X-ray unit, 35 kV, basic unit

09058.99

Operating Instructions

CE

The unit complies with the corresponding EC guidelines.

PHYWE SYSTEME GMBH · Robert-Bosch-Breite 10 · D-37079 · Göttingen · Telefon (05 51) 6 04-0 · Telefax(05 51) 60 41 07

A GENERAL INFORMATION

1. Requirements of the German X-ray Regulations

The operation of an X-ray apparatus is governed in Germany by the requirements stipulated in the X-ray Regulations. This X-ray unit fulfils the obligatory conditions specified in these Regulations, not only as an X-ray apparatus for educational use in schools, but also as a completely protected apparatus.

The operation of the unit does not require official permission, but it is obligatory to report it. This can be done by filling out a form and submitting it to the responsible authorities. The unit must only be operated by staff who have been appropriately trained and instructed.

When the unit is running at the specified maximum values, the local dosage rate at a distance of 0.1 m from the parts of the casing which can be touched is less than 1 µSv/h. This value corresponds roughly to the natural radiation dose.

Two safety circuits which act independently of each other monitor the opening of the sliding door to the experimenting area. The production of X-rays is only possible when this sliding door is properly locked. Safety circuits also prevent the maximum permissible tube operating specifications from being exceeded.

The authorization to operate the unit expires as soon as manipulations other than those required to set it up, or to carry out experiments, are carried out on the unit. The safety screws on the steel sheet casing must on no account be detached. Repairs are to be carried out exclusively by the manufacturer.

2. Safety precautions

As the X-ray unit produces radiation which is hazardous to health, it must only be operated by appropriately instructed and qualified staff.

During the handling of the X-ray unit, all of the obligatory measures and duties detailed in the X-ray Regulations must be strictly followed.

The operator must pay particular attention to the following:

- The X-ray unit must be so protected that it cannot be accessed by unauthorized persons.
- The X-ray unit should not be kept in operation for longer than necessary.
- When the unit is in operation, no person should stay longer than necessary in its immediate vicinity.

Operation of the unit is forbidden, when

- the sliding door which is made of acrylic glass containing lead and opens the experimenting area, or the protective glass window for observation of the X-ray tube, or the fluorescent screen is damaged.
- the ventilator on the tube insertion side inside the unit does not work (acoustic test).
- the safety circuits for interrupting the operation of the tube on opening the sliding door do not work flawlessly.

3. Purpose of the unit

The X-ray unit has been specially developed to fulfil the needs of an educational unit for demonstration purposes and for practical work in schools and high schools. In addition to its application in teaching Physics, however, it is also excellently suitable for use in medical technology and related technical disciplines. A particularly noteworthy distinguishing feature of this microprocessor-controlled compact unit is the quick-tube-change technique, which enables experiments to be carried out with diverse X-ray tubes having different anode materials.

The available choice of X-ray tubes, each prepared ready-for-use as a special insert, is as follows:

-- Insert with Cu X-ray tube Order no. 09058.50
-- Insert with Mo X-ray tube Order no. 09058.60
-- Insert with Fe X-ray tube Order no. 09058.70

Alongside simple fluoroscopic experiments and experiments on dosimetry, the use of the rate-meter installed in the unit and the goniometer, which is available as accessory, enable spectroscopic experiments on atomic physics and solid-state physics to be carried out.

X-ray spectra can be registered with a directly connected xy-recorder or a computer. All operating and controlling parameters can be set either manually or with a computer.

Two demonstrative digital displays serve both to present all operating and controlling parameters as well to display measured values.

The following experiments can be carried out with the X-ray unit and appropriate accessories:

- Radiation through objects using a luminous screen for observation
- Preparation of X-ray films from irradiated objects
- Detection of the ionizing effect of X-rays (dosimetry)
- Detection of Bragg reflection
- Registration of X-ray spectra
- Determination of the characteristic X-ray lines of various anode materials (Cu, Mo, Fe), thereby verifying Moseley's Law
- Detection of the characteristic lines $K\alpha 1$ and $K\alpha 2$ in higher order diffraction
- Monochromatisation of X-rays with single-crystals or metal foil
- Analysis of crystal structure by means of X-ray spectroscopy, the Laue and Debye-Scherrer methods
- Determination of Planck's quantum of action from the short-wave limit of the retardation spectrum (Duane-Hunt's Law of Displacement)
- Determination of the Rydberg constant
- Determination of absorptions coefficients as function of the thickness and the atomic number of the absorber material and the photon energy
- Detection of edge absorption
- Demonstration of the action of contrast media in medicine
- Compton scattering

B DESCRIPTION OF THE COMPONENTS

1. The basic unit (Fig.1)

The following functional elements are contained in the basic unit:

1 Experimenting area
Space for holding additional equipment, such as a goniometer or other experimental material.

2 Control panel
For setting all operating values and control quantities, as well as for the ouput of all available measured values.

3 Observation window
For observation of the X-ray tube, even during operation.

4 Digital displays
Two 4-digit LED displays with diode matrices for selection of parallel displays of operating and measured values.

5 The tube-insert compartment for the various X-ray tubes

6 Fluorescent screen

7 The accessory box
Additional equipment can be placed here so that they are readily available.

8 Door-lock

9 Mains connection (at the back)
With mains connection socket, on/off switch and fuse box.

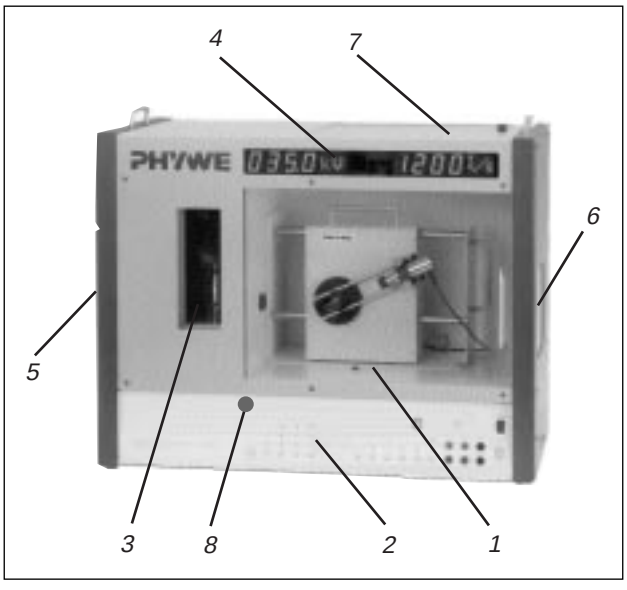


Fig. 1 Basic unit (09058.99)
with goniometer (09058.10) installed.

2 The experimenting area (Fig. 2)

The experimenting area contains the following functional elements:

1 The sliding door
Made of acrylic glass containing lead. The door can only be opened after undoing the corresponding lock. To do this, push the locking-knob in to the stop and hold it there while you rotate it a quarter turn to the right so that it engages. The X-ray unit will only operate when the door is locked. To do this, rotate the locking-knob a quarter turn to the left.

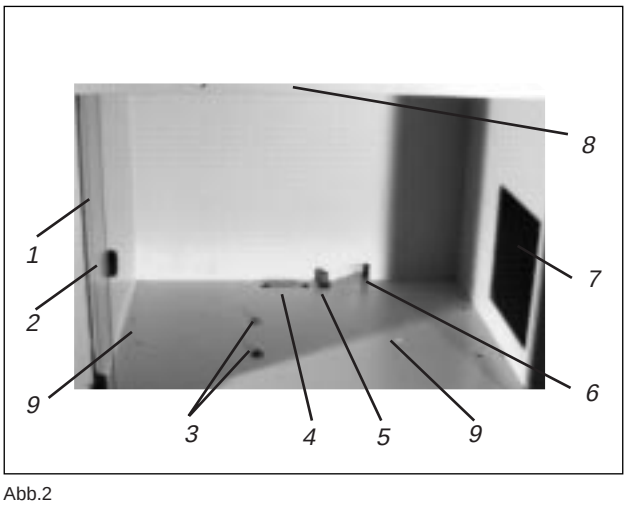
2 Radiation outlet
This accepts a metal tube with a circular double diaphragm which generates a beam suited to the particular experiment.

3 Pair of sockets
Pair of 4 mm sockets for connection of the capacitor plates (order no. 09058.05) for dosimeter experiments.

4 SUB-D socket
For connection to the insertable goniometer. The unit must be switched off before the connecting cable of the goniometer is fitted into this socket.

5 BNC socket
For connection of a Geiger-Müller counter to the internal rate meter.

6 Working channel
Inlet opening which can be used from the outside during operation, e.g. to introduce contrast medium into the experimenting area.



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7 Fluorescent screen
Acrylic glass which contains lead and has a fluorescing coating for observing the X-ray image in fluoroscopic experiments.

8 Internal lighting
24 V / 10 W lamp which can be switched on to illuminate the experimenting area.

9 Threaded drillhole for fixing the goniometer

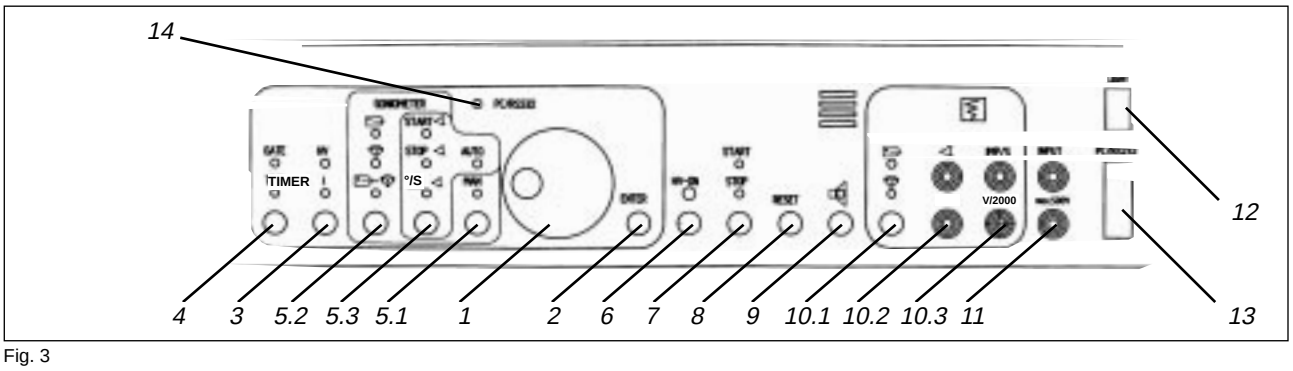


Fig. 3

3. The control panel (Fig. 3)

The inwardly inclined, shear-protected control panel holds all the operating elements for putting the X-ray unit, and the goniometer, to use.

1 Adjusting wheel
For setting all variable functions. This dynamically working incremental generator can be turned backwards or forwards. When it is turned more quickly, the steps are greater. The adjusted value is only entered after the "ENTER" button is pressed. Values set with the incremental generator are shown in the upper left digital display.

2 The "ENTER" button
For entering the operating and functional values set with the adjusting wheel.

3 The "HV-I" button
Pressing this button alternately activates the adjustment possibilities for the tube high-voltage (0.0 kV ... 35.0 kV) or the emission current for the X-ray tube (0.00 mA ... 1.00 mA). The corresponding LED and the digital display each indicate which of the two operating quantities, "HV" or "I", has been selected. Use the adjusting wheel to adjust "HV" or "I" to the operating value required, and successively confirm by pressing "ENTER".

4 The "GATE-TIME" button
For selection of either the counting time "GATE" (0.5 s ... 100 s) of the incorporated rate-meter, or the exposure time (1 min ... 10000 min) for X-ray photographs. Use the adjusting wheel to adjust the selected time to the value required, and subsequently confirm it by pressing "ENTER". The set "GATE" value for the counting time of the rate meter is also simultaneously the time for an angle step of the counting tube or sample holder alone or for both together in a 2:1 coupled mode.

5 Panel section for controlling the goniometer

5.1 The "MAN-AUTO" button
For selection of manual or automatic rotation of the counter tube or sample holder. In manual operation, rotation is achieved by turning the adjusting wheel.

5.2 The button with symbols for counter tube - crystal - counter tube + crystal
For selection of the drive of the sample or counting tube holder, either separately or both synchronously.

5.3 The "START - STOP - ^{0}/S" button
For selection of the starting angle "START", the stopping angle "STOP" and the stepping "^{0}/S".
The required values of the angles are again set using the adjusting wheel and then confirmed with "ENTER".
The selected angles, and the actual angle, are shown in the left digital display.

6 The "HV-ON" button
A press on this button activates the tube high-voltage and emission current of the values previously set., and also lights up the red LED signal. A further press on the button switches the tube high-voltage and tube cathode heating off and extinguishes the LED.

7 The "START-STOP" button
To start or stop the automatic drive of the sample holder and/or counting tube holder, as well as to start exposure times.

8 The "RESET" button
For driving the counting tube holder and sample holder back to their previously selected starting position.

9 Button with a loudspeaker symbol
For switching on the rate-meter loudspeaker to have events acoustically signalled.

10 Panel section for "analogue output"

10.1 Button with counting tube and crystal symbols
For choice of output of the analogue voltage for the angular position of the sample holder or counting tube holder at the pair of sockets 10.2.

10.2 Pair of sockets with angle symbol
Pair of 4 mm sockets for pick-up of a direct voltage proportional to the angle, giving the angular position of the sample holder or counting tube holder.

10.3 Pair of sockets "IMP/S"
Pair of 4 mm sockets for pick-up of a direct voltage proportional to the counting rate.

11 Pair of sockets "INPUT"
Pair of 4 mm sockets for feeding a voltage (max.500 V) into the experimenting area. The sockets are connected to the two sockets in the base plate of the experimental area.

12 "LIGHT" switch
For switching the interior lighting on and off.

13 Socket "PC/RS232"
SUB-D socket for connection of a PC for complete control of the system.
When the socket is engaged, LED 14 lights up.

14 LED
Display to show that the SUB-D socket is engaged.

4 The observation window

This is an opening covered with radiation-protective glass for safe observation of the X-ray tube while it is in operation.

5 The digital displays

Two 4-digit LED displays with diode matrices for selection of parallel displays of operating and measured values with their corresponding units.

The LED display on the left can be used selectively to display the following quantities:

- Tube voltage (kV) and emmission current strength (mA)
- Starting and stopping angle of the counter tube holder or crystal holder (with angle symbol)
- Actual angular position of the counter tube holder or crystal holder (with angle symbol)
- Angle stepping (with angle symbol) and angle speed (with angle symbol/S)
- Exposure time (min)
- After the unit is switched on, the tube type in use (Cu or Mo or Fe) is shown for about 3 seconds
- The LED display on the right displays the counting rate (I/s)

  The maximum counting capacity of the internal rate meter is (8192 = 2^{14}) counts/s. Should this be exceeded, "9999" appears in the display.

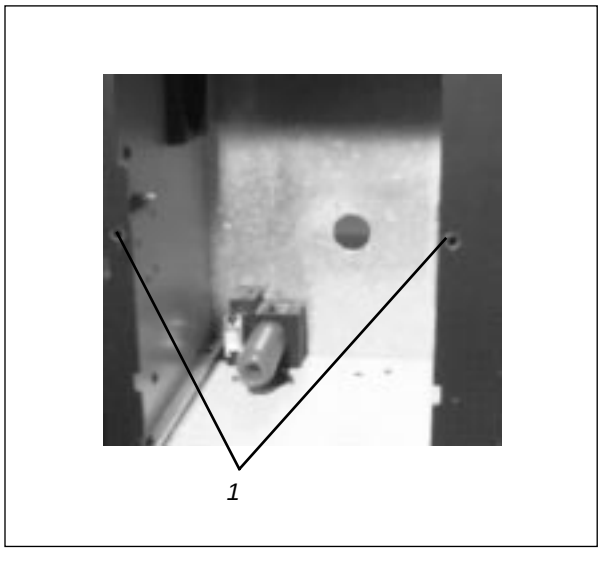


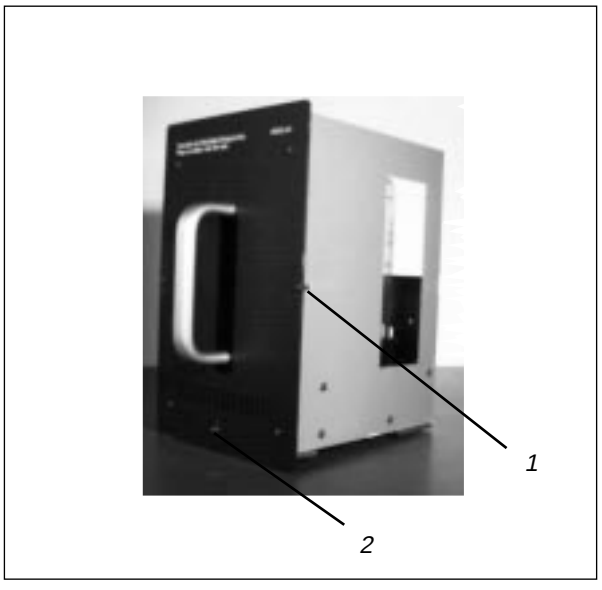
Fig. 4

6 The tube-insert compartment (Fig. 4)

The opening in the left side of the unit is a compartment which accepts any one of the various, ready-to-use X-ray tube inserts. At the sides of the compartment there are connecting plug sockets (1) connected with safety switches. Two switching pins on each X-ray tube insert are appropriately positioned, so that the microswitches only close the safety circuit supervising the tube high-voltage when the insert is correctly inserted and fixed in position.

7 The accessory box

A storage box on the top of the unit which can be closed with the sliding cover. Accessories can be placed in it for immediate availabilty.



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C The X-ray tube inserts (Fig. 5)

(These are avalable as accessories. They are not supplied with the basic unit)

The following X-ray tubes are available, each as a ready-for-use insert:

- Insert with Cu X-ray tube Order no. 09058.50
- Insert with Mo X-ray tube Order no. 09058.60
- Insert with Fe X-ray tube Order no. 09058.70

(Refer to the Appendix for the wavelengths and energies of the characteristic X-ray lines of each of these)

Each insert consists of a sheet steel housing with an X-ray tube which has been factory adjusted.

To prevent harmful overheating of the tubes during their operation, each is surrounded by a Duran glass cylinder, the side ends of which are subjected to forced air cooling by means of the ventilator in the basic unit.

Each insert has an HV plug and a plug for the tube cathode heating, so that it can accept the tube operating quantities from the corresponding basic unit plug sockets. Two switching pins (1) on the sides of each insert only operate the correspondingly positioned microswitches in the side walls of the tube-insert compartment when the insert is correctly inserted.

A mechanical lock (2) at the bottom edge of the front plate of each insert must be released by lifting up the safety catch before the insert can be taken out or inserted.

D The goniometer (Fig. 6)

(not standardly supplied with the basic unit)

The goniometer block has two stepping motors, which work completely independently of each other, and with the help of which the sample holder (crystal or Compton scattering body) or the counting tube holder (Geiger-Müller counting tube) can be rotated separately or also coupled in a 2:1 angular relationship.

Caution!

<u>When mounting the goniometer in position, always ensure that the basic unit is switched off before connecting the goniometer cable to the SUB-D socket in the base plate of the experimenting area!</u>

Similarly, the basic unit must be also be switched off before the goniometer cable is disconnected from the SUB-D socket.

Fix the goniometer firmly to the base plate of the experimenting area with the two milled screws (1).

In order to be able to utilize the complete -10° to +170° rotation range, we recommend the use of the Geiger-Müller counter tube Type B (order no. 09005.00). When fitting the counting tube in the slidable counting tube holder (2), push it to the stop and fix it in position with the milled screw (3). The milled screw of the holder (4) serves to fix it on its guide rods. The counting tube holder is equipped with a slit diaphragm holder (5) which can be removed if required by unscrewing the milled screw (6). Absorption foil (order no. 09056.02) can also be inserted in the diaphragm holder.

The angle resolution can be varied by displacing the counting tube holder on its guide rods (7). The maximum angle resolution is obtained when the counter tube holder is at its furthest position to the right.

The complete goniometer block (8) can also be moved in the horizontal direction. To enable such a displacement to be reproducibly made, the base plate of the goniometer has a slit and there is a line marked underneath the front plate of the goniometer block. When the goniometer block is at the far right, the maximum angle of rotation of the counter tube holder is 170°, when the block is at the far left, the counter tube holder can only be rotated through approx. 102°.

At positions in-between, the maximum rotation angles are approx. 135°, 120° and 112°. These cannot be exceeded, even in automatic operation when larger final angles are inadvertently selected. This limitation of the rotating range is effected by a light barrier system inside the goniometer block, and it ensures that the counting tube does not hit against the inside of the housing.

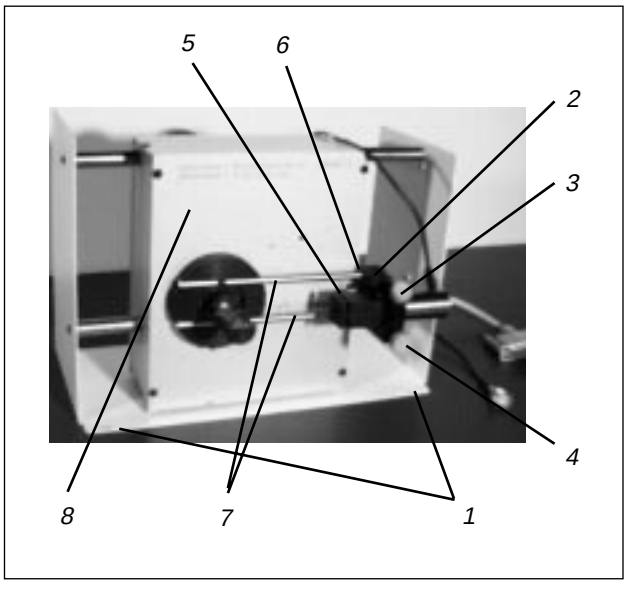

Fig. 6

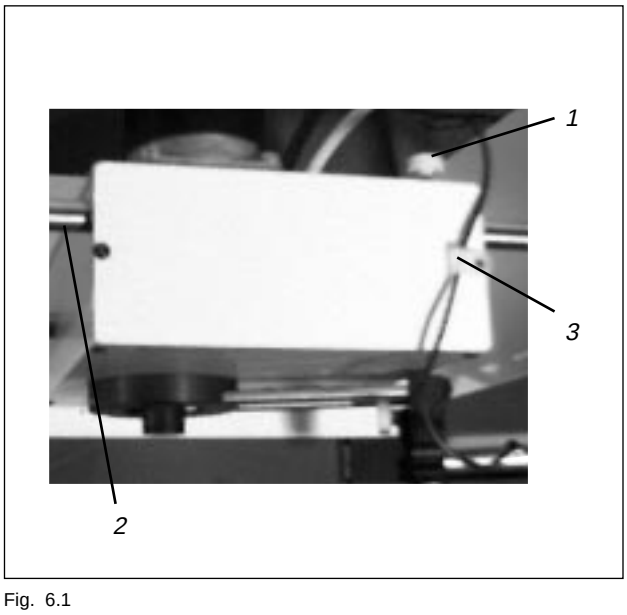

Fig. 6.1

A milled screw (1) at the back of the goniometer block (Fig. 6.1) allows this to be fixed on its guide rod (2). The cable of the counting tube is best clamped in the clip (3) on the top of the block.

E HANDLING

1. Switching the basic unit on

Switch the on/off switch at the back of the unit to on. The display briefly shows the symbol for the tube insert in use, Fe, Cu or Mo.

2. Fitting in and changing X-ray tube inserts

Caution!

Before changing inserts, first interrupt X-ray tube usage with the"HV-ON" button.

To remove an insert, first lift up the safety lever which is below the handle and only then withdraw the insert. To insert an insert, fit it in with its guide tongues in the guide rails of the tube-insert compartment without tilting it. To ensure that all plug connections make firm contact, push the insert completely in up to the stop with the safety lever lifted up.

3. Using an X-ray tube insert

3.1 First use of an X-ray tube insert

An X-ray tube should not be immediately run at full power when first used. On first use, we recommend that you run in a tube by putting it to use for about 10 minutes at maximum radiation current, but with a tube acceleration voltage which is **not above 25 kV**. This running in procedure should also be carried out when a tube has not been used for some weeks.

3.2 Setting the tube operating values

Please note: For safety reasons, after closing and locking the sliding door, the locking-knob must be first fully pressed fully in once again before the high voltage can be re-activated.

Anode voltage: Use the "HV-I" button to select the "HV" function, turn the adjusting wheel until the required voltage value is reached and confirm it with "ENTER".

Anode current: Use the "HV-I" button to select the "I" function, turn the adjusting wheel until the required value for the anode current is reached and confirm it with "ENTER".

Press the "HV-ON" button for the X-ray tube to start operating with these settings of the operating values. The red signal lamp and the X-ray tube light up. X-rays are now produced.

Changing the tube operating values:

Changes in the current and voltage settings can be made directly with a tube in operation.

The new values must in each case be confirmed with "ENTER", however.

Press the "HV-ON" button to again switch off the high voltage.

4. Setting the exposure time

Set the required values for the anode voltage and the emission current and confirm them with "ENTER".

Use "GATE-TIME" to select the "TIME" function, turn the adjusting wheel until the required exposure time is reached and confirm it with "ENTER".. Following this, press the "HV-ON" button and immediately start the timer (LED display) with "START". The LED display shows the exposure time remaining. The X-ray tube is automatically switched off at the end of the set exposure time. An intermediate press on the "STOP" button stops the timer, but does not switch the tube off, i.e does not stop exposure.

5. Using the goniometer

(The installation of the goniometer is described in section D).

5.1 Manual operation

To turn either the sample holder or the counting tube holder alone: First use "MAN-AUTO" to select the operating mode "MAN", then select the required holder with the (symbol for crystal or counting tube) button and confirm with "ENTER".

To turn the sample holder and the counting tube holder in a 2:1 angle ratio: First select the required operating mode with the (symbol for crystal or counting tube) button and confirm with "ENTER".

In either case, rotate the selected holder with the adjusting wheel.

5.2 Automatic operation

Select the "AUTO" operating mode. Successively activate the functions "START" - "STOP" - "^{o}/S" and again set the required values with the adjusting wheel. After each setting, confirm with "ENTER".

Select the (symbol for crystal + counting tube) coupling mode and start the rotation with "START". The sample holder and counting tube holder now rotate through the selected angle range with their angles coupled 2:1. You can interrupt the rotation at any angle by pressing "STOP", and start the rotation up again by pressing "START".

To bring the the sample holder and the counting tube holder back to their zero position, press "RESET". To again start rotation at the previously selected starting angle press "START". For automatic rotation of either the sample holder or the counting tube holder alone, call up the corresponding functions.

To adust the angle stepping speed (= gate time of the ratemeter):

First select "MAN" , then "GATE", adjust to the required value with the adjusting wheel and confirm with "ENTER".

5.3 Re-adjusting the goniometer

Analyzing crystals can, although rarely, have an error in their orientation, a deviation of a few 1/10° from their principle crystallographic axis, so that the characteristic X-ray lines are not to be found at the theoretically expected glancing angles. This error can be corrected as follows; Bring the analyzing crystal to the theoretical glancing angle position ϑ in the manual operating mode (the counting tube holder correspondingly to 2ϑ). Repeatedly rotate the crystal and counting tube by a few ±1/10° about this angular position and look for the maximum intensity of the line. Bring the crystal back to the zero position, corrected for the deviating angle, in coupled mode and confirm this with "ENTER".

(Example: The maximum intensity of a characteristic Roentgen line is at $\Delta\vartheta = \pm$ 0.X° above/below the theoretical glancing angle value. The zero position must be corrected by ±0.X° and confirmed with "ENTER").

The newly configurated zero position of the goniometer system is preserved even after the X-ray unit is switched off.

5.4 Data output

Direct voltages which are proportional to the angle and the counting rate can be picked up from the output sockets "angle symbol" and "IMP/s" for plotting them with an xy-recorder.

The voltage changes after each completed gate time (= angle stepping speed).

The (symbol for crystal or counting tube) button in the output section of the control panel enables the output voltage of the angular position of either the sample holder or the

crystal holder to be selected.
When the unit is switched on, it automatically selects the analogue voltage for the position of the sample holder.

6. Changing the fuse

Draw out the fuse holder, which is situated under the mains switch at the back of the mains connection unit, remove the defect fuse and replace it with a new one (M 1.6 A). Ensure that the fuse holder is properly positioned on pushing it back in.

F ACCESSORIES

(not included in the equipment supplied with the basic unit)

LiF single-crystal, mounted	09056.05
KBr single-crystal, mounted	09056.01
NaCl single-crystal, set of 3	09058.01
Universal crystal holder	09058.02
Absorption set for X-rays	09056.02
Diaphragm tube with Ni foil	09056.03
Diaphragm tube with Zr foil	09058.03
Chemical set for edge absorption	09056.04
Capacitor plates for X-ray unit	09058.05
Compton attachment	09058.04
Model filler for contrast medium	09058.06
Film holder	09058.08
Polaroid film, ISO 3000/36°, pack of 20	09058.20
Developing cassette for single films	09058.21
or	
X-ray film, 90 mm x 120 mm, 10 sheets	06696.03
X-ray film developer, for 4.5 l sol	06696.20
X-ray film fixer, for 4.5 l sol	06696.30
Software for X-ray spectroscopy	14407.61

G NOTES ON EXPERIMENTS

All experiments can be carried out with your choice of X-ray tubes from those listed.

1. Laue and Debye-Scherrer photographs

Material

X-ray unit, 35 kV, basic unit	09058.99
Insert with Cu X-ray tube	09058.50
or	
Insert with Mo X-ray tube	09058.60
or	
Insert with Fe X-ray tube	09058.70
Crystal holder for Laue photographs	09058.11
LiF single-crystal, mounted	09056.05
or	
NaCl single-crystal, set of 3	09058.01
Film holder	09058.08
Polaroid film, ISO 3000/36°, pack of 20	09058.20
Developing cassette for single films	09058.21
or	
X-ray film, 90 mm x 120 mm, 10 sheets	06696.03
X-ray film developer, for 4.5 l sol	06696.20
X-ray film fixer, for 4.5 l sol	06696.30

Experimental parameters:
Anode voltage 35 kV, anode current 1 mA, tube with 2 mm ∅ diaphragm.

Laue photographs (roentgenograms):
Position the crystal directly in front of the diaphragm tube, LiF crystal: Film-crystal distance approx. 2 cm; exposure time approx. 15 min. with Polaroid film ISO 3000/36°.

NaCl crystal:
Film-crystal distance approx. 3 cm; exposure time approx. 2 h with Polaroid film ISO 3000/36°.

Debye-Scherrer photographs (roentgenograms):
Bring an approx. 0.2 mm layer of finely ground (mortar) polycrystalline powder (e.g. KBr) held between two strips of Sellotape (Scotch tape) in front of the diaphragm tube. Sample-film distance approx. 2 cm; exposure time approx. 2 h with Polaroid film ISO 3000/36°.

2. Compton scattering

Material

X-ray unit, 35 kV, basic unit	09058.99
Insert with Cu X-ray tube	09058.50
or	
Insert with Mo X-ray tube	09058.60
or	
Insert with Fe X-ray tube	09058.70
Compton attachment	09058.04
Counter tube type B	09005.00
Goniometer	09058.10
LiF single-crystal, mounted	09056.05

Allow the X-rays to be scattered at 90° by the plexiglas (perspex) scattering object of the Compton attachment and registered by the counting tube. Following this, first position the aluminium absorber in front of the scattering object (1) and then clamp it behind the scattering object on the guide rod in front of the counter with slit adapter (2).
Determine the Compton wavelength from the different transmission values and the previously determined transmission curve for aluminium. As the counting rates are relatively low, reduce the statistical variation by always registering counts of some thousands and first determining the background radiation so that this can also be taken into consideration. When determining the transmission curve, taken the dead time of the counting tube into consideration with high counting rates.

Experimental parameters:
Anode voltage 35 kV, anode current 1 mA, tube with 2 mm diaphragm.

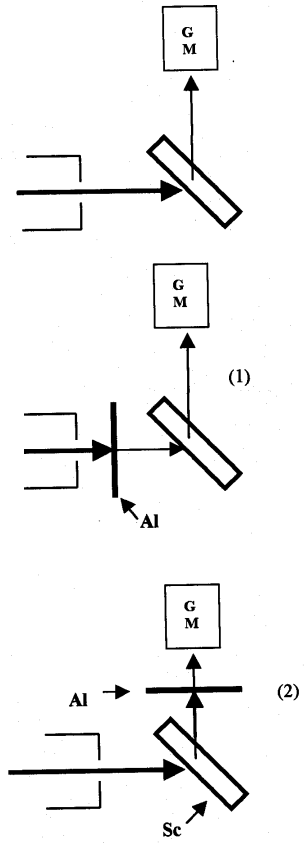

Fig. 7: Arrangement for Compton scattering

3. Registration of X-ray spectra

Material

X-ray unit, 35 kV, basic unit	09058.99
Insert with Cu X-ray tube	09058.50
or	
Insert with Mo X-ray tube	09058.60
or	
Insert with Fe X-ray tube	09058.70
Goniometer	09058.10
LiF single-crystal, mounted	09056.05
Counter tube type B	09005.00
xy Recorder	11416.97
Connecting cable, 100 cm (2 x)	
or	
Software	14407.61
Data cable	14602.00

Measurement example (Fig. 8):
X-ray spectrum of copper
Experimental parameters:
Anode voltage 35 kV, anode current 1 mA, LiF analyzing crystal
Goniometer: Starting angle 4.0° and stopping angle 60.0° for the sample holder, angle stepping 0.1°, gate time 1 s.
Diaphragm tube 2 mm ∅.

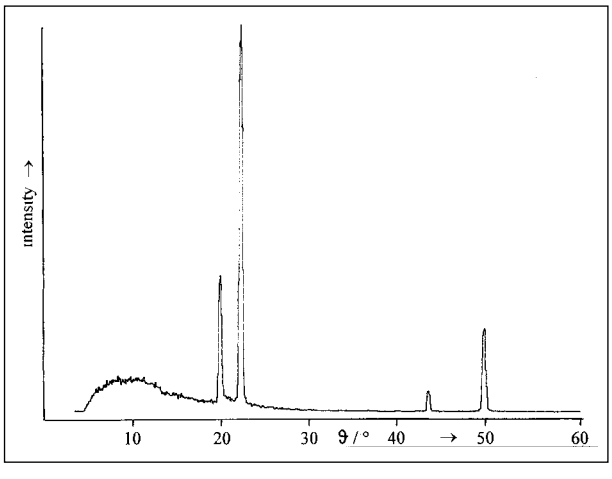

Fig. 8: X-ray spectrum of copper

4. Monochromatization of X-rays

Material as under 3. above, with the addition of:

Diaphragm tube with Ni foil (for Cu rays)	09056.03
Diaphragm tube with Zr foil (for Mo rays)	09058.03

Experimental parameters as under 3. above.

5. Absorption experiments

Material as under 3. above, but without the recorder and with the addition of:

Absorption set for X-rays	09056.02

Determine the counting rates at different angles (wavelengths) with and without absorbing foil. Place the absorber foils in the slit of the counting tube adapter.

6. Ionizing power of X-rays

Material	
X-ray unit, 35 kV, basic unit	09058.99
Insert with Cu X-ray tube	09058.50
or	
Insert with Mo X-ray tube	09058.60
or	
Insert with Fe X-ray tube	09058.70
Capacitor plates for X-ray unit	09058.05
Power supply, 0...600 VDC	13672.93
DC measuring amplifier	13620.93
High-value resistor, 50 megohms	07159.00
Adapter, socket-plug, 4 mm	07542.20
Screened cable, BNC, l = 750 mm	07542.11
Digital multimeter(2x)	07134.00
Connecting cables	

Connect the plate capacitor to the appropriate sockets in the experimental area (Fig. 2), which are connected to the pair of sockets designated 11 on the control panel (Fig. 3). The circuit is connected up as shown in Fig. 9.

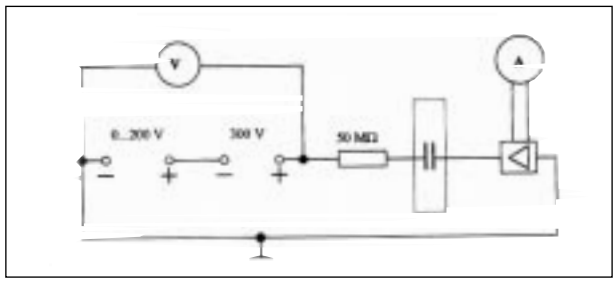

Fig. 9: Circuit diagram principle for determining ionic currents

The ionization current which is to be measured is a function of the anode voltage and the anode current, the air volume of the capacitor which is passed through (by use of different diaphragm diameters) and the voltage at the capacitor plates (max. 500 V).

H SPECIFICATIONS

Tube and goniometer operation	Microprocessor controlled
Tube voltage (electronically controlled)	0.0...35.0 kV
Emission current (electronically controlled)	0.00...1.00 mA
Integrated rate-meter	
Counter tube voltage	500 V
Counting time (rate)	0.5 s...100 s
Goniometer, stepping motor controlled	
Mode of operation	Manual or automatic for sample holder and counting tube holder and 2:1 coupling
Angle steps	0.1°...10°
Angle range	Sample holder 0...360°; counting tube holder -10°...+170°
Angle speed	(0.5 s...100 s) / angle step
Scanning range	Selectable

Two 4-digit, 25 mm high demonstration displays with diode matrices for selectable parallel display of operating and measured values, with corresponding units, for tube voltage and tube current, scanning start and scanning end, actual values for stepping, angle speed and angular position of crystals or counting tube; counts/s

Exposure time for X-ray photographs	1 min...1000 min
Outputs; pairs of 4 mm sockets	
Analogue voltages for crystal or counting tube position	10 mV/° of 20 mV/°
Counting rate	1 V/2000 counts/s
PC control	SUB-D socket
Input; pair of 4 mm sockets	
For supplying capacitor plates in dosimetry experiments	max. 500 V
Experimenting area	(370 x 357 x 280) mm
Fluorescent screen	(120 x 130) mm
Working channel (cross-section)	(17 x 20 mm)
Interior lighting	24 V / 10 W
Accessory box (on top)	(260 x 250 x 6) mm
Casing dimensions (L x W x H)	(595 x 335 x 465) mm
Electrical supply	110...240 VAC / 50...60 Hz
Safety fuse	M 1.6 A
Power consumption	160 VA
Mass of the:	
Basic unit	33 kg
X-ray tube inserts	each 4.3 kg
Goniometer	4.1 kg
Registration of design	
Lower Saxony 601/01 X-ray	Fully protected X-ray unit
Lower Saxony 602/01 X-ray	School X-ray unit

I Appendix

1. Energy levels of various anode materials

	E_K / eV	E_{L1} / eV	E_{L2} / eV	E_{L3} / eV	E_{M1} / eV	$E_{M2/3}$ / eV	E_{M2} / eV	E_{M3} / eV
Fe (Z = 26)	7112.0	846.1	721.1	708.1	92.9	54.0	-	-
Cu (Z = 29)	8978.9	1096.1	951.0	931.4	119.8	73.6	-	-
Mo (Z = 42)	19999.5	2865.5	2625.1	2520.2	504.6	-	409.7	392.3

2. Characteristic X-ray lines of various anode materials

	E-Kα_1 / eV	E-Kα_2 / eV	E-Kβ / eV	λ- Kα_1 / pm	λ- Kα_2 / pm	λ- Kβ / pm
Fe (Z = 26)	6404	6391	7058	194.00	193.60	175.66
Cu (Z = 29)	8048	8028	8905	154.05	154.44	139.23
Mo (Z = 42)	17479	17374	19599	70.93	71.36	63.26

3. Lattice constants and lattice plane spacings of various crystals

Kristall	Typ	$a_{(100)}$ / pm	$d_{(110)}$ / pm	$d_{(111)}$ / pm
LiF	fcc	402.8	297.6	243.0
KBr	fcc	658.0	465.3	379.9
NaCl	fcc	564.1	398.8	325.6
KCl	fcc	629.3	444.1	362.6
Cu	fcc	361.5	255.6	208.7
Al	fcc	404.1	285.7	233.3
Ta	bcc	329.1	232.7	190.0
Mo	bcc	314.0	222.0	181.3
Ge	Diamant	565.8	400.1	326.7
Si	Diamant	543.1	384.0	313.6
		a / pm	c/ pm	
Zn	hex.	266.5	494.7	
Graphit	hex.	246.1	670.8	

4. Edge absorption of some elements

Element	**Z**	**λ_K / pm**		**Element**	**Z**	**λ_K / pm**
Li	3	22662.0		Zn	30	128.3
C	6	4364.8		Ge	32	111.6
O	8	2330.1		As	33	104.4
F	9	1791.3		Se	34	97.9
Na	11	1147.8		Br	35	91.99
Al	13	795.1		Rb	37	81.55
Si	14	674.46		Sr	38	76.97
S	16	501.82		Mo	42	61.98
Cl	17	439.69		Ag	47	48.58
K	19	343.65		Sn	50	42.47
Mn	25	189.6		W	74	17.84
Fe	26	174.3		Au	79	15.34
Ni	28	148.8		Hg	80	14.92
Cu	29	138.0		Pb	82	14.08
				Bi	83	13.69

5. Mass weakening coefficients of some substances

	Al Z=13	Fe Z=26	Cu Z=29	Zn Z=30	Ag Z=47	Sn Z=50	Pb Z=92
ρ / g cm^{-3}	2.69	7.86	8.92	7.14	10.50	7.28	11.34
λ / pm							
71 (Mo-Kα)	5.2	38.5	51	58	28	-	140
154 (Cu-Kα)	49	328	49	59	225	256	230
194 (Fe-Kα)	94	71	98	115	410	-	420

J NOTE ON THE GUARANTEE

We guarantee the instrument supplied by us for a period of 6 months. This guarantee does not cover natural wear nor damage resulting from improper handling.

The manufacturer can only be held responsible for the function and safety characteristics of the instrument, when maintenance, repairs and changes to the instrument are only carried out by the manufacturer or by personnel who have been explicitly authorized by him to do so.