Surface Analysis Technology

Vacuum Components

Surface Analysis System Software

Computer Technology

XRC 1000

X-ray Source Control

High Voltage Supply

2.3

User Manual for XRC 1000.

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Chapter 1

Introduction

1.1 Overview

The X-Ray source control XRC 1000 is a state-of-the-art power supply for high-intensity twin anode X-ray sources optimized for XPS (ESCA) experiments in order to produce low energy X-ray quanta. Additionally, the supply can be used to control a X-ray monochromator.

The standard XRC 1000 supports a twin anode X-ray source, i.e. it is designed to supply two filaments and ensures continuous operational power of 1000 W. SPECS offers analog/digital interfaces for complete remote control and the capability of "soft start."

The SPECS power supply XRC 1000 operates normally with the X-ray source XR-50 and the cooling control unit CCX 60. The user manual for the X-ray source normally accompanies this manual, while the water cooling unit is described separately in its own manual.

This manual addresses the installation of the XRC 1000, its initial commissioning, its normal operation, and troubleshooting procedures.

1.2 Safety Instructions

Warning!

Beware! Lethal high voltages up to 15 kV are applied to the X-ray source. Hazardous voltages are present, therefore only trained, qualified personnel are allowed to carry out the installation, adjustment and repair work.

All national, federal, state, and company or department internal regulations, restrictions, codes, and rules for protection against radiation sources have to be observed during installation and operation of the X-ray source at its site!
Consult your safety inspector in case of a primary installation and in case of any

doubt. The users are responsible for the correct labelling of the source and its power supplies, and for providing safety instructions in their native language, if required by law.

Before any electrical or electronic operations please consult the "SPECS Safety Instructions" manual and follow it carefully.

Some tests which might have to be carried out according to this manual are hazardous. These parts are indicated by a warning label:

!Warning!

The following tests described here have to be performed on connectors of the electronics not plugged into the source. Hazardous voltages are present, therefore only trained, qualified personnel are allowed to do the job.

Perform the measurements only with specially insulated tools designed for voltages greater than 20 kV.

1.3 Soft X-ray Radiation Protection

Supplementary to the regulations, restrictions, codes, and rules for protection against radiation which have to be legally observed at the operational site of the XRC 1000 and X-ray sources SPECS recommends the following:

- Cover all window flanges additionally by X-ray protective lead glass. Applying window flanges with lead glass are useful but normally not necessary.
- All flanges of the chamber attached to the X-ray source have to be closed by blank flanges or compact UHV components made of stainless steel. If larger components of other materials (e.g. glass) are installed, consult your safety inspector for suitable solutions.
- Pregnant women should inform their supervisor or safety inspector of their current status, in the event that additional safety measures are required.

Note:

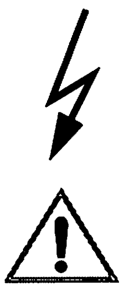
If using an acceleration voltage beneath 20 kV, the local dose performance of <0.1 µSv/h will not be obtained or exceeded anywhere at the source within a distance of 0.1 m. Note that the source runs in vacuum only, i.e. if the plant itself is not providing the radiation, working with an open flange is not possible.
Normally stainless steel chambers and components as well as viewports >1.5 mm thickness (DN16CF windows) are not permeable for this kind of radiation because of the similar wall thickness to the source body.

1.4 Vacuum Conditions

The XRC 1000 can work satisfactorily in the pressure range of the X-ray source below 1 x 10^{-5} mbar. Nevertheless, vacuum conditions in the 10^{-8} mbar range or better are strongly recommended to prevent contamination of the volume around the anode. Good vacuum conditions will prevent oxidation of the filaments while in use, ensure a longer lifetime of anode and window, reduce the risk of spark-over between the anode and grounded parts, and will result in a longer lifetime of the X-ray source at full intensity.

1.5 Special Instructions

The XRC 1000 generates high voltages up to 15 kV that are hazardous to life! You should therefore follow the safety instructions given below:



- The XRC 1000 accepts line voltages of 90 - 260 VAC.
- Use only original cables, connectors, and flexible conduits from SPECS. Ensure that all cables and water lines are free of physical or electrical defects. In case of doubt, the cable or the water line has to be replaced by an original SPECS part.
- Please connect the X-ray source with only a high frequency, low impedance cable to the power supply ground screw. Large contact areas are important. A proper connection will protect the sensitive electronic units of your system and in the surrounding area.
- Never run the X-ray source without a grounding cable or with a loose ground connection.
- All shields for interlock, remote and other connections must be grounded with a proper high frequency rating, too.
- Operate the XRC 1000 only with a fully closed protection cover at the X-ray source and properly fixed cable conduit for high voltage and water supply. Open slits and holes could be hazardous to health and violate the regulations regarding X-ray protection.
- Do not operate the X-ray source if your system pressure is above 10^{-6} mbar.
- Do not operate the X-ray source without cooling water for the anode. Cooling the housing jacket limits the temperature increase of an irradiated sample during continuous operation.
- Before switching on the power units, the electrical and physical installation has to be completed. The interlocks for vacuum, water, and HV guard have to be correctly activated and tested for safe and proper functioning.
- Never short the HV guard and water interlock system.
- Never operate the power supplies with removed housing parts.
- Connect the X-ray source only when the power supply has been turned off.
- After switching off the power unit the operator must wait at least 3 minutes before disconnecting devices, the power supplies or the X-ray source protection cover.

- In case the XRC 1000 gets wet (by the cooling water, for example), a complete drying of the modules, the protection cover and the cables is strongly recommended.
- Never run a wet XRC 1000 unit or wet inner parts of the other X-ray source parts.
- In case of operating the XRC 1000 with other equipment than delivered by SPECS, you may void your warranty. In case of doubt please contact the SPECS service department (support@specs.de).

Chapter 2

Contents and Connections

2.1 Contents of the XRC 1000 Package

The XRC 1000 electronics package consists of:

1. Power supply XRC 1000.
2. HV cable (normally connects to the CCX 60 cooling unit)
3. Filament cable
4. Vacuum interlock plug, see "Interlocks" on page 19. (The short circuit of pin 1 and 2 is necessary for HV to be on! Please check/modify the delivered plug, if not used as vacuum interlock.)
5. HV guard cable
6. Water interlock cable
7. Ground cable (not shown)

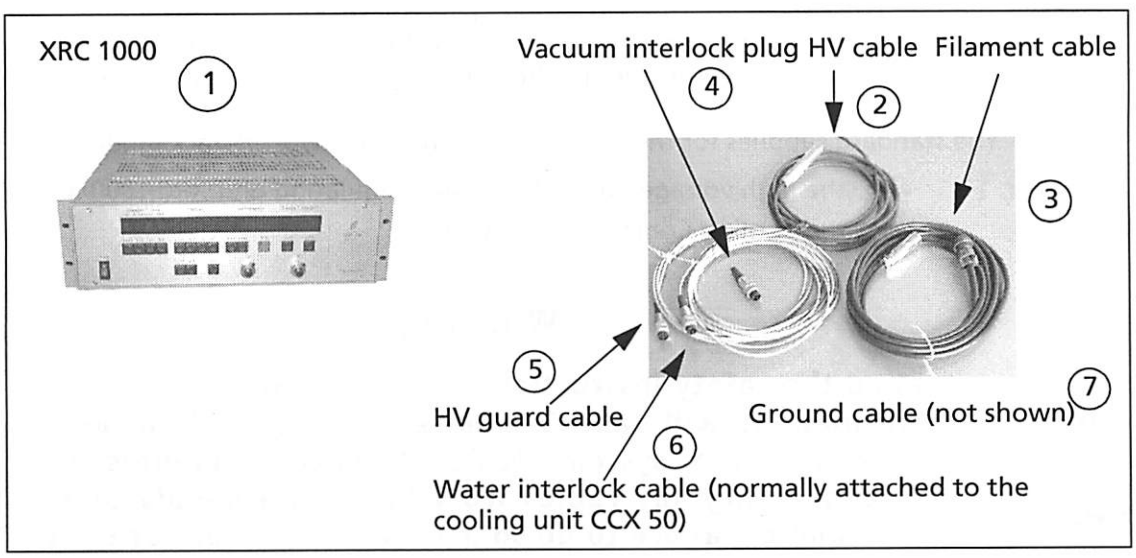


Figure 1 **Contents of the XRC 1000 package**

2.2 Electrical Connections

1. The high voltage unit has to be connected directly to the mains supply (90 - 260 V, 50 - 60 Hz, 1300 VA).
2. The high voltage line between the cooling unit and further to the anode is the most critical connection. Careful installation is necessary.
3. The high voltage connection between the Cooling Control Unit/Anode of the X-ray source and the X-Ray source control has to be fit with traction reliefs on both sides.
4. Check that the X-ray source (or system) is connected with a low impedance cable to the power supply ground (usually the ground screw at the cooling unit as the central ground potential). Large contact areas are important. Such a connection is also important to protect the sensitive electronic units of your system. An additional ground connection between the Cooling Control Unit and the XRC 1000 has to also be made.
5. The screen of the high voltage cable has to be connected to the back side of the source's casing.
   A perfect screen of the high voltage cable protects your life, your additional electronic equipment and the X-ray source.
6. The safety interlock for the cooling water (Cooling Control Unit CCX 60,'Water' interlock), the safety HV-cover switch of the X-ray source and the vacuum interlock have to be plugged into the respective sockets („WATER", „HV-GUARD" and „VACUUM") at the rear panel of the X-ray power supply. Because the vacuum interlock is not supported by the SPECS X-ray source equipment, the pin 1 and 2 on the vacuum interlock socket have to be shorted by a vacuum interlock unit, e.g. a relay output of a vacuum gauge. If no vacuum interlock is used pin 1 and pin 2 should be shorted (see "Interlocks" on page 19)!
7. The water cooling unit is connected by plugging the HV plug into the HV socket of the XRC 1000. The HV socket is interlock-protected by a micro switch and therefore together with the interlock line from the HV-cover safety switch, these form part of the "HV-Guard" protection!

The standard supplies for the X-ray source consists of two 19"-rack modules:

- the high voltage power & emission regulation unit XRC 1000 and
- the Cooling Control Unit CCX 60

!Warning!

Mind the safety instructions given on page 1!
Warning: It will take 3 minutes before all high voltages have left the system. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray source. Failure to do so may result in injury or death!

Typical connections with XR-50 X-ray source and CCX 60 cooling control unit are shown in figure 2.

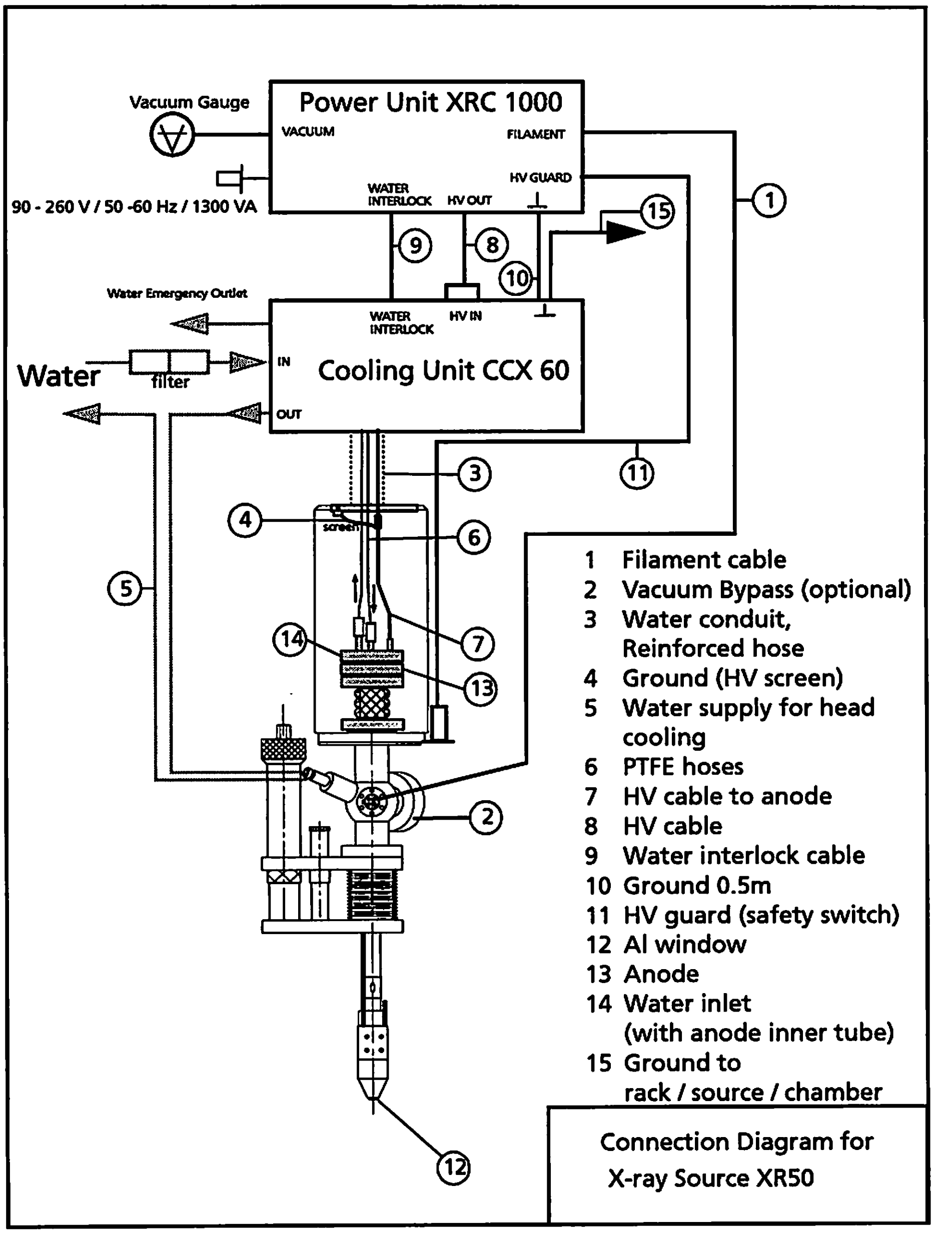


Figure 2 **Schematic Connection diagram**

Chapter

3

Description of the Electronics

!Warning!

Mind the safety instructions given on page 1!
Beware! Lethal high voltage is applied to the water within the hoses during operation.

Warning: It will take 3 minutes after the high voltage is turned off before the system reaches a voltage of zero. Wait at least 3 minutes before opening the protection cover and disconnecting any cables from the power supplies or the X-ray source. Failure to do so may result in injury or death.

This chapter deals with the electronics and operation of the X-ray Source Control XRC 1000 in conjunction with the SPECS X-ray source XR-50 and the Water Control Unit CCX 60.

The XRC 1000 supplies all voltages and currents needed for the operation of the source XR-50. This power supply is also capable of powering X-ray sources other than the XR-50.

The functions and controls of the XRC 1000 can be divided into five main parts:

1. Front panel control
2. Rear panel control
3. Emission control
4. HV control
5. Remote control

The front panel provides a number of buttons, indicators, and displays allowing the user to control the power supply.

On the rear panel, a number of sockets and status indicators are provided for interlock control, filament supply, and high voltage supply.

The emission control supplies the filament current and regulates the emission current. Two different anodes can be easily selected by push-buttons.

The HV control supplies the anode voltage up to 15kV / 66mA. The high voltage output is short circuit and arc protected.

The optional remote control allows remote control via RS232 or CAN bus. This unit is also capable of ramping the high voltage automatically, e.g. after each bakeout.

Figure 3 **XRC 1000 front view**

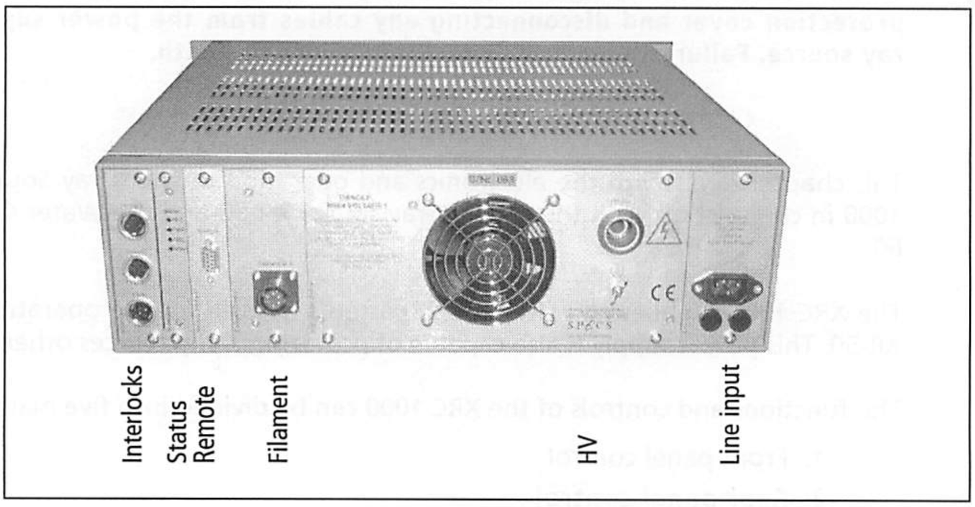


Figure 4 **XRC 1000 rear view**

Size / Height:	19"(W) x 132 mm (H, 3 chassis units) x 495 mm (T) +10 mm (plug)
Depth:	495 mm (+ 80 mm for cable plugs)
Weight:	18.5 kg

High Voltage:	0 - 15 kV, continuous
Emission Current:	variable, standard up to 66mA
Cathode Supply:	0 - 8 A, 0 - 12 V
Power:	1000 W[1]
Mains:	90 - 260 V, 50 - 60 Hz, 1300 VA , Fuse please check: see page 27.
Interlock:	HV Guard, Vacuum, Water
Optional	
Remote:	Refer to the remote control manual
Soft start	Variable ramp for voltage and emission current

3.1 X-ray Source Voltages and Currents

This document deals with different voltages, currents, and powers of the X-ray source. For better understanding, a block diagram is depicted below showing the source voltages and currents, which are described below in more detail.

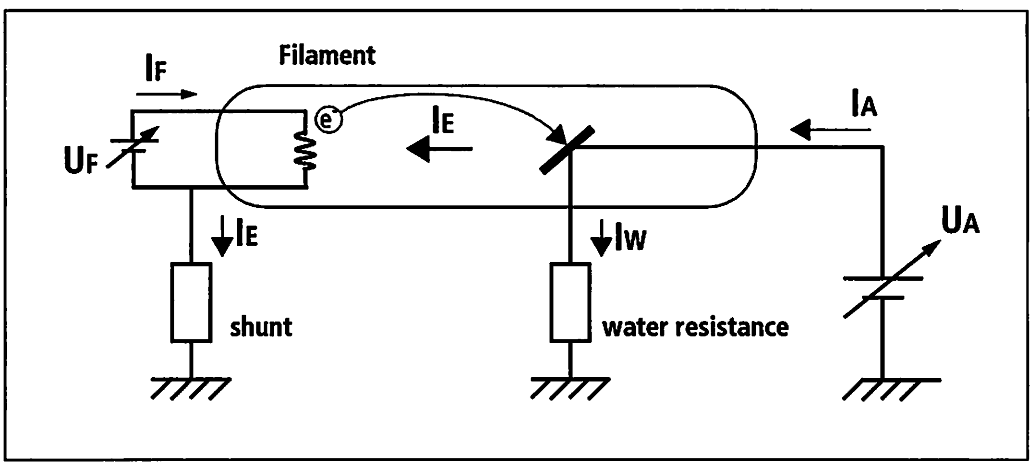


Figure 5 **Block diagram of the principle of operation**

1. The X-ray power is calculated by emission current I_E and high voltage. The total power (of the supply) is the product of anode current I_A and high voltage. The anode current consists of emission current I_E and Water current I_W.
(see section 3.1 , "X-ray Source Voltages and Currents" on page 11)

3.1.1 Anode Voltage (U_A) and Anode Current (I_A)

The output voltage of the XRC 1000 is applied to the source anode. This voltage is called anode voltage, U_A, and can be set to a value in the range of 0 to 15 kV. The output current flowing to the source anode is called anode current I_A, and can be in the range of 0 to 66 mA.

The anode current is divided into two parts: One part of the anode current, called cooling water current I_W, flows through the cooling water to ground. The other part of the anode current, called emission current I_E, flows through the source filament to ground.

3.1.2 Cooling Water Current

With the XR-50, cooling water is applied for anode heat sinking. The cooling water at the water output of the source has the same potential as the anode itself. Due to the water conductivity a leakage current, called cooling water current, flows through the water to ground. The amount of this current depends on the water conductivity, the length, and the thickness of the water hoses.

The anode net power consists of X-ray radiation and heat dissipation. The anode gross power includes the additional voltage drop from the water influx and reflux lines for the anode cooling (cooling water current, I_W), usually because the water cooling box is grounded.

The difference between gross and net anode power will increase when the water resistance decreases or when the water conductivity increases.

If the difference between gross and net emission currents (so-called "water current", I_W) exceed an amount where the sum of emission power and the power loss due to the water current is larger than the maximum power of the supply, the supply will fail.
Normal values are between 2 and 10 mA for the water current at 15 kV anode voltage. If the water resistance is too large ("water current"< 2 mA at 15 kV), intensive corrosion can occur.

Please check the instructions given in your X-ray source manual.

3.1.3 Emission Current (I_E)

By heating the source filament, electrons are emitted and accelerated toward the anode. Thus an emission current, I_E, flows from the filament (electrons) through the anode to ground. The amount of the emission current depends on the filament current, I_F, and the acceleration voltage, U_A. The emission current flows through a shunt resistor to the ground allowing the current measurement. The emission control unit of the XRC 1000 measures the emission current and controls the filament current such that a constant emission current is achieved. The maximum emission current is internally set to 66 mA.

3.1.4 Filament Voltage and Current

The emission control unit of the XRC 1000 supplies the filament voltage, U_F , and the filament current, I_F , and is capable of powering the filament up to 10 V/8 A.

The emission control unit is equipped with two fuses (see figure 6). Fuse no. 1 with 200 mA/230 V (slow blow) is situated at the input circuit. Fuse no. 2 with 6.3 A/230 V (slow blow) is located near the boards panel (part of the rear side of the XRC 1000) at the output circuit. Its value corresponds to the maximum filament current when in operation.

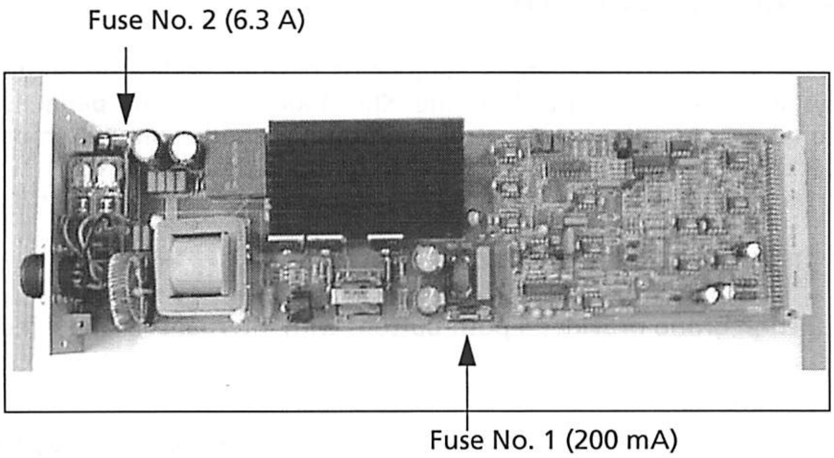


Figure 6 **Fuses for emission regulator**

3.1.5 Source Power Dissipation

The power dissipation of the X-ray source can be divided into 3 parts:

1. The anode power dissipation
2. The cooling water power dissipation
3. The filament power dissipation

The total power dissipation at the source anode is:

$$P_{total} = I_A \times U_A \qquad \textit{(EQ 1)}$$

The anode power dissipation P_A (nearly proportional to the X-ray radiation power) depends on the emission current and the anode voltage and can be calculated by the formula:

$$P_A = I_E \times U_A \text{, where } I_E = I_A - I_W \qquad \textit{(EQ 2)}$$

The water power dissipation P_W depends on the resistance of the cooling water. With the water current and the anode voltage the water power dissipation can be calculated by the formula:

$$P_W = I_W \times U_A \qquad (EQ\ 3)$$

The total power that has to be delivered by the high voltage control of the XRC 1000 is:

$$P_{total} = P_A + P_W \qquad (EQ\ 4)$$

The filament power dissipation depends on the filament current and the filament voltage and can be calculated by the formula:

$$P_{filament} = I_F \times U_F \qquad (EQ\ 5)$$

3.2 Front Panel Control

On the front panel there are a number of buttons, indicators, potentiometers, and displays allowing the control of the XRC 1000. The front panel is divided into 5 functional groups: interlocks/control, monitoring, anode voltage, emission current, and limit setting. The following describes each group in detail.

3.2.1 Interlocks and Control

This function group provides 4 push-buttons with internal LED and 4 indicators.

3.2.1.1 Indicators

- Water — Lamp is on if the water interlock switch is open, e.g. if the water flow fails.
- Vacuum — Lamp is on if the vacuum interlock switch is open.
- HV Lock — Lamp is on if the source cover is not in position or if the HV connector is removed from the power supply.
- Failure — Lamp is on if the internal power supply of the XRC 1000 is not ready.

3.2.1.2 Push-buttons

- WATER — To switch on the cooling water circuit. LED flashes if there is a failure within the circuit or if the interlock is not connected.
- DEGAS — To enable filament degassing. The button "Ramp" is used to increase the current from zero up to the maximum filament current in 32 steps, see also "Filament Degassing".
- RAMP — This button is usually used in conjuction with the DEGAS button so to increase the filament current. It can also be used in conjunction with the optional remote interface. Upon pushing this button (without pushing the DEGAS button) the high voltage and the emission current are ramped slowly. This function is usually used to start up the source automatically after

each bakeout. The LED is on if ramping is in progress. For more details see also the user manual of the remote interface.

- REMOTE — The LED on this button is on if the unit is operating in REMOTE mode. In this case no manual control is possible through the front panel. Upon pushing the button, the unit is released from remote control and can be manually controlled, e.g. in case of emergency.

3.2.2 Monitoring

This function group consists of one digital panel meter and 7 push-buttons with internal LEDs.
The digital panel meter (DPM) is used to show the voltages, currents, or powers selected by the 6 push-buttons. The "Limit" button allows one to display both the operational values and the limit values.

There are two monitoring modes, the operational mode and the limit mode, which can be selected with the "Limit" button.

Operation Mode:

To enter the operation mode press the "Limit" button (LED off). The DPM displays the operating values:

- I_A [mA] — Button to select the display of the anode current. Note that the anode current is the sum of the emission current and the cooling water current. Button LED is on if the anode current is displayed. LED blinks if the anode current exceeds the limit of 66mA.
- I_E [mA] — Button to select the display of the emission current. LED is on if the emission current is being displayed. LED will blink if the emission current exceeds the limit set by the user.
- I_F [A] — Button to select the display of the filament current. Button LED is on if the filament current is displayed. LED will blink if the filament current exceeds the user selected limit.
- I_S [A] — This button is only used in limit mode to display the standby current limit. It is locked in operational mode since it does not make any sense to display the operational standby current. Instead the button I_F is used for the operating filament current.
- P_A[W] — Button to select the display of the anode power. Note that the anode dissipation power depends on the emission current and anode voltage, i.e. $P_A = I_E \times U_A$ (equation (EQ 2) on page 13). Button LED is on if the anode

power is displayed. LED will blink if the anode power exceeds the user selected limit.

- U_F [V] — Button to display the filament voltage. Button LED is on if the filament voltage is displayed. LED will blink if the filament voltage exceeds the user selected limit or if the filament is not connected.

Limit Mode:

To enter the limit mode, the push the "Limit" button (LED blinking). The DPM displays the limit values of the selected anode by using the buttons ANODE 1 or ANODE 2:

- I_A [mA] — To display the anode current limit. LED is on if the anode current limit is being displayed. LED will blink if the anode current exceeds the limit set by the user
- I_E [mA] — To display the emission current limit. LED is on if the emission current limit is being displayed. LED will blink if the emission current exceeds the limit set by the user.
- I_F [A] — To display the maximum filament current (in OPERATE mode) set by the user. LED is on if the maximum current is being displayed. LED will blink if the filament current exceeds the limit set by the user.
- I_S [A] — To display the filament current (in STANDBY mode) set by the user. LED is on if the standby current is being displayed.
- P_A [W] — To display the anode power limit. LED is on if the power limit is being displayed. LED will blink if the power exceeds the limit set by the user.
- U_F [V] — To display the filament voltage limit. Button LED is on if the filament voltage is being displayed. LED will blink if the filament voltage exceeds the user selected limit or if the filament is not connected.

3.2.3 Anode Voltage

This function group consists of a digital panel meter, a potentiometer, and 3 push-buttons with internal LEDs.
The digital panel meter with 3 1/2 digits is used to show the high voltage of the selected anode up to 15 kV.
The 10-turn potentiometer is used to set the anode voltage in the range of 0 to +15 kV.

The functionality of the three buttons are described below:

- ANODE 1 / ANODE 2 — Buttons to select the desired anode. Push-button LED illuminates indicating the selected anode.
- HV On — Button to switch on the anode high voltage. LED is on if the high voltage is turned on and the desired value is reached. LED will blink during change of the voltage or

if control unit can not supply the desired high voltage, e.g. in case of current limitation.

3.2.4 Emission Current

This function group consists of a digital panel meter, a potentiometer, and 2 push-buttons with internal LEDs.
The digital panel meter is used to show the emission current up to 66 mA.
The 10-turn potentiometer is used to set the emission current in the range of 0 to 66 mA.

The functionality of the two push-buttons is given below:

- STANDBY — This button is pressed to select STANDBY mode (LED on) or to turn the filament off (LED off).
- OPERATE — Button to select the OPERATE mode. The control unit goes to this mode only if standby is on, the high voltage is on, and then this button is pressed. The OPERATE LED will light up and the STANDBY LED should turn off.

3.3 Limit Setting

The limit of relevant voltages, currents and powers can be set by the user through potentiometers located on the top side of the front panel printed circuit board. The potentiometers can be accessed from the top side by removing the unit cover. Figure 7 depicts the position of each potentiometer.

Limits for Anode 1:

Before changing the limits, ensure the high voltage is turned off and the button LED of ANODE 1 is on. Use the push-buttons and panel meter in the Monitoring function group.
Press the "Limit" button (LED blinking) to enter the limit setting mode.
Use the potentiometers for ANODE 1 (see figure 7).

Limits for Anode 2:

Before changing the limits, ensure the high voltage is turned off and the button LED of ANODE 2 is on. Use the push-buttons and panel meter in the Monitoring function group.
Press the "Limit" button (LED blinking) to enter the limit setting mode.
Use the potentiometers for ANODE 2 (see figure 7).

- Anode Current — Press the **I_A[mA]** button. The panel meter shows the present limit of the anode current. Use the potentiometer **I_A** to set a new limit. The limit can be set in the range of 0 to 66 mA.
- Emission Current — Press the button **I_E[mA]**. The panel meter shows the present limit of the emission current. Use the potentiometer **I_E** to set a new limit. The limit can be set in the range of 0 to 66 mA.

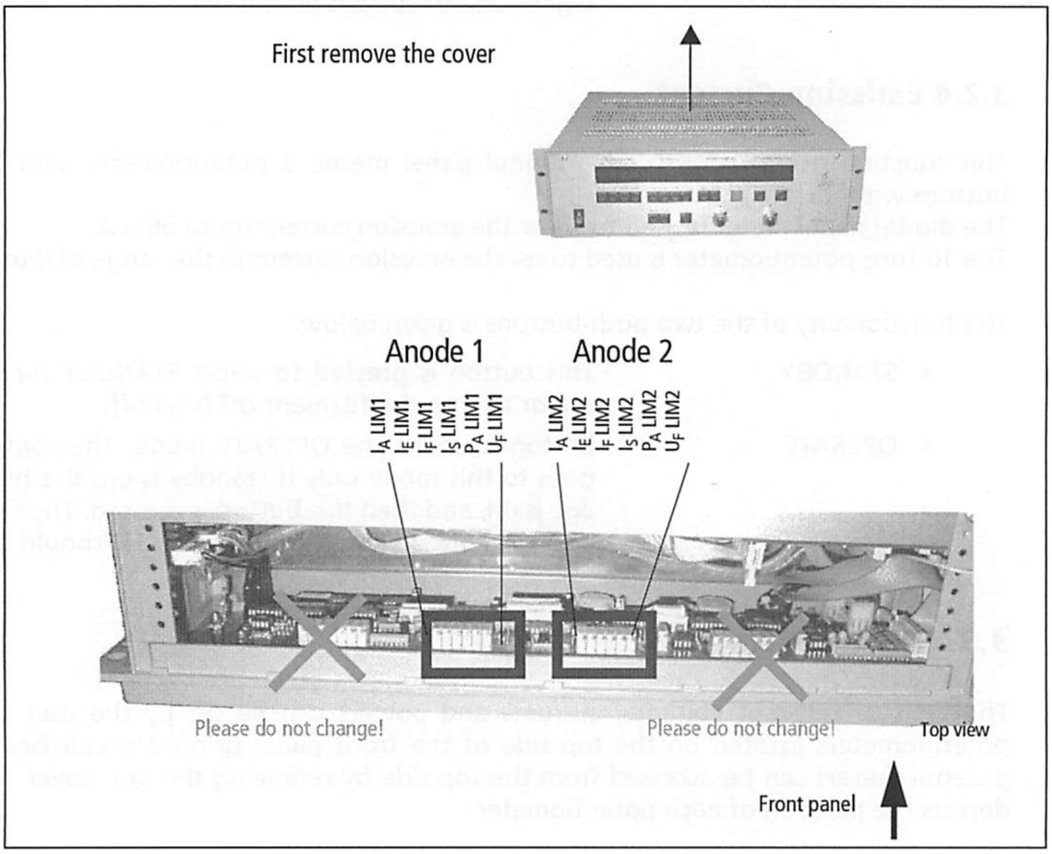


Figure 7 **Limits Setting**

- Operate Current — Press the button **I_F[A]**. The panel meter shows the present limit of the filament current in OPERATE mode. Use the potentiometer **I_F** to set a new limit. The limit can be set in the range of 0 to 8 A.
- Standby Current — Press the button **I_S[A]**. The panel meter shows the present limit of the filament current in STANDBY mode. Use the potentiometer **I_S** to set a new limit. The limit can be set in the range of 0 to 8 A.
- Anode Power Limit — Press the button **P_A[W]**. The panel meter shows the present limit of the anode power. Use the potentiometer **P_A** to set a new limit. The limit can be set in the range of 0 to 1000 W.
- Filament Voltage — Press the button **U_F[V]**. The panel meter shows the present limit of the filament voltage. Use the potentiometer U_F to set a new limit. The limit can be set in the range of 0 to 12 V.

3.3.1 Emission Current at Standby

The limit of the standby current is chosen such that the emission current in STANDBY mode is in the range of 0.1 to 2 mA. Under certain circumstances, e.g. after a filament change, the emission current in STANDBY mode could possibly exceed a few milliamperes and reach very high values. This is nothing to worry about, and can be considered normal in these situations.

To ensure safe operation of the source, two regulation circuits are activated when in STANDBY mode. Thus two limits are used for STANDBY mode, one for standby filament current and one for the standby emission current. These two limits are not exceeded at any time. The limit of the emission current in STANDBY mode is factory set to 1 mA.

3.4 Rear Panel Control

3.4.1 Line Voltage Input

The XRC 1000 uses a PFC-module (power factor correction module) for converting the line voltage to DC voltage and accepts line voltages in the range of 90 V to 260 V_{AC}.
A 3-pole line input socket and two fuse holders are provided on the rear panel.

For line voltages in the range of 90 to 120 V_{AC}, the PFC-module provides a maximum power of 750 W. However, the XRC 1000 can supply a maximum power of approx. 600 W. In this case 10 A slow blow fuse should be used.

For line voltage of 200 V_{AC}, the PFC-module provides a maximum power of 1000 W. However, the XRC 1000 can supply a maximum output power of approx. 800 W. In this case a 6.3 A slow blow fuse should be used.

For line voltages in the range of 220 to 260 V_{AC}, the PFC-module provides a maximum power of 1200 W. However, the XRC 1000 can supply a maximum output power of 1000 W. In this case a 6.3 A slow blow fuse should be used.

3.4.2 Interlocks

On the back panel, three sockets are provided for interlocks and cooling water control:

- HV Lock — 3-pole socket. Pin 1 is internally connected through a resistor of 5kΩ to +5 V. Pin 2 is the signal input. Pin 3 is not used. If pin 1 and 2 are connected to each other, the interlock is closed.
- Vacuum — 4-pole socket. Pin 1 is internally connected through a resistor of 5 kΩ to +5 V. Pin 2 is the signal input. Pin 3 and 4 are not used. If pin 1 and 2 are connected to each other, the interlock is closed.
- Water — 6-pole socket. Pin 1 is internally connected through a resistor of 5kΩ to +5 V. Pin 2 is the signal input. Pin 3

and 4 are not used. Pin 5 is connected to ground. Pin 6 supplies +24 V/1 A if the WATER push-button has been pressed. If pin 1 and 2 are connected to each other, the interlock is closed.

3.4.3 HV Output

A LEMO socket is provided on the rear panel for high voltage output. This socket includes an interlock switch inside. The high voltage is only enabled if the high voltage connector of the source is plugged in.

3.4.4 Filament Connector

On the rear panel a 6-pole socket is provided for filament supply. The pin assignment is given below:

- Pin A — Filament 2, negative electrode
- Pin B — Filament 1, negative electrode
- Pin C — Filament 1, positive electrode
- Pin D — Filament 2, positive electrode
- Pin E — No connection
- Pin F — No connection

3.4.5 Status Indicators

Four indicators mounted on the rear panel are provided to show the status of the control unit.

- PFC — LED on if the internal PFC module is not ready.
- PWR — LED is on if the internal low voltage power supply fails.
- ARC — LED is on if the high voltage is turned off after arc occurrences.
- RSV — Reserved, not used.

3.5 Grounding

The control unit is connected to the protective earth through the line voltage cord. However, a ground screw is provided on the rear panel for additional grounding. For a good system grounding, it is recommended to connect the source flange directly to the ground screw of the unit by using an appropriate cable. This arrangement eliminates ground loop problems and ensures a safe operation of the electronics in the immediate surroundings, in case of arcing occurring in the source.

3.6 Remote Control

The XRC 1000 can be remotely controlled by using one of the two available remote interfaces, analog/digital-interface (standard) , or RS232/CAN-interface (optional).

3.6.1 Analog/Digital-Interface

The XRC 1000 comes with an analog/digital-interface allowing two modes of remote operation, TTL-remote and analog/digital-remote operation. Two control signals are provided for selecting the REMOTE mode.

The TTL-REMOTE mode is usually used for simple remote operations using only TTL-signals but no analog signals, e.g. for turning on and off the high voltage and selecting operation modes as well as the anodes. The analog parameters, high voltage and emission current must be set manually by using the potentiometers on the front panel.

The analog/digital-REMOTE mode is used for full remote controls. For setting the high voltage and emission current, analog signals must be applied. TTL-signals are used to control high voltage, anode selection and operation modes.

3.6.1.1 Remote Control Signals

A 25-pin connector is provided on the back panel of the interface board. Each TTL-input exhibits one LS-load. All output gates have the drive capability of one LS-load. The analog inputs have a minimum input resistance of 100 kΩ. The analog outputs have a maximum output resistance of 1 kΩ.. The pin assignments and a brief signal description are given below:

- Pin 1 — Ground
- Pin 2 — InterlockFail: This TTL output signal is 5 V if interlock fails
- Pin 3 — FilamentCurrentMonitor: This output signal ranges from 0 V to10 V corresponding to 0 - 8 A
- Pin 4 — EmissionLimit: This TTL output signal is 0 V if emission current limit is reached
- Pin 5 — AnodeCurrentMonitor: This output signal is in the range of 0 - 10V corresponding to 0 - 66 mA
- Pin 6 — Anode1/2: This TTL input signal must be 5 V or 0 V, respectively, for anode1 or anode2 to be selected
- Pin 7 — FilamentOn: This TTL input signal must be 0 V or 5 V, respectively, for the filament current to be turned on or off
- Pin 8 — Operate/Standby: This TTL Input signal must be 5 V or 0 V respectively, for the OPERATE mode or STANDBY mode to be selected
- Pin 9 — FilamentVoltageLimit: This TTL output signal is 0 V if the filament voltage limit is reached

• Pin 10	Ground
• Pin 11	FullRemoteMode: This TTL input signal must be 0 V if analog/digital-remote operation is to be used
• Pin 12	CoolingOn: This TTL input signal must be 0 V to enable the cooling water
• Pin 13	Ground
• Pin 14	LocalMode: This TTL output signal is 0 V to indicate that the power supply is in local control mode
• Pin 15	FilamentVoltageMonitor: This output signal is in the range of 0 to 10 V corresponding to the 0 to 10 V filament voltage
• Pin 16	FocusModeOn: This input signal is reserved for XRC 1000M (monochromator power supply) and is not used on XRC 1000
• Pin 17	AnodeVoltageMonitor: This output signal is in the range of 0 to 10 V corresponding to the anode voltage of 0 to 15 kV
• Pin 18	Ground
• Pin 19	FilamentCurrentLimit: This TTL output signal goes to 0 V if the current limit is reached
• Pin 20	EmissionCurrentSet: This input signal is in the range of 0 V to 10 V corresponding to 0 to 66 mA of emission current
• Pin 21	EmissionCurrentMonitor: This output signal is in the range of 0 V to 10 V corresponding to 0 to 66 mA of emission current
• Pin 22	AnodeVoltageFail: This TTL output signal goes to 0 V if the anode high voltage fails
• Pin 23	AnodeVoltageSet: This input signal is in the range of 0 V to 10 V corresponding to anode voltage of 0 V to 15 kV
• Pin 24	HighVoltageOn: This TTL input signal must be set to 0 V to turn on the anode high voltage
• Pin 25	TTL-RemoteMode: This TTL input signal must be set to 0 V to select the TTL-remote mode

3.6.1.2 Remote Operation

As an example, the following instructions can be performed by a remote control program to operate and shut down the XRC 1000.

1. Upon program reset, set all the control signals to high.
2. If the unit should be remotely controlled, then perform the next steps
3. Set the signal FullRemoteMode or TTL-RemoteMode to low. The LED REMOTE on the front panel illuminates immediately.
4. Select ANODE 1 or ANODE 2 by using the signal Anode1/2.

5. Set the CoolingOn signal to low.
6. Wait 4 seconds for the cooling water and then read out the signal InterlockFail. If the signal is low (interlocks ok), proceed to the next step.
7. Turn on the filament current by setting both signals FilamentOn and Operate/Standby to low. The unit goes to the STANDBY mode.
8. Turn on the anode voltage by setting the signal HighVoltageOn to low.
9. Set the signal AnodeVoltageSet to 0 - 10 V corresponding to 0 - 15 kV if the full REMOTE mode is selected. In case the TTL REMOTE mode is selected, the anode voltage must be preset by the potentiometer on the front panel
10. Wait approx. 30 seconds until the high voltage ramping is finished. Check AnodeVoltageFail. If high (i.e. voltage ok), proceed to the next step
11. Set the signal Operate/Standby to high. The unit goes to OPERATE mode.
12. Set the signal EmissionCurrentSet to 0 - 10 V corresponding to 0 - 66 mA if the full REMOTE mode is selected. In case the TTL REMOTE mode is selected, the emission current must be preset by the potentiometer on the front panel
13. To shut down the XRC 1000, set all the control signals to high.

3.6.2 RS232/CAN-Interface

This optional remote interface allows remote control via RS232 or CAN bus. This unit is also capable of ramping the high voltage automatically, e.g. after each bake out.

3.6.2.1 RS 232

For the connection with the PC, a 1:1 cable socket-socket is used. At least the pins 2,3 and 5 must be connected.

Table 1 Parameter

Parameter	Value
Baud rate	9600
Bits	8
Parity	none

Commands may be maximum 80 bytes long. i.e. 80 bytes (with CR, LF) can be sent without waiting for an answer. Only the upper-case part of a command name is significant. Lower case letters in the command name are irrelevant and don't need to be typed, they will simply be ignored by the unit. With more than one parameter these must be separated by spaces.

Command lines are ended by CR (0Dh) and/or LF (0Ah). Inquiry commands must contain a question mark (e.g. "SCN?"). The answer consists of parameter, value, CR, LF (e.g. "SCN 1.2e3\n\r"). Empty command lines are ignored (only CR or LF after CR). For successful recognition of a command line, the character ">" must be returned. Otherwise one of the following error messages is sent:

Table 2 **Error messages**

"Remote Locked !"
"Not in Remote !"
"Misplaced Query !"
"Argument missing !"
"Value to big or to low !"
"Parameter unknown !"
"Command not found !"
"Unexpected Error code !"

Table 3 **Commands (In the local mode only inquiries can be send)**

Command	Purpose
"REMote"	Switches into the remote mode
"LOCal"	Switches into the local mode
"REMote ?"	Inquiry: 0 = local, 2 = remote
"IEM 20e-3"	Sets emission current 0... 66.6e-3 (e.g. 20mA)
"IEM ? "	Emission current (actual value) queries
"UAN 10e3"	Sets anode voltage 0... 15e3 (e.g. 10kV)
"UAN ? "	Anode voltage (actual value) query
"IHV ? "	Total value of current query
"IFI ? "	Filament current query
"UFI ? "	Filament voltage query
"PAN ? "	Power anode query
"SERNO ?"	Internal serial number (14 digits in hexadecimals) query, e.g. SERNO:0000003BDD1B28
"OFF"	Switch off
"COOLing"	Cooling on
"STANdby"	Cooling on, preheat filament
"UAON"	Cooling on, preheat filament, voltage anode on
"OPErate"	Cooling on, voltage anode on, filament on
"OPErate ?"	Inquiry: 0 = off, 1 = cooling on, 2 = preheating, 3 = anode voltage, 4 = on
"ANOde 1"	Select anode 1
"ANOde 2"	Select anode 2

Table 3 Commands (In the local mode only inquiries can be send)

Command	Purpose
"ANOde ?"	Inquiry: 0 =cooling mode or off, 1 = anode 1, 2 = anode 2
"STAT ?"	Inquiry status (6 digits hexadecimal) Digit 5,4 = remote status Digit 3,2 = operate status Digit 1,0 = Error code

The error code is formed by AND operation of the hexadecimal values.

Table 4 Error code

DEFINE	Value	Meaning
ERR_COOL	1	Cooling error
ERR_VAC	2	Bad vacuum
ERR_GUARD	4	Interlock
ERR_HV	8	HV power supply error
ERR_ILIM	0x10	Current overload
ERR_TOUT	0x80	Time out

With the status inquiry the error bits are cleared if the error is no longer present. Each error causes the switch into the condition "off".

3.6.2.2 CAN Interface

Table 5 XRC 1000 CAN command format

can_msg[0]	can_msg[1]	can_msg[2..5]
Set Remote	value (byte)	
Set Operate	value (byte)	
Set Anode	value (byte)	
Set Value	channel (byte)	value (float)
Get Value	channel (byte)	

Table 6 XRC 1000 CAN response format

can_msg[0]	can_msg[1]	can_msg[2]	can_msg[3]	can_msg[4,5]
Get Status	remote mode	operate mode	anode	operate errors
Get Type	type	major version	minor version	
Get ID	7 bytes (can_msg[1..7])			
Get Value	channel (byte)value (float = can_msg[2..5])			

DeviceType of DeviceNet-XRAY-Gun:

- #define DNXR_DEVTYPE_XRC1000 0x03

Commands accepted by DeviceNet-XRAY-Gun:

- #define DNXR_GET_STATUS 0x00
- #define DNXR_GET_DEVTYPE 0x01
- #define DNXR_GET_DEVICEID 0x02
- #define DNXR_SET_REMOTE 0x10
- #define DNXR_SET_OPERATE 0x11
- #define DNXR_SET_ANODE 0x12
- #define DNXR_SET_VAL 0x13
- #define DNXR_GET_VAL 0x14

Responses sent by DeviceNet-XRAY-Gun:

- #define DNXR_RESPONSE_STATUS 0x01
- #define DNXR_RESPONSE_DEVTYPE 0x02
- #define DNXR_RESPONSE_DEVICEID 0x03
- #define DNXR_RESPONSE_GET_VAL 0x04
- #define DNXR_RESPONSE_COSM 0x05

Return Execution Status:

- #define DNXR_NO_ERROR 0
- #define DNXR_REMOTE_LOCKED 249 // opposite interface in remote
- #define DNXR_NO_REMOTE 250 // remote required
- #define DNXR_NO_QUERY 251
- #define DNXR_MISSING_VALS 252
- #define DNXR_OUT_OF_RANGE 253
- #define DNXR_OUT_OF_PARAMETERS 254
- #define DNXR_COMMAND_UNKNOWN 255

Analog Parameters:

- #define DNXR_UANODE 0 // I/O
- #define DNXR_IEMISSION 1 // I/O
- #define DNXR_IHV 2 // Input only
- #define DNXR_UFILAMENT 3 // -"-
- #define DNXR_IFILAMENT 4 // -"-
- #define DNXR_PANODE 5 // -"-
- #define DNXR_TEMPERATURE 6 // -"_

REMOTE Modes:

- #define DNXR_LOCAL 0
- #define DNXR_REMOTE_CAN 1
- #define DNXR_REMOTE_UART 2
- #define DNXR_REMOTE_RAMP 3 // Ramp X-Ray source

Operating Modes:

- #define DNXR_OFF 0
- #define DNXR_COOLING 1
- #define DNXR_STANDBY 2
- #define DNXR_UAON 3
- #define DNXR_OPERATE 4
- #define DNXR_ANODEOFF 0 // state OFF, COOLING
- #define DNXR_ANODE1 1
- #define DNXR_ANODE2 2

Error Codes:

- #define DNXR_ERR_COOL 1 // cooling error
- #define DNXR_ERR_VAC 2 // bad vacuum
- #define DNXR_ERR_GUARD 4 // interlock
- #define DNXR_ERR_HV 8 // HV power supply error
- #define DNXR_ERR_ILIM 0x10 // current overload
- #define DNXR_ERR_LOCAL 0x20 // emergency switch to local
- #define DNXR_ERR_TOUT 0x80 // time out

3.7 Technical Specifications

Line Input	90 - 260 V_{AC}, 50 Hz - 60 Hz, 1300 VA
Fuse	10 A slow blow @ 90 - 120 V_{AC} 6.3 A slow blow @ 200 - 260 V_{AC}
Anode Power	600 W @ 90 - 120 V_{AC} line voltage 800 W @ 200 V_{AC} line voltage 1000 W @ 220 - 260 V_{AC} line voltage
Filament Power	0 to 8 A, 12 V
Anode Voltage	15 kV/66 mA Panel meter displays the anode voltage. 10-turn potentiometer sets the voltage. HV On button with LED turns the voltage on and off. Push-button LED blinks if the anode voltage is changing or can not be reached.

ANODE 1 and ANODE 2, buttons to select anode 1 or anode 2. LED is on indicating the selected anode.

Emission Current

0-66 mA

Panel meter displays the current

10-turn potentiometer sets the current.

STANDBY button with LED selects STANDBY mode.

OPERATE button with LED selects OPERATE mode.

Monitoring

The panel meter and 6 selection buttons with LED are provided to display both operational and limit values of the following parameters:

I_A anode current

I_E emission current

I_F filament current

I_S standby filament current

P_A anode power

U_F filament voltage

Interlocks/Control

Indicators

Failure light is on if the internal power supply fails.

HV Lock is on if the interlock is open.

Vacuum is on if the interlock is open.

Water is on if the interlock is open.

Push-buttons

REMOTE button is on if unit is being remote-controlled.

Ramp button starts and stops the soft start (only with remote interface).

DEGAS button is used to enable the filament degassing.

WATER button turns the cooling water on and off. LED will blink if the water supply fails.

Interlocks Input

HV Lock, 3-pole socket connected to the source cover

Vacuum, 4-pole socket connected to the vacuum meter

Water, 6-pole socket connected to the water box

HV socket, if HV connector is not plugged in the high voltage is inhibited.

Remote Control

An optional interface is used for remote control and soft start. For more details see the remote control manual.

Limits Setting	12 easily accessible potentiometers are provided on the rear side of the front panel allowing the adjustment of the following limits: $I_A$anode1 / I_A anode2, anode current limit. I_E anode1 / I_E anode2, emission current limit. I_F anode1 / I_F anode2. filament current limit in OPERATE mode. I_S anode1 / I_S anode2, filament current limit in STANDBY mode. P_A anode1 / P_A anode2, anode power limit. U_F anode1 / U_F anode2, filament volatge limit.
Physical Dimensions	19 inch rack mount case, height 3 unit, depth 495 mm, weight 18.5 kg

Chapter

4

Operating the XRC 1000

!Warning!

Mind the safety instructions given on page 1!

For the initial commissioning and after each venting of the vacuum system or in a situation after experiencing bad vacuum conditions, a careful setup of the X-ray source is recommended.

Note: Some steps described here result in pressure increases due to gas desorption. The pressure will continuously decrease thereafter. Each step should be maintained as long as the pressure is no longer decreasing, especially at higher voltages. A rapid increase of the high voltage can lead to violent plasma discharges and sparking, and may result in damage to the X-ray source and/or the electronics.

If stable operation of the X-ray source was observed previously over a few hours before, the procedure described here can be to shortened when repeating your experiments. The high voltages and the emission currents can be automatically set by the power supply.

4.1 Test Prior To Installation

1. Check that the mains fit to the recommended voltage range and power consumption.
2. Check all cables for possible damage.
3. If a complete X-ray package was not delivered by SPECS, the set standby current and the maximum current limits might not fit to your equipment. Please check section 3.3 , "Limit Setting" on page 17.

4.2 Initial Setup

For the initial commissioning and after each venting of the vacuum system or in a situation after bad vacuum conditions, a careful setup of the X-ray source is recommended.

Please check the instructions given in your source manual (XR50: see initial setup of the source).

4.2.1 Filament Degassing

Prior to the source operation, the filament should be degassed to prevent any deformation of the filament.

1. Check vacuum, the vacuum should be better than 1 x 10^{-5} mbar.
2. Turn on the power supply.
3. Select the anode 1 by pushing the button ANODE 1.
4. Press the DEGAS button.
5. Press the button I_F button to display the filament current, which should be zero.
6. Press the RAMP button once. The filament current is increased by 1/32 of the filament current limit (I_F-limit). The I_F-limit is almost reached after pressing the RAMP button 31 times. Upon pushing the RAMP button once again, the filament current jumps to the standby limit (I_S-limit) instead of going to the I_F-limit.
7. It is also possible to ramp the filament current automatically. This is done by pressing and holding the RAMP for approx. 4 seconds after which the filament current is increased step by step. After 30 minutes the I_F-limit is almost reached, and thereafter the current jumps to the standby limit in order to avoid filament damage.
8. Select the anode 2 by pushing the button ANODE 2 and proceed as in case of ANODE 1.
9. The degassing procedure can be canceled at any time by pressing the DEGAS button.

4.2.2 Anode Degassing

If your supply is capable of a soft start ramp simply push the RAMP button. The RAMP push-button can only be used in conjunction with the optional RS232/CAN-interface. Upon pushing this button the high voltage and the emission current are ramped slowly for both anodes. This function is usually used to start up the source automatically after each bakeout. The LED's on REMOTE and RAMP are on if the ramp is in progress.

4.3 Operation

1. Check vacuum, the vacuum should be better than 1×10^{-7} mbar.
2. POWER on (switch left side at the front panel). The display comes up and the interlock lamps indicate the actual status. The lamp for the interlock WATER is on.
3. If any of the other interlock indicators are lit up, check the appropriate connection, refer to the fault finding guide in section 5.1 , "Power Supply Troubleshooting Guide" on page 35.
4. Push WATER button. Now the cooling water circuit is switched on i.e. the valve for the water flow is opened. After a few seconds the interlock indicator lamp switches off.
5. Select the anode by pushing the button ANODE 1 or ANODE 2.
6. Push STANDBY (right side). This will set filament current to the standby current within few seconds. You may check this pressing I_F button below the monitoring display.
7. Choose the desired voltage with SET potentiometer below the 'Anode Voltage (kV)' section and switch HV ON (red button). Wait for the end of the voltage ramp.
8. SET the emission current to the desired value and start the emission regulation circuit by pushing the OPERATE button.
9. You can watch total current, power, filament current and filament voltage supplied to the anode in the power supply display by pressing the inscribed buttons (see section 3.2.2 , "Monitoring" on page 15).
10. Wait until the system has become stable (monitoring the pressure).

In case the high voltage is automatically switched off due to an interrupt of water flow (e.g. air bubbles) or due to activation of vacuum safety control the above described procedure should be repeated to turn on the high voltage again.

!Beware!

If in the OPERATE mode the I_F is blinking and the "current limit" is active, then the filament assembly is shorted or the preset high voltage is not sufficient to enable the chosen emission current. Check filament resistance! In the second case it is necessary to immediately increase the high voltage or decrease the emission current. Otherwise the lifetime of the filament will be reduced or cathode material could be evaporated onto the anode faces or the Al-window.

- **Never short the interlock system for HV Guard and Cooling.**
- **Never operate the X-ray source without cooling! The anode coatings will be evaporated immediately and the anode can be cracked.**

4.4 Switching-Off

1. To turn off the power supply push the **HV on** button. HV will be switched off and the filament goes immediately into STANDBY mode (The LED of this button should then be active).
2. Push STANDBY to switch off the filament (LED of this button is off).
3. Wait one minute then turn off the water circuit by pushing the WATER button.
   The water cooling should not be allowed to continue, otherwise the anode will be cooled down and become the coldest surface of the analysis system. Intense condensation of contaminants at the anode surface would then be the undesirable result.
4. POWER will switch off the power supply.
5. Turn off the water support from (and to) the cooling unit. For a longer non-operational period it is recommended to remove the water supply and to clear the water out of the pipes.

!Warning!

Mind the safety instructions given on page 1!
Warning: It takes 3 minutes before all high voltages in the system have gone. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray SOURCE.

Chapter

5

Troubleshooting

5.1 Power Supply Troubleshooting Guide

Problem:	Check:
Panel meters not on	Check line fuses on rear panel or line cable
Water indicator on	Water interlock not connected, cooling circuit is not working, water flow is insufficient
Vacuum indicator on	Check interlock connection and chamber pressure
HV Lock indicator on	HV connector is not plugged in, Interlock cable is not connected, the source cover switch is open
Failure indicator on	Upon turning on the control unit, the failure indicator illuminates for a few seconds indicating that the internal power supply is starting up. If the indicator is on for more than 5 sec., the internal power supply is defective.
HVOn	XRC 1000 can not supply the high voltage. Check the line voltage.

LED blinking:

I_A — The anode current limit is reached. Check if there is a short between anode and ground.

I_E — Emission current limit is reached. Check the high voltage and the filament current.

I_F — Filament current limit is reached. Choose a lower emission current or a higher voltage. Check the resistance of the filament.

U_F — Filament voltage limit is reached. Measure the resistance of the filament.

P_A — The power at the anode reaches the preset limit. Check emission currentand high voltage settings.

5.2 HV Spark-over

If HV sparks occur, normally the power supply will switch off the HV and go into STANDBY mode. At the beginning of the source operation and after venting or replacement of source parts some sparks may occur. Normally the amount of such sparking will decrease.

Possible sources for HV sparks are:

- bad ground connections
- bad vacuum conditions
- water leakage inside the protection cover
- the protection cover itself (PTFE isolation)
- the HV cable or the HV supply
- the anode
  (especially the critical distance between anode and Al window rod which suppress the crosstalk). Overload, contaminations, dust particles or cooling problems promote the creation of small spots with a crater shape and sharp edges. HV sparks force the creation of such pits. This is accompanied by an evaporation of the anode material or in the worst case a cracked anode with water injection into the vacuum chamber.

!Warning!

Mind the safety instructions given on page 1!
Warning: It takes 3 minutes before all high voltages have left the system. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray source.

If the frequency of sparks increases it is absolutely necessary to determine the cause. Please try to determine whether the sparks are outside or inside the source (vacuum). Please contact SPECS prior to dangerous test procedures. Ask yourself the following:

1. Do the sparks affect the pressure inside the vacuum chamber or not? Please consider that even in case of HV sparks outside the source module the vacuum, the reading at the controller can be influenced by electromagnetic pulse EMP, appearing as a false pressure increase.
2. Do the sparks depend on OPERATE / STANDBY mode and / or the absolute value of high voltage?
3. Is the PTFE shield inside the protection cover incomplete and / or does it show traces of HV and / or is it dirty / wet?
4. Switch off the HV and check the HV cable insulation between line and screen. Disconnect the HV cable at the source (banana plug) and insulate this contact very well.

!WARNING!
HAZARDOUS VOLTAGE! DANGEROUS TO LIFE!

5. Do sparks still occur in STANDBY mode?
   (Do not perform operate, because the filament current will goes to I_M. This will decrease the filament life time.)

   If sparks still occur:
   HV sparks are in the supply, the protection cover, or the HV cable.
   Separate the source by disconnecting the supply line step-by-step.

   Note that there is an interlock in the HV socket at the rear of the XRC 1000. If the HV plug is removed no HV can be set.

Reassemble the unit to its previous configuration to avoid any danger. When in doubt, please contact the SPECS service department (support@specs.de).

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