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Instruction Manual

for

MODEL S-2500
SCANNING ELECTRON MICROSCOPE

Part No. 48E-8001
YN-T (HYR-LT)

MODEL S-2500
SCANNING ELECTRON MICROSCOPE

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ANALYSIS OF DEFICIENT IMAGES IN SCANNING ELECTRON MICROSCOPE

PRECAUTIONS ON HANDLING

For the sake of safety, the following points should be taken into consideration.

1. PRECAUTIONS FOR TRANSPORT

(1) Do not lift the instrument by holding the table. The strength of table fitting is not sufficient for bearing the weight of display unit which weighs about 145 kg. Should the table be lifted, the display unit might slip off and crash.

(2) The housing supports should be fitted in place before transport.

2. PRECAUTIONS FOR POWER CONNECTION

(1) When removing the cover of the main console and the front/rear covers of the display unit, turn off the AC power without fail. The internal high voltage circuit constitutes a shock hazard.

(2) Connect the grounding wire correctly. Otherwise, not only will the instrument fail to operate normally but there is a shock hazard.

(3) Avoid touching the connector of high voltage unit and the cable head of high voltage transformer. The high voltage unit and the high voltage transformer are at voltages as high as 0.5 ∿ 30 kV, so handling of dangerous parts such as high voltage connector and cable head should be left to the servicemen.

(4) Do not touch the areas marked DANGER. These areas are supplied with high voltage.

(5) Do not touch the rear of cathode-ray tube. The tube is supplied with about 10 kV.

(6) When replacing a fuse, turn off the main switch on the switchboard, and make sure that the AC power supply is cut off. If not, AC power line near the fuse box may cause shock.

(7) Before replacing the scintillator, make sure that the [DISPLAY POWER] switch is turned off.

Otherwise, a shock hazard might be caused since some parts around the scintillator carry a high voltage of 10 kV unless the switch is turned off.

(8) Allow an interval of at least 30 seconds between turning on and off the [EVAC POWER] or [DISPLAY POWER] switch.

(9) Replace the oil filter of the oil rotary pump every 6 months.

3. GENERAL PRECAUTIONS

The maintenance items other than those described in this manual should be left to the servicemen.

4. MEASURES FOR EMERGENCY CASE

(1) Turn off the main switch on the switchboard.

(2) If water is leaking, close the valve of cooling water to cut off the water supply.

(3) After taking steps (1) and (2), carry out other suitable measures.

(4) Inform the service shop.

5. MEASURES AT POWER FAILURE

(1) Set both the [EVAC POWER] and [DISPLAY] switches to [OFF].

(2) Turn off the main switch on the power distribution board.

(3) To energize the electron microscope again, follow the instructions given below.

(a) Turn on the main switch on the power distribution board.

(b) Set both the [EVAC POWER] and [DISPLAY] switches to [ON].

6. MEASURES AT WATER SHUTOFF

(1) Set the [EVAC POWER] and [DISPLAY] switches to [OFF].

(2) Turn off the main switch on the power distribution.

(3) If cooling water is shut off, or if water flow rate is extremely reduced, the overheat protection circuit is automatically activated. (At this time, a buzzer keeps sounding to warn the operator.)

Set the [EVAC POWER] switch to [OFF], and then eliminate the cause of overheat. Then, set back the [EVAC POWER] switch to [ON].

After eliminating the overheat cause, be sure to wait for at least 15 minutes before setting back the [EVAC POWER] switch to [ON].

7. OTHERS

(1) Keep the instrument installation room under the following conditions even when the instrument is not in operation.

Room temperature ..... 5 ∿ 35°C

Relative humidity ..... Less than 70 %

Evacuate the instrument at least one day every week even if the instrument is not used for a long time.

(2) Do not locate the DP drain port 20 cm or more above the installation floor.

SPECIFICATIONS

(1) Standard Specifications

	Item	S-2500 (With Standard Specimen Stage)
Performance	Secondary electron image resolution	35 Å guaranteed
	Magnification	20 ∿ 100,000× (WD = 35 mm) 500 ∿ 200,000× (WD = -2 mm)
Electron optical system	Accelerating voltage	0.5 ∿ 3 kV in 100 V steps 3 ∿ 30 kV in 1 kV steps
	Beam current	300 μA max.
	Filament	Pre-centered hairpin type
	Bias	Auto bias system
	Filament exchange	Requires air leak
	Alignment	2-stage electromagnetic alignment
	Lens system	3-stage electromagnetic lens reduction system (high-excitation objective lens)
	Objective lens aperture	Movable aperture (4 openings selectable and finely adjustable from outside vacuum) Self-cleaning type thin film aperture
	Stigmator coil	Electromagnetic
	Scanning coil	2-stage electromagnetic deflection system
Specimen goniometer stage	Shiftable range	X ..... 0 ∿ 80 mm Y ..... 0 ∿ 40 mm Z ..... 5 ∿ 35 mm (continuous) Tilting ..... -20 ∿ +90° (continuous) Rotation ..... 360° (continuous)

(cont'd)

	Item	S-2500 (With Standard Specimen Stage)
Specimen goniometer stage	Specimen size	200 mm dia. (max.)
	Specimen stub size	6 mm dia. (for ultrahigh resolution), 15 mm dia., 50 mm dia.
	Specimen exchange	Requires air leak
Display unit	Viewing CRT	12" wide screen type (effective area 196 × 160 mm)
	Photographing CRT	High resolution type (effective area 120 × 90 mm)
	Scanning speed (50 Hz, ( ) ... 60 Hz)	0.03, 0.5, 1, 10 (9), 40 (50) sec/frame for observation 40 (35), 80 (100), 200 sec/frame for photographing
	Scan mode	Full rapid scan, selected area, slow scan, photo scan, split screen, dynamic focus, waveform, oblique
	Signal processing mode	Automatic bright./contrast control, gamma control, polarity reversion, dynamic stigmator monitor, auto focus, auto stigmatism, fully automated data display (on CRT), key-in data display
	Electrical field shift	±20 μm (with accelerating voltage 30 kV, working distance 35 mm)
	Data recording	Film number, accelerating voltage, micron marker and magnification can be marked on film.
	Image signal	Secondary electron image, back-scattered electron image (with POST HV OFF)
Evacuating system	System	Fully automated
	Vacuum gauge	Pirani gauge (with vacuum meter)
	Ultimate vacuum	7×10^{-4} Pa or better
	Vacuum pump	Oil rotary pump 160 ℓ/min (at 60 Hz) × 1 Oil diffusion pump 570 ℓ/sec × 1
	Safety device	Safety devices for power interruption, water supply interruption and vacuum deterioration are provided.
	Water facilities	Flow rate : 1.0 ∿ 1.5 ℓ/min Pressure : 0.5 ∿ 1 kg/cm^2 Temperature: 10 ∿ 20°C Supply port: 10 mm dia. chemical faucet × 1 Drain port : × 1, 20 mm dia. or more, at floor level (natural drainage) (Note) Follow the standard for water temperature and flow rate.

(cont'd)

	Item	S-2500 (With Standard Specimen Stage)
Dimen-sions	Main console	680 (W) × 900 (D) × 1640 (H) mm, 250 kg
	Display unit	1100 (W) × 900 (D) × 1170 (H) mm, 145 kg

(2) Standard Equipment

- o Main console 1
- o Display unit 1
- o Oil rotary pump 1
- o Air compressor 1
- o Cleaning unit 1
- o Standard tools ..... 1 set
- o Spares and consumables ..... 1 set
- o Instruction manual 1

1. INSTALLATION

1-1 Installation Requirements

1-1-1 General

For installing the Model S-2500, the locations and conditions mentioned below must be avoided.

(1) Room located in the vicinity of transformer substation

(2) Room located in the vicinity of elevator

(3) Location near electric equipment consuming a large power (e.g., electric furnace) or its power supply

(4) Location near spark discharge source or high-frequency apparatus

(5) Room filled with gas which corrodes metals, etc.

(6) Place exposed to direct sunlight or strong draft

(7) Dusty place

(8) Location subjected to severe vibrations

(9) Shared use of ground wire with other electrical equipment

(10) Location adjacent to radio or sound wave source

1-1-2 Room Temperature and Humidity

(1) Room temperature ... 15 ∿ 30°C

Temperature fluctuation should preferably be less than 5°C during operation of the instrument.

(2) Humidity ... 70 % or less

The instrument should desirably be operated in air-conditioned room.

1-1-3 Line Power Requirements

(1) Single-phase 200 ∿ 240 V AC, 3 kVA, 50/60 Hz (for main unit)

Single-phase 200 ∿ 240 V AC, 2 kVA, 50/60 Hz (for optional accessory)

Continuous energization is unnecessary, and allowable line power fluctuation is ±10 % max.

(Note) Line power fluctuation should be slow, and no abrupt fluctuation is allowable.

(2) The main console should be located within 10 m of the switchboard on the wall (since input AC cord is only 10 m long).

(3) Be sure to use an exclusive power switch on the switchboard and feed the power through the switch.

1-1-4 Grounding

It is recommended to ground the instrument at a grounding resistance lower than 100 ohms. The grounding terminal should not be shared with other electrical equipment. An independent grounding is required.

1-1-5 Water Supply/Drain

Water must be supplied at a flow rate of 1.0 ∿ 1.5 liters/min, pressure 0.5 ∿ 1 kg/cm^2, temperature 10 ∿ 20°C and drained naturally (drain port should be nearly level with the floor surface). Use city water and employ a filter if the water supplied to the instrument contains much mineral deposit. Water pressure must not excessively fluctuate for a short period of time.

1-1-6 Stray Magnetic Field

When the stray magnetic field measured at the installation site before introducing the instrument complies with the requirements given in Table 1-1, image trouble will not occur.

Avoid locations where an abrupt electric current change or magnetic field change might occur due to a large-sized magnetic clutch or power cable for other equipment.

Table 1-1 Stray Magnetic Field

	DC Component*1	AC Components*2			
		Same Frequency Component as That of AC Line Supplied to Model S-2500			Different Frequency Component from That of AC Power Supply Used in S-2500
		Observation	Scanning in Synchronization with Power Supply	Scanning not in Synchronization with Power Supply	
		Photographing	All SCAN SPEED Settings		
Maximum allowable magnitude	50 mG	3 mG		0.05 mG*3	0.05 mG
Maximum allowable fluctuation*4	1 mG/5 min	1 mG/5 min		0.3 mG/5 min	0.3 mG/5 min

(Notes)

*1. The components due to terrestrial magnetic field are excluded from the values.

Terrestrial magnetic field in Japan:

Horizontal component ... 300 mG

Vertical component ..... 350 mG

*2. All values of AC components are effective values.

*3. A magnitude of less than 2 mG constitutes no serious trouble in particular.

*4. AC and DC stray magnetic field fluctuation is defined as varying monotonously and gradually with time. Thus, magnetic field fluctuation with pulse or step waveform should not occur.

1-1-7 Vibration

When the floor vibration measured at the installation site before introducing the instrument complies with the requirements given in Table 1-2, image trouble will not occur.

If the instrument is installed on the first floor in a building made of reinforced concrete, the instrument performance will not be degraded by external vibrations so long as vibration sources such as heavy-duty machine tools or transportation facilities (electric car, for example) are not operated nearby.

Table 1-2 Allowable Vibration

Frequency	Amplitude
5 Hz	3 μm_{p-p} max.
10 Hz	5 μm_{p-p} max.
50 Hz	7 μm_{p-p} max.

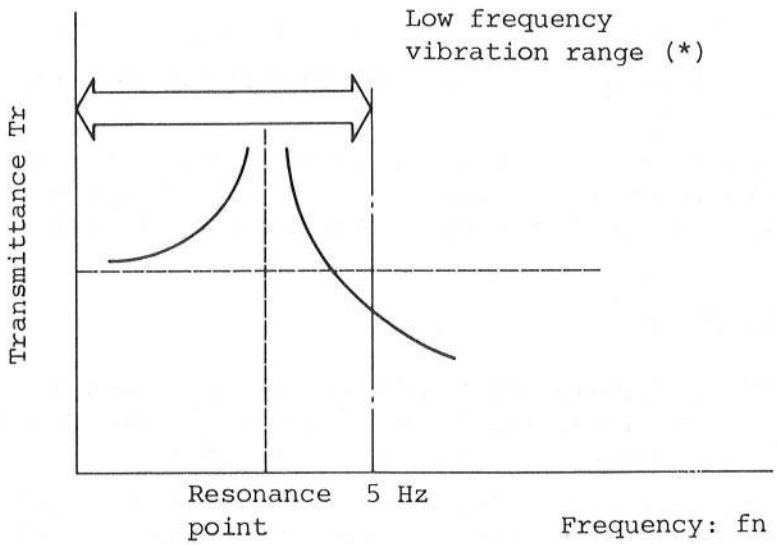
(Notes) 1. With respect to low frequency vibration (*) of 5 Hz or less, a sufficient effect cannot be obtained with the present vibration eliminating (vibration preventive) techniques.

In order to obtain the maximum performance (resolution, magnification, etc.) from the instrument, it is necessary to reduce the amplitude of vibration (to 0.6 μm_{p-p} or less) at 5 Hz or below.

2. For the 5 to 50 Hz range, carry out interpolation on the allowable values via connecting lines.

In the range above 50 Hz, it will be within the allowable value for 50 Hz.

3. If there is floor vibration exceeding the allowable value (vibration should be measured in advance if it is expected to cause a disturbance), then consult with the Hitachi representatives.



1-1-8 External Noise

If any equipment shown in Table 1-3 or its power line is placed in the vicinity of the Model S-2500, or if an equipment carrying a large current is located even at a distance, then image trouble will occur. To prevent this, the installation site should be selected after confirming that such equipments do not exist.

If an equipment which uses a power frequency differing from the line frequency used for the S-2500, or the power line of such equipment, is placed near the S-2500, the power frequency-synchronized scan becomes ineffective. Such a location should be avoided.

Table 1-3 External Noise Source

Classification		Noise Source	Source Equipment
Small-sized electric equipments (general/ home electrical appliances)	Electric equipment with contacts	Electric discharge (spark, arc)	Flasher (neon sign, ornamental electric bulb), relay, electromagnetic conductor, thermostat (warmer, refrigerator, iron), electronic calculator, cash register
	Equipment utilizing commutator motor	Electric discharge (spark, arc), sliding contact	Electric drill, laboratory engine, motor of sewing machine, cleaner, mixer, shaver, massaging machine
	Electric discharge tube	Glow discharge	Neon discharge tube, high pressure mercury arc lamp
	Controller utilizing semiconductor	Phase control (transient noise)	Thyristor dimmer, inverter
Equipment using high frequency	Industrial high frequency equipment	Unnecessary signal*	Industrial high frequency heater, high frequency electric welder, electronic oven
	Medical high frequency equipment	Unnecessary signal*	VHF/UHF fulgurators, electric scalpel

(cont'd)

Classification		Noise Source	Source Equipment
Equipment using high frequency	Equipment utilizing ultrasonic wave	Unnecessary signal*	Flaw detector, depth sounder, fishfinder, ultrasonic cleaner
Power equipment	Power cable (transmission line)	High voltage, large current	Induction of commercial frequency (electrostatic induction, electromagnetic induction, current leaking in ground)
		Electric discharge (corona, arc)	Corona, poor insulator, poor contact due to corroded metal (arc discharge)
	Electric car	Electric discharge (spark, arc)	Trolley wire, internal equipment, rectifier
	Electric car	Reflection	From car body
Internal combustion engine	Automobile	Electric discharge	Ignition system
		Other	Dynamo, voltage regulator, wiper, horn, winker
Wireless communication equipment	Large power sending/receiving equipment	Signal radiation*	Broadcasting equipment, radar
		Unnecessary radiation	Transmitter using high frequency

(Note) The signal marked "*" is used normally in the relevant system, but becomes a disturbance for other systems.

1-1-9 Disturbance by Sound Wave

Sound waves (vibrations of air) adversely affect the S-2500 regardless of their frequency and may cause image trouble. To prevent this, confirm before installation that an equipment which may cause a sonic disturbance is not located in the vicinity of the S-2500.

If such equipments exist, then check for noise level.
When conversation is possible in a usual voice around the installation site, the noise level is allowable. But if conversation is possible only in a loud voice due to abnormal noise of the equipment, sonic disturbance may occur.

1-1-10 Site Requirements

(1) Space required

A room of about 2.8 m × 2.8 m or more is recommended.

(Minimum space: 2.6 m × 2.6 m)

(2) Dimensions of entrance

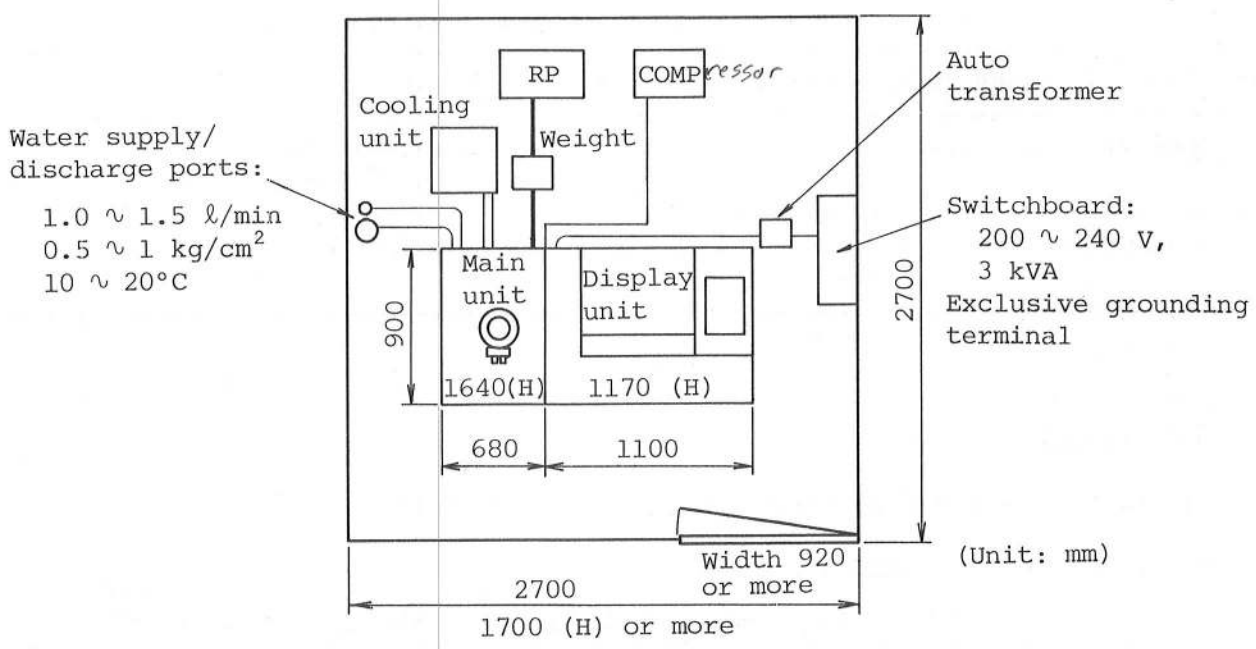
0.92 (W) m × 1.7 (H) m at minimum

(3) Durability of floor

$$\frac{\text{Floor strength (kg/m}^2\text{)}}{3} \geqq \frac{\text{Total weight of instruments installed in the room (kg)}}{\text{Floor area of the room (m}^2\text{)}}$$

(4) Others

- Sliding blackout curtains around the instrument are convenient.
- See Fig. 1-1 for installation layout.



- RP ..... 230 × 500 × 450 (H)
- COMP ..... 230 × 390 × 560 (H)
- Cooling unit ..... 320 × 350 × 320 (H)

(Note) This figure indicates minimal installation area for the standard equipment.

Fig. 1-1 Installation Layout

1-2 Materials or Instruments to Be Prepared by User

See Table 1-4.

Table 1-4 Materials or Instruments to Be Prepared by User

Name	Q'ty	Remarks
Acetone	500 g	Used for cleaning parts
Vacuum evaporator	1	Used to evaporate metal onto specimen or bake out aperture plate
Ultrasonic cleaner	1	Used for cleaning parts
Freon solvent T-WD602	18 ℓ	Used for ultrasonic cleaning (made by DUPONT)
Tungsten wire (∿ 0.5 mm dia.)	1 m	For vacuum evaporator (for filament)
Golden wire (∿ 0.2 mm dia.)	10 m	For coating specimen
Freon gas spray (with nozzle)	400 g	For blowing off dust
Optical microscope.	1	For checking specimen and centering filament
Coolant for cleaning unit	1 can	Coolant (2-ℓ can) for Aluminum engine

1-3 Wiring

Only cautions with respect to wiring are described here.

(1) Power and Ground Wirings

The instrument operates normally only when it receives a power supply of 100 V. When using a power voltage other than 100 V, the auto transformer is required.

However, the voltage must be connected to the instrument after confirming with the aid of a voltmeter that the auto transformer outputs 100 V.

Fig. 1-2 shows tap voltages of the auto transformer.

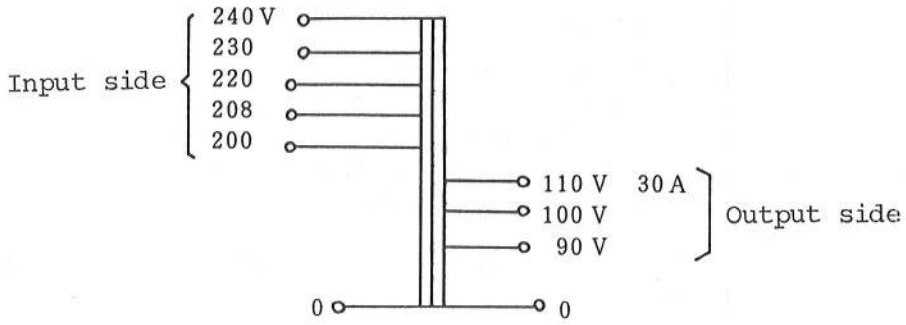
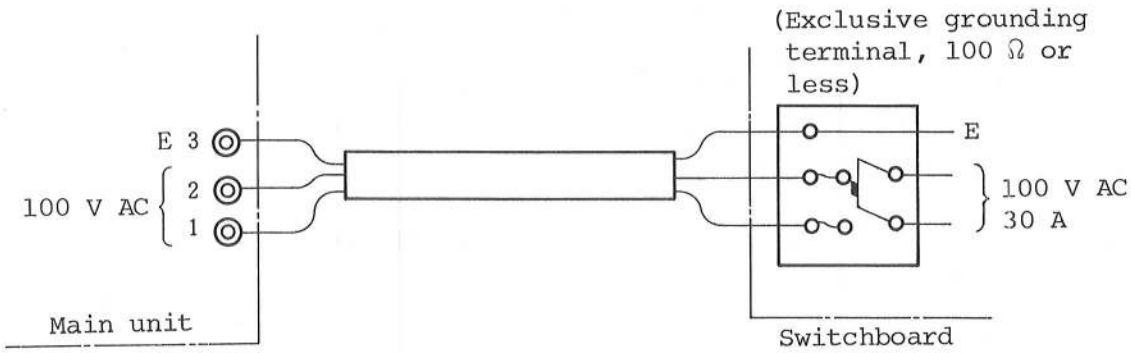
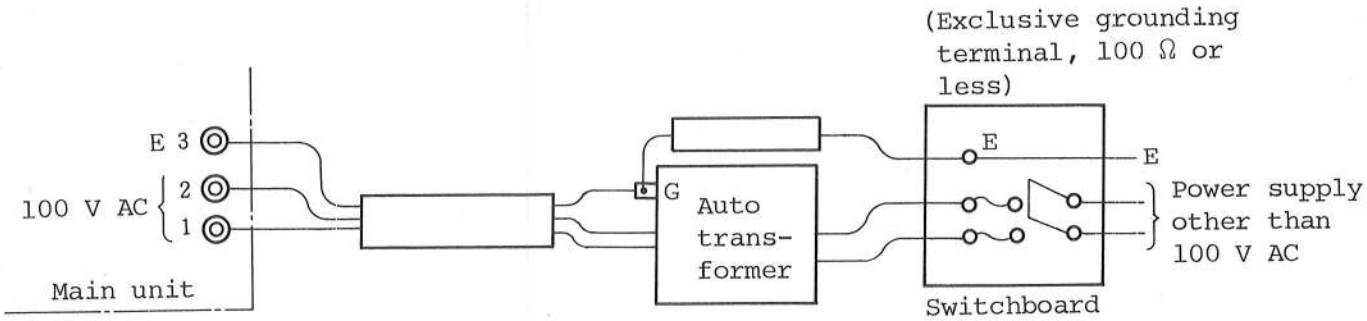


Fig. 1-2 Auto Transformer Voltage

Fig. 1-3 shows wiring from the switchboard.
The instrument should be grounded not via a water pipe or the like but by an exclusive means.



(a) When auto transformer is not employed



(b) When auto transformer is employed

Fig. 1-3 Power Wiring

(2) Room Light Switch Wiring

Connect the [ROOM LIGHT] switch on the evacuating system operation panel to a room light or spot light as shown in Fig. 1-4, using the furnished plug. When employing a fluorescent lamp, use 100 W or less, though allowable up to 300 W, since starting current is large.

(Note) Before wiring, turn off the power supply (MAIN switch) of main unit.

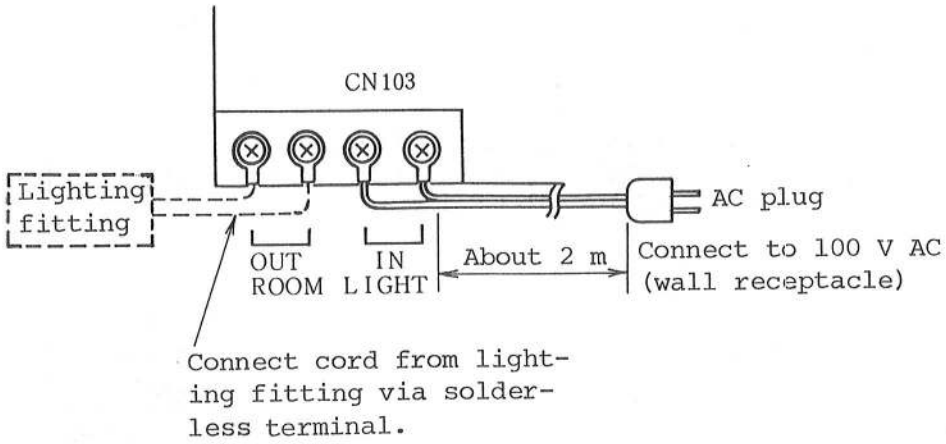


Fig. 1-4 Room Lamp Wiring

2. FUNCTIONS

Fig. 2-1 shows the appearance of the Model S-2500.

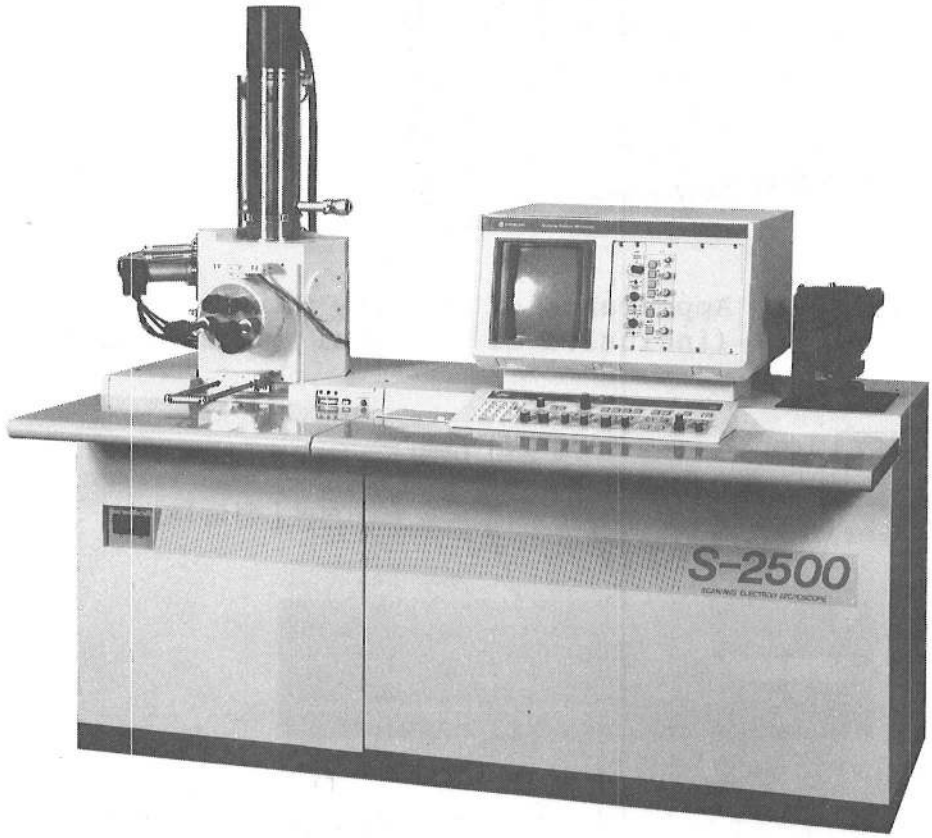


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Fig. 2-1 Appearance of Model S-2500
(inclusive of optional accessories)

2-1 Control Knobs and Switches of Display Unit

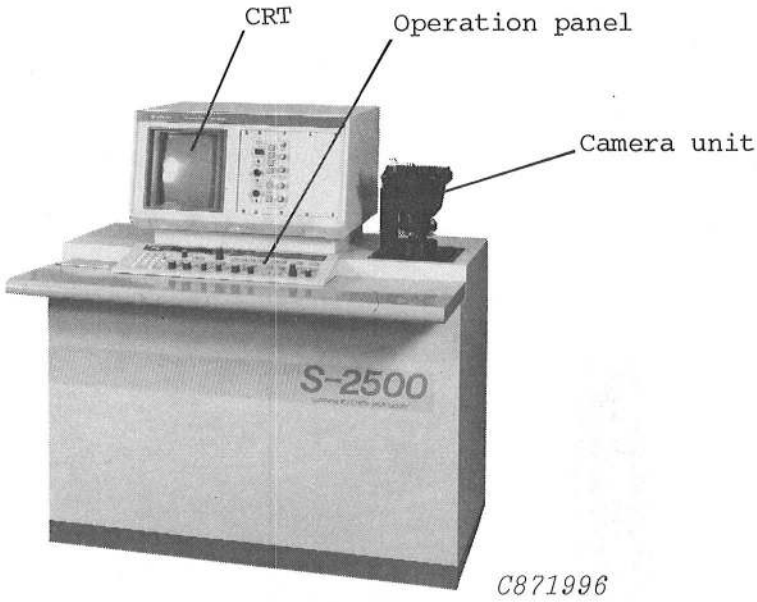


Fig. 2-2 Appearance of Display Unit
(inclusive of optional accessories)

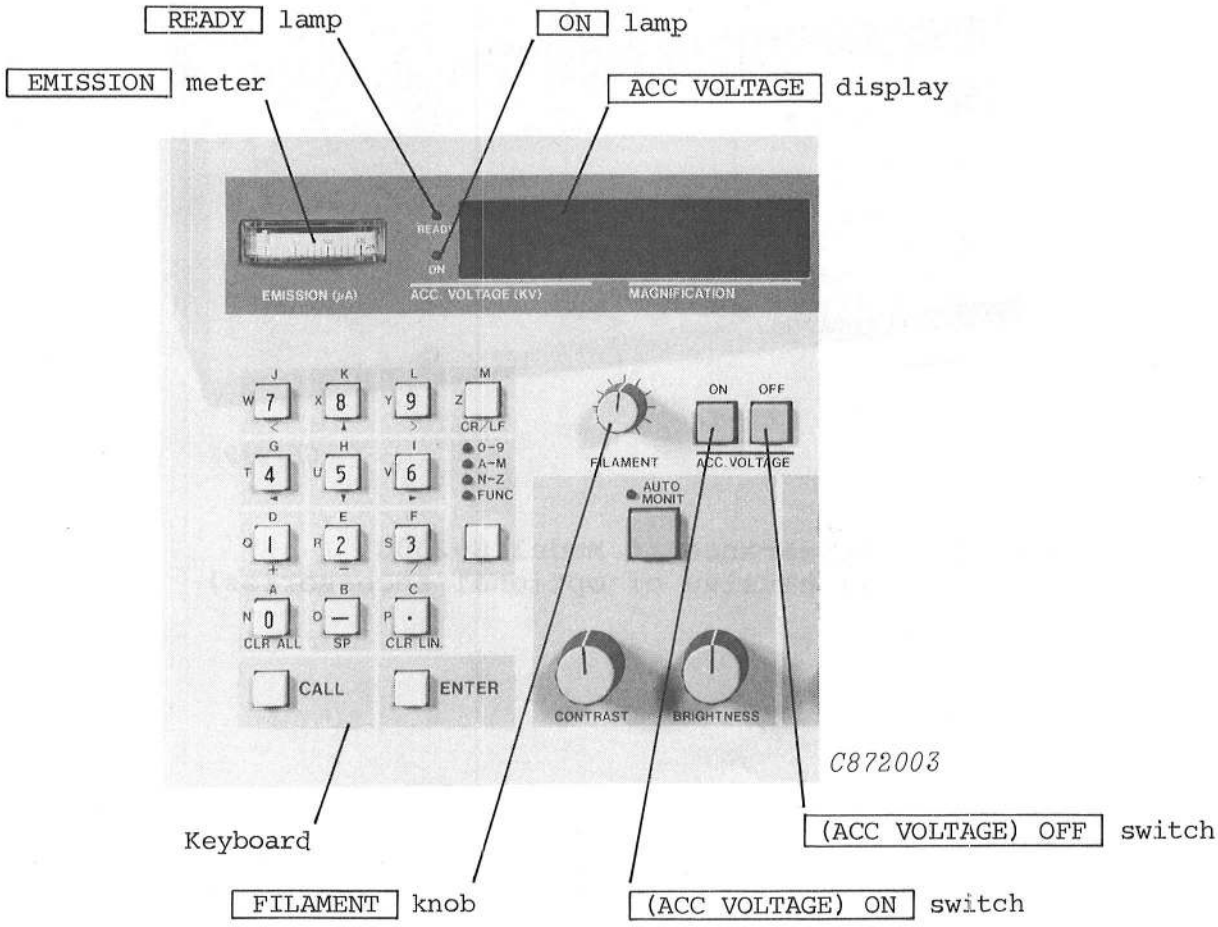


Fig. 2-3 Keyboard and Electron Gun Controls

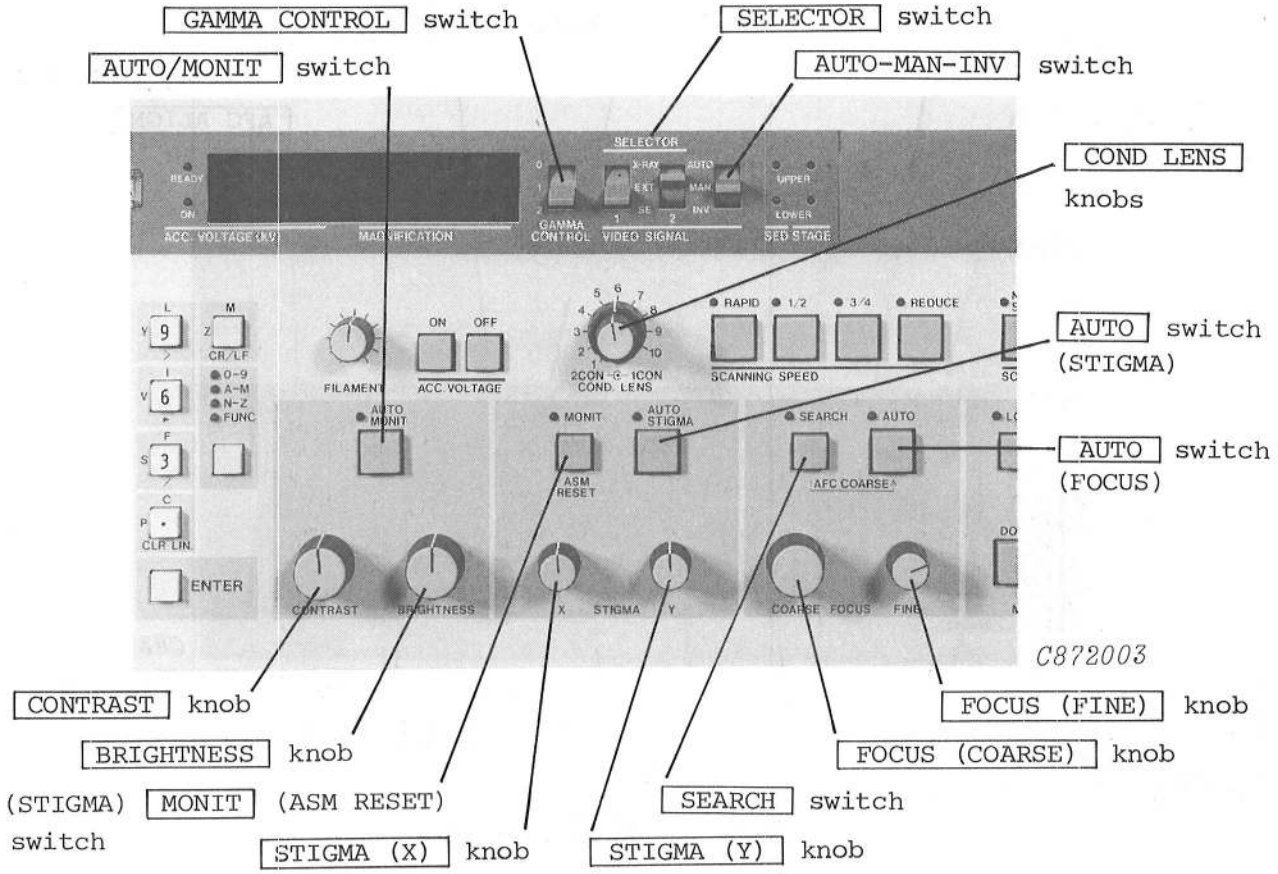


Fig. 2-4 Image Controls and Electron Probe Controls

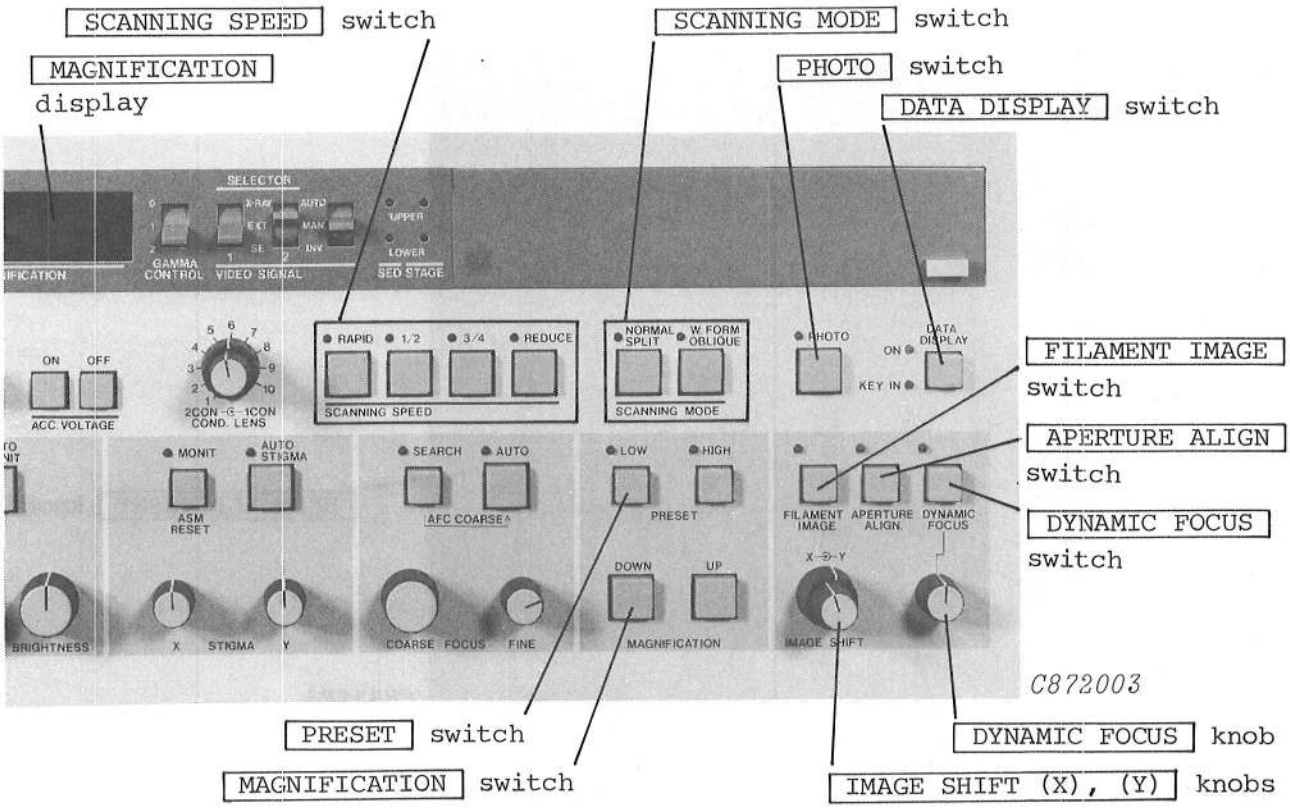


Fig. 2-5 Magnification, Scan Mode and Scanning Speed Controls, etc.

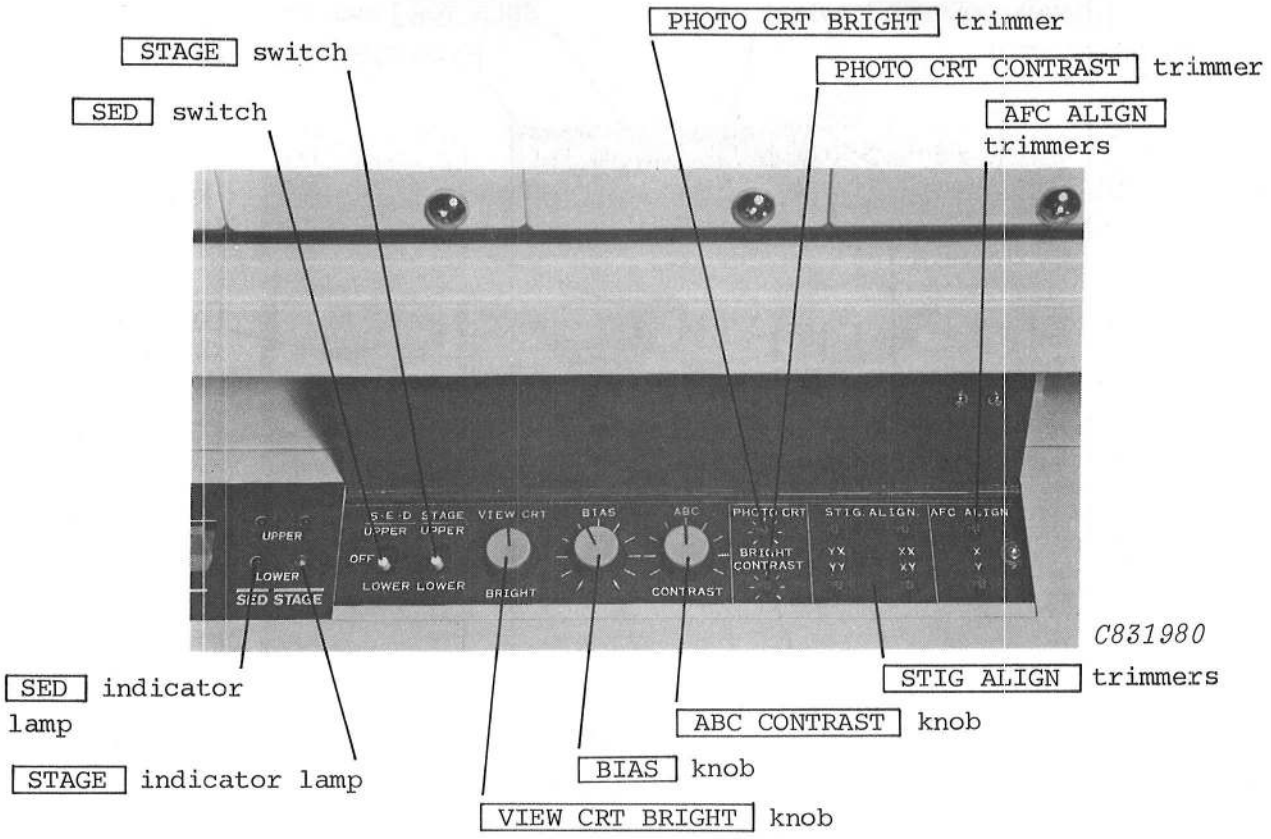


Fig. 2-6 Controls Provided inside Cover

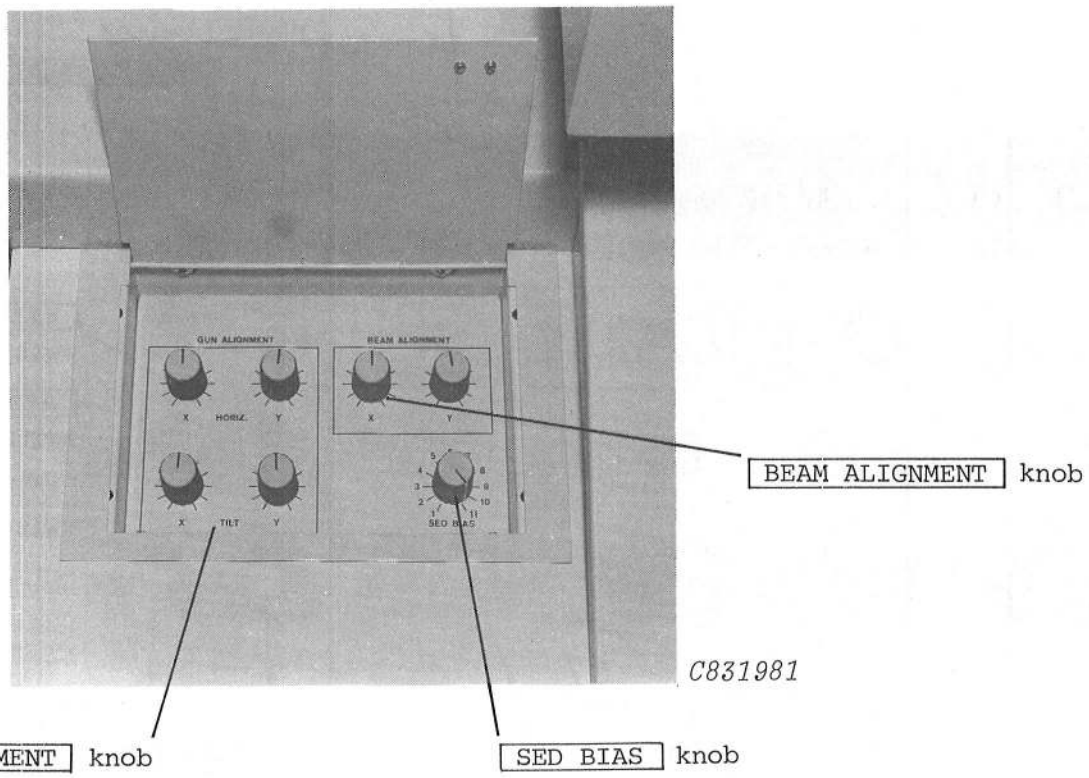


Fig. 2-7 Alignment Unit

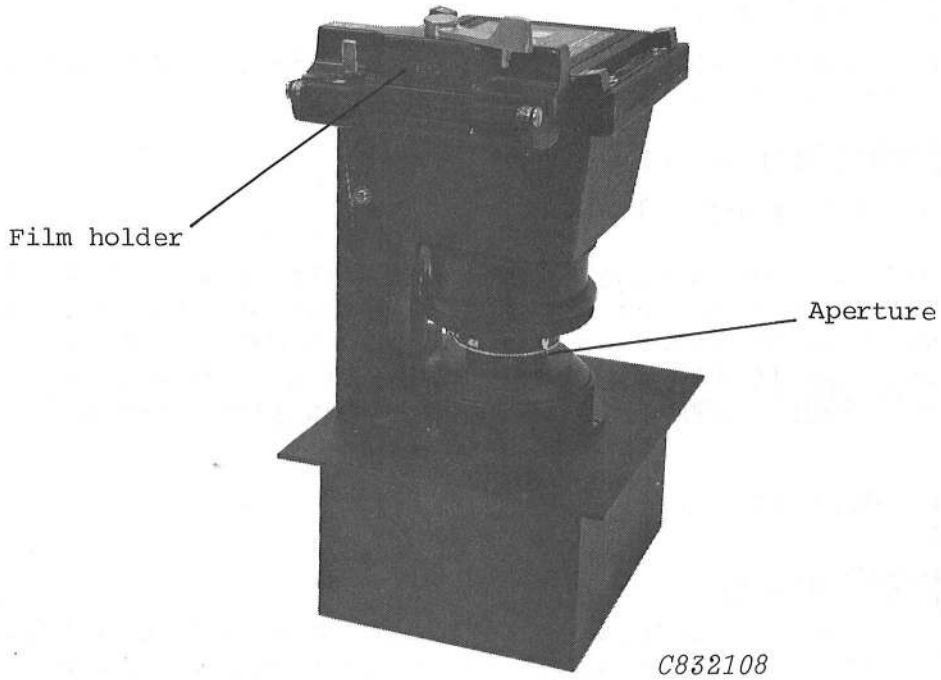


Fig. 2-8 Camera Unit (option)

2-1-1 Keyboard (Fig. 2-3)

Used for setting the accelerating voltage, working distance and other conditions and for marking character data on image. For details, refer to 3-4-1.

2-1-2 Electron Gun Controls (Fig. 2-3)

[EMISSION] meter

Indicates emission current (full scale 300 μA).

[READY] lamp

Indicates that electron gun vacuum is high enough to allow application of an accelerating voltage.

[ON] lamp

Indicates that an accelerating voltage is applied.

[ACC VOLTAGE] display

Indicates an operating accelerating voltage in steps of kV.

[FILAMENT] knob

Alters filament current in order to adjust emission current. Saturation point of the filament is searched in the filament image mode explained later while watching the [EMISSION] meter.

[(ACC VOLTAGE) ON] switch

Applies accelerating voltage. This switch is ineffective when the [READY] lamp is not lit.

[(ACC VOLTAGE) OFF] switch

Turns OFF accelerating voltage.

(Note) Accelerating voltage is automatically turned OFF if vacuum in the electron gun housing is deteriorated or if an excessively large emission current is flowed due to electric discharge in the electron gun. In this case, wait until the [READY] lamp comes on, and then press the [ON] switch.

2-1-3 Image Controls (Fig. 2-4)

[GAMMA CONTROL] switch

Softens or reduces an excessive contrast or brightness locally appearing on image. Gamma control is intensified in the following sequence; 0 → 1 → 2.

[SELECTOR] switch

Selects image signal for CRT display. Signal is selected with the switch [1] usually. In the split screen mode, the upper half must be selected with the switch [1], and the lower half with the switch [2]. EXT is used when the accessory for back-scattered electron image, transmitted electron image, etc. is incorporated. X-RAY is employed for observing X-ray image when the X-ray spectrometer is combined.

[AUTO-MAN-INV] switch

Selects automatic or manual adjustment of image contrast and brightness, and inverts the polarity (white/black) of image.

AUTO: Effects automatic adjustment.

MAN : Selects manual adjustment (with [CONTRAST] and [BRIGHTNESS] knobs).

INV : Inverts image polarity. (At INV, image can be adjusted only manually).

[AUTO/MONIT] switch

Starts ABC (auto brightness and contrast control) when the above [AUTO-MAN-INV] switch is set at AUTO. When pressing this switch, ABC starts. It completes within 5 sec and usual status is automatically restored. When the [AUTO-MAN-INV] switch is set at MAN or INV, monitor mode is activated and CRT displays signal waveform. Usual image display status is restored by pressing the switch again.

[CONTRAST] knob

Adjusts contrast of secondary electron image. Turned clockwise to strengthen the contrast.

[BRIGHTNESS] knob

Adjusts brightness of secondary electron image. Turned clockwise to brighten the image.

These two knobs do not function when the [AUTO-MAN-INV] switch is set at AUTO.

2-1-4 Electron Probe Controls (Fig. 2-4)

[COND LENS (2CON, 1CON)] knobs

Adjusts specimen irradiation current. [2CON] operates stepwise and is set in accordance with necessary conditions such as magnification range. [1CON] is continuously variable. When turning either knob clockwise, irradiation current decreases, while probe diameter is reduced.

[AUTO] switch (STIGMA)

Automatically corrects astigmatism.

[(STIGMA) MONIT (ASM RESET)] switch

Puts the instrument in stigmator monitor mode. When this switch is pressed, the amount of astigmatism correction by the auto stigmator is set to zero. Usual image display mode returns upon pressing this switch again.

[STIGMA (X), (Y)] knobs

Correct astigmatism of electron probe. Facilitated in the stigmator monitor mode mentioned above.

[FOCUS (COARSE, FINE)] knobs

Focus image. [COARSE] is used usually, and [FINE] is employed for fine adjustment at high magnifications.

[SEARCH] switch

Used for efficient focusing in case image is out of focus to such an extent that its profile cannot be confirmed. When pressed, waveform display mode is set. Adjust the [FOCUS (COARSE)] knob so that waveform shows the sharpest possible change, and then press the switch. A nearly focused image will appear.

[AUTO] switch (FOCUS)

Auto focus switch. Usable in two ways as described below.

(1) Operate the [AUTO] switch alone when defocus amount is less (image profile can be seen).

(2) Operate the [SEARCH] switch and [AUTO] switch in this order when defocus amount is larger (image profile cannot be seen).

2-1-5 Magnification Controls (Fig. 2-5)

[MAGNIFICATION] switch

Changes over magnifications.

[PRESET 1, 2] switches

Pressed to provide a predetermined magnification (requires setting from the aforementioned keyboard). Pressed again to return to the original magnification. When operating the [MAGNIFICATION] switches rather than returning to the original magnification, magnification increases or decreases from the preset value.

[MAGNIFICATION] display

Indicates operating magnification.

2-1-6 Scan Mode and Scanning Speed Controls (Fig. 2-5)

[SCANNING SPEED] switches

[RAPID] switch

Effects full frame rapid scan.

[1/2] switch

Selects 0.5 sec/frame and 1 sec/frame alternately.

[3/4] switch

Selects 10 (9) sec/frame and 40 (50) sec/frame alternately (parenthesized value indicates use in 60 Hz region).

[REDUCE] switch

Effects selected area scan. Fast and slow speeds selected alternately.

[SCANNING MODE] switches

[NORMAL/SPLIT] switch

Selects NORMAL mode (usual image observation mode) and split screen mode (CRT screen divided into upper and lower halves for observing different images of the same field) alternately. The latter mode can be easily judged since a black line appears at the center of CRT.

[W FORM/OBLIQUE] switch

Selects waveform mode (for observing signal waveform) and oblique mode (also called "Y-modulated image or Y-modulation mode") alternately.

[PHOTO] switch

Starts photographing. When pressed, a single raster scan is performed at a determined photo speed (set with the aforementioned keyboard in advance), and then the original image observation mode returns. The photo CRT displays an image during the single raster scan only, so the camera shutter need not be operated.

Press the switch again to release photographing status if you desire to interrupt photographing at a mid-point.

2-1-7 Data Display Section and Other (Fig. 2-5)

[DATA DISPLAY] switch

Displays characters on CRT and selects any of the following states.

(1) OFF : Avoids data display.

(2) ON : Displays film number, accelerating voltage, magnification and micron marker at the bottom of CRT.

(3) ON, KEY-IN: Enables writing desired alphanumerics on CRT together with the above data (with use of the keyboard).

(4) KEY-IN : Displays only the data written from the keyboard (other data at the bottom of CRT does not appear).

[FILAMENT IMAGE] switch

Press, and filament image appears. Press again, and usual image observation mode returns.

[APERTURE ALIGN] switch

Press before axial alignment of the objective lens aperture. Press again, and usual image observation mode returns.

[DYNAMIC FOCUS] switch and knob

Adjust focus over the entire image by compensating for defocus in the tilt axis when specimen is tilted. This function is usable when working distance (WD) is around 15 mm.

[IMAGE SHIFT (X), (Y)] knobs

Shift the field of view at high magnifications.

2-1-8 Switches and Knobs inside Cover (Fig. 2-6)

[STAGE] switch

Changes over objective lens exciting conditions, etc. Set to LOWER when specimen is located below WD 0 mm position, and to UPPER when it is located above WD 0 mm position.

[SED] switch

Selects either of the two secondary electron detectors according to desired microscopic conditions when the [STAGE] switch is set at LOWER.

UPPER: Selects upper detector (through-the-lens system).

LOWER: Selects lower detector.

OFF : Avoids detection of secondary electron image (back-scattered electron image is selected).

Note that the upper detector is activated regardless of setting of the [SED] switch when the [STAGE] switch is set at UPPER.

[SED], [STAGE] indicator lamps

Indicate settings of [SED] and [STAGE] switches.

[VIEW CRT BRIGHT] knob

Adjusts brightness on the viewing CRT.

[BIAS] knob

Adjusts bias voltage to be applied to the electron gun.

[ABC CONTRAST] knob

Adjusts contrast which will be automatically set with ABC (Automatic Brightness and Contrast) control function.

[PHOTO CRT BRIGHT, CONTRAST] trimmers

Set brightness and contrast of photographed image. (Knob is not provided for preventing careless touch. For adjustment, use a screwdriver.)

[STIG ALIGN] trimmer

Prevents image from being shifted when moving the [STIGMA] knob. This trimmer needs to be adjusted, for example after disassembling the objective lens section of the column.

[AFC ALIGN] trimmer

Improves accuracy of the auto focus function. Adjust is required in SYSTEM CHECK mode after disassembling the objective lens section of the column or if accuracy of the auto focus function is degraded. (See 4-8-1.)

2-1-9 Alignment Unit (Fig. 2-7)

[GUN ALIGNMENT] knobs

Align the axis of electron gun.

[SED BIAS] knob

Adjusts secondary electron beam extracting voltage when using the upper secondary electron detector (through-the-lens system).

[BEAM ALIGNMENT] knobs

Exclusive for optional accessories. Ordinarily unused.

2-1-10 Photographing Camera Unit (Fig. 2-8)

Film holder

Holds film for photographing.
(The figure added to this manual indicates the external view of the 4 × 5 Polaroid film holder. Other kinds of film holders may be delivered according to the specifications of the customer.)

Aperture

Dial for selecting camera aperture.

2-2 Control Knobs and Switches on Main Console

2-2-1 Microscope Column

Fig. 2-9 shows the appearance of the microscope column.

Figs. 2-10, 2-11 and 2-12 show the sectional view of column, and block diagrams of S-2500 system and evacuating system, respectively.

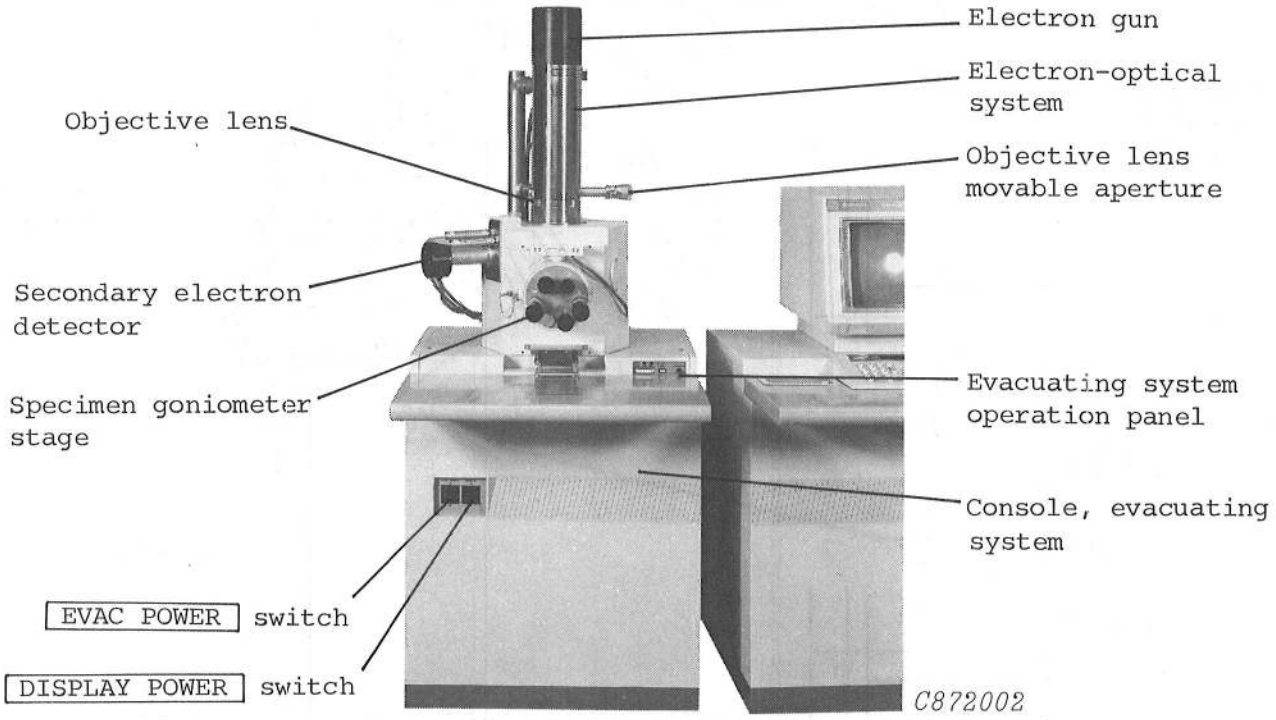


Fig. 2-9 Appearance of Microscope Column

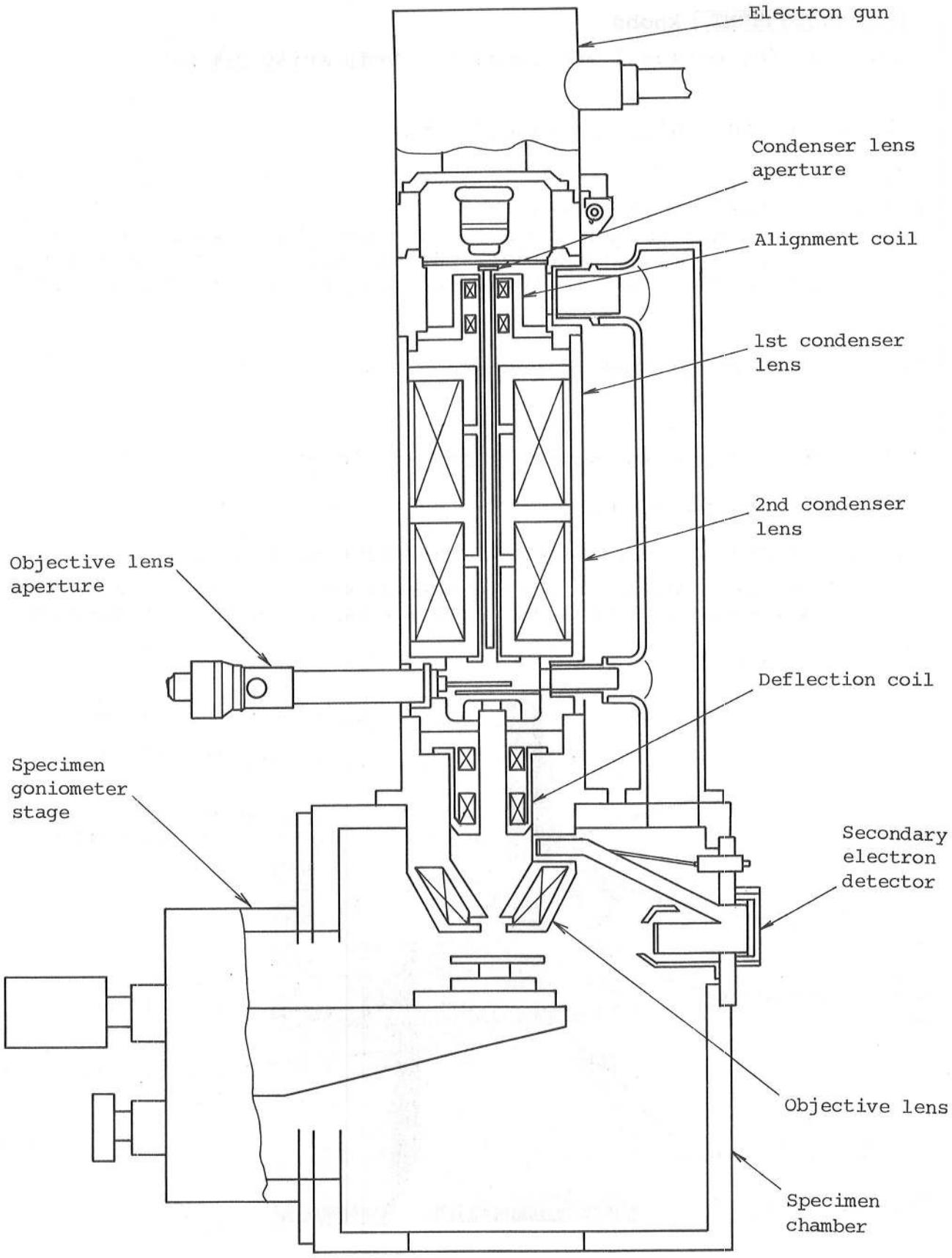


Fig. 2-10 Sectional View of Microscope Column

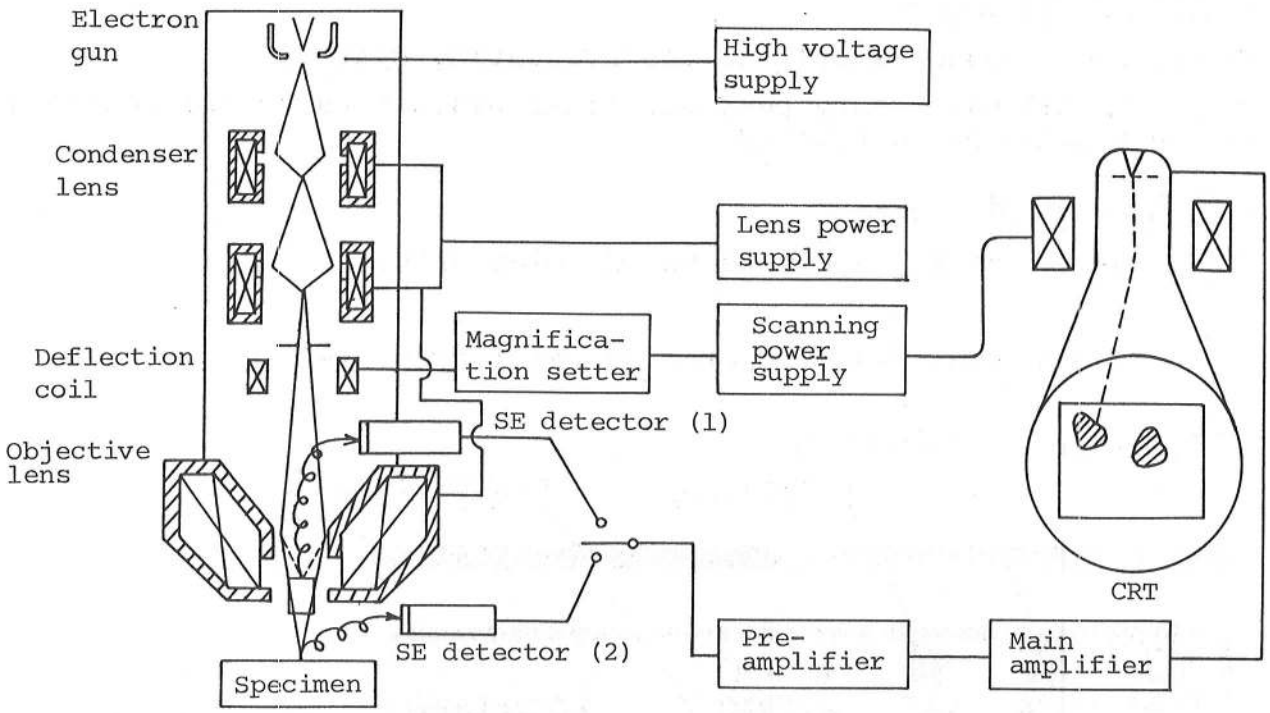


Fig. 2-11 Block Diagram of S-2500 System

	Symbol	Name
Pneumatic valve	A1	Main valve
	A2	Main unit preevacuation valve
	A3	DP backpressure valve
Electromagnetic valve	E1	Main unit leak valve
	E2	RP leak valve

DP : Oil diffusion pump

RP : Oil rotary pump

PIG: Pirani gauge

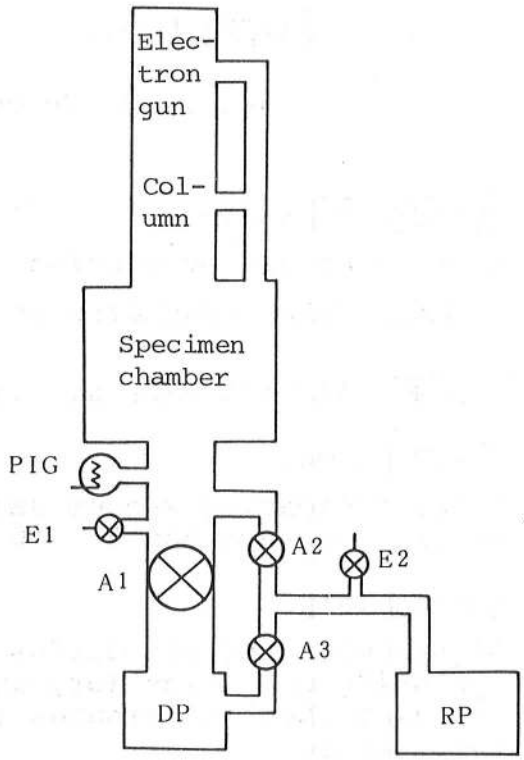


Fig. 2-12 Block Diagram of Evacuating System

[EVAC POWER] switch

Turns on/off power supply to the evacuating system.

Turn on, and the rotary pump and other evacuating system components are automatically activated.

[DISPLAY POWER] switch

Turns on/off power supply to the display unit.

2-2-2 Evacuating System Operation Panel (Fig. 2-13)

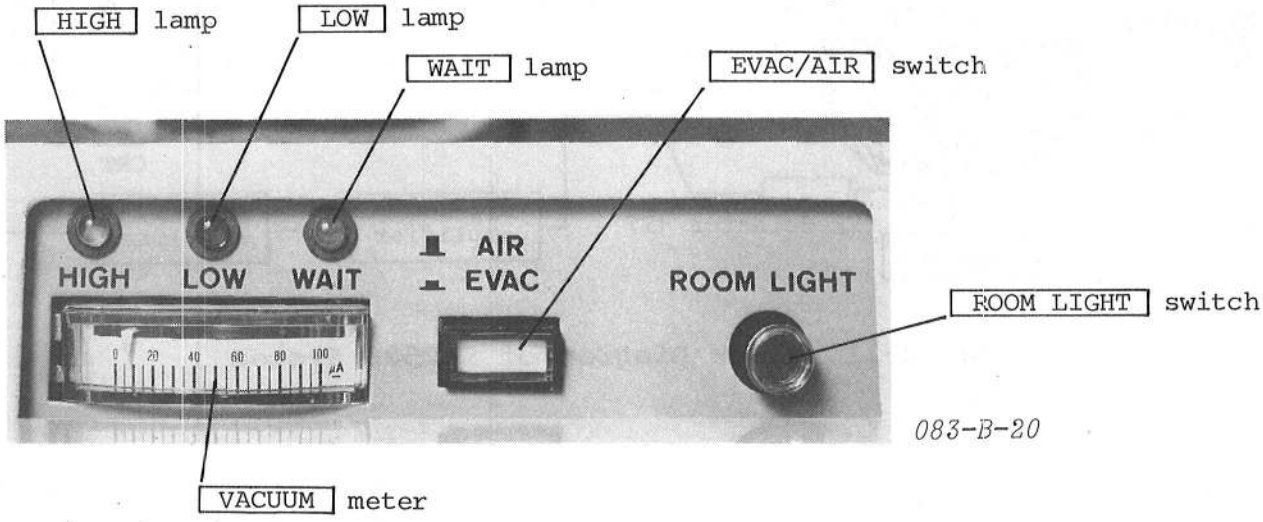


Fig. 2-13 Evacuating System Operation Panel

[EVAC/AIR] switch

Selects column evacuation or airleak.

[⊥] EVAC: Evacuates column. (Yellow switch face)

[⊥] AIR : Admits air into the column.

[VACUUM] meter

Meter indicating vacuum degree. It indicates 100 μA under atmospheric pressure and 5 ∿ 10 μA at ultimate vacuum.

[WAIT] lamp

Lights when the oil diffusion pump has not completely reached operating condition (or, when it has not been warmed up completely). It takes about 15 minutes to warm up the diffusion pump from room temperature.

[LOW] lamp

Indicates that the column has not yet been evacuated to a high vacuum allowing application of high voltage (red lamp).

Turn System On

① turn on cold sink water
turn on gas pressure (40 Psi), it runs the valves
turn on Evac Power, make sure Evac button is not depressed
② when the yellow Wait light turns off, depress the Air Evac button
③ wait for the red Low light to turn off (~ 8 μA) and the Green High light turns on
④ turn on the refrigerated recirculator and the display power

Turn System Off

~~Turn display power off~~
turn down filament and Bias
turn acc. voltage off
turn display power off, turn off refrigerated recirculator
undepress Air Evac button, wait until air leaks in (10 - 15 sec)
turn off Evac Power
turn off gas pressure
wait 30 min
turn off water

[HIGH] lamp

Lights when the column has been evacuated to a high vacuum allowing application of high voltage (green lamp).

[ROOM LIGHT] switch

Turns on/off room illumination, provided wiring be made by the user.

2-2-3 Specimen Goniometer Stage (Fig. 2-14)

o Standard Stage

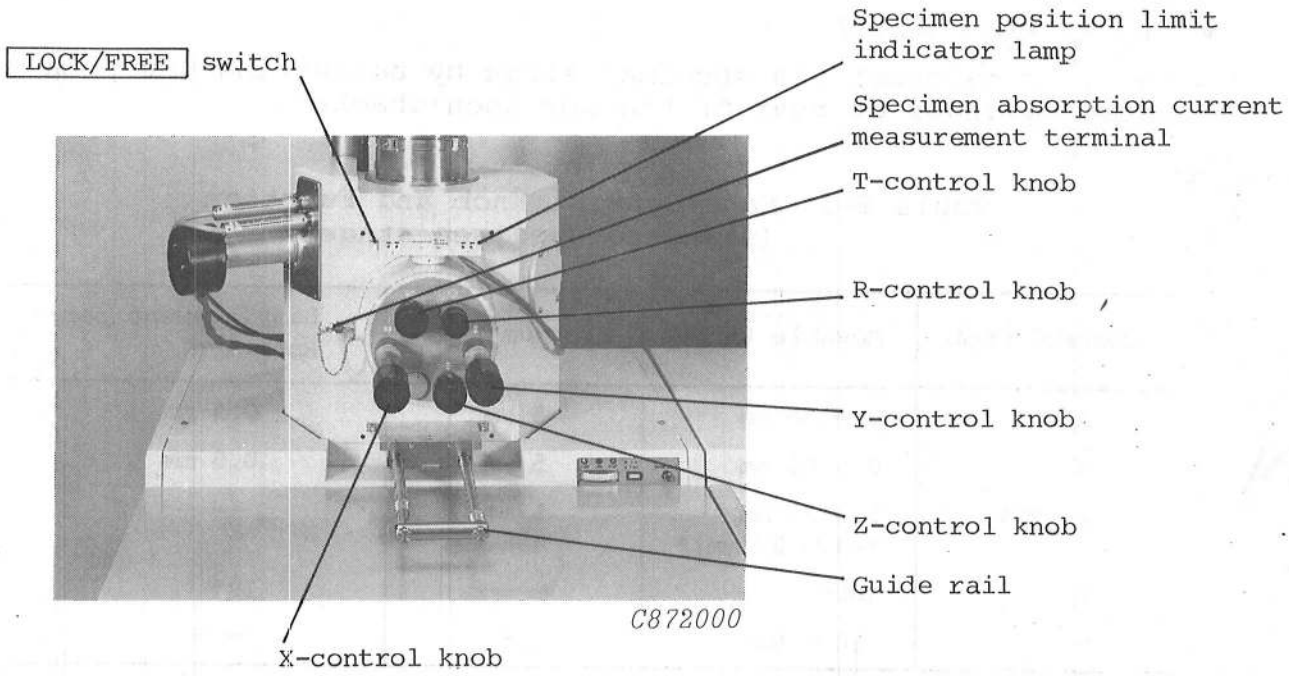


Fig. 2-14 Standard Stage

- X-control knob

  Moves a specimen crosswise facing the main unit (0 ∿ 80 mm).

- Y-control knob

  Moves a specimen laterally facing the main unit (0 ∿ 40 mm).

- Z-control knob

  Moves a specimen vertically with respect to the objective lens (within a working distance range of 5 ∿ 35 mm)

- T-control knob

  Tilts a specimen (-20 ∿ +90°)

- R-control knob

  Rotates a specimen (360° continuously).

- Specimen absorption current measurement terminal

  Specimen absorption current is readable through this terminal.

- Guide rail

  Guides introducing and taking out the specimen stage.

- Specimen position limit indicator lamp

  Indicates specimen position limit in the ultrahigh resolution mode in which specimen is located inside the objective lens. (Refer to 3-3-2.)

- [LOCK/FREE] switch

  Locks or releases the specimen stage by activating the pneumatic cylinder at rear of the specimen chamber.

Table 2-1 Each Control Knob and Function (standard specimen stage)

Control Knob	Movable Range	Minimum Sacle	Displacement per Rotation
X	0 ∿ 80 mm	5 μm	0.5 mm
Y	0 ∿ 40 mm	5 μm	0.5 mm
Z (WD)	5 ∿ 35 mm (-3 ∿ 27 mm)*	1 mm	——
R	360°	——	18°
T	-20 ∿ 90°	10°	——

(Note) Asterisked range is applied when the high resolution specimen holder is used.

2-2-4 Objective Lens Movable Aperture (Fig. 2-15)

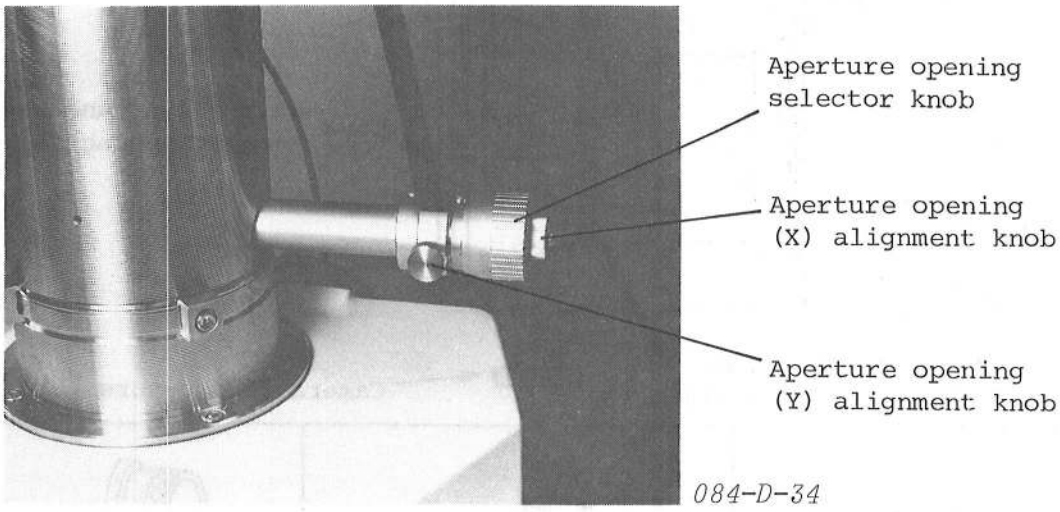


Fig. 2-15 Objective Lens Movable Aperture

- Aperture opening selector knob

  Selects any of aperture openings (4).

- Aperture opening (X) alignment knob

  Precisely aligns aperture opening in the axial direction (insert/take-out direction).

- Aperture opening (Y) alignment knob

  Precisely aligns aperture opening in the direction orthogoal to the above X direction.

2-3 Camera Unit(option)

This is a universal camera unit used for photographing an image on the photographing CRT. Its main body consists of lens, body, hood, etc. 6 cm × 7 cm roll film, 107 Polaroid film and 4" × 5" Polaroid film are usable by attaching various units.

2-3-1 Composition

Fig. 2-16 shows the composition of the camera unit. Other components must be specified as a unit which varies with the film used.

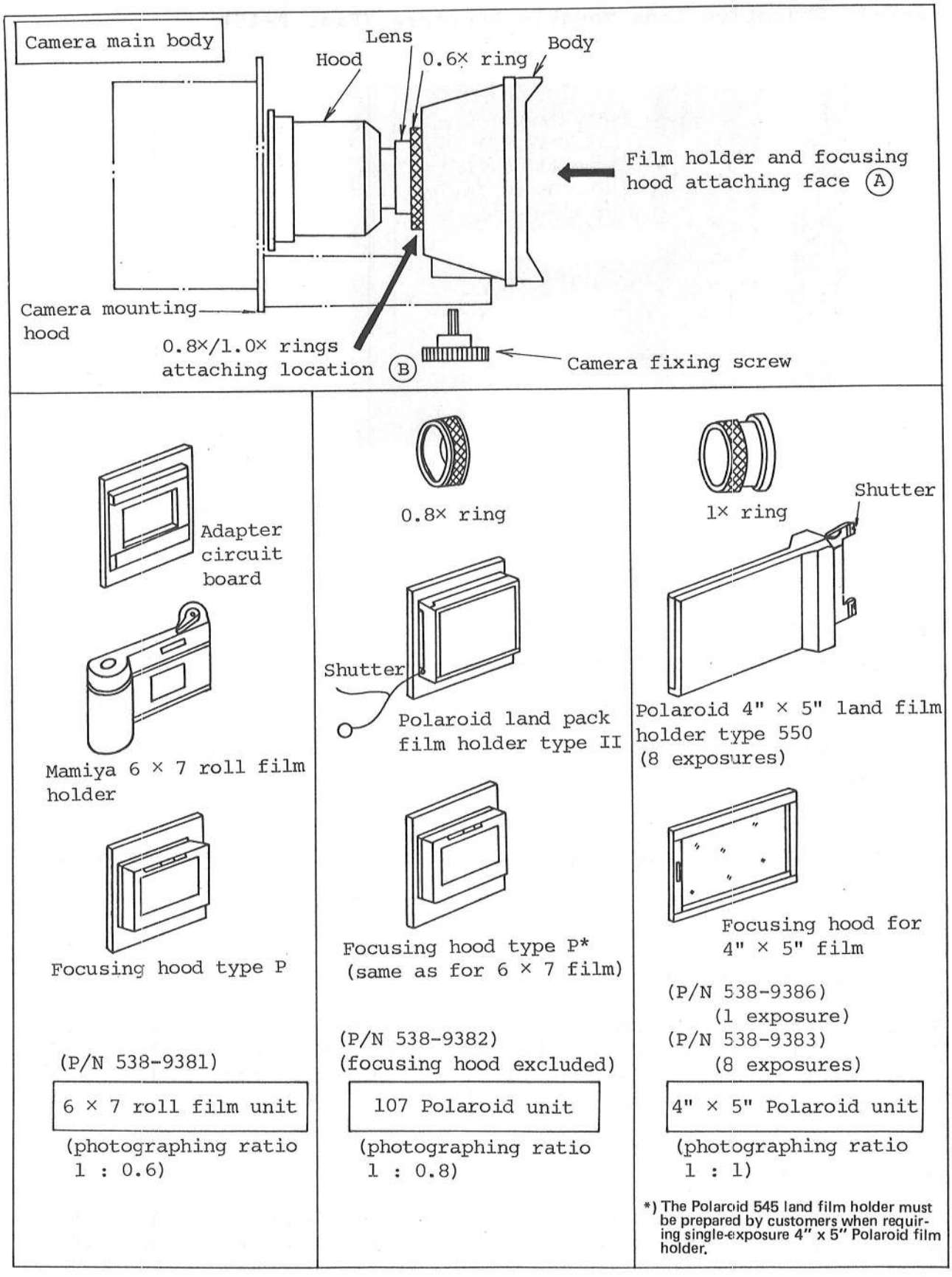


Fig. 2-16 Composition of Camera Unit

2-3-2 Assembly

(1) 6 × 7 Roll Film (photographing ratio 1 : 0.6)

(a) Attach the focusing hood type P to the face Ⓐ.

(b) Loosen the camera fixing screw and move the camera body so as to bring the scanning lines on CRT into camera focus. Darken the room so that the scanning lines can be seen clearly.

(c) Fix the camera body by tightening the camera fixing screw.

(d) Remove the focusing hood, and attach the adapter circuit board and 6 × 7 roll film holder.

(2) 107 Polaroid Film (photographing ratio 1 : 0.8)

(a) Completely loosen the camera fixing screw.

(b) Extract the body.

(c) Remove the 0.6× ring from the body by turning counter-clockwise. A bayonet mechanism is employed for attaching/detaching the ring.

(d) Add the 0.8× ring to the 0.6× ring, and attach them to the portion Ⓑ of the body.

(e) Attach the camera body to the camera mounting hood and temporarily fasten it with the camera fixing screw.

(f) Attach the focusing hood type P to the face Ⓐ and bring the scanning lines on CRT into focus with reference to (1)-(a) and (1)-(b), then completely tighten the screw.

(g) Remove the focusing hood type P and attach the film holder type II.

(3) 4" × 5" Polaroid Film (photographing ratio 1 : 1.0)

(a) Perform the steps (a) through (c) in above (2) in order to detach the camera.

(b) Add the 1× ring to the 0.6× ring, and attach them to the portion Ⓑ of the body.

(c) Set the camera in the same manner as in step (e) of (2).

(d) Attach the 4" × 5" focusing hood to the face Ⓐ, and bring the scanning lines on CRT into focus in reference to (1)-(b).

(e) Fasten the body by tightening the camera fixing screw.

(f) Remove the focusing hood and attach the film holder.

(Note) When focusing the camera attached to the camera mounting hood, adjustment must be made to around the indication mark for mounting each unit (indication provided at the base of the camera mounting hood).

2-3-3 Specifications

(1) Photographing ratio	1 : 1.0, 1 : 0.8, 1 : 0.6
(2) Lens	F = 75 mm
(3) Aperture	f = 5.6 ∿ 22, manual (5.6, 8, 11, 16, 22)
(4) Focusing	Manual adjustment (preset when the unit is delivered together with scanning electron microscope)
(5) Film (prepared by customer)	120 roll film (6 × 7) Polaroid type 107 (667), 105 (665) Polaroid type 52, P/N 55

< Reference >

Film exposure size with various film and unit combinations is shown in the table below.

Table 2-2 Effective Display Area on CRT and Film Size

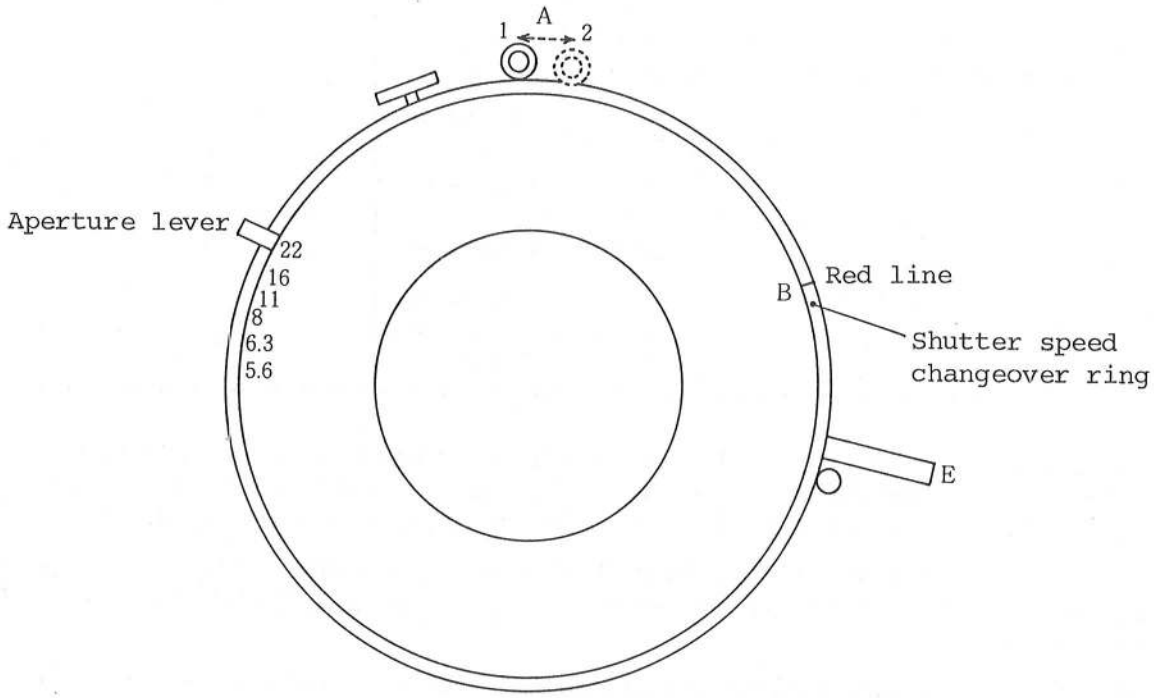
			Polaroid 52, 55 4" × 5"	Polaroid 107, 105	Roll Film 120, 220 6 × 7
			Exposed Area on Film		
Effective Display Area on CRT	Photographing Ratio	Picture Size on Film through Lens	118 × 90	95 × 73	68 × 56
CRT 120 × 90	0.6×	72 × 54	NO	NO	
	0.8×	96 × 72	NO		NO
	1.0×	120 × 90		NO	NO

2-3-4 Setting Film Sensitivity and Aperture

Set the film sensitivity according to the kind of film. (See (1)-(f) in 3-4-1.)

At the same time, set the camera aperture in accordance with the following.

Film Sensitivity	Aperture
ASA 50	f = 8
ASA 100	f = 8
ASA 400	f = 16
ASA 3000	f = 22



< How to set camera aperture >

(1) Align the red line of the shutter speed changeover ring with B.

(2) Remove the knob E (which has been screwed in).

(3) Shift the lever A from 2 to 1.

(4) Screw in the knob E completely. This opens the shutter.

(5) Set the aperture lever to a desired aperture.

(Caution) If the shutter speed changeover ring is shifted from B after step (5), the shutter closes. Although it can be opened by changing over the lever from 1 to 2, the aperture becomes unchangeable by the aperture lever. So, set the camera aperture again as instructed above.

< Reference >

Kinds and sensitivities of film

Kinds of Film				Sensitivities (ASA)
Roll film (Brownie size)		SS	Negative	100
		SSS	"	400
		TRI-X	"	400
Polaroid	Card-size	105	Positive Negative	75
		107	Positive	3000
	4" × 5"	P/N55	Positive Negative	50
		52	Positive	400

Avoid using the P/N 55 Polaroid film at photo speed 1 (50 sec), and the 107 Polaroid film at photo speed 3 (200 sec) or 4 (400 sec), since these usages do not ensure satisfactory results.

With the P/N 55 and 107 Polaroid films, a slight brightness adjustment may be required in addition to the aperture setting mentioned above.

Exposure is automatically compensated for changeover of photo speed (scanning speed for photographing), so the camera aperture need not be changed. When using photo speed 4 (400 sec) for other than X-ray image, however, the aperture values in the above table must be reduced to half (e.g., from f = 8 to f = 11).

< Reference >

Example of film processing method

	Processing Solution	Processing Time (min)	Caution
Development	D-76	7 ∿ 9 (20°C)	Use developing solution while adding supplement. Prolong the developing time by 10 % for every development.
	Polydol or Fujidol	8 (20°C)	
	Microdol-X or Microfine	10 ∿ 12 (20°C)	
	D-76: Water = 1 : 1	7 ∿ 9 (23°C)	Discard developing solution after completion of each development.
Stop	Acetic acid 15 cc/ 1 ℓ water	0.5	
Fixing	Ordinary type	5 ∿ 10	Exchange solution when the time required for making the unexposed part transparent has doubled.
	Rapid type	3 ∿ 5	
Rinsing	Water	15 ∿ 30	Running water

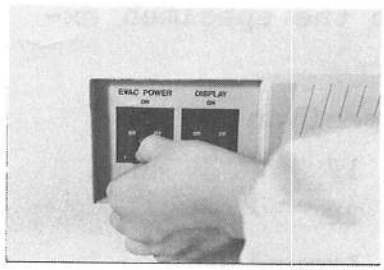
(Note) The above processing time indicates an example of TRI-X (Kodak).

3. OPERATION

3-1 Preliminary Operation

(1) Run cooling water.

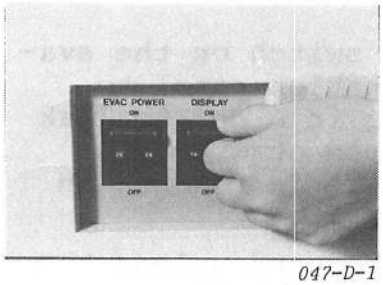
(2) Turn on the main switch of the switchboard.



047-C-42

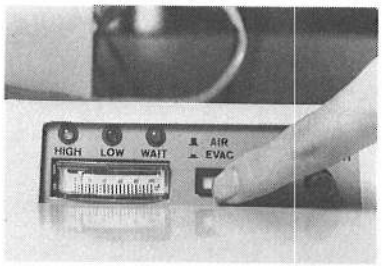
(3) Turn on the [EVAC POWER] switch on the microscope column console. The oil rotary pump starts and [WAIT] lamp is lit. The air compressor also starts if its pressure is reduced (to lower than 3 kg/cm^2).

(Note) Buzzer sounds if cooling water is not running or if air compressor pressure is inadequate. So check cooling water. As for air compressor pressure, it will rise to the specified level in about 1 minute.



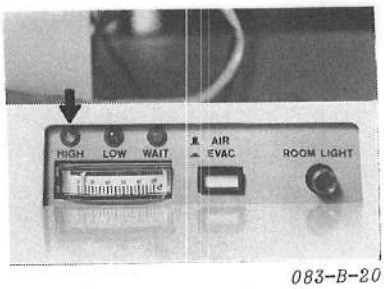
047-D-1

(4) Turn on the [DISPLAY] switch.



083-B-21

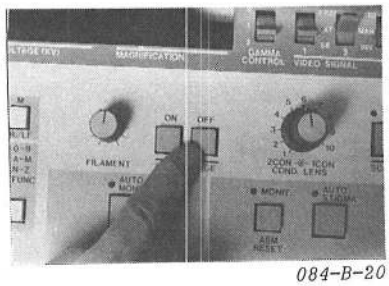
(5) Depress the [EVAC/AIR] switch on the evacuating system operation panel, thereby setting to EVAC.
(Ordinarily, this switch is kept depressed, so it need not be pressed.



083-B-20

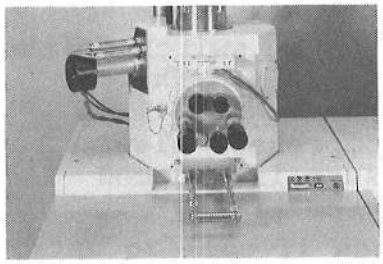
(6) Evacuation automatically proceeds and completes when the [HIGH] lamp is lit (in green). This sequence takes about 20 minutes.

3-2 Specimen Exchange



084-B-20

(1) Press the [(ACC VOLTAGE) OFF] switch of the display unit in order to cut off the high voltage supply.



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(2) Set each control knob of the specimen goniometer stage to the specimen exchange position.

- With standard specimen stage

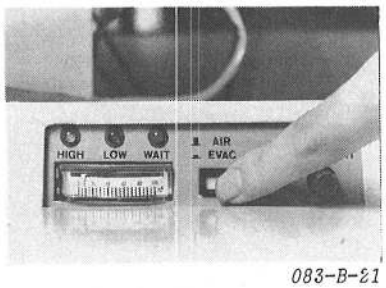
  X-control knob: 17

  Y-control knob: 20

  T-control knob: Around 0°

  Z-control knob: [EX]

The [SC AIR POSSIBLE] lamp is lit (in green). This indicates that setting the specimen exchange position is completed.

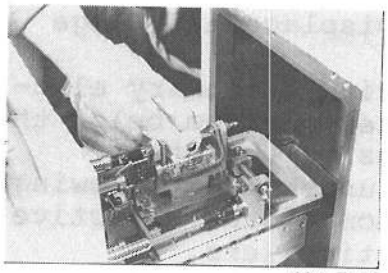


083-B-21

(3) Set the [EVAC/AIR] switch on the evacuating system operation panel to AIR [■] by pressing in order to leak air into the specimen chamber. (Atmospheric pressure is reached in about half a minute.)

(Air cannot be introduced unless the [SC AIR POSSIBLE] lamp is lit.)

(4) After completion of air leak, pull out the specimen stage toward you.



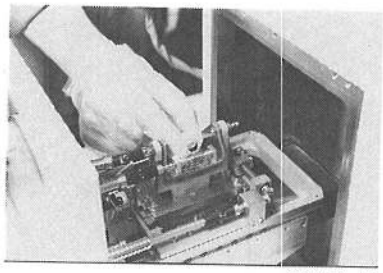
084-F-41

(5) Remove the specimen holder.

(6) Remove the specimen stub for the previous observation from the holder screw.

(7) Fix a new specimen to the holder screw.

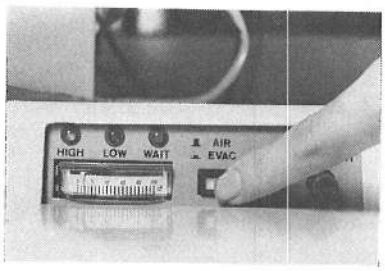
(8) Loosen the lock screw and align the height of specimen surface with the gauge, then fix the screw. The reference position of height adjustment varies with specimen stub. So make setting in reference to Fig. 3-3.



084-F-41

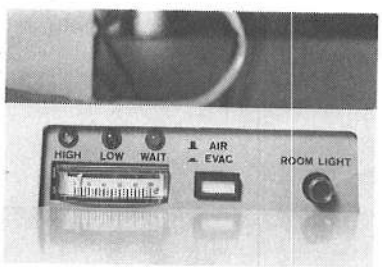
(9) Mount the specimen holder assembly on the specimen stage.

(10) Install the specimen stage in the specimen chamber.



083-B-21

(11) Set the [EVAC/AIR] switch to EVAC [▬]. Evacuating sequence will automatically start.



083-B-20

(12) When the [HIGH] lamp is lit, evacuation is completed.

3-3 Setting Specimen and Allowable Specimen Displacement Range

This instrument permits two methods for detecting secondary electron signal. By one method, the signal is detected from below the objective lens, and another from above the lens by the other method. This second method allows microscopy under the following conditions; (1) specimen brought near the bottom of the objective lens and (2) specimen located inside the objective lens.
In these case, the objective lens is focused at an extremely short distance, so various lens aberrations are minimized, ensuring a high resolution.

With this instrument, a specimen is set by the different procedures according to microscopic purposes, as detailed below.

- Standard setting
- High resolution setting
- Ultrahigh resolution setting

Operating conditions by each setting method are given in the table below.

Table 3-1 Setting of Specimen and Selection of Secondary Electron Detector

Setting Method	WD range	Illustration of Specimen Setting	Selection of SE Detecting Method
Standard setting	Standard stage 5 ∿ 35 mm	See Fig. 3-3 (a), (b)	Secondary electrons can be detected from either below or above the objective lens. Use proper detecting method depending on specimen setting.
High resolution setting	Standard stage 1 ∿ 31 mm	See Fig. 3-3 (c), (d)	
Ultrahigh resolution setting	Standard stage -3 ∿ 0 mm	See Fig. 3-3 (e)	

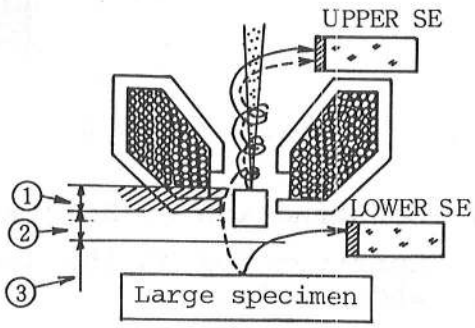
(Note)

SED BIAS knob setting

Vacc = 0.5 ∿ 2 kV: Full CCW

Vacc = 3 ∿ 30 kV : Adjust for best image quality (Ordinary Full CW)

(SED BIAS functions only with upper detector)



① Ultrahigh resolution setting (with upper detector UPPER SE)

WD = -3 ∿ 0 mm

(maximum specimen size: 6 mm dia.)

② High resolution setting (with upper detector UPPER SE)

WD = 1 ∿ 10 mm

③ Standard setting (with lower detector LOWER SE)

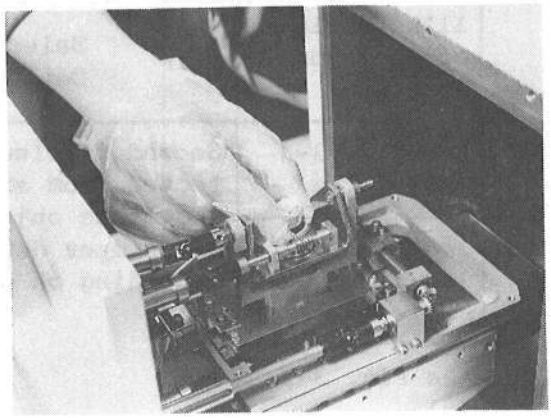
WD = 10 ∿ 35 mm

Selection of the upper and lower detectors also differs depending on specimen size. So, use proper detector with reference to this table.

3-3-1 Standard Stage

(1) Insertion/Removal of Specimen into/from Microscopic Position

The specimen holder accommodating a specimen is mounted and dismounted to/from the specimen stage as shown below.



084-F-41

Fig. 3-1 Mounting/Dismounting Standard Holder

(2) Construction of Specimen Holder and Specimen Stub

Construction of the specimen holder and specimen stub is shown below.

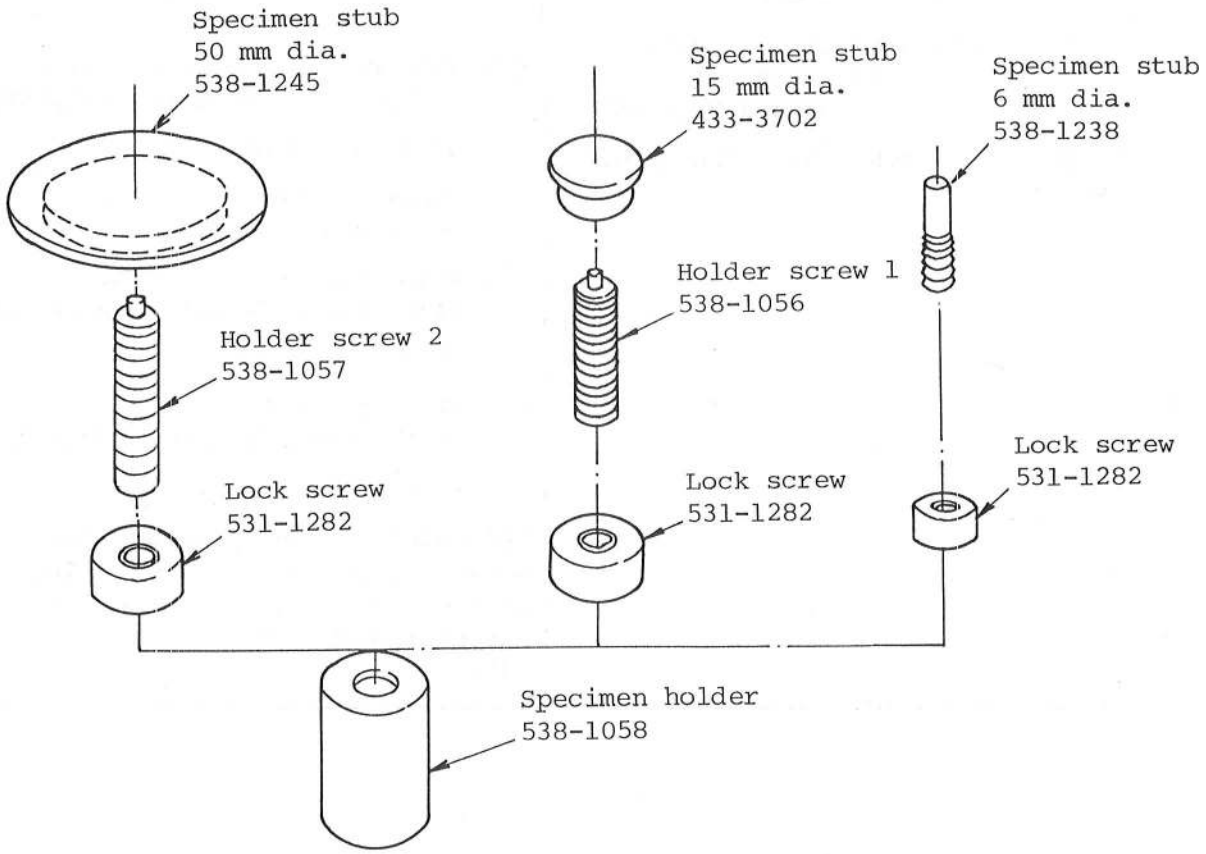


Fig. 3-2-(a) Construction of Specimen Holder and Specimen Stub (for standard and ultrahigh resolution setting with standard stage)

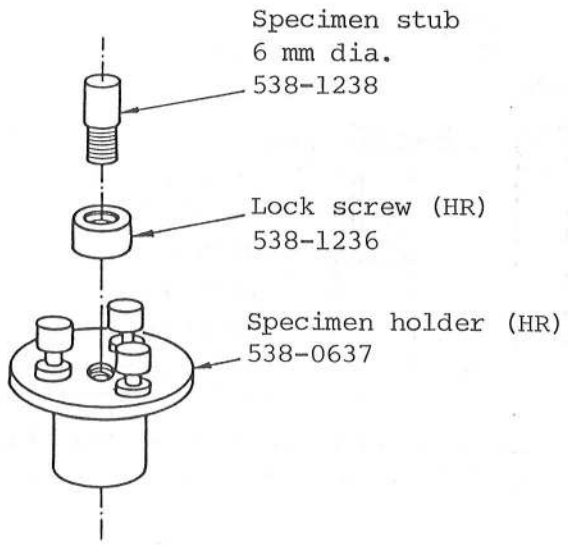


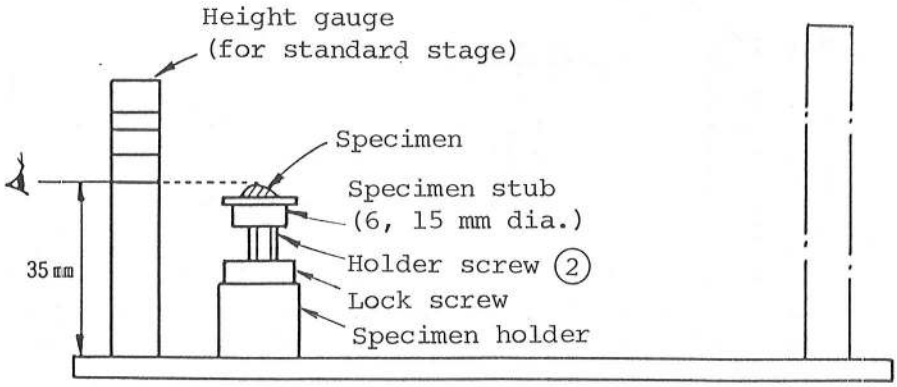
Fig. 3-2-(b) Construction of Specimen Holder and Specimen Stub (for ultrahigh resolution setting with standard stage)

(3) Adjustment of Specimen Height

The height of a specimen mounted on the specimen stub must be adjusted with the aid of the height gauge as shown in Fig. 3-3.

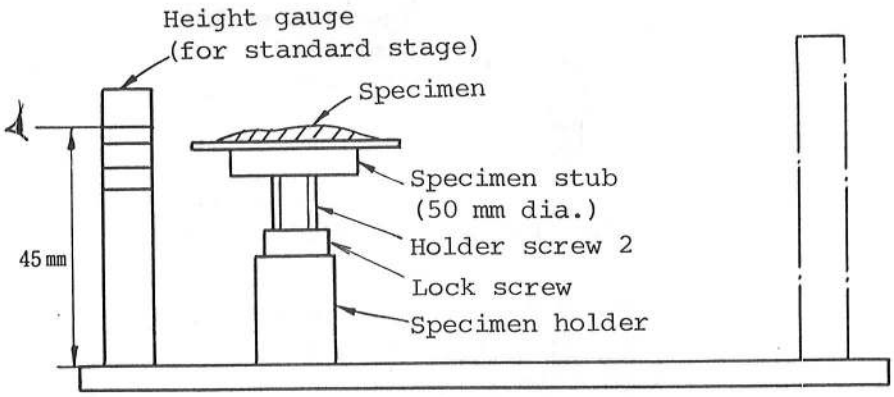
Attention must be paid since this adjustment depends on specimen size.

When using the ultrahigh resolution specimen holder, specimen height should not surpass the level indicated on the height gauge.

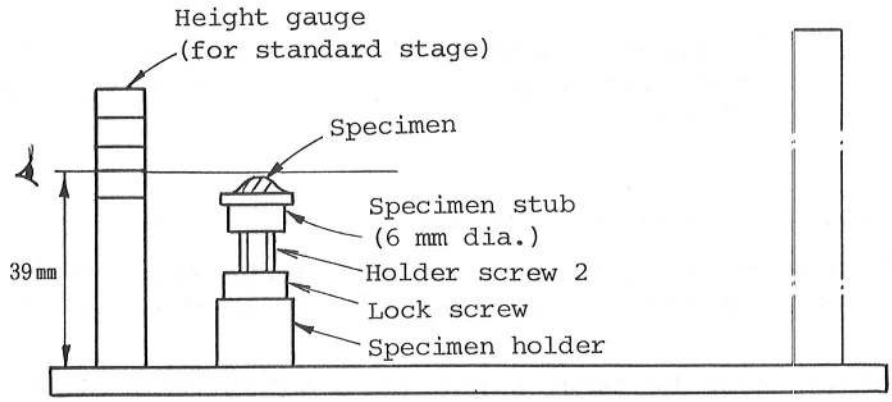


(a) Specimen Height Adjustment for Standard Setting (with 6 and 15 mm dia. specimen stubs)

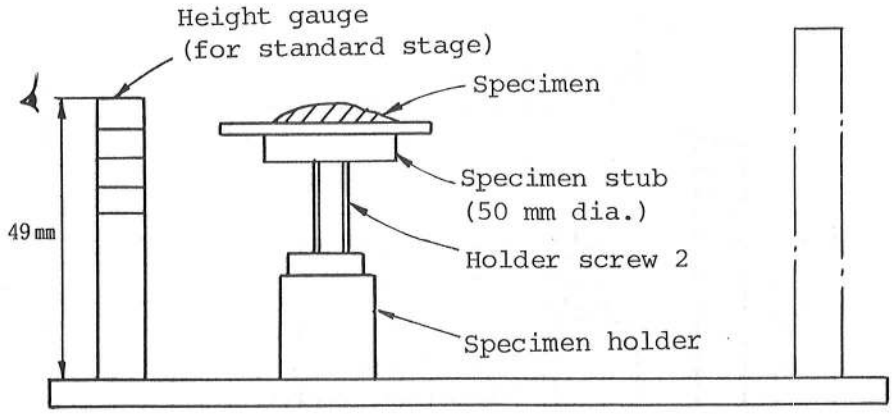
Fig. 3-3 Specimen Height Adjustment (with standard stage) 1/3



(b) Specimen Height Adjustment for Standard Setting
(with 50 mm dia. specimen stub)

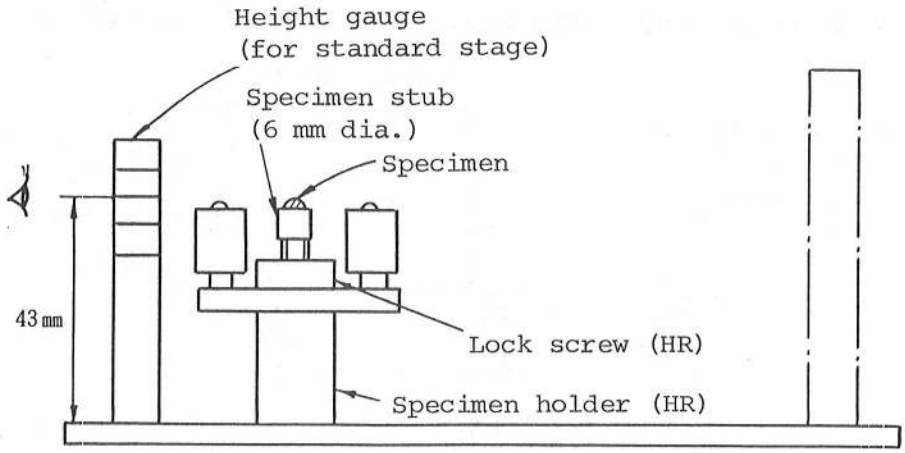


(c) Specimen Height Adjustment for High Resolution Setting
(with 6 mm dia. specimen stub)



(d) Specimen Height Adjustment for High Resolution Setting
(with 50 mm dia. specimen stub)

Fig. 3-3 Specimen Height Adjustment (with standard stage) 2/3



(e) Specimen Height Adjustment for Ultrahigh Resolution (with 6 mm dia. specimen stub)

Fig. 3-3 Specimen Height Adjustment (with standard stage) 3/3

(4) Specimen Size and Allowable Specimen Displacement Range

Even when the specimen height is set to a standard in above (3), displacement in Z direction (displacement in specimen height direction) is restricted related with the specimen tilt angle. For example, if a large specimen stub is excessively tilted, it would touch the objective lens. In such a case, the angle should be reduced or the specimen position should be lowered.

Figs. 3-5 through 3-9 illustrate specimen sizes, scale Z number* on the Z-control knob and movable ranges in function of specimen tilt angle θ.

Figs. 3-10 and 3-11 show the movable range of specimen in X and Y directions when specimen of 150 mm diameter or 200 mm diameter is to be observed (at T = 0°, WD = 5 or more).

(Note*) Indicates working distance (WD) at a specimen tilt angle of 0°, or distance between the lower surface of the objective lens and specimen.

Take reading of a graduation on the Z-control knob as illustrated in Fig. 3-4 at a standard point corresponding to the particular specimen stub employed.

Graduations on the Z-control knob are shown below.

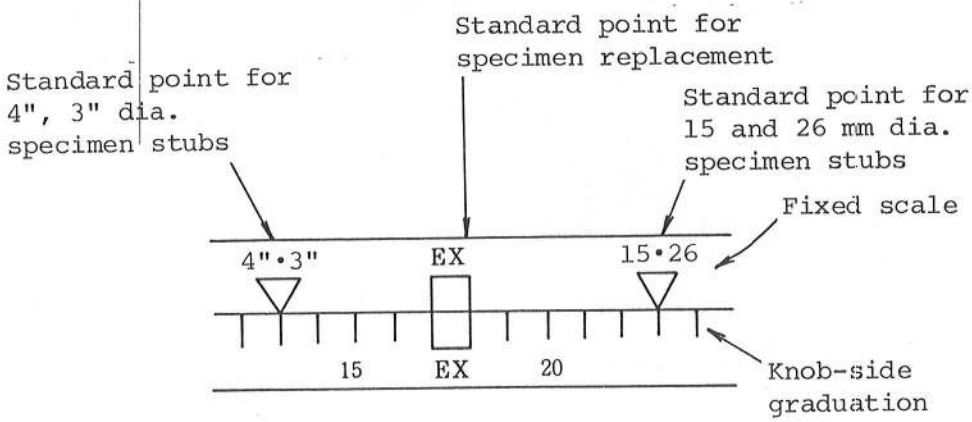


Fig. 3-4 Graduations on Z-Control Knob

With the ultrahigh resolution specimen holder, the working distance becomes -2 to -3 mm when setting the specimen height according to (3) and Z number to 5 mm. Specimen cannot be tilted in the ultrahigh resolution mode. In addition, the specimen shiftable range is limited to ±2.5 mm for X-control knob at 17 mm position, and ±2.5 mm for Y-control knob at 20 mm position.

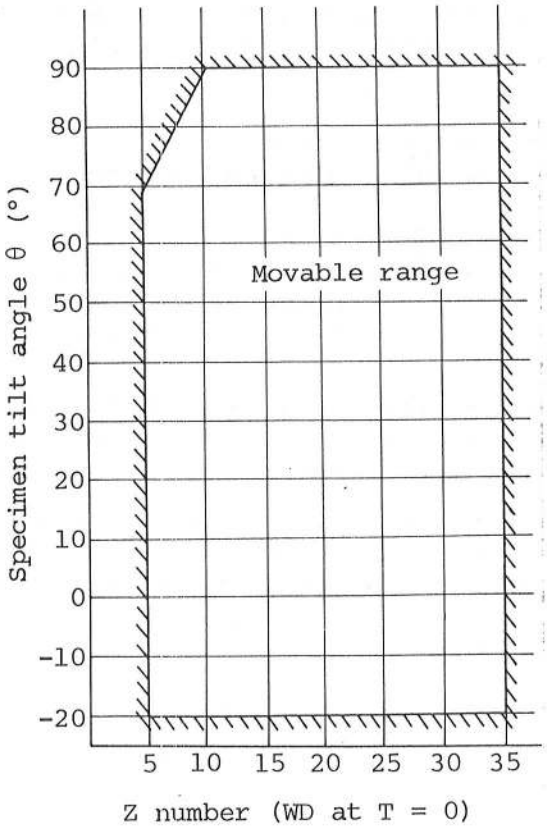


Fig. 3-5 Relationship between Z Number and Specimen Tilt Angle on 15 and 26 mm Dia. Specimen Stubs

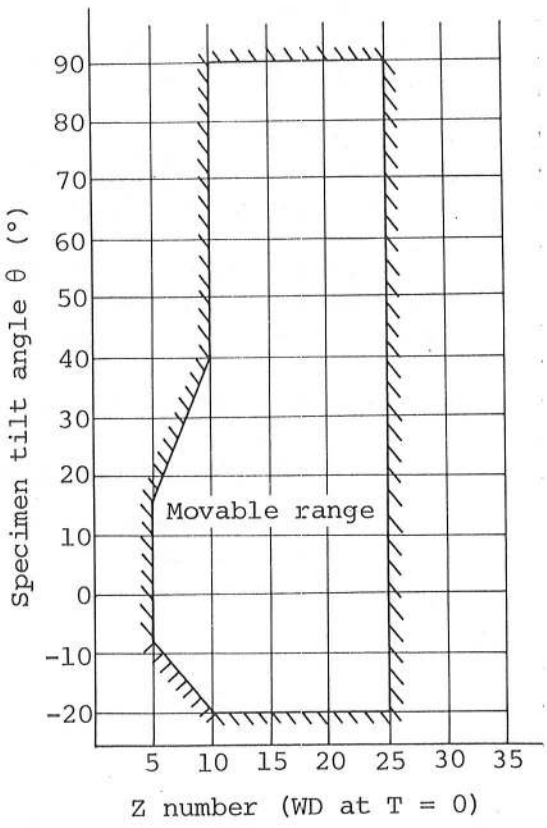


Fig. 3-6 Relationship between Z Number and Specimen Tilt Angle on 50 mm Dia. Specimen Stub

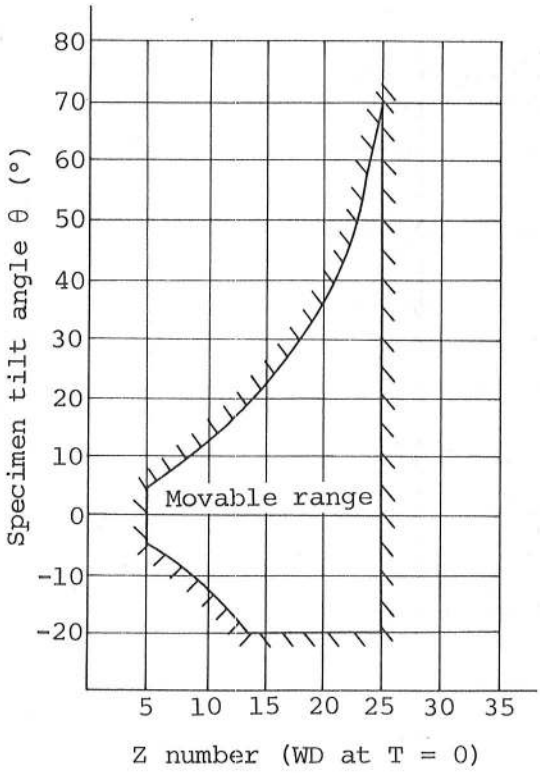


Fig. 3-7 Relationship between Z Number and Specimen Tilt Angle on 78 mm Dia. Specimen Stub

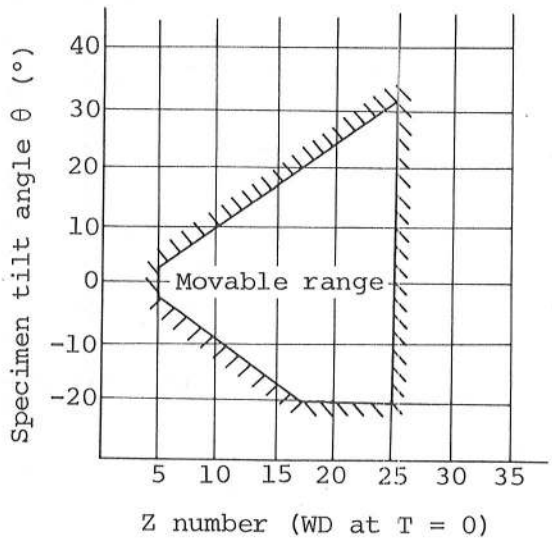


Fig. 3-8 Relationship between Z Number and Specimen Tilt Angle on 100 mm Dia. Specimen Stub

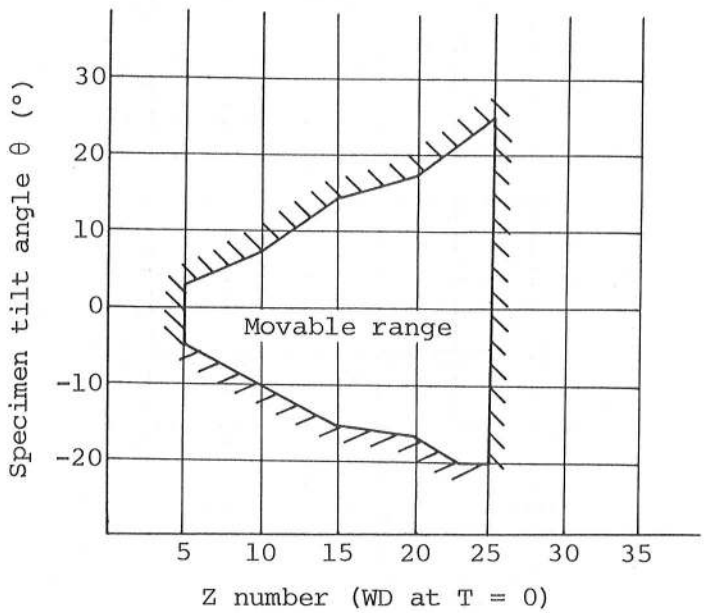


Fig. 3-9 Relationship between Z Number and Specimen Tilt Angle on 125 mm Dia. Specimen Stub

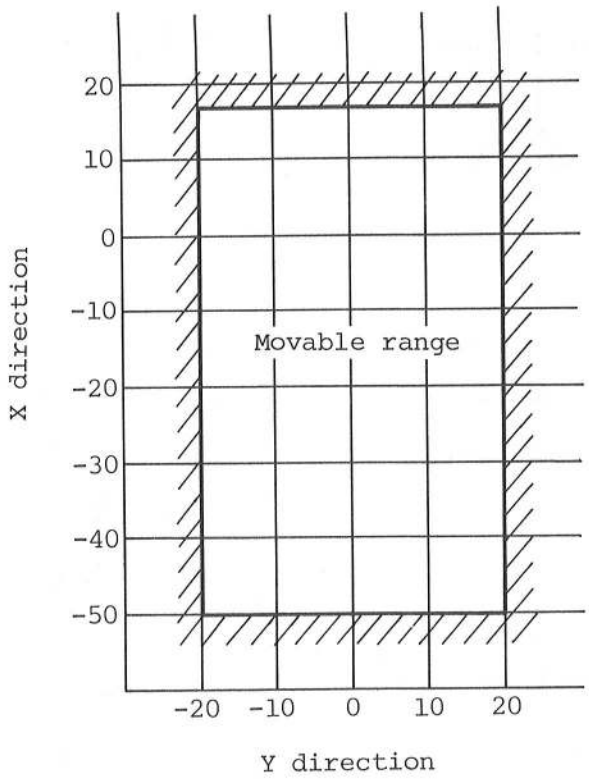


Fig. 3-10 Movable Range of 150 mm Diameter Specimen in X/Y Direction (T = 0°, WD = 5 or more)

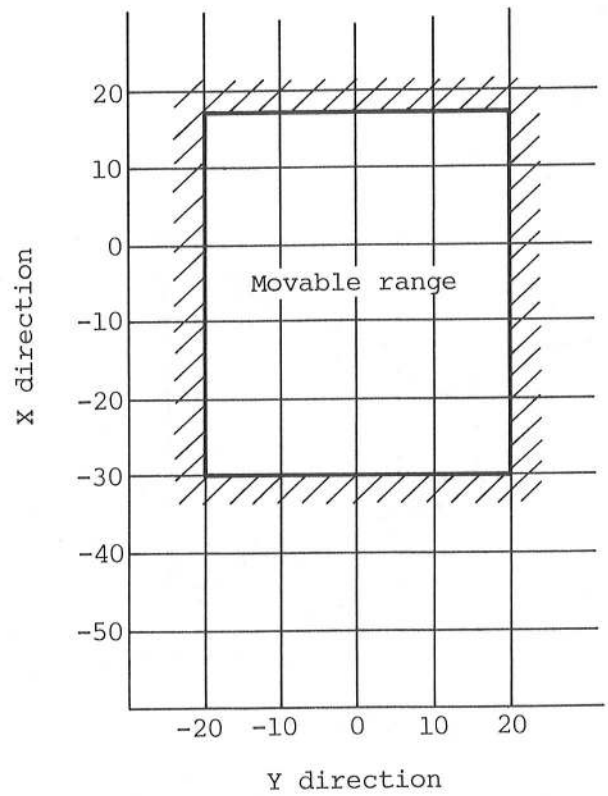
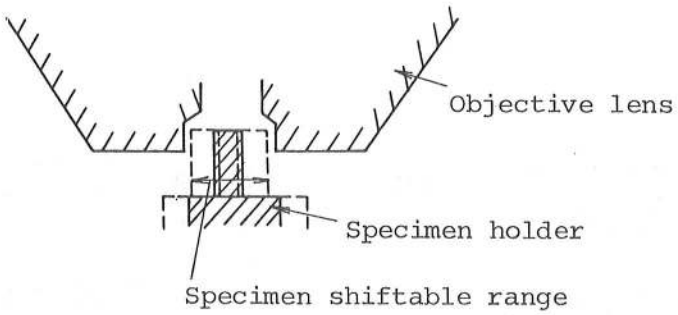


Fig. 3-11 Movable Range of 200 mm Diameter Specimen in X/Y Direction (T = 0°, WD = 5 or more)

3-3-2 Cautions on Use at Ultrahigh-Resolution Position

When employing the ultrahigh resolution setting (WD 0 ∿ -3 mm), the allowable displacement range of the specimen stage is limited to ±2.5 mm on the X and Y axes since a specimen is located inside the objective lens.



However, the specimen stage itself has a wider movable range. So, when employing the ultrahigh resolution setting, the specimen position limiter is used which generates an alarm if the allowable displacement range is surpassed.

(1) Functions of Specimen Position Limiter

(a) Buzzer sounds intermittently if the allowable displacement range is exceeded on the X or Y axis.

(b) The moving direction indicator lamp is lit to tell you which control knob X or Y must be manipulated in which direction. According to the lamp, turn the control knob, and the specimen stage will return to the allowable displacement range.

(c) The limiter provides the following protection.
Air cannot be leaked into the specimen chamber even by turning the [EVAC/AIR] switch to AIR [▟] on the evacuating system operation panel unless the Z-control knob of the specimen stage is set to the specimen exchange position.

(d) Alarm function is provided only when the [PROTECTION] switch is turned on, though protective function with regard to air leak is always activated.

(2) Restriction on Magnification for Image Observation

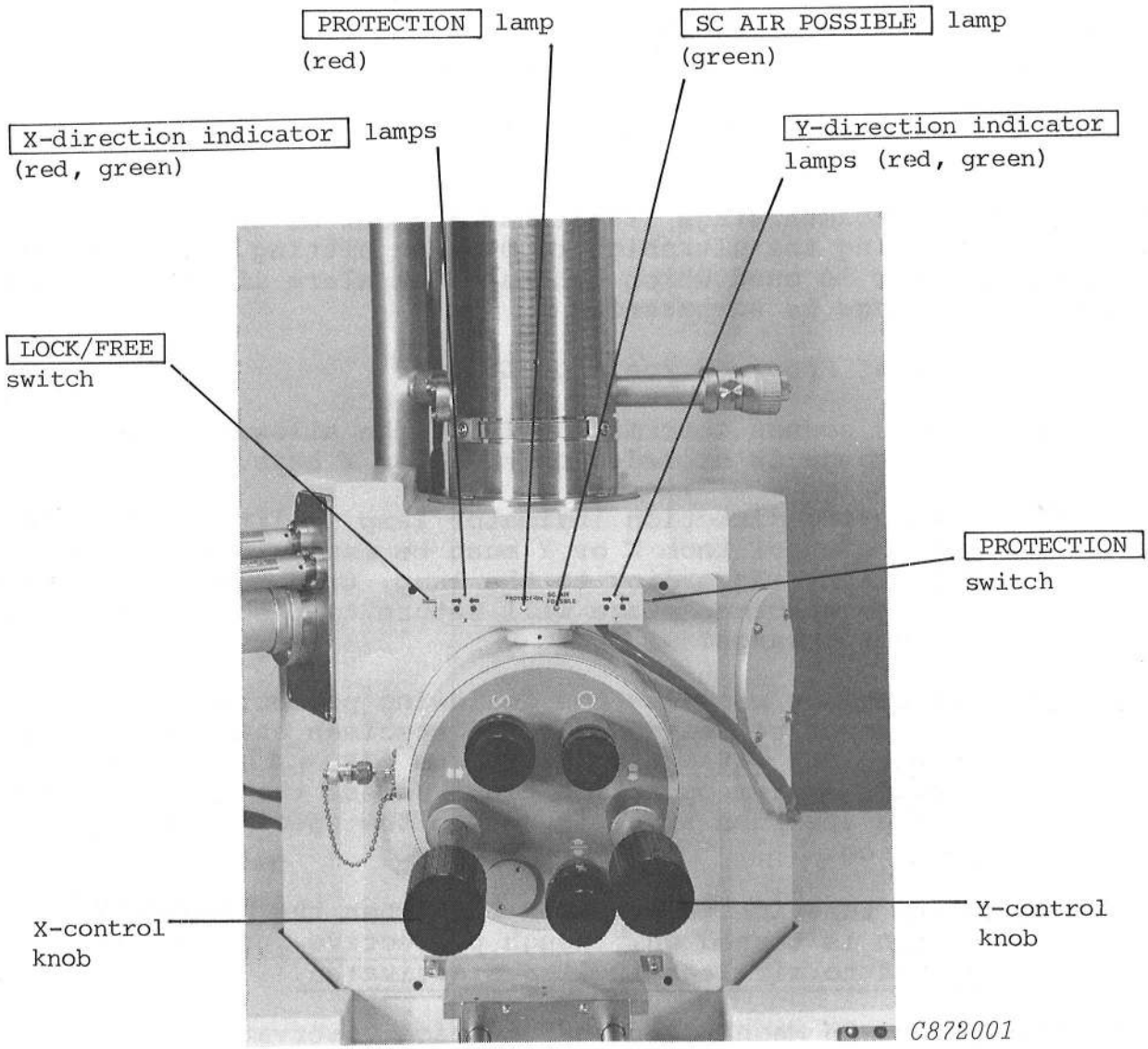
Although the ultrahigh resolution setting (WD = 0 ∿ -3 mm) allows a low magnification, for example, about 200× at minimum with WD -2 mm, an image blurs on its circumference. So, such low magnifications must be used for selecting the field of view only.

It is recommended for a quality micrograph to employ a magnification of 500× or higher in this setting.

(3) If a specimen is observed at high magnification with the instrument floor vibrating considerably, the LOCK/FREE switch should be set to LOCK.

To exchange a specimen or when not observing it at high magnification, set the LOCK/FREE switch to FREE.

(4) Components



Standard Stage

Fig. 3-12 Specimen Position Limiter

[PROTECTION] switch

Activates/inactivates alarm function.

[PROTECTION] lamp

Indicates that alarm function is activated.

[SC AIR POSSIBLE] lamp

Indicates that Z axis is located at the specimen exchange position and that air leak is possible.

[X-direction indicator] lamps

Indicate turning direction of the X-control knob for returning to the allowable displacement range.

[Y-direction indicator] lamps

Indicate turning direction of the Y-control knob for returning to the allowable displacement range.

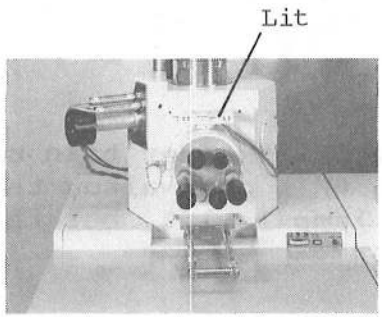
(Red and green colors are used for the direction indicator lamps in order to facilitate discriminating them from each other even in a dark room.)

- o When red lamp is lit, turn control knob clockwise.
- o When green lamp is lit, turn control knob counterclockwise.

[LOCK/FREE] switch

Locks or releases the base of specimen stage.

(5) Operating Procedures at Ultrahigh Resolution Position



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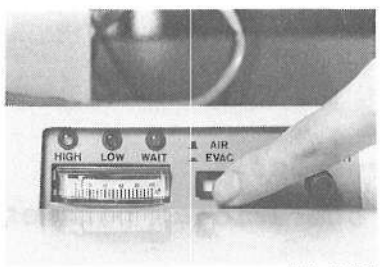
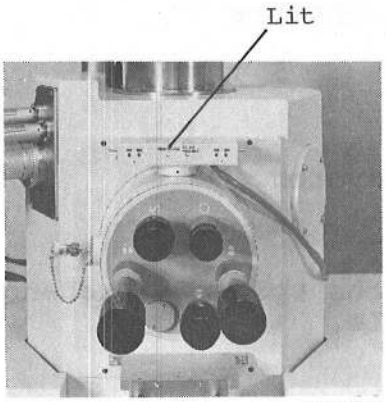
(a) Set the Z axis of the specimen stage at the specimen exchange position. (Confirm that the [SC AIR POSSIBLE] lamp is lit.)



083-B-21

(b) Turn the [EVAC/AIR] switch to AIR [▟] , thereby leaking air into the specimen chamber.

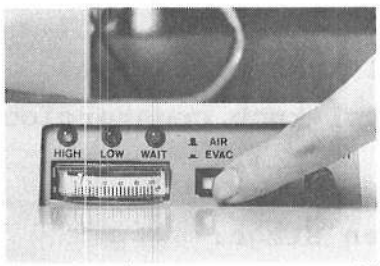
(c) Mount the specimen holder which has been set for ultrahigh resolution.



C872001

(d) Turn on the [PROTECTION] switch and confirm that the [PROTECTION] lamp is lit.

(e) If X or Y position is not within the allowable displacement range, the [X or Y-direction indicator] lamp is lit. According to the arrow marked below the lit lamp, turn the X or Y control knob, so that four lamps are all extinguished. (The buzzer will not sound when the Z axis is located at the specimen exchange position.)



083-B-21

(f) Introduce the specimen stage into the specimen chamber and start evacuation.

(g) After completion of evacuation, set the Z-control knob to 5 mm for the standard stage, and to 20 mm for the large-sized stage. The specimen will be set at the ultrahigh resolution position.

(Note) Turn off the [PROTECTION] switch at other than ultrahigh resolution position. In this case also, the [X or Y-direction indicator] lamp is lit, but the buzzer does not sound.

3-4 Operation

3-4-1 Keyboard Operation

The keyboard is used for the following purposes.

- o Setting accelerating voltage and other operational parameters
- o Reading each operational parameter
- o Writing character data onto CRT

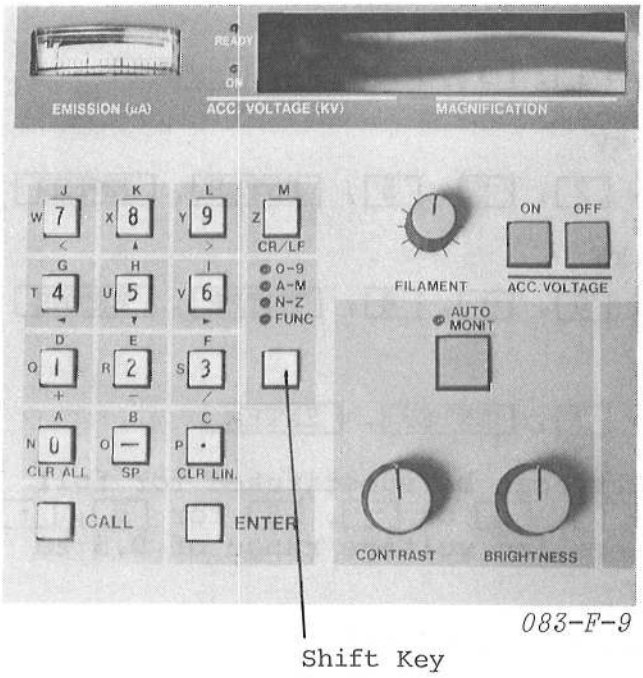


Fig. 3-13 Keyboard

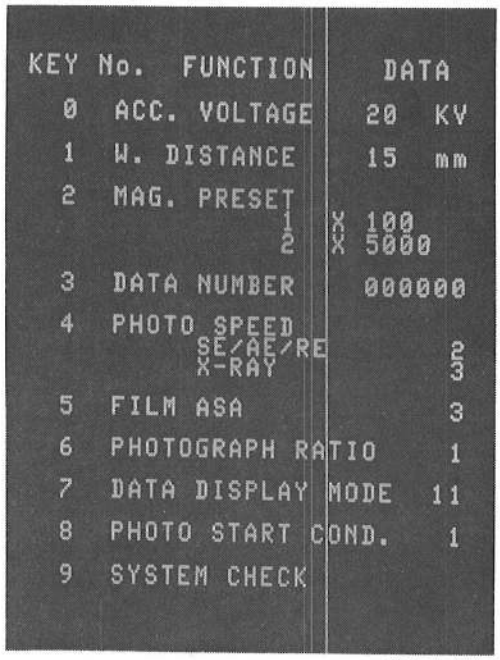


Fig. 3-14 Data List

(1) Setting Parameters

Press the [CALL] key. CRT displays a data list of various operational parameters and input becomes possible. Upon selecting the key number assigned to each parameter, blinking occurs in the area requiring input. Enter a necessary numeral there. After completion of input, press the [ENTER] key and confirm the entry in the data list. Then press the [ENTER] key again, and usual image observation mode returns.

Keyboard operation for each parameter is exemplified below. Note that each set value is retained even after power supply is cut off.

(a) Setting Accelerating Voltage (ACC VOLTAGE)

[CALL] ... Displays data list.

↓

[0] ... Selects ACC VOLTAGE entry.

↓

[(Voltage value)] ... Enters 2 or 3-digit value.

↓

[ENTER] ... Confirms list.

↓

[ENTER] ... Returns usual image observation mode.

(Ex. 1) Setting 13 kV

[CALL], [0], [1], [3], [ENTER], [ENTER]

(Ex. 2) Setting 2.5 kV

[CALL], [0], [2], [·], [5], [ENTER], [ENTER]

(Ex. 3) Setting 0.8 kV

[CALL], [0], [0], [·], [8], [ENTER], [ENTER]

(Ex. 4) Setting 7 kV

[CALL], [0], [7], [ENTER], [ENTER]

(Note) Simplified entry can be substituted for full entry (e.g., [0], [5] or [·], [5] for [0], [·], [5]) at accelerating voltage range of 0.5 to 0.9 kV.

(b) Setting Working Distance (W DISTANCE)

The focal length of objective lens is set according to input. If a specimen must be set at the determined working distance, e.g., in X-ray analysis, specimen position is accurately settable by adjusting the Z-control knob of the specimen stage so as to obtain focus after setting the focal length.

[CALL]

↓

[1] ... Selects W DISTANCE entry.

↓

[Working distance value] ... Enter 1 or 2-digit value.

↓

[ENTER]

↓

[ENTER]

(Ex. 1) Setting WD 32 mm

[CALL], [1], [3], [2], [ENTER], [ENTER]

(Ex. 2) Setting WD 8 mm

[CALL], [1], [8], [ENTER], [ENTER]

(Ex. 3) Setting WD -2 mm

[CALL], [1], [-], [2], [ENTER], [ENTER]

(Note) Valid numerals are 1, 0, -1 ∿ -3 with the [STAGE] switch at UPPER, and 0 ∿ 69 with the switch at LOWER.

(c) Setting Preset Magnification (MAG PRESET)

This parameter determines the preset magnification which can be called out by the [PRESET 1 and 2] switches at the magnification control section.

[CALL]
↓
[2] ... Selects MAG PRESET entry.
↓
[(PRESET 1 value)] ... Enters a numeral of 1 to 5 digits.
↓
[ENTER]
↓
[(PRESET 2 value)] ... Enters a numeral of 1 to 5 digits.
↓
[ENTER]
↓
[ENTER]

(Ex.) Entry for setting magnifications of 35× on PRESET 1 side and 7500× on PRESET 2 side

[CALL], [2], [3], [5], [ENTER], [7], [5], [0], [0], [ENTER], [ENTER]

(d) Setting Data No. (DATA NUMBER)

This parameter sets data no. (film no.) among the data to be displayed at the bottom of CRT. The lowest 2 digits value of each data no. increments by 1 whenever recording an image.

[CALL]
↓
[3] ... Selects DATA NUMBER entry.
↓
[(Data no.)] ... Enters a numeral of 6 digits.
↓
[ENTER]
↓
[ENTER]

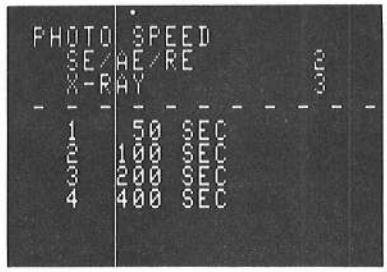
(Ex.) Setting data no. 570100

[CALL], [3], [5], [7], [0], [1], [0], [0], [ENTER], [ENTER]

(e) Setting Photo Scan Speed (PHOTO SPEED)

Photo scan speed is settable in 4 steps each for X-ray image and other signal image such as secondary electron image. Usually, SE/AE/RE is set at 2 (100 sec), and X-RAY at 3 (200 sec).

[CALL]
↓
[4] ... Selects PHOTO SPEED entry. Data list is changed.
↓
[(SE/RE value)] ... Enters 1-digit numeral.
↓
[ENTER]
↓
[(X-RAY value)] ... Enters 1-digit numeral.
↓
[ENTER]
↓
[ENTER]



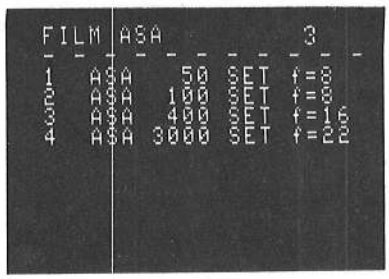
(Ex.) Setting SE/RE to 100 sec (2) and X-RAY to 200 sec (3)

[CALL], [4], [2], [ENTER], [3], [ENTER], [ENTER]

(f) Setting Film Sensitivity (FILM ASA)

This parameter sets the sensitivity of a film used. Brightness of the photographing CRT is compensated according to the set sensitivity. At the same time, CRT indicates a proper camera aperture under the selected condition. So set the camera aperture accordingly.

[CALL]
↓
[5] ... Selects FILM ASA entry. Data list is changed.
↓
[(Film sensitivity)] ... Enters 1-digit numeral.
↓
[ENTER]
↓
[ENTER]



(Ex.) When using film of sensitivity ASA 400:

[CALL], [5], [3], [ENTER], [ENTER]

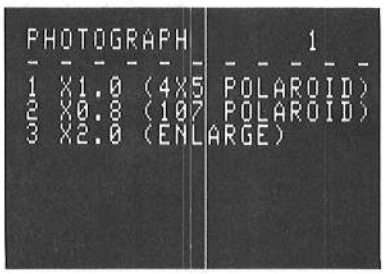
(Set camera aperture f to 16 according to CRT display.)

(g) Setting Photographing Ratio (PHOTOGRAPH)

This parameter sets display magnification according to the size of film used or photograph after enlargement so that the final image provides a proper magnification. The photographing ratio indicates the ratio of effective exposure area on the film to image size on photographing CRT. It becomes 1.0 when using a film of 4" × 5" size.

Photographing ratio 0.8× is used for Poraloid types 107 and 105. It must be considered that a negative film will be enlarged usually. So employ either 1.0× (photograph is enlarged so that the micron marker has a length of 3 cm) or 2.0× (photograph is enlarged so that the micron marker has a length of 6 cm, or it has 1/6 size). With ratios 0.8× and 2.0×, two and three "." marks appear at the top left of the data display area at the bottom of CRT respectively in order to facilitate discrimination from each other.

[CALL]
↓
[6] ... Selects PHOTOGRAPH entry. Data list is changed.
↓
[(Photographing ratio)] ... Enters 1-digit numeral.
↓
[ENTER]
↓
[ENTER]



(Ex.) When using type 107 Polaroid film (setting 0.8×):

[CALL], [6], [2], [ENTER], [ENTER]

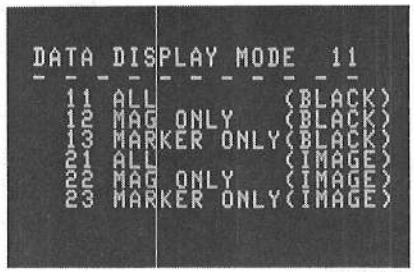
(h) Setting Data Display Mode (DATA DISPLAY MODE)

Through this parameter, black background is selected or avoided for character display on CRT. In addition, either or both of magnification and micron marker displays are selectable.

[CALL]

↓

[7] ... Selects DATA DISPLAY MODE entry. Data list is changed.



C872617

↓

[(Display mode)] ... Enters 2-digit numeral.

↓

[ENTER]

↓

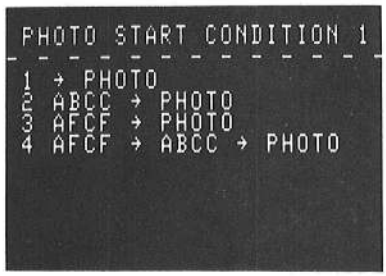
[ENTER]

(Ex.) Selecting black background for character display and display of micron marker only

[CALL], [7], [1], [3], [ENTER], [ENTER]

(i) Setting Photographing Start Condition (PHOTO START CONDITION)

This parameter enables the [PHOTO] switch to record an image after automatic execution of the ABC (automatic image adjustment) and/or AFC (auto focus) function just by one touch.



In this case, the ABC function is activated even when the [AUTO-MAN-INV] switch is at [MANUAL]. So this parameter is convenient for image observations which require increasing contrast beyond the optimal condition for photographing, for example, when operating the microscope under a comparatively high illumination.

[CALL]

↓

[8] ... Selects PHOTO START CONDITION entry.

↓

[(Input)] ... Enters 1-digit numeral.

↓

[ENTER]

↓

[ENTER]

(Ex.) Setting image recording after execution of ABC function

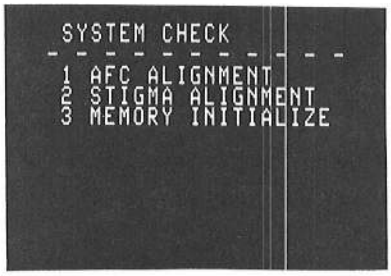
[CALL], [8], [2], [ENTER], [ENTER]

(j) SYSTEM CHECK

Used for system adjustment, etc.

1) AFC ALIGNMENT

Used for adjusting the [AFC ALIGN] trimmer inside the operation panel cover in order to activate the auto focus and auto stigma function accurately.



[CALL]

↓

[9]

↓

[1]

↓

[(Make adjustment)]

↓

[ENTER] ... Normal status returns.

2) STIGMA ALIGNMENT

Used for adjusting the [STIG ALIGN] trimmer provided inside the operation panel cover to make the auto stigmator operate efficiently.

[CALL]

↓

[9]

↓

↓

[2]

↓

[(Make adjustment)]

↓

[ENTER] ... Normal status returns.

3) MEMORY INITIALIZE

The system is initialized if an abnormality occurs in display, contents of data list on the operation panel because the contents of memory become abnormal due to external disturbance, etc. Attention must be paid to use of this function since system conditions are set to the values shown in Fig. 3-14 indifferent to the previous settings.

[CALL]

↓

[3] ..... Initializes system.

The above explanation is given in cases where only one parameter is entered. When entering two or more parameters continuously, omit [ENTER] at the final step for each parameter and enter the key no. of the next parameter. The [ENTER] keys must be pressed twice at the end of the final parameter.

(Ex.) Setting accelerating voltage 21 kV and working distance 15 mm

[CALL] ... Calls out data list.

↓

[0]

↓

[2], [1] } ... Enters accelerating voltage.

↓

[ENTER]

↓

[1]

↓

[1], [5] } ... Enters working distance.

↓

[ENTER]

↓

[ENTER] ... Image display mode returns.

(2) Reading Various Conditions

The set conditions can be read from the data list which is called out by pressing the [CALL] key. In particular, W DISTANCE indicates a working distance at which focus is obtained at that time, irrespective of input. So, the specimen set position can be known by reading the working distance after focusing an image. When pressing the [ENTER] key without data entry, the original image display mode returns.

(3) Writing Character Data onto Image

From the keyboard, characters (alphanumerics and symbols) can be written at any location on CRT when the [DATA DISPLAY] switch is set so that the KEY-IN lamp is lit. The "*" mark (cursor) appears at a location where a character is written.

Each key has the following functions:

(a) Numeral and [-], [.]

(b) A ∿ M

(c) N ∿ Z

(d) Symbol and special function

These functions can be changed over sequentially by the shift key.

Functions other than alphanumerics and symbols are listed below.

▲ ▼ ◀ ▶	: Move cursor.
CLR ALL	: Erases all characters displayed.
CLR LIN	: Erases characters on line marked by cursor.
SP	: Space
CR/LF	: Feeds line.

(Ex.)

```
SAMPLE NO. 5
    M-FA
```

For this display, key entry illustrated below is required.

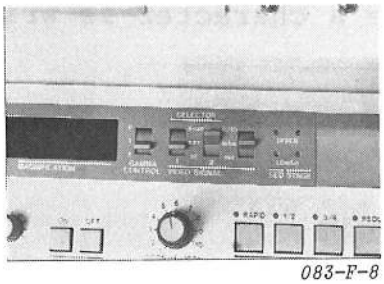
[Shift] (N-Z), [S], [Shift] (A-M), [A], [M], [Shift] (N-Z), [P], [Shift] (A-M), [L], [E], [Shift] (FUNC), [SP], [Shift] (N-Z), [N], [O], [Shift] (FUNC), [SP], [Shift] (0-9), [5], [Shift] (FUNC), [CR/LF], [▶], [▶], [▶], [Shift] (A-M), [M], [Shift] (0-9), [-], [Shift] (A-M), [F], [A]

3-4-2 Secondary Electron Image Observation and Photographing

General operating procedure is described here.
After exchanging the filament, cleaning the column, or widely changing the accelerating voltage, condenser lens current, etc., adjustment is required. For this, refer to 3-4-3.

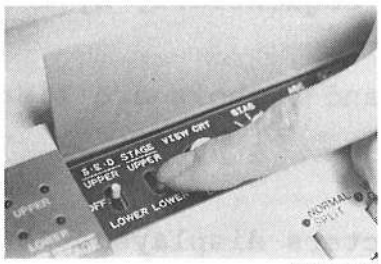
(1) Image Observation

(a) Press the [CALL] key to call out the data list and confirm the set conditions. Renew any condition if necessary, referring to 3-4-1. Then press the [ENTER] key to erase the data list.



083-F-8

(b) Set both (SIGNAL) [SELECTOR] switches [1] and [2] to [SE].

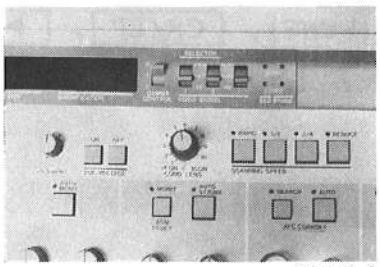


083-E-30

(c) Set the [STAGE] and [SED] switches according to the working distance of the specimen stage. The table below is readable as a general reference.
(The optimum setting of the [SED] switch may differ depending on specimen size, etc.)

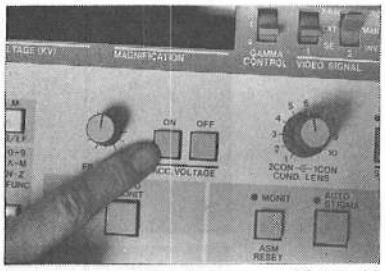
Table 3-2 Switch Settings according to Working Distance

WD	STAGE	SED
0 ∿ -3 mm	UPPER	UPPER
0 ∿ +10 mm	LOWER	
More than +10 mm		LOWER



083-F-6

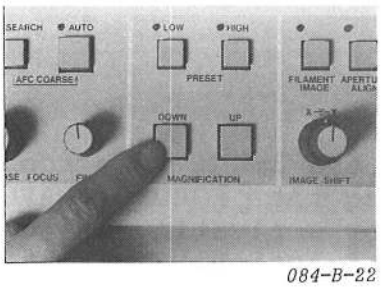
(d) Confirm the setting of the [COND LENS] knob, referring to 3-4-9.



084-B-19

(e) Confirm that the [READY] lamp is lit, and then press the [(ACC VOLTAGE)] [ON] switch. An image will appear so far as a high voltage is applied and the [FILAMENT] knob is set properly.

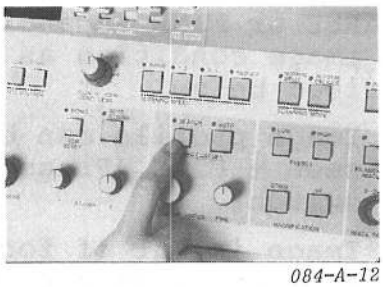
- o With the [AUTO-MAN-INV] switch at [AUTO], a just-focus image will appear since the automatic focus adjustment (auto focus) is made.
- o Adjust image brightness and contrast by [BRIGHTNESS] and [CONTRAST] knobs when the [AUTO-MAN-INV] switch is set at MAN.
- o Operation in 3-4-6 is required if the [FILAMENT] knob has not yet been set or if emission current does not flow.



084-B-22

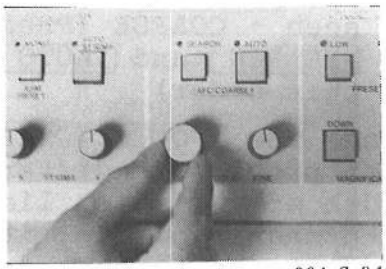
(f) If image cannot be observed:

1) Press the [MAGNIFICATION] [DOWN] switch to set a low magnification of a few hundred times.



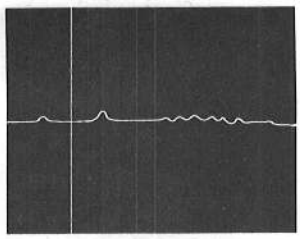
084-A-12

2) Effect auto focus (operate COARSE, press [SEARCH] and [AUTO] in this order). Or, press the [SEARCH] switch and adjust the [FOCUS (COARSE)] knob so that CRT waveform is changed.

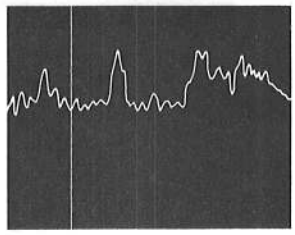


084-C-24

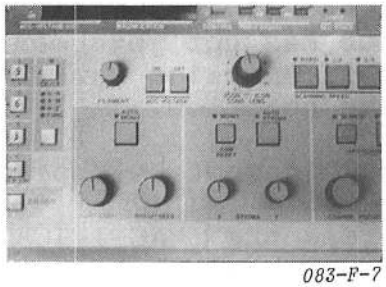
from



to

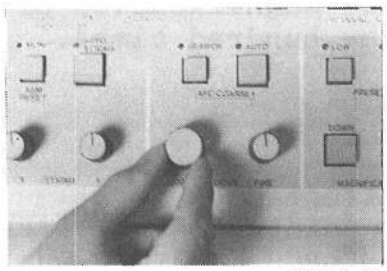


and press the [SEARCH] switch again.
By either method, an image will appear.



083-F-7

(g) Adjust image brightness and contrast by the control knobs in MAN mode, and by pressing the [AUTO/MONIT] switch in AUTO mode.

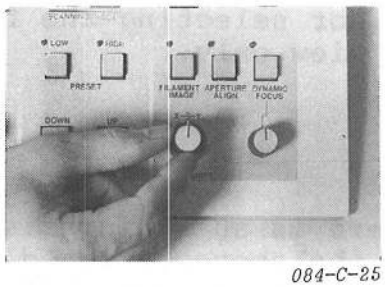


084-C-24

(h) Bring the image into focus by turning the [FOCUS (COARSE)] knob or activating the auto focus function.

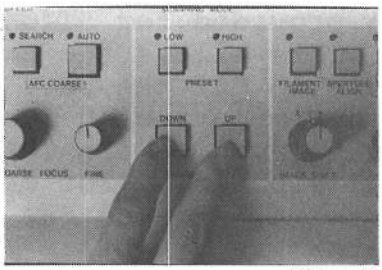
- o Use either auto focus COARSE or FINE depending on image condition as described below.
  - *) Image profile can be seen → FINE (Press [AUTO] switch)
  - *) Image is out of focus to such an extent that its profile cannot be seen → COARSE (Press [SEARCH] and [AUTO] in this order)
- o Since the [FOCUS (COARSE)] knob provides a different width of variation linked with magnification, it needs to be turned many times if an image is not focused even roughly at high magnifications.

In such cases, first reduce the magnification (using the [MAG PRESET] switch is convenient) and focus the image, and then proceed to focusing at a desired high magnification.



084-C-25

(i) In order to select the field of view, shift the specimen stage at low to intermediate magnification range. Use the [IMAGE SHIFT] (X) and (Y) knobs for fine adjustment at high magnifications.



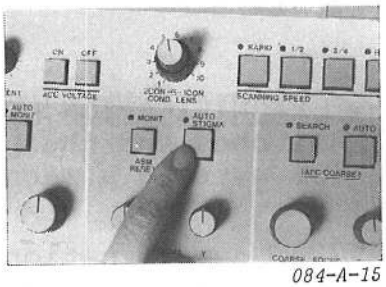
084-C-23

(j) Use the [MAGNIFICATION] [UP] and [DOWN] switches and the [PRESET] switch for setting a magnification.

- [PRESET] magnification is set from the keyboard. (See 3-4-1-(1)-(c).) Routine operation may be facilitated by setting the [PRESET 1] side near the lowest magnification (20×) and the [PRESET 2] side at a magnification most frequently utilized.
- When the [FOCUS (COARSE)] knob is moved, magnification becomes a somewhat complicated value. In this case, press the [MAGNIFICATION] switch, and the value is automatically corrected to a simple one.
- Although low magnifications from 500× to about 200× are settable with WD -2 mm, an image blurs on its circumference and increases its distortion. So, such magnifications must be used for selecting the field of view only, and an image must be photographed at 500× or higher in this WD setting.

A slight distortion occurs on the circumference of an image also at the lowest magnification with WDs other than for ultrahigh resolution setting. It is therefore recommended to use the lowest magnification at each WD for selecting the field of view only.

(k) Astigmatism correction



084-A-15

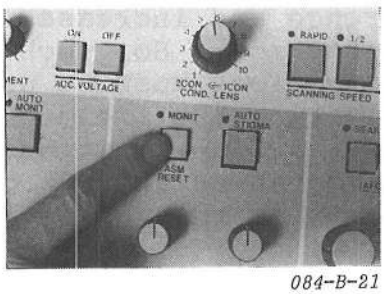
1) If there is an astigmatism even after the abovementioned adjustment, press the [AUTO] switch provided for STIGMA mode. This allows the existing image to go off the CRT, and an astigmatism-corrected image is then displayed on the CRT after several seconds. (For details, refer to (4) "How to Use Auto Stigmator" in 3-4-4.)

2) If the auto stigmator fails to operate normally, turn the [X] and [Y] knobs of the [STIGMA] until astigmatism is corrected properly. If the astigmatism cannot be corrected by turning the [X] and [Y] knobs fully, it is probable that the correction amount by the auto stigmator is overlapped. In such a case, press the (STIGMA) [MONIT/ASM RESET] switch to set the correction amount to zero. This allows the astigmatism correction to be carried out in stigmator monitor mode (see 3) below).

   Or press the (STIGMA) [MONIT/ASM RESET] switch again to correct the astigmatism with the usual image displayed on the CRT.

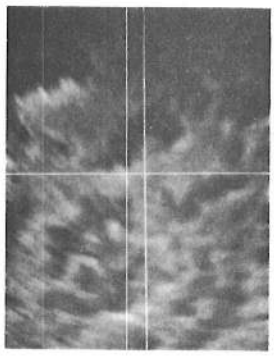
3) Astigmatism correction in stigmator monitor mode

   a) Set the magnification to several thousand times.

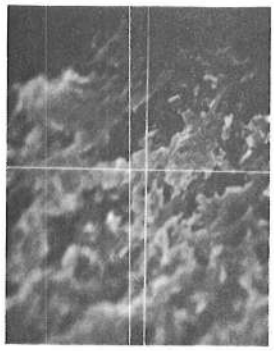


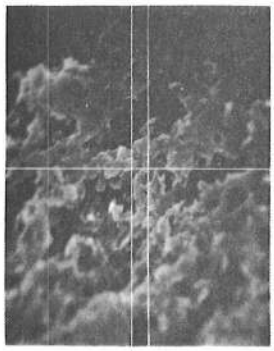
084-B-21

   b) Press the (STIGMA) [MONIT/ASM RESET] switch. A cross mark appears on CRT and an image whose focus is only locally obtained is formed.

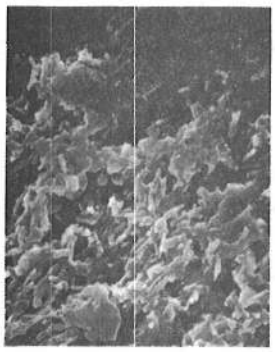


c) If the image is not brought into complete focus, an image drift occurs as shown at the left. In this case, adjust either [FOCUS] (COARSE or FINE) control until the image drift disappears.





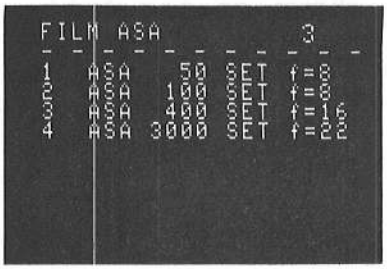
d) Adjust the [STIGMA (X) and (Y)] knobs so that the focused location in the image coincides with the crossover point of the cross mark.

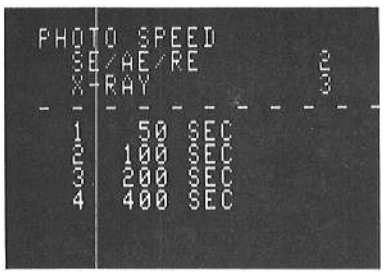


e) Press the (STIGMA) [MONIT/ASM RESET] switch, and the usual image reappears, this time astigmatism corrected.

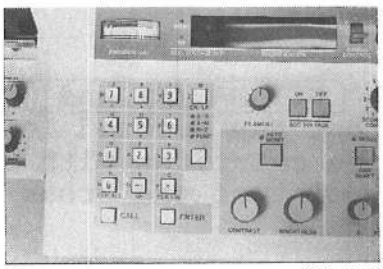
f) At high magnifications, a still more accurate correction is required with the [FOCUS (FINE)] and [STIGMA (X) and (Y)] knobs.

(2) Photo Recording

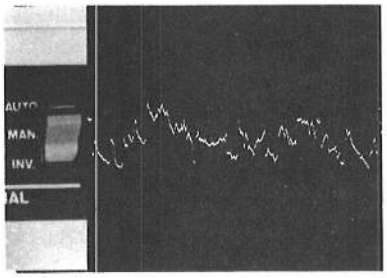


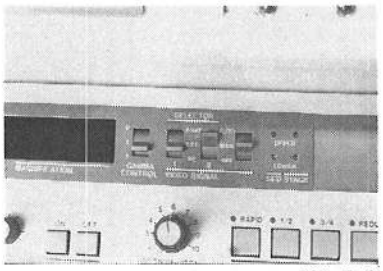


(a) Prior to photographing, confirm film sensitivity (FILM ASA) and photographing scan speed (PHOTO SPEED) settings for the film employed, with the data list called out. (See 3-4-1-(1) (e) and (f).)



083-F-9



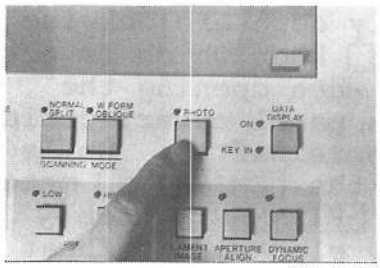


083-F-8

(b) Adjustment of brightness and contrast

- With the [AUTO-MAN-INV] switch at MAN, press the [AUTO/MONIT] switch and adjust the [BRIGHTNESS] and [CONTRAST] knobs so that the waveform on CRT appears within the central zone in which brightness is lower. After completion of this adjustment, press the [AUTO/MONIT] switch again to resume ordinary image display.

- In the AUTO mode, image brightness and contrast are automatically adjusted just by pressing the [AUTO/MONIT] switch.



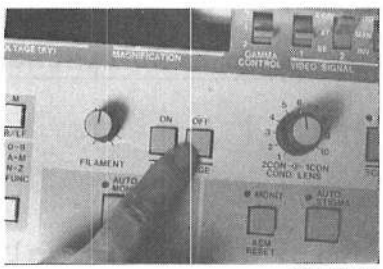
084-B-18

(c) Confirm that a film is loaded in the camera unit, and then press the [PHOTO] switch. The switch lamp is lit during film exposure. Upon completion of exposure, the buzzer sounds and usual image observation mode is automatically activated again.

- o The raster on the viewing CRT is located matched with that on the photo CRT during photographing, so it does not coincide with the original location under image observation.

(d) A convenient photographing mode is usable, by which the above steps (a) and (b) can be omitted. For this mode, refer to 3-4-4-(11).

(3) Termination of Image Observation



084-B-20

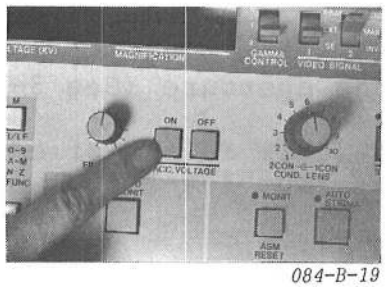
When image observation is finished, turn off the high voltage by pressing the (ACC VOLTAGE) [OFF] switch. The [FILAMENT] knob need not be manipulated.

3-4-3 Supplementary Adjustment and Operation

This paragraph describes the adjustment and operation required when exchanging the filament, cleaning the column or widely changing the accelerating voltage, condenser lens current, etc.

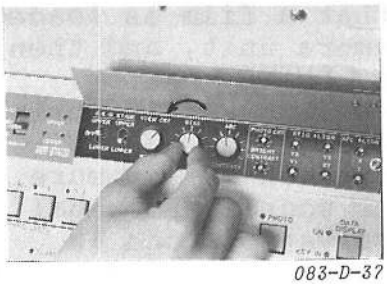
(1) After Exchanging Filament or Cleaning Column

(a) When a low accelerating voltage has been employed, increase it to 10 kV or more.

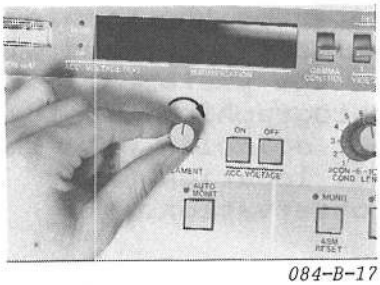


084-B-19

(b) Turn the [FILAMENT] knob fully counterclockwise and confirm that the [READY] lamp is lit. Then press the [ON] (ACC VOLTAGE) switch to apply the high voltage.



083-D-37



084-B-17

(c) Turn fully counterclockwise the [BIAS] knob which is accessible when opening the operation panel cover, called "Cover" hereinafter. While watching the [EMISSION] meter, turn the [FILAMENT] knob gradually clockwise to heat the filament. (A reference must be made to 3-4-6 for setting the [FILAMENT] knob and adjusting the emission current.)

(d) Make axial alignment of the electron gun. (See 3-4-7.)

(e) Set a desired accelerating voltage value. This operation does not require turning off high voltage.

(f) If desiring an accelerating voltage value differing widely from the value used when performing the above steps (c) and (d), these steps must be carried out again (with an accuracy enough to obtain maximum brightness).

(g) Set the [COND LENS] knob. (See 3-4-9.)

(h) Form an image according to 3-4-2.

(i) Select an objective lens aperture and make axial alignment. (See 3-4-8.)

(j) Observe the image with reference to 3-4-2.

(2) After Changing over Accelerating Voltage

Whenever changing over accelerating voltage, the following adjustments are required.

In order to change the accelerating voltage widely, for example, from 20 to 1 kV, reduce it stepwise in the following sequence; 20 → 10 → 5 → 3 → 1 kV.

(a) Readjustment of the [FILAMENT] knob and emission current (See 3-4-6.)

(b) Axial alignment of objective lens aperture (See 3-4-8.)

(c) Axial alignment of electron gun (this is satisfied when maximum brightness is obtained) (See 3-4-7.)

(d) Set the [COND LENS] knob. (See 3-4-9.)

(3) After Altering Condenser Lens Current

After condenser lens current is widely altered, in particular with [2CON], the following adjustment is required.

o Axial alignment of the objective lens aperture (See 3-4-8.)

(4) After SED Changeover

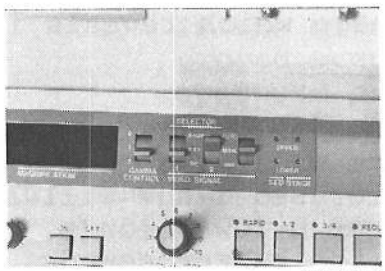
After the [SED] switch is changed over from UPPER to LOWER or vice versa, the following adjustments are required.

(a) Adjustment of image brightness and contrast

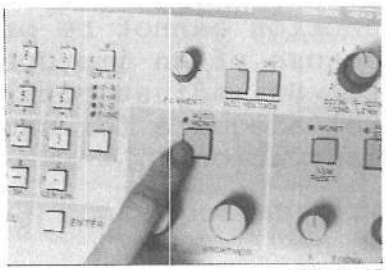
(b) Axial alignment of the objective lens aperture (See 3-4-8.)

3-4-4 Usage of Various Functions

(1) Automatic Image Adjustment



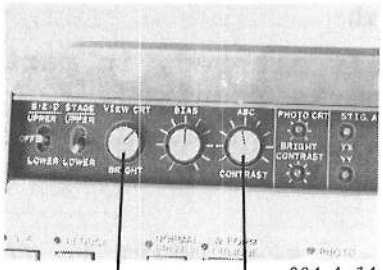
083-F-8



084-A-13

(a) With the [AUTO-MAN-INV] switch at AUTO, image brightness and contrast are automatically adjusted just by pressing the [AUTO/MONIT] switch. This takes only 5 seconds or less. While this function is activated, the [CONTRAST] and [BRIGHTNESS] knobs do not function.

(b) If condenser current is altered later or if contrast is changed in a new field of view, adjustment is automatically made by pressing the [AUTO/MONIT] switch again.



084-A-14

Adjusts brightness on viewing CRT

Adjusts contrast

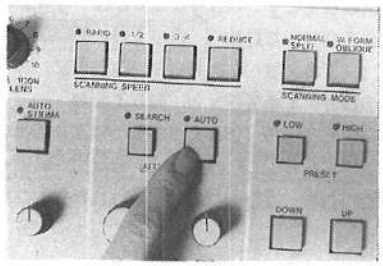
(c) The contrast level given by the automatic adjustment is adjustable by the [ABC CONTRAST] knob inside the cover, while the automatic adjustment provides a determined brightness. If an image cannot be seen easily due to room illumination, etc., brightness of the viewing CRT must be adjusted by moving the [CRT BRIGHT] knob inside the cover.

(2) Auto Focus

This function can be utilized in two different ways depending on defocus of an image.

(a) AFC FINE

Used for fine focusing of an image which reveals its profile slightly.

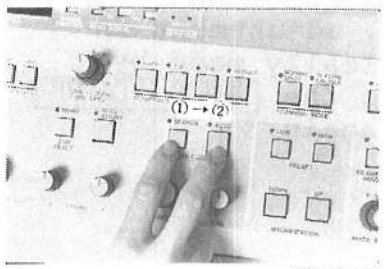


084-A-16

Press the [AUTO] (FOCUS) switch. CRT image will disappear, and then a focused image will appear after a few seconds. In case the buzzer sounds, you must understand that the auto focus function cannot be provided because of an improper contrast. So, adjust contrast to a level adequate for usual image observation.

(b) AFC COARSE

Usable for focusing an image which does not reveal its profile at all so far as the specimen is located within the determined working distance.

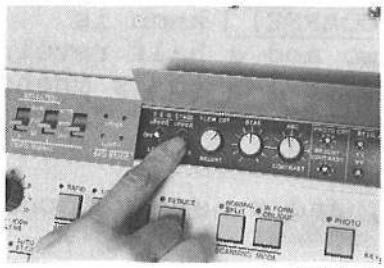


084-A-11

1) Operation requires 2 steps.

Press the [SEARCH] and [AUTO] switches in this order.

2) If an image on CRT is not completely focused, the AFC FINE mode in (a) must be activated.



083-C-35

3) The adjustable range of focus is divided into 2 with reference to the working distance 0 mm. So, the auto focus function cannot be normally activated unless the [STAGE] switch is properly set according to 3-4-2-(1)-(c).

(c) Adjustment for Accurate Focusing

1) Accuracy becomes poor if the objective lens aperture is not properly aligned. In such conditions, an image drifts when changing the focus manually. (For alignment, refer to 3-4-8.)

2) If the auto focus function does not provide an improved accuracy after aligning the objective lens aperture properly, "Auto Focus Alignment" in 4-8-1 is required.

(d) The auto focus function may not work normally under the undesirable conditions listed below.

1) In case where an image cannot be seen clearly since signal intensity is too low. In particular, the AFC COARSE mode is difficult to be activated normally. In this case, manually focus the image by using the focus search function mentioned below.

2) In case where a specimen consists of few structural components such as glass surface, silicone wafer or polished face.

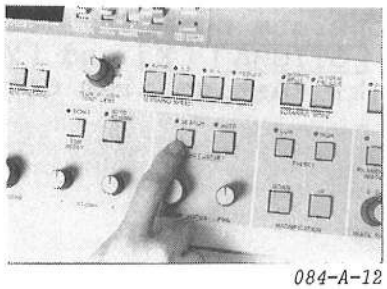
3) In case where charge-up occurs on specimen.

4) At very low ACC voltage (lower than 2 kV)

Note that the AFC FINE mode may be usable normally when the AFC COARSE mode cannot be activated normally.

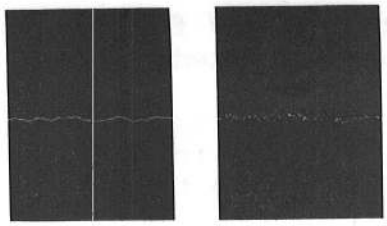
(3) Focus Search

Used for manually focusing an image whose profile cannot be seen at all.



084-A-12

(a) When pressing the [SEARCH] switch, a signal waveform appears and magnification is reduced to a low value.

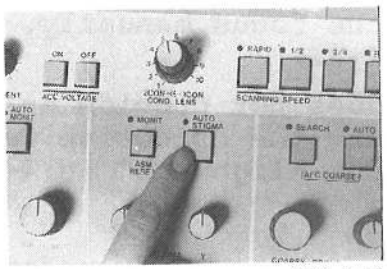


(b) Adjust the [FOCUS (COARSE)] knob so that the waveform becomes the sharpest. When the [FOCUS (COARSE)] knob is turned two and a half revolutions, focal length is changed over the full working distance.

(c) Press the [SEARCH] switch again, and a nearly focused image will appear.

(d) This operation is effective only when the [STAGE] switch is properly set according to 3-4-2-(1)-(c).

(4) How to Use Auto Stigmator



084-A-15

(a) If there is an astigmatism even after focusing an image with the auto focus/focus search function, press the [AUTO] switch of the STIGMA mode.

Pressing the [AUTO] switch allows the existing image to go off the CRT, and an astigmatism-corrected image is displayed on the CRT after several seconds.

(b) Adjustments Necessary for Accurate Astigmatism Correction

1) If the objective lens aperture is adjusted improperly, the accuracy of astigmatism correction will become poor. (For the adjustment procedure, refer to 3-4-8.)

2) If the auto focus is aligned improperly, the accuracy of astigmatism correction will become poor. (For the alignment procedure, refer to 4-8-1.)

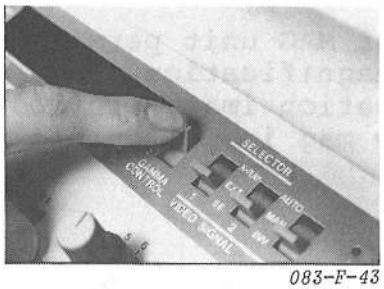
3) If the stigmator is aligned improperly, the accuracy of astigmatism correction will become poor. (For the alignment procedure, refer to 4-8-2.)

(c) In case of poor condition like in (2)-(d) of 3-4-4, the auto stigmator may fail to operate normally as in the auto focus function.

(d) If the auto stigmator fails to operate normally, astigmatism should be corrected by the [STIGMA] [X] and [Y] knobs. (For details, refer to (k) "Astigmatism Correction" described in 3-4-2-(1).)

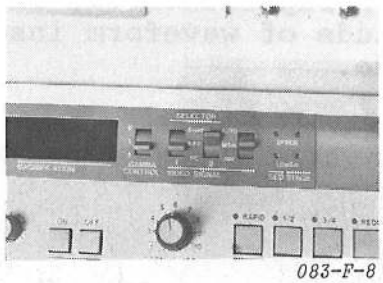
(5) Gamma Control, Inverted Image

(a) Gamma Control



083-F-43

Used for suppressing contrast when it is excessively high in a limited area on an image. Contrast can be suppressed in 3 steps by the [GAMMA] switch. Usually, notch 0 is used. Effect of compensation is larger at notch 1, and the largest at notch 2.


083-F-8

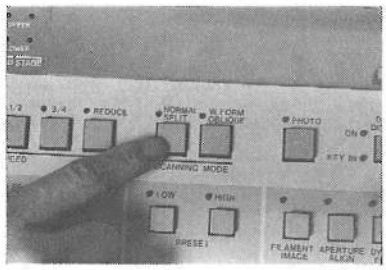
(b) Inverted Image

Employed when an image needs to be observed with the dark and bright fields inverted. Set the [AUTO-MAN-INV] to INV, and an image will reappear with its dark and bright fields inverted.

(6) Split Screen Mode

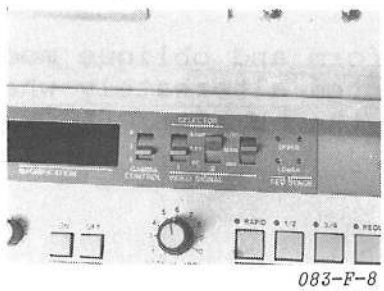
CRT screen is divided into top and bottom sections, and an image from the same field of view is formed on each section.

(a) Simultaneous Display of Different-signal Images



084-C-26

1) Press the [NORMAL/SPLIT] switch. CRT screen will be divided into 2. An image from the same field of view will appear on both sections.


083-F-8

2) Select image signal for the top section by the (SIGNAL) [SELECTOR] switch [1], and that for the bottom section by the switch [2]. (For using EXT and X-ray signals, each optional accessory is required.)

3) When recording SE and X-ray images, scanning speed is automatically switched at a point where the field of view changes (according to the set value from the keyboard).

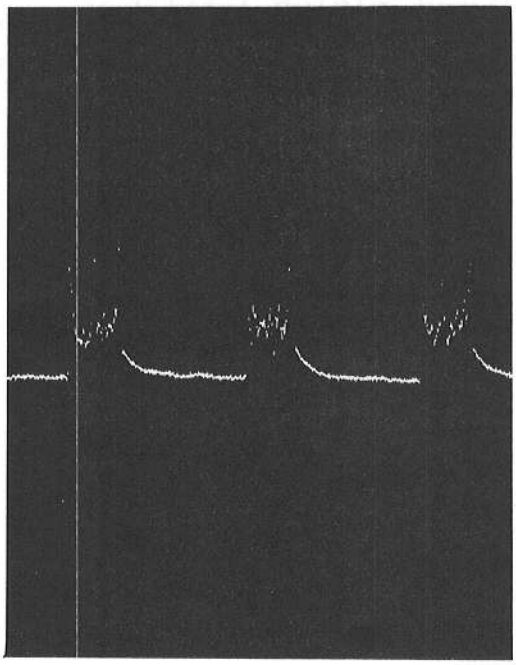
4) Usual image will reappear upon pressing the [NORMAL/SPLIT] switch again.

(b) Simultaneous Display of Different-magnification Images

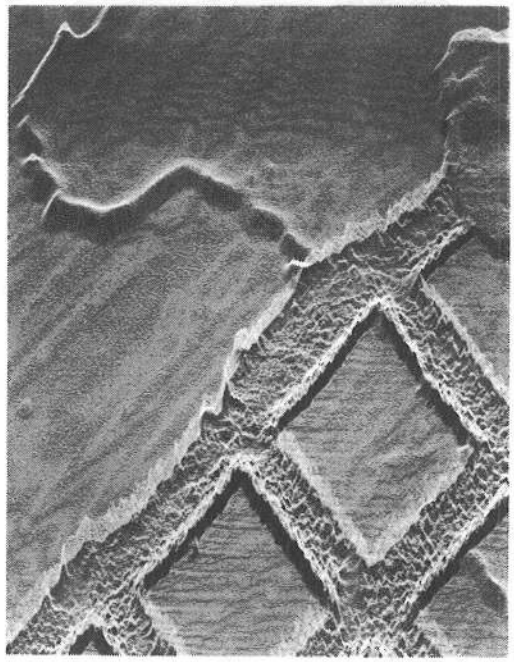
The optional accessory MODE/DUAL MAG unit permits a simultaneous display of a low magnification image on the top section and a high magnification image (formed by enlarging a small area on a low mag image) on the bottom section.

(7) Waveform and Oblique Modes

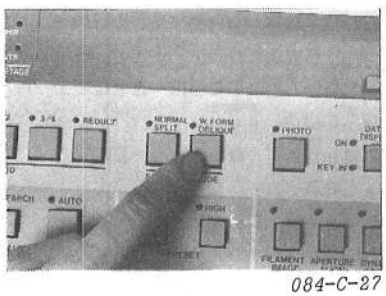
Waveform of image signal is traced on CRT in the waveform mode, and CRT displays an image which represents the intensity of image signal with the amplitude of waveform instead of CRT brightness in the oblique mode.



Waveform



Oblique Image



084-C-27

(a) The waveform and oblique modes are selected alternately whenever pressing the [W FORM/OBLIQUE] switch.

(b) Upon pressing the [NORMAL/SPLIT] switch, usual image will reappear.

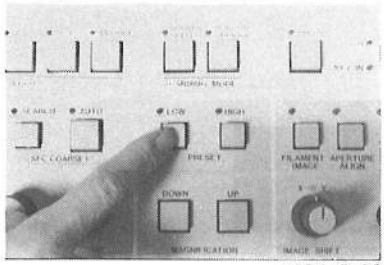
(c) Scanning speed for forming an oblique image is changeable by the [SCANNING SPEED] switch.

(8) Magnification Preset Switch

Although magnification is usually adjusted by the [MAGNIFICATION] [UP] and [DOWN] switches, the magnification preset switch will provide a greater efficiency if a specific magnification is frequently used or magnification is often decreased to a low value in order to search for the filed of interest.

(a) Setting Preset Magnification

Preset magnification is freely settable from the keyboard. (See 3-4-1.)



084-C-28

(b) Upon pressing either [PRESET 1] or [PRESET 2] switch, magnification is changed from the present value to a preset value. (Switch lamp is lit.)

1) When pressing the same [PRESET 1] or [PRESET 2] switch, the original magnification is set again.

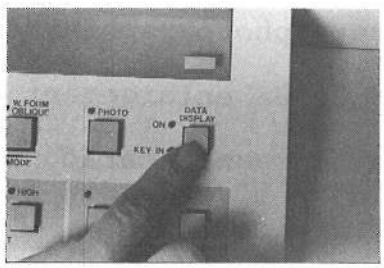
2) When pressing the [UP] or [DOWN] switch, magnification can be increased or decreased from the preset value. (The original magnification becomes invalid.)

(c) If a magnification set to the preset switch is lower than the minimum value available, presetting is made to a value most approximating the set value within the permissible range.

(9) Data Display

This instrument enables the operator to both display data in the bottommost area on CRT image in the determined format and write alphanumerics at a desired location on the image.

(a) Procedure for Display



084-D-29

By pressing the [DATA DISPLAY] switch, the following conditions can be changed over.

1) [ON] lamp lit

Data displayed in the bottommost area.

2) Both [ON] and [KEY-IN] lamps lit

Data displayed in the bottommost area and writing desired data enabled.

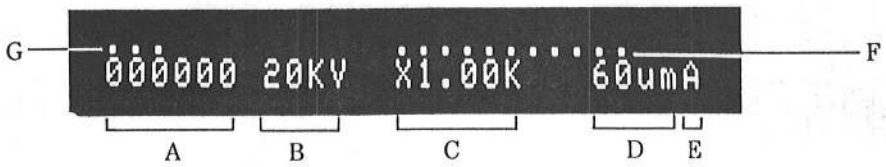
3) [KEY-IN] lamp lit

Writing desired data enabled.

4) Lamp extinguished.

Data not displayed.

(b) Contents of Display



A: Data no.

Set from the keyboard. (See 3-4-1.)
The lowest 2-digit value increments by 1 each time recording an image.

B: Accelerating voltage

C: Magnification

D: Length of micron marker

Indicates the length of F (micron marker).

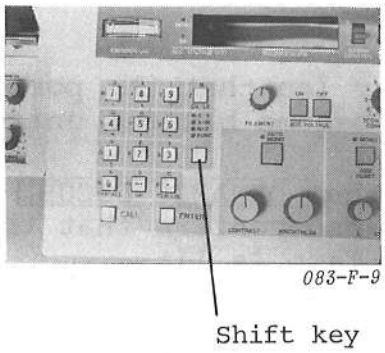
E: Enlarging ratio used in dual mag mode

F: Micron marker

Corresponds to a length of 30 mm on a film with photographing ratio 1×.

G: Photographing ratio

Two "·" marks appear to indicate photographing ratio 0.8× (with 107 Polaroid film).
Three "·" marks appear to denote 2× enlargement after exposure of negative film.
Photograph matches the displayed magnification at photographing ratio 1× (with 4" × 5" Polaroid film) when "·" mark does not appear.



(c) Writing Desired Data (See 3-4-1.)

This requires entry from the keyboard. Characters are written at the location where the cursor (* mark) appears.
Each key on the keyboard are usable in 4 ways which are changed over by the shift key and indicated by the lamp.
Functions of the keys other than character entry (when the shift key is set to FUNC) are shown below.

◄, ►, ▲, ▼	: Move cursor as directed by arrow.
CR/LF	: Feeds line
SP	: Provides space
CLR ALL	: Erases all characters on screen.
CLR LIN	: Erases characters on line indicated by cursor.

(d) Changeover of Display Mode

Refer to 3-4-1.

(10) Dynamic Focus

When a specimen is tilted, focusing the entire image may sometimes be impossible because the focal length differs between both ends of screen. This function is used on such occasions.

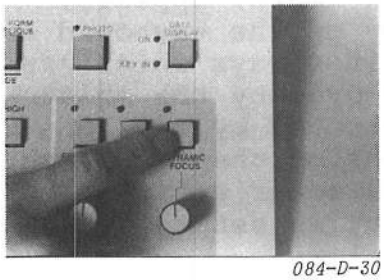
(a) Restriction on Use

Since the scanning direction of electron beam varies at different focal lengths, operation is possible at only the working distance (15 mm) at which electron beam scanning direction matches specimen tilting direction.

For use at other working distances, the raster rotation unit (optional accessory) is required.

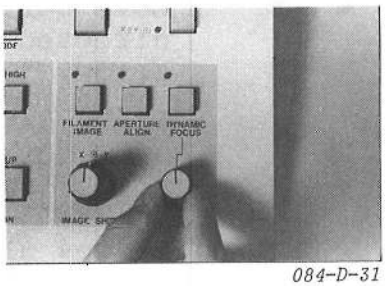
(b) Operating Procedure

1) Focus an image at its center (so that the portions above and below the center become blurred uniformly).



084-D-30

2) Press the [DYNAMIC FOCUS] switch and confirm that the switch lamp is lit.



084-D-31

3) Adjust the [DYNAMIC FOCUS] knob so that the overall area of the image is brought into focus.

- o Use a scan speed other than [RAPID].
- o Be sure to turn off the [DYNAMIC FOCUS] switch when a specimen is kept horizontal or when a working distance other than 15 mm is used. Otherwise, focus might not be matched between both ends of image.

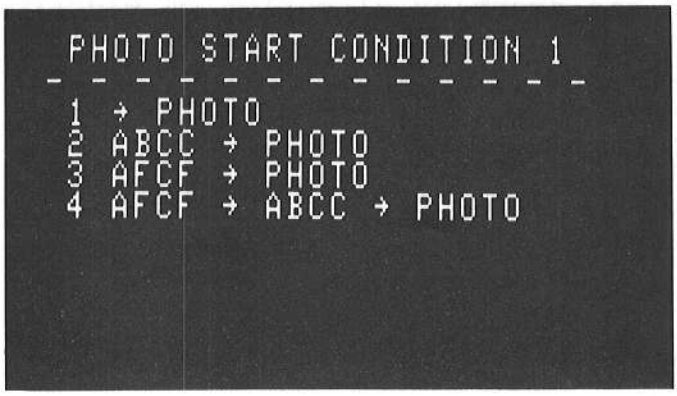
(11) Auto Photo Mode

A focused image can be recorded at optimum contrast and brightness just by pressing the [PHOTO] switch.

This function requires PHOTO START CONDITION setting with the data list called out.

(a) PHOTO START CONDITION Setting

For procedure, refer to 3-4-1.



(b) Description of Each Mode

1) → PHOTO

Photographing is performed by pressing the [PHOTO] switch.

2) ABCC → PHOTO

Automatic image adjustment is made prior to film exposure. Brightness and contrast are automatically determined indifferent to whether or not they are set to any level manually (with the [AUTO-MAN-INV] switch at MAN). This saves readjustment for each photographing and ensures ease of operation in cases where a higher contrast than optimum for photographing is required for image observation, e.g., under a high room illumination.

- o Photographing inverted images is impossible in this mode.

3) AFCF → PHOTO

Auto focus function is automatically activated before film exposure. So, photographing is possible immediately after determining the field of view without meticulous focusing.

- o For this mode, a specimen must meet some conditions that facilitate activation of the auto focus function.

4) AFCF → ABCC → PHOTO

An image is automatically focused and adjusted for optimum brightness and contrast before film exposure.

3-4-5 Filament Exchange and Setting

(1) Exchange

(a) Press the [HV OFF] switch.

(b) Press the [EVAC/AIR] switch (to [▮]) in order to leak air into the column.

(c) Lift up the electron gun diagonally toward the rear right.

(d) Remove the filament assembly from the gun.
(The filament is heated to a high temperature after a long operation. In this case, wait until it cools down sufficiently.)

(e) Exchange the filament according to "Filament Setting" in 3-4-5-(2).

(f) Mount the filament assembly on the gun and securely fasten it by the fixing cap nut.

(g) Make sure that there is no dust nor scratches on the O-ring of the gun, and then mount the gun to the column.

(h) Press the [EVAC/AIR] switch (to [▬]) in order to evacuate the column. The vacuum sequence automatically proceeds.

(i) When the [HIGH] lamp is lit, evacuation is completed.

(2) Setting

(a) Remove the Wehnelt cylinder. If the inside of the Wehnelt hole is contaminated, clean with absorbent cotton wound on a bamboo stick and moistened with polishing paste, and then absorbent cotton soaked in acetone. (It is recommended to use an ultrasonic cleaner, if available.)
Also clean the anode if it is contaminated.

(b) Place the filament assembly on the filament exchange jig.

(c) Loosen the two filament centering screws which are diametrically opposite each other.
(If the four filament centering screws are all loosened, it is hard to perform centering of the filament.)

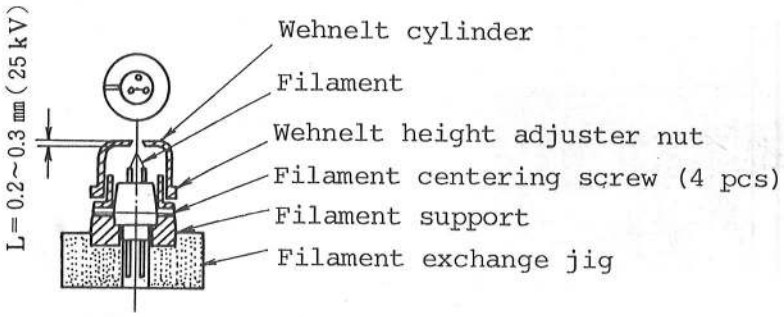
(d) Mount a new filament.

(e) Mount the Wehnelt cylinder.
(The Wehnelt height adjuster nut is fixed by the setscrew from the side. For adjustment, loosen the setscrew.)

(f) Align the tip of the filament with the Wehnelt cylinder opening.
(Accurate alignment is enabled by use of an optical microscope having a magnification of several ten times.)

(Note) The distance L between the filament and Wehnelt cylinder must be varied depending on accelerating voltage.

Accelerating Voltage (kV)	L (mm)
10 ∿ 30	0.2 ∿ 0.3
3 ∿ 10	0.1 ∿ 0.2
0.5 ∿ 3	0 ∿ 0.1



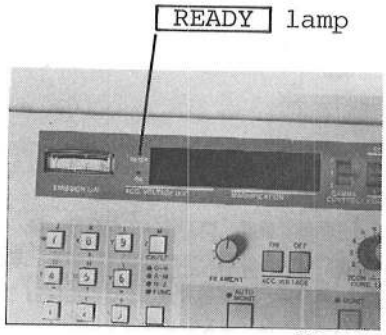
(Note) Image observation is possible at an accelerating voltage lower than 25 kV with the distance L at 0.2 ∿ 0.3 mm, but image quality is poor because of decrease in electron gun brightness. Therefore, when using a low accelerating voltage, locate the filament tip in line with the Wehnelt hole or slightly below it. This enhances gun brightness and thereby ensures quality images.

3-4-6 Adjustment of Emission Current

This paragraph explains the procedures for setting the filament current and adjusting the emission current.

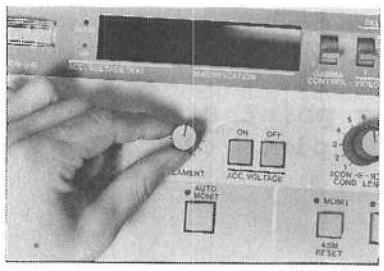
Only the asterisked steps need to be effected for simple adjustments due to change in accelerating voltage without exchanging the filament or cleaning the column.

(1) Adjustment of Filament Current



083-F-10

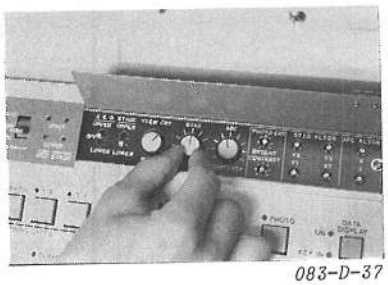
(a) Make sure that the [READY] lamp is lit.



084-B-17

Turn the [SCANNING SPEED] switch to [RAPID].

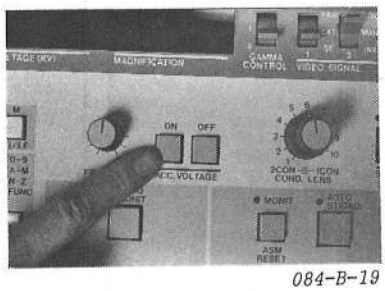
Turn fully counterclockwise the [FILAMENT] knob and the [BIAS] knob inside the cover.



083-D-37

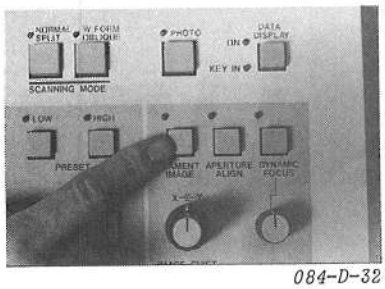
Set accelerating voltage to 10 kV or more.

Extract the objective lens movable aperture.



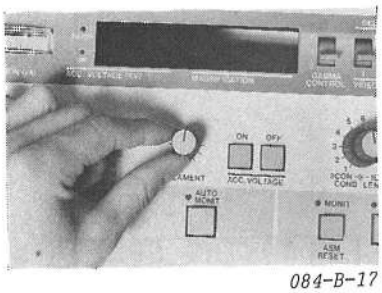
084-B-19

(b) Press the (ACC VOLTAGE) [ON] switch to apply high voltage.



084-D-32

*(c) Turn the [AUTO-MAN-INV] switch to MAN, and press the [FILAMENT IMAGE] switch to set the filament image mode.

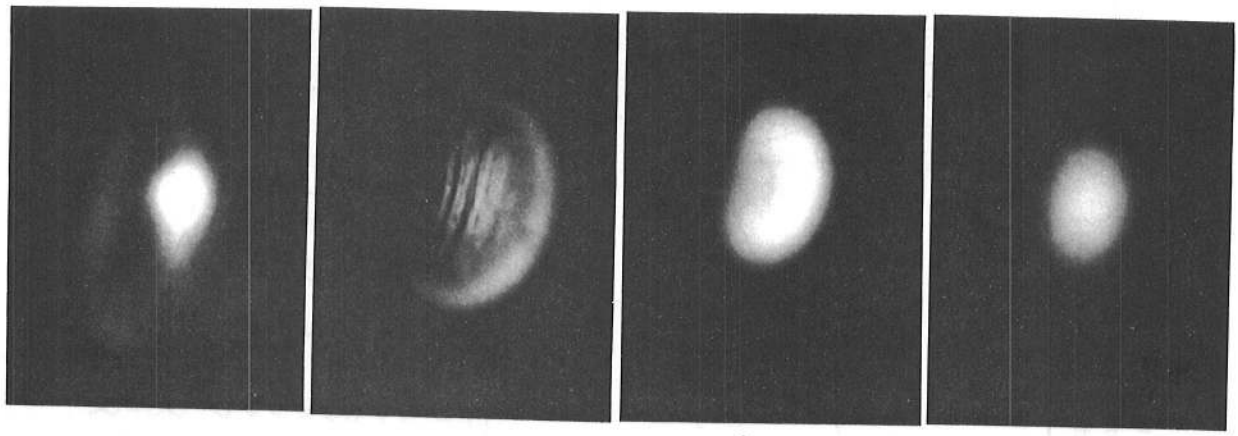


084-B-17

*(d) Gradually turn the [FILAMENT] knob clockwise until the [EMISSION] meter provides a slight indication. Adjust the [CONTRAST] and [BRIGHTNESS] knobs so that a crossover image of the filament appears on CRT.

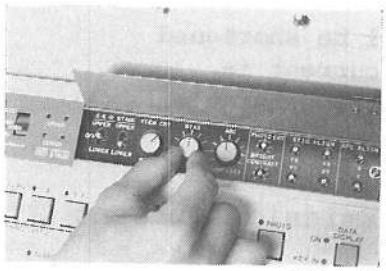
*(e) Set the [FILAMENT] knob to a point at which the crossover image becomes a complete circle.

Not saturated ——————————→ Saturated



Small ——— Filament current ———→ Large

- Although the crossover image does not change for increase in the filament current after the image is saturated, the lifetime of the filament is shortened. In order to ensure the full life span, therefore, the [FILAMENT] knob must be set at a point just before the filament is saturated.



083-D-37

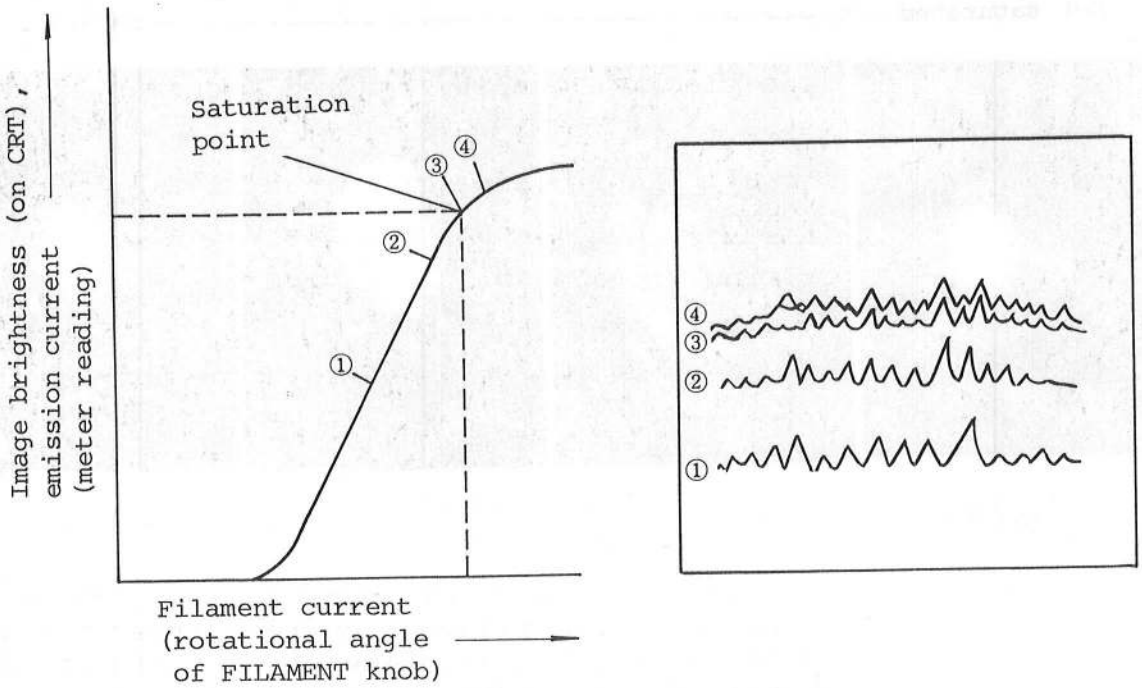
- If the emission meter overshoots, suppress emission current by turning clockwise the [BIAS] knob inside the cover.

  (If emission current is overshot, the over-current protection might be activated to turn off the high voltage. In this case, apply the high voltage again with the [BIAS] knob turned slightly in the clock-wise direction.)

(f) A wide change in accelerating voltage alters the filament current which saturates emission current. So, perform step (e) again.

*(g) Usual image display returns upon pressing the [FILAMENT IMAGE] switch again.

(h) Filament current can also be set by monitoring indication on the [EMISSION] meter and image brightness (location of waveform in the waveform mode). The relationship between filament current (rotational angle of [FILAMENT] knob) and image brightness is shown below.



(a) Image Brightness and Filament Current

(b) CRT Waveform in W. FORM Mode

(Caution) The filament life will be shortened even if the emission current is slightly higher than the saturation point.

Fig. 3-15 Saturation Point of Emission Current

(2) Adjustment of Emission Current

(a) When the filament has been set according to "Filament Setting" in (2) of 3-4-5, an emission current of about 150 ∿ 200 μA is obtainable by applying an accelerating voltage of 25 kV with the [BIAS] knob turned fully counterclockwise.

(b) When the filament is set for low accelerating voltages (located in line with or about 0.1 mm below the Wehnelt hole), increasing the accelerating voltage may flow an excessively large emission current (overcurrent) which will turn off the high voltage. In this case, turn the [BIAS] knob clockwise to reduce the emission current to a moderate level. But this adjustment is effective for a voltage of up to about 10 ∿ 15 kV, so the filament must be set again in such case.

3-4-7 Axial Alignment of Electron Gun

Axial alignment of the electron gun is required whenever exchanging the filament.

(1) Confirm that the HV [READY] lamp (green) is lit.

Set [MAGNIFICATION] to the lowest possible value.

Set the accelerating voltage to 20 ∿ 25 kV.

Set the objective lens aperture to No. 3.

Make sure that a specimen is set in the specimen stage.

Move the 2CON knob of [COND LENS] to set at [5] or [6] and the 1CON knob to the center.

(2) Turn on the [HV] switch, and turn the [FILAMENT] knob clockwise until the emission current saturates while watching the emission meter.

(3) Adjust the [HORIZ] X and Y controls of [GUN ALIGNMENT] so as to maximize image brightness on CRT.

(4) Set a magnification of about 1000×, press the [APERTURE ALIGN] switch, and perform the axial alignment of the objective lens aperture. (See 3-4-8.)

Increase magnification to a few ten thousand times and perform the axial alignment of the objective lens aperture.

(5) Adjust the [TILT] X and Y controls of [GUN ALIGNMENT] so that brightness changes and image does not drift when moving the 1CON knob of [COND LENS] around the center with the 2CON knob set at [6].

(6) Align the objective lens aperture as per step (4), effect step (5) under the highest brightness obtainable by moving the [HORIZ] X and Y controls, and adjust the [TILT] X and Y controls so that the image does not shift.

(Notes) 1. A slight shift of an image does not constitute a problem at a magnification of 10000× or higher.

2. If changing the accelerating voltage widely after completion of the axial alignment, the [HORIZ] X and Y controls of [GUN ALIGNMENT] must be adjusted so as to obtain the highest brightness. For a misalignment at this time, press the [APERTURE ALIGN] switch and align the objective lens aperture so that the image does not shift.

3-4-8 Axial Alignment of Objective Lens Aperture

The objective lens aperture requires axial alignment in the following cases.

- After changeover of objective lens aperture

- o After wide change of accelerating voltage
- o After wide change of condenser lens current
- o After changeover of secondary electron detector (between upper and lower detectors)

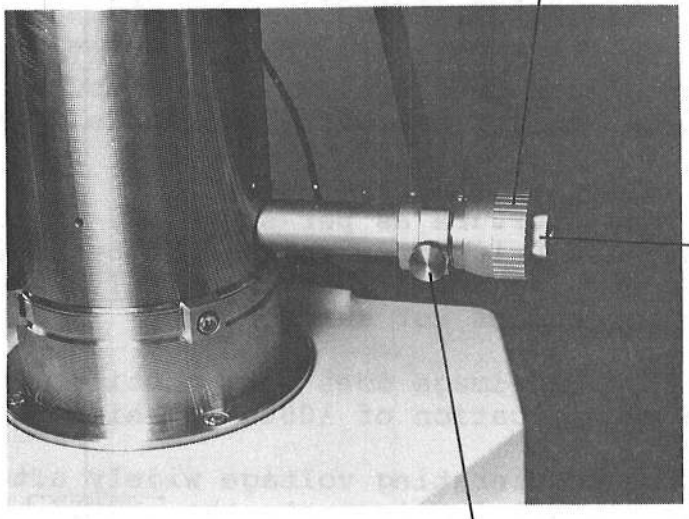
Perform the axial alignment in the following manner.

(1) Set magnification to about 1000× with an image presented on CRT.

(2) Press the [APERTURE ALIGN] switch, and the objective lens currents change alternately. While observing the CRT image, adjust the aperture opening (X and Y) alignment knobs of the objective lens movable aperture so that the image will not drift in either direction. In this step, the image needs to be observed with the [SCANNING SPEED] at [RAPID].

(3) Increase magnification to about 10000× and perform step (2) again.

(4) After completion of the alignment, press the [APERTURE ALIGN] switch again, and usual image mode will return.



Graduation	0	1	2	3	4
Aperture opening diameter (μm)	Blank	300	70	50	30

Fig. 3-16 Objective Lens Aperture Graduations and Opening Diameters

3-4-9 How to Determine Microscopic Conditions

For a better image quality, the instrument requires optimum settings or selections of accelerating voltage, condenser lens current which controls the intensity of specimen irradiating electron beam, opening diameter of the objective lens aperture, etc.

This paragraph describes basic considerations required for determining the conditions of the instrument.

(1) Selection of Accelerating Voltage

Table 3-3 indicates the relationship between accelerating voltage and image quality.

Accelerating voltages of 20 ∿ 25 kV are employed for ordinary observations. However, it is necessary to increase or decrease these voltages according to kind of specimen, etc.

Table 3-3 Relationship between Accelerating Voltage and Image Quality

Item \ Accelerating Voltage (kV)	0.5 1 — 5 — 10 — 15 — 20 — 25 — 30
Resolution	Low ⟶ High
Charge-up	Little ⟶ Much
Non-evaporated observation	Easy ⟵
X-ray analysis	X-ray
Secondary electron signal	Strong ⟵ ⟶ Weak
Effect by disturbances	Large ⟵ ⟶ Small

Low accelerating voltages from 0.5 to 3 kV, in particular, are variable in 100 V steps. So, select a proper voltage around 1 kV, for example, when observing a resist pattern. The following must be confirmed or adjusted when changing the accelerating voltage.

(a) When a high accelerating voltage (10 kV or higher) is reduced to about 1 kV, emission current decreases. To compensate for this, turn the [BIAS] knob inside the cover fully counterclockwise. If the knob remains turned clockwise, the emission current becomes unavailable.

At low accelerating voltages, a bright image can be obtained by setting the filament according to "Filament Setting" in (2) of 3-4-5.

(b) Adjust the [HORIZ] X and Y knobs of [GUN ALIGNMENT] so as to obtain the brightest image.

(c) Adjust the brightness to a moderate level by turning the [CONDENSER LENS] [1CON] knob.

(d) Align the objective lens aperture according to "3-4-8 Axial Alignment of Objective Lens Aperture".

(e) Also refer to "3-4-8 Axial Alignment of Objective Lens Aperture" after changing over the objective lens aperture or after switching the condenser lens knobs, in particular the [2CON] knob.

(f) Perform step (d) when the secondary electron detector SED is changed over from UPPER to LOWER or vice versa.

(2) Setting Condenser Lens Current and Objective Lens Aperture

Condenser lens current is adjusted by the [1CON] and [2CON] knobs in order to change specimen irradiating current depending on specimen or microscopic conditions.

(a) Table 3-4 indicates the relationship between condenser lens current and image quality.

Table 3-4 Relationship between Condenser Lens Current and Image Quality

Condenser lens current	Small ← → Large
Specimen irradiating current (A)	10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
Resolution	Low ← → High
Secondary electron signal	Strong ← → Weak
Roughness of image	Fine ← → Rough
Secondary electron image	SE
Reflected electron image	RE
Absorbed electron image	AE
X-ray analysis WDX EDX	WDX EDX

(b) Selection of Objective Lens Aperture Opening Diameter

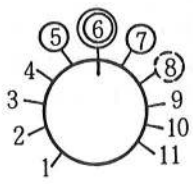
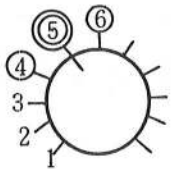
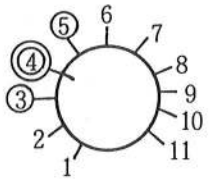
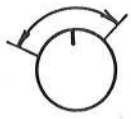
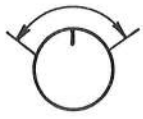
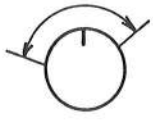
Table 3-5 indicates the relationship among opening diameter of objective lens aperture, resolution, specimen current, focal depth and operation mode.

Table 3-5 Relationship between Objective Lens Aperture and Image Quality

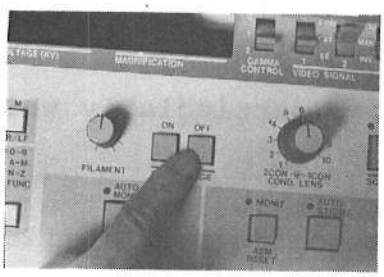
Notch no.	1	2	3	4
Aperture opening diameter (μm)	300	70	50	30
Depth of focus	Shallow ← → Deep			
Resolution	Low ← → High			
Specimen current	Large ← → Small			
Operation mode	X-ray analysis WDX	X-ray analysis EDX	SE image	SE image

(c) Table 3-6 indicates settings of the condenser lens and objective lens aperture corresponding to various image modes.

Table 3-6 Settings of Condenser Lens and Objective Lens Aperture

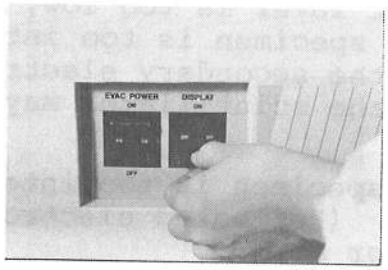
Item \ Kind of Image	Secondary Electron Image	Reflected Electron/ Absorbed Electron Images X-ray Analysis (EDX)	CL Image X-ray Analysis (WDX)
Specimen current (A)	$10^{-11} \sim 10^{-12}$	$10^{-9} \sim 10^{-11}$ A	$10^{-7} \sim 10^{-9}$ A
Objective lens aperture notch	No. 3 or No. 4	No. 2 or No. 3	No. 1
Settings of condenser lens knobs — 2CON			
Settings of condenser lens knobs — 1CON			
(1) Adjust CRT image by turning 1CON knob clockwise or counterclockwise with 2CON knob set at enclosed notches. (2) Use 1 step smaller number of 2CON knob at Acc voltage lower than 5 kV.			

3-5 Shutdown



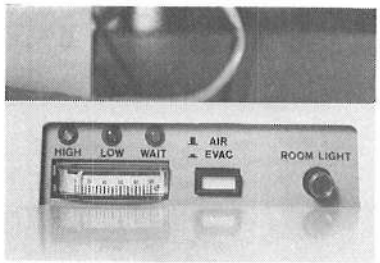
084-B-20

(1) Press the (ACC VOLTAGE) [OFF] switch.



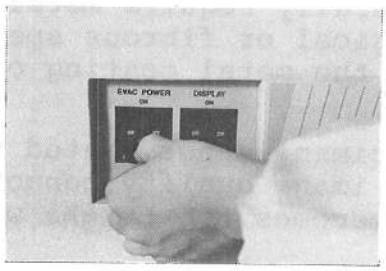
047-C-43

(2) Turn off the [DISPLAY POWER] switch of the main unit.



083-B-20

(3) Confirm that the [VACUUM] [HIGH] lamp is lit on the evacuating system operation panel.



047-C-42

(4) Turn off the [EVAC POWER] switch.

(5) After about 15 minutes, stop the cooling water supply.

3-6 Cautions on Operation

When operating the instrument, take consideration of the following items.

(1) Wear clean gloves whenever exchanging specimens or filament.

(2) Avoid using an excess amount of conductive paste for fixing the specimen onto the specimen stub and introducing the specimen stage into the specimen chamber before the paste is dried up.

Reason: Drying the paste in air takes a longer time when its amount is larger, and vacuum is degraded if insufficiently dried paste is introduced into the specimen chamber, which might cause contamination.

(3) Avoid giving a shock to the instrument (particularly while taking photograph).

(4) Avoid turning the [COND LENS] knobs excessively in the counterclockwise direction while emission current is flowed in the [SE] mode.

Reason: If the condenser lens current level is too low, the electron beam bombarding the specimen is too intense and the signal intensity to the secondary electron detector grows so high that the scintillator may be damaged.

If the electron beam bombarding the specimen is too intense, the [SED] switch must be turned off. (Reflected electron image can be observed with WD 10 mm or more.)

(5) When observing a large or bulk specimen at a short working distance, specimen tilt angle must be set to around 0°.

3-7 Specimen Coating

3-7-1 Introduction

Electrically non-conductive specimens generally require metal coating. Particularly when observing a biological or fibrous specimen having complicated topographical details, the metal coating often causes image troubles.

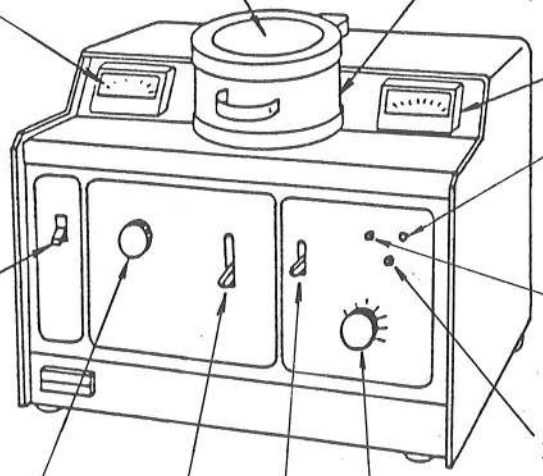
If the coated film is too thin or the specimen is not coated evenly over the topographical details, a uniform image quality cannot be expected and a certain part of the image becomes too bright while another part too dark.

Furthermore, in the worst case, lateral bright lines appear on the image, astigmatism increases and resolution drops.

To prevent these problems, the specimen should be coated with care.

3-7-2 Evaporating Method with Ion Sputtering Device

In the case of an electrically non-conductive specimen, its surface must be subjected to metal coating by use of an ion sputtering device after fixed on the specimen stub. A coating film thickness of about 100 to 200 Å is adequate for usual observation.



Vacuum chamber

Incorporates a target electrode in the upper section and can be opened/closed like a hinged door at the time of specimen exchange. Upon opening the chamber while pushing backward, it stops at about 45° position. For closing, pull in the 45° direction and lower.

Window

Electric discharge can be monitored through this window.

Vacuum meter

Reads Pirani gauge vacuum on the Torr/ Pascal scales.

Ion current indicator

Reads ion current on the upper scale.

VACUUM indicator lamp

Lit to indicate that high voltage is applicable.

POWER switch

Pushed up to turn on the power supply and the rotary pump starts evacuation. Pushed down to turn off the power supply and admit air into the pump.

HV indicator lamp

Lit while high voltage is applied.

HV START/STOP switch

Pressed to turn on high voltage when the high voltage indicator lamp is extinguished and turn it off when the lamp is lit.

VACUUM CONTROL knob

A needle-type leak valve. Turned counterclockwise from CLOSE to increase leakage.

TIMER set knob

Sets the electronic timer freely within a range of 0 to 10 minutes. When a set time has elapsed, high voltage is cut off.

MAIN VALVE selector lever

Pushed up to evacuate the vacuum chamber (OPEN) and pushed down to CLOSE. Upon turning off the power switch with this valve set at CLOSE, the vacuum chamber retains vacuum.

COATING/CLEANING selector switch

Coating/ion bombardment hydrophilization selector switch. Turned upward to select coating and pushed down to select hydrophilization.

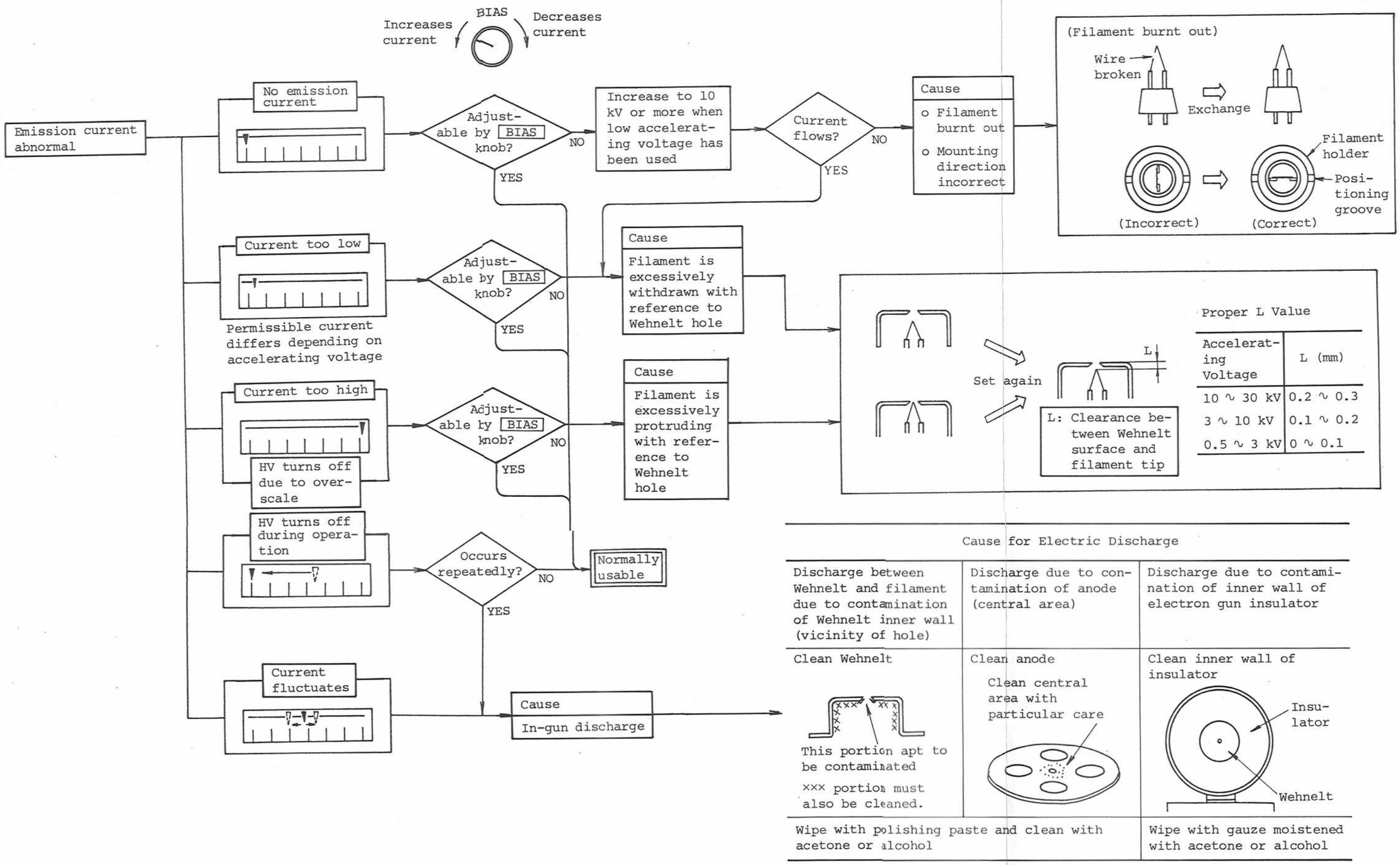
(Note) Also available as ion sputtering devices are the Model E-102, 105 and 106 which are capable of changing over high voltage and mounting different targets such as of Pt and Pt-Pd.

Fig. 3-17 Composition and Functions of Control Knobs and Switches (E-101 Ion Sputtering Device)

4. MAINTENANCE

4-1 Troubleshooting when Emission Current Abnormal

If reading on the emission current meter is abnormal, localize and eliminate the cause as per Fig. 4-1.



Cause for Electric Discharge

Discharge between Wehnelt and filament due to contamination of Wehnelt inner wall (vicinity of hole)	Discharge due to contamination of anode (central area)	Discharge due to contamination of inner wall of electron gun insulator
Clean Wehnelt This portion apt to be contaminated ××× portion must also be cleaned.	Clean anode Clean central area with particular care 	Clean inner wall of insulator
Wipe with polishing paste and clean with acetone or alcohol		Wipe with gauze moistened with acetone or alcohol

Fig. 4-1 Troubleshooting when Emission Current Abnormal

4-2 Exchange of Condenser Lens Fixed Aperture

Exchange the condenser lens fixed aperture every 3 to 6 months.

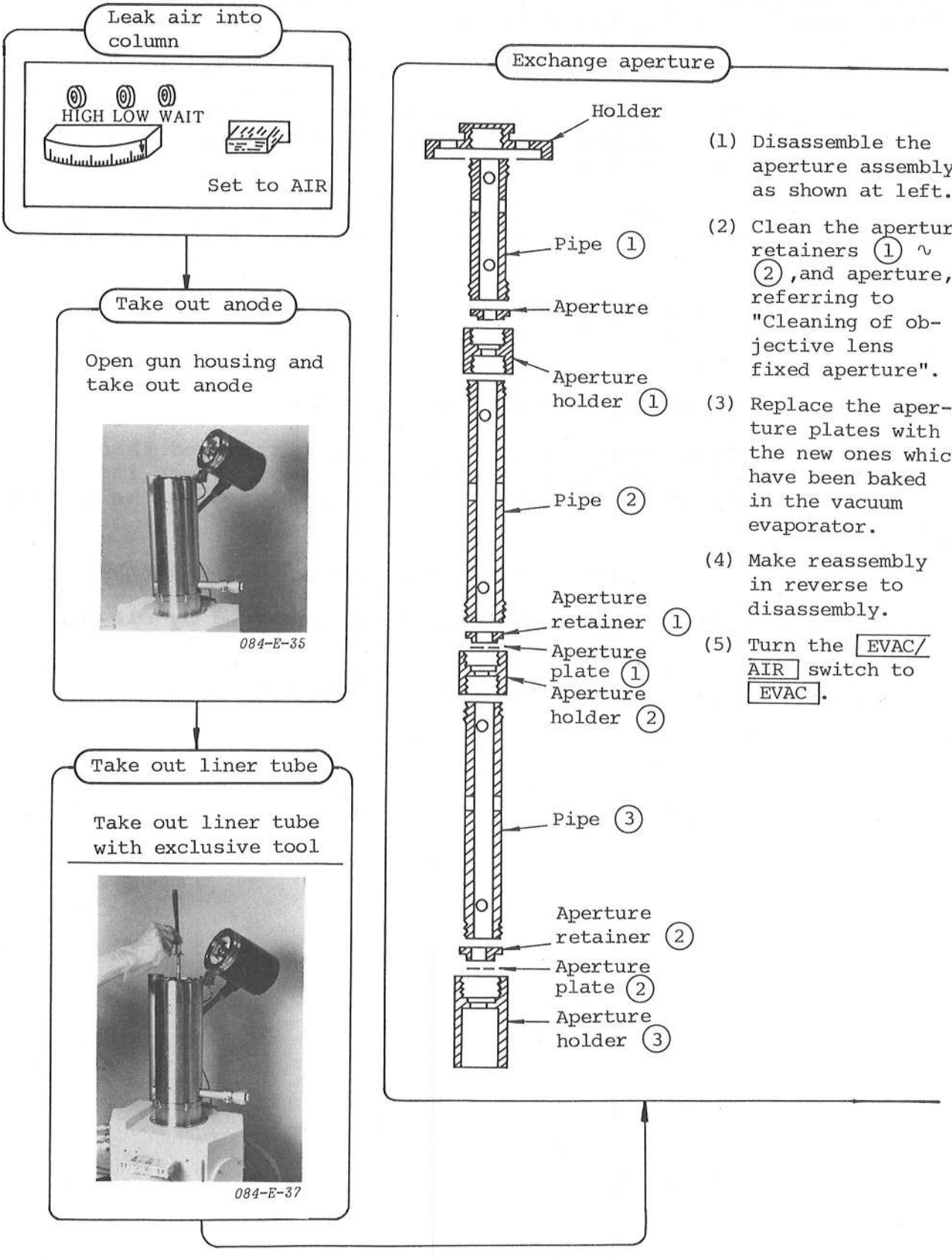


Fig. 4-2 Exchange of Condenser Lens Fixed Aperture

4-3 Cleaning of Objective Lens Movable Aperture

Contamination of the objective lens movable aperture might increase astigmatism and largely affect image resolution. Observe the following instructions.

(1) Clean the aperture periodically, usually every 3 months.

(2) Clean the aperture if image resolution is degraded and it appears that this poor performance is caused by contaminated aperture. (See 4-9-2.)

(3) When low accelerating voltages of up to 5 kV are mainly used, shortening the interval of periodical cleaning may be required.

(4) Cleaning must be done with reference to Fig. 4-3.

4-4 Cleaning of Objective Lens Fixed Aperture

The objective lens fixed aperture is less contaminated than the movable aperture, and its contamination does not affect image resolution so largely. However, it must be cleaned in the following cases.

(1) After use for 1 year usually (as a periodical cleaning)

(2) If normal image resolution cannot be recovered by cleaning the movable aperture (See 4-9-2.)

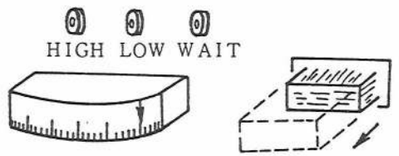
(3) Cleaning must be done with reference to Fig. 4-3.

Clean objective lens movable aperture every 3 months and fixed aperture yearly

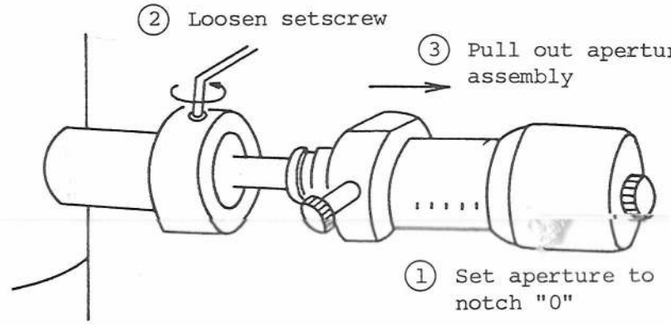
(Note)

The fixed aperture need not be cleaned except when image quality cannot be improved by cleaning the movable aperture.

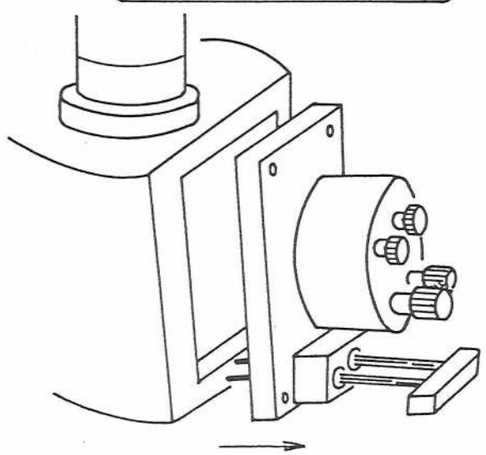
Air leak into column



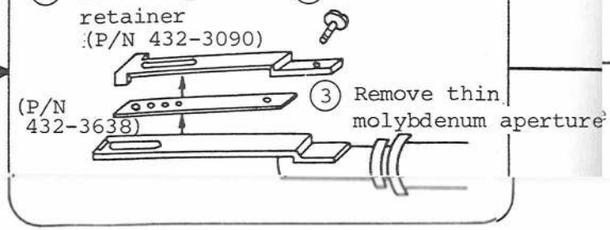
Removal of movable aperture assembly



Removal of specimen stage



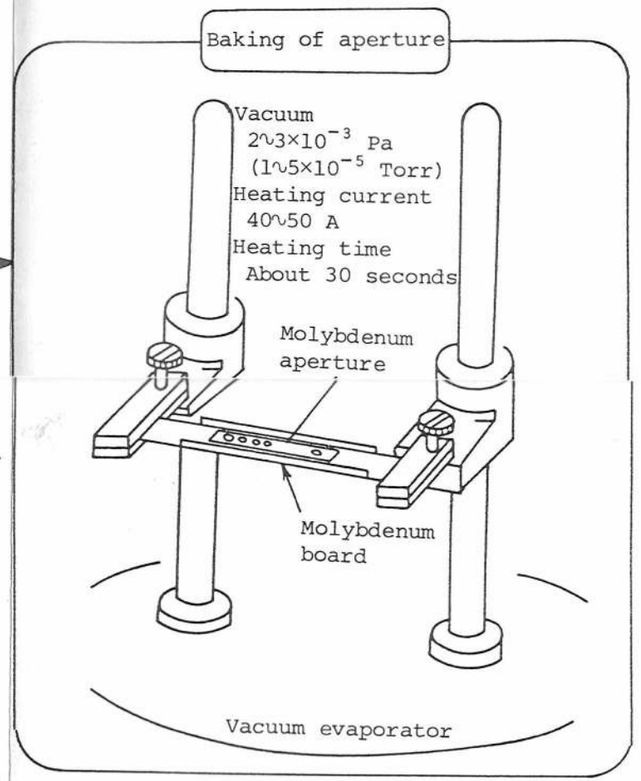
Removal of thin molybdenum aperture



(Note)

Before leaking air, wait about 5 minutes after completion of baking in the vacuum evaporator.

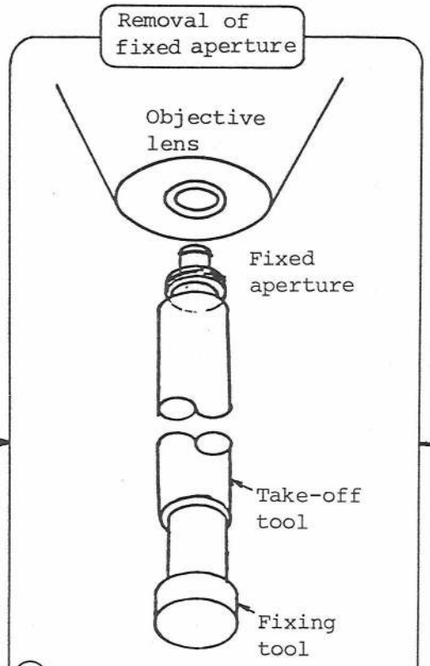
Baking of aperture



(Note)

After using the polishing paste, eliminate it completely with acetone.

Removal of fixed aperture



④ While pressing fixing tool upward by right hand, turn take-off tool by left hand until it engages with threads of fixed aperture and pull it out.

Cleaning of aperture

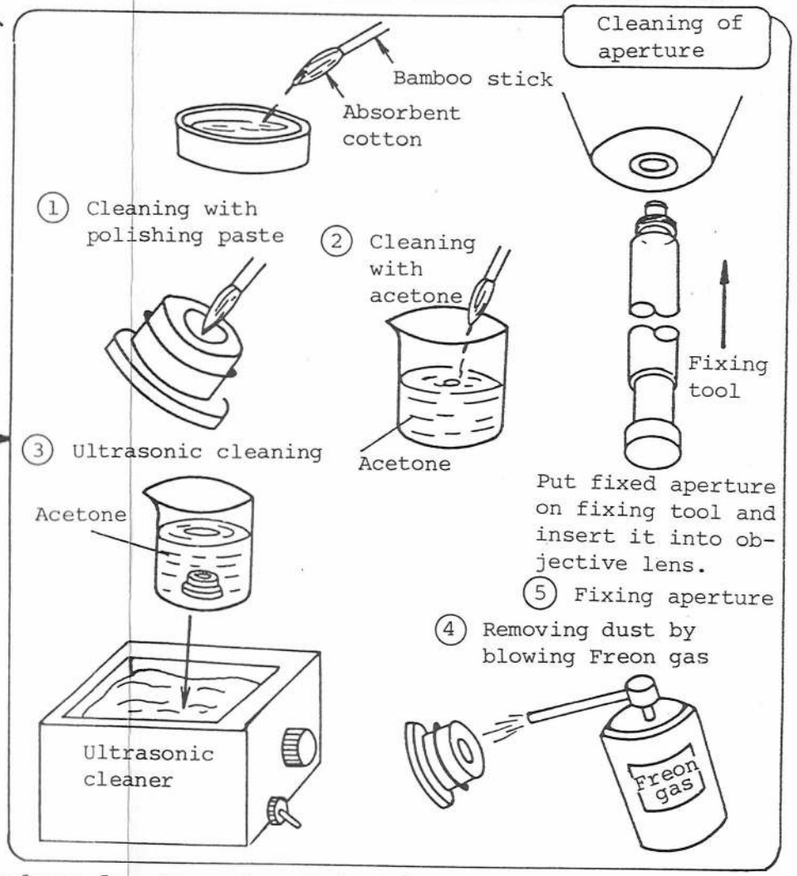


Fig. 4-3 Procedure for Cleaning Objective Lens Movable Aperture

4-5 Maintenance of Secondary Electron Detector

The scintillator (material which produces a small flash of light as a result of the impact of radiation) is gradually deteriorated since it is always subjected to the impact while the detector is activated. If peeling occurs on the surface, a microdischarge will be generated, which might increase noise. The scintillator must be replaced annually or biennially and if an abnormal noise appears on secondary electron images.

If an image trouble occurs, check whether or not the scintillator is normal by the following procedures.

(1) With an accelerating voltage applied, reduce the emission current to zero by turning the [FILAMENT] knob fully counter-clockwise.

(2) Locate the [CONTRAST] knob at 2 o'clock position and set the [STAGE] switch inside the cover to LOWER.

(3) Change over the [SED] switch. In case noise is abnormally high on the UPPER side, the upper SE detector can be considered abnormal, and the lower SE detector considered abnormal in case noise is abnormally high on the LOWER side.

(Note) Scintillator replacement should be left to the serviceman.

4-6 Maintenance of Cooling Unit

The cooling unit is used for cooling the objective lens through circulation of an exclusive corrosion and rust-preventive coolant (coolant for aluminum engine).

(1) Confirm that coolant level in the tank is normal every month.

(2) Replace the coolant with new one every year.

< Level Check and Replenishment of Coolant >

The coolant must be contained at least up to the level marked "700 cc" on the cooling unit. If the coolant level is lower than this, replenish the coolant adequately. (See Fig. 4-4 (a).)

< Exchange of Coolant >

1) Turn off the [DISPLAY POWER] switch of the main unit.

2) Remove the screw from the cover of the cooling unit and detach the cover.

3) Remove the cap from the coolant tank. After placing a vessel (having a capacity of 700 cc or more) below the coolant pipe joint of the cooling unit, disconnect the pipe in reference to Fig. 4-4 (b) and (c).

4) Leave the coolant flowing out of the tank. When the coolant no longer flows out, lift and incline the cooling unit in order to discharge the remaining coolant which still occupies 30 to 40 % of the full tank capacity. (See Fig. 4-4 (d).)

5) Reconnect the coolant pipe and fill the coolant tank with new coolant which must be a 1 : 3 mixture of coolant for Al-engine and distilled water.

6) Tighten the cap of the coolant tank and turn on the [DISPLAY POWER] switch of the main unit to start the pump. After confirming that the coolant does not leak from the pipe joint, etc., attach the cover to the cooling unit.

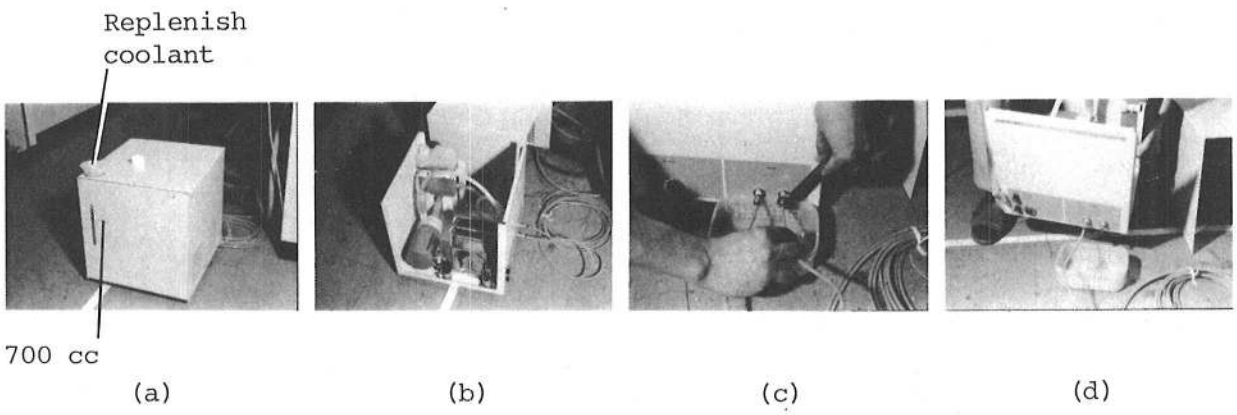


Fig. 4-4 Maintenance of Cooling Unit

4-7 Maintenance of Oil Rotary Pump and Air Compressor

4-7-1 Oil Rotary Pump

Periodical check and maintenance are necessary for normal operation of the oil rotary pump.

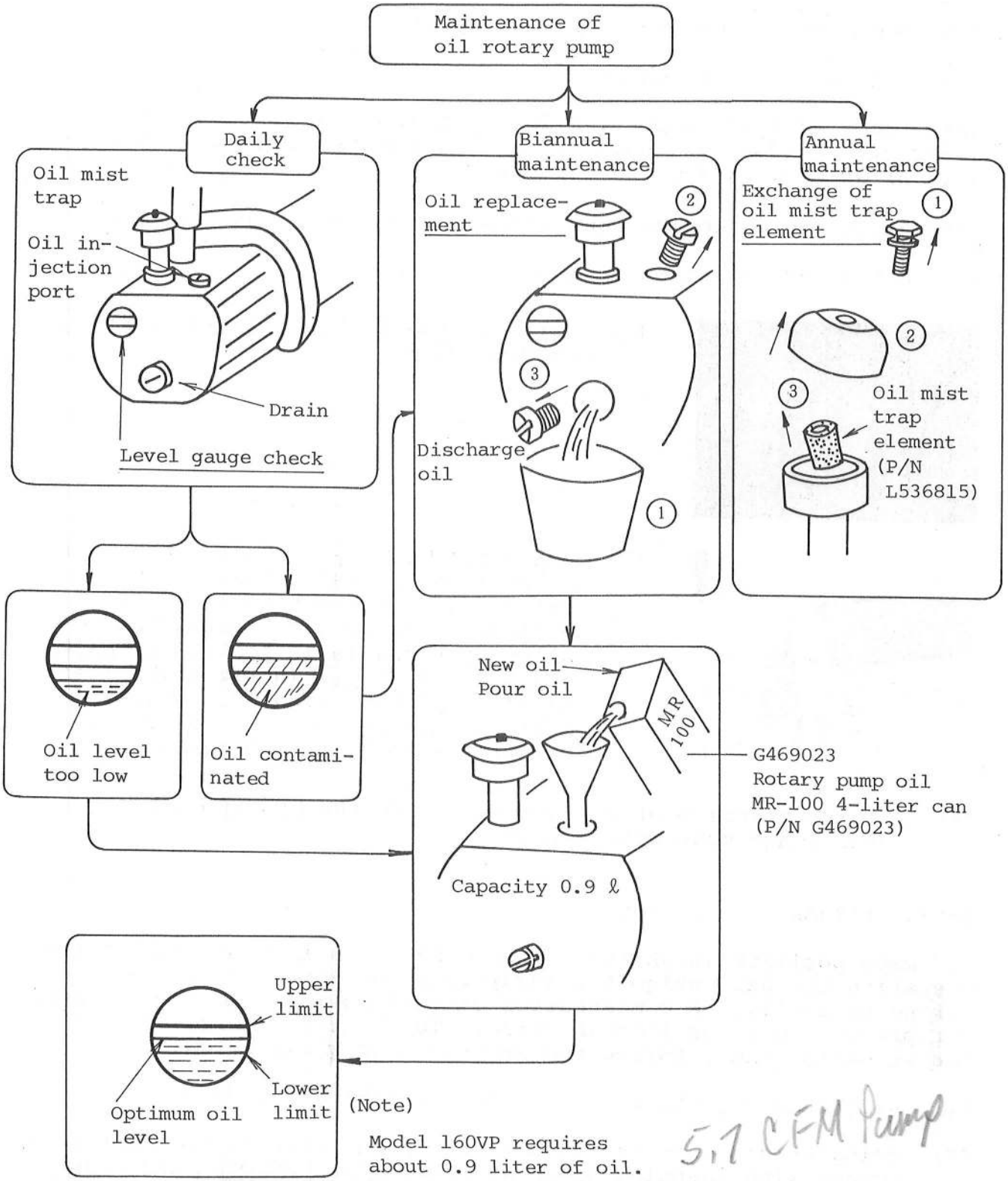


Fig. 4-5 Maintenance of Oil Rotary Pump

4-7-2 Air Compressor

The air compressor must be checked and maintained according to the furnished "Instruction Manual for the Hitachi SUPER-BEBICON".

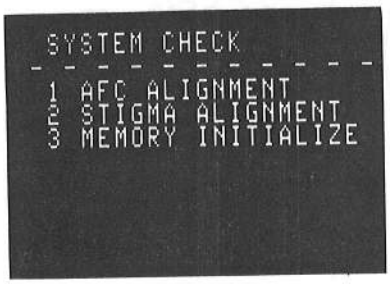
4-8 Check and Maintenance of Display Unit

4-8-1 Auto Focus Alignment

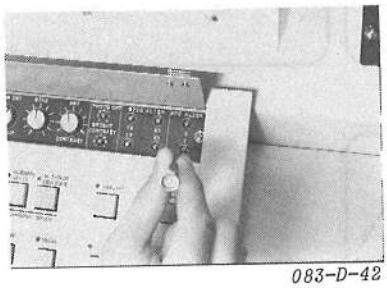
Auto focus must be properly aligned in order to provide a high accuracy. Perform alignment if a high accuracy becomes unavailable or after cleaning the column.

(1) Align the objective lens movable aperture. (See 3-4-8.)

(2) Set a magnification of about 10000×.



(3) Call out the data list, and select [9] SYSTEM CHECK.


083-D-42

(4) Press the [1] key. Usual image mode returns and focus changes periodically. If the image moves in the horizontal or vertical direction along with change in focus, the [AFC ALIGN] trimmer [X] (horizontal direction) or [Y] (vertical direction) must be adjusted so that the image does not move (with a screwdriver).

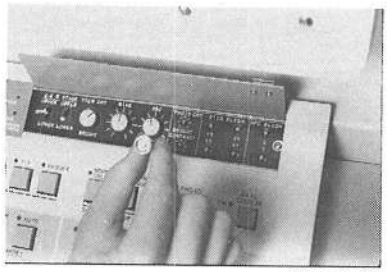
(5) After completion of adjustment, press the [ENTER] key. Usual image mode will return.

4-8-2 Stigmator Alignment

If image position is shifted by turning the stigmator knob or for operating the auto stigmator accurately, astigmatism will not be corrected easily. A compensation circuit is added to the stigmator for preventing image from shifting. To shift the image by turning the stigmator knob, follow the instructions given below.

(1) Align the objective lens movable aperture. (See 3-4-8.)

(2) Bring an easy-to-observe portion of an image at the center of screen with scanning speed at [RAPID] or [REDUCE] and magnification at about 10000×.



083-D-39

(3) Move the [STIGMA (X)] knob clockwise and counterclockwise, and adjust the [STG ALIGN] trimmers [XY] (for vertical direction) and [XX] (for horizontal direction) so that the image does not drift with a screwdriver.

(4) Turn the [STIGMA (Y)] knob clockwise and counterclockwise, and adjust the [STG ALIGN] trimmers [YY] (for vertical direction) and [YX] (for horizontal direction) so that the image does not drift.

4-9 Check and Adjustment when Full Function Unavailable

4-9-1 Absence of Image on CRT

If an image cannot be displayed on CRT, various causes are assumed besides troubles in the instrument itself.

Table 4-1 shows the troubleshooting procedure for each possible cause.

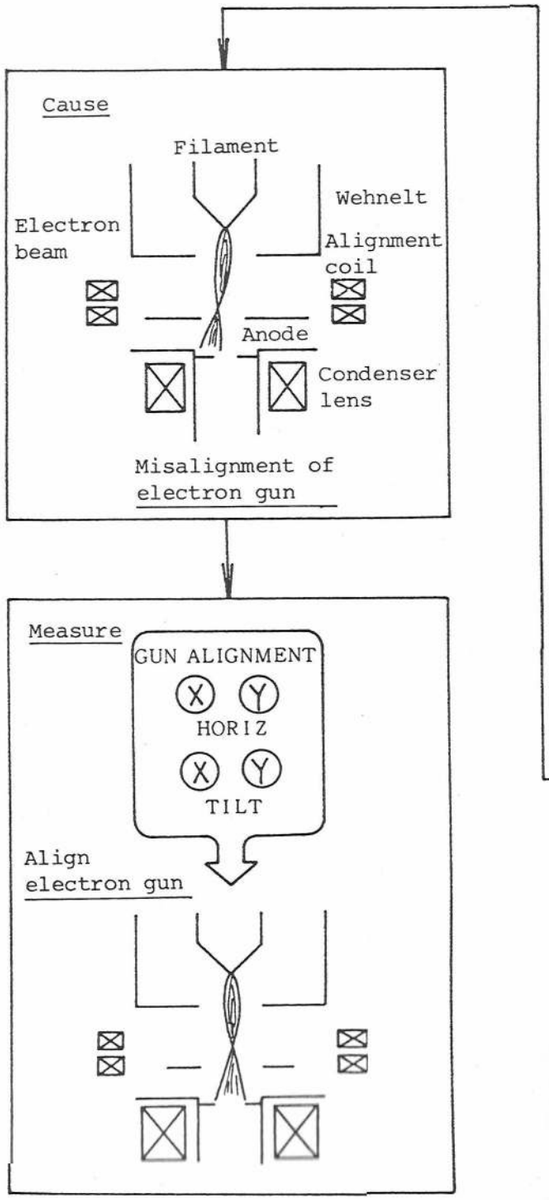
Fig. 4-6 illustrates a simple checking procedure in flowchart format.

Before checking each section, set an accelerating voltage of 10 kV or higher since adjustment is not easy at lower accelerating voltages.

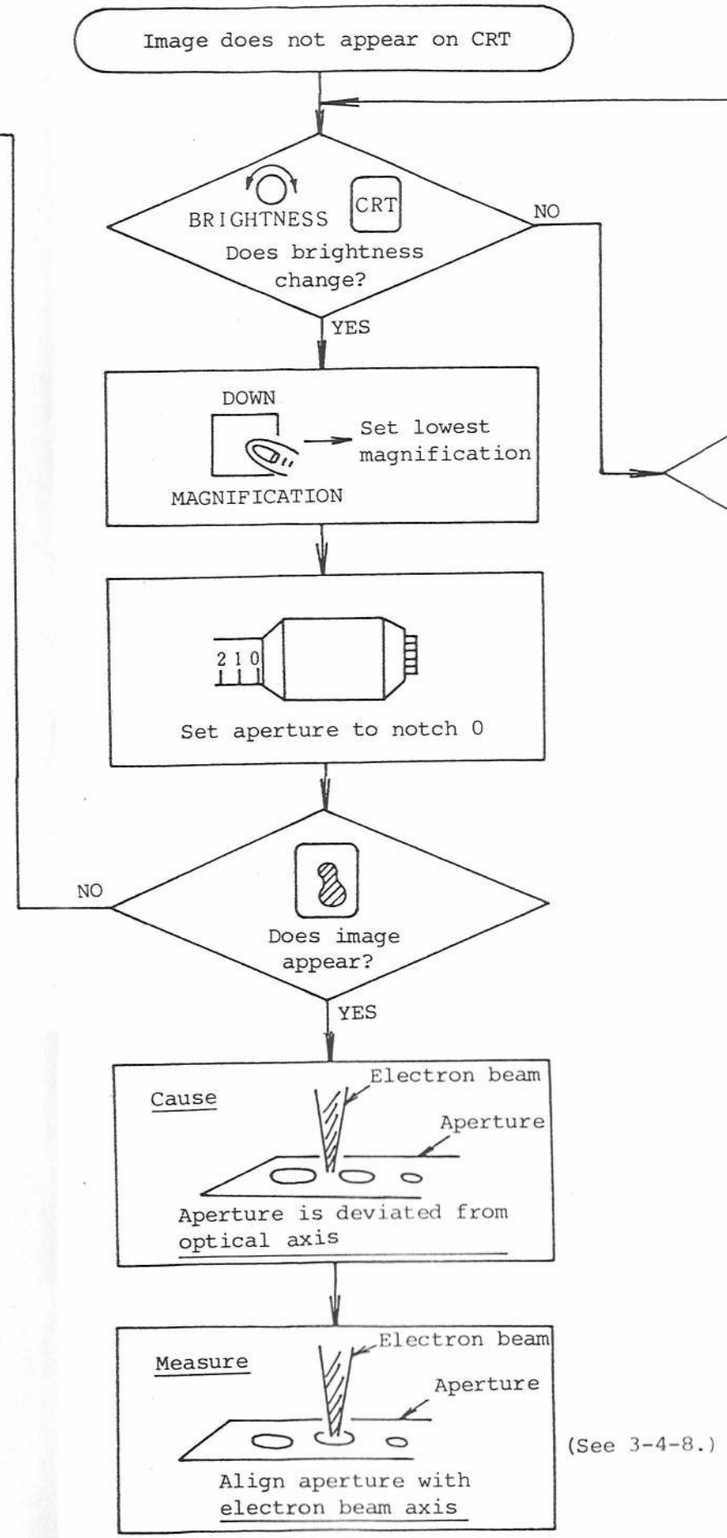
Table 4-1 Troubleshooting Procedure for Each Possible Cause when Image does not Appear on CRT

Symptom	Possible Cause	Check	Remedy
CRT does not brighten	1) Improper setting of switch or knob	Check each setting of switches and knobs	(a) Set [SCANNING MODE] switch to [NORMAL/SPLIT] (b) Set [SCANNING SPEED] switch to [1/2] (c) Set [SELECTOR] switch to [SE] (d) Set [AUTO-MAN-INV] switch to MAN (e) Turn off [AUTO/MONIT], [SEARCH] and [FILAMENT IMAGE] switches (each switch lamp goes out) (f) Turn [BRIGHTNESS] knob clockwise
	2) Circuit overheat protection is activated	Buzzer continues sounding	(g) Turn off [DISPLAY POWER] switch and wait for about 10 minutes, than turn on the switch. If circuit protection is activated again, it is defective.
Image signal is not detected (image cannot be brightened by turning [CONTRAST] knob clockwise, or only noise appears)	1) Emission current is not flowed	Check reading on [EMISSION] meter	(h) Refer to "4-1 Troubleshooting when Emission Current Abnormal"
	2) Improper setting of switch or knob	Check each setting of switches and knobs	(i) Confirm above steps (a) through (e) (j) Set [STAGE] switch to UPPER for WD -3 ∿ +10 mm, and to LOWER for more than +10 mm
	3) Condenser lens current is too large or small	Check selected notch of [COND LENS] knob	(k) Set both [1CON] and [2CON] knobs to a notch between 4 and 6 (notch 3 or 4 with accelerating voltage 5 kV or less)
	4) Objective lens movable aperture is misaligned	Set movable aperture to notch "0"	(l) In case signal is detected at notch 0, obtain the brightest image by adjusting [GUN ALIGNMENT] knob of alignment unit, and then by adjusting aperture opening alignment (X), (Y) knobs at notch 1. After this, select necessary aperture opening dia. and make axial alignment, referring to "3-4-8 Axial Alignment of Objective Lens Aperture" (Image becomes darker when reducing opening diameter. So turn [CONTRAST] knob clockwise whenever reducing the diameter.)
	5) Electron gun is misaligned	Form filament image	(m) Set objective lens aperture at notch 0 and activate [FILAMENT IMAGE] mode. Observe crossover image at enhanced contrast. Adjust [GUN ALIGNMENT] knob so as to match image center roughly with CRT center if deviated widely. (n) Turn off [FILAMENT IMAGE] switch by pressing again and adjust [GUN ALIGNMENT] knob so as to obtain maximum image brightness, referring to "3-4-7 Axial Alignment of Electron Gun". Then set objective lens movable aperture to desired notch.
Signal is detected, but image cannot be seen clearly (just-focus image unobtainable)	1) Magnification is too high	Set the lowest magnification	(o) Keep pressing [MAGNIFICATION] [DOWN] switch until the lowest magnification is obtained (p) Set slightly higher contrast. (Turn [CONTRAST] knob clockwise. When brightness becomes too high, reduce it to a moderate level by adjusting [BRIGHTNESS] knob.) (q) Focus image.
	2) Setting of [STAGE] switch is improper	Check setting	(r) Set to UPPER for WD -3 ∿ 0 mm, and to LOWER for WD 0 ∿ +60 mm. After changing switch position, set the lowest magnification again and focus image.

(Note) If an image cannot be observed despite the above procedures, contact servicemen.



(See 3-4-7.)



(See 3-4-8.)

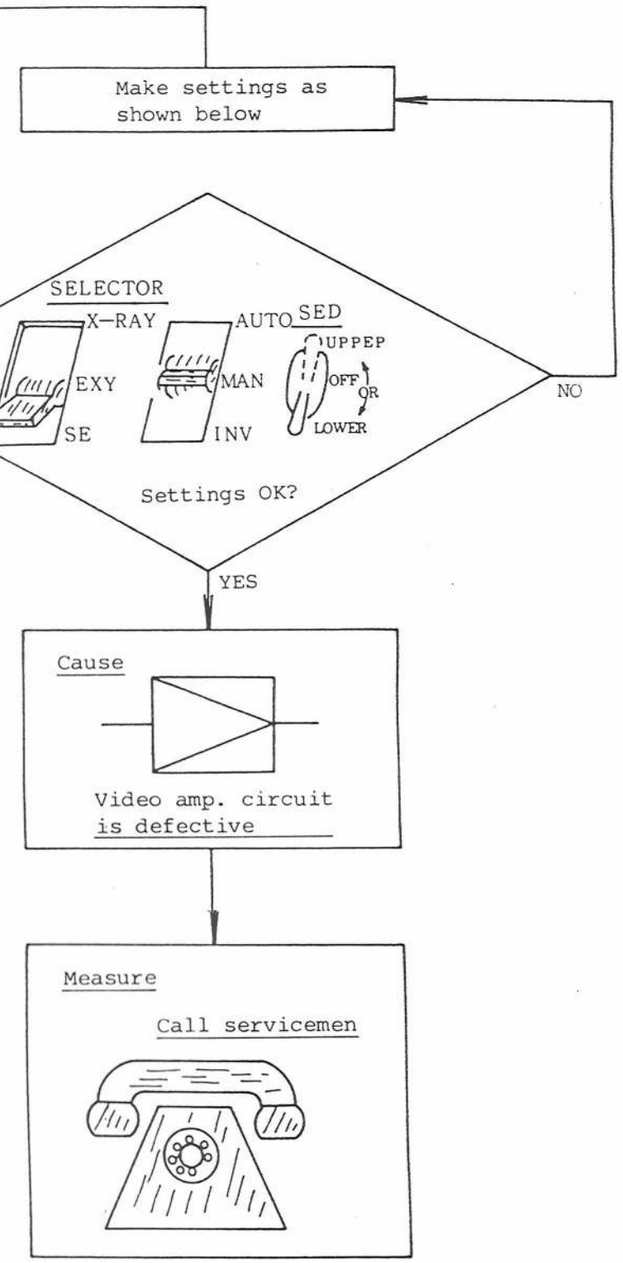


Fig. 4-6 Checking Procedure when Image does not Appear on CRT

4-9-2 High Resolution Image Unobtainable

A high resolution image will be presented only when the following conditions are satisfied.

(1) Electron gun has an adequate brightness.

(a) Check if emission current is too low.

(b) Check if emission current is saturated.

See 3-4-6.

(2) Electron gun axis is aligned properly.

o Check if the [GUN ALIGNMENT] knob is adjusted so as to obtain maximum image brightness.

See 3-4-7.

(3) Condenser current level is appropriate.

See 3-4-9.

(4) A proper opening diameter of the objective lens movable aperture is selected.

See 3-4-9.

(5) Axis of the objective lens movable aperture is aligned properly.

(a) If the objective lens movable aperture is deviated from the electron-optical axis, the electron beam does not pass the center of the lens. This increases various aberrations, so a quality image cannot be obtained.

(b) If the objective lens movable aperture is not aligned with the optical axis, an image drifts along with movement of the [FOCUS] knob. In this case, adjustment is required. (Although an image revolves around the center of CRT when turning the [FOCUS COARSE] knob at a low magnification, this does not constitute a problem.)

See 3-4-8.

(6) Selection of accelerating voltage is proper.

(a) Accelerating voltage must be selected with utmost care when observing a specimen which is electrically non-conductive or vulnerable to damage by electron beam bombardment.

(b) Resolution is degraded at lower accelerating voltages usually.

See 3-4-9.

(7) Specimen preparation is proper.

o A quality image cannot be expected from a specimen which is electrically non-conductive or causes a local charge-up.

See 3-7.

(8) Astigmatism is corrected.

(a) Finely correct astigmatism, referring to 3-4-2-(1)-(k).

(b) Note that astigmatism may become particularly large at low accelerating voltages.

See 3-4-2-(1)-(k).

(9) Objective lens aperture is not contaminated.

Astigmatism may not be corrected even though the conditions (1) to (7) are met, and an image may not become sharp even though image astigmatism is not conspicuous. In such cases, the objective lens aperture is assumed to be contaminated.

(a) Change the objective lens movable aperture to a different notch (though this requires axial alignment). If image quality is improved or degraded, the movable aperture requires cleaning.

See 4-3.

(b) If image quality remains the same for a change in the objective lens movable aperture notch, the fixed aperture requires cleaning.

See 4-4.

4-9-3 Excessively Short Lifetime of Filament

The filament has a lifetime of about 20 ∿ 40 hours, though it depends on operating conditions such as emission current.

If the filament has worn out too early, an abnormality exists. So localize it as per Fig. 4-7.

To prolong the filament lifetime, take the following into consideration.

(1) The filament is usable longer by use of low emission currents.

When the accelerating voltage is the same, emission saturates at smaller emission or heating currents than at larger currents (though this degrades resolution due to resultant decrease in brightness). Therefore, when employing a low magnification, set the filament current (saturation point) with the filament withdrawn a little wider than in 3-4-5 or with the emission current suppressed by adjusting the [BIAS] knob. This will lead to a prolonged filament lifetime.

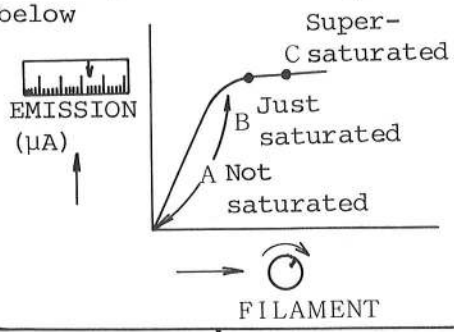
(2) For the same reason as above, filament current can be reduced slightly from the saturation point by returning the FILAMENT knob counterclockwise when using a lower magnification.

(3) The filament becomes thin, the longer it is used. If the same heating current as employed for a new filament is flowed in this status, the filament temperature rises excessively. So, set the saturation point of emission current again about 10 hours after replacing with a new filament. This ensures a better result.

Filament life is too short

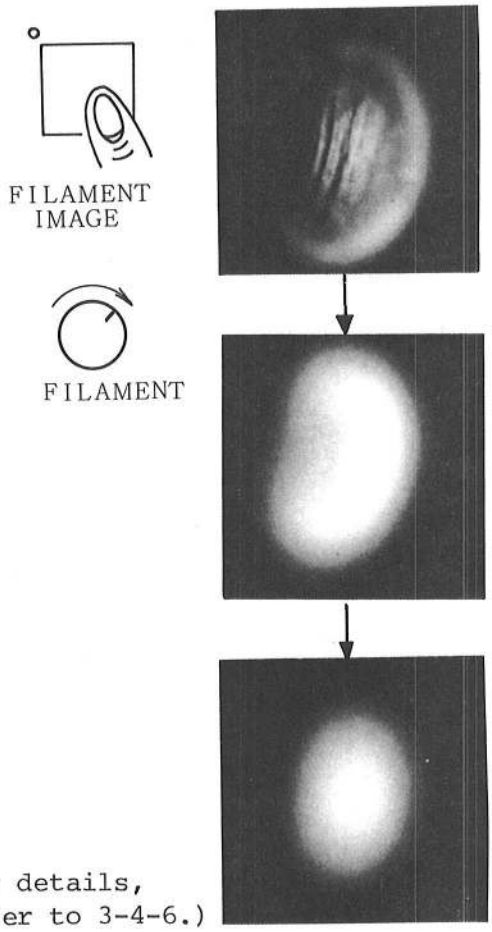
Improper setting of filament

Filament life becomes extremely short when emission current is set at supersaturation point "C" in figure below



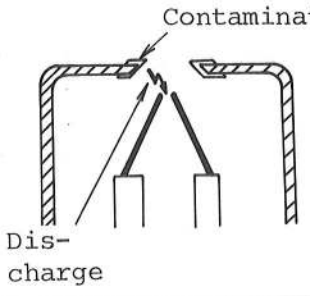
Set filament knob so as to meet point B

Set to point B while observing filament image

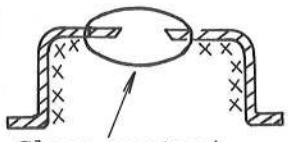


(For details, refer to 3-4-6.)

Discharge due to contamination of Wehnelt



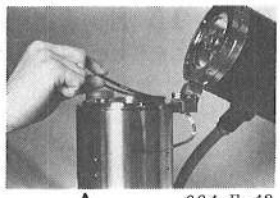
Cleaning



Clean contaminated portion

××× portion must also be cleaned.

Poor vacuum



084-F-42

O-ring contaminated

Cleaning

① Clean O-ring with acetone

② Sparingly apply vacuum grease, and then attach

Fig. 4-7 Checking Procedure when Filament Life Is too Short

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5. PARTS REPLACEMENT

5-1 Consumables and Spare Parts

5-1-1 Consumables

The items shown in Table 5-1 should always be on hand for normal operation.

Table 5-1 Consumables

Part No.	Part Name	Use	Remarks
G370009	Conductive paint		30 g
G370250	Metal polishing paste		50 g
G743002	Bamboo stick		10 pcs
S370061	Absorbent cotton		
S370059	Gauze		
S269003	Aluminum foil		
G465001	Vacuum grease	For vacuum seal	
535-1289	Fixed aperture	For liner tube	(made of molybdenum, 20-sheet set)
432-3638	Objective lens aperture plate		
777-0179	Filament		10 pcs
533-0286	Scintillator	For lower detector	
830-4183	Scintillator	For upper detector	
———	Acetone	For cleaning	
533-1337	Molybdenum board	For baking aperture plate	
S263003	Nylon gloves		
532-0292	DP oil (LION S)		100 cc
G469023	RP oil (MATSUMURA SEKIYU MR-100)		4 ℓ
L536185	Oil trap element	For rotary pump	
538-1308	Coolant for aluminum engine	For cooling unit	

(Note) Use acetone available on the market.

5-1-2 Spare Parts

Table 5-2 lists spare parts for long term operation. Prepare each part in the necessary quantity according to usage of the instrument.

Table 5-2 Spare Parts

Part No.	Part Name	Location	Remarks
L456529	O-ring AS568-239 NBR	Electron gun, condenser lens	
L456464	O-ring AS568-115 NBR	Condenser lens	
L456008	O-ring P10A NBR	Condenser lens	
L456462	O-ring AS568-113 NBR	Objective lens	
L456015	O-ring P20 NBR	Objective lens	
L456564	O-ring AS568-274 NBR	Specimen stage (front plate)	
L456026	O-ring P36 NBR	Specimen stage (lock)	
L456005	O-ring P8 NBR	Specimen stage X, Y control knobs	
L456002	O-ring P5 NBR	Specimen stage R, T, Z control knobs	
L456536	O-ring AS568-246 NBR	SE detector	
L456411	O-ring AS568-012 NBR	Objective lens movable aperture	
L456515	O-ring AS568-225 NBR	Specimen chamber port	
L456510	O-ring AS568-220 NBR	Evacuation pipe	
L456527	O-ring AS568-237 NBR	Valve	
L456461	O-ring AS568-112 NBR	Valve	
L456462	O-ring AS568-113 NBR	Valve	
L456525	O-ring AS568-235 NBR	DP evacuation pipe	
538-1427	DP heater		500 W
J821026	Fuse 1 A		
J821027	Fuse 2 A		
J821028	Fuse 3 A		
J821030	Fuse 5 A		
433-3702	Specimen stube 15 mm dia.		
433-3703	Specimen stub 26 mm dia.		
531-1145	Specimen stub 3 in dia.		
531-1111	Specimen stub 4 in dia.		
K433004	Pirani gauge bulb		
J386012	Photomultiplier R268		
531-0601	Holder (15 mm dia. × 4)		
531-0602	Holder (6 mm dia. × 10)		
533-2277	Holder for evaporation		

ANALYSIS OF DEFICIENT IMAGES IN SCANNING ELECTRON MICROSCOPE

ANALYSIS OF DEFICIENT IMAGES IN SCANNING ELECTRON MICROSCOPE

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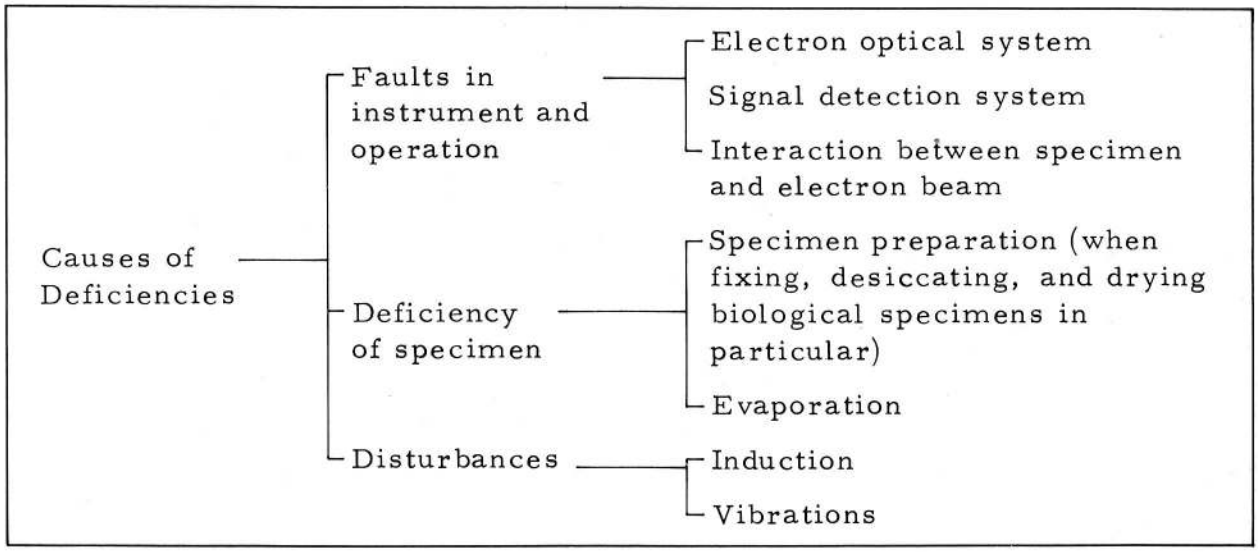
On the other hand, these phenomena can roughly be divided as shown in Table 2 according to their causes.

Table 2 Causes of Deficiencies in Scanning Electron Microscopy



1. CAUSES OF DEFICIENT IMAGES IN ELECTRON OPTICAL SYSTEM AND SIGNAL SYSTEM

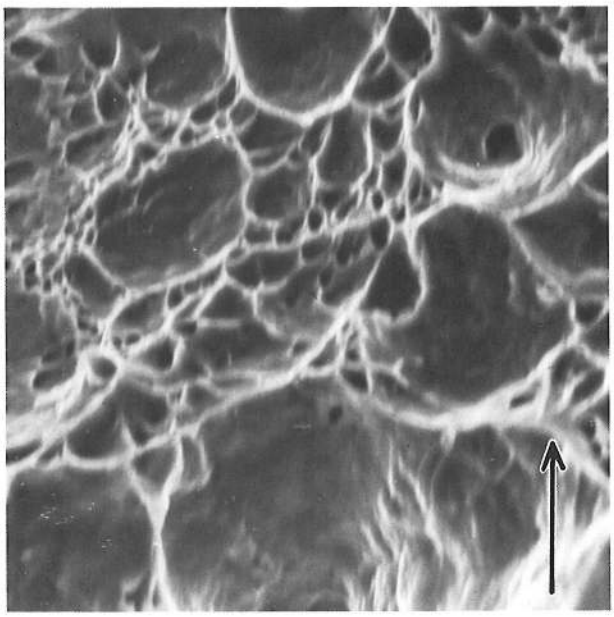
The definite causes of deficient images in the electron optical system are as shown in Table 3.

Table 3 Causes of Deficient Images in Electron Optical System

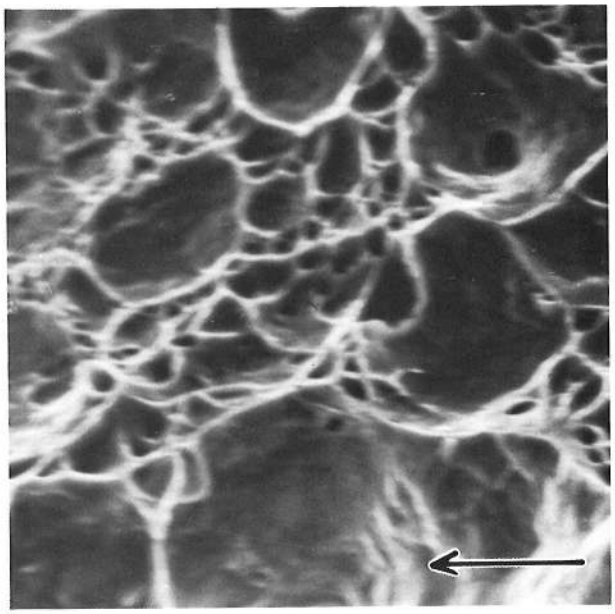
(1)	Unstable electron beam in the axial direction
	Unstable high voltage
	Discharge of electron gun
	Unstable filament current
(2)	Unstable electron beam in the perpendicular direction
	Micro-discharge in microscope column due to internal contamination
	Unstable lens exciting current
	Effects of external magnetic fields
(3)	Deformation or insufficient reduction of electron probe
	Improper axial alignment
	Insufficient astigmatism correction
	Contamination of apertures
	Improper selection of aperture diameter

These causes result in poor resolution of SEM. Fig. 1 indicates examples of deficient images due to insufficient astigmatism correction.

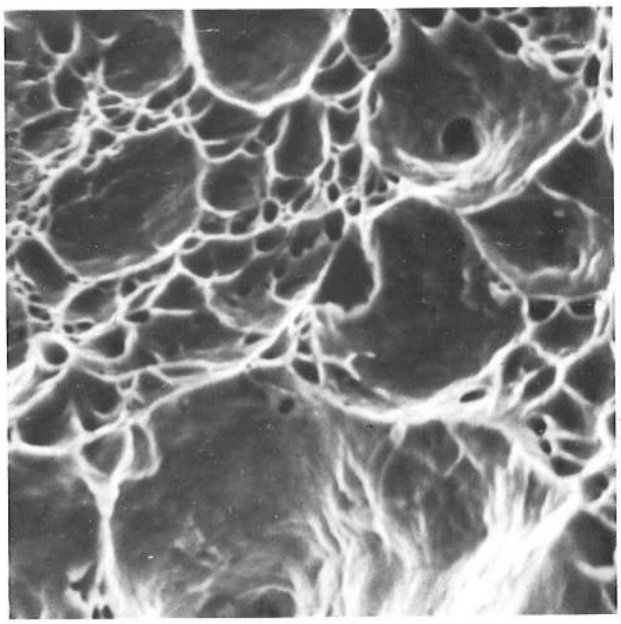
1. Under-Focused (with astigmatism)



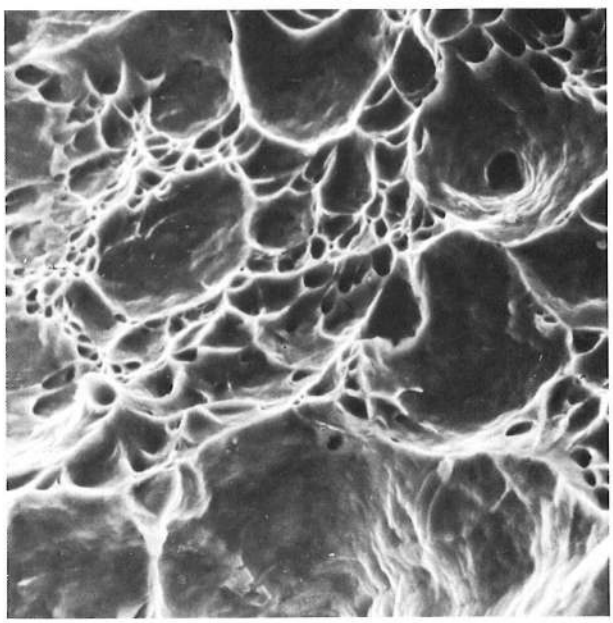
2. Over-Focused (with astigmatism)



3. Just Focused (with astigmatism)



4. Just Focused (without astimatism)



2 μm

Specimen: Fracture of steel

Fig. 1 Effects due to Astigmatism (The right lower arrows in pictures 1 and 2 indicate the astigmatism direction)

* It should be noted that if astigmatism appears, the image is not sharp even when just focused.

On the other hand, all deficiencies in the signal detection system appear as a phenomenon of deteriorated image quality. These can be divided roughly into two cases as described previously; one appears as noise and the other appears as insufficient image contrast. The former occurs when the performance of the signal detection system is faulty or deteriorated, while the latter occurs due to unskilled operation of the instrument in most cases.

2. INTERACTION BETWEEN ELECTRON BEAM AND SPECIMEN

Let's examine the deficiencies caused by interaction between the electron beam and specimen by tracing to see in what form the secondary electrons emitted from the specimen by bombardment of the electron beam contribute to the secondary electron image.

2.1 Secondary Electron Emission

When a solid is irradiated with an electron having an energy of E_o, an electron having the energy shown in Fig. 2 is emitted. The SEM employs secondary electrons having an energy lower than 100 eV as an information source.

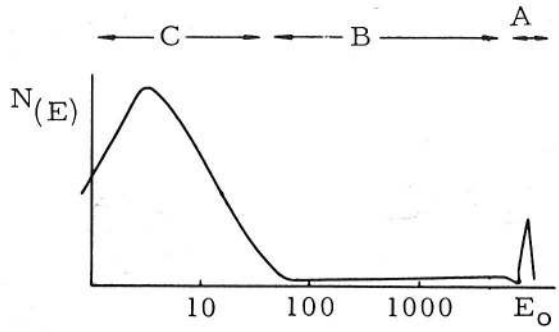


Fig. 2 Energy Distribution of Electrons Emitted by E_o = 10 kV Electrons

Assuming that the primary electron is I_p and the secondary electron emitted from specimen is I_s, the secondary emission coefficient (or yield) (S) can be expressed as $S = I_s/I_p$. The secondary emission coefficient differs according to the energy of the primary electron beam irradiated onto specimen and the specimen material.

Fig. 3 indicates the change of the secondary emission coefficient (yield) when changing the accelerating voltage of the primary electron.

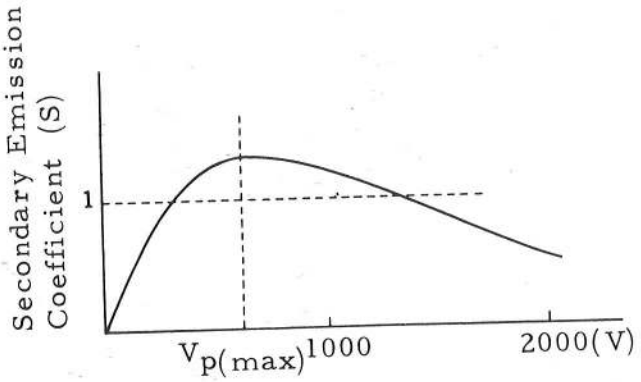


Fig. 3 Secondary Emission Coefficient (S) as a Function of Beam Voltage

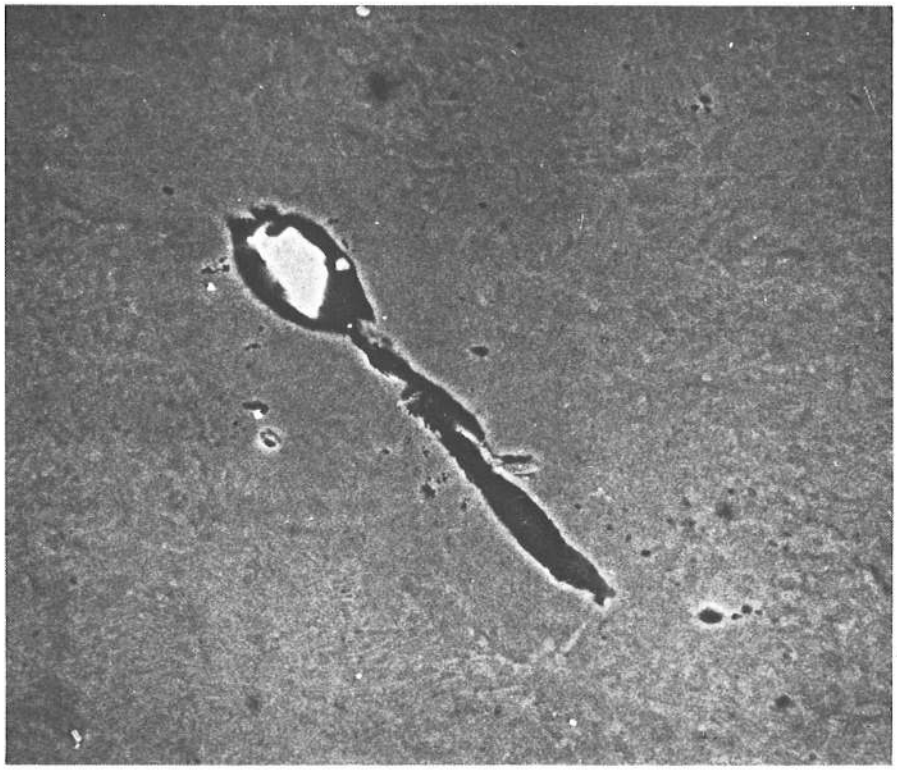
Also, the secondary emission coefficient differs according to substances as shown in Table 4, and a slight difference of contrast is produced by the difference of elements.

S_{max} lies between 1 and 2 in case of metallic materials as shown in Table 4, but is 5 ~ 10 or over in oxides.

Now, let's see to what extent the secondary electron emission source spreads when specimen is irradiated with a very fine electron beam.

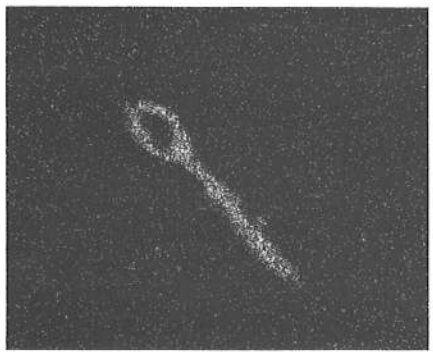
Table 4 Maximum Secondary Emission Coefficient, and Corresponding V_{pmax}, for Different Elements

Element	S_{max}	V_{pmax}	Element	S_{max}	V_{pmax}
Ag	1.5	800	Pb	1.1	500
Al	1.0	300	Pt	1.8	800
Au	1.46	750	Rb	0.9	350
B	1.2	150	Si	1.1	250
Ba	0.83	400	Sn	1.35	500
Bi	1.15	550	Ti	0.9	280
Be	0.53	200	W	1.4	700
C	1.0	300	Zr	1.1	350
Cd	1.1	400	Pd	>1.3	>250
Co	1.2	700			
Cs	0.72	400			
Cu	1.3	600			
Fe	1.3	350			
Ge	1.2	400			
K	0.75	200			
Li	0.5	85			
Mg	0.95	300			
Mo	1.25	375			
Nb	1.2	375			
Ni	1.3	550			



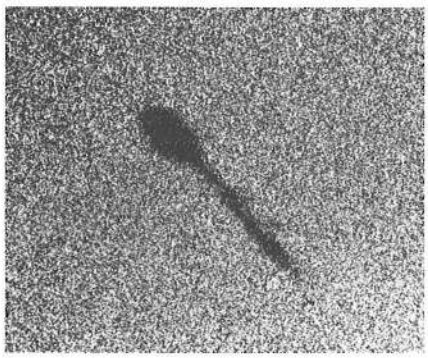
(a)

10 μm



(b) Mn-Kα

(c) Zr-Lα



(d) Fe-Kα

Specimen: Fe-Mn-Zr

Fig. 4 Secondary Electron Image Showing Atomic Number Effect (a), and Characteristic X-ray Images (b), (c), and (d) (Accelerating Voltage 25 kV)

When specimen is irradiated with electron beam, the incident electron gradually loses its energy while repeating internal scattering, and the secondary electron is created. However, since the secondary electron energy is lower than 100 eV as described previously, the secondary electron created within a depth of about 100 A at best is emitted from the specimen surface (see Fig. 5).

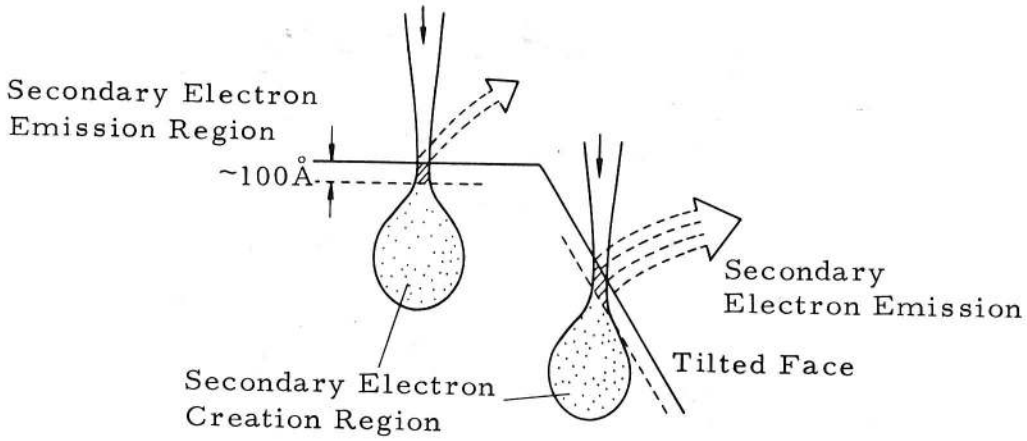


Fig. 5 Region of Secondary Electron Creation and Emission

2.2 Edge Effect

The quantity of secondary electron emission from specimen surface varies according to the incident angle of electron beam bombarded onto the specimen. As this incident angle becomes larger, the quantity of secondary electron emission increases. The angle effect between specimen and primary electron due to the topographical unevenness of specimen surface produces the contrast of secondary electron image to a great extent. Namely, secondary electrons are emitted in large quantity from a specimen portion having an acute angle or from fine particles of about a micron as shown in Fig. 6, and as a result, unnatural enhanced brightness appears on the secondary electron image. This is called edge effect. Fig. 7 indicates a definite example of this edge effect. Note that the acute angle portion of metal fracture is extremely bright.

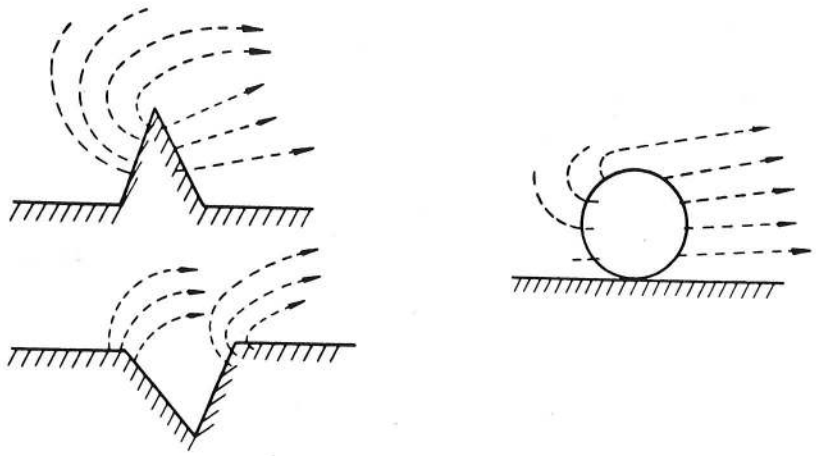


Fig. 6 Enhancement of Secondary Electron Emission According to Specimen Shape

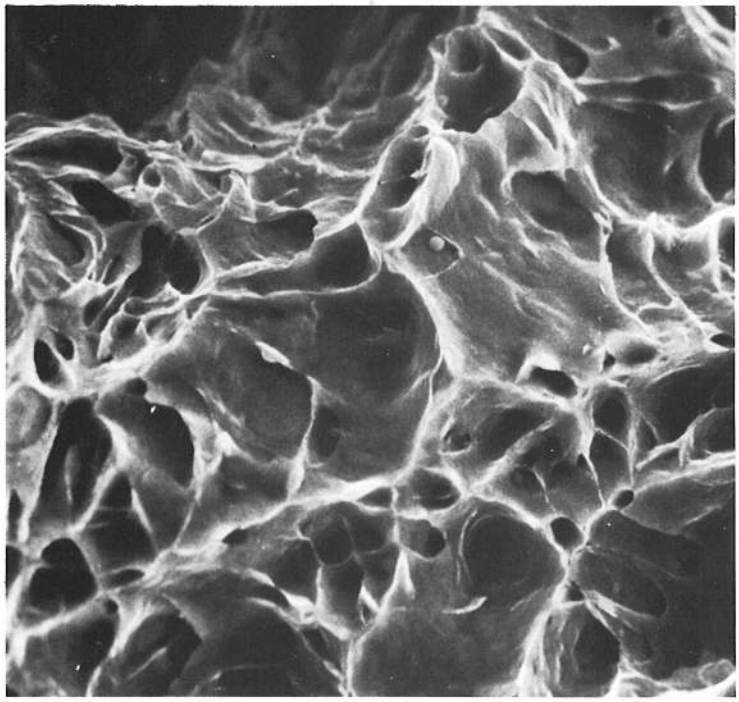


Fig. 7 Edge Effect

Specimen: Steel Fracture
(Beam Voltage: 20 kV)

2.3 Charge-Up Effect

Let's consider the movement of electrical charge on a conductive specimen surface having ground potential when the specimen surface is irradiated with electron beam. See Fig. 8.

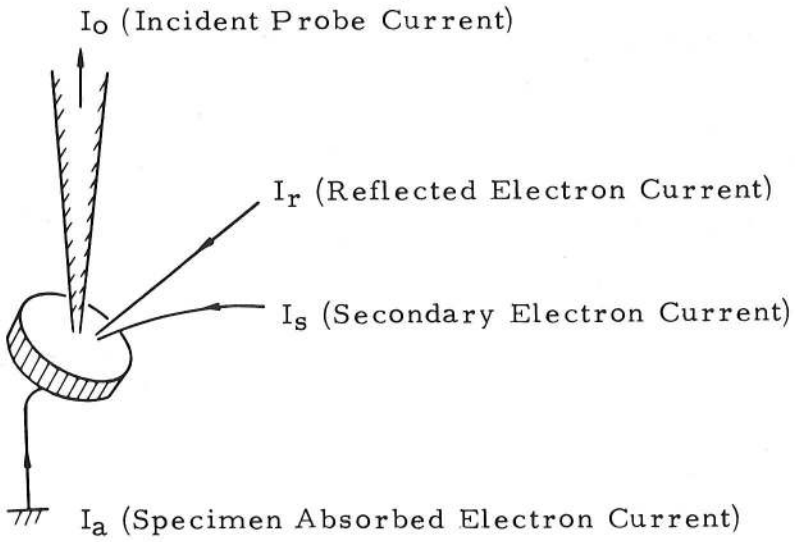


Fig. 8 Currents in Specimen

The following relation holds among incident electron beam current I_o, reflected electron current I_r, secondary electron current I_s, and specimen absorbed electron current I_a.

$$I_a = I_o - I_r - I_s$$

Using back-scattering coefficient "r" and secondary emission coefficient "S" for I_r/I_o and I_s/I_o respectively, $I_a = (1-r-S)\, I_o$ is obtained.

The accelerating voltage employed in SEM in ordinary cases ranges from 10 to 20 kV, and $1 > r + S$ remains unchanged under this condition. ($I_a = 0.5 \sim 0.7 I_o$ usually)

If a part of the specimen surface has an impedance of Z ohms with reference to ground, potential $V_s(t)$ at that point becomes

$$V_s(t) = ZI_a = Z(1-r-S)\, I_o \qquad \text{(Fig. 9)}$$

Accordingly, when Z is a very large value like in an insulator, the charge is accumulated, causing a considerable load potential V_s.

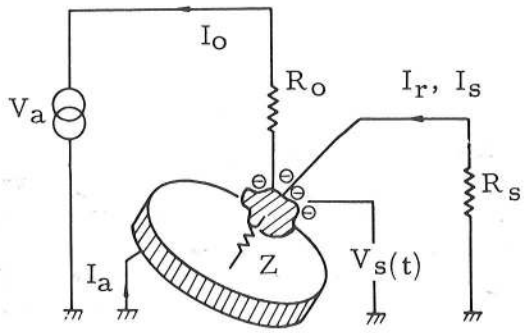


Fig. 9 Charge-Up on Specimen Surface

This phenomenon is called charge-up, and it generally appears on the secondary electron image in the following form. (See Figs. 10 ~ 12)

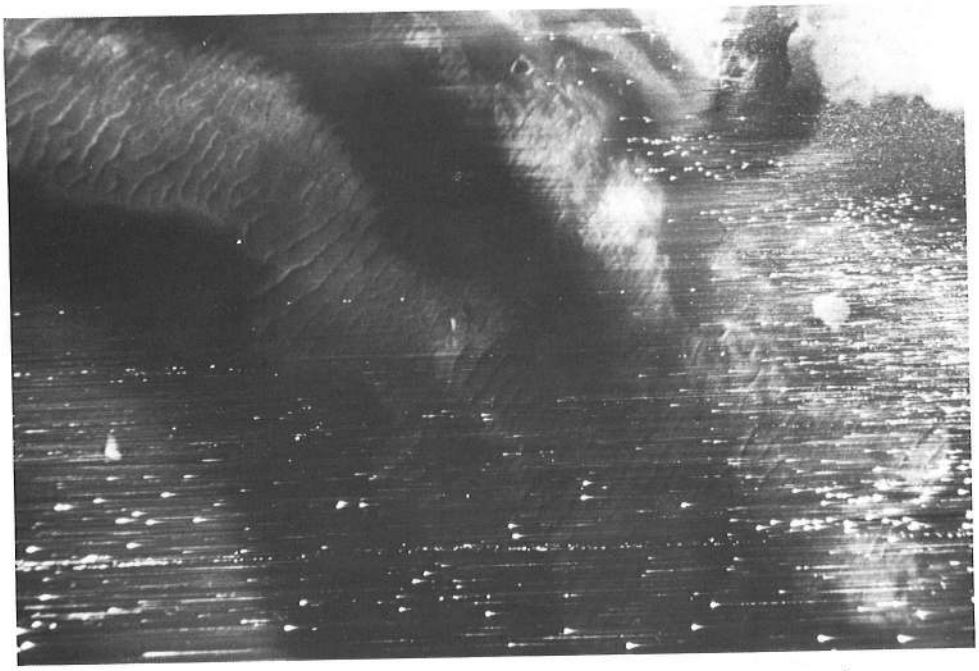


Fig. 10 Example of Macro-Discharge

Fig. 11 Distortion, or Irregular Image Shift

0.2 mm

Fig. 12 Example of Contrast Having Abnormal Enhanced Brightness and Darkness

1) Macro-discharge (irregular bright spots or lines)

2) Distortion, or irregular image shift

3) Contrast representing abnormal enhanced brightness and darkness

As is understood from the above equation, these charge-up phenomena are eliminated by:

(a) Reducing Z.→Evaporate specimen with metal sufficiently for the purpose of making the specimen surfaces conductive.

(b) Minimizing I_a.→For this purpose, decrease the accelerating voltage V_a and increase secondary emission coefficient S so that r + S approaches 1.

Maximum value of secondary emission coefficient S is within 1 - 2 kV in practical cases. (However, since the decrease of V_a causes poor resolution of image, this should be avoided except for special purposes.)

* If the accelerating voltage is excessively lowered, it is possible that $r + S > 1$, and a positive charge-up may occur.

2.4 Electron Beam Damage

The greater part of energy of electron beam irradiated onto specimen is lost in the form of "heat" at the irradiating point. The degree of this temperature rise differs according to the following conditions:

1) Accelerating voltage, current density, duration of electron beam irradiation

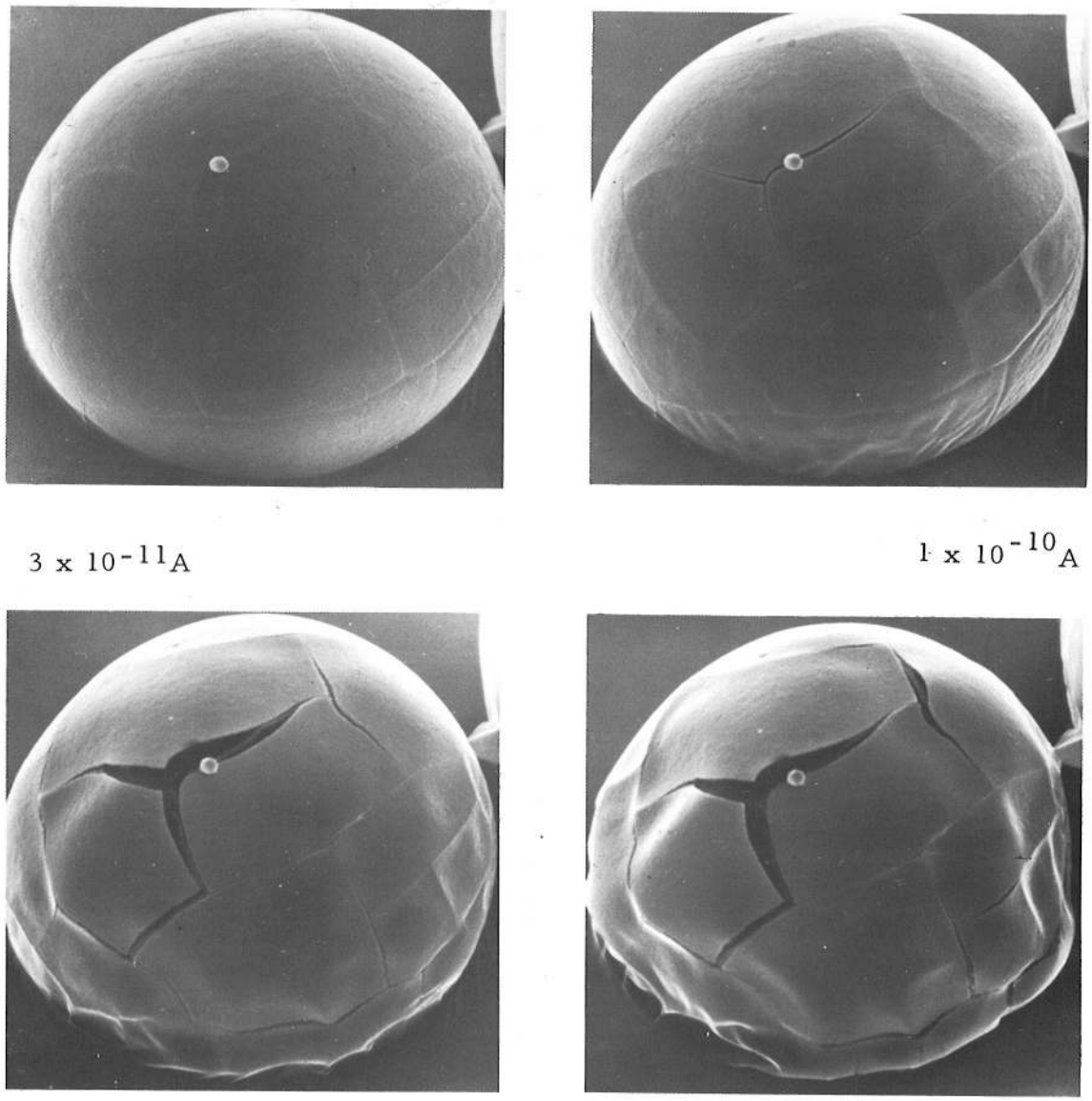
2) Thermal conductivity of specimen

Generally, high polymer materials or biological specimens have a low thermal conductivity and therefore are subjected to electron beam damage. The electron beam damage appears in the secondary electron image in the form of decomposition and sublimation of specimen or deformation, contraction, and cracks of specimen. In addition, electron beam damage is apt to occur as the "electron current density x irradiating time" becomes larger (or, when a high magnification image is obtained). The most effective way to avoid such electron beam damage is to evaporate specimen surfaces with metals such as Au, etc. Since the evaporated gold serves to prevent electron beam damage in many cases, and to feature a large secondary electron emission, the Au evaporation technique is an indispensable means. It is also necessary to observe the specimen with the specimen irradiating current minimized. In addition, the specimen is cooled for the purpose of preventing temperature rise on its surface.

Fig. 13 indicates the behaviour of increasing electron beam damage due to increase of the irradiating current onto starchy particles. Figs. 14 ~ 16 represent other examples of electron beam damage.

5×10^{-12}A

1×10^{-11}A

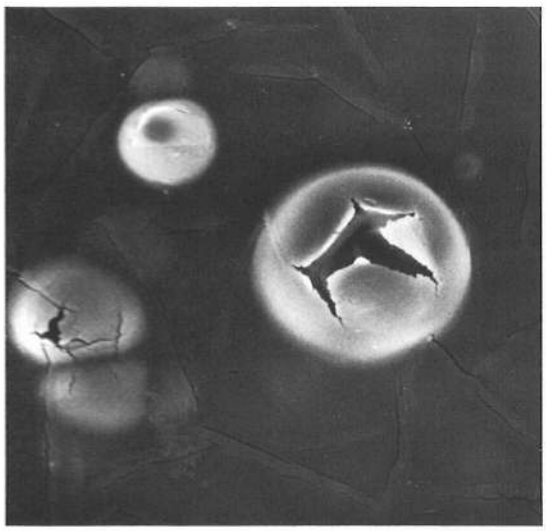


3×10^{-11}A

1×10^{-10}A

2.5 μm

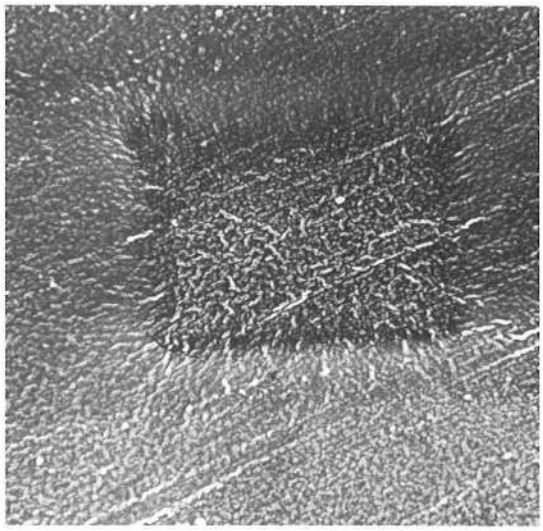
Fig. 13 Electron Beam Damage to Starchy Particles
(Beam Voltage: 15 kV)



2 μm

Fig. 14 Cracks due to Electron Beam Damage

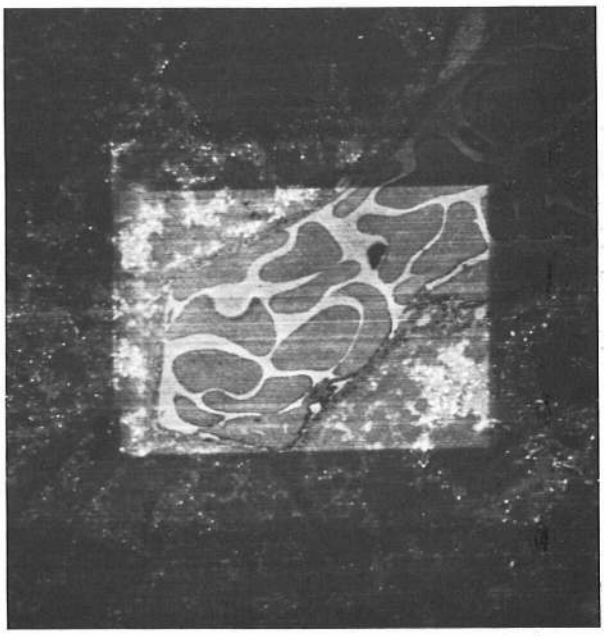
Specimen: Monochrome Film
(Beam Voltage: 10 kV)



10 μm

Fig. 15 Contraction due to Electron Beam Damage

Specimen: High Polymer Film
(Beam Voltage: 10 kV)



3 μm

Fig. 16 Sublimation of Epoxy Resin
(Scanning Transmission Image)

Specimen: Biological Section
(Beam Voltage: 25 kV)

2.5 Contamination

The remaining organic molecules in the microscope column are decomposed by electron beam, and as a result, carbon and sulfuric compounds are adsorbed onto the specimen surface. This phenomenon is called beam-induced contamination. The contamination degree is determined by the "current density x scanning time". (It is also influenced by vacuum quality, vacuum degree, specimen material, etc.) This contamination affects the secondary electron image as follows:

1) Since carbon and sulfuric compounds reduce the secondary electron emission quantity, the image becomes darker.

2) The fine topographical structures on the specimen surface are eliminated.

3) The charge-up phenomenon may occur.

The most effective way to avoid contamination is to evacuate the specimen chamber to 10^{-6} Torr or better. A dry vacuum system using an ion pump permits reducing contamination to a very large extent.

Contamination comes into question in the following cases:

(a) Lowering of resolution when observing high magnification images

(b) Sensitivity drop and increase of background in surface analyses (elementary analyses such as x-ray analysis, Auger electron analysis, etc.)

Fig. 17 indicates an example of fine topographical structure of a magnetic tape surface gradually buried by contamination when the specimen is scanned for a long time.

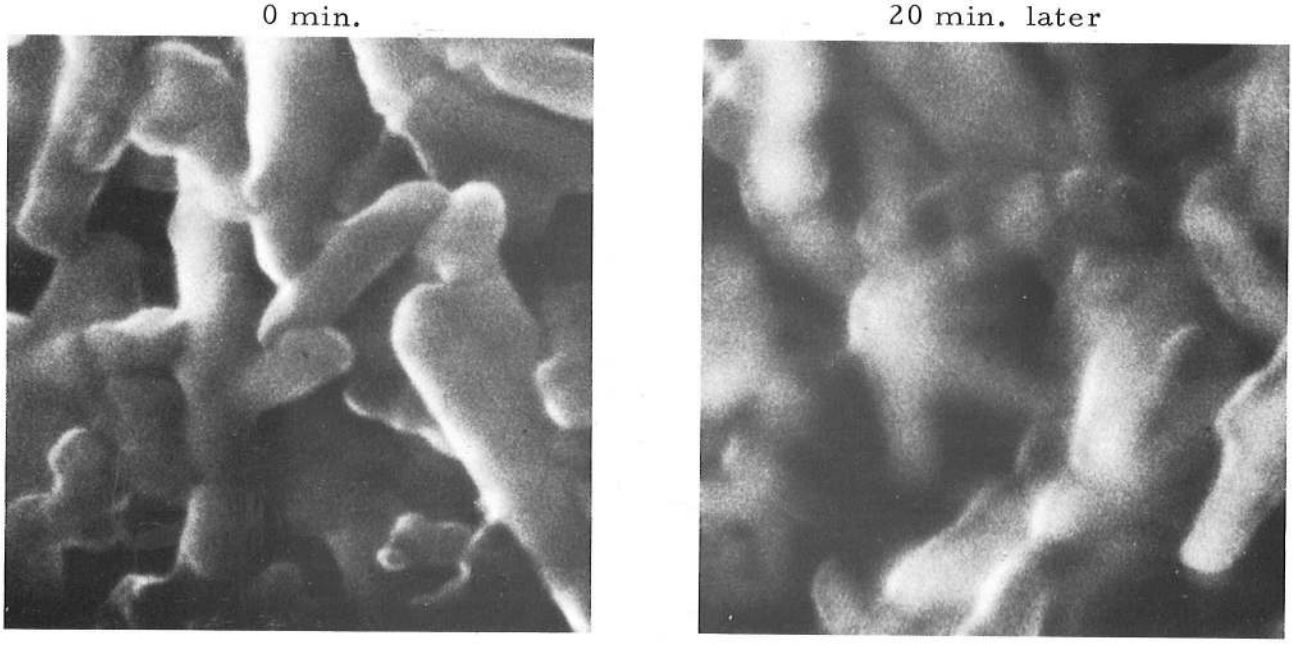


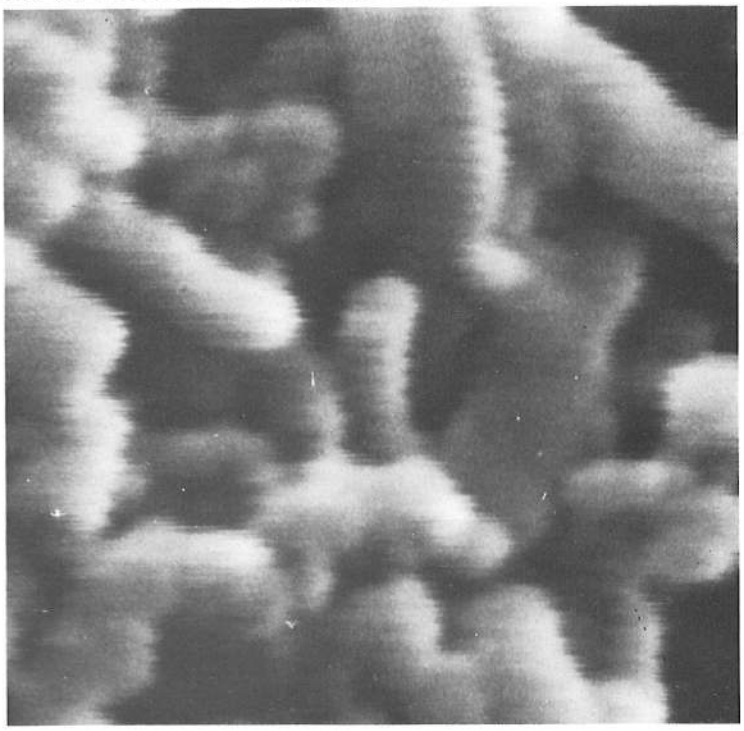
Fig. 17 Elimination of Fine Structure due to Contamination

Beam Voltage : 20 kV
Vacuum : 3×10^{-5} Torr
Specimen : Magnetic tape

3. DISTURBANCES

The deficiencies due to disturbances are caused by the effects of electrical/electromagnetic induction and external magnetic field, vibrations, etc. When largely affected by external magnetic field or vibrations, the contour of the image becomes rough and notched, causing deteriorated resolution of the image. (Fig. 18)

Effect of External Magnetic Field



Effect of Vibration

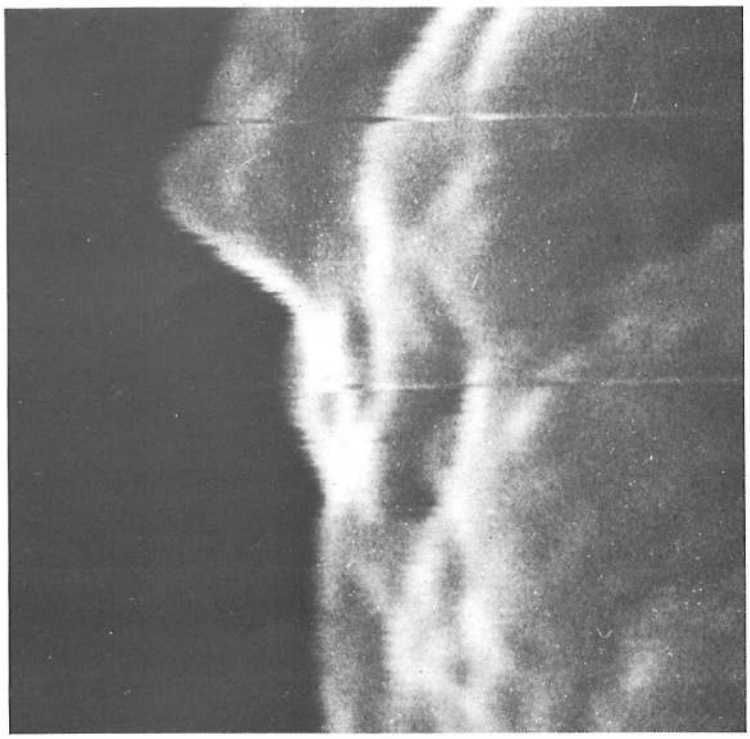


Fig. 18 Effects of External Magnetic Field and Vibration

When an electrical/electromagnetic induction is introduced into the image, stripe patterns or bright lines will appear at certain intervals as shown in Fig. 19. These faults may often be caused by incomplete installation conditions of the instrument or grounding failure.

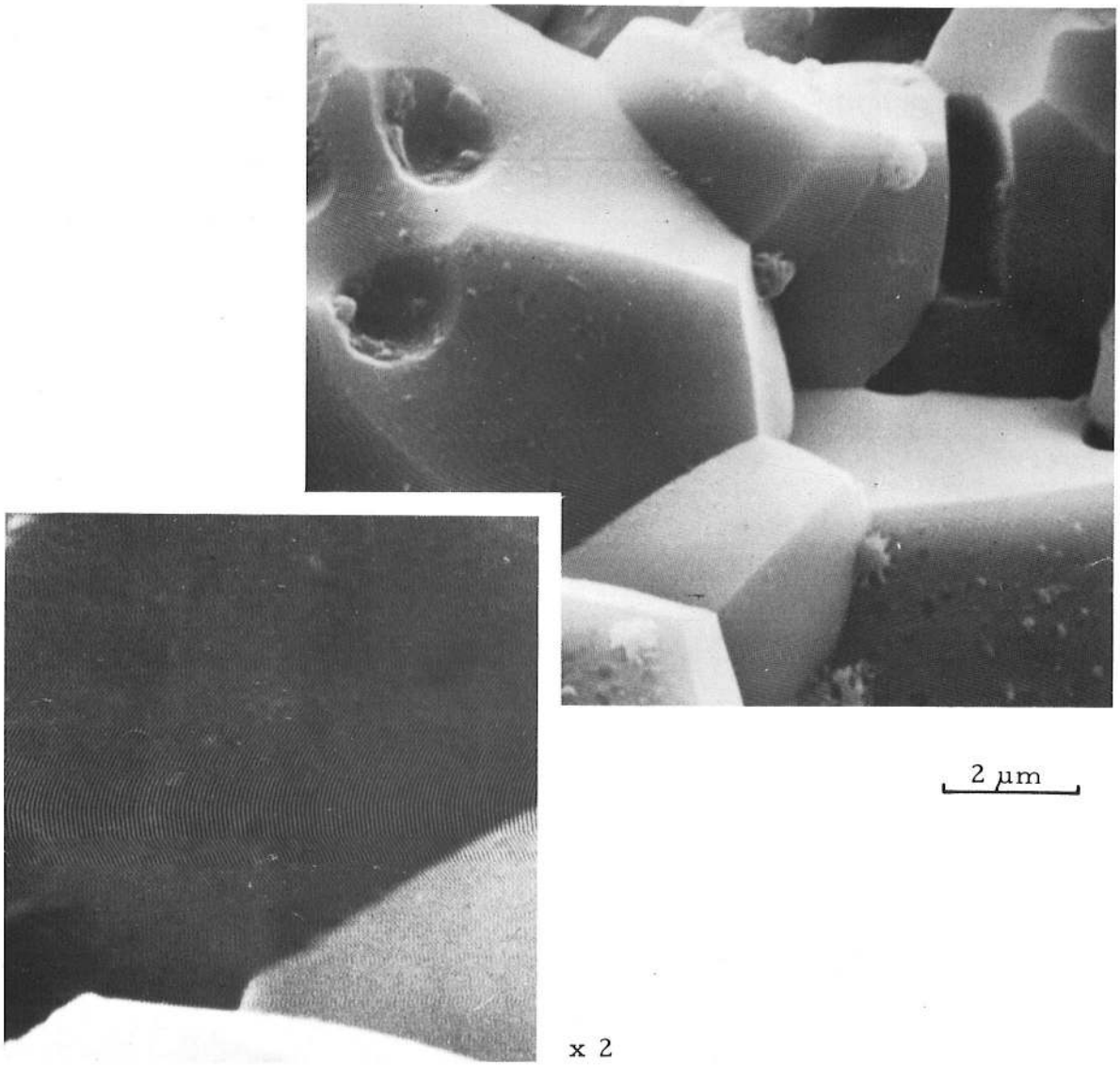


Fig. 19 Effect due to Induction (10 kHz)

Specimen: Mineral

4. DEFICIENCY OF SPECIMENS THEMSELVES

Deficiencies in the course of specimen preparation often occur in biological specimens which require complicated preparation procedures before observation.

These deficiencies can be divided roughly into the following four:

1) Deformation of specimen in the course of treating it

2) Covering specimen with impurities which are not objects of observation

3) Deposit of impurities as a result of specimen preparation

4) Evaporation

For items 1) and 2), refer to Hitachi Technical Data ⟩SEM, Sheet No. 3.

Regarding the deposit of impurities in specimen preparation, crystals of the substances included in a detergent or an anhydrating agent are often deposited onto the specimen surface in the course of drying their tissues. Such a deficiency occurs particularly when alcohol anhydrated by copper sulfate is employed.

5. EVAPORATION

Electrically non-conductive substances as well as materials that are easily affected by heat are observed after evaporating their surfaces with a thin coat of metallic film (about 300 Å). Gold (Au) is generally employed as evaporating material because of the following reasons.

1) Low melting point (1,063°C) and easy evaporation

2) No chemical reaction between heater (tungsten wire) and gold

3) Large secondary emission coefficient

4) Stable evaporating film

Observation Using a TEM

Observation Using an SEM

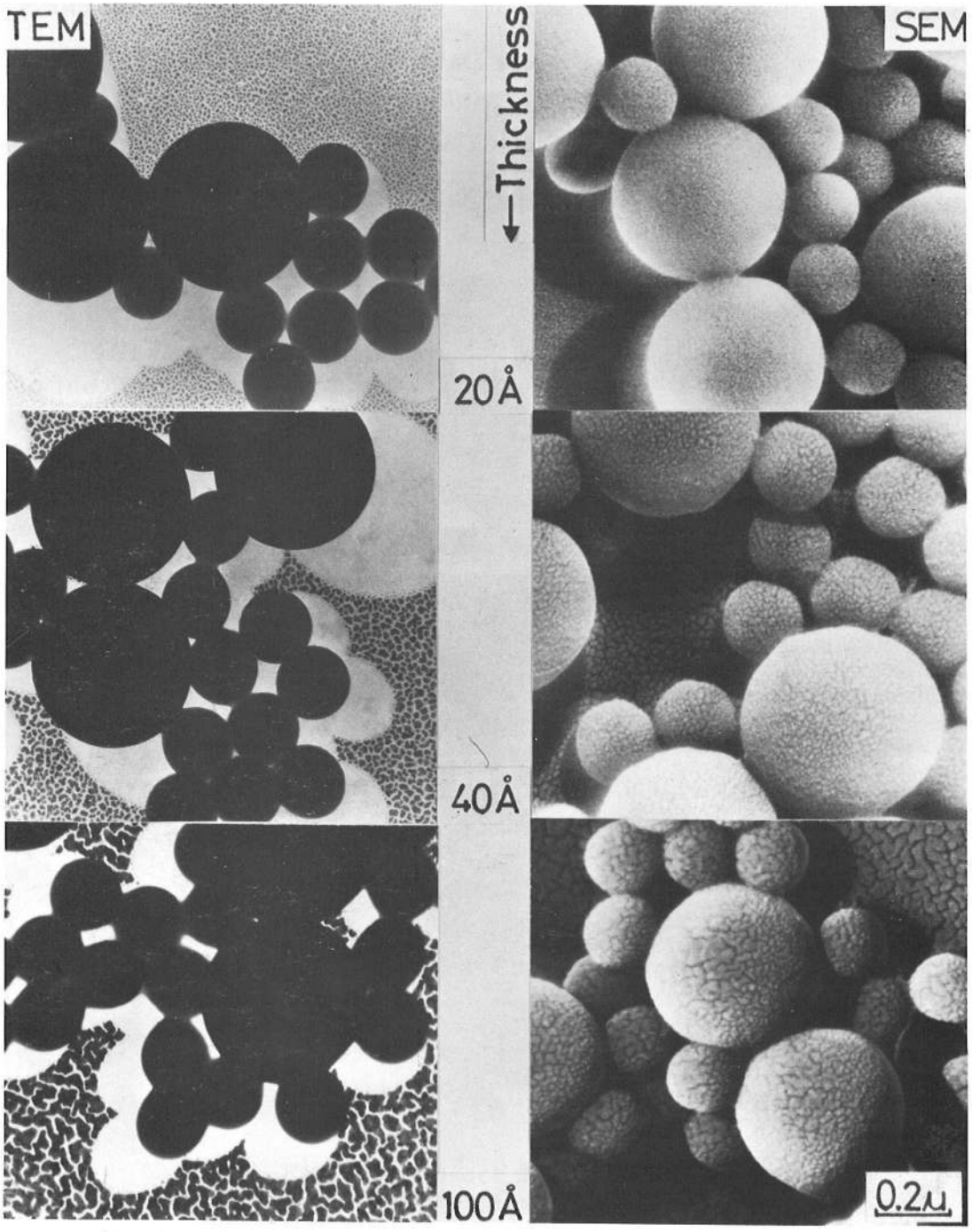


Fig. 20 Change of Particle Image due to Difference of Evaporated Au Film Thickness

Since SEM specimens have topographical surface profiles in general, the gimbal mechanism is employed so as to evaporate the specimens uniformly by turning and tilting them in the course of evaporation. The heating of specimen by means of thermal radiation from the basket during evaporation should be carefully decreased particularly when high polymer materials which are easily affected by heat are evaporated. However, this Au evaporation is not always applicable to all specimens, and comes into question particularly when high resolution images ($\lesssim$ 100 Å) are observed. It should be noted that since the Au evaporation often produces large "island-shaped structure" particles, these structures should not be erroneously judged as the fine structures of specimen surfaces.

The preparation of a fine particle evaporation film has been examined as a high-resolution replica film for TEM (shadowing). In the case of SEM, a fine particle film can be obtained using Au-Pd alloy, Pt-C, etc. Figs. 20 and 21 indicate examples of the change of particle image when changing the gold film thickness evaporated onto latex surfaces, and also examples of the change of particle diameters due to evaporating substances Au, Au-Pd, and Pt-Pd with the evaporating film thickness kept constant.

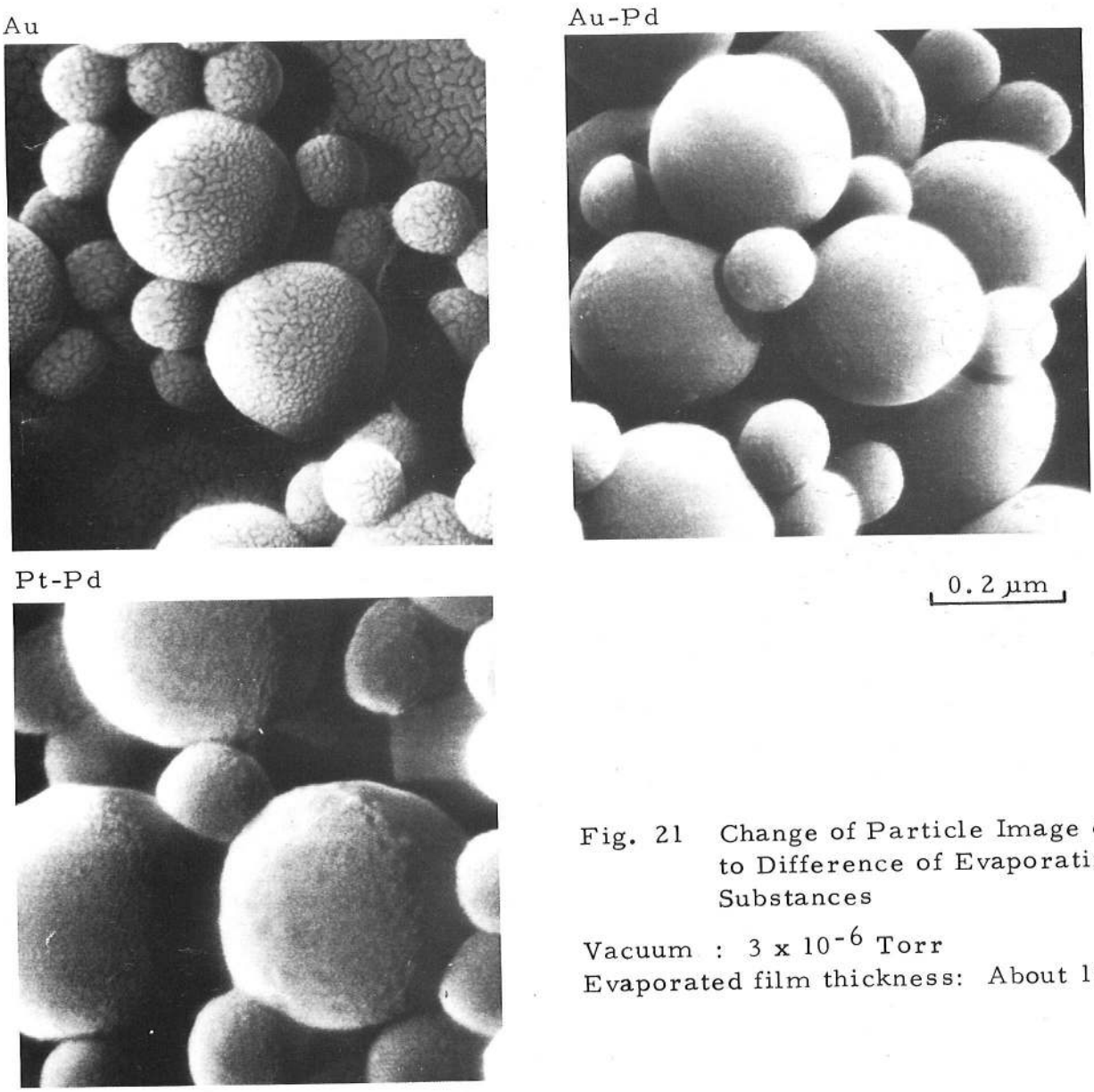


Fig. 21 Change of Particle Image due to Difference of Evaporating Substances

Vacuum : 3×10^{-6} Torr
Evaporated film thickness: About 100 Å