X-RAY DIFFRACTION

GLASS TUBE

INSTRUCTION MANUAL

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ACKNOWLEDGMENTS.

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1. INTRODUCTION.

1.1 Scope.

This instruction manual describes how to operate the:

X-RAY DIFFRACTION GLASS TUBE.

This tube is available with the following focal spots:

NORMAL FOCUS (NF)
BROAD FOCUS (BF)
FINE FOCUS (FF)
LONG FINE FOCUS (LFF)

and with the following targets:

Cr, Fe, Co, Cu, Mo, Ag, W.

The BF Cu tube is also available with large window diameter (Kratky) and with 8 windows with large diameter (8-window Kratky). All types are available in a short and in a long version. Refer to appendix G for the difference in dimensions.

Please contact your supplier for information regarding type numbers, delivery times and ordering procedure.

1.2 Warnings and cautions.

The meaning and format of WARNINGS and CAUTIONS in this manual are:

WARNING!	**INFORMATION THAT, IF DISREGARDED, MAY RESULT IN DANGER TO HEALTH OR SAFETY OF THE OPERATOR, SERVICE ENGINEER OR ANY OTHER PERSON IN THE VICINITY.**

CAUTION:	**Information that, if disregarded, may result in damage to, excessive wear or unsatisfactory performance of the equipment.**

1.3 Safety precautions.

WARNING!	**X-RAYS ARE HARMFUL TO THE HUMAN BODY. ALL WORK MUST BE CARRIED OUT IN ACCORDANCE WITH ALL APPLICABLE NATIONAL SAFETY REGULATIONS.**

WARNING!	**FUMES OR DUST FROM BERYLLIUM METAL (OR ITS COMPOUNDS) CAN BE HAZARDOUS IF INHALED. DURING USE CORROSION OF THE BERYLLIUM WINDOW MAY OCCUR. THE WINDOWS MUST NOT BE CUT, MACHINED OR OTHERWISE REMOVED. TUBE DISPOSAL MUST COMPLY WITH ALL NATIONAL AND LOCAL REGULATIONS GOVERNING BERYLLIUM. ALTHOUGH THE BERYLLIUM WINDOWS HAVE BEEN COATED WITH A PROTECTIVE LAYER, AVOID CONTACT. FOR FURTHER INFORMATION PLEASE REFER TO APPENDIX A.**

CAUTION:	**X-ray tubes are delicate components and must be handled with care at all times. A minor shock, such as can occur when a tube is placed on a table, can cause damage.**

1.4 General product information.

This information is to inform customers about materials used in the tube and to ensure correct handling and disposal. Local rules take precedence.
X-ray tubes are used to analyse materials in a non destructive way and will produce dangerous X-rays only when a high voltage is applied.

The tube contains:

- an evacuated envelope with a glass insulator;
- less than 0.6 gram beryllium metal;
- common parts of steel, brass, copper and small amounts of gold, silver, tungsten etc.;
- various anode coatings (target materials) such as copper, tungsten, molybdenum, cobalt, iron, chromium or silver;
- no oil;
- less than 50 grams of lead.

Refer to appendix A for the hazards of beryllium.

It is hereby declared that:

- the tube has been manufactured in The Netherlands;
- the tube does not contain radio-active material;
- the tube does not destroy the ozone layer;
- the tube has been tested and found to be functioning in compliance with relevant specifications;
- the tube has been tested and found to be in compliance with requirements with regard to radiation safety.

Please note that installation, operation, maintenance or storage not in compliance with this manual, may cause the warranty to expire.

2. UNPACKING.

2.1 Contents.

Besides general packing material the following items should be present:

1. Self adhesive folder.
2. Instruction manual.
3. Information sheet.
4. Tube report form.
5. Questionnaire.
6. Pre addressed envelope.
7. Stickers.
8. X-ray tube.
9. Two M6x20 screws.

The adhesive folder can be used to store these documents in a convenient place, e.g. against the inside of the system; the envelope to return the questionnaire and the stickers in case of a return shipment (e.g. for disposal).
The tube is packed in a plastic bag and contains two protective covers for the water connections and a cover to protect the windows.
Please refer to appendix B for location.
The window protection contains a beryllium warning and a warning not to handle the tube by this cover.

2.2 Initial inspection.

Inspect the tube carefully and, if you are not satisfied in any way with the condition in which you have received it, or if there are unmistakable signs of damage to box or contents, file a claim with the supplier immediately, using the Tube Report Form.

3. INSTALLATION.

Take the tube out of the plastic bag and remove the protective covers (see appendix B).
Keep the protective covers for possible future use (storage, return shipment).
To minimize the chance of dirt, fingerprints etc. on the windows leave the window protection in place as long as possible.
Before being installed the tube should be dry, clean and dust free.
Use a soft cloth to clean the tube and use a dust free and dry air flow to remove dust.
The use of alcohol, acetone etc. on painted surfaces is advised against as it might damage the paint.
Check, and if necessary clean and dry, the environment in which the tube will be put into operation.

Take care when mounting the tube, excessive force should never be used.
When placing the tube in the system every precaution should be taken to prevent damage to or contamination of the tube, especially the windows.
Mechanical connections to the tube must be firm and secure but not so tight as to cause damage to either the tube structure or the terminals.

To protect the lifetime of the tube, effective cooling is essential. The water flow must have the correct direction and all connections must be water tight.
Check the water flow before switching on the power.
An uninterrupted water flow (as specified in chapter 7) is required for adequate heat transfer.

The cooling water should not cause corrosion or deposits in the tube.
Please refer to appendix C for more detailed information.

CAUTION!	**Low cooling water temperature and high air humidity can lead to condensation and cause corrosion. To prevent this it is recommended to keep the temperature above dew point - see appendix J.**

The focal spot can be regarded as a line when seen through two opposite windows and as a point when seen through the two other windows.
The windows, through which the focal spot is seen as a line, are identifiable by an oblique part on the edge of the cooling plate, near the window.

4. OPERATION.

4.1 General.

Please note that there are definite limits on filament voltage and current, high tension, tube current and power.

CAUTION:	**Exceeding these limits will cause unacceptable heat levels leading to severe damage to target or filament. Please refer to chapter 7: Specifications.**

It is recommended:

- to use standby settings when the tube will not be in use for more than one hour;
- to switch off the H.T. (and a few minutes later the flow of cooling water) when the tube will not be in use for more than 2 weeks;
- to remove the tube from the system and store it in accordance to § 6.1 when it will not be in use for more than 10 weeks.

4.2 Switching ON/OFF.

The switching ON/OFF procedures are carried out automatically, under control of the appropriate firmware, whenever the HT ON/OFF switch is operated.
The switch ON procedure leaves the tube at minimum kV and minimum mA.
How to proceed after switching ON is described in chapter 4.3: Conditioning procedure.

Before activating the HT OFF switch: firstly reduce the tube current (mA) to a minimum and secondly reduce the high tension (kV) to a minimum.

CAUTION:	**Never switch off the water supply as a means of switching off the instrument.**

4.3 Conditioning.

The following scheme indicates how to start operation after switch ON:

	Time since last switch OFF:	
	<= 100 hrs	> 100 hrs
Tube has **NOT** been removed from the system	conditioning **NOT** required	first execute **SHORT** conditioning program
Tube has been removed from the system	first execute **SHORT** conditioning program	first execute **LONG** conditioning program

New tubes should always be put into operation via the long conditioning procedure.

If flashes are observed at minimum kV-setting the tube should be replaced; if not the conditioning procedure can be started.
When using the automatic conditioning procedure the firmware will control the process.

In case of manual conditioning the following steps have to be executed, with 1 minute between each step for the short and 3 minutes for the long program:

1.	Change settings to:	30 kV / 10 mA;
2.	Change to:	40 kV / 10 mA;
3.	Change to:	45 kV / 10 mA;
4.	Change to:	50 kV / 10 mA;
5.	Change to:	55 kV / 10 mA;
6.	Change to:	60 kV / 10 mA.

If no flashes have been observed proceed according to chapter 4.4: Operational switching.
If a flash is observed go back one step and wait 5 minutes before proceeding with the next step.
If the occurrence of flashes is persistent during the short program start the long program.
If the occurrence of flashes is persistent during the long program leave the tube for 1 hour at 30 kV / 10 mA and try again.
If the situation does not improve the tube should be replaced.

4.4 Operational switching.

If changes in operational settings are not controlled by firmware switch from kV_1 / mA_1 to kV_2 / mA_2 in the following way:

	$kV_1 < kV_2$	$kV_1 > kV_2$
$mA_1 < mA_2$	First increase kV, then increase mA.	Use isoWatt settings as much as possible.
$mA_1 > mA_2$	Use isoWatt settings as much as possible.	First decrease mA, then decrease kV.

CAUTION:	**The tube should always be used within the limits indicated in appendix D.**

5. MAINTENANCE.

5.1 General.

CAUTION:	**The glass surface should be kept clean and dry at all times. If necessary clean with soft, lint free cloth with alcohol.**

All electrical contacts should be free of dirt and grease, clean with alcohol when necessary.
In extreme cases a rotating metal brush can be used to remove deposit that prevents good electrical contact.
In such a case the surfaces around the contact should be cleaned carefully to remove all metal particles.

Effective cooling is absolutely essential to maintain the quality of the tube.
Therefore it is recommended that, at least after initial installation and after modifications, the cooling circuit is inspected every month and cleaned when necessary.
From the results of this monthly inspection the minimum frequency for normal operation should be deduced; at least once every 6 months is strongly advised.

The most critical part in the cooling circuit is the cooling side of the anode (see appendix H).

5.2 Inspecting / cleaning the cooling circuit of the tube.

For all maintenance activities refer to the service drawing (appendix H).
For information on replaceable parts refer to appendix F.

The cooling circuit is made watertight with two (three in case of long tubes) sealing rings.
These sealing rings may be damaged when the circuit is opened. So do not start without new sealing rings being available.

5.2.1 Opening the cooling circuit.

1. Switch off and wait until the tube is cooled down. Remove it from the system and place it in the tube stand (cooling plate at the top). Make sure that it can not fall.
2. Mount the window protection.
3. Remove the two screws next to the type plate and then unscrew the two screws beneath the type plate. Take off the cooling plate.
4. Please note that one of the screws is placed eccentrically to prevent incorrect positioning of the cooling plate.
5. Check the position of the nozzle (see appendix I). If the position of the nozzle is too low the tube has not been assembled correctly on the previous inspection. In such a case inform involved persons.
6. Remove and inspect the large sealing ring; when necessary clean or replace it.
7. In case of a long tube remove the spacer ring. Remove and inspect the large sealing ring; when necessary clean or replace it.

8. Remove and inspect the nozzle and the water filter; when necessary clean or replace. The slit in the water nozzle should be free of obstructions. Clean with lint free cloth with alcohol or with fine sandpaper.
9. Remove and inspect the small sealing ring; when necessary clean or replace it.

5.2.2 Inspecting / cleaning the cooling side of the anode.

It is possible that the cooling side of the anode shows a discolouration (dark spot), reflecting the orientation of the focal spot.
Such a spot indicates that cleaning is necessary, especially when it is non transparent black and large.
When this spot covers most of the cooling side of the anode cleaning is not enough: the cooling system and the quality of the water should be checked.

The deposits on the anode act as a resistance to heat transfer and lead to overheating of the target side of the anode. It indicates unacceptably high concentration of strange materials in the cooling water.
Appendix C gives detailed information regarding cooling system and water quality.
When necessary clean the cooling side of the anode in the following way:

1. Fill the cooling circuit with acetic acid 10% (CH3 COOH).
2. Wait 10 minutes; take a small, soft brush with the hairs cut short. Scrub the cooling side of the anode in different directions.
3. Refresh the acid and repeat the process until the anode is clean.
4. Pour out the acid and flush the cooling circuit with water. Take care not to spill water accidentally on the windows. Remove spilt water with a soft tissue, followed by a flow of dry, warm air (max. 100 °C, max. 0.1 MPa) e.g. from a hair drier.

5.2.3 Re-assembling the tube.

CAUTION:	**Before placing sealing rings grease them lightly with acid-free grease to prevent water leakage. Silicon P4 is not acid-free!**

1. In case of long tubes: place a large sealing ring on the spacer ring and position the ring on the tube. Align the four holes in the ring with the holes in the tube (one of them is positioned eccentric).
2. Place the small sealing ring.
3. Place the filter and the nozzle (see appendix I).
4. Place the large sealing ring.
5. Position the cooling plate so that the four holes align with the four holes in the tube (and spacer ring).
6. Screw the two screws under the type place without fastening and place the other two screws. Just before fastening move the cooling plate to centre the heads of these two screws in the openings in the cooling plate. Tighten all screws.

Before replacing the tube in the system do not forget to remove the window protection.

6. STORAGE / DISPOSAL.

6.1 Storage.

The tube should be clean and dry.
Clean the cooling side of the anode as described in chapter 5.

CAUTION!	**All water should be removed from the cooling circuit of the tube.**

Please use pressurized air (normal flow direction) for long enough to ensure complete removal.

Only in extreme cases should the tube Be-window be cleaned. This can be done with a soft clean cloth, dampened with alcohol.
Consult appendix A regarding the hazards of Be.

Replace the window protection and the covers for the water IN/OUT.
Tubes must be stored in a clean and dry environment (preferably in the original packing).
The storage temperature should be between -40°C and +70°C.

CAUTION!	**Spare tubes should be put into operation for a few hours every six months. The procedure as described in chapter 4 must be strictly followed.**

6.2 Disposal.

WARNING!	**TUBE DISPOSAL MUST COMPLY WITH ALL NATIONAL AND LOCAL REGULATIONS GOVERNING BERYLLIUM.**

The tube should be clean and dry.
All water should be removed from the cooling circuit(s) of the tube.
Please use pressurized air (normal flow direction) for long enough to ensure complete removal.
Consult appendix A regarding the hazards of Be.
Place the window protection, the covers for the water IN/OUT and put the tube in its original plastic bag and close the bag.
Use the original box to transport the tube.
In case of transport of more tubes please use one separate box for each tube to prevent breakage of glass and risk of injury to people.

In case the tube is returned to the supplier "FOR DISPOSAL ONLY" the window area may be covered with adhesive tape to prevent the deposit from spreading.
This should not be done with tubes that will be returned as a warranty claim or for investigation and repair.

7. SPECIFICATION.

7.1 General.

The tube consists of a metal tubular body with an anode and four Be windows. This body is mounted in a glass housing to insulate the cathode from earth.
The anode is kept at ground potential and the cathode at a high negative potential.

7.2 Mechanical.

Dimensions:		See appendix G
Weight:	short version:	1.5 kg
	long version:	1.8 kg

7.3 Functional.

7.3.1 Electrical.

Maximum H.T.:		60 kV
Maximum anode current:	NF:	50 mA
	BF:	60
	FF:	40
	LFF:	55
Maximum power:		See appendix D (graph)
Standby setting:		40 kV / 10 mA
Maximum filament voltage Vf:		12 V
Maximum filament current If:		3.8 A (See appendix E for typical emission characteristic)
Minimum total series resistance of the H.T. transformer:		50 kΩ
Minimum capacitance of undamped circuit:		500 pF
Permitted settings:		See appendix D (table)

CAUTION:	**To improve the lifetime of the tube, any change in power should be less than 1000 W per step. Do not leave the tube in standby mode at high current (e.g. 55 mA) as this will significantly reduce the lifetime of the filament.**

In all circuits without a capacitor the total series resistance includes the internal resistance of the H.T. transformer and the control circuit.
In the case of capacitor circuits the resistance must be connected between capacitor and tube.

7.3.2 Environment.

Temperature environment:		
	operation:	+5 °C to 40 °C
	storage:	-40 °C to +70 °C
Electrical safety:		IEC1010-1

Radiation safety with standard tube shield:
< 1 μSv / hr measured at 10 cm distance.

7.3.3 Cooling.

A stable and uninterrupted flow of cooling water is necessary.

Continuity:		in case of interruption of the flow the high tension should be switched off within 0.1 seconds.
Water:	quality:	refer to appendix C
Flow	min.:	3.5 l/min.
	max.:	6 l/min.
Pressure	max.:	0.8 MPa
Temperature	min.:	> dew point (refer to appendix J)
	max.:	35 °C / 95 °F

7.4 Miscellaneous.

7.4.1 Be window.

The window is coated to protect it from moisture.

Diameter:		14 mm
	Kratky:	20 mm
Thickness Be:		300 μm
Transmission:	CrKα:	82 %
	FeKα:	89
	CoKα:	92
	CuKα:	94
	W Lα:	95
	MoKα:	98
	AgKα:	99

7.4.2 Focal spot.

Dimensions (typical values):

	Normal Focus:	1.0 x 10 mm
	Broad Focus:	2.0 x 12
	Fine Focus:	0.4 x 8
	Long Fine Focus:	0.4 x 12

Visibility angle (with no intensity loss over range):

standard:	line focus:	0 – 12 °
	point focus:	0 – 20 °
Kratky:	line focus:	0 – 16 °
	point focus:	0 – 26 °

The two windows through which the focal spot is seen as a line are identifiable by an oblique part on the edge of the cooling plate near the window.

APPENDIX A:

HANDLING OF X-RAY TUBES IN RELATION TO THE HAZARDS OF BERYLLIUM.

(beryllium: beware and be aware)

INTRODUCTION.

Be advised that beryllium as present in X-ray tubes is recognised as a hazardous substance and may create hazards to persons when not handled and disposed of properly.
To avoid any such hazards the material must be handled with great care and always in accordance with the instructions below in connection with the installation, operation and servicing of the equipment.
Disposal of beryllium should further be handled in accordance with local laws, regulations and requirements.

OCCURRENCE, PROPERTIES AND USE.

Beryllium is a lightweight, strong metal and, compared with other metals, hardly absorbs X-rays.
It is present in X-ray tubes only in "massive" form: the windows.
This guarantees minimal absorption of the radiation generated inside the tube.

HAZARDS.

National and international health organisations have classified beryllium and its compounds (with the exception of aluminium beryllium silicates) as follows:

Classification		Description
R49	Carcinogen cat. 2	May cause cancer by inhalation
R26	Very toxic	Very toxic by inhalation
R25	Toxic	Toxic if swallowed
R48/23	Toxic	Toxic: danger of serious damage to health by prolonged exposure through inhalation.
R36/37/38	Irritant	Irritating to eyes, respiratory system and skin.
R43		May cause sensitisation by skin contact.

The dangers to health which can arise from beryllium are mainly due to inhaling the substance. Inhaling dust or fumes containing beryllium may cause serious, chronic lung disease called Chronic Beryllium Disease (CBD). Soluble salts of beryllium may present additional ingestive, eye and skin hazards.

So, when working with beryllium metal, compounds and alloys it is important to distinguish between the massive form and dust or fumes:
if beryllium can enter the body as dust, fume or soluble salt it can damage your health.

Beryllium metal (in massive form) is not easily absorbed by the human digestive system and there is no evidence that it is poisonous when swallowed.
The hazard "Toxic if swallowed" applies to certain soluble beryllium salts and is therefore added to the classification. Large pieces of beryllium are unlikely to cause any ill effects.
Normal handling of beryllium does not cause skin effects. Cuts should be properly cleaned and dressed; embedded material (swarf, splinters) should be removed.

RISKS.

Beryllium and beryllium containing materials present health hazards by the inhalation route only.
Soluble salts of beryllium may present additional ingestive, eye and skin hazards.
Normal use of an X-ray tube does not present danger to the health as it will not generate beryllium dust or fumes.
As no indications have been found that corrosion products (which could be soluble beryllium salts) spread there will be no danger when standard industrial hygiene rules are applied when handling tubes.

The presence of Be in X-ray tubes does not present any danger to the operator whatsoever, providing standard industrial hygiene is applied during installation, operation, service and removal.

REFERENCES.

Material Safety Data Sheet (no. M10) Beryllium Solid

Health & Safety Executive, Control of Substances Hazardous to Health (H.S.E./COSHH Regulations)
Guidance Note EH13: Beryllium, health and safety precautions.

If you need any additional information on handling X-ray tubes with respect to the hazards of beryllium please contact your supplier.

INSTRUCTIONS FOR HANDLING TUBES.

When handling tubes observe the following rules:

A. General.

1. Do not manipulate (machine, weld, grind, saw, polish etc.) the beryllium windows in any way that may cause dust or fumes.
2. Check the beryllium windows whenever possible for corrosion (corrosion usually indicates incorrect circumstances under which the tube has been operated). Correct the circumstances that have caused the corrosion, but do not remove the corrosion.
3. Put the window protection on the tube whenever possible.
4. Do not touch the beryllium windows at all.
5. Do not eat, drink or smoke while handling tubes.
6. Wash hands afterwards.

B. Installation.

1. Unpack the tube without touching the windows. Keep the plastic bag and the window protection at hand, you may need them later.
2. Do not remove the window protection until really necessary.
3. If there is dust on the windows remove it with a flow of dry, clean air (pressure < 0.1 MPa). Do NOT use human breath as this contains moisture.
4. Ensure that the windows do not become contaminated with water, dirt, grease and dust etc. Besides the possible formation of dangerous soluble Be-salts it will most likely cause corrosion that will decrease the life time of the tube.
5. Check, and if necessary clean and dry, the environment in which the tube will be put into operation.

C. Operation.

1. Check the beryllium windows whenever possible for corrosion, but do not remove the corrosion.
2. Verify the functional performance of the tube regularly.
3. Ensure that both tube and environment stay clean and dry.

D: Service.

1. Remove the tube without touching the windows.
2. Take care not to spill water on the windows. If this occurs remove the water by absorbing it with a soft tissue **(without exerting pressure on the window)** followed by a flow of dry, warm air (max. 100 °C, max. 0.1 MPa) e.g. from a hair drier.
3. Check the beryllium windows for corrosion (corrosion usually indicates incorrect circumstances under which the tube has been operated). Find and correct the circumstances that have caused the corrosion, but do not remove the corrosion.

4. Check whether the deposit on the windows could have been caused by sample rests spilled on the window.
5. When no other cause for deposits can be established it should be assumed that white (light brownish) spots on the window consist of BeO. Avoid contact.
6. White deposit around the windows does not usually consist of BeO. However, to be on the safe side, avoid contact.
7. If there is deposit on the windows but there are no indications
   - that the performance of the tube has become unacceptable
   - that the performance will become unacceptable in the near future
   - that the deposit will cause a bad vacuum inside the tube
   - that the deposit will spread around

   put the window protection back in place (if this is no objection to further activities) and perform all necessary service activities but do not violate the "general" rules.
8. Put the tube back into operation taking into account all relevant "installation" rules.

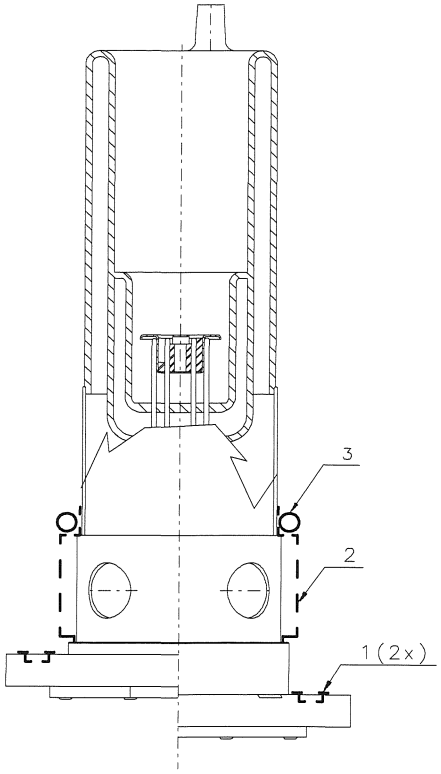
E. Removal / storage.

1. Remove the tube from the system in accordance with rules D1/D7.
2. When the tube is not put back into operation all water should be removed from the cooling circuit(s) of the tube. Please use pressurized air (normal flow direction) for long enough to ensure complete removal.
3. Ensure that the outside of the tube is dry.
4. Put the window protection back in place, put the tube in its original plastic bag and close the bag.
5. In case the tube is returned to the supplier "FOR DISPOSAL ONLY" the window area may be covered with adhesive tape to prevent the deposit from spreading. This should not be done with tubes that will be returned as a warranty claim or for investigation and repair.

APPENDIX B.

PROTECTIVE COVERS.

(to be removed before installation)



short version long version

1. Cover water IN / OUT.
2. Window protection, to remove separate closing side with tip of thumb and index finger.
3. Rubber ring to keep protection in place.

APPENDIX C.

COOLING.

This high power X-ray tube is designed and manufactured according to the highest possible quality standards. To ensure optimal performance and life time a recirculating, closed cooling system should be used to control the quality of the cooling water.
This cooling system should meet the following requirements:

Piping system, coolers, pumps etc:
Use the same materials as much as possible.
Synthetic materials are preferred, if not possible use stainless steel, copper or brass.
To prevent algae growth non transparent materials should be used.

Water.
The cooling water flow must be stable and uninterrupted, in case of interruption of the flow the high tension should be switched off within 0.1 seconds.
The cooling water should not cause corrosion of or deposit in the tube.
The nozzle, filter and cooling circuit of the tube should be inspected/cleaned regularly.

Water with the following properties should be used:

10 µS/cm < specific conductivity < 250 µS/cm
1 D < hardness in German degrees < 4 D
7.5 < acidity (pH) < 9.5

Atmospheric air should not have access to the water.
Whenever possible use old / boiled water (less aggressive than fresh water).
Flow should be between 3.5 and 6 l/min. It is better / safer to keep the flow clearly above the minimum.
A high water pressure (> 0.1 MPa overpressure after the tube) is recommended.
Water temperature: above dew point (refer to appendix J).

In practice for a recirculating cooling system the water quality can be realised by using a mixture of demineralized water and tap water and regular checks have to be done to see whether the quality is stable.
When the conductivity is outside the limits it can easily be corrected by adding tap water or demineralized water.
Flow and temperature can be controlled by the cooling system, pH value can be increased by adding NaOH.

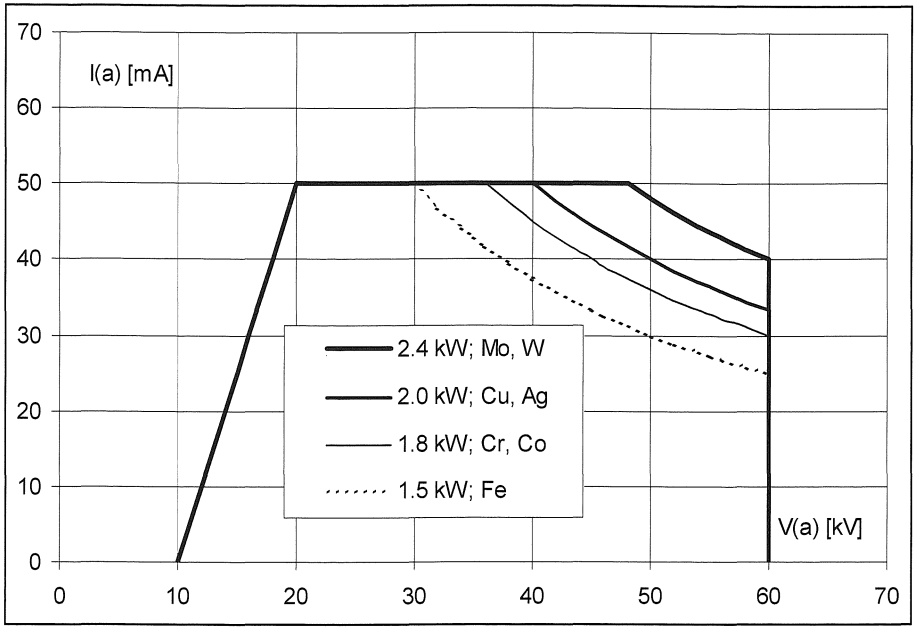
The hardness of the water in a non-recirculating system can be controlled using a filter.
However, recommended values of acidity and specific conductivity are very difficult to achieve.
Therefore, a recirculating system is preferred.

APPENDIX D.

X-RAY DIFFRACTION GLASS TUBE:

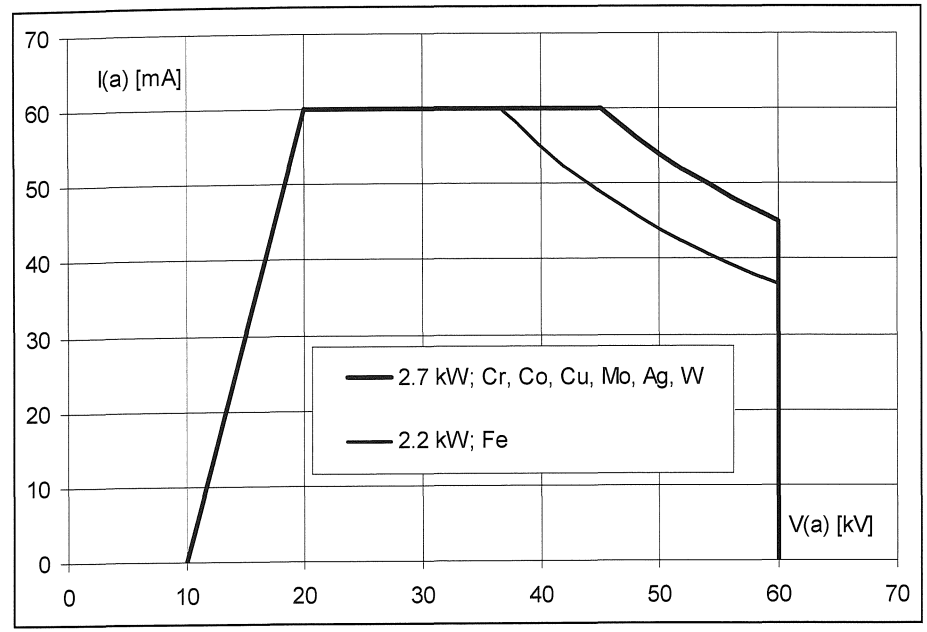
MAXIMUM POWER (kW) and MAXIMUM ANODE CURRENT (mA) AS FUNCTION OF THE H.T.(kV):

NORMAL FOCUS:



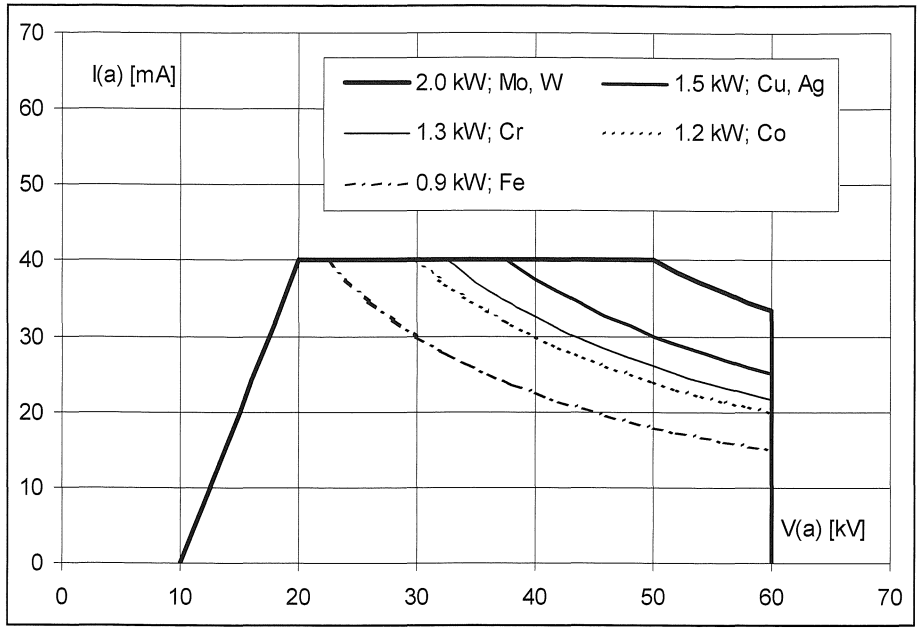
Target material	15 kV	20 kV	25 kV	30 kV	35 kV	40 kV	45 kV	50 kV	55 kV	60 kV
Mo, W	25	50	50	50	50	50	50	48	43.6	40
Cu, Ag	25	50	50	50	50	50	44.4	40	36.3	33.3
Cr, Co	25	50	50	50	50	45	40	36	32.7	30
Fe	25	50	50	50	42.8	37.5	33.3	30	27.2	25

BROAD FOCUS:



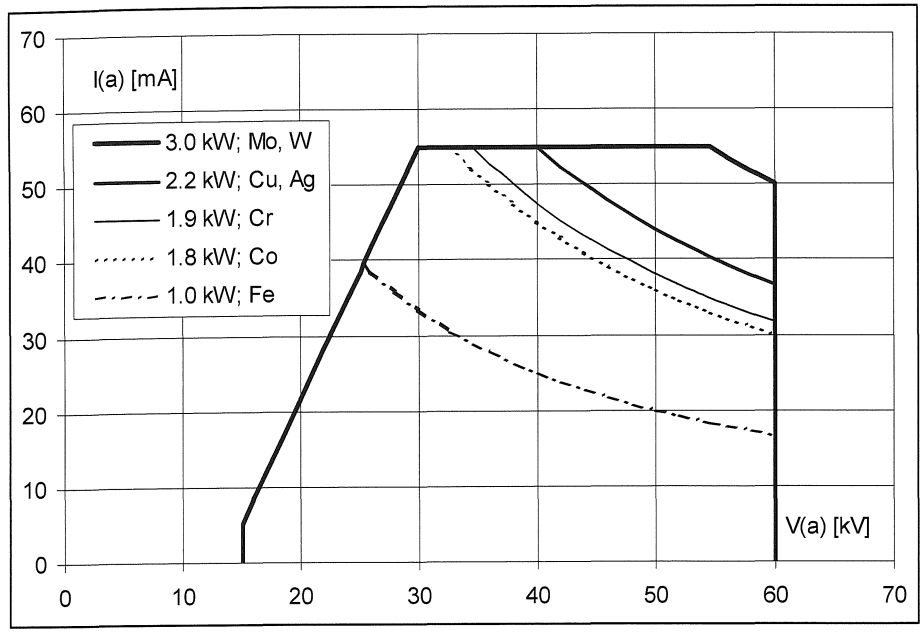
Target material	15 kV	20 kV	25 kV	30 kV	35 kV	40 kV	45 kV	50 kV	55 kV	60 kV
Cr, Co, Cu, Mo, Ag, W	30	60	60	60	60	60	60	54	49	45
Fe	30	60	60	60	60	55	48.8	44	40	36.6

FINE FOCUS:



Target material	15 kV	20 kV	25 kV	30 kV	35 kV	40 kV	45 kV	50 kV	55 kV	60 kV
Mo, W	20	40	40	40	40	40	40	40	36.3	33.3
Cu, Ag	20	40	40	40	40	37.5	33.3	30	27.2	25
Cr	20	40	40	40	37.1	32.5	28.8	26	23.6	21.6
Co	20	40	40	40	34.2	30	26.6	24	21.8	20
Fe	20	40	36	30	25.7	22.5	20	18	16.3	15

LONG FINE FOCUS:



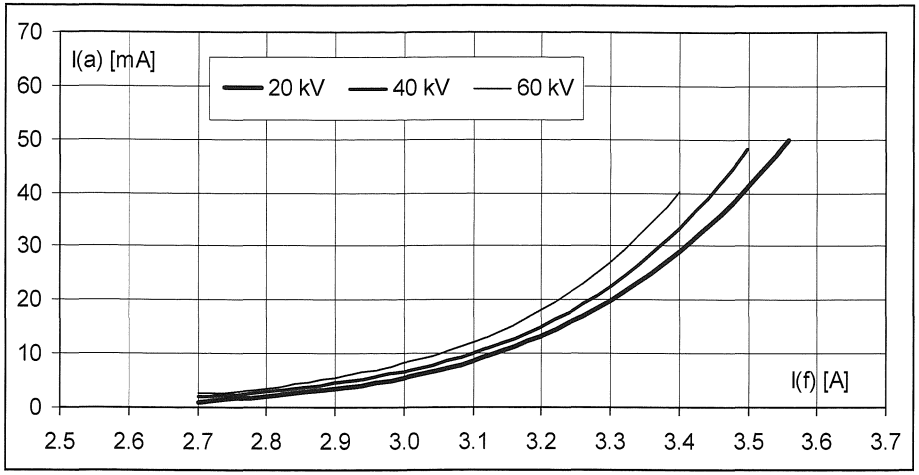
Target material	15 kV	20 kV	25 kV	30 kV	35 kV	40 kV	45 kV	50 kV	55 kV	60 kV
Mo, W	5	21.7	38.3	55	55	55	55	55	54.5	50
Cu, Ag	5	21.7	38.3	55	55	55	48.8	44	40	36.6
Cr	5	21.7	38.3	55	54.2	47.5	42.2	38	34.5	31.6
Co	5	21.7	38.3	55	51.4	30	26.6	24	21.8	20
Fe	5	21.7	38.3	33.3	28.6	25	22.2	20	18.1	16.6

APPENDIX E.

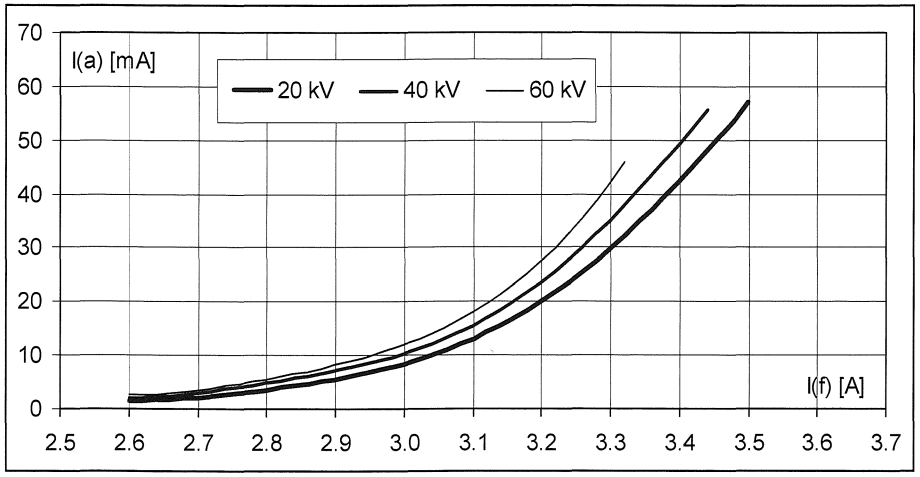
X-RAY DIFFRACTION GLASS TUBE:

TYPICAL EMISSION CHARACTERISTIC: anode current [mA] as function of the filament current [A].

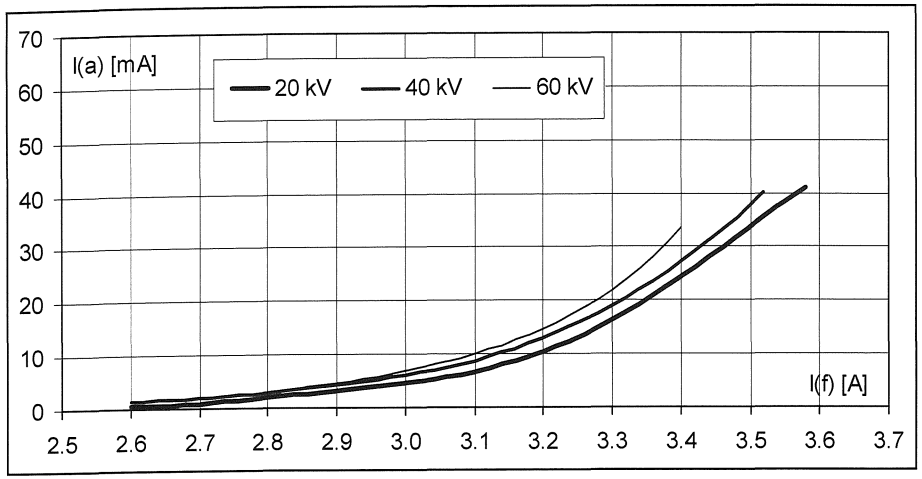
NORMAL FOCUS.



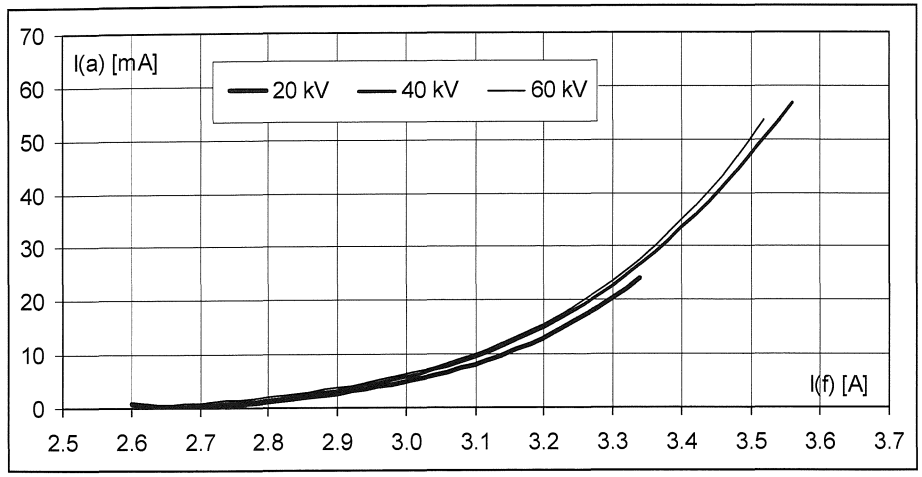
BROAD FOCUS.



FINE FOCUS.



LONG FINE FOCUS.



APPENDIX F.

REPLACEABLE PARTS AND TOOLS.

Replaceable parts for the X-ray diffraction glass tube:

Large sealing ring	Viton, 31.47 x 1.78 mm
Small sealing ring	Viton, 9.25 x 1.78 mm
Water filter	
Nozzle, short	
Nozzle, long	

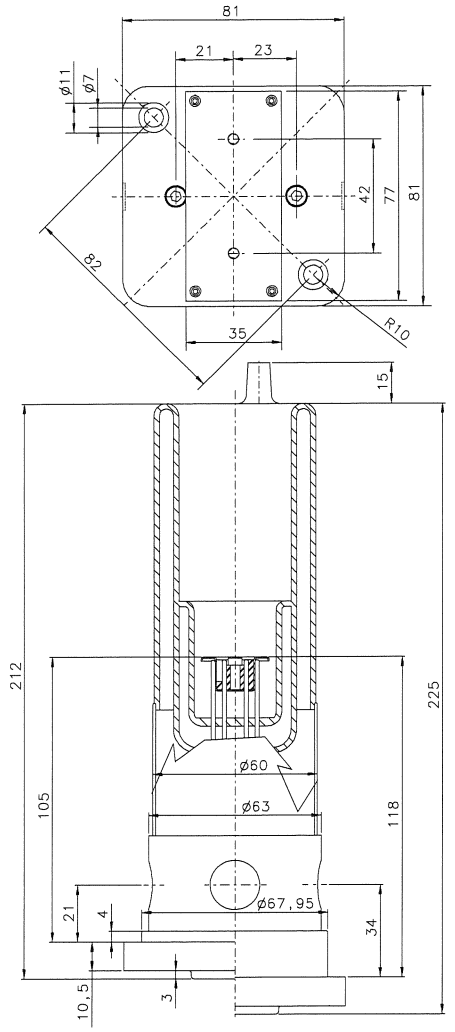
For maintenance of the X-ray diffraction tube the use of following (non standard) item is recommended:

Universal tube stand
Acid-free grease (e.g. Apiezon M)

For code numbers and ordering information please contact your supplier.

APPENDIX G.

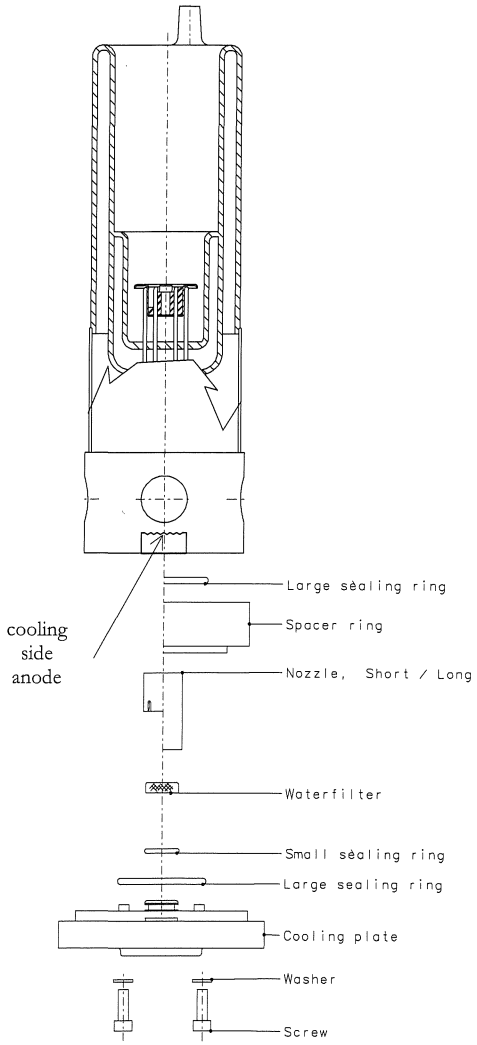
DIMENSIONS.



short version long version

APPENDIX H.

SERVICE DRAWING.



short version long version

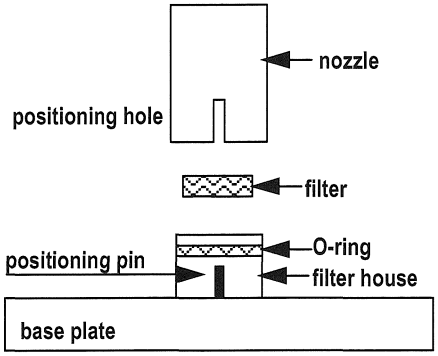
APPENDIX I.

POSITIONING THE NOZZLE.

The water cooling of the tube is less efficient when the nozzle is not in the correct position. The energy density of the focal spot on the anode is extremely high (up to about 600 W/mm^2), so an efficient cooling is absolutely necessary. Therefore the nozzle must be in the correct position.

The correct position of the nozzle is when the top (=side with slit) is flush against the cooling side of the anode. The slit should be parallel to the focal spot; to ensure this the nozzle has a positioning hole which should be placed over the positioning pin next to the filter house. Distance **and** orientation of the nozzle are important.

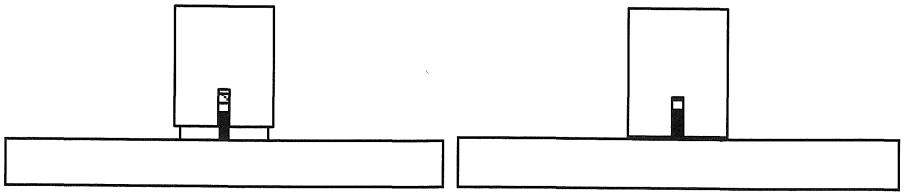
Take the following precautions to ensure a correct position of the nozzle during operation of the tube:



1. Do not deform the nozzle when removing (do not use pliers when the nozzle is stuck).
2. Replace the nozzle when the cross section is not circular anymore or when it is corroded.
3. Clean the cooling plate, including the filter house and the pin.
4. Replace the sealing ring when it is not flexible any more.
5. Clean and slightly grease the sealing ring.
6. If necessary clean the filter and place it in the nozzle.
7. Place the nozzle over the filter house with the positioning hole just over the positioning pin).
8. The distance between nozzle and cooling plate should be as large as possible but it should not be possible to rotate the nozzle (i.e. positioning hole slightly over positioning pin).

When the combination cooling plate/nozzle is mounted on the tube the nozzle will automatically be placed in the correct position: against the cooling side of the anode.
As long as movement of the nozzle does not require too much force the water pressure will keep the nozzle pressed against the anode.
Experience has shown that the water pressure is not always sufficient to press the nozzle against the cooling side of the anode when the nozzle is not in the correct position at the beginning.

After separating tube and cooling plate the position of the nozzle should be as illustrated in situation A:



Situation A. **Situation B.**

When the distance between cooling plate and nozzle is practically zero (situation B) the cooling efficiency will be decreased to such an extent that tube life time will most likely be reduced.

APPENDIX J.

DEW POINT.

Approx. values for dew point as function of temperature and relative humidity.

Relative humidity (%)	Room temperature (°C)					
	15	**20**	**25**	**30**	**35**	**40**
100	15	20	25	30	35	40
90	13	17	23	28	33	38
80	12	15	21	26	31	36
70	11	13	19	24	29	34
60	10	11	16	21	26	31
50	9	10	13	18	23	28

Note: The temperature of the cooling water should be based on the maximum dew point possible with practical temperature/humidity combinations.
Do not use temperature and humidity at the moment; next month they may not be valid any more.