FEI CM20UT CompuStage Instructions

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The CompuStage is a motor-driven goniometer that provides computer-controlled movement of the specimen on five axes (X, Y, Z, α, β). The CompuStage consists of the following elements:

- Hardware (the goniometer), including motor drives and position-measuring system.
- Control electronics, including a dedicated microprocessor.
- CompuStage server software which provides the link between the user interface (software and hardware controls like the track ball for X-Y motion) and the CompuStage microprocessor.
- Hardware controls, consisting of a track ball for X-Y motion and pressure-sensitive up-down switches for Z, α, β.
- User interface software with translates operator input into goniometer actions. The definition of the physical position of the stage axes in the microscope column is covered in a separate section.

1 Specimen holders

The CompuStage can be equipped with a variety of holders, which are inserted or removed via an airlock. Specimen holders are inserted into ultra-high vacuum and must be kept clean. Special handling instructions for specimen holders should be adhered to.

2 Eucentric height

The a tilt of the CompuStage is constructed in such a way that it is possible to tilt around it without having large apparent movements of the point of interest on the specimen. This is called eucentric tilting and is achieved by bringing the point of interest to the same height (with the Z axis) as the a tilt axis itself: the eucentric height. The eucentric height is important because it not only provides an easy way of tilting without having to correct specimen position continuously, but it also defines the reference point inside the microscope for all alignments, magnification, camera lengths, and so on. In general one should work at the eucentric height (the only reason for deviating could be that at very high β tilts and specimen positions away from the center, the range of the Z axis may not be sufficient to bring the specimen to the eucentric height).

2.1 To set the specimen to the eucentric height

2.1.1 Method 1 Eucentric Focus Preset

Once the microscope has been aligned (as it normally should be), the eucentric focus preset (obtained by pressing the Eucentric Focus button) sets the objective-lens setting to the correct value for a

[1]These updated instructions for the FEI CM20UT CompuStage are adapted from the Technai F20/30 column manual.

specimen that would be exactly at the eucentric height. If the specimen is not at the eucentric height, it will appear out of focus. If you now bring the specimen into focus by changing the Z height, not the focus, it will go to the eucentric height. It may help to switch on the wobbler, since the apparent displacement between the two wobbler images makes it easy to see whether the height is changed in the right direction (the displacement between the images becomes smaller).

2.1.2 Method 2 The Alpha Wobbler

Since the image displacement on tilting is minimised at the eucentric height, the eucentric height can be set by minimising the displacement while the stage is tilting. For this purpose the CompuStage has the Alpha Wobbler function. When this function is activated, the CompuStage is tilted continuously between two preset tilts (typically -15 and +15°). Change the Z height to make the displacement smaller. When the displacement is minimised the specimen is at the eucentric height.

3 Safety features

For safety the CompuStage is equipped with a number of special features like the MaxiTilt system which allows maximum use of the available space between the pole piece for tilting while guarding against damage of holder, pole pieces and other objects in the pole-piece gap like the objective aperture holder.

Another feature is the sEntry system which guards against insertion of holders that are incompatible (too big) for the objective-lens pole-piece configuration of the microscope.

3.1 MaxiTilt system

Because tilting takes place around the eucentric point, the motion of the specimen holder may require a lot of space (see picture below). In the restricted space available between the pole pieces of some objective lens types, there may not be enough room to tilt very far. But the pictures above demonstrate that the available tilt range is very much dependent on the position of the stage (mostly the Y and Z axes). The MaxiTilt system of the CompuStage provides a flexible way of keeping the tilt within a safe range, while at the same time maximising the tilt available. The MaxiTilt senses what the maximum tilt is for the current stage position. If this range is exceeded (a situation called a pole hit), the CompuStage will move a little bit back on the axis that was changed last.

If there is no axis identifiable, the β or α tilt will move back. The microscope will display an information message that a pole hit has been detected.

3.2 sEntry system

The CompuStage is equipped with a SafeEntry (or sEntry) system that prevents holders from being inserted into microscopes where the objective-lens pole-piece configuration is not compatible with the particular holder (like thick holders into objective lenses with a gap that is too narrow for the holder to fit).

The sEntry system consists of a key (a pin varying in shape and diameter) on the holder defining the holder dimensions and a lock on the CompuStage defining the pole-piece configuration. The length of the sEntry key is such that if an incompatible holder is inserted, the key (blocked by the lock) prevents the holder from going between the pole pieces.

Although older specimen holders designed fo the manual goniometer will fit in the CompuStage (provided their O-ring is exchanged for a – thicker – CompuStage O-ring), these holders are not equipped with a sEntry key and may therefore be unsafe with objective pole-piece configurations with narrow gaps such as the U-TWIN.

4 Red CompuStage light

The red CompuStage light has a more generic function than previously used on manual goniometers. It simply means that no airlock actions (insertion or removal) should be executed. This will happen of course while the airlock is being pumped when a holder is inserted into the microscope. It can also mean that it is unsafe to extract the holder under the current conditions (when the β tilt is more than 5 degrees or during movement the red light will also be on). In that case, the unsafe situation must be rectified before the holder can be extracted (reset β tilt to zero or wait until movement is finished).

5 Homing

Before the CompuStage is ready for use (when the microscope has been switched off altogether or after the CompuStage has been disabled), it must be homed, a procedure in which it finds the zero positions.

During homing the CompuStage will move each of the four fixed axes (X, Y, Z and α; the β tilt axis is homed separately whenever a double-tilt holder is inserted) to one extreme. Because of the high tilt applied, this procedure must be executed without a specimen holder. In order to make sure that there is no specimen holder present, the microscope has to ask the operator to identify the specimen holder (which in this case should be 'No specimen holder', otherwise the homing cannot proceed).

If no user interface is active, there is no way for communicating with the operator. Consequently, the homing procedure after a start-up will only proceed once the user interface has started. Even if the user interface does not show a message to select a specimen holder after a restart of the microscope, but the CompuStage does not move (easily checked by moving the right-hand track ball a bit), it is very likely that the CompuStage has not been homed. Select the Stage Settings Control Panel and press the Enabled button. The homing procedure will start.

6 Parking position

Occasionally it is necessary to get the specimen and/or specimen holder out of the way (for example, when no electron beam is visible initially or in some alignment steps if the specimen blocks the beam). Although it is possible to retract the holder fully and turn it slightly (the initial part of removing the specimen holder), it is better not to do this, because it can lead to a potential leak. The preferred method to 'remove' the specimen holder is to retract[2] it about one or two centimeters and stick something elongated (a pen with a diameter of a centimeter or so will do nicely[3]) between the inside

[2]Always retract the holder slowly to allow the O-ring to keep the seal.

[3]Manual-goniometer specimen holders with the sapphire at the end have a longer tip than CompuStage holders and must be retracted at least three centimeters before they are clear from the field of view.

cap of the holder and the CompuStage. The 'elongated' item will prevent the holder from moving back in and the distance is sufficient to remove any obstruction from the field of view.

7 Specimen-holder handling

7.1 Specimen-holder selection

There are two ways for informing the microscope which specimen holder is being used:

- **Not automatic:** Each time a holder is inserted, the holder must be selected from the list that pops up in the message area of the Tecnai user interface.
- **Default:** Only for single-tilt holders, the last-used setting is selected automatically.

The CompuStage is equipped with the sEntry system. Associated with this system is an up-down switch on the outer panel of the CompuStage. The top part of the switch depends on the type of objective lens (with smaller lens gaps, the hole in the top is made smaller so only specific types of holders will fit).

The shield of the CompuStage showing the position of the holder-selection switch (gray). The switch itself is controlled by a notch in the lower rectangle. The actual shape of the top of the switch varies and on some microscope will block the sEntry key of the specimen holder from being inserted.

- In the up position (left-hand picture above), the Default holder selection is enabled. In this case the microscope will automatically select a single-tilt holder. In case there are more single-tilt holders present on the system (e.g. normal single- tilt and cryo holder), the holder selected is the last one chosen. If there are more single-tilt holders present, then for the first insertion, move the switch down, insert and identify the holder you are using, then move the switch up again. Thereafter the microscope will automatically select the same holder again.
- In the down position, the holder used must be identified by the user. This must always be done for double-tilt holders (the reason this is necessary has to do with the β tilt cable which must be connected before the holder can be inserted into the microscope), so do not use the switch up position with double-tilt holders.

7.2 Handling instructions

Specimen holders are a bridge between the air pressure outside the column and the ultra-high vacuum inside. Their cleanliness is an important factor in keeping contamination down (specimen holders are the second-most important source of the contamination - specimens themselves are the primary source nowadays). Caution should therefore applied to handling specimen holders. The following instructions should be adhered to:

- Always use clean nylon or similar gloves when handling specimen-holder parts that enter the vacuum (that is, between the tip of the holder and the sealing O-ring).
- Clean the tip of the holder only with special cleaning fluids or with a fresh piece of window-cleaning (chamois) leather.

- Specimen, spacing washers and clamping devices should be manipulated only using pointed tweezers or the tools provided. Tools like the hex-ring tool or the needle for levering the single-tilt holder clamp should never be touched by hand on the wrong side (in the case of the hex-ring tool the use of gloves is advised because it is easy to pick it up at the wrong end). Clean the washers, tools and tweezers on a regular basis.

- The O-ring on the specimen-holder rod should be checked for possible dirt or excessive quantities of grease although it should not be completely dry. A very light coating of Fomblin grease (supplied with the microscope) is advised. Take care not apply grease to the conical part of the holder (the part between the thicker and thinner sections of the rod). The conical part is the area where the holder is 'seated' in the CompuStage. Any grease there will very likely result in drift in excess of specimen.

- When a specimen holder is not in use, insert it in the protective holder cover supplied or reinsert it into the microscope. The latter keeps the holder thermally equilibrated with the microscope and CompuStage, thereby reducing drift after holder insertion (especially if there is a considerable temperature difference between the room and the microscope column).

7.3 Inserting a specimen into the single-tilt holder

(Instructions for mounting specimens in other holders are covered in the manual accompanying these holders.) Note: For easy removal of specimens from the holder, a notch is provided on the holder (see the images below). One tip of a pair of tweezers can be inserted in this notch underneath the specimen (once the clamp has been lifted), making it easy to take the specimen out of the holder.

- If necessary, remove the cap at the end of the tube of the specimen-holder cover.

- Check that the tip of the holder and the clamping device are clean and dry.

- Keep one hand against the cap of the holder, making sure it cannot move out of the cover tube.

- Fit the tool (stored in one of the holes in the supports of the cover tube) into the hole in front of the clamp. Then lift the clamp to its fullest extent.

- Place the specimen in the (roughly) circular recess of the specimen-holder tip. If the specimen is on a re-insertable grid, place the 'ear' of the grid in the 'ear' recess.

- Carefully lower the clamp with the tool onto the specimen. Make sure the specimen remains correctly in position. **Caution:** The specimen-securing clamp must be lowered carefully, otherwise the specimen and/or clamp can be damaged.

- Retract the holder slightly in the cover and turn it upside down. Tap the cap at the end a few times. Turn the holder back and check that the specimen has not moved (movement is a sign that it isn't clamped properly). Note: Never mount magnetic specimens (disks) in the single-tilt holder. The clamp is normally not strong enough to prevent the specimen from flying out due to the objective-lens magnetic field and sticking to the objective-lens pole pieces.

7.4 Inserting a specimen holder into the microscope

Caution: The following instructions apply to all specimen holders and must be followed completely or damage to airlock, specimen holder or specimen stage may result.[4]

The FEG microscopes are equipped with a turbo-molecular pump: The turbo-molecular pump (which should not remain running under normal microscopy because of the vibrations it causes) takes several minutes (2-3) to reach operational speed. To speed up specimen exchange, it is advised to switch the pump on (use the toolbar button) before extracting the holder. By the time the specimen has been exchanged the turbo-molecular pump will be near or at its operation speed and pumping on the airlock will begin (almost) immediately. Switch the pump off again after the holder has been inserted fully into the microscope.

If the turbo-molecular pump is running on when the specimen holder is inserted into the airlock, the pump will first spin up and only after a few minutes start pumping on the airlock. In this situation (holder triggers the pump), the pump will be switched off automatically after pumping on the airlock has finished.

The specimen airlock of the CompuStage and the specimen holder consist of fine, high-quality mechanics. If considerable force is needed for any manual actions on the holder or CompuStage, it is a sign of something being wrong. It should never be necessary to exert strong force and doing so may well result in damage to specimen holder or CompuStage.

It is not necessary to switch off high tension or filament during specimen-holder insertion, since the gun is separated from the column by the gun valve (V7) which is closed during specimen insertion (even if the user doesn't close the column valves, the microscope will automatically do so when it detects that a specimen holder has been inserted; it is good practice, however, to close the column valves before extracting the specimen holder from the microscope so they will still be closed when a holder is inserted again). It is advised, however, to keep the column valves closed after insertion of the holder (typically for a few minutes) while the specimen-area vacuum recovers – if only to reduce contamination of the specimen. Using the cold trap is advised to trap water vapour quickly (ion-getter pumps have difficulty in pumping water).

Always carry out the complete insertion procedure. If the specimen is left in a retracted position, vacuum leakage can occur with consequent contamination (or, if left for a long period, loss of vacuum in the airlock and a crash of the column if the specimen holder is then inserted). If you do not want to insert the specimen holder after all (or if the airlock isn't pumped properly, for example because of a leaking O-ring), leave the airlock cycle to finish pumping (the red LED on the CompuStage goes off) before removing the holder from the airlock. Do not extract the holder while the airlock is being pumped. The specimen holder is introduced through a pre-pumped airlock which ensures that air, introduced with the holder, is pumped away before the airlock is opened to the microscope column.

7.5 Procedure

- Hold the specimen holder with the airlock trigger pin parallel to the small slit in the CompuStage front plate (at roughly four o'clock). Carefully insert the end of the specimen holder into the airlock cylinder and slide the holder in until a stop is reached. At this point the prepumping of the airlock will start as indicated by the red CompuStage light which will be illuminated. If the light does not come on, the trigger has not been positioned correctly.

[4] Read the specimen-holder handling instructions before proceeding.

Slowly turn the holder slightly to the left and the right until it will go in a bit further (the airlock trigger pin now falls properly into its groove).

- The Tecnai user interface will display a message asking for identification of the specimen holder. Select the type of holder from the list and press the Enter button.

8 Stage movement

The specimen stage movement is controlled by a track ball (normally the right-hand one, but the assignment can be changed by the user) and/or by Multifunction knob. The movement has two modes of operation:

- The track ball (discontinuous movement) mode.
- The 'joy stick' (continuous movement) mode.

In the track ball mode (the default) the stage will move whenever the track ball has been moved, in the direction and with a displacement related to the direction and displacement of the track ball. As soon as the track ball stops moving, the stage will stop moving as well. For normal operation at moderate to high magnifications this is the preferred mode. However, for searching at low magnifications the track ball mode requires that the user keeps moving the track ball continuously.

In the 'joy stick' mode the stage will move in the direction indicated by the movement of the track ball and with a speed related to the displacement of the track ball, and the stage will keep moving in the indicated direction without requiring further input through the track ball. The direction and speed of movement can be influenced by further control of the track ball. To stop the stage movement in the 'joy stick' mode, press one of the track ball buttons.

Switching between the two modes is achieved by pressing the two track ball buttons simultaneously.

8.1 Speed control

The speed of movement of the stage is related to three parameters:

- The speed value setting (1 to 9) as defined by pressing the left- (speed down) and right-hand (speed up) track ball buttons.
- The current magnification.[5][6]
- The displacement of the track ball.

[5] One exception is at the lowermost speed setting. In this case the CompuStage will make its smallest steps, independent of magnification. At low magnifications this may mean that the stage doesn't seem to move at all. If the latter is the case, click once on the right-hand track-ball button to switch the speed one step up.

[6] At very low magnifications the speed control may appear to function no longer (speed up doesn't increase the speed of the CompuStage). This means that the CompuStage has reached its maximum speed and can go no faster.

8.2 Specimen stage movement by Multifunction knob

The specimen stage movement can also be assigned to the Multifunction knobs. In this case the Multifunction knobs duplicate the track ball directions (that is, Multifunction X = track ball X). The knobs are thus not connected directly to a stage axis (technically this is not possible within the software architecture). For most microscopes this means that the X axis (the direction of the a tilt axis) is approximately connected to the Multifunction Y knob.

8.3 Stage Axes

The CompuStage is a goniometer with five axes. Three of these are orthogonal translation movements X, Y and Z. The other two are mutually perpendicular rotation movements, a and b. The a tilt is parallel to the X axis and b tilt parallel to the Y axis.

The orientation in space of these axes can only be described at a tilt at 0° (since the other axes are mounted on top of the a tilt, they will change their orientation with it). At a tilt 0° the X and Y axes are horizontal and the Z axis vertical. The X axis runs along the rod of the specimen holder. If you look down on the microscope and define the front of the microscope as south, the X axis thus runs NW-SE, with SE in the + direction and the Y axis NE-SW with NE as the + direction. Up is the + direction of the Z axis.

The X axis describes a truly linear motion, the Y and Z are in fact circular motions but with such a wide radius that the motion remains close to linear. The Y and Z motions cause the specimen holder rod to pivot around the conical face where it narrows down, just beyond the O-ring.

Because of this pivoting motion, the end of the holder on the outside of the CompuStage moves in the opposite direction! Below is a schematic 3-D view of the specimen holder tip and the orientation of the stage axes.

Note: The notation differs from that on the earlier CompuStage of the CM microscopes where the sign of the X and Y axes is reversed.