Instruction Manual

for the

MODEL HU-12A
ELECTRON MICROSCOPE

February 1973
N-5256E

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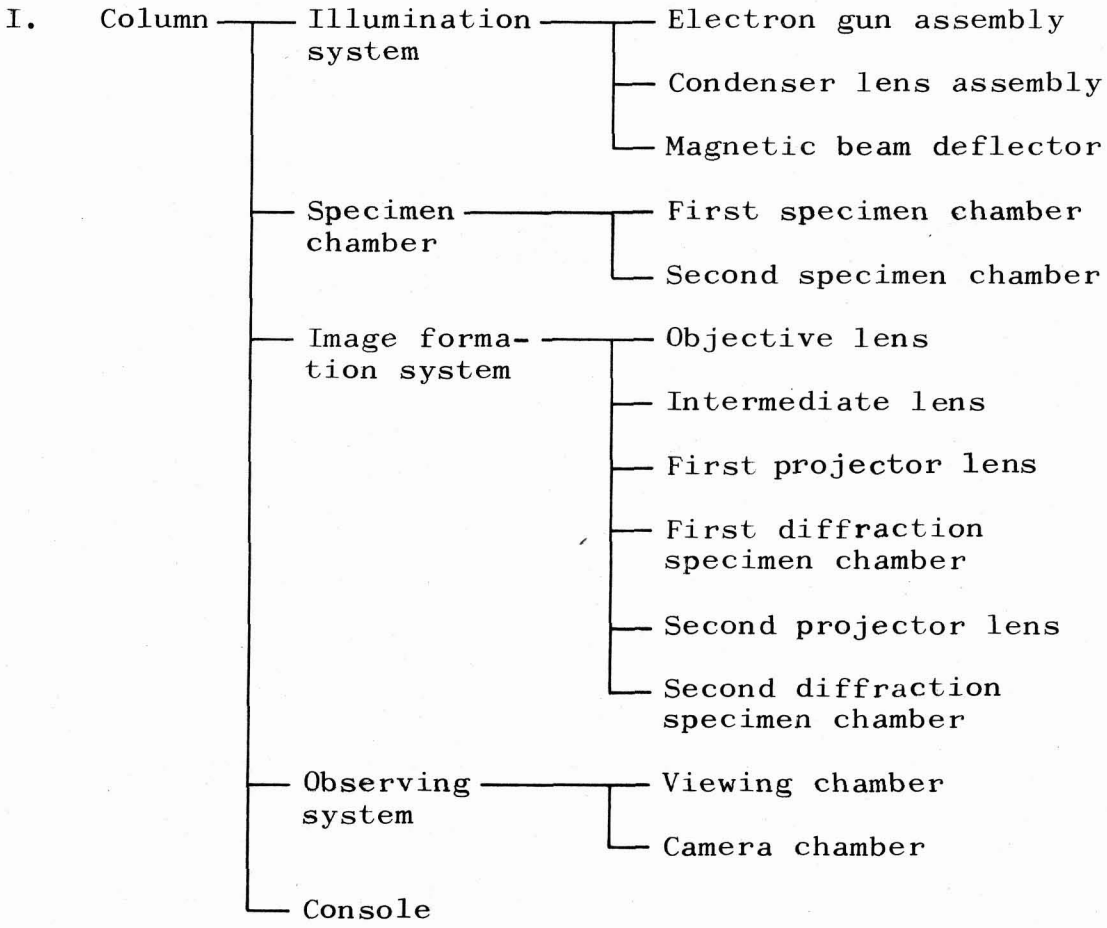
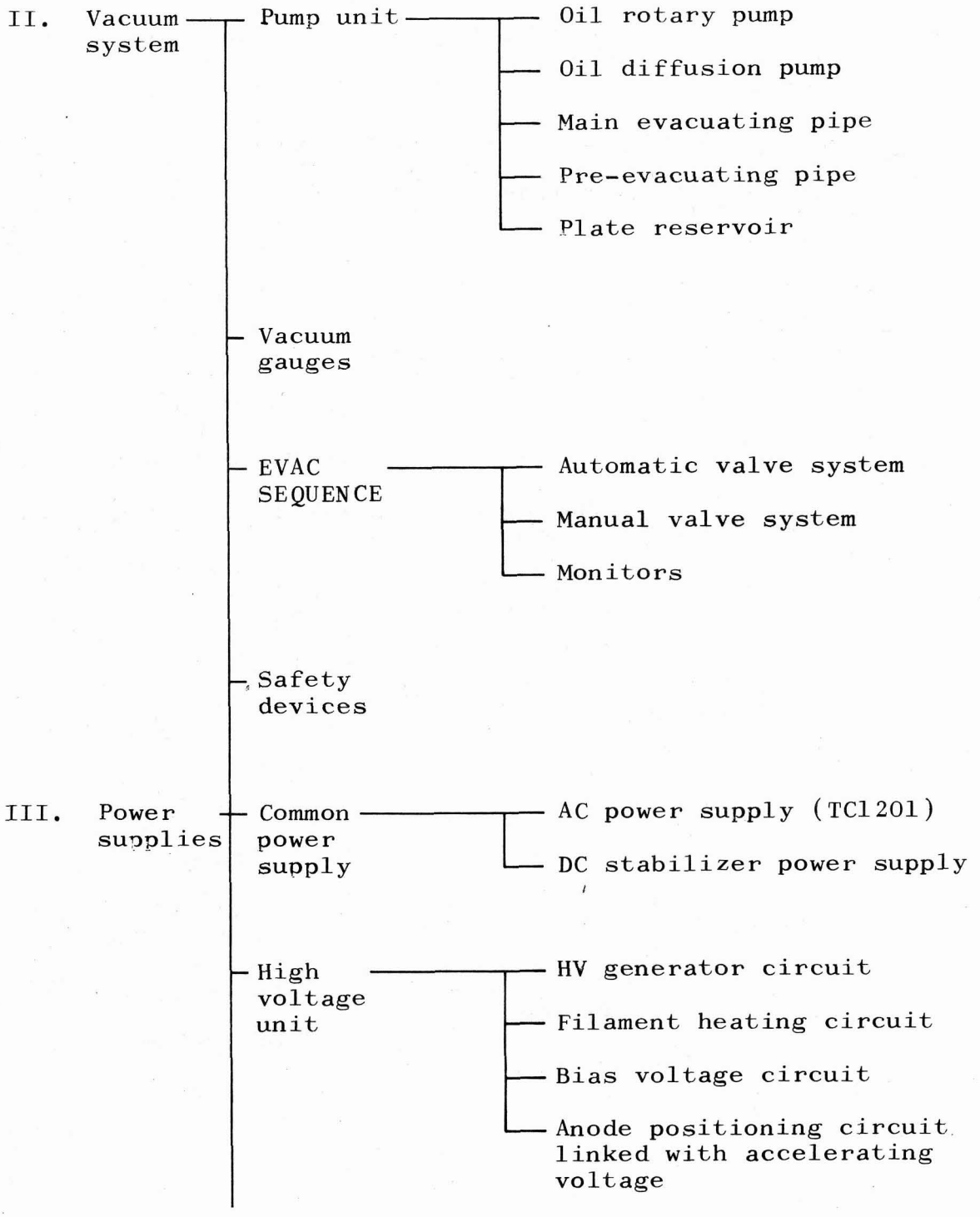
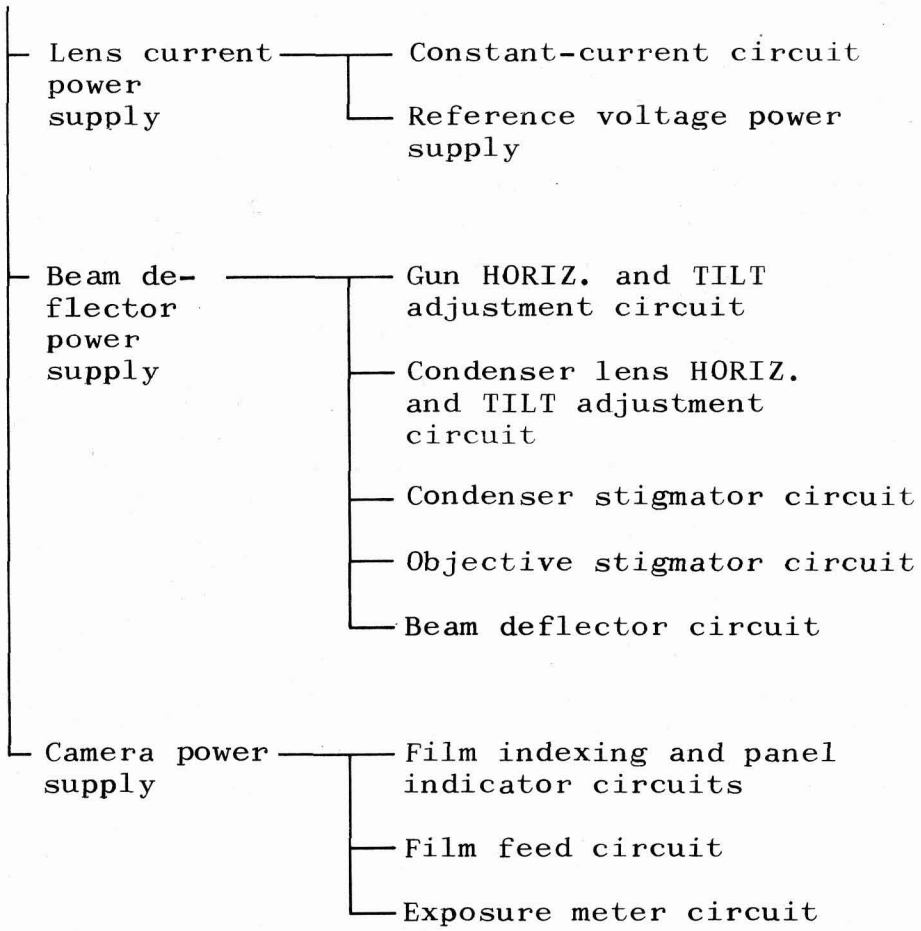
GENERAL DESCRIPTION

The Hitachi Model HU-12A Electron Microscope is composed of three main sections: column; vacuum system; and power supplies.




II. Vacuum system
Pump unit
Oil rotary pump
Oil diffusion pump
Main evacuating pipe
Pre-evacuating pipe
Plate reservoir
Vacuum gauges
EVAC SEQUENCE
Automatic valve system
Manual valve system
Monitors
Safety devices
III. Power supplies
Common power supply
AC power supply (TC1201)
DC stabilizer power supply
High voltage unit
HV generator circuit
Filament heating circuit
Bias voltage circuit
Anode positioning circuit linked with accelerating voltage


Lens current power supply
Constant-current circuit
Reference voltage power supply
Beam deflector power supply
Gun HORIZ. and TILT adjustment circuit
Condenser lens HORIZ. and TILT adjustment circuit
Condenser stigmator circuit
Objective stigmator circuit
Beam deflector circuit
Camera power supply
Film indexing and panel indicator circuits
Film feed circuit
Exposure meter circuit

I. COLUMN CONSTRUCTION

1. COLUMN CONSTRUCTION

Fig. 1-2 shows the general construction of the microscope column.

The component parts of various systems are shown in Figs. 1-3 and 1-4.

I-1 Illumination System

I-1-1 Electron Gun Assembly

The electron gun is the source of electrons in the electron microscope. It is similar to a triode in construction. The gun contains a filament, Wehnelt cylinder, and an anode to accelerate the electrons emitted from the filament.

Fig. 1-5 shows the structure of the electron gun assembly.

The accelerating voltage (10 kV for scanning electron image, 25 kV, 50 kV, 75 kV, 100 kV, and 125 kV) is applied to the cathode assembly through the high voltage cable, which is connected to the high voltage unit.

In the HU-12A Electron Microscope, the height

adjustment of the anode is linked to the accelerating voltage over a wide range of 10 kV to 125 kV. The distance between the anode and Wehnelt cylinder is adjusted automatically with change in accelerating voltage. The "fixed" bias voltage is stabilized with a range of 0 to 1500 V, in addition to the self-bias. The 0 to 1500 V is covered with a continuous control, thus allowing optimum adjustment for pointed filament operation. The gun can be easily opened to exchange the filament (Fig. 1-7). Each filament is precentered so it is not necessary to center it after each exchange. The gun housing is also provided with an airlock device which shuts off the gun housing from the evacuation and lens systems. These features considerably reduce the time required for exchange of the filament. Evacuation is fully automated, and the whole sequence from airlock or air introduction to pumping is performed by one control knob. As the vacuum valves are operated automatically through detection of the vacuum level, there is no fear of misoperation. The electron gun is aligned by tilting or adjusting in traverse the electron beam relative to the first

condenser lens with a two-stage beam deflector (Fig. 1-6).

I-1-2 Condenser Lens Assembly

The condenser lens of the HU-12A Electron Microscope is a double condenser lens system.

Fig. 1-8 is a sectional diagram of the condenser lens assembly.

The construction of this lens utilizes a double magnetic yoke system, which means that the lenses are contained in a magnetic shield cylinder. Magnetic coupling between lenses is reduced to offer freedom from unwanted beam shifts.

The spot size (illuminated area on specimen) is selectable in four steps (2 μ, 5 μ, 10 μ and 15 μ diameter) through control of the first condenser lens current. In addition, if the FINE control is used, any spot size can be obtained within a range of 0.3 μ to 50 μ. If a pointed filament is used, a spot size of 0.1 μ is obtainable.

The second condenser lens is provided with a movable aperture (Fig. 1-9) which has four (4) aperture openings (0.7, 0.5, 0.5, 0.3 mm ϕ) selectable by

click-stop operation.

The brightness of the final image is adjustable by controlling the excitation current of the second condenser lens.

The magnetic stigmator consists of two pairs of rectangular coil type correcting elements (Hitachi patent) built in the second condenser lens pole piece. These elements produce an asymmetrical magnetic field. The asymmetrical magnetic field is superimposed on the magnetic field of the second condenser lens to correct the astigmatism (X, Y system). The astigmatic difference produced by the correcting lens is proportional to the vector sum of the current flowing to each correcting element. The excitation current of the stigmator changes together with acceleration voltage to eliminate the need for readjustment with voltage selection.

I-1-3 Magnetic Beam Deflector

The magnetic beam deflector consists of a coil assembly, an operation panel and a power supply unit. The deflecting coil assembly is located between the second condenser lens and specimen chamber. (Fig. 1-8)

The beam deflector is used to align the whole illumination system to the objective lens. In the HU-12A, it is also used to align the beam spot on the specimen; to superimpose the ac current for wobbler focusing; and to tilt the electron beam in relation to the specimen for dark field observation.

The coil assembly consists of beam tilting and beam centering coils, each having X and Y coils.

The beam tilting coil is a two-stage (upper and lower) coil as illustrated in Fig. 1-12.

The beam is deflected from the optical axis by the upper coil, and is reverse deflected to meet the optical axis on the specimen by means of the lower coil. The beam centering coil is built in the lower stage coil and used to adjust the brightness.

The X and Y coils are excited independently to deflect the beam in any azimuth, the deflection being dependent on the resultant vector of X and Y axes. The excitation currents are supplied from the deflector (for dark field observation), wobbler, and beam centering power supplies respectively.

These power supplies are independent and can be controlled individually. The deflection power supply

for dark field observation contains a special stigmator power supply, so that astigmatism of the beam spot is corrected even at high-angle deflection. This permits quick selection of dark and bright field images.

I-2 Specimen Chamber

I-2-1 First Specimen Chamber

The first specimen chamber is magnetically shielded, and is located between the illumination system and objective lens. Fig. 1-8 shows a cross section of the specimen chamber. The specimen chamber has a window in front and an evacuation manifold on the back. A liquid nitrogen cold trap is built in the evacuation manifold to collect residual organic gases and keep the chamber in clean vacuum.

The specimen exchange device (Fig. 1-10) is attached at the right of the specimen chamber. It functions as the airlock device of the specimen chamber. A safety device is provided so that the exchange device cannot be inserted into the specimen chamber until the chamber is pre-evacuated and attains the required vacuum level. Check if the evacuating

monitor lamp lights before inserting the exchange device. The specimen chamber is pre-evacuated by the EVAC-AIR switch. If another section of the electron microscope is under pre-evacuation, the pre-evacuation of the specimen chamber is given precedence and performed immediately (by means of the sequence monitoring device). The pre-evacuation system returns to the preceding evacuation automatically after the specimen chamber is pre-evacuated. The specimen exchange device (Fig. 1-11) accommodates six specimens simultaneously, and thus permits successive observation of six specimens with only one pre-evacuation.

The specimen stage consists of a specimen holder and control mechanism (Fig. 1-13). In the HU-12A, a specimen rotating device is built into the specimen holder to permit rotation of the visual field during observation.

The objective lens coil is cooled by water. In order to maintain thermal balance, the specimen stage is in contact over a large area with the upper part of the objective lens. A thin phosphor bronze plate is inserted between them to facilitate

movement of the stage. Bending of this phosphor bronze plate, or dust on it, will not only cause movement to become less smooth but will cause the specimen to drift. Maintenance of this section, therefore, requires special care. The specimen stage controls are located on the operation panel.

The specimen position can be read by the graduated scale on the arm. The left side of the specimen chamber is provided with a cover plate which is removed to attach a specimen tilting device or other accessories.

I-2-2 Second Specimen Chamber

The second specimen chamber is located between the objective and the intermediate lens assembly. (Fig. 1-14)

Although the range of magnification change can be increased by adoption of a four-stage lens system, this usually sacrifices the resolution at low magnification. It is extremely difficult to observe a wide area of a specimen without any distortion. This means that to obtain

a very low magnification with a four-stage lens system, all lenses have to be used in weak excitation, which increases the aberrations of the electron lens. A three-stage lens system is thus adopted for the Model HU-12A Electron Microscope, and a second specimen chamber is provided to produce low magnification and wide field image in relatively strong excitation. The second specimen chamber can be provided with an airlock device, and accommodates a six-specimen holder. This specimen holder for very low magnification is available as an optional accessory.

It has built-in specimen movement controls (X-Y) and permits quick exchange of specimens by click-stops. The magnification range with the second specimen chamber holder is from 50X to 3,000X. Since the visual area on the specimen is 2 mm ø, even at the lowest magnification, the large fluorescent screen (190 mm ø) can be filled with an undistorted magnified image. Also, a built-in $\pm 10^{o}$ stereoscopic mechanism permits stereo-photographing.

The second specimen chamber is also provided with a field limiting aperture. The field limiting aperture

has six holes which are selectable by click-stops. This aperture is used in selected area diffraction micrography, or as a contrast aperture in ordinary observation.

I-3 Image Formation System

The HU-12A uses a four-stage lens system, consisting of objective, intermediate, first projector and second projector lenses. The objective lens is used to focus the image, while the other three lenses are for magnification change. Although numerous combinations of the four lenses are possible, the optimum combinations are limited in number.

In the HU-12A, the optimum range is divided into 35 steps. All lens conditions were calculated by computer to minimize astigmatism, field aberrations and chromatic aberrations.

Each lens consists of its own independent magnetic circuit, which is contained in a magnetic shield cylinder to prevent mutual magnetic interference. The magnetic shield also serves as a protection against external stray fields.

In electron microscopes, focus varies with magnification

change, so that the instrument has to be brought into focus each time after magnification change. This is very annoying to the operator, especially when the magnification change is large. In the HU-12A, the problem has been reduced by the unique "Zoom system". It is a centralized lens control system which is interconnected with the focusing mechanism. An in-focus image is thus assured without readjustment at each step of magnification change.

I-3-1 Objective Lens (See Fig. 1-14)

The objective lens is the most important part of an electron microscope. From a practical point of view, aberrations and astigmatism which affect the resolution of the electron microscope are unavoidable parameters of the objective lens. In the Model HU-12A, a block pole piece is adopted for the objective lens and aberrations and astigmatism are minimized through strong lens excitation. In addition, the magnetic circuit is machined for perfect axial symmetry with little leakage flux, thus assuring perfect alignment of voltage and current centers. These features of the HU-12A are not affected by substantial changes of excitation current. The objective lens excitation current is divided

into six (6) ranges. Due to the incorporation of the zoom system, only four (4) of these ranges are needed during normal operation. In actual operation, only fine adjustment of focus is required as coarse adjustments are performed by the zoom system. Focusing is extremely easy because, in addition to this effective system, the difference in focus is emphasized by the image wobbler. The image wobbler of the HU-12A is adjustable in magnitude, and is very useful even at high magnification. The intrinsic astigmatism of the objective lens is below 0.7 μ. To correct this astigmatism, as well as astigmatism due to contamination of the lens and aperture, a stigmator is built into the objective lens.

The objective lens stigmator consists of two pairs of rectangular coils (Hitachi patent). These coils produce asymmetrical magnetic fields, which are superimposed over the magnetic field of the objective lens to compensate the astigmatism (X, Y system).

The astigmatism correction is done by the OBJ. STIGM-X, Y control knob on the left subpanel. Since an electrical centering device is built into the objective stigmator,

there is almost no image shift during astigmatism correction. The objective lens is provided with a movable aperture which has four holes of 20, 30, 50 and 70 μ in diameter.
(Fig. 1-15)
These apertures are easily and freely selectable by click-stops. The aperture plate is thin molybdenum and has an extremely low contamination rate.
The second specimen chamber is provided with a field limiting aperture (Fig. 1-16) of click-stop type. It is used for field limiting in selected area electron diffraction. The six apertures of 0.05, 0.1, 0.2, 0.5, 1 and 2 mm in diameter can be selected according to specimen sizes and magnification. The field limiting aperture can be used to eliminate the scattered electron beam for contrast enhancement. When the field limiting aperture is used as a contrast aperture, the smallest opening that will not limit the final image on the screen is used (this aperture size varies with magnification).
A liquid nitrogen trap and water cooling baffle for the oil diffusion pump are provided in the vacuum system to reduce back-streaming of oil vapor. Although

most contaminants are eliminated by these traps, a cold finger (Fig. 1-17) is also provided to further reduce contamination and this is used for specimens which are highly susceptible to contamination.
The cold finger is inserted in the objective lens assembly and placed near the specimen. When cooled by liquid nitrogen, the tip of the cold finger is kept below -170° C.
This is cold enough to prevent contamination completely. The cold finger can be used for more than three hours with one filling of liquid nitrogen.

I-3-2 Intermediate Lens (See Fig. 1-18)

The intermediate lens projects a magnified image produced by the objective lens onto the objective plane of the projector lens. The magnification of the intermediate lens is changed by varying the excitation current. The intermediate lens is used for camera length control in selected area diffraction.
As mentioned previously (see 1-2-2), the intermediate lens is also used as the objective lens in low-magnification/wide-field observation. The intermediate lens itself forms an independent magnetic circuit,

which is built into a magnetic shield cylinder for protection against magnetic interference. Also, it can be aligned with the objective lens (although this alignment is normally not performed by the customer).

I-3-3 First Projector Lens (See Fig. 1-18)

In addition to magnification change, the first projector lens is used for camera length control in selected area diffraction. As mentioned in Section 1-2-2, it is also used as the intermediate lens for magnification change in low-magnification/wide-field observation. Like other lenses, the first projection lens forms an independent magnetic circuit built into a magnetic shield cylinder and is free from magnetic interference. There is a provision for aligning the first projector lens with the objective lens (as with the intermediate lens, this alignment is performed very infrequently).

I-3-4 First Diffraction Specimen Chamber (Fig. 1-18)

The first diffraction specimen chamber is placed between the first and second projector lenses. The specimen chamber is provided with a window in front and an auto shutter (slide system driven by

air pressure) at the back. The left and right sides of the chamber are provided with ports which are used for attachment of various electron diffraction specimen holders or airlock devices (optional accessories).

This diffraction specimen chamber permits high resolution diffraction and reflection diffraction work (heating and cooling is possible) by utilizing the microbeam spot produced by the lens system above the first projector lens.

The fixed camera length is 505 mm, with the resolution index 1×10^{-6}. These features are quite comparable with those of specialized instruments for diffraction work. Moreover, camera length can be extended to 2 m (maximum) if the second projector lens is located just below the first diffraction specimen chamber. This is especially useful in high dispersion electron diffraction or in electron diffraction of polymers that have wide lattice spacings.

I-3-5 Second Projector Lens (See Fig. 1-19)

The second projector lens is the final lens in the microscope. It is used for electron diffraction with

the second specimen chamber and for camera length control in high dispersion electron diffraction.

The second projector lens is an independent magnetic circuit built into a magnetic shield cylinder. Like other magnetic circuits, it is completely free of magnetic interference. This lens also permits alignment of the objective lens. (As in the case of the intermediate lens, alignment is seldom necessary.)

I-3-6 Second Diffraction Specimen Chamber

The second diffraction specimen chamber is located between the second projector lens and the viewing chamber (Fig. 1-19). The chamber is provided with a front window. A covered port is provided at both the right and left. Various specimen holders for electron diffraction work can be used if the port cover is taken off.

The second diffraction specimen chamber enables high resolution and reflected electron diffraction (heating and cooling possible). The fixed camera length is 395 mm and the resolution index 1×10^{-6}, which may be compared quite favorably with those of special instruments for diffraction work.

I-4 Observing System

I-4-1 Viewing Chamber

Fig. 1-20 shows a section of the viewing chamber. The viewing chamber has three large windows on three sides for simultaneous observation by several persons (panoramic viewing system).

The magnification of the binocular viewer for focusing is 7X, and its visual field is 30 mm ϕ. The outer main fluorescent screen is 190 mm in diameter and accommodates an inner main screen (120 mm ϕ) in the center. The inner main screen serves as the shutter, as well as a viewing screen. The fluorescent screen for focusing is 40 mm in diameter and can optionally be moved inside or outside the electron beam path by the left-side lever.

It is always positioned at a right angle to the binocular viewer in the electron beam path. This fluorescent screen also serves as the beam detector of the exposure meter. The fluorescent screen for axial alignment is 40 mm in diameter and protects the main screen from damage by strong beam irradiation during axial alignment. This screen is usually not on the electron beam path but easily set to the beam

path by the knob on the left upper part of the viewing chamber when axial alignment is done.

Remarks: Never fail to take the fluorescent screen for axial alignment out of the electron beam path after completion of axial alignment, otherwise the main fluorescent screen may be damaged.

As the exposure meter detector, the focusing fluorescent screen is used so that the electron beam irradiating the fluorescent screen is indicated on the exposure meter in combination with the exposure meter timer.

(Coulometric indication: Electron beam intensity x timer setting.)

When the focusing fluorescent screen is positioned on the electron beam path (when the shutter is closed), the beam intensity is indicated by the meter. When the shutter lever is opened, the shutter timer operates. The auto shutter is linked with the shutter lever and shuts off the electron beam as the lever is tilted and exposes the film when the shutter lever is lifted fully. The exposure time of the auto shutter is selectable in 7 steps; 0.5, 1, 2, 4, 8, 16, and 32

seconds. The timer is set to an appropriate value so as to shut off the electron beam automatically for optimum exposure.

After the exposed film is marked with photographic data, it is automatically advanced.

1-4-2 Camera Chamber

Fig. 1-22 shows an outer view of the camera chamber. It consists of the airlock device (driven by pneumatic pressure) for vacuum isolation with the column, film feed mechanism (motor-driven), film marking device, exposure size selector, and film exchange device. The film is fed from the plate cassette to the exposure position by push-button operation, and a new film is fed after photographing by the automated mechanism linked with shutter. The entire sequence including exposure, film marking, and feeding is automatic and the possibility of double exposure is eliminated.

The exposure sizes are 75 mm x 90 mm (full size) and 50 mm x 70 mm (half size). Either is selectable simply by air leak of the camera chamber. Set the FULL-HALF selector switch on the left side of the camera

chamber front to the desired size. When the full size is selected, push the mask selector knob in the camera chamber until it reaches the stopper. When the half size is selected, pull the mask selector knob toward you until the stopper operates.

Remarks: Never fail to change the mask by manipulating the mask selector knob when the FULL-HALF selector switch is changed over.

The exposed film is marked with film number, accelerating voltage, lens conditions and magnification.

The evacuation of the camera chamber .... airlock, air introduction, pre-evacuation, column evacuation..... is controlled simply by one control knob. The evacuating system is fully automatic and controlled by the vacuum level, so is protected from misoperation.

I-5 Console

I-5-1 Console

The console of the HU-12A is composed of three sections: one for supporting the column and the other two for supporting the table and operation panels of the electric system. Thus, the operation panels and table are completely separated from the column so

that no vibration is transmitted to the column.

I-5-2 Table and Operation Panels

The table and operation panels consisting of the main operation and indicator panels are separated from the column.

The knobs relating to adjustment and special operation are conveniently placed on the subpanels, lens unit, and BD unit within easy reach of the operator. Fig. 1-22 shows these operation knobs.

Left indicator panel (LIP)

Beam current meter (BEAM CURRENT)	(1)
Film counters (UNEXPOSED FILM, FILM NO.)	(2) (3)
Film position pilot lamps (STAND BY, EXPOSE)	(4) (5)
HV pilot lamp (HV)	(6)
Lens condition pilot lamp (MODE)	(7)
Magnification indicator (MAGNIFICATION)	(8)

Left main panel (LMP)

Filament current control (FILAMENT)	(16)
Bias voltage adjusting knob (BIAS)	(17)
HV reset switch (HV RESET)	(18)

Voltage module switch (HV MODUL) (19)

HV selector switch (HV) (20)

Camera length selector (CAMERA LENGTH) (25)

Magnification control (MAGNIFICATION) (27)

Brightness control (C-2) (BRIGHTNESS) (32)

Mode selector switches (DIFF. SA. SCAN. ZOOM) (21) (22) (23) (24)

Focus adjusting knob for selected area diffraction and very low magnification (SELECTED AREA) (26)

Lens condition selector switches (RESOL. CONTR. STD. ACC) (28) (29)

Wobbler switch and amplitude adjusting knobs (WOBBLER) (30) (31)

Left subpanel (LSP)

Gun tilt control (GUN TILT) (41)

Gun horiz. control (GUN HORIZ) (42)

Spot size selector knob (SPOT SIZE) (43)

Current center alignment knob (OBJ. MODUL) (44)

Objective stigmator (OBJ. STIGM) (45) (46) (47)

Right indicator panel (RIP)

Exposure meter timer adjust knob (EXPOSE. TIME) (9)

Exposure pilot lamp (EXPOSING) (11)

Vacuum gauge selector knob (EXPOS. COL. COL R.P) (13)

Exposure and vacuum meter (EXPOSURE & VACUUM) (12)

Vacuum system operation pilot lamp (LINE, WARM UP, LOW, HIGH) (14)

Vacuum sequence pilot lamp (VACUUM SEQUENCE) (15)

Film feed ON/OFF switch (FEED STOP) (10)

Right main panel (RMP)

Film feed switch (FILM FEED) (33)

Focusing control (OBJ-FINE. MEDIUM. COARSE) (35) (36) (37)

Brightness centering knob (BRIGHTNESS CENTERING) (38)

Specimen chamber valve switch (SPECIMEN CHAMBER) (34)

Lighting switches (PANEL, ROOM) (lighting) (39) (40)

Right subpanel (RSP)

Condenser stigmator (COND. STIGM) (48) (49)

Beam tilt control (BEAM TILT) (50)

Condenser stigmator for dark field observation (COND. STIGM) (52)

Bright/dark field selector switch (BRIGHT DARK) (51)

Beam tilt control for dark field observation (BEAM TILT) (53)

Brightness centering control for dark-field (BRIGHTNESS) (54)

Vacuum system main switch (MAIN SW-EVAC) (55)

Stabilizer power switch (MAIN SW-COL) (56)

Column evacuating system switch (COLUMN EVAC-EVAC. CLOSE. AIR) (57) (58) (59)

Lens unit (left console)

Lens current selector switch (STD. ACC) (60)

Lens current switches (C1, C2, OBJ, INT. P1, P2) (61) (62) (63) (64) (65) (66)

Mode selector switch (FREE, NORMAL) (67)

Objective lens function selector switch (OBJ) (68)

Condenser lens current control (69)

Objective lens current control (70)

Intermediate lens current control (71)

First projector lens current control (72)

Second projector lens current control (73)

Magnetic beam deflector (BD) unit (right console)

Scan positioning knob (74) (75)

II. CONSTRUCTION OF VACUUM SYSTEM

II. CONSTRUCTION OF VACUUM SYSTEM

The most important requirement in designing a vacuum system for an electron microscope is that a "clean vacuum" containing few hydrocarbon molecules be obtained. This allows the formation of clear high-quality images of specimens. In addition, the vacuum system must be simple to operate and not too susceptible to misoperation or damage in the event of power or water supply failure. The operation of the vacuum system in the Model HU-12A is fully automatic with numerous safety devices, and special effort has been made to improve the ultimate vacuum and to increase the pumping speed. Figs. 2-1 and 2-2 show the construction of the vacuum system, which is composed mainly of the pump unit, operation panels, evacuating system sequence circuit, and vacuum gauges.

II-1 Pump Unit

Figs. 2-3 and 2-4 show the pump unit.

The vacuum system of the HU-12A consists of main evacuation and pre-evacuation systems. The main evacuation system contains a 4" oil diffusion pump (DP), buffer tank (BT), and 100 ℓ/min oil rotary pump (RP-1). The pre-evacuation system is a 100 ℓ/min. oil rotary

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2 x

pump (RP-1), which pre-evacuates the gun housing, specimen chamber, camera chamber, and plate reservoir (PR). The DP-1 of the main evacuation system is to obtain a high vacuum. Above the DP-1 is a water cooling baffle which prevents any back-streaming of oil vapor from the DP-1. Also, a cold trap (Hitachi patent) is installed at the junction of the main evacuation pipe and the specimen chamber evacuation pipe, to prevent contamination of the specimen and gun electrodes.

Pneumatic valves (MV-2 ~ MN-7, AV-1 ~ AV-3, GV, CV) are used in the vacuum system and electromagnetic valves are used as air inlet valves MVL-1 ~ MVL-7. These valves are designed to close when the power supply is turned off. Should the power supply fail, therefore, all the valves are closed automatically to safeguard the instrument. The main evacuating pipe is made of 3" stainless steel, and designed to evacuate the gun housing, specimen chamber, image formation system, and viewing chamber efficiently without impairing the pumping speed of DP (400 ℓ/sec.)

P12,32

The Pirani gauges are attached to the main evacuating and pre-evacuating pipes, and a Penning gauge is

installed onto the main evacuating pipe. A thermostat switch (T.S) is mounted onto the heater of DP to check the operating range of DP.

II-2 EVAC. SEQUENCE

The evacuation section of the electron microscope is divided into gun housing, lens system (including the viewing chamber), specimen chamber, camera chamber, and plate reservoir. Each of these sub-systems requires pre- and main evacuation. The EVAC. SEQUENCE circuit is designed to perform the complex evacuating operation efficiently and automatically.

In addition, this circuit contains a safety circuit for the accelerating voltage. A manual control circuit allows operation of the vacuum system in the event that the automatic evacuation control circuit fails. The manual system facilitates troubleshooting of the SEQUENCE circuit. Fig. 2-5 shows the EVAC. SEQUENCE board which is located in the right console. The board contains a relay and a timer circuit. Switches are provided for manual control of the vacuum system, and a display panel indicates the operating mode of all vacuum system components.

Fig. 2-6 shows the sequence flow chart and Fig. 2-7 the circuit diagram.

II-3 Safety Devices

II-3-1 Water Failure

In the event that the cooling water for DP is shut down, the water pressure switch is actuated. This turns the valve operation circuit of SEQUENCE off, and turns on an alarm.

II-3-2 Power Failure

The valves used in the vacuum system are all pneumatically operated and have a very rapid response, and are designed to close on failure of the power supply. During power interruption, the 8-1 buffer tank prevents back-streaming of oil vapor. When the power supply is restored, the pressure of the compressor, vacuum levels in various parts of the instrument, temperature of DP heater, etc., are detected, and the valves are opened or closed according to the appropriate sequence. This control system is also in operation during startup of the instrument.

II-3-3 Vacuum Failure

An increase of pressure during operation due to some failure or misoperation is detected by the Penning and Pirani gauges. The safety circuit then operates so that the accelerating voltage is turned off and the main valve is closed to prevent deterioration and back-streaming of DP oil. If an air leak occurs in the manifolds, vacuum chambers, or vacuum seals during pre-evacuation, the sequence will not proceed to the next step. The failure is monitored by flickering of the EVAC. SEQUENCE pilot lamps (Fig. 2-4).

II-3-4 Failure of DP Heater

If the power to the DP heater fails, the temperature change is detected by the thermal switch (TS), and the sequence is prevented from proceeding beyond pre-evacuation. The failure of the DP heater is easily detected as the WARM UP pilot lamp remains lighted.

II-3-5 Failure of Compressor

If the pressure of the compressed air for the vacuum valves remains below 2.5 kg/cm^2 due to failure of the

compressor or an air leak in the air pipe, the air pressure switch operates to turn off the valve power supply.

II-3-6 Circuits to Prevent Misoperation

(1) Pre-evacuation Priority Sequence

A priority sequence is programmed in the sequence circuit for pre-evacuation of various vacuum chambers including the column (the priority differs depending on the state of the DP heater). Any operation not in conformity with the priority sequence is halted. Hence the evacuation sequence does not proceed without the following operation.

(i) During DP warmup (i.e., thermostat "ON")
Specimen Chamber > Column Gun Housing,
Camera Chamber Plate Reservoir

(ii) After DP warmup (i.e., thermostat "OFF")

(ii) Specimen Chamber, Column > Gun Housing,
Camera Chamber > Plate Reservoir

(iii) For gun housing pre-evacuation, the closure of GV and AV-2 is checked by a microswitch (GV-L) before the valve (MV-4)

is opened.

(iv) For camera chamber pre-evacuation the circuit is built in such a way that closure of CV and AV-3, as well as of the camera chamber door, is checked by microswitch CV-L prior to the opening of the pre-evacuation valve.

(v) For specimen chamber pre-evacuation, the insertion of the specimen exchange holder, and the airlock of the specimen chamber are checked by the microswitch (SV-L).

(vi) The thermal switch (TS-HIGH TEMP) is provided for preventing the oil diffusion pump (DP) from being overheated. If the DP is heated above 250^{o} C, a switch is operated, which shuts the heater off and closes the main valve (AV-1).

(vii) The Penning gauge is easily contaminated in a poor vacuum. To avoid this, the power source for the Penning gauge is turned on after the main valve (AV-1) opens and a high vacuum is attained.

(2) Main evacuation

(i) The main valve (AV-1) opens only with the column vacuum at 1 x 10^{-1} Torr or better, the DP warmed up, and the thermostat turned off.

(ii) Valves GV, AV-2, CV, AV-3, and SV in the gun housing, camera chamber, and specimen chamber open only when pre-evacuation valves MV-4, MV-6, and MV-5 are opened and vacuum level (Pl-2) reaches 7 x 10^{-2} Torr or higher.

(3) Air introduction

(i) To introduce air into the column, air leak valves MVL-3, MVL-4, MVL-6 open 3 seconds after the column, gun housing, and camera chamber vacuum valves are all closed by depressing the AIR pushbutton of COLUMN EVAC.

This protects valves GV, AV-2, CV, and AV-3 connecting the column, gun housing, and camera chamber against back pressure.

(ii) To introduce air into the gun housing, set the GUN EVAC knob at the right upper part of the vacuum system head to AIR, and air

leak valve MVL-4 opens 3 seconds after the closure of valves GV and AV-2 is checked by microswitch GV-L.

(iii) To introduce air into the camera chamber, set the CAMERA EVAC knob to AIR, and air leak valve MVL-6 operates 3 seconds after the closure of valves CV and AV-3 is checked.

(iv) To introduce air into the plate reservoir, turn the switch to AIR, and the air leak valve MV-7 opens 3 seconds after the closure of vacuum valve MV-7.

II-3-7 Manual Operation (MANUAL)

Each valve works in manual operation as follows:

MV-3	Time lag 1 sec
MV-4	Time lag 1 sec
MV-5	Opens while MVL-5 is closed, time lag 1 sec.
MV-7	Opens while MVL-7 is closed, time lag 1 sec
AV-1	Opens when the switch is turned on.

GV, AV-2	Time lag 3 sec.
CV, AV-3	Opens when the switch is turned on.
MVL-3	Opens while AV-1 is closed, time lag 3 sec
MVL-4	Opens while GV and AV-2 are closed, time lag 3 sec.
MVL-5	Opens while MV-5 is closed. Opens only when SV-L switch operates.
MVL-6	Opens while CV and AV-3 are closed, time lag 3 sec.
MVL-7	Opens while MV-7 is closed, time lag 3 sec.
DP heater	Turned on when cooling water pressure is appropriate.

III. ELECTRONICS

III. ELECTRONICS

The electronics of the HU-12A can be divided into the common power supply, high voltage unit, lens current power supply, beam deflector current power supplies, and camera power supply. They are, for the most part, composed of printed-circuit boards. Fig. 3-1 shows a general block diagram of the electric system.

III-1 Common Power Supply

The common power supply consists of AC power supply (TC1201) unit and DC stabilized power unit.

The TC1201 unit feeds AC current to each system while the DC stabilized power unit feeds DC current.

DC power supplies are as follows:

Voltage	Current	Use
+40 V	2.5 A	HV power unit
±15 V	0.5 A	HV power unit
+50 V	16 A	Lens power supply
-15 V	0.5 A	Lens power supply
±15 V	16 A	Beam deflector power supply
+24 V	7.5 A	Relay power supply
		Lamp power supply

III-2 High Voltage Unit

The high voltage unit consists of the following four circuits.

1. HV generator circuit (Cockcroft-Walton circuit)
2. Filament heating circuit
3. Bias voltage circuit
4. Anode positioning circuit linked with accelerating voltage

These circuits are shown schematically in Fig. 3-2.

In the HV generator circuit, the DC input is converted into a high frequency signal through the high frequency inverter driven by the oscillator and then boosted and rectified.

The output is detected by the detector circuit and balanced with the reference voltage. The error component thus obtained is amplified by the feedback amplifier to control the DC input to the inverter so that the high voltage is stabilized.

In the filament and bias circuits, the DC input is converted into a high frequency signal through the high frequency inverter driven by the oscillator and is fed to the rectifier circuit via the insulating transformer.

Their performance is described below with reference to the operation of the electron microscope. (See Figs. 1-22-1 and 1-22-2)

i) For safety, the following two conditions are to be met when applying accelerating voltage to the electron gun.

   a) The column vacuum must be better than 5×10^{-4} Torr as measured by the Penning gauge.

   b) The high voltage must be applied with a beam current of 225 μA or lower as indicated by the HV beam current meter.

   The high voltage circuit is turned off if, for example, the surge current due to discharge exceeds this limit. The accelerating voltage set on the HV selector knob (20) is applied to the electron gun only when these two conditions are met.

ii) Set the HV selector knob (20) to 25 kV and then depress the HV RESET button (18). Since the HV reset button (18) is turned off once the high voltage is turned off, repeat this operation.

iii) The filament heating circuit is turned on with the filament current control (20) set to "F",

and is adjustable by the filament current control (16). Its maximum voltage is DC 2.5 V when the filament resistance is 1 Ω.

iv) The bias voltage is adjusted by the BIAS voltage adjusting knob (17). The adjustable range is 50 to 1200 V with the self-bias and fixed bias voltages combined.

v) The HV selector knob (20) has 11 notches, with which accelerating voltage is selectable in 5 steps; 25 kV, 50 kV, 75 kV, 100 kV, and 125 kV. Each accelerating voltage step has two settings, one being used for voltage imposition only and the other for voltage imposition plus filament heating. The bias voltage is always imposed while the accelerating voltage is applied.
The accelerating voltage of 10 kV is used for observing scanning electron images (optional attachment). When applying 10 kV, set the 10 kV - 25 kV selector switch in the lens unit (left console) to 10 kV.
The anode driving is done by the HV selector knob (20) and linked with the accelerating voltage.
It is adjustable in two steps; 0, 25, 75 kV and

100, 125 kV.

vi) When the accelerating voltage is reduced from 100 kV to 75 kV, a temporary dark current may flow the instant the anode shifts from the 100/125 kV position to 50/75 kV position.

vii) The BEAM CURRENT meter (1) on the left indicator panel indicates the sum of the output current of the accelerating voltage circuit and detecting resistor current.

viii) An AC voltage of 2 Hz can be superimposed on the accelerating voltage for axial alignment of the voltage center of the electron optical system. This is turned on or off by the HV MODUL switch (19).

ix) The HV RESET switch (18) is used when the accelerating voltage circuit is shut down by the safety device in the high voltage circuit. However, always check the vacuum level before depressing the HV RESET button.

x) The fuses for the high voltage unit are as follows:

Part No.	Capacity	Use
CT181 F3	3 A	+24 V COL
CT181 F4	1 A	+24 V COL switch

xi) The imposition of the accelerating voltage is indicated by the BEAM CURRENT meter (1) and HV pilot lamp (6) on the left indicator panel. When the pilot lamp (6) lights, the accelerating voltage is imposed on the electron gun. BEAM CURRENT meter (1) indicates the accelerating voltage plus the beam current. Therefore, when reading the beam current, subtract the accelerating voltage value from the meter reading. Meter (1) is graduated every 5 μA.

III-3 Lens Current Power Supply

The lens current power supply consists of the following six systems.

1. First condenser lens (C1)
2. Second condenser lens (C2)
3. Objective lens (OBJ)

4. Intermediate lens (INT)

5. First projector lens (P1)

6. Second projector lens (P2)

The lens current power supply is composed of the lens printed-circuit boards comprising built-in amplifiers for 6 systems and heat sink with transistors.

These circuits are shown schematically in Fig. 3-3, and are explained below with special reference to the operation of the HU-12A (see Figs. 1-22-2 and 1-22-6).

i) These circuits supply highly stabilized currents of 0 to 4A to the excitation coils of the electron lenses. The current value for each coil is determined by the composition of the electron optical system of the electron microscope, which has five functions. Each of the five functions is divided further depending on requirements.

Table 1

Function	Number of Steps	
1 ZOOM	RESOL STD Magnification x 35	OBJ step focusing
2	ACC Magnification x 35	

3		CONTR STD	Magnification	x 35	OBJ step focusing
4	SEL AREA	RESOL STD	Magnification	x 20	INT continuous (SA focusing)
5		ACC	Magnification	x 20	INT continuous (SA focusing)
6		CONTR STD	Magnification	x 20	INT continuous (SA focusing)
7	SCAN		Magnification	x 1	
8	DIFF		Camera Length	x 5	INT continuous (diffraction spot)
9	FREE		OBJ. I, P1, P2 Continuous C1: 4 steps C2: continuous		

In the ZOOM function for example, magnification is divided into 35 steps, while in SELECTED AREA it is divided into 20 steps. In the function of DIFF, camera length is divided into 5 steps. The lens currents of these six systems are set respectively to satisfy these functions. In Fig. 3-3, "Mode Selector and Current Program" is the block where the settings of these currents are

performed. The lens current power supply circuits of six systems are controlled by each current stabilizer, and their currents are set to the normal values through a high-accuracy reference voltage.

ii) AC Line Power Supply

The AC power is supplied through the knife switch (SW011) and COL switch (56) in the common power supply and also through the bimetal contact which is turned off when the cooling fan for the control transistors of the heat sink is heated above 40^{o} C.

iii) Check Terminal

The check terminal of the lens current power supply is built in the printed-circuit board and is used for monitoring the terminal voltage of each detecting resistor of the constant-current circuit and IC drive power supply ($\pm$15 V) of the six systems.

iv) OBJ. MODUL (44)

An oscillator is inserted into the reference voltage branch of the objective lens current circuit in order to superimpose a ripple current

of 2 Hz for alignment of the current center.

v) Fuses

The fuses relating to the lens current power supply are located on the left distributor (CT501) in the left operation panel.

F1	5A	COND. 1
F2	5A	COND. 2
F3	5A	OBJ.
F4	5A	INT.
F5	5A	PROJ. 1
F6	5A	PROJ. 2

vi) Function Pilot Lamp (7)

The nine functions of the lens shown in Table 2 are selected by the function selector switches (21) - (24) and lens condition selector switches (28) and (29). These conditions are displayed by the pilot lamps as shown in Table 2.

Table 2

Function selector switch		Lens condition selector switch		Pilot lamp display
1	ZOOM	RESOL	STD	RESOL
2			ACC	ACC
3		CONTR	STD	CONTR
4	SA	RESOL	STD	SA RESOL
5			ACC	SA ACC
6		CONTR	STD	SA CONTR
7	SCAN			
8	DIFF			

III-4 Beam Deflector Power Supplies

The beam deflector power supplies are comprised of the beam deflector and stigmator power supplies. These supply power for: (See Figs. 1-22-3, 1-22-5 and 1-22-6).

1. Gun HORIZ. and TILT adjustments
2. Brightness HORIZ, and TILT adjustments
3. Condenser lens stigmator
4. Objective lens stigmator

i) Fig. 3-4 is a block diagram which illustrates the operation of the beam deflector power supply. The traverse and tilt deflecting coils are connected respectively to the stabilizers using power ICs of X and Y systems, which permit reversing the polarity of the coil current. The currents of Horiz. and Tilt adjusting coils for brightness can be controlled individually by means of DARK/BRIGHT selector switch (51). The traverse adjustment in bright field is called BRIGHTNESS CENTERING, whereas the tilt adjustment is called BEAM TILT in both bright and dark fields.

ii) The image wobbler for focusing employs the beam deflector tilt coil of brightness, on which is superimposed a commercial ac voltage. The wobbler can be used for both bright field and dark field observation.

The device is controlled by the wobbler switch (30) and wobbler amplitude control (31) on the left main panel.

The superimposition of the wobber stops when releasing the wobbler switch (30).

iii) The stigmator circuit consists of two systems of X and Y directions, which are stabilized through current stabilizer circuit for the beam deflector.

The condenser stigmator and objective stigmator employ the same circuit system.

The condenser lens stigmator can compensate the astigmatism for bright and dark fields individually by the COND STIGM knob (49) and COND STIGMA knob (52) on the right subpanel.

COND STIGMA switches (48) (51) are used for both bright field and dark field observation.

The objective stigmator can be operated by objective stigmator switches (45) (46) (47) on the left subpanel.

iv) The terminal for operation check of the magnetic beam deflector power supply is located on the

beam deflector power PCB (CT211) and monitors the voltage drop of the detecting resistors of the current stabilizer.

The output voltage of $\pm$15 V of the common power supply for the beam deflector power supply can also be checked by this check terminal.

v) All deflector coil currents are linked with change in accelerating voltage so that the coils are supplied with current in proportion to $\sqrt{E}$ (E : Accelerating voltage).

If the HV selector switch (20) is set to OFF, a coil current corresponding to 25 kV will flow to the coils.

vi) The following fuses relating to the beam deflector power supply are located on the beam deflector power PCB (CT211):

F1	1A	GUN TILT-X
F2	1A	GUN TILT-Y
F3	1A	GUN HORIZ-X
F4	1A	GUN HORIZ-Y
F5	1A	BEAM TILT-X

F6	1A	BEAM TILT-Y
F7	1A	BEAM HORIZ-X
F8	1A	BEAM HORIZ-Y

III-5 Electric Circuit of Camera Unit

The camera unit is comprises the film feeder, photographic condition recording device, and auto shutter.

Consequently, the electric circuitry for the camera unit consists essentially of the following three circuits (Fig. 3-5).

1. Circuit for film indexing device
2. Circuit for film feed
3. Circuit for exposure meter and auto shutter

i) The circuit is provided to mark film number, magnification, acceleration voltage, and lens operating condition on each exposed film. The film number is marked on the film with a four-digit magnetic counter. To print the magnification, acceleration voltage, and lens operating condition on the film, three recording devices are used. These photographic conditions (film number, magnification, acceleration voltage, lens

operating condition) are also displayed on the indicator panel. The recording devices and the panel film number indicator are electrically connected in parallel. Fig. 3-5 is the block diagram of the recording device circuit. The recording device is a transparent plastic plate with figures engraved in dots, which reflect the incident light and display the figures. One recording device can mark eleven figures.

ii) Adjustment of Film Indexing Device

As this recording device prints figures on the electron microscope film with the light from a lamp, the exposure must match the sensitivity of the film. The standard exposure time under normal conditions is approximately 5 seconds.

iii) Circuit of Film Feed

The film feed circuit does not operate while the camera valves are closed or while the recording device circuit is in operation or during exposure time. The film feed is driven by an ac motor, which is shut down by a microswitch inserted in the power supply circuit of the motor. The

microswitch is pushed and acts to turn off the motor when the film is delivered to the proper position.

The film feed motor is a reversible type operated on a 100 V ac supply. The film feeding operation is done in the film drive control block shown in Fig. 3-5. An unexposed film in the cassette reservoir is indicated by "0", and is advanced to "1" or "2" when exposed. After exposure, the film counter returns to "0".

iv) Relation between film position and pilot lamps:
The STAND BY (5) and EXPOSE (4) lamps are provided on the left indicator panel for indicating the film positions. The film number indicator and the magnetic counter for recording in the camera chamber are advanced by 1 when the film position is changed from STAND BY to EXPOSE. Fig. 3-6 shows the relation between the film position and indicator lamps (in MANUAL FEED).

v) The marking recorded on the exposed film is as shown in Fig. 3-7.

vi) Circuit for exposure meter and auto shutter
Fig. 3-5 shows the operating principle of the

circuit. For detecting the electron beam, the fluorescent screen for focusing is used as a Faraday cage.

Exposure meter (12) on the right indicator panel indicates the electron beam in coulomb units by the composition of the signal from the Faraday cage and that from the EXPOS TIME selector switch (9) on the right indicator panel. When the shutter speed is set to a coulomb value appropriate to the film, the relay is operated after a preset time to drive the pneumatic auto shutter so that the beam path is shut off.

When the fluorescent screen for focusing is irradiated with the electron beam, the value in coulomb units is indicated on the EXPOSURE meter (12). The coulomb value is adjusted by the EXPOS TIME selector switch (9) and BRIGHTNESS (C2) knob (32).

vii) Time chart for camera sequence

Fig. 3-8 shows the camera sequence time chart. When the FEED pushbutton is depressed, the film shifts to the exposure position from the cassette

reservoir.

The sequence chart starts with the state in which the manual operation shutter (120 ϕ fluorescent screen) is closed and the auto shutter (pneumatic shutter in diffraction specimen chamber) is open, and the image is on the screen. When the manual operation shutter begins opening (position (1) in Fig. 3-8), the auto shutter is closed to shut off the beam path. When the manual operation shutter is fully open (position (2) in Fig. 3-8), the auto shutter opens to irradiate the electron beam. In this case,

a) the shutter timer operates,

b) the pilot lamp of the film indexing device lights up, and

c) the EXPOSING lamp (11) lights up.

The pilot lamp of the film indexing device lights for the preset time according to the film sensitivity (standard setting: 5 sec). EXPOSING lamp (11) lights during the exposure time (when the film is irradiated with electron beam). When the preset shutter time has elapsed, the

electron beam is shut off by the auto shutter and the EXPOSING lamp (11) goes out.

Then, the operator checks the EXPOSING lamp (11) (it should be turned off) and fluorescent screen (image should be absent) and closes the manual operation shutter (position (4) in Fig. 3-8).

When the manual operation shutter is fully closed (position (5) in Fig. 3-8), the auto shutter opens and the electron beam image re-appears on the fluorescent screen.

After completion of film marking, the film is fed to the next visual field or cassette reservoir.

viii) Shutter speed

The shutter speed is selectable in 7 steps (0.5, 1, 2, 4, 8, 16, 32 sec.) by changing EXPOS TIME knob (9) (see Fig. 1-22-4).

IV. OPERATING INSTRUCTIONS

IV. OPERATING INSTRUCTIONS

IV-1 Daily Operation (Fig. 1-22)

IV-1-1 Startup

i) Turn on the MAIN switch (SW011) of the common power supply, and LINE pilot lamp (14) on the right indicator panel lights. Depress the EVAC pushbutton (55) of MAIN SW on the right subpanel after making sure that the LINE lamp lights up. If cooling water is absent, the alarm sounds. Supply cooling water until the alarm stops. About 2 ℓ/min of water will be required for the diffusion pump of the vacuum system and about 2 ℓ/min of cooling water for the stabilizer.

Remarks: Periodically check the terminals and fuses of the switchboard, grounding wire, connection of hose to water faucet, water supply (check for overflow or leak) etc., and keep them in good condition.

ii) Depress the EVAC pushbutton (57) of COLUMN EVAC.

iii) Depress COL button switch (56) of MAIN SW if the

instrument is used right away.

Remarks: Turn on the COL pushbutton switch (56) 30 minutes before using the instrument for warm up.

Also, turn on the lens current switches (61) .... (66), SW1 (GUN) and SW2 (BD) on the BD unit (right console).

At this point the starting operation is completed. LINE and WARM UP of the vacuum sequence pilot lamp (14) will light up. The vacuum control valves will operate when the DP reaches the required temperature. If the DP is below the required temperature, the main valve will not open even if pre-evacuation of the column is completed.

IV-1-2 Shutdown

i) Turn off COL pushbutton (56) and EVAC pushbutton (55) of MAIN SW on the right subpanel.

ii) Stop water supply about 15 minutes after power shutdown. Cooling water can be shut down automatically if a magnetic valve (optional) is attached to the water jacket.

IV-1-3 High Voltage Imposition

i) Check to ensure that VACUUM SYSTEM operation pilot lamp (14), VACUUM SEQUENCE pilot lamp

(15) are turned on (except LINE) and that VACUUM gauge (12) is indicating a vacuum degree of 5×10^{-4} Torr or better, setting the vacuum meter selector knob (13) to the COL. PE position.

ii) Set the H.V. selector (20) to 25 kV, push H.V. RESET button (18) on the LMP, and set FILAMENT control (16) at its lowest setting by turning it fully counterclockwise.

iii) Turn H.V. selector (20) stepwise through 25 kV, 50 kV, 75 kV, and so on to the desired voltage. When the instrument starts, the reset switch (18) may sometimes be shut off by a surge current. Should this happen, push the H.V. reset button again (check that vacuum pressure is normal). Do not turn the H.V. selector (20) while the reset button (18) is depressed. The reset button (18) must be pushed each time the reset switch is turned off.

If the switch is turned off frequently, set accelerating voltage one step lower and wait until the high voltage stabilizes before stepping it up.

iv) Set H.V. selector (20) to "F", and turn BIAS control (17) fully clockwise.

v) Turn FILAMENT control (16) clockwise gradually. The emission of an electron beam is shown on the BEAM. CURRENT meter (1). Stop the FILAMENT control knob (16) at a point where the filament current is saturated.

vi) Adjust the beam current to 20 to 30 μA with the BIAS control (17). A beam spot should now appear on the fluorescent screen unless the axial alignment has been disturbed. If the electron beam fails to reach the fluorescent screen, check the following points.

1. Take out the C2 movable aperture.
2. Take out the objective aperture.
3. Remove the specimen.
4. Check the field limiting aperture (whether it is correctly located).
5. Check if the switch (51) of bright-dark field is set to BRIGHT.
6. Push the SCAN button.
7. Turn all lens currents off.
8. Turn off SW1 (GUN) and SW2 (BD) of the BD unit. (See Fig. 1-22-8)

9. Vary the filament heating current near the saturation point.

10. Check that the gun airlock is open.

11. Check that the airlocks of the second specimen chamber, diffraction chamber, etc. (are open).

vii) Align the beam spot with the center of the screen by adjusting BRIGHTNESS (C2) (32) and BRIGHTNESS CENTERING (X-Y) (38) controls.

IV-1-4 Axial Alignment of Illumination System

The illumination system will have to be realigned if the electron optical system has been disturbed (e.g., filament exchange, aperture cleaning, etc.).

i) Take the movable apertures and specimen out of the beam axis.

ii) Rotate the BRIGHTNESS control knob (32) fully with operating mode selector (21) set at DIFF. As the crossover image appears on the fluorescent screen, focus it in the center of the screen with the BRIGHTNESS CENTERING (X-Y) (38) control. Insert the second condenser (C2) movable aperture and align it with

the electron beam. The C2 aperture is in alignment if the focused spot does not sweep on turning the BRIGHTNESS control. Set the SPOT SIZE selector (43) to 5 or 10 μφ.

iii) Adjust the FILAMENT control (16) so that the crossover image looks like a doughnut (Fig. 4-1-1). If the electron beam is off axis, the crossover image will appear like in Fig. 4-1-2 or 4-1-3. If this is the case, align the beam with the GUN TILT (41) (in dark direction) and GUN HORIZ. (42) (in bright direction) controls. The crossover image becomes distinct as the C2 aperture is inserted. The doughnut image is difficult to botain if the fixed bias voltage is too high.

iv) To align the electron gun of the first condenser lens, select the 2 μ spot size and align the crossover image with the screen center by adjusting BRIGHTNESS CENTERING (X-Y) (38). Then make the spot size 10 μ and align it using the GUN TILT (X-Y) (41) and GUN HORIZ. (X-Y) (42) controls. Repeat these adjustments using

the BRIGHTNESS CENTERING and GUN ALIGNMENT controls alternately until sweep of the crossover image by spot size selection is eliminated. When the gun is aligned, increase the filament heating current to saturate it. Optimum beam current will be 15 to 30 μA.

How to choose the C2 movable aperture:

1. Use a large aperture for a specimen which is resistant to the electron beam, and with which a bright image is difficult to obtain (e.g., thick specimen, metal film, etc.).
2. Use a small aperture if the specimen is susceptible to damage by irradiation (e.g., when high resolution is required as for crystal lattice, biological specimens, vapor particles, etc.).
3. Use an aperture of about 0.5 mm ϕ for ordinary specimens.

IV-1-5 Checks before Photographing

i) Check accelerating voltage and vacuum level (must be better than 5×10^{-5} Torr). When FILAMENT is turned off, the beam current meter

indicates each accelerating voltage. In this case, the meter should be stable without dark current.

ii) Check beam current intensity (bias control). The optimum beam current will be 10 to 30 μA for crystal lattice, biological and high molecular specimens and 30 to 50 μA for metal films, etc.

iii) Check filament heating current for over- or under-heating.
Adjust the filament heating current so that the black ring is scarcely visible in the cross-over image.

iv) Check spot size.
Spot size is 2 to 5 μ for ordinary specimens and 2 μ for specimens requiring high resolution.

v) Check voltage and current center alignments.
Align either voltage or current center.

vi) Check camera, film and cassette receiver loading. Also check FILM NO. indicator and field mask size (full or half size). Check that VACUUM SEQUENCE pilot lamps (15) are all turned on. If the film feed mechanism is

operated without the cassette receiver, it may get broken.

vii) Check EXPOSURE meter for film timer setting.

IV-1-6 Specimen Exchange

i) Insert the specimen into the grid holder. Check the holder to be used -- either the long HR (high resolution) holder or short HC (high contrast) holder.

ii) Set SPECIMEN CHAMBER VALVE selector (34) to AIR and open the specimen pre-evacuation chamber door. Insert the grid holder into the pre-evacuation chamber.

iii) Set SPECIMEN CHAMBER VALVE selector (34) to EVAC and close the pre-evacuation chamber door. Permit a time lag of about 3 seconds.

iv) Transfer the specimen to the specimen exchange device from the specimen holder.

v) Wait until pre-evacuation is completed and the VACUUM SEQUENCE pilot lamp (15) for specimen exchange is turned on. Insert the specimen exchange device into the specimen chamber by turning it 270° (3/4 turn) clockwise. The exchange device cannot be turned until

evacuation is completed (safety device). Do not insert the exchange device into the specimen chamber unless the VACUUM SEQUENCE pilot lamp is turned on.

vi) Turn the specimen lifting knob (106) on the specimen exchange device fully clockwise without pressing the knob. When the grid holder is engaged with the specimen stage, turn the knob (106) counterclockwise while pressing it. Check that the grid holder is securely attached to the specimen stage. It is possible to check whether the grid holder is left on the specimen stage, if the exchange device is turned 90^{o} clockwise before pulling it out.

vii) Withdraw the specimen exchange device fully, and turn it 270^{o} (3/4 turn) counterclockwise to clamp firmly. Air cannot be introduced unless the exchange device is pulled out fully.

viii) To take out the inserted specimen, set SPECIMEN CHAMBER VALVE selector (34) to AIR and then to EVAC immediately. The pre-evacuation chamber is evacuated if it is not in vacuum. On the other hand, the blue pilot lamp will light if the

chamber is in vacuum. The AIR-EVAC selection by the selector (34) should be done in quick succession so as not to allow the delay relay to operate. This procedure assures adequate vacuum in the specimen pre-evacuation chamber.

ix) Insert the specimen exchange device into the specimen chamber, and turn the knob (106) clockwise fully without pushing. When the cylinder engages the grid holder, turn the knob (106) counterclockwise without pushing. Before the exchange device is pulled out, check through the window that the grid holder has been picked up by the exchange device.

x) Pull out the specimen exchange device fully and turn it 270° (3/4 turn) counterclockwise.

xi) Transfer the grid holder to the turret in the specimen pre-evacuation chamber. Procedure is the same as in (iv).

xii) Turn the turret 180°, set switch (34) to AIR. (See Fig. 1-11).

xiii) When the specimen pre-evacuation chamber door opens, take out the grid holder with the tweezers (supplied with the instrument).

IV-1-7 Visual Field Selection, Magnification Change, Site Selection (Specimen Rotation), Brightness Control, and Focusing (See Fig. 4-7)

i) Pull out objective movable aperture (107), and depress SCAN button (23). As a grid image appears on the screen, bring the desired grid to the center of "scan" image.
If the center of the "scan" image is out of that of the fluorescent screen, adjust the SCAN POSITION adjusting knobs on the B.D unit (right console) until the scan image is positioned at the center of the fluorescent screen.

ii) Push ZOOM button (24) and check the visual field. Then insert the objective movable aperture. If it is difficult to adjust the aperture to the center of the screen, turn DIFF button (21) on and adjust the aperture position.

iii) Magnification is selected by MAGNIFICATION knob (27) with ZOOM button (24) depressed.
Before setting the knob to high magnification, check focus once at low magnification (5,000X) by means of image wobbler.

iv) Select the desired visual field and magnifica-

tion. If the magnification to be used is below 10,000X, use both the viewer and image wobbler to focus the image.

Remarks: The exposure timer is set according to the film sensitivity and kind of specimen and usually set to 2 or 4 sec. The exposure meter is indicated by coulomb (or product of brightness and exposure time).

Therefore, determine the coulomb according to kind of film, and then determine the exposure time.

v) Depress FILM FEED button (33), and the film counter (2) operates with EXPOSE lamp (4) lit.

vi) Pull the shutter lever (112) gently toward you. The image will disappear from the screen, but it will appear again when the shutter lever is fully retracted (microswitch operates).

vii) Exposure is controlled by the auto shutter. Return the shutter lever when the image disappears.

viii) When FEED STOP switch (10) is turned on, the film is automatically fed to the next position.

In case of one visual-field exposure on a film, the exposed film is fed to the cassette receiver with STAND BY lamp (5) lit. In case of two visual-field exposures on a film, the EXPOSE lamp (4) lights up again for the next photographing.

When STAND BY lamp (5) lights up, depress FILM FEED button (33) to turn on EXPOSE lamp (4). Now, the film is ready for exposure. The film counter display is reduced each time the FILM FEED button (33) is depressed until it becomes zero.

If FILM FEED button (33) is depressed while the film counter indicates zero, the chime sounds to announce that the cassette magazine is empty.

ix) If the visual field is not adequate in trimming of film, check the rotating direction and angle of specimen field and depress SCAN button (23) to obtain the scan image. Check the visual field, and rotate the specimen with the specimen rotation knob (96). Then, center the visual field with the specimen stage control and push the ZOOM button (24). Check the visual field

again.

IV-1-8 Selected-area Diffraction Photography

(See Fig. 4-7)

i) Push SELECTED AREA (S.A) button (22), and turn the zoom dial (27) to set magnification so as to obtain the image for diffraction. Insert a field limiting aperture (108) suited for the specimen.

ii) Focus the image on the edge of the field limiting aperture by turning SELECTED AREA knob (26). Use the objective aperture for photographing the magnified image, because this will improve contrast. Remove the objective aperture for diffraction micrography.

iii) Depress DIFF button (21), and focus the image to the spot by turning the small control of CAMERA LENGTH dial (25).

iv) Select an appropriate camera length with the large control of CAMERA LENGTH dial (25), and bring the image in focus with the small control. Camera length is adjustable in 5 steps. Approximate values are given in the table. Using a standard specimen (e.g., gold foil), exact

values to suit the individual instrument can be determined.

v) Adjust brightness with BRIGHTNESS control (32), and expose the film. The spot will be less sharp if it is too bright. Adjust the brightness so that exposure is 30 seconds to one minute.

IV-1-9 Dark Field Photography

i) Obtain a selected area diffraction image. Check the position of the main (center) spot, and turn DARK/BRIGHT selector (51) to DARK. Then adjust BEAM TILT (X-Y) controls (53) of the dark field control panel so that the desired diffraction spot is brought to the position of the main spot.

ii) While adjusting the brightness with BRIGHTNESS control (32), align the spot with BRIGHTNESS (X-Y) controls (54).

iii) If the spot is distorted, correct it with the stigmator (52). Appropriate spot size will be 5 to 10 μ, and beam current 30 to 50 μA. Adjust

the values when the specimen is liable to be damaged by electron beam irradiation.

iv) Limit the visual field to the area around the desired diffraction spot (the spot brought to the center of visual field) with the objective aperture (107). If a diffraction ring, instead of a diffraction spot, is to be observed, align the appropriate point of the ring to the center and insert the objective aperture.

v) Depress ZOOM button (24) to obtain the magnified image.

vi) Adjust BRIGHTNESS (C2) knob (32), focus the image, and expose the film. The wobbler can be used for focusing a magnified image at low magnification though the image becomes rather dark. The dark field image is usually somewhat dark and high in contrast, so it is almost impossible to use the exposure meter. Make the crossover image about the size of the inner main screen, and make an exposure.

IV-1-10 Low Magnification/Wide Field Observation, Micrography (Optional Accessory)

i) Remove the field limiting aperture.

ii) Insert the grid holder HSS-1 type (Fig. 4-8) with the specimen mounted into the second specimen chamber, and pre-evacuate the chamber.

iii) Depress SA button (22), and place the specimen under the electron beam.

iv) Set magnification with the zoom dial (27), and focus the image with SELECTED AREA knob (26). Magnification change by the zoom dial is provided in 21 steps. Digital indication of magnification is possible at option. If continuous magnification change is required, set FREE-NORMAL switch (67) to FREE, focus the image with INT. control (71), and change the magnification with PROJ. 1 (72) and PROJ. 2 (73) controls. Since the magnification depends on the combination of PROJ. 1 and PROJ. 2 current values, a graph showing the relationship should be prepared by testing.

v) Adjust the specimen stage with the X-Y controls of the specimen exchange device of the second specimen chamber.

IV-1-11 Film Exchange (Photography)

i) Do not touch the emulsion surface when the film (or plate) is loaded in the cassette (see Fig. 4-9). When unloading the film, make sure that STAND BY lamp (5) on the left indicator panel lights.

ii) Turn camera valve selector (77) to AIR. This airlocks the camera and then introduces air into the camera chamber automatically (about 3 minutes) (Fig. 2-4).

iii) Open the camera chamber door by pulling it out (Fig. 4-10).

iv) Remove the cassette receiver (Fig. 4-11).

v) Pull out the tray in the camera chamber to take out the cassette reservoir by lifting the stopper of the handle (Fig. 4-12).

vi) Put a new cassette reservoir in the tray and push it into the chamber.

vii) Set an empty cassette receiver in place. Do not feed films without mounting the cassette receiver.

viii) Close the door, and turn the camera valve selector (77) to H VAC, while pressing it lightly.

This will open the camera airlock automatically after pre-evacuation.

ix) When the airlock opens, feed out the shield plate (this facilitates evacuation) and set the film counter (4) (5) to the number of films loaded. When the number of films is the same as the previous one, depress the reset button.

x) If only pre-evacuation is required, set the camera valve selector at L VAC.

xi) If the exposed film has to be left in the camera until the next morning, set the selector at CLOSE. This keeps the camera in vacuum and makes the chamber completely light-tight.

IV-1-12 Suggestions for Optimum Photography

i) Do not use unnecessarily high magnification. As the negative image is enlarged to 460 x 560 mm size in print, consider the magnification in terms of the final print, not the film size. For example, the enlargement from the full film size (75 x 90 mm) to 460 x 560 mm print will be 6x (or 8x from the half size).

Hence, if the final magnification to be obtained is 200,000x, the direct magnification will be 30,000x to 35,000x for the full-size and about 25,000x for the half-size film.

ii) The standard conditions for photography are as follows.

Spot Size:	2 - 5 μφ
Beam Current:	Below 20 μA (with hairpin type filament)
C2 movable aperture:	0.3 - 0.5 μφ

Although the image becomes brighter with reduction in spot size, the specimen will be more affected -- swept or damaged -- by the stronger electron beam. Do not increase the current beyond the point at which the specimen is swept by irradiation.

iii) Let the crossover image fill the fluorescent screen, so that reduction in depth of focus of the image on the specimen is avoided.

iv) When the required visual field is selected, set the fousing screen onto the optical axis and focus the binocular viewer on it. Then make the crossover image

smaller (brighter) until adequate brightness is obtained for focusing. Focus the image with the image wobbler.

v) If the image is too dark and difficult to focus, make the crossover image smaller. After focusing, magnify the image.

vi) In case of biological specimens, underfocus the image by 1,000 to 2,000 Å to improve the contrast of pictures.

vii) The optimum exposure time is 3 to 6 seconds.

viii) Do not touch the specimen stage after the visual field is selected and oriented for photography. In particular, avoid operation of the specimen stage after focusing.

IV-1-13 Pointed Filament

The use of a pointed filament provides high resolution electron images, so it is widely applied to observation of animate and inanimate specimens. Electron image formation is due to the scattering contrast and the phase contrast. With a specimen which scatters most of the electrons incident on it (i.e., one with a large difference in thickness

or density with specimen spots), images with sufficient contrast (scattering contrast) are formed. On the other hand, with one having lower scattering efficiency, image formation is due primarily to the contrast by electron interference (phase contrast). This means that by using an electron beam which causes much interference, sufficiently contrasted images can be obtained even with a specimen which produces little scattering. The degree of interference depends upon the coherence of the irradiating electron beam. To increase the coherence of the beam, the electron source should be made as small as possible by a condenser lens, i.e., the first condenser lens should be excited as strongly as possible. However, by doing so, the electron beam is greatly broadened and its density decreases. This makes photographing at high magnifications impossible. The pointed filament serves as a very small electron source and is extremely rich in electrons as compared with the hairpin filament. Accordingly it produces an electron beam with high coherence. By utilizing the pointed filament, sufficiently bright images as

well as high resolution ones can be obtained with a low energy electron current without damaging specimens.

IV-1-14 Positioning of Pointed Filament

To obtain a bright and small spot with the electron beam, the geometry of the Wehnelt cylinder and pointed filament tip is very critical. Fig. 4-13 shows this relation. Adjust the disc plate (4432-2161, see Fig. 1-5-2) by using a magnifying glass so that the filament tip is centered in the Wehnelt cylinder opening.

Note: The tip of the pointed filament is sharper than a hair-pin tip.
Do not touch it with a finger nor anything else.

IV-1-15 Axial Alignment of Pointed Filament

i) After checking for proper vacuum, apply an accelerating voltage of 50 or 75 kV. If discharge occurs, the filament tip will be damaged. Therefore, perform the following operations making certain that no discharge occurs.

ii) Fully turn the bias voltage control (16) clockwise.

iii) Slowly turn the filament current control (15) clockwise until the beam current comes between 50 and 100 μA (approaching the saturation point).

iv) Reduce the beam current to between 30 and 50 μA with the bias voltage control (17).

v) Form a crossover image with the BRIGHTNESS control (C_2) (32) and then bring it to the center of the fluorescent screen with the BRIGHTNESS CENTERING controls (38) and (36). The SPOT SIZE selector (43) should be set at the 2 or 5 μ position. After the crossover image is formed, bring the magnification to between 5,000x and 10,000x.

vi) When the pointed filament is properly aligned, the crossover image is formed as shown in Fig. 4-1-1, 2, and 3. Then set the aperture plate No. 3 or No. 4 of the second condenser lens movable aperture (80).

vii) Adjust the GUN TILT control (41) and GUN HORIZ. control (42) to form a ring-shaped

crossover image as shown in Fig. 4-1-4. This is accomplished by shifting the crossover image previously obtained in the arrow direction in Fig. 4-1-1, 2, 3 with the GUN TILT control or shifting it in the opposite direction with the GUN HORIZ. control.

If the image is out of the fluorescent screen, return it to the center of the screen by operating the BRIGHTNESS CENTERING controls (38).

viii) When the ring-shaped crossover image is formed, make axial alignment of the electron optical system.

Set the SPOT SIZE selector (43) to the 2 μ position and bring the crossover image to the center of the fluorescent screen by operating the BRIGHTNESS CENTERING controls (38).

Switch the selector (43) to the 5 or 10 μ position, and the image will shift from the center of the screen. Then bring the crossover image back into place with the GUN TILT control (41) and GUN HORIZ. control (42), while maintaining it in a ring shape.

Repeat the procedure above until the crossover image is maintained in the center of the screen (120 ϕ fluorescent screen) at any position between 2 and 10 μ. Thus the axial alignment is completed.

ix) Turn the bias voltage control (17) counterclockwise to apply the bias voltage and focus the ring-shaped crossover image into such as that shown in Fig. 4-1-5 and 6. If the ring is distorted during this operation, correct it to a full ring with the GUN TILT control (41) and GUN HORIZ. control (42) whenever necessary. If the electron current stops before a sufficiently small spot is attained, supply current again by operating the filament current control (16). Under the optimum condition, the beam current attainable is 5 μA or less.

Turning the bias voltage control (17) clockwise, a dark spot appears in the crossover image, and when turning it counterclockwise, the image becomes bright and subsequently dark. The bias voltage at which the image is brightest should

be selected. In this case, the spot size is between 0.3 and 0.5 μ in diameter (see Fig. 4-1-7) when the SPOT SIZE selector (43) is set at the 2 μ position.

As the bias voltage and the filament current are increased, the image becomes brighter, but the life of the filament is shortened.

x) When the standard Wehnelt cylinder (with 1.5 mm ϕ opening) is used, a crossover image between 0.3 and 0.5 μ in diameter is attainable with the SPOT SIZE selector (43) set at the 2 μ position, and a brightness corresponding to exposure for about 5 seconds is also attainable at a magnification of 500,000x.

xi) When the accelerating voltage is changed, the shape of the crossover image may change because of a variation of the electric field around the Wehnelt cylinder. In such a case, readjustment is required.

IV-2 Automatic Operation

(Fig. 2-4)

In case of automatic operation, once the vacuum system

is set in operation with MAIN SW-EVAC switch (55) turned on, the valves are operated automatically by means of EVAC SEQUENCE circuit. It is only necessary to depress EVAC., CLOSE or AIR button according to the instructions.
These mechanisms will be explained below.
The operation of the vacuum system can be checked through the VACUUM SEQUENCE pilot lamps (14) in the RIP and/or EVAC PANEL pilot (15) lamps in the relay box (R).
The gun housing valve switch is a rotary switch (76), and is contained in the console. The specimen chamber valve switch (34) is located in the RMP as it is frequently used. The MAIN SW-EVAC (55) and COLUMN EVAN (57) (58) (59) switches are push buttons and are located in the RSP, whereas the camera chamber valve switch (77) is a rotary switch placed at the right of the camera chamber front.
The plate reservoir-valve switch (78) is located above the door handle and performs EVAC-AIR operation.
The EVAC PANEL contains the vacuum system diagram and indicates the operation of all vacuum valves, vacuum pumps and vacuum gauges, as well as the supply of water and compressed air.

The VACUUM SEQUENCE monitor panel is located in the RIP, EVAC. (blue), CLOSE (yellow) or AIR (red) is displayed for gun housing, column, specimen chamber and camera chamber respectively by pilot lamps (15). Also displayed is LINE (red), WARM UP (of DP) (yellow), LOW VAC (green) and HIGH VAC (blue) of the main vacuum system with pilot lamps (14). The HIGH VAC lamp is interconnected with the Penning gauge, and the instrument is ready for high voltage imposition when it is illuminated. The VACUUM meter (12) is placed in the center of RIP. With a selector (13), the meter provides three readings, COL. (Penning), COL. (Pirani), and RP (Pirani).

IV-2-1 Preparation

i) Open the door on the right console, in which the sequence relay box (Fig. 2-5) is contained.
Turn the MANUAL-AUTO switch to AUTO.
Turn all the other switches to CLOSE.

ii) Turn GUN VALVE (76), COLUMN VALVE (57) and CAMERA VALVE (77) switches to CLOSE, and the specimen chamber valve (34) and PR valve switches (78) to EVAC.

iii) Supply DP cooling water (15 to 25° C, 2 to 3 ℓ/min.).

IV-2-2 Starting

i) Turn MAIN SW-EVAC switch (55) on.
This turns RP-1, RP-2, compressor, and vacuum gauges on, and closes the RP air leak valves MVL-1 and MVL-2.

ii) The vacuum sequence does not operate until the pressure of the compressed air attains 2.5 kg/cm^2. When the air pressure attains 2.5 kg/cm^2, the compressor pilot lamp in the EVAC diagram (R) is turned on.

iii) MV-2 valve opens 15 seconds after step (2) to evacuate BT and the DP heater is turned on simultaneously.

iv) In the pre-evacuation system, the plate reservoir is evacuated 15 seconds later until the evacuation signal of the column, gun housing, specimen chamber, and camera chamber is issued, and specimen chamber pre-evacuation valve MV-5 opens 1 second after the specimen chamber pre-evacuation signal is issued.

Remarks: As mentioned in Section II-3-6, these vacuum chambers are to be pre-evacuated according to the priority sequence.

IV-2-3 Column Evacuation (During DP heating)

(DP thermostat "off")

The pre-evacuation procedure for the column differs depending upon the temperature of the DP.

i) Turn COLUMN VALVE-EVAC switch (57) to EVAC.

ii) When the column vacuum (Pl-2) is better than 1×10^{-1} Torr, RP-2 will evacuate another part of the instrument (e.g., PR, MV-7) until the DP heater reaches the required temperature (until the thermoswitch is turned on).

iii) If the column vacuum (Pl-2) is lower than 1×10^{-1} Torr, MV-7 is closed. After one second, MV-3 opens and the column is pre-evacuated.

iv) When the column vacuum has attained 1×10^{-1} Torr, MV-3 is closed and RP-2 will evacuate the PR as in step (2).

v) Main valve AV-1 does not open until the TS is turned on.

vi) The TS is turned on when the DP is heated to the

required temperature. AV-1 opens 10 seconds after the TS is turned on to evacuate the column to high vacuum. At this point the Penning gauge is also turned on.

Remark: Due to the priority sequence, MV-3 does not open while MV-5 is open.

IV-2-4 Column Evacuation (DP Hot) (DP thermostat "on")

As described in Section IV-2-3 (p. 4-32). the pre-evacuating procedure after the DP is heated is different from that during DP heating. The following is the procedure after heating, when the DP thermostat is connected.

i) Turn COLUMN VALVE-EVAC switch (57) to EVAC.

ii) If the column vacuum (P1-2) is 1×10^{-1} Torr or better, AV-1 is opened 10 seconds after step (1) to evacuate the column to high vacuum.

iii) If the column vacuum is below 1×10^{-1} Torr, MV-3 is opened for column pre-evacuation.

iv) As the column vacuum (P1-2) attains 1×10^{-1} Torr, MV-3 is closed, and AV-1 opens 10 seconds after this.

v) The Penning gauge is turned on.

vi) The column is ready for high voltage imposition when the Penning gauge attains 8×10^{-4} Torr.

IV-2-5 Gun Housing Evacuation

i) COLUMN EVAC-EVAC switch (57) is assumed to be already turned on.

ii) Turn GUN VALVE switch (76) in the console to EVAC.

iii) If MV-7 is open, it closes and MV-4 opens for gun housing pre-evacuation.

iv) When the gun housing vacuum (Pl-3) attains 7×10^{-2} Torr, GV, AV-2 are opened to connect the gun housing to the column.

v) If the column vacuum (Pl-2) is below 1×10^{-1} Torr, the column pre-evacuation is continued through MV-4 and MV-3.

vi) When the column vacuum (Pl-2) attains 1×10^{-1} Torr, with MV-3 closed and AV-1 opened, MV-4 is closed. This completes gun housing pre-evacuation.

vii) If the column is under main (high vacuum) evacuation and AV-1 is open, MV-4 closes

immediately. MV-7 opens after one second to evacuate the plate reservoir.

Remarks: Due to the priority sequence, MV-4 does not open while MV-5 is open.

IV-2-6 Specimen Chamber Evacuation

i) Turn SPECIMEN CHAMBER VALVE button (34) to EVAC.

ii) If MV-3, MV-4, MV-6 and MV-7 are open, these are closed, and after one second MV-5 opens to pre-evacuate the specimen chamber.

iii) When the specimen chamber vacuum (Pl-3) attains 7×10^{-2} Torr, MV-5 closes and pre-evacuation is completed. After one second, the vacuum valve under operation in step (2) (either MV-3, MV-4, MV-6, or MV-7) is opened.

IV-2-7 Camera Chamber Evacuation

i) COLUMN EVAC-EVAC switch button (57) is assumed to be already "on".

ii) Turn on H-VAC of CAMERA VALVE switch (77) at the right of camera chamber.

iii) If MV-7 is open, it is then closed and one second after the closure MV-6 opens for camera chamber

pre-evacuation.

iv) The airlock valve (CV) is opened to connect the camera chamber to the column, when the camera chamber vacuum (Pl-3) has attained 7×10^{-2} Torr.

v) If the column is under pre-evacuation (Pl-2 indicates vacuum level below 1×10^{-1} Torr), MV-6 is opened and the column is pre-evacuated through both MV-6 and MV-3.

vi) When the column vacuum has attained 1×10^{-1} Torr, with MV-3 closed and AV-1 opened; MV-6 is closed and AV-3 is opened to evacuate the camera chamber to high vacuum.

vii) If the column is under high vacuum evacuation and AV-1 is opened after step (4), MV-6 is closed immediately and AV-3 is opened.

viii) After one second, MV-7 is opened for PR pre-evacuation.

ix) If CAMERA VALVE switch (77) is set at LOW VAC., the sequence is shut down at step (3) and the camera chamber is continuously pre-evacuated. The LOW VAC is used when film which has not been pre-evacuated is loaded.

Remarks: Owing to the priority for specimen chamber evacuation, MV-4 does not open while MV-5 is open.

IV-2-8 Plate Reservoir Pre-evacuation

When the valve switch (78) of the plate reservoir is turned to EVAC, the plate reservoir is pre-evacuated automatically after column, gun housing, specimen chamber or camera chamber are pre-evacuated.

IV-2-9 Evacuation Shutdown

If the vacuum operation must be partially shut down, the procedure below should be followed.

i) CLOSURE OF COLUMN VALVE

If COLUMN EVAC-CLOSE button (58) is turned to CLOSE, the column, gun housing, and camera chamber valves are closed. That is, MV-3, 4, 6, AV-1, 2, GV, AV-3 valves are all closed though GUN VALVE and CAMERA VALVE buttons (76) (77) are set at EVAC.

ii) CLOSURE OF GUN VALVE

If GUN VALVE switch (76) is turned to CLOSE, AV-2, GV, MV-4 are closed, hence the gun housing is closed.

iii) CLOSURE OF CAMERA CHAMBER

If CAMERA VALVE switch is turned to CLOSE, CV, AV-3, and MV-6 are closed to shut only the camera chamber.

iv) The specimen chamber and plate reservoir are not provided with "CLOSE" switches.

IV-2-10 Air Introduction

To introduce air into each vacuum section, use the following procedure.

i) Column

Depress COLUMN EVAC-AIR valve switch (59), which closes all vacuum valves of column, gun housing and camera chamber. After 3 seconds, the leak valves MVL-3, MVL-4, and MVL-6 are opened to introduce air into the column, gun housing and camera chamber simultaneously.

ii) Gun housing

Turn GUN VALVE switch to AIR. This closes GV, AV-2 and MV-4. After 3 seconds, MVL-4 is opened to introduce air into the gun housing.

iii) Camera chamber

Turn CAMERA VALVE switch to AIR. This closes

CV, AV-3 and MV-6 and opens, after 3 seconds, MVL-6 for air introduction to the camera chamber.

iv) Specimen chamber

Turn SPECIMEN CHAMBER VALVE switch (34) to AIR. This closes MV-5 and opens MVL-5 with 3 seconds' time lag. The door for specimen exchange chamber also opens.

v) Plate reservoir

Turn the valve switch (78) at the PR handle to AIR. MV-7 is closed and after 3 seconds, MVL-7 is opened for air introduction to the plate reservoir.

IV-2-11 Shutdown

i) Turn COLUMN EVAC-CLOSE switch (58) to CLOSE.

ii) The other valve switches can be left at EVAC.

iii) Turn MAIN SW-EVAC (55) off.

iv) This closes all valves and turns RP-1, RP-2, DP, compressor and vacuum gauges off and MVL-1 and MVL-2 are opened to introduce air into RP-1 and RP-2.

IV-3 Manual Operation (Fig. 4-14)

The MV-1, MV-2, MV-3, MV-6, AV-1, GV and AV-2, CV and AV-3 can all be operated separately from one another. On the other hand, for the MV-5 and MVL-5 of the specimen chamber and the MV-7 and MVL-7 of the plate reservoir, AUTO/MANUAL switching is not available.

IV-3-1 AUTO-MANUAL Switch Operation

i) Turn GUN (76) and CAMERA (77) VALVE switches to CLOSE and depress COLUMN EVAC-CLOSE (58). Turn SPECIMEN CHAMBER (34) and PR (78) VALVE switches to EVAC.

ii) Turn all MANUAL switches in front of EVAC. SEQUENCE box (R) to OFF (or CLOSE).

iii) Turn AUTO/MANUAL selector to MANUAL.

iv) The instrument is now ready for manual operation. While observing EVAC. PANEL pilot lamps, operate the manual switches as outlined below.

IV-3-2 Main Evacuation

i) Check that RP-1 and RP-2 are in operation, and open MV-2.

ii) Turn the DP switch on.

iii) Wait until the DP is heated (until WARM UP pilot lamp (14) is turned off).

iv) Check that the column is pre-evacuated and that Pl-2 has attained 1 x 10^{-1} Torr, and open the main valve (AV-1) (AV-1 does not open, however, if MV-2 is closed at this time).

IV-3-3 Column Pre-evacuation

i) Check that MVL-3 (air leak valve) is closed.

ii) Open MV-3 (pre-evacuation valve) to pre-evacuate the column.

iii) Check that the column vacuum (Pl-2) is better than 1 x 10^{-1} Torr.

iv) Close MV-3.

v) Open AV-1 (main valve) to evacuate the column to high vacuum.

IV-3-4 Gun Housing

Before operation, check that the column is under pre- or main evacuation.

i) Close GV, AV-2 (gun valves), and MVL-4 (leak valve).

ii) Close MV-5, MV-6 and MV-7.

iii) Open MV-4 (pre-evacuation valve) to pre-evacuate the gun housing.

iv) Check that the pre-evacuation vacuum (Pl-3) is better than 7×10^{-2} Torr.

v) Check that the column vacuum (Pl-2) is better than 1×10^{-1} Torr, and open GV and AV-2 to connect the gun housing to the column.

vi) Close MV-4.

IV-3-5 Specimen Chamber

The evacuating procedure for the specimen chamber is common to both manual and automatic operations. Therefore, refer to Section IV-2-6 (p. 4-35).

The vacuum degree can be monitored on the vacuum meter (11).

IV-3-6 Camera Chamber

i) Check that the column is under pre- or high vacuum evacuation.

ii) Close CV, MV-4, MV-5, MV-7 and AV-3.

iii) Open MV-6 to pre-evacuate the camera chamber.

iv) Check that the pre-evacuation vacuum (Pl-3) is better than 7×10^{-2} Torr.

v) Check that the column vacuum (Pl-2) is better

than 1 x 10^{-1} Torr.

vi) Close CV.

vii) Open AV-1 (main valve).

viii) Close MV-6.

ix) Open AV-3 to evacuate the camera chamber to high vacuum.

IV-3-7 Plate Reservoir

The evacuating procedure for the plate reservoir is common to both manual and automatic operations. Therefore, refer to Section IV-2-8 (p. 4-37). The vacuum degree can be monitored on the vacuum meter (11).

IV-3-8 Air Introduction to the Column

i) Turn the acceleration voltage off.

ii) Set the condenser, objective and field limiting movable apertures to the "0" position.

iii) Take the specimen out of the column.

iv) Close AV-1, AV-3, MV-3, MV-4 and MV-6.

v) Open MVL-3, MVL-4 and MVL-6 to introduce air into the column, gun housing, and camera chamber (when air is introduced into the column, it must also be admitted into the gun housing and

camera chamber).

vi) Close the air leak valves after air introduction.

(MVL-3, MVL-4 and MVL-6 are closed with 3 seconds' time lag after the switch actuation.)

IV-3-9 Air Introduction to the Gun Housing

i) Turn the acceleration voltage off.

ii) Close GV, AV-2 and MV-4.

iii) Open MVL-4 (3 seconds' time lag) to introduce air into the gun housing.

iv) Close the air leak valve after air introduction.

IV-3-10 Air Introduction to the Specimen Chamber

The air-introducing procedure for the specimen chamber is common to both manual and automatic operations. Therefore, refer to Section IV-2-10.

IV-3-11 Air Introduction to the Camera Chamber

i) Close CV, AV-3 and MV-6.

ii) Open MVL-6 to introduce air into the camera chamber.

iii) Open the camera chamber door and make sure that air has been introduced. The close MVL-6.

IV-3-12 Plate Reservoir

The air-introducing procedure for the plate reservoir is common to both manual and automatic operations. Therefore, refer to Section IV-2-10 (p. 4-38).

IV-3-13 Shutdown

i) Turn the accelerating voltage off.

ii) Close GV, AV-2, AV-1, AV-3 and CV.

iii) Close MV-3, MV-4, and MV-6.

iv) Turn DP off.

v) Close MV-2.

vi) Turn MAIN SW-EVAC. switch (55) on the RSP off. This turns the vacuum gauges and RP off and opens MVL-1 and MVL-2 (leak valves for RP).

vii) Stop water supply 15 minutes after the shutdown.

IV-3-14 MANUAL AUTO Selection

i) Turn all vacuum switches to CLOSE.

ii) Perform steps (1) to (5) of IV-3-13 (Shutdown) and turn all MANUAL switches to OFF (CLOSE).

iii) Turn the MANUAL switch to AUTO.

iv) This actuates the automatic operation circuit. The valves do not operate with the manual

switches.

Remarks: AUTO-MANUAL selection must be performed with all manual switches off.

V. ELECTRON OPTICAL ALIGNMENT

V. ELECTRON OPTICAL ALIGNMENT

V-1 COLUMN MAINTENANCE

V-1-1 Astigmatism Correction (Objective Lens)

i) Astigmatism is the formation of two mutually perpendicular line foci on different planes as shown in Fig. 5-2-1. In electron microscopy, this is caused chiefly by an asymmetrical field due to inhomogeneities and imperfections in the lens material and construction (residual astigmatism) and by disturbances due to external stray fields and electrostatic charge effects resulting from contamination (secondary astigmatism). Although secondary astigmatism is extremely difficult to remedy, the primary one can be corrected by means of a stigmator. In the HU-12A Electron Microscope, the stigmator is an eight polar long-coil built in the lower pole piece of the objective lens (Fig. 5-1).

ii) Astigmatism measurement: Measure the fringe widths in X and Y directions accurately in a picture (Fig. 5-2-1), and divide the measured values by the degree of magnification to obtain

the fringe widths of the specimen.

Example: Suppose the fringe width is "a". Then the shift of focus from the correct focus, ℓ, is given by

$$\ell = \frac{a^2}{3.2\lambda}$$

a: fringe width

λ: wavelength of electron beam

Hence, the shift of focus from correct focus in X direction is

$\ell x = \frac{ax^2}{3.2\lambda}$ and in Y direction

$\ell y = \frac{ay^2}{3.2\lambda}$.

The astigmatic difference is $|\ell x - \ell y| = \Delta\ell$

The deterioration of resolution due to astigmatism is given by $\delta a = \frac{\alpha \Delta \ell}{2}$

where, δa: disturbance of image

$\Delta\ell$: astigmatic difference

α: objective aperture angle

Hence $\delta a = 5 \times 10^{-3} \times 1 \times 10^{-4} \div 2 = 2.5$ Å.

when $\Delta\ell = 0.1\ \mu$.

iii) Astigmatism correction: Use as a specimen a film hole as close to a circle as possible, such as a hole in a collodion film. Align the current center accurately, and set the magnification between 30,000x and 50,000x.

(i) The magnification for the astigmatism correcting operation may be 1.5 to 2 times the magnification for ordinary observation, but it must be higher than 30,000x.

(ii) Astigmatism is corrected with the objective movable aperture in place. However, clean the aperture before correcting if the astigmatic direction changes with displacement of the aperture.

(iii) Focus the image somewhat in overfocus as in Fig. 5-2-1, and ascertain the direction in which the overfocused fringe is stronger.

(iv) Using the stigmator, focus the image of the objective lens back and forth between exact focus and slight overfocus, until the overfocused fringe appears uniform all around as in Fig. 5-2-2.

(v) Take a picture, measure the fringe widths accurately, and obtain the astigmatic difference.

V-1-2 Current and Voltage Center Alignments

i) In a three- or four-stage magnifying lens system, the magnification changes and the image shifts radially as the accelerating voltage varies. This is a field chromatic aberration, and is known as radial chromatic aberration. Given a radial chromatic aberration coefficient C_{FV} and an accelerating voltage fluctuation $\Delta V/V$, the image displacement δ_{FV} is

$$\delta_{FV} = C_{FV} \cdot r \quad \frac{\Delta V}{V}$$

and is proportional to the distance from the center r. Hence, image disturbance should be minimal when the radial center of image shift under a fluctuation of the accelerating voltage (called voltage center) is aligned with the center of the film.

ii) The image rotates when the objective and projector lens excitation currents vary. This is

known as rotational chromatic aberration.

Given a rotational chromatic aberration coefficient C_{FI} and a current fluctuation $\frac{2\Delta I}{I}$, the image displacement δ_{FI} is

$$\delta_{FI} = C_{FI} \cdot r \frac{2\Delta I}{I}$$

and is also proportional to the distance from the center.

Consequently, image disturbance will be minimal when the center of the rotating image under a fluctuation of the objective excitation current (called current center) is brought to the center of the film. Chromatic aberrations may be devided into axial and field chromatic aberrations. Axial chromatic aberration is proportional to the aperture angle of the objective lens, and the whole image appears blurred as a result.

With field chromatic aberration, the image becomes more and more blurred toward the edge. The displacement of the image due to field chromatic aberrations is given as the resultant of the radial and rotational chromatic aberrations.

The rotational chromatic aberration can be compensated by making the rotational directions of the objective and projector lenses oppose each other. The radial chromatic aberration cannot be eliminated completely under normal conditions of lens excitation. Although it is compensated to some extent by the intermediate lens, the correction is somewhat limited. Consequently, the radial center (voltage center) should be aligned in preference to the rotational center (current center).

iii) When aligning the voltage center, use a specimen having a uniform pattern (e.g., grid mesh) and obtain an image of 5,000x to 10,000x (See Figs. 1-22-2, 3, 5). The final image will fluctuate in radial direction as H.V. MODUL switch (19) on the LMP is turned on. Ascertain the voltage center from the direction of image fluctuation, and align the center with the center of the fluorescent screen by adjusting BEAM TILT (X-Y) controls (50). If the brightness leaves the screen center during alignment, bring it back with BRIGHTNESS CENTERING (X-Y) controls (38).

iv) To align the current center, obtain a final image in the same manner as in voltage center alignment and set OBJ. MODUL control knob (44) from OFF to 1, 2, or 3 according to magnification. As the final image moves like the hairspring of a watch, ascertain the current center from the direction of image movement and align the center with the center of the fluorescent screen by means of BEAM TILT (X-Y) controls (50).

The voltage and current centers may not be in perfect coincidence with each other. This arises from the fact that the optical axes of the intermediate and first condenser lenses are not in perfect alignment with the axis of the objective lens. The misalignment of the lens axes may be corrected by mechanical adjustment of the lens parts. The performance of the instrument is, however, virtually unaffected if the two centers are in the picture area at the magnification with which the picture is taken. If the two centers are not in the picture area, align the voltage center

rather than the current center.

v) Alignment of scanning image center: Since the radial center of the scan image does not usually agree with that of a zoom image (usual magnifying image), the center of the scan image is not in the screen center when the zoom image is switched to the scan image mode. In this case, bring the scan image to the screen center by adjusting SCAN POSITION adjusting knobs (74) and (75) (See Fig. 1-22-8). DARK/BRIGHT field selector (43) must be turned each time the scan image is switched to the zoom image and vice versa.

Shift of the beam spot occurs with spot size selection, if the electron beam strikes the first condenser lens (c1) at an angle to its axis. This is corrected with the gun alignment controls (GUN TILT (41) and GUN HORIZ. (42) controls).

Set SPOT SIZE selector (43) to 2 μ, and align the crossover image with the center of the fluorescent screen by means of the BRIGHTNESS CENTERING controls (38). Then, set the spot

size selector (43) to 5 μ (or 10 μ) and align the image with the screen center by adjusting GUN TILT (41) and GUN HORIZ. (42) controls. Using the brightness centering and gun alignment controls, repeat these alignments until the image center remains in the screen center and no further alignments are necessary. During aligning, the filament current control should be slightly under saturation, so that the crossover image assumes a doughnut form.

V-2 COLUMN MAINTENANCE

V-2-1 Filament Exchange and Gun Cleaning

i) Turn the gun evacuation control switch to AIR. Refer to Section IV-2-1 (P. 4-31).

ii) Open the gun housing by flipping it backward as shown in Fig. 1-7.
When taking out the cathode assembly, be careful not to let dust fall on the gun housing.

iii) Check to ensure, by means of earth ring (45321041, Fig. 1-5-1) that the metal part of cable head (2) is grounded, and remove the set ring (44322169) by turning it counterclockwise. The whole cathode assembly is then taken out.

iv) Take off the grid cap (44322156), and exchange the filament.

v) If the inside of the grid cap is badly contaminated, clean it thoroughly with a fine, cotton-tipped bamboo stick to which metal polish has been applied. Polish the area around the grid aperture with special care.
After polishing, wipe off the polishing agent completely with solvent such as acetone or ether. The grid aperture should be cleaned very carefully and scrutinized with a magnifier. Detach the grid cap from the gun housing and clean it after

disassembling. To remove the grid plate (44322161), loosen two of the four centering screws (44322166) (Note: Do not use ultrasonic cleaning on any pole piece.) positioned at right angles to each other and then unscrew the setting of the grid (44322156). If only the vicinity of the grid aperture is to be cleaned, it is not necessary to disassemble the grid cap.

vi) Cover the filament with the grid cap, and check to ensure that the filament tip is at the center of the grid aperture. The filament is aligned by adjusting the position of the grid plate. To do this, loosen slightly the setscrew on one side and push out the plate with the setscrew on the other side. The two centering screws at right angles to each other are tightened at this time. If all setscrews are loosened, the direction in which the plate is shifted may not be maintained.

vii) Position the tip of the filament about 0.5 to 0.7 mm (i.e., about half the diameter of the grid aperture, 1.5 mmø) inside the grid aperture. If a brighter image is desired, position the filament tip closer to the grid aperture (0 to 0.3 mm).

viii) If the insulator becomes yellowish after long service, remove it from the gun housing and clean well. To remove the insulator, loosen the three setscrews (A) holding the cable head, and pull the insulator upward.

Handle the insulator with care.

Scratches on the metal part will cause discharges.

ix) When cleaning the insulator, polish the surface with metal polishing paste applied to a dry cloth. After polishing, wipe off the polishing agent completely, first with a clean dry cloth and then with gauze soaked in acetone or ether. Finally, wipe out dust and lint wiyh clean chamois or well-washed cloth. Before putting the insulator back in the gun housing, check to be sure that the surface is completely free from dust and lint.

To prevent the polishing agent and solvent from getting between the metal part and insulator, clean the insulator with the metal part upward. Dust or lint on the insulator and metal surfaces metal surfaces will cause discharges.

x) The inside of the gun housing can be cleaned in

the same manner as the insulator.

However, wiping only with a dry cloth or chamois is usually sufficient for cleaning the gun housing. Also, clean the glass cylinder (44323751) in the same manner. Any projection on the surfaces to which high voltage is applied, such as the inner wall of the gun housing and anode surface, causes discharges. Hence, these surfaces should be handled with care to avoid any scratching, and dust must be removed thoroughly and carefully.

xi) If the anode is contaminated, remove the anode plate (86) (See Fig. 1-3) by turning it counter-clockwise and clean it with polishing agent.

xii) After the filament is attached, close the gun housing and check that the housing is properly mounted on the O-ring. Then, turn the gun evacuation control switch (76) to EVAC. Pre-evacuation of the gun housing and opening of the gun airlock valve is automated and does not require further attention.

Check the O-ring for lint or dust. Do not grease the O-ring.

xiii) Unless the filament tip is badly misaligned, the

axial alignment after filament exchange should be accomplished at about the saturation point of the beam current with the GUN TILT (41) and GUN HORIZ (42) controls.

V-2-2 Anode Positioning Cylinder (See Fig. 1-6)

i) Remove the glass cylinder (44323751) from the gun housing.

ii) Loosen the two set rings (9602011) fixing the electron gun cover (45321071), and remove the six bolts (B) by lifting the electron gun cover. Loosen the set ring for electron gun evacuating pipe and remove the main evacuating pipe. (See Fig. 5-5)

iii) Lift the gun housing by means of a lifting device and turn it counterclockwise. (See Fig. 5-6)

iv) Detach the anode (45321031) by turning it counterclockwise, and also remove the anode positioning cylinder (45321030).

v) Remove the four bolts (C) of the magnetic yoke cover, and detach the anode positioning mechanism.

vi) Remove the airlock device.

vii) Clean the inside of the anode, anode positioning cylinder, and anode positioning mechanism with polishing paste, wash out the paste completely with organic solvent, and put them back in position.

Remarks: Replace the two O-rings of the mechanism once every year without fail and apply grease to them. The O-rings can be detached from the lower portion after step vi) above.

V-2-3 First Condenser Lens Fixed Aperture (See Fig. 1-8)

i) Introduce air into the column (see step (i) in IV-2-10) by loosening the set ring of the evacuating pipe of the gun chamber, and detach the pipe. Remove the four bolts (C) of the magnetic yoke cover. Raise the gun assembly gently with the lifting device (by its handle) until it stops. This reveals the first condenser lens. Turn the raised gun assembly counterclockwise.

ii) Remove the first condenser lens fixed aperture (45321063) from the first condenser lens, and clean the inside, especially in the vicinity of the aperture opening, with metal polishing paste, and completely wash it in an ultrasonic cleaner.

Remarks: The first condenser lens section is more susceptible to contamination than any other section in the column. If contaminated, the

crossover image becomes irregular. (Clean it once every three to six months.) With a magnifier, check that the polishing paste is completely washed out of the aperture, otherwise the electron beam is deflected by the paste residue.

iii) Set the aperture to the first condenser lens assembly as it was.

V-2-4 First Condenser Lens Pole Piece (See Fig. 1-8)

i) Remove the set ring (44321091) by turning it counterclockwise, and the first condenser lens pole piece (93) (see Fig. 1-4) can be detached.

Remark: It is not necessary to clean the pole piece unless it is badly contaminated.

ii) Clean the inside of the pole piece with a cotton-tipped bamboo stick using acetone or ether.

Remark: Do not damage or scratch the pole piece while cleaning.

iii) After cleaning, check with a magnifier that the pole piece is free of dust. Then, put it back in place and fix it with the set ring.

iv) Check that the O-ring is free of dust, and lower the gun assembly with the lifting device.

Remark: Check the O-ring grooves for dust. Do not grease the O-ring.

V-2-5 Second Condenser Lens (See Fig. 1-8)

(Cleaning: Every 6 months to one year)

i) The cylinder (second condenser lens fixed aperture; 45321012) in the second condenser lens stigmator can be detached by using the special tweezers (tweezers for specimen exchange) after removing the first condenser lens (44320102).

ii) To remove the second condenser lens stigmator (it is sufficient for ordinary cleaning to remove the cylinder only), detach it by removing the magnetic yoke cover (15321051) from the first condenser lens magnetic yoke.

Remark: Take cords, compressed air pipes, water pipes, and any other damageable parts out. When the water pipes are disconnected, be careful not to wet the instrument or the surrounding area. After the pipes are removed, cover the water inlets with vinyl bags.

iii) Put the stigmator and gun assembly back in position, and lower the part above the first condenser lens with the lifting device.

Remark: Check that the O-ring is free of dust. Apply a very small amount of grease to the sliding surface of the O-ring.

iv) Tighten the cap nut of the gun housing evacuating pipe.

v) Connect the lead wires and water pipes and open the water valve.

V-2-6 Cold Finger (See Figs. 1-17, 5-4)

(Cleaning: Every one to three months)

i) Introduce air into the column. Remove the cover (45321192) and then setscrews (9600119), and pull out the cold finger gently.

Remark: If the aperture of the cold finger is badly contaminated, the effect is similar to an increase in objective lens astigmatism.

ii) Loosen the setscrew (44322931) to take out the cold finger (45320169) at the tip.

iii) Polish the cold finger with polishing paste. In particular, clean the inside of the aperture opening with a cotton-tipped bamboo stick using polishing paste.

Remark: Do not bend the cold finger (45320169) or it may contact the specimen or movable aperture.

iv) After polishing, wash the aperture plate in an ultrasonic cleaner. Check that the plate is free of dust, and put it back mounting, the aperture opening upward.

v) Put it back in the objective lens assembly. The movable aperture and specimen must not be in place at this time. Look at the cold finger through the insertion port for the movable aperture, and align it accurately. The adjusting screw (45321193) is used for lateral and up-and-down adjustment, whereas the adjusting screw (45321560) is used for back-and-forth adjustment.

Remark: The cold finger is placed between the specimen and movable aperture.

V-2-7 Grid Holder

(Cleaning: Every one to three months)

i) Before the grid holder is disassembled, remove the cap and measure the height accurately. (With a micrometer if possible) (Fig. 1-11-2)

ii) Loosen the small setscrews (9602401) (it is unnecessary to remove them), and detach the cylinder (44321414) by turning it counter-clockwise.

iii) Clean the inside of the cylinder carefully (the other parts may also be cleaned at this time).

iv) Wash it in an ultrasonic cleaner and reassemble. Set the height of the cylinder at the original position, and fix it with the setscrews (9602401).

(v) Clean the outside of the cylinder.

Remarks:

A) When the grid holder is contaminated, the crossover image shifts irregularly or the specimen drifts (the image moves depending on the intensity of the electron beam).

B) The image goes out of focus when the height of the cylinder is changed. To place the cylinder in the focus position, adjust the cylinder height with all focus controls set at mid range.

The specimen must be flat and placed with the surface downward.

V-2-8 Cleaning of Movable Apertures

i) The second condenser (C2) and objective (Obj.) apertures are molybdenum plates. If contamination is slight, these apertures can be cleaned by irradiating with the electron beam.

The movable apertures are the second condenser lens, objective lens and field limiting apertures. When the C2 aperture is contaminated, the cross-over astigmatism increases, and the resolution deteriorates when the objective aperture is contaminated. If the field limiting aperture is contaminated, the diffraction image is distorted and the resolution index is lowered. In order not to damage the main fluorescent screen, excite all lenses and use the auxiliary screen.

Contamination is accelerated by poor vacuum conditions. Use liquid nitrogen as much as possible.

When cleaning the C2 aperture, insert the aperture in place and heat it by irradiating with a beam current of 50 to 100 μA for 30 seconds to one minute. The spot size is set at 20 to 50 μ (50 μ spot can be obtained by using the C1 fine control) and the accelerating voltage at 100 kV.

To clean the objective aperture, take out the specimen and C2 aperture from the column and

focus a crossover image of 50 μ on the objective aperture. Irradiate the aperture opening uniformly with the electron beam while adjusting the objective aperture aligning knob so that the aperture opening receives about 80% of the beam.

ii) The field limiting aperture can be removed easily through the airlocking. Hence, it is better to take it out and clean it in a vacuum evaporator.

iii) The C2 and objective apertures should be cleaned by vacuum-heat cleaning, if contamination remains after irradiation or if there is dust on these apertures. Break the column vacuum, and take the apertures out of the column. Clean the aperture plate by vacuum-heating and the aperture holder with metal polishing agent. After polishing the holder, the polishing agent should be washed out completely with an ultrasonic cleaner.

(iv) When subjected to the electron beam cleaning method once a week, the C2 and objective apertures may be used for one to three months without needing vacuum-heat cleaning (this depends on the kind of specimen examined and the duration of service). It is recommended that the apertures

be cleaned by electron beam irradiation even while the instrument is not in use.

(v) When to Clean the Apertures

C2 Aperture ..... Clean the aperture when the crossover image shifts with displacement of the aperture.

Obj. Aperture ... While observing a high magnification image of a collodion film hole, displace the aperture a little. The image shifts or astigmatism varies at this time when the aperture is contaminated.

Diff. Aperture .. Obtain a SA image. If charge up is observed on the edge of the aperture, the aperture requires cleaning.
When the aperture plate and holder are badly contaminated, the main (center) spot looks like a rod rather than a spot.

V-2-9 Objective Stigmator (See Fig. 1-14)

(Cleaning: Every 6 to 12 months)

i) Remove the cap nut (45321428) (See Fig. 1-8) of the main specimen chamber evacuation pipe and its pre-evacuating pipe with a hex key. Also, remove the cap nut of the gun housing evacuating pipe.

ii) Remove the four screw-bolts (D) (See Fig. 1-3) fixing the specimen chamber, and raise the part above the specimen chamber with the lifting device until it stops. When it is fully raised, turn the assembly to the left.

iii) Remove the four screws (45321161, See Fig. 1-14) and universal joint of the specimen positioning device so as to detach the specimen rotation stage.

Remark: Also remove the objective lens movable aperture and cold finger.

iv) Remove the set ring (44321559, See Fig. 1-14), and take out the objective lens pole piece (97) (See Fig. 1-4).

v) Hold the groove on the top of the stigmator firmly with the special tweezers (tweezers for specimen exchange) and pull it out upward.

vi) Polish the stigmator and its inner walls surfaces of electron beam passage) with metal polishing paste.

vii) Wipe off the paste with cotton soaked in organic solvent.

(Do not wash the stigmator in an ultrasonic cleaner.)

Remark: Do not damage coil or lead wires, or contaminate them with polishing paste.

viii) Put the stigmator back in place. Be sure that the terminal is properly oriented.

Rmmark: The stigmator should fit easily. Do not force it in.

ix) Put the pole piece back in position. While looking through the insertion port of the objective movable aperture, align the aperture with the insertion port and fix the pole piece with the set ring.

x) Assemble the parts above the specimen chamber as they were. Do not forget to connect the main and pre-evacuation pipes, water pipes, air pipes, cords, etc., properly.

Caution: When reassembling the specimen chamber

by using a lifting device, take care not to strike the set ring (45321428) of the specimen chamber rear evacuation pipe against the set knob (44321708) of the objective lens magnetic yoke during the lowering operation of the specimen chamber to prevent the set ring from being damaged.

V-2-10 Intermediate Lens Fixed Aperture (See Fig. 1-18)

When the fixed aperture of the intermediate lens and the inner wall of the stigmator are contaminated, the electron diffraction spot deforms. It is necessary to clean it once every 6 to 12 months.

i) Raise the part above the specimen chamber with the lifting device in the manner outlined in V-2-9.

Remarks: Since the part to be raised is very heavy, the magnetic yoke may move backward when the column is fully raised by the lifting device. Therefore, push the evacuating pipes into the column to make sufficient space before the column is raised.

ii) Remove the second specimen chamber evacuating pipe (45321429) Fig. 1-14), cooling water pipe, and selected area aperture and base in the second specimen chamber.

Detach the specimen stage control rod by loosening the locking screws (45321511).

iii) Remove the four bolts (E) (See Fig. 1-3) from the magnetic yoke cover, and disassemble the objective lens assembly by using the attached tools. Don't damage the contact surface of the O-ring.

iv) Take out the intermediate lens fixed aperture (44322787: See Fig. 1-18) with the special tweezers, and polish the aperture with metal polishing paste. After ultrasonic washing, put it back in position.

VI. MAINTENANCE AND CHECK OF THE ELECTRONIC SYSTEM

VI. MAINTENANCE AND CHECK OF THE ELECTRONIC SYSTEM

VI-1 Unit Code and Part Code

The electronic and evacuation units built into the microscope console and power supply cabinet are coded with four digit numbers. The first two digits of the code number are "12", denoting the Model HU-12A. The last two digits represent a consecutive unit number. There are 24 units thus designated by the unit code system. The unit codes are listed in Table 1. Fig. 6-1 shows the arrangement of the units. Various parts of the electric system are designated by part code.

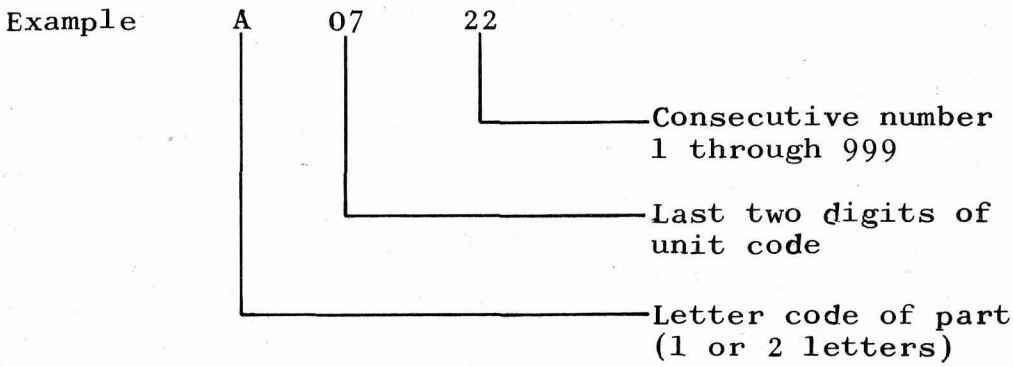

Table 2 lists the letter codes of parts. Printed-circuit board parts having the same function are designated by the same part code, and can be specified by circuit board number (example: CT-151, CT-371, etc.). Various marks and abbreviations used in drawings and on equipment are given in Table 3.

Table 1 Table of Unit Codes (1)

Unit	Code	Unit
01	COMMON POWER SUPPLY	AC POWER SUPPLY
02	"	DC POWER SUPPLY
03	"	HIGH VOLTAGE TRANSFORMER
04	(Blank)	
05	(Blank)	
06	(Blank)	
07	COLUMN CAMERA	
08	EVACUATION SYSTEM	
09	VAC GAUGE	
10	RIGHT CONTROL PANEL ASSEMBLY	
11	RIGHT SUB PANEL	
12	RIGHT MAIN PANEL	
13	OBJ. COARSE PRINTED CIRCUIT BOARD	
14	RIGHT INDICATOR PANEL	
15	EVAC INDICATING PRINTED-CIRCUIT BOARD	
16	CAMERA SEQUENCE PRINTED-CIRCUIT BOARD	

Unit	Code	Unit
17	EXPOSURE TIME PRINTED-CIRCUIT BOARD	
18	RIGHT DIST. PRINTED-CIRCUIT BOARD	
19	(Blank)	
20	RIGHT CONSOLE	
21	BEAM DEFLECTOR POWER SUPPLY	
22	EVAC SEQUENCE	
23	RIGHT CONNECTOR BOARD	
30	LEFT CONTROL PANEL ASSEMBLY	
31	LEFT SUB PANEL	
32	SPOT SIZE PRINTED-CIRCUIT BOARD	
33	OBJ MODUL PRINTED-CIRCUIT BOARD	
34	BANK PRINTED-CIRCUIT BOARD	
35	LEFT MAIN PANEL	
36	MODE SWITCH PRINTED-CIRCUIT BOARD	
37	HV SWITCH PRINTED-CIRCUIT BOARD	

Unit	Code	Unit
38	LEFT INDICATOR PANEL	
39	MODE INDICATOR PRINTED-CIRCUIT BOARD	
40	LEFT CONSOLE	
41	LEFT PRINTED-CIRCUIT BOARD	
42	HV PRINTED-CIRCUIT BOARD	
43	LENS CURRENT REFERENCE RESISTOR	
45	HEAT SINK LENS PRINTED CIRCUIT BOARD	
46	MAGNIFICATION UNIT	
48	LEFT CONNECTOR BOARD	
50	LEFT DIST. PRINTED-CIRCUIT BOARD	

Table 2 Table of Part Codes (1)

Code Letter	Part
A	Connector
B	Pilot lamp
C	Capacitor
CT	Printed circuit doard

Code Letter	Part
D	Diode, rectifier
ET	Counter, Nova lamp
F	Fuse
IC	IC, Micro module
L	Inductor coil, Choke coil
M	Motor, Meter
Q	Transistor
R	Resistor, Thermistor
SW	Switch (Lever, Rotary, Toggle, Slide), Microswitch
T	Transformer
TP	Terminal, test point
VR	Variable resistor
Y	Relay
ZD	Zener diode

Table 3 List of Marks and Abbreviations

AC ..... Alternating Current

ACC ..... Accessory

ACCEL ..... Accelerating Voltage

ADJ ..... Adjustment

AIR ..... Air leak

AMP ..... Amplifier

APS ..... Air pressure switch

BD ..... Beam deflector power supply

BT ..... Buffer tank

BZ ..... Buzzer

CCT ..... Circuit

COL ..... Column

COMP ..... Compressor

CONN ..... Connector, connection

CONTR ..... Contrast, high contrast

CV ..... Camera valve

C1 ..... First condenser lens

C2 ..... Second condenser lens

DC ..... Direct current

DIFF ..... Diffraction

DIST ..... Distributor printed circuit board

DP ..... Diffusion pump

ERR ..... Error

EVAC ..... Evacuation

FIL ..... Filament

G ..... Grid

GV ..... Gun valve

HIGH ..... High vacuum

HORIZ ..... Horizontal

HV ..... High voltage

INT ..... Intermediate lens

LENS ..... Lens current stabilizer circuit

LIP ..... Left indicator panel

LMP ..... Left main panel

LOW ..... Low vacuum

LSP ..... Left sub panel

MAG ..... Magnification

MODUL ..... Modulation

MV ..... Magnetic valve

MVL ..... Magnetic leak valve

OBJ ..... Objective lens

PE ..... Penning gauge

PI ..... Pirani gauge

PROJ ..... Projector lens

RESOL ..... Resolution, high resolution specimen holder

RIP ..... Right indicator panel

RMP ..... Right main panel

RP ..... Rotary pump

RSP ..... Right sub panel

SA ..... Selected area

SEQ ..... Sequence

STB ..... Stability, stabilizer

STD ..... Standard

STIGM ..... Stigmator

TILT ..... Tilting

TRS ..... Transistor

VAC ..... Vacuum

WPS ..... Water pressure switch

VI-2 Check Terminals

The check terminals required for the electric circuit are built in the lens power supply PCB, HV stabilizer PCB, bank PCB, and camera sequence PCB. For each terminal, see the circuit diagram. However, these terminals are not necessary for ordinary check (See Fig. 6-2).

VI-3 Changing Fuses

The arrangement of power supply fuses is shown in Fig. 6-3.

The specifications for these fuses are given in Table 4.

i) When a fuse is blown, check and ascertain the cause of failure before inserting a new one.

ii) Do not use fuses not specified in the table below.

iii) Turn off the power supply when the fuses are changed.

iv) Thermal relays are incorporated in COL and EVAC switches to shut down overcurrents. Of the three fuses (23A, 27A, 32A), the current should be set to 23A for proper operation.

Table 4 Table of Power Supply Fuses

UNIT NAME	FUSE NO.	REMARKS	DESCRIPTION
AC POWER	F011	5A	EVAC DC24V
SUPPLY	F012	10A	EVAC AC100V
(01 UNIT)	F013	10A	EVAC AC100V
	F014	1A	COL AC100V
	F015	1A	COL AC100V
	F016	50A	MAIN SW AC100V
	F017	50A	MAIN SW AC100V
	F018	3A	SUB CONCENTRE AC100V
	F019	3A	SUB CONCENTRE AC100V
RIGHT DIST.	F1	1A	EVAC AC100V
PRINTED-	F2	1A	EVAC AC100V
CIRCUIT BOARD	F3	3A	COL, LAMP DC24V
(18 UNIT)	F4	1A	MAIN SW DC24V
(CT181)			

UNIT NAME	FUSE NO.	REMARKS	DESCRIPTION
LEFT DIST.	F1	5A	LENS COND 1
PRINTED-	F2	5A	LENS COND 2
CIRCUIT BOARD	F3	5A	LENS OBJ
(50 UNIT)	F4	5A	LENS INT
(CT501)	F5	5A	LENS PROJ 1
	F6	5A	LENS PROJ 2
BEAM	F1	1A	GUN TILT-X
DEFLECTOR	F2	1A	GUN TILT-Y
POWER SUPPLY	F3	1A	GUN HORIZ-X
(21 UNIT)	F4	1A	GUN HORIZ-Y
(CT211)	F5	1A	BEAM TILT-X
	F6	1A	BEAM TILT-Y
	F7	1A	BEAM HORIZ-X
VACUUM	F8	1A	BEAM HORIZ-Y
GAUGE	F091	2A	VACUUM GAUGE AC100V
(09 UNIT)			

When the thermal relay has been actuated, turn COL (56) and EVAC (55) button switches of MAIN SW off and check the cause of failure. To turn on COL and EVAC switches after failures, depress the white translucent reset lever and reset the thermal relay.

VI-4 Electromagnetic Cooling Water Valve (Optional Accessory)

The electromagnetic cooling water valve is an automatically operated valve for cooling water supply, and is fitted to the water pipe close to the water jacket. It is open while the MAIN switch (SW011) of the common power supply is on and closes 15 to 30 minutes (set by a motor timer) after power shutdown. The connection of the electromagnetic valve is shown in Fig. 6-5.

With the electromagnetic water valve, the cooling water is not only supplied when the main switch is turned on, but is also shut down automatically when the main switch is turned off.

Thus the water supply is stopped by means of the timer after the DP is cooled down.

For the rated supply voltage and current of the electromagnetic valve, use about 240V, 2A at maximum to meet wiring capacity. The timer should be set at 20 to 30

minutes for proper operation. Before the timer dial is set, do not forget to turn off the knife switch at the switchboard mounted in the room. If the dial is turned while the timer is supplied with power, the timer will be broken.

VI-5 Grounding of Power Supplies

The electric systems of Model HU-12 are, as a rule, grounded through one system. That is, the grounding systems of various electric systems are concentrated at the grounding board at the rear of right and left consoles, and a ground wire is installed from the board to the switchboard through the common power supply. The grounding at the switchboard should be better than 10Ω, but must not exceed 100Ω.

VI-6 Room Lighting Switch

The installation room lamp can be turned on and off by the ROOM LIGHTING switch on the right main panel. Connect the lamp power supply to TP013, 11, and 12 of the common power supply as shown in Fig. 6-6. (A current of 3A max. is recommended to meet the wiring capacity.)

VII. SPECIFICATIONS

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Accelerating voltage: 10, 25, 50, 75, 100, 125 kV

Stability: 3×10^{-6}/min.

Magnification range

First specimen chamber

- 1,000x to 500,000x (HR)
- 600x to 300,000x (HC)
- 4,000x to 250,000x (SA)
- 250x (scanning image)

(direct reading through digital display)

- 500x to 500,000x (HR, continuously variable)
- 300x to 300,000x (HC, continuously variable)

Second specimen chamber (Extremely low magnification)

Optional

50x to 3,000x

Resolution: 2 Å (lattice) or 3 Å (point-to-point)

Electron diffraction	Camera length	Resolution index
Selected area diffraction		
	100 to 2,000 mm	5×10^{-6}
High dispersion diffraction		
	500 to 30,000 mm	2×10^{-6}
High resolution diffraction		
	395 mm, 505 mm	1×10^{-6}

Magnifications selection	Zoom lens system, magnification selectable in 35 steps Bright/Dark image, instantaneous selection
Photography/Recording	Focusing with image wobbler Fully automatic shutter linked to exposure meter Automatic recording: film number, accelerating voltage, lens operating condition, magnification
Electron gun	Hairpin type filament or pointed filament, DC heating 0 to 1,500V continuously variable Semi-fixed bias system Anode positioning linked to accelerating voltage Axial alignment: magnetic deflector Airlock: automatic valve system
Condenser lens	Double condenser lens system Specimen illumination area: 2, 5, 10, 15 μφ (4 steps), fine adjustment possible for 0.1 μ to 50 μφ Second condenser lens with magnetic stigmator Movable aperture: 4 openings, click-stop type Molybdenum aperture: self-cleaning type

First specimen chamber	Specimen pre-evacuation chamber Automatic valve system with priority sequence Number of specimens to be accommodated: 6, simultaneously Specimen stage control: $\pm$1 mm in either X or Y direction Specimen supporting grid: 3.2 mmϕ (standardized product)
Anticontamination device	Double contamination prevention system: Cold trap in evacuation pipe Cold finger adjacent to lens Contamination rate: 0.1 Å/min. or less
Objective lens	Intrinsic astigmatism 0.7 μ or better, compensatable to 0.01 μ With magnetic stigmator Maximum correction: 3 μ Movable aperture: 4 openings, clickstop type Molybdenum aperture: self-cleaning type

Focusing	Image wobbler system
	Click-stop focus adjustment system:
	Very fine: 50 Å/step — each adjustment in 22 steps
	Fine : 500 Å/step — each adjustment in 22 steps
	Medium : 5,000 Å/step — each adjustment in 22 steps
	Coarse : 5 μ/step — each adjustment in 22 steps
Second specimen chamber	Field limiting aperture device
	(standard equipment):
	6 openings, click-stop type
	Six-position specimen exchange holder
	and airlock device (special accessories)
	for click-stop specimen exchange
	Simultaneous loading of 6 specimens
	and $\pm 10^{o}$ specimen tilt (stereo) possible
Lens current stability	Objective lens 1.5×10^{-6}/min.
	Intermediate lens 5×10^{-6}/min.
	First projector lens 5×10^{-6}/min.
	Second projector lens 5×10^{-6}/min.
Viewing chamber	Window 130 mm x 100 mm (three sides)
	Fluorescent screen 190mmø (1 pc)
	40mmø (2 pcs)
	(for focusing and axial alignment)

Exposure meter	Beam detection system
	Readout of electron current possible
	Detecting range: 10^{-8} to 10^{-12} A/cm^2
	Shutter speed (exposure time): 1/2 to 32 seconds
Camera system	Automatic film feeding
	Film size: 82.5 x 118 mm (Japan)
	3-1/4" x 4" (U.S.A.)
	90 x 120 mm (Europe)
	No. of films loaded: 24
	Exposure size: 55 x 70 mm
	(48 exposures or half size)
	75 x 90 mm (24 exposures or full size)
	Residual film no. and film zero indications with chime
	Half size/Full size selectable
	Airlock: automatic valve system
	Plate reservoir: 4 cassette magazine accommodation, automatic evacuation
Vacuum system	Fully automatic sequence control
	Ultimate vacuum: 5 x 10^{-6} Torr
	Oil diffusion pump (column): 400 ℓ/sec. (1 set)

	Buffer tank
	Oil rotary pump: 100 ℓ/min. (2 sets)
	Cold trap: liquid nitrogen (2 sets)
	Vacuum gauges: Pirani gauges (2 sets), Penning gauge (1 set)
	Air compressor (1 set)
Safety devices	Safety device against power failure
	Safety device against water failure (with alarm)
	Safety device against overheating of DP
	Safety device against vacuum leaks
	Safety device against excess currents
	Safety device against electron gun discharge
	Safety device against excessive temperature of power transistors and reference resistors
Monitoring systems	Vacuum system operation indicator panel
	Lens condition indicator panel
Installation	
Ambient conditions	Room temperature: Less than 30°C

	Humidity: Less than 70%
Power service	3.5 kVA, single phase, AC100V
	Single phase 90, 100, 115, 200, 220, 240V
	(overseas)
	50 Hz or 60 Hz
Water service	Flow: 4 ℓ /min.
	Water pressure: 0.5 - 2 kg/cm^2
	Water temperature: Less than 25^{o}C
	Drainage: Ordinary drain port

Dimensions and weight

	Dimensions	Height	Weight
Main console	199 x 144 cm	255 cm	1,230 kg
Power cabinet	80 x 57 cm	80 cm	120 kg (150 kg for overseas)
Oil rotary pump	31 x 57 cm	60 cm	100 kg
Compressor	25 x 59 cm	53 cm	26 kg