grinder baseplate and contains the internal 24Vdc power supply, lower lamp, conventional IC voltage regulators to control motor speed, 1.5V supply, and the Autostop circuit. When AUTO switch S4 is pressed capacitor C2 charges pulling in the relay K1 and closing contacts K1-1. The contacts K1-1 apply holding (latching) power to K1 (via dropping resistor R6) and also the motor power to switches S1, S2 (via CR3). As the specimen reaches the grinding limit the stylus S6 grounds, shorting out holding power for K1 causing it to drop and remove power from the motors. To reset the relay the capacitor C2 must be discharged by pressing the auto switch to the UP position .

4. OPERATION

4.1. Principles (see figures 5 & 6)

To produce a dimple, the point of contact between the specimen and the grinding wheel must be on the axis of specimen rotation. This requires that the grinding wheel rotation axis is exactly orthogonal to and intersect the vertical specimen rotation axis. The precision alignment of the pivoted arm and precise taper bearing fit between the grinding wheels and the axle assembly ensures that the center plane of the grinding wheel contains the vertical specimen rotation axis and hence contacts the specimen at the correct point.

If the diameter of the wheel is changed, the wheel tilts and its rotation axis moves away from the horizontal, causing the contact point to move away from the vertical specimen rotation axis. This is corrected for by changing the specimen height with different sized specimen mounts.

The Dimple Grinder incorporates two measuring devices: an analog dial indicator and a micrometer with a digital display. The stylus of the dial indicator is sprung loaded so that it presses downwards and normally contacts the end face of the micrometer drive. **Note**: it is important to realize that the dial indicator is an integral part of the pivoted arm and is rigidly connected to the grinding wheel. Any change in height of the grinding wheel produces an identical movement of the dial indicator relative to the micrometer end face and an appropriate movement of the dial indicator needle.

Thus the dial indicator fulfills the dual roles of sensitive indicator of contact between grinding wheel and specimen and easily discernible analog display of dimpling progress.

There are two ways in which the measuring system can be used when grinding specimens. To grind a dimple of specific depth (see figure 7a), the micrometer is zeroed at the upper surface of the specimen. This method is the more accurate way to grind specimens but it is necessary to know the original specimen thickness precisely and the micrometer zero must be set for each specimen. This method is used when very thin (<20 μm) specimens are being ground.

The alternative method of setting the final specimen thicknesss (see figure 7b) requires zeroing the micrometer at the upper surface of the specimen mount without any specimen. This method has the advantages that it is not necessary to know the original specimen thickness and the micrometer zero only needs to be set once to allow a number of specimens to be dimpled. However, it is less accurate than the previous method because the specimen mount may not seat at precisely the same height each time and no account is taken of the thickness of the mounting wax. It cannot, therefore, be employed to prepare very thin specimens.

The rate of removal of material by grinding depends on several factors. Generally, increasing the load and/or grinding wheel speed will increase the rate of removal of material. However, this will also produce a thicker damage layer. It should also be noted that some hard metals work harden significantly and that they are best dimpled at a slow speed with reduced load.

4.2. Dial Indicator Zero

The zero of the dial indicator should always be checked prior to dimpling. **Note**: the care with which the zero is set will determine the accuracy of the measuring systems.

a) With the arm in the upright position, remove the specimen mount from the magnetic turntable.
b) Lower the arm onto the cam.
c) Check that both motors are **off** and set a load of 20 g.
d) Lower the micrometer drive (clockwise) until it bottoms against the base.
e) With the cam, lower the arm.
f) Raise the micrometer (counter-clockwise) until the dial indicator needle has rotated just over one complete turn and comes to rest at or near the 12 o'clock position. **Note**: it is **not** necessary for the needle to be exactly at the 12 o'clock position.
g) Rotate the face of the dial indicator until the zero is positioned exactly under the needle, taking care to avoid parallax errors. Pressing down on the arm to adjust the dial indicator will not cause any damage, provided the force is not excessive, but structural flexing will produce a small change in the needle position.

4.3. Preparing the Specimen

Specimens must have perfectly parallel faces. A 1° deviation results in approximately a 25 μm overestimate of the thickness of a 3 mm disc when measured with a micrometer, clearly unacceptable if attempting to produce a 5 μm thick specimen. Any variation of thickness of the starting disc can be checked by noting the change in focus across the disc when observed by light microscope. Discs must be prepared for dimpling by careful grinding and the Gatan Model

623 Disc Grinder is recommended for consistently producing suitable discs.

If the method of setting the dimple depth is to be employed, the initial specimen thickness must be determined accurately. Whatever method is used the specimen thickness must be less than 200 μm, the maximum range of the dial indicator. However, an initial thickness of 100 μm is recommended as this will reduce the time needed for dimpling yet still provide a sufficiently strong supporting rim.

The surface(s) of the specimen coming into contact with the specimen mount must have a good finish. For normal dimpling, disc grinding can be completed on a 15 μm grit but for thinning of specimens to less than 20 μm, the final stage of disc grinding should done with a 3 μm grit. If mechanically thinning to electron transparency, the disc should be finished on a polishing cloth with 2-4 μm diamond paste followed with 0.05 μm alumina.

4.4. Specimen Mounting

The specimen is fixed to the mount with a low melting point, thermoplastic wax. The wax supplied is liquid at 130 °C. **Note**: if the temperature of the wax is allowed to exceed 130 °C it will start to decompose. While this may not appear to affect its ability to fix the specimen to the mount, the specimen may become detached later, during grinding. Care must also be taken to keep the wax perfectly clean and free from dirt. Particles as small as a few microns between the specimen and mount will adversely affect performance. The Gatan Model 623-40 Specimen Mounting Hot Plate is recommended.

a) Place the specimen mount on the hot plate, set at 130 °C
b) Touch the end of one of the wax sticks against the surface of the mount, only a small quantity (about 1 mm dia.) is necessary. Allow the wax to melt.
c) Carefully place the specimen on the mount, polished surface down.
d) Gently press the specimen onto the mount and move in small circles to ensure that the wax is evenly and thinly distributed. Avoid getting wax on the upper surface of the specimen.
e) Remove the mount from the hot plate and allow to cool.
f) Use chloroform or acetone and a cotton bud to gently remove excess wax from the specimen mount.
g) Until you have perfected the technique for mounting specimens, check the thickness of the wax layer. It should not be more than 3 μm.

4.5. Specimen Positioning

The magnetic specimen turntable and light microscope allow the dimple to be located at any point on the specimen disc. However, unless there is a reason to do otherwise, the dimple should be positioned close to the center of the disc to obtain the maximum benefit of a supporting rim.

a) Place the specimen mount (and centering ring) on the turntable. The turntable and bottom of the mount may be wiped with lint-free paper, moistened with a small amount of vacuum grease, to remove any dirt and to ensure that the mount slides freely.
b) Gently position the light microscope on the housing surrounding the specimen turntable. **Note**: the contacting surfaces of the microscope and housing must be clean or the microscope will not position correctly and the dimple will not be in the correct place.
c) Insert the connector into the illuminator power socket.
d) Rotate the microscope eyepiece to focus the center spot.
e) Focus the microscope on the specimen.
f) Slide the specimen mount horizontally until the desired point on the specimen coincides with the centering spot.
g) Check correct centering by turning on (Table) the turntable motor. The specimen should rotate about the centering spot. If not, check the cleanliness of the contacting surfaces of the microscope and housing.
h) Remove the microscope.

4.6. Grinding by Setting the Dimple Depth

a) Set the required load (usually about 20 g) and grinding wheel speed. Check that both motors are off and lower the micrometer.
b) Place the mount, with specimen, on the turntable and carefully, with the cam, lower the grinding wheel onto the specimen.
c) Raise the micrometer until the dial indicator has rotated just over one complete turn and the needle just reaches zero. **Note**: take care not to raise the micrometer past the dial indicator zero.
d) Zero the micrometer digital display.
e) Lower the micrometer (turn clockwise) until its display shows the required depth of dimple. The dial indicator initially displays the same reading.

f) With a cocktail stick, place a **small** amount of diamond compound on the wheel and on the specimen and moisten with distilled water.
g) Turn on both motors. The dial indicator shows the progress of dimpling.
h) The autoterminator may now be armed if required. When the dial indicator reaches within 2-3 μm of zero, it will automatically switch off the specimen turntable and grinding wheel motors. Grinding of the remaining 2-3 μm may be undertaken with reduced load and grinding speed and the progress of grinding monitored with the light microscope.
i) As the specimen nears the required thickness, it may improve the final specimen quality if the load and rotational speed of the grinding wheel are reduced.

Note: the specimen surface and grinding wheel must not be allowed to dry out and a small pocket of dilute paste should be present on the specimen at all times. It is recommended that the wheel and specimen are occasionally cleaned and fresh diamond compound applied.

4.7. Grinding by Setting the Final Thickness

a) Set the required load and grinding wheel speed. Check that both motors are off.
b) Place the mount, without any specimen, on the turntable.
c) Carefully, with the cam, lower the grinding wheel onto specimen mount.
d) Raise the micrometer until the dial indicator has rotated just over one complete turn and the needle just reaches zero. **Note**: take care not to raise the micrometer past the dial indicator zero.
e) Zero the micrometer digital display. This setting may be used for any number of specimens.
f) Raise the arm, remove the mount and attach the specimen. Replace the mount on the turntable.
g) Raise the micrometer (turn counter clockwise) until the display shows the required final thickness.
h) Carefully, with the cam, lower the arm onto the specimen - the dial indicator shows the the thickness of material to be removed. This value **plus** the micrometer reading are the thickness of the specimen plus the thickness of the mounting wax.
i) With a cocktail stick, place a **small** amount of diamond compound on the wheel and on the specimen and moisten with distilled water.
j) Turn on both motors. The dial indicator shows the progress of dimpling.
k) The autoterminator may now be armed if required. When the dial indicator reaches within 2-3 μm of zero, it will automatically switch off the specimen turntable and grinding wheel motors. Grinding of the remaining 2-3 μm may be undertaken with reduced load and grinding speed and the progress of grinding monitored with the light microscope.
l) As the specimen nears the required thickness, it may improve the final specimen quality if the load and rotational speed of the grinding wheel are reduced.

Note: the specimen surface and grinding wheel must not be allowed to dry out and a small pocket of dilute paste should be present on the specimen at all times. It is recommended that the wheel and specimen are occasionally cleaned and fresh diamond compound applied.

4.8. Polishing

Although not essential, a final polishing treatment improves the specimen quality produced by subsequent thinning. When grinding has reduced the specimen thickness to within a few microns of the final thickness required, the grinding wheel is replaced with a felt polishing wheel.

a) Remove the specimen mount from the Dimple Grinder and thoroughly clean off grinding compound with a cotton swab and distilled water followed by freon. Replace the mount on the specimen turntable and center using the light microscope. **Note**: exact re-centering is not necessary for the final polishing step.
b) Carefully lower the polishing wheel onto the specimen.
c) Apply a small quantity of 0.05 μm alumina suspension to both the felt strip and specimen.
d) Select a higher rotational speed for the polishing wheel and a load of about 25 g.
e) The softness of the felt polishing wheels makes the measuring system inaccurate. From time to time, monitor the progress of polishing with the light microscope in reflected light or in transmitted light for transparent specimens on glass mounts. The time needed to polish the specimen will vary, depending on hardness.

4.9. Specimen Removal

Once grinding and polishing are completed, the specimen is removed from the mount. Extreme care is required to prevent damage to the thinned area.

a) Slide the specimen mount off the turntable.
b) Place the specimen mount on the hot plate, set at 130 °C.
c) Wait until the wax is completely melted and then slide the specimen sideways off the mount with a cocktail stick.
d) The mounting wax must be completely removed from the specimen. Submerge the specimen in chloroform or

acetone and clean with an ultrasonic cleaner. **Note**: the use of an ultrasonic cleaner may damage some specimens. The specimens should be washed in several changes of clean solvent, until completely clean.

4.10. Double Sided Dimpling

Dimpling the specimen on both sides prior to further thinning allows the electron transparent area to be positioned at a selected depth in the specimen to view interfaces. Additionally, the residual stresses are better balanced.

It is necessary to know the original specimen thickness accurately and only the method of grinding by setting the dimple depth can be employed. Obviously, the depth of the two dimples must be set so that together they come to less than the original specimen thickness.

After dimpling the first side of the specimen, it is removed from the mount. **Note**: the specimen still needs thorough cleaning in order to ensure the accuracy of the measuring system. Care must be taken in mounting the specimen for the second time to ensure that no air bubble is trapped in the lower dimple, otherwise the unsupported thin area will collapse.

a) Place the specimen mount on the hot plate, at 130 °C.
b) Place the specimen, dimpled side **uppermost** on the hot plate.
c) Melt a **small** amount of wax at the center of the specimen mount.
d) Melt a **small** amount of wax into the dimple of the specimen.
e) With a fine pair of tweezers, carefully lift the specimen, turn it over and gently drop onto the melted wax on the specimen mount.
f) Proceed as for normal dimpling.

4.11. Final Thickness < 20 μm

For thicknesses less than 20 μm, an extended polishing process with the felt polishing wheels is followed. This is divided into two stages: Coarse Polishing and Fine Polishing. During neither stage is the measuring system used since the softness of the felt makes it impossible to obtain an accurate reading. Therefore the micrometer head should be completely lowered. Instead, the progress of dimpling is monitored by light microscopy. This technique is particularly effective and easy if glass specimen mounts are employed and the specimen is viewed with transmitted light. In the case of semiconductors, the color of the specimen, as seen with transmitted light, is closely related to thickness. For silicon, red indicates a thickness of about 10 μm while yellow indicates a thickness around 5 μm.

4.11.1. Coarse Polishing

When a specimen thickness of 15-20 μm has been reached by grinding, the specimen is thoroughly cleaned and the grinding wheel replaced with a felt polishing wheel. The coarse polishing stage is carried out with 2-4 μm diamond compound, a 30 g load and with the grinding wheel speed control set at position 5. The object of the coarse polishing stage is to remove the scratches and other mechanical damage resulting from grinding and to produce a specular surface. For silicon, the coarse polishing normally requires about 5 minutes. This period should be split into short periods, interspersed by cleaning of the specimen and wheel with a cotton swab and distilled water followed by freon.

4.11.2. Fine Polishing

The object of the fine polishing stage is to very gently reduce the specimen thickness to that required, normally less than 2 μm. A new, clean felt polishing wheel is required and a 0.05 μm gamma alumina suspension is used for the polishing compound. The specimen must be completely cleaned of the previous polishing compound. Lack of care in accomplishing this will make it impossible to thin the specimen as required. The load should be reduced to 25 g, although the rotational speed remains unchanged. The time necessary to complete fine polishing will depend on the initial and final thicknesses and the specific material. In the case of silicon, it will normally take 15 to 20 minutes to achieve a thickness of 2-3 μm. Again, this time should be broken into short periods, interspersed by occasional cleaning and careful monitoring of the progress of polishing by light microscopy.

4.12. Taper Sections

Dimpled specimens are ideal for analysis of surface segregation, platings, coatings etc. For Auger or SIMS, there is no necessity for sputtering to penetrate into the specimen, so speeding analysis, and in the case of SEM, a simple EDX elemental line trace provides an immediate depth profile. The 'depth' into the surface is calculated from knowing the diameter of the grinding wheel (2R), the radius of the dimple (r) and the distance in from the edge of the dimple (x). Then :

$$\text{depth} = x (2r - x) / 2R$$

This approximation always gives a value slightly less than the correct value, with a maximum error of less than 10%. The correct value is given by :

$$\text{depth} = \{ R^2 - (r-x)^2 \}^{1/2} - \{ R^2 - r^2 \}^{1/2}$$

5. PERFORMANCE CHECK

A complete check of the performance of the Model 656 Dimple Grinder comprises, in addition to the dial indicator zero check, the following steps :

1) Arm pivot friction
2) Load scale zero
3) Eccentricity (run-out) of grinding wheel/axle assembly
4) Vertical movement of specimen turntable
5) Grinding wheel positioning
6) Zero stop adjust

5.1. Arm Pivot Friction

To achieve an accurate response of the measuring system, the friction in the arm pivots must be very low.

a) With the cam, lift the arm off the micrometer drive, disconnect the two wires leading to the arm and temporarily secure them to the arm with sticky tape.
b) With the tip of one finger, support the arm at about 20° above horizontal. **Caution** : Take care not to drop the arm.
c) Adjust the balance of the arm with the counterweight until the arm is exactly balanced at this position. **Note**: this is **not** the zero of the load scale as the dial indicator stylus is sprung loaded.
d) Adjustment of the counterweight by ± 2 g should cause the arm to gently fall towards the horizontal or rise to about 60°.

5.2. Counterweight Scale Zero

The black load scale is friction coupled to the counterweight and is free to rotate and slide. In setting the zero of the load scale, account is taken of the spring tension in the dial indicator stylus and the weight of the grinding wheel.

a) Ensure that 4.2 Dial Indicator Zero has been performed and that a grinding wheel is in place.
b) With the cam, carefully raise the arm off the micrometer drive and support the arm by hand at approximately 30° above horizontal. Adjust the counterweight to balance the arm at this position.
d) Screw the counterweight in two complete turns - this applies the load necessary to overcome the stylus spring.
e) With the cam, gently lower the arm onto the micrometer head. The dial indicator needle will rotate clockwise and creep towards zero when the Dimple Grinder base is gently tapped. If the needle rotates hard towards zero, raise the arm and reduce the load until the needle settles within one division of zero.
f) With the arm raised on the cam, hold firmly the metal counterweight and rotate and slide the black load scale to align the zero.
g) It should be possible to position the dial indicator needle within one division of zero by adjusting the counterweight no more than ± 2 g away from the loadscale zero.

5.3. Eccentricity (Run-out) of Grinding Wheel/Axle Assembly

Excessive vertical movement of the arm makes it impossible to accurately monitor the progress of dimpling and to determine the final thickness.

a) Place a standard grinding wheel on the axle and position the specimen mount, with a specimen.
Caution: do not allow the grinding wheel to rotate against the specimen mount.
b) Ensure that the specimen turntable motor is off.
c) Set a load of 20 g and a slow rotation speed for the grinding wheel.
d) Switch on the grinding wheel motor.
e) Lubricate the grinding wheel with a drop of water.
f) With the cam, carefully lower the grinding wheel onto the specimen.
g) Adjust the micrometer drive to obtain a reading on the dial indicator.
h) The reading on the dial indicator must change by less than ±1 μm.

Should the needle move by more than this amount :

a) Clean male and female wheel bearing surfaces with lint-free tissue moistened with solvent. **Caution** : do not flood

with solvent, as this may wash grit into the axle assembly.

b) Rotate the wheel with respect to the axle and find the alignment which gives the minimum run-out.
c) Check that the grinding wheel does not have a flat. If it does, the wheel must be replaced.
d) Try another grinding wheel - if this solves the problem, the female wheel bearing surface is damaged and the wheel should be discarded.
e) If the same run-out occurs with other wheels either the male taper bearing is damaged or the axle assembly is damaged or worn. Minor damage to the male taper bearing surface can be repaired by turning on the motor at full speed and carefully lapping against the female taper of a wheel with a minute quantity of diamond compound. Do not let the diamond compound get near the axle.
f) If excessive run-out persists, the axle assembly must be replaced.

5.4. Vertical Movement of the Specimen Turntable

Excessive vertical movement of the specimen causes similar problems to excessive run-out of the grinding wheel axis.

a) Proceed as 5.3
b) Ensure that the grinding wheel motor is off and the specimen turntable motor is on.
c) The reading on the dial indicator must change by less than ±1 µm.

Should the needle move by more than this amount :

a) Check that the turntable surface and specimen mounts are clean.
b) Check the specimen mount top surface for damage, flatness and that it is parallel to its base (use a light microscope).
c) If the cause of the vertical movement cannot be identified, the complete turntable assembly must be replaced.

5.5. Grinding Wheel Position

The contact point between the grinding wheel and the specimen should be on the rotation axis of the specimen. This is more critical for spherical edged wheels than for flat edged wheels.

a) Set up the Dimple Grinder as for grinding a specimen.
b) With both the specimen turntable and grinding wheel motors switched on, carefully lower the grinding wheel onto the specimen so that contact is just made, as shown by the dial indicator, for a few seconds.
c) Raise the arm to its upper position, switch off both motors and place the light microscope over the specimen turntable. Ensure that it is correctly seated.
d) The point of contact should be visible on the specimen surface as a small, circular mark (not a ring),centered under the marker in the light microscope eyepiece. If not, first try cleaning the contacting surfaces of the microscope base and the turntable housing.
e) Turn on the turntable motor; the mark must be the center of rotation.

Special tools are used to set the x, y alignment screws which are sealed at the factory and the user should not attempt to adjust them. Contact Gatan service for advice.

5.6 Zero Stop Adjust

This procedure should only be performed if the dial indicator needle zero position is more than ± 10µm away from the 12 o'clock position.

a) Proceed as 4.2 Dial Indicator Zero but do not adjust the position of the dial indicator face.
b) With the 3/32" hexagonal tool provided, rotate the zero stop until the dial indicator needle is at the 12 o'clock position. **Note**: repeated adjustment of the zero stop will loosen it and result in a loss of accuracy.
c) Set the zero of dial indicator as 4.2 by rotating the face.

6. SPARES AND CONSUMABLES

Spare Parts

656-0117	Magnetic turntable (table only)
656-0117C	Magnetic turntable (complete with housing and bearings)
656-0137	Drive coupling
656-0126	Grinding wheel clamping screw
656-0150	Grinding wheel bearing assembly
656-0310	PC board
656-03-B1	Turntable motor with gearbox
656-03-B2	Grinding wheel motor
656-03-DS4/DS5	28V, 170mA Illuminator bulb x 5
656-03-F1	250mA Fuse x 5 (same for 115 and 230V)

Grinding/Polishing Wheels (supplied in boxes of 4)

656-0106	Spherical - specify 10, 15 or 20 mm diameter (phosphor bronze)
656-0135	Flat 15mm diameter only (phosphor bronze)
656-0154	Felt polishing - specify 10, 15 or 20 mm diameter

Specimen Mounts

656-0116	For 10 mm wheels, x 4
623-0008	For 15 mm wheels, x 4 (stainless steel or pyrex glass)
656-0140	Centering ring for 623-0008
656-0142	For 20 mm wheels x 4

Consumables

656-04-001	5 g syringe of diamond polishing compound, 2-4 µm
623-00-006	Mounting wax (12 rods, 3.5 mm x 32mm)
656-00-002	Container of 0.05 µm alumina polishing suspension
656-01-040	Adhesive polishing strips for 656-0154 (packet of 50)-specify wheel diameter

7. WARRANTY

7.1 Mainland USA

Gatan warrants its products to be free from defects in materials and workmanship for a period of one year from the date of receipt of the instrument by the purchaser. Consumable, expendable and spare parts are not included in this warranty. Upon prompt notification by the purchaser, Gatan will correct any defects in the instrument either by repair in its own facilities or by replacing the defective part or by any other means that Gatan deems appropriate. Shipping and packing charges will be paid by Gatan for items sent to the purchaser but the purchaser is responsible for all charges incurred in the return of items to Gatan.

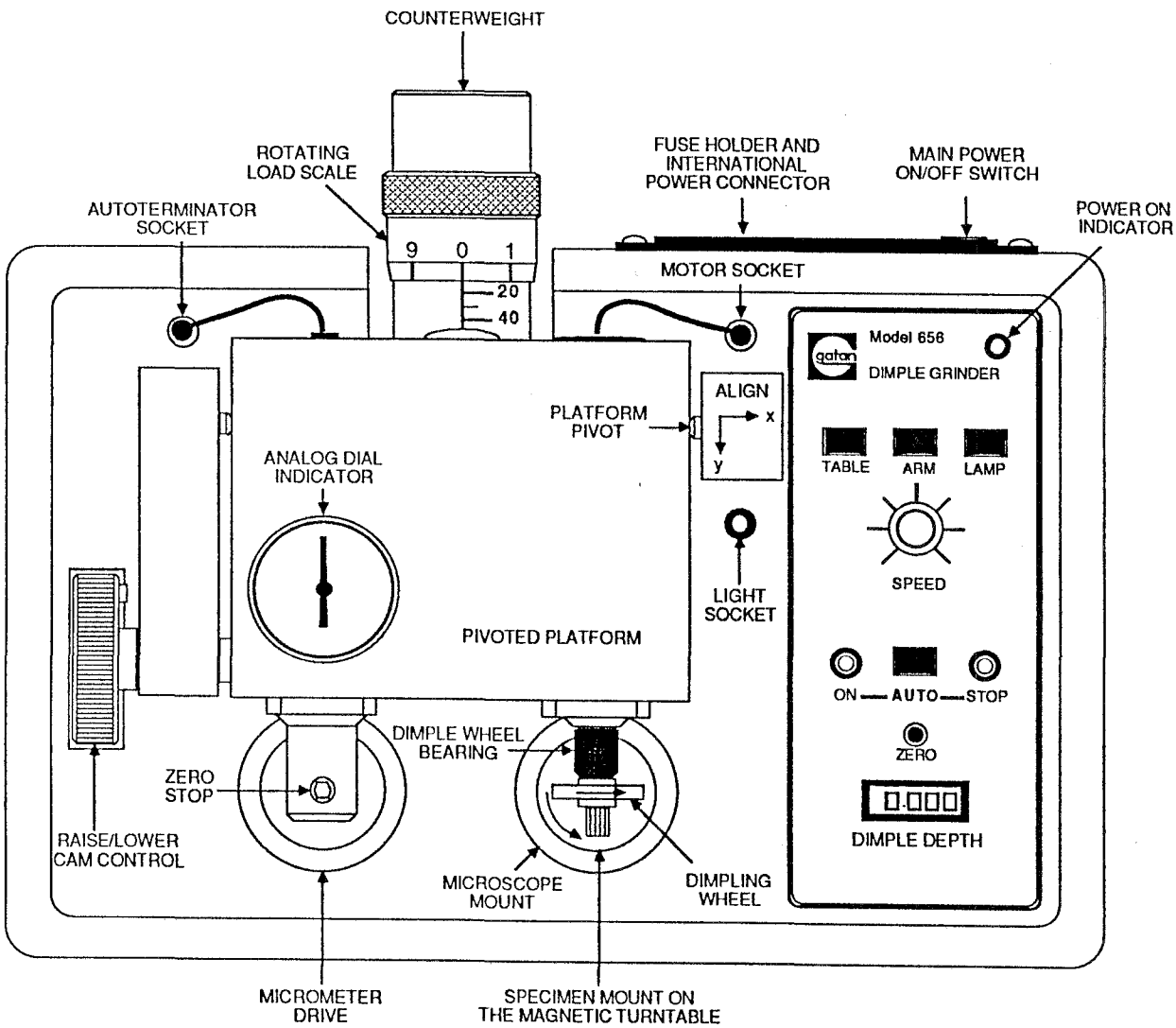
This warranty does not cover any faults resulting from improper operation or maintenance or the failure to follow the instructions in this manual. Operators should take particular note of the warnings or cautions contained in this manual or otherwise communicated. Operator maintenance must not exceed or deviate from that detailed in the appropriate section of this manual. If service is requested during the warranty period to correct faults arising from improper maintenance or operation or the failure to follow recommended procedures then Gatan will charge the standard service rates. Gatan alone will decide if any fault, defect or failure is the consequence of misuse, modification, incorrect operation or abnormal conditions of operation.

Gatan reserves the right to make changes in the design, operation or construction of its products at any time without incurring any obligationto make any changes whatsoever on previous units. However, Gatan will endeavor to ensure that it is possible to retrofit design improvements to previous instruments. The purchaser will be responsible for all costs incurred in undertaking such modifications.

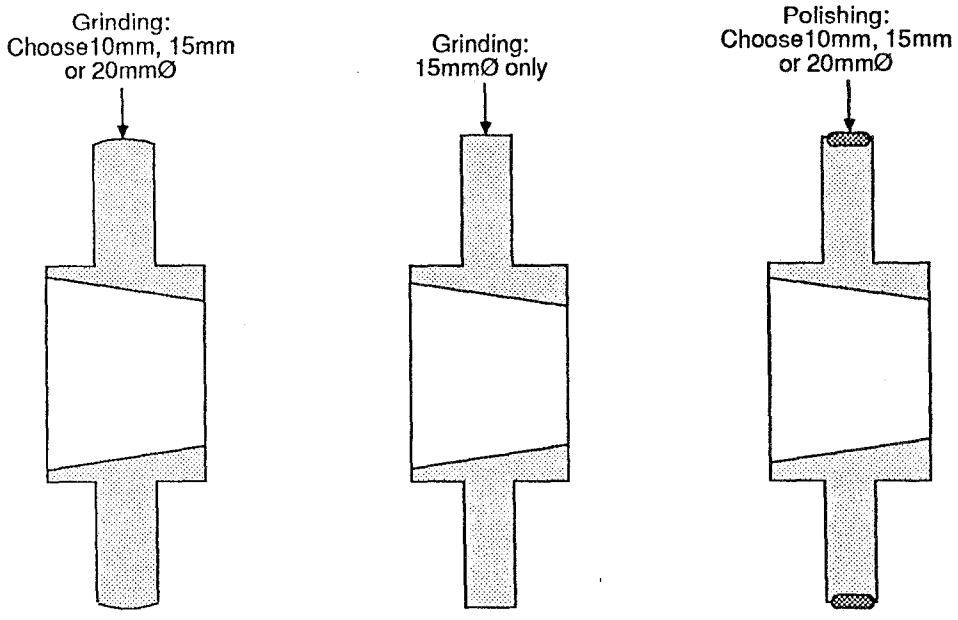
This warranty is expressly made by Gatan and accepted by the purchaser in lieu of all other warranties including warranties of merchantability and fitness for particular purpose whether written, oral, implied or statutory. Gatan neither assumes nor authorizes any personto assume for it other liabilities with respect to its products. Gatan shall not be liable for normal wear and tear, not for any contingent, incidental or consequential damage or expense due to partial or complete inoperability of its products for any reason whatsoever.

7.2 Outside Mainland USA

In general, the above terms apply outside the USA but it is the responsibility of the purchaser to check with the appropriate Gatan distributor for the warranty terms applicable in that distributors area.



Notes:
1. Special instruments are used to set the x,y alignment screws. The screws are sealed at the factory and the user should not attempt to readjust them.
2. The dimpling wheel bearing is the most critical component of the Dimple Grinder. Be careful not wash abrasives into it by excessive use of cleaning fluids around the grinding wheel.



Note: When replacing the felt strips the wheel rim must be immaculately clean and free from grease to achieve good adhesion.

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Figure 2 . The different types of wheels available

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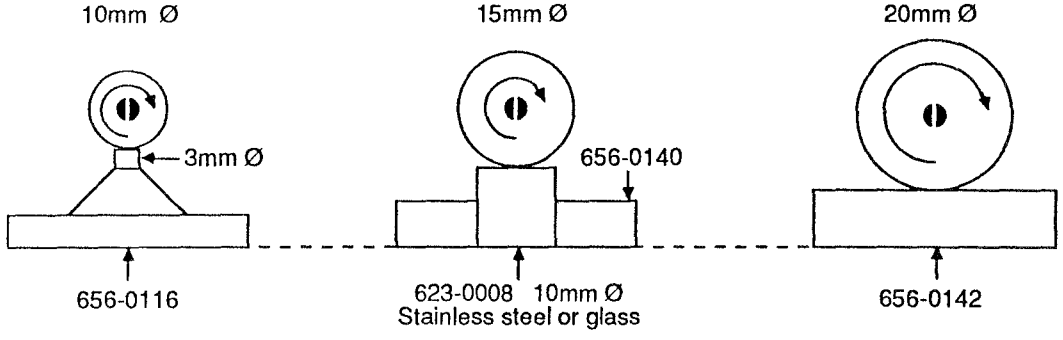

The specimen mounts used for different sized wheels all sit on the same base line and have heights chosen so that the grinding wheel axis is always horizontal.

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Figure 3. The specimen mounts used for 10mm, 15mm and 20mm Ø wheels

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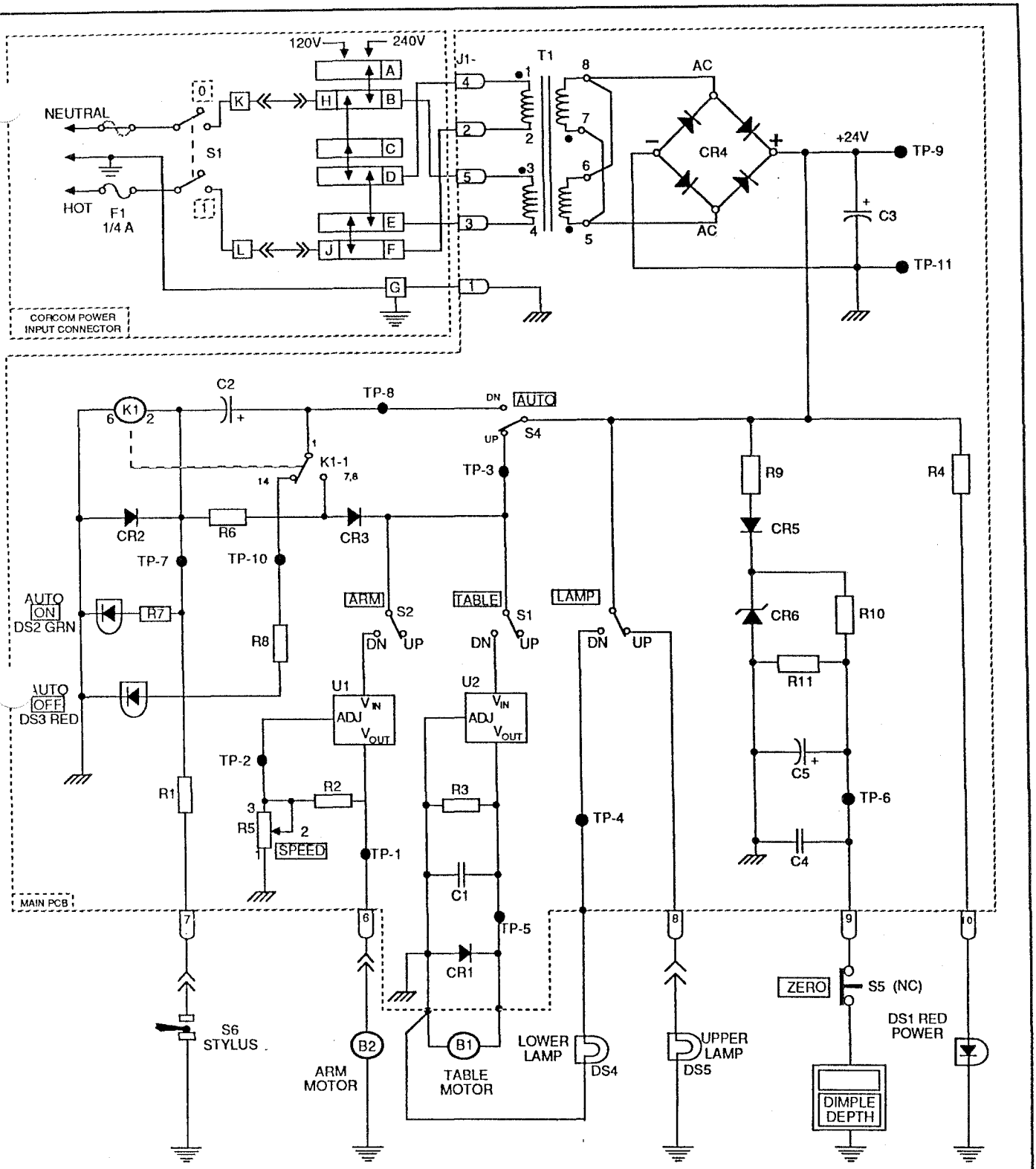

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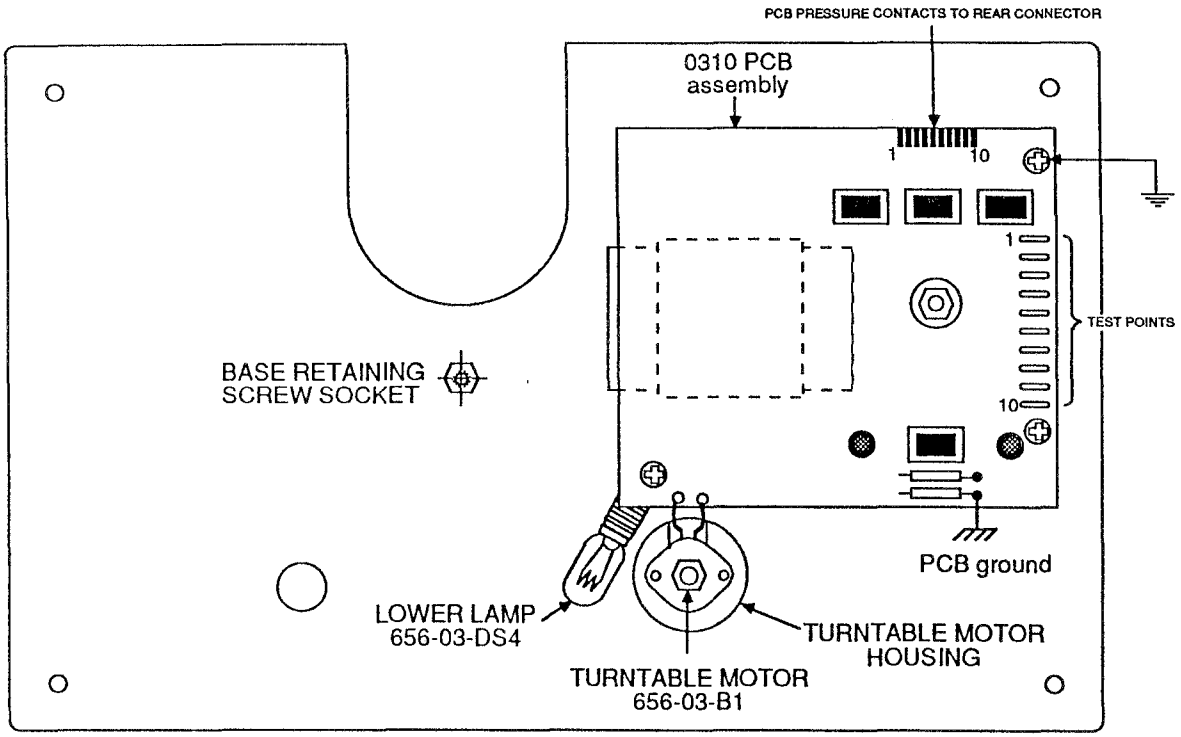
Figure 4a Circuit Diagram of Model 656 Dimple Grinder



Electrical parts list (See Figure 6a)

656-03-B1,B2	Motor
656-03-C1	1μF 50V
656-03-C2	10μF 50V (electrolytic)
656-03-C3	470μF 35V(electrolytic)
656-03-C4	0.1μF 25V
656-03-C5	100μF 50V(electrolytic)
656-03-CR1	1N4008
656-03-CR2	1N4148
656-03-CR3	1N4004
656-03-CR4	Bridge 2A 400V
656-03-CR5	1N4148
656-03-CR6	Zener 1N751 5.1V
656-03-DS2	LED green MV5453
656-03-DS3	LED red MV5753
656-03-DS4	Lamp #1821, 28V
656-03-K1	Relay #W172DIP-3 (12V)
656-03-U1,U2	Regulator IC Adj LM317T
656-03-R1	10Ω 1/4W CF
656-03-R2	470Ω 1/4W CF
656-03-R3	240Ω 1/4W CF
656-03-R4	1KΩ 1/4W CF
656-03-R5	5KΩ variable
656-03-R6	100Ω 3W oxide
656-03-R7	330Ω 1/4W CF
656-03-R8	1.8KΩ 1/4W CF
656-03-R9	2.2KΩ 1/4W CF
656-03-R10	750Ω 1/4W CF
656-03-R11	330Ω 1/4W CF
656-03-S1,S2,S4	Switch DPDT/ALT
656-03-S3	Switch DPDT/MOM
656-03-T1	Transformer 115/230//17V

Test point voltages* (remove speed control knob and lift off panel to expose test points. Perform tests with power on).

1. Arm motor voltage, 1.2V to 13.9V, as set by SPEED control (ARM switch on, AUTO stop off). May also be read at arm motor jack.

2. Arm motor regulator control voltage, 0V to 12.7V, as set by SPEED control (ARM switch on, AUTO stop off).

3. Motor power, +22 to +26V (AUTO stop off).

4. Lamp power, +22 to +26V when LAMP switch is pressed.

5. Table motor power, +1.2V (TABLE switch on, AUTO stop off).

6. Digital micrometer power, +1.5V

7. Auto stop latch, normally 0V. When AUTO stop mode is on (switch in) reads +12 to 14V until auto stop point is reached. May also be read at stylus jack.

8. Auto stop mode power, 22 to 26V when AUTO stop switch on.

9. Main DC power, 22 to 26V (unregulated, nominally +24V).

10. Auto stop limit. Normally 0V, switches to +24V when AUTO stop switch is in (on) and grinding limit is reached.

*Electrical servicing should only be performed by a qualified electrician.

Replacing lower lamp or turntable motor *

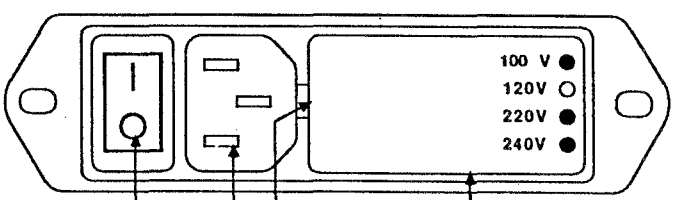
1. Remove power cord from Corcom connector.

2. Remove base retaining screw at top of casting and lift dimple grinder base straight up to expose electronics .

3. Unscrew the light bulb or unsolder motor/gearbox leads (as appropriate) and replace with correct spare part. The motor/gearbox can be removed from its mount simply by pulling up on the hexagonal shaft. The new motor is installed in the reverse manner.

4. Carefully lower base onto electronics platform and firmly tighten base retaining screw.

Replacing a fuse or changing input voltage



1) Switch off ac power.

2) Disconnect ac power cord

3) Pry out fuse cover here to expose fuse (1/4A 250v). Replace new fuse in reverse manner

4) To change line voltage withdraw voltage selector card from housing and rotate 180° in plane of card. Move white plastic indicator to opposite edge of card. Reinsert card and replace fuse cover.

5) Verify that white pin now appears in the correct voltage marker hole of fuse cover.

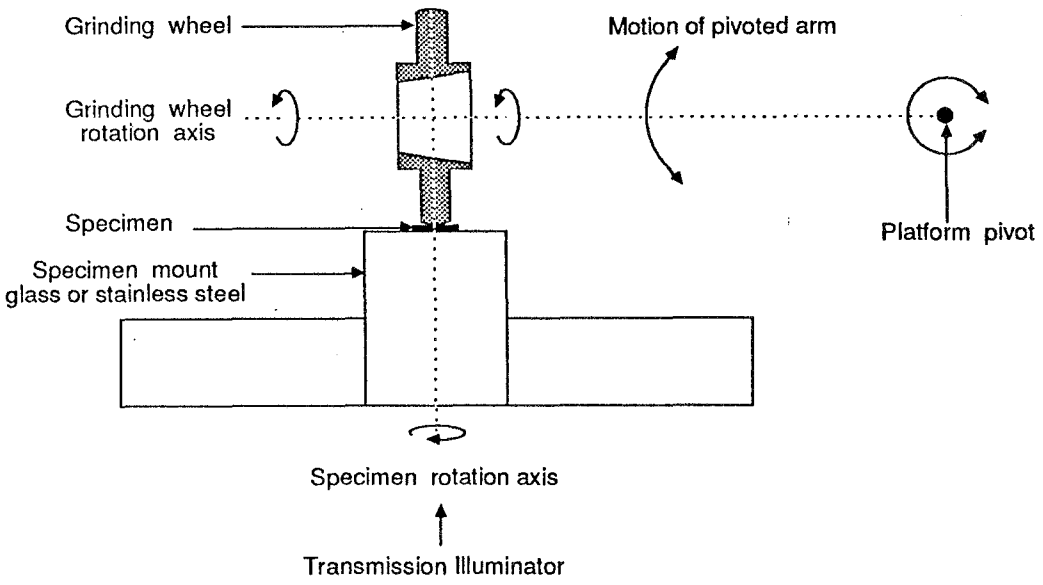


Figure 5 . Specimen rotation and grinding wheel axes

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Note: The angular tilt (ß) of the grinding wheel axis has been greatly exagerated for clarity. If the geometry shown in this drawing applied in practice then the large wheel would produce a doughnut shaped dimple. The Model 656 overcomes this problem by varying the height of the specimen mounts so that the grinding wheel axis is always horizontal , i.e. ß=0°

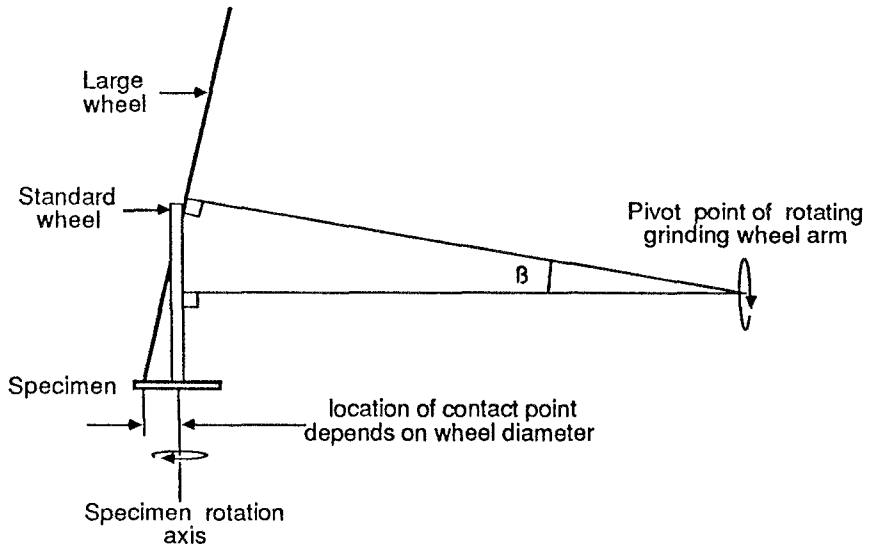

Figure 6 . Illustrating why grinding wheel rotation axis should not be tilted

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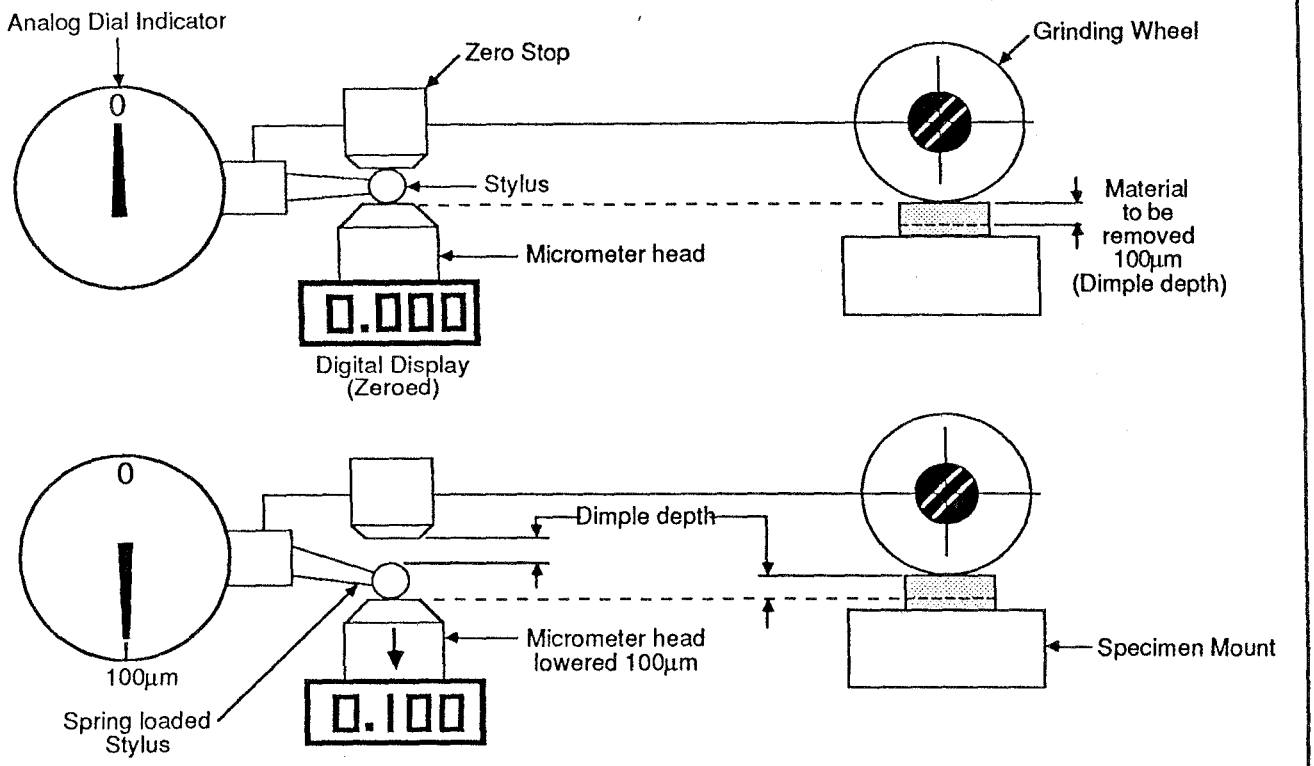

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Figure 7a. Grinding By Setting Dimple Depth

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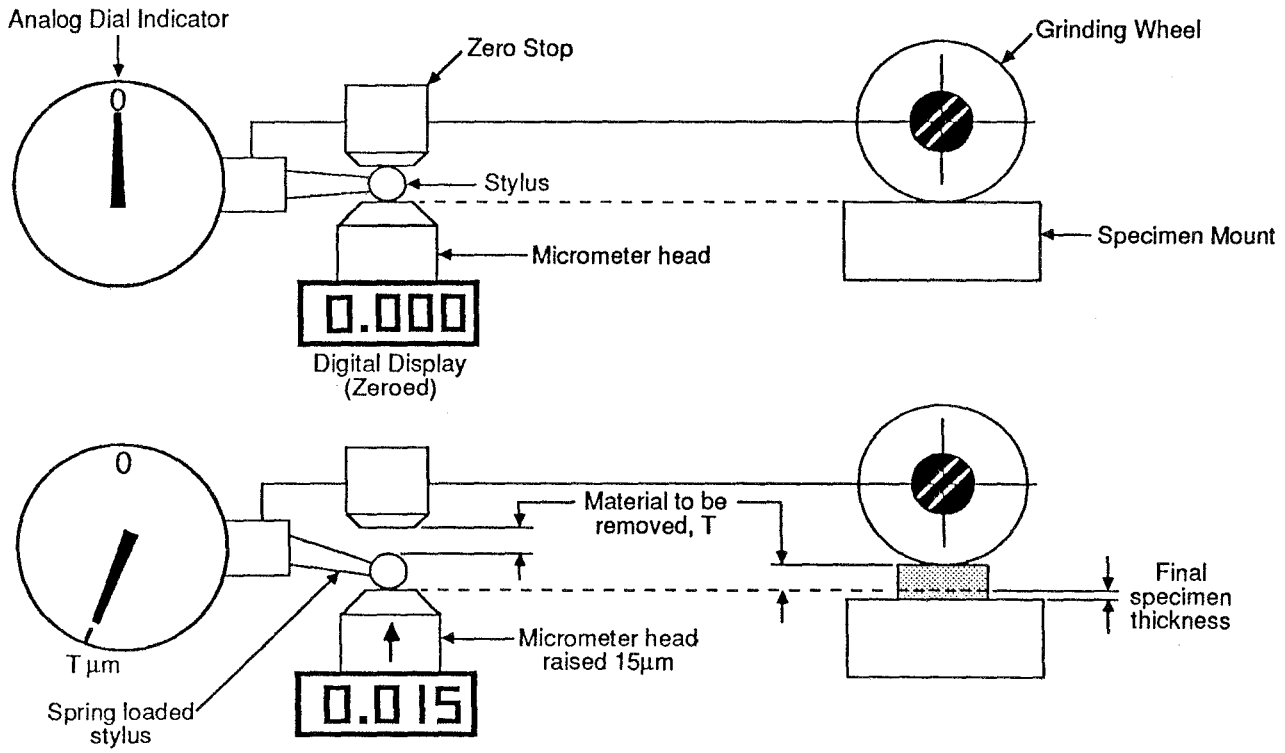

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Figure 7b. Grinding By Setting Final Specimen Thickness

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