



NIR User Manual

NIR is a type of machinery that can expose a radioactive source for a defined time. It is applied in the test procedure of radiation detectors used in nuclear security.

Jan Paepen



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1 General information

1.1 General description – intended use

This user manual relates to the device with name NIR. NIR is machinery that exposes a radioactive source for a defined time, applied in the test process of radiation detectors. The user manual contains the "original instructions" required to transport, install and use the device.

This device is only intended to be used in the process of testing the performance of radiation detection equipment. Other use is prohibited. The device does not contain radioactive sources. The user is responsible for the selection and installation of the proper type of radioactive source suitable for the tests to be done. The device is not intended to be used with radioactive sources for which the provided shielding is not adequate. See Table 1 for specifications about the shielding.

The device is intended for indoor use only. Other reasonably foreseeable misuse of the machinery is listed in the table with residual risks (Table 4).

1.2 Terminology

In this document and in the control software, when not specified, the term "exposure" relates to "exposure to ionising radiation".

1.3 Icons used

Following icons are used throughout the manual. Make sure that these are understood before using the device.



Information

Important information and instructions.



Warning

Danger

Injury may occur if these instructions are not met.



Warning

Dangerous voltage

Injury by electrocution may occur if these instructions are not met.



Danger

Ionising radiation

Exposure to ionising radiation may occur if these instructions are not met.



Danger

Hazardous (toxic) materials

Exposure to toxic materials may occur if these instructions are not met.

1.4 Disclaimer

The mention of specific commercially available instruments or parts does not imply endorsement by the author or the manufacturer of this device.

1.5 Manufacturer

The manufacturer of this device is mentioned on the EC declaration of conformity and on the device's label. For technical questions relating the device, contact Mr. Jan Paepen (jan.paepen@ec.europa.eu) from the Institute for Reference Materials and Measurements (IRMM), Geel, Belgium. For questions about the application of the device in the test process of radiation detectors, contact Mss. Montserrat Marin-Ferrer (montserrat.marin-ferrer@jrc.ec.europa.eu) from the Institute for Transuranium Elements (ITU), Ispra, Italy.

1.6 EC declaration of conformity

Ref. Ares(2011)1005628 - 22/09/2011



EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Reference Materials and Measurements

EC – DECLARATION OF CONFORMITY

We, the manufacturer,

European Commission
Joint Research Centre
Institute for Reference Materials and Measurements
Retieseweg 111
B – 2440 Geel
Belgium

Represented by the Director, Mr. K. Maruszewski, hereby declare that:

Equipment: Machinery that exposes a radioactive source (not included) for a defined time, applied in the test process of radiation detectors.
Types: NIR – gamma, NIR – neutron
Serial numbers: NIRG001, NIRG002, NIRN001, NIRN002

Is in conformity with the following Directives:

- Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC;
- Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC;

And also declare conformity of the equipment with the following standards:

Ref. No.	Title	Edition/date
EN 60204-1	Safety of machinery. Electrical equipment of machines. General requirements.	2006
EN 954-1 cat.3	Safety of machinery. Safety-related parts of control systems.	1996
EN 61000-6-1	Electromagnetic compatibility (EMC). Generic standards. Immunity for residential, commercial and light-industrial environments.	2001
EN 61000-6-3	Electromagnetic compatibility (EMC). Generic standards. Emission standard for residential, commercial and light-industrial environments.	2001

I hereby declare that the equipment named above has been designed to comply with the relevant sections of the above referenced specifications.

Signed:



Name: K. Maruszewski
Position: Director
Place: Geel, Belgium
On:

22/09/2011

The person authorised to compile the technical file is Jan Paepen, JRC-IRMM, Retieseweg 111, 2440 Geel, Belgium

2 Safety instructions

Here, the most important safety instructions are explained. The reader can refer to the manuals of the different parts for more information. All relevant manuals are included on the NIR Installation and Documentation DVD and on the PC delivered with the instrument.

2.1 Liability

The manufacturer is not liable for any damage to the device nor injury or death caused by failure to observe the warnings and safety instructions mentioned on the device and in this manual.



Note

Before being used, the safety instructions in this manual must be read and understood. The safety instructions must be observed at all times. If the documentation is not clearly understood or is incomplete, please inform the manufacturer.

In accordance with this manual or the warnings on the product itself, anyone involved in planning, installing, mounting, commissioning and operating the product shall be sufficiently familiar with all warnings and precautionary measures in these operating instructions and shall have the appropriate qualification.

2.2 Danger through incorrect use



Warning

Danger

Incorrect use of the irradiator device and failure to follow the warnings in this manual, as well as incorrect manipulation of safety equipment can cause material damage, injury, electric shock, exposure to ionising radiation and in extreme cases, even be fatal.



Warning

Danger of burning

Surfaces of the motor, actuator and motor controller may be hot!

Do not touch the surface of the housing in the vicinity of hot sources! After switching the device off, leave it for 10 minutes to cool down before touching. If you touch hot parts of the device such as the motor controller housing which contains the heat sink and resistors, you may burn yourself!



Warning

Dangerous voltage

High electrical voltage and high working current.
Danger of death or serious injury due to electrical shock.

Before switching on the device fit the covers and safety components and close the door of the electrical cabinet so that the electrical connections of the device can not be touched. Do not open covers or doors during operation. Do not touch the electrical connections when the device is switched on.



Warning

Dangerous movements

Danger of death, serious injury or damage to property due to unintentional movement of the actuator / source holder.

Before switching on the device, fit the covers and safety components (guiding tube and guard switches) so that injury is prevented. Check the proper state of the guard switch pins.



Warning

Heavy equipment – high centre of gravity – risk for tipping over

Danger of death, serious injury or damage to property due to improper handling and transport of the equipment

- Observe the general regulations on setting up and safety when handling and assembling.
- Use suitable assembly and transport devices, and use them in a correct manner.
- Because of the risk for tipping over, care shall be taken when a forklift is used to lift the irradiator. Fix the irradiator to the forklift using a belt to prevent it from tipping over. The use of a manual pallet truck / jack is recommended. Verify that the lifting capacity is sufficient. See heading 4 "Transport and installation".
- Prevent clamping and squashing (of fingers).
- Use only appropriate tools. If specified, use special tools.
- If necessary, use suitable protective equipment (e.g. safety shoes, safety gloves to handle the shielding material).



Danger

Hazardous (toxic) materials used: cadmium and lead

Exposure to toxic materials may occur if the device is not used correctly. Make sure that cover panels are always installed when operating the device so that contact with hazardous materials is avoided.

2.3 General safety information



Warning

Use only accessories and spare parts which are approved of by the manufacturer. Safety components should only be replaced with identical models from the same manufacturer. Refer to heading 9, "Maintenance and repairs".



Warning

When labels are damaged or removed, they shall be replaced.

2.4 Safety instructions for assembly and maintenance

For assembling and maintaining the system, the relevant EN and IEC regulations, as well as all national and local safety and accident prevention regulations must always be observed.



Warning

Dangerous voltage

High electrical voltage and high working current
Danger of death or serious injury due to electrical shock

Before performing maintenance on the device, switch off the power using the main switch. Disconnect the mains plug X15 and wait for 5 minutes until all residual

charge has disappeared. During maintenance, put mains plug X15 in the sight of the operator.



Danger

Hazardous (toxic) materials used: cadmium and lead

During assembly and maintenance there is higher risk for exposure to hazardous materials. Wear appropriate personal protective equipment (PPE) when manipulating cadmium and/or lead. Refer to the Material Safety Datasheets for further instructions (heading 10).

2.5 Protection from dangerous movements

Dangerous movements can be caused by incorrect control of the motor. There are various causes:

- Unsafe or faulty circuitry or cabling;
- Faults in operating the components;
- Faults in the measured value and signal encoder;
- Defective or non-EMC conformant components;
- Errors in the software of the higher-level control system.

These faults can occur immediately after the device is switched on or after a certain period of operation.



Warning

Dangerous movements

Danger of death, serious injury or damage to property due to unintentional movement of the actuator / source holder

Before switching on the device, fit the covers and safety components (guiding tube and guard switch) so that injury is prevented.

Only use a PC (for the control software) that conforms to EMC requirements.

Malfunctioning components shall only be replaced with identical models from the same manufacturer.

For the above-mentioned reasons, the protection of human beings must be ensured with the aid of monitoring systems or by measures which are of higher order than the system. The manufacturer has foreseen measures on the specific features of a danger and fault. The monitoring functions in the components exclude to a large extent the possibility of incorrect operation. With regard to the protection of human beings, especially the danger of bodily injury and/or material damage, one must not rely on these circumstances alone.

The safety regulations applicable to the device must be observed as well. Undesired movements of the machinery or other incorrect functions can occur as a result of switching off, avoiding or failing to activate safety devices.

See heading 6, “Safety performance” for detailed information.

2.6 Acoustic noise level

The acoustic noise level generated by the irradiator is lower than 70 dB(A), measured at 1 m distance. The noise level of the acoustic signal on the beacon can be set according to instructions mentioned in heading 7.10.

2.7 Exposure to ionising radiation – danger zone

NIR is designed to expose a radioactive source for a certain amount of time, and then to shield the source again. This implies that there will always be a risk for exposure to ionising radiation when radioactive source are used in the device.



Danger

Ionising radiation

The radiation shielding of the device is primarily designed to hide the source completely from the radiation detector to be tested. The shield will also provide adequate shielding to limit exposure to men, if the activity of the sources is limited. The maximum activity of the source being used will depend on the type of source (energy and type of radiation) and local safety regulations. The user shall perform a safety assessment in order to determine if the shielding is adequate, and perform proper measures to limit the exposure to men. Het shall verify that the source is suitable to be used in the device.

In a typical test setup, several radiation detectors are placed around the irradiator in a circular pattern, maintaining the same distance from the radioactive source to the sensitive volume of the detector (Figure 1). When the source is exposed, there will an increase of the radiation intensity in the vicinity of the irradiator, resulting in a danger zone with an elevated risk to exposure to ionising radiation.

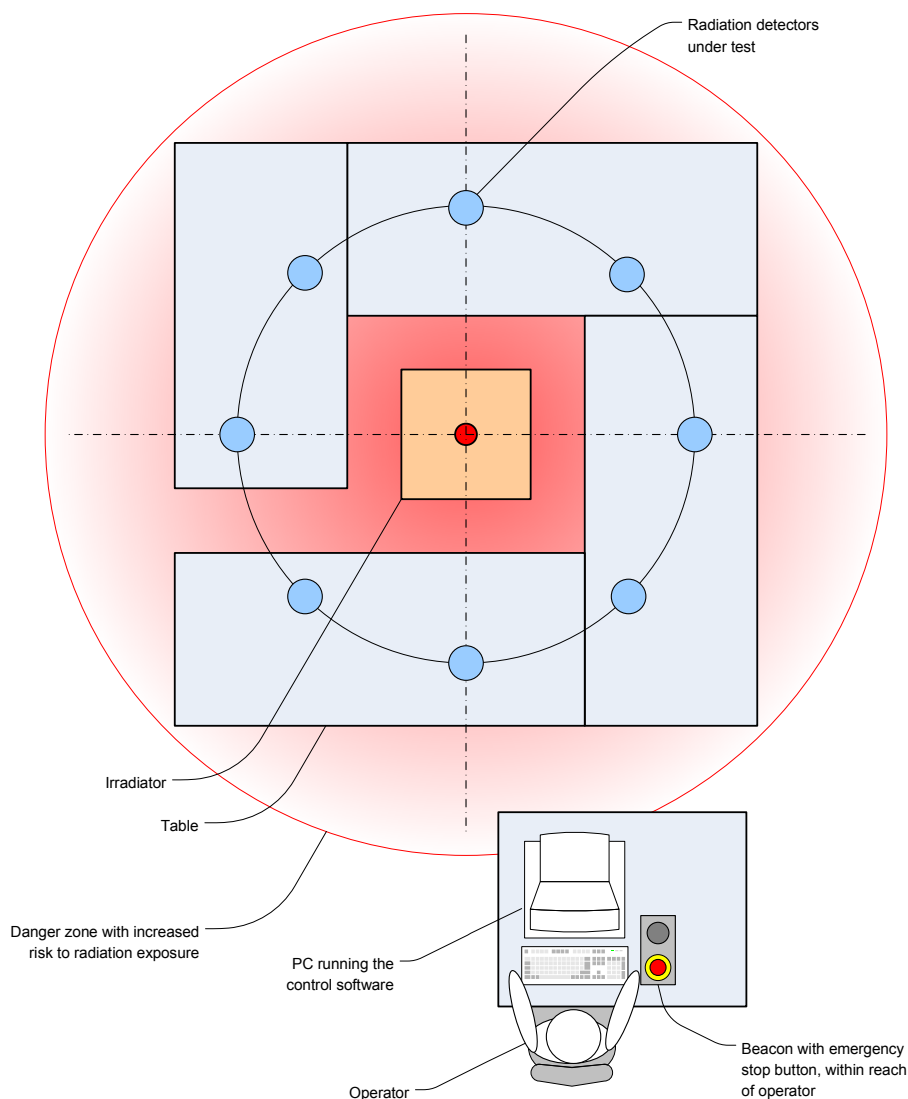


Figure 1: A typical test setup.

3 Properties

This section explains the major features of NIR, its properties, main components and basic functioning.

3.1 Gamma and neutron type

Because of the different shielding requirements for gamma and neutron radiation, there are two types of the NIR irradiator device:

- NIR - gamma is suitable for radioactive sources that mainly emit gamma radiation.
- NIR - neutron is suitable to hold neutron emitting sources.



Danger

Ionising radiation

The proper NIR type (gamma or neutron) shall be chosen in function of the type and activity of the radioactive source that will be used. Never use open sources or radioactive solutions.

The serial number indicates the type: NIRGxxx for NIR – gamma, NIRNxxx for NIR – neutron.

3.2 Properties

The specific properties of both types of the device are listed in Table 1.

Type	NIR - gamma	NIR - neutron
Footprint	660 mm x 660 mm	660 mm x 660 mm
Height, excluding guiding tube	1350 mm	1350 mm
Height, including guiding tube	1700 mm	1750 mm
Guiding tube, material and dimensions	PTFE, Outer diameter = 48 mm Inner diameter = 40 mm Wall thickness = 4 mm	Aluminium, Outer diameter = 100 mm Inner diameter = 95 mm Wall thickness = 2.5 mm
Total mass	1700 kg	370 kg
Shielding type and thickness	Lead, Minimum 218 mm around source, 157 mm above and below source holder	HDPE, Minimum 200 mm around source; 174 below, 192 above source holder + 1 mm of Aluminium + 1 mm of Cadmium + 1 mm of Aluminium
Maximum size of the source (cylindrical)	Diameter 30 mm Height 95 mm	Diameter 81 mm Height 100 mm
Mass of the source holder	4.35 kg	3.51 kg
Maximum mass of the source	5.7 kg	6.5 kg

Table 1: Specific properties of gamma and neutron type of the NIR device.

The source holder travels over a distance of 380 mm, with an acceleration of 6 m/s^2 and a maximum speed of 800 mm/s.

3.3 Main components

The main components of the NIR irradiator device are shown in Figure 2. In this document, the "device" refers to the complete system as shown in the figure. The main components of the device are the irradiator, the beacon and the PC with control software.

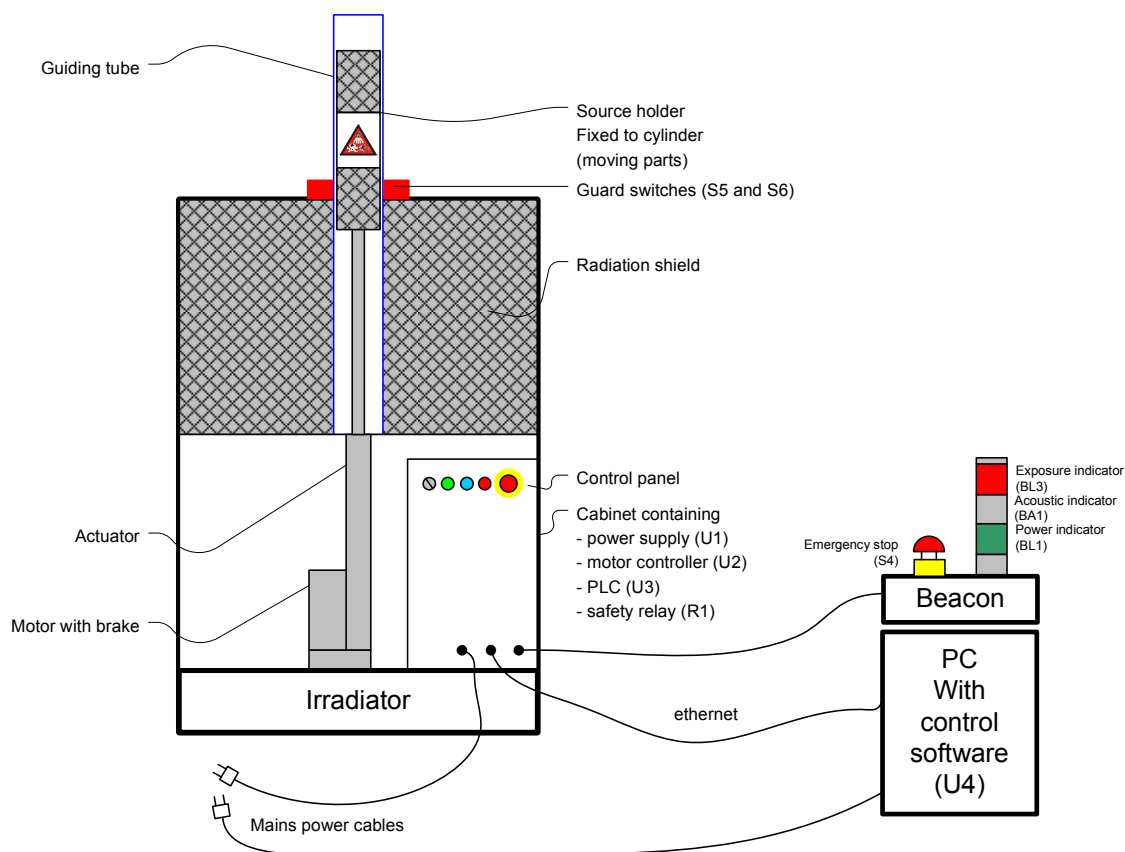


Figure 2: Main components of NIR.

3.4 Basic functioning

The actuator is driven by a servomotor that moves the source holder out and back into the radiation shield. A guiding tube is placed around the source holder, to ensure a smooth and safe operation of the device. The motor is equipped with a brake that is capable of holding the load in case of emergency stop or power interruption.

The cabinet contains a 24 V DC power supply, a motor controller, a programmable logic controller (PLC), a safety relay and other relays and fuses. The power supply delivers the voltage used in the control circuitry. The motor controller provides the power to the servomotor and controls its movement. The position, speed and acceleration are precisely controlled in a feedback loop. The PLC keeps track of the state of the device and sends commands to the motor controller. The safety relay monitors the emergency stop buttons and the presence of the guiding tube to ensure a safe operation. The control panel consists of the main switch, a reset switch, emergency stop button and three visual indicators that show the state of the device. A beacon is connected to the cabinet and shows exposure and power information. It is provided with a second emergency stop button, in reach of the operator.

The control software running on a PC communicates with the PLC to receive status information and to operate the device. Starting the movement of the actuator is only possible using the control software.

3.5 Performance

The motor controller has a feature that allows recording a number of values as a function of time, including the signal received from the PLC to start the motion, the "target reached" signal and the position of the cylinder. This feature is ideally suited to test the performance of NIR. One can think of various tests, but the most important performance issues are reproducibility of the exposures and resolution of the exposure time. For these tests, FCT is setup as in the procedure 7.6 "Correction of exposure time". However, this time the exposure time is set to e.g. 3000 ms. A number of exposures are performed and the trace data recorded using FCT, and the data of each exposure is imported to the Excel sheet (NIR Exposure Time Correction.xls) to calculate the actual exposure time.

3.5.1 Reproducibility of the exposures

In the test procedure for radiation detectors many exposures are required where the same source is put in the same position with the same exposure time. The total reproducibility of the exposures is determined by:

- The precise vertical positioning of the source holder, reproducible within ± 0.02 mm (manufacturer's specification).
- The horizontal movement of the source holder and guiding tube with respect to the frame of the irradiator.
- The movement of the source inside the source holder. This is totally determined by the user.
- The precise timing of the exposures. A test consisting of 60 exposures of 3 s each showed that the spread (difference between highest and lowest value) of the actual exposure time is 1.5 ms and the standard deviation 0.5 ms.

3.5.2 Resolution of the exposure time

The NIR Control Software allows to enter the exposure time with a resolution of 1 ms. However, it is the limited PLC cycle time of 10 ms that determines the actual exposure time. In practice, this means that the actual exposure time will always change with 10 ms steps. This is demonstrated in Figure 3, where the exposure time was varied between 3000 ms and 3014 ms. At every exposure time 10 exposures were performed and the actual exposure time calculated. The error bars represent one standard deviation.

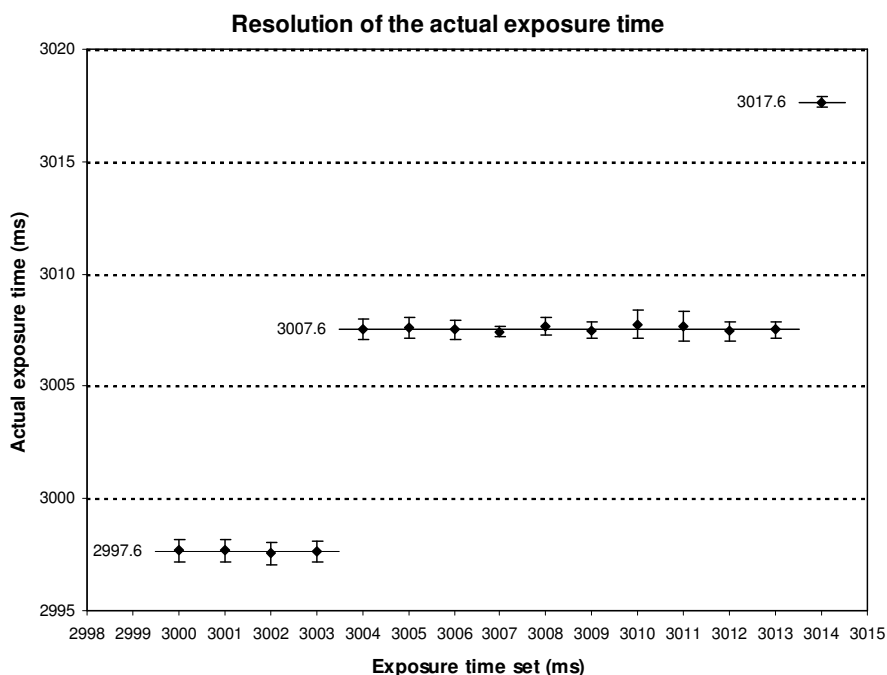


Figure 3: The resolution of the exposure time is 10 ms, determined by the cycle time of the PLC.

The actual exposure time not only is determined by the exposure time set in the control software, but also by the selection of the reference positions on the holder and the irradiator (the x value in Heading 7.6). When the exact value of the exposure time needs to be known with a precision better than 10 ms, it is recommended to perform a test by using FCT as described in the mentioned procedure.

4 Transport and installation

4.1 Transport



Warning

Heavy equipment – high centre of gravity – risk for tipping over

Danger of death, serious injury or damage due to improper handling and transport of the equipment

- Because of the risk for tipping over, care shall be taken when a forklift is used to lift the irradiator. Fix the irradiator to the forklift using a belt to prevent it from tipping over. The use of a manual pallet truck / jack is recommended. Verify that the lifting capacity is sufficient. The angles at which the device will tip over are 17° and 21° for NIR – gamma and NIR – neutron, respectively (see also Figure 5).
- Keep the irradiator levelled during lifting and moving.
- Use suitable personal protective equipment (e.g. safety shoes).



Information

Only narrow-sized manual pallet trucks with a fork width less than 52 cm will fit in the slots.

The total mass of the irradiator is mentioned on the label on the device and in Table 1 of the manual. Use the slots for lifting (see Figure 4).

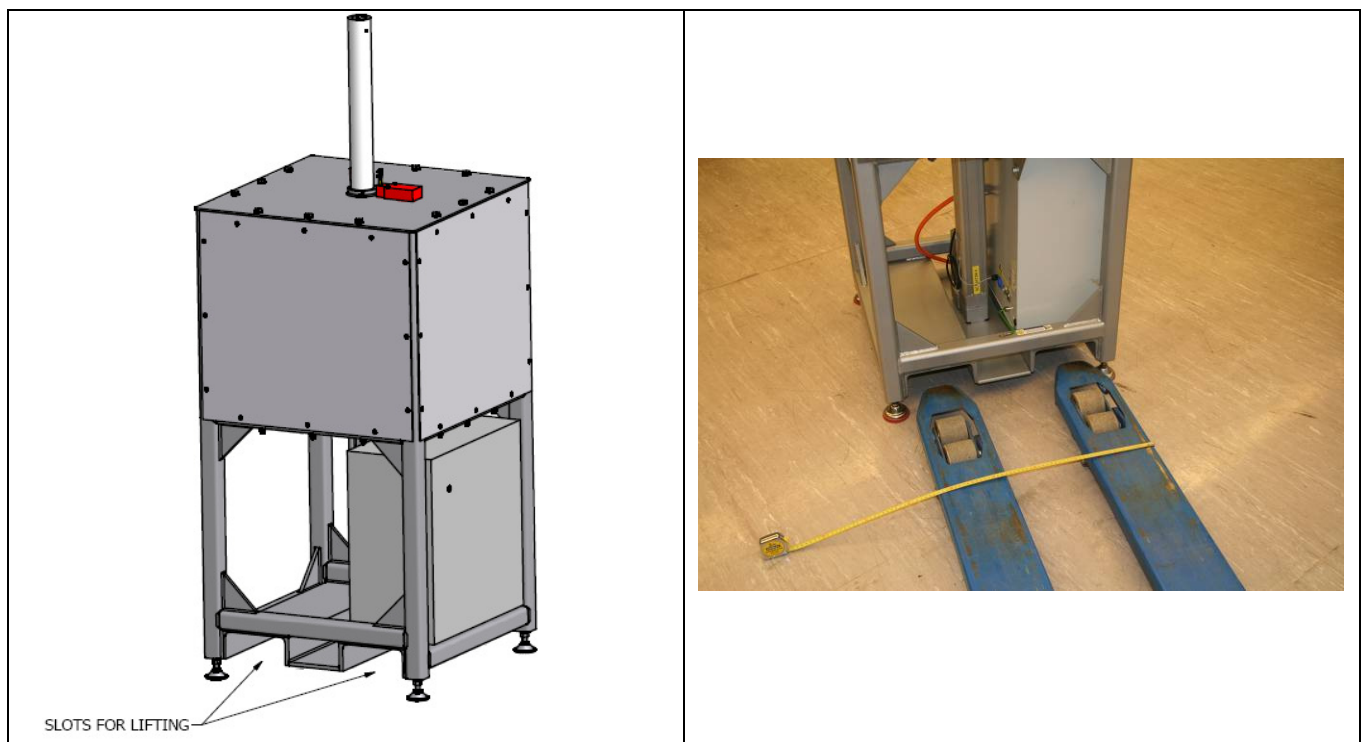


Figure 4: Slots for lifting the device with a manual pallet jack or a forklift truck (fork width less than 52 cm).

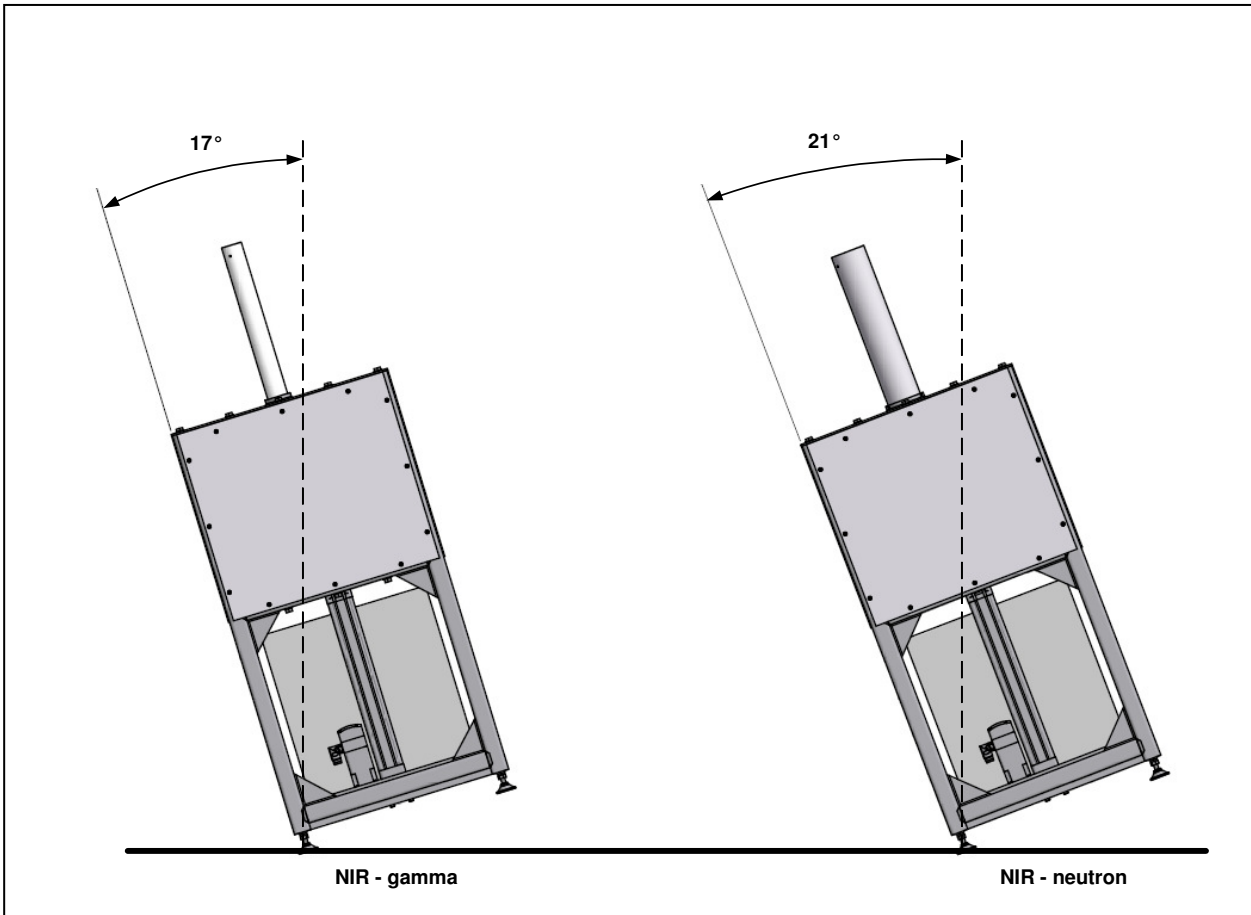


Figure 5: Due to the high position of the centre of gravity, the angles at which the gamma and neutron devices will tip over are 17° and 21° respectively.

Keep the irradiator levelled at all times during lifting and transport. Pay special attention to transport on road in mountain areas, or by plane. It is recommended to remove the radiation shield and transport it separately if there is a risk for tipping-over during transport. Refer to heading 4.5.

4.2 Installation

NIR was built to withstand the external influences listed in Table 5 (heading 6.9 “External influences”).

Install the irradiator on a flat surface that is suitable to support its weight, in a place where there is enough light to safely operate the device. Avoid mechanical shocks when lowering the irradiator down. After transport, all electrical connections (screws, bolts) shall be tightened with the appropriate torque in accordance with the recommendations of the manufacturer of the particular component.



Warning

Heavy equipment – high centre of gravity

Danger of death, serious injury or damage due to improper handling and transport of the equipment.

Install the PC that runs the control software on a convenient place with sufficient light. Install the beacon next to the PC that runs the control software.



Warning

Safety risk – placement of the mobile emergency stop

It is a safety requirement that the beacon with the emergency stop button is placed within reach of the operator of the device, being the user of the control software.

The operator shall always have a visual contact with the irradiator so that he can verify that there is nobody present in the zone with elevated radiation level during exposure. This especially applies when the remote interface to the control software is used. In that case, the PC running the control software shall be locked and the beacon placed within reach of the operator that actually controls the start of an exposure.

4.3 Requirements for the electrical supply (mains distribution)

Following requirements apply for the mains supply network to which NIR is connected.



Warning

Failure to observe following requirements can lead to damage to the device or unsafe situations (risk for fire, electric shock, injury or even death).

- NIR needs electrical supply from a single-phase TN-network.
- Connection to the supply network shall be made in accordance to local regulations.
- Over-tension protection, e.g. against lightning, shall be foreseen on the supply network, in function of local requirements and in accordance to local regulations.
- The device operates with a supply voltage of at least 100 V AC up to 230 V AC ($\pm 10\%$), 50 Hz or 60 Hz frequency.
- The power socket to which NIR is connected, shall to be protected with a circuit breaker of at least 16 A and shall have a 300 mA all-current sensitive fault-current circuit breaker (RCD = Residual Current protective Device).
- NIR's breaking capacity is 5 kA, equal to the expected short circuit current when the device is connected to the mains using the cable provided and when the upstream short circuit current is less than 40 kA.
- An additional ground connection needs to be established from the irradiator “additional ground point” to the building ground, using a copper insulated wire with a cross section of at least 10 mm². The wire insulation shall have a green/yellow colour. The section shall never be smaller than 10 mm² from the irradiator all the way to the earth.

The nominal power consumption for NIR is 1.2 kW when connected to a 230 VAC supply and 1.0 kW at 110 V AC.

4.4 Cable connections

When setting-up the device, make the connections in the same order as following. After using the device, remove the cables in the reverse order.



Warning

Risk for damage to the cables – risk for stumbling over the cables

When installing cables make sure that they are laying flat on the work floor, that they will not be damaged or squeezed, e.g. by lifting equipment, tables or chairs. Prevent stumbling over the cables by taping them onto the floor.



Warning

Dangerous voltage and high working current.

Danger of death or serious injury due to electrical shock.

1. With the mains plug X15 disconnected, check that main circuit breaker F1 is ON, and verify that fuses F2, F3 and F4 are not blown, of the correct type and properly installed.
2. Close the electrical cabinet. Lock it and remove the key from the lock.
3. Make sure that the main switch S1 is in "O" position.
4. Make the additional ground connection from the additional ground point on the irradiator to the building ground, using a green/yellow copper wire with a section not smaller than 10 mm² from the irradiator all the way to the earth.
5. Verify that the guard switch connection (X18) is made. (Located behind the side cover plate of the irradiator, on the right hand side looking at the cabinet.)
6. Connect the beacon cable to the irradiator cabinet, connector X13. Without the beacon connected it is impossible to operate the device.
7. Connect one side of the provided Ethernet cable to the irradiator cabinet, X12, and the other side directly to the PC, or to an Ethernet switch if the irradiator is used within a network. If necessary, any standard category 5 (straight) Ethernet cable can be used to connect the irradiator to the PC or a network.
8. Connect the power connector X14.
9. Verifying the electrical requirements and connect the mains plug X15 to a mains outlet.
10. Connect the PC's power cable.



Note

The nominal current of main fuse F1 is 16 A, regardless of the supply voltage.

Other fuses:

- F2: slow blow, 4 A
- F3 and F4: slow blow, 1 A

4.5 Installing and removing the shield

This procedure is indicative and shall only be executed in agreement with the manufacturer.



Warning

Risk for serious injury – heavy parts – hazardous materials

The shielding material is:

- Heavy: up to 50 kg per individual piece;
- Toxic: lead and cadmium are used. Refer to the MSDS in heading 10.

Handle with care and wear protective equipment (gloves, safety shoes).



Danger

Hazardous (toxic) materials used: cadmium and lead

During assembly and maintenance there is higher risk for exposure to hazardous materials. Wear appropriate personal protective equipment (PPE) when manipulating cadmium and/or lead. Refer to the Material Safety Datasheets for further instructions (heading 10).

The procedure for removing the shield is the reverse of the installation procedure.

4.5.1 Installation procedure shield NIR – gamma

1. With the source holder in shielded (down) position, place central lead bricks, numbered 1 to 5, as shown in Figure 6 and Figure 7. Be aware that brick 1 is different from the other 4. Pay attention to the orientation of the bricks (Figure 7). The guiding tube can be helpful to align the bricks.

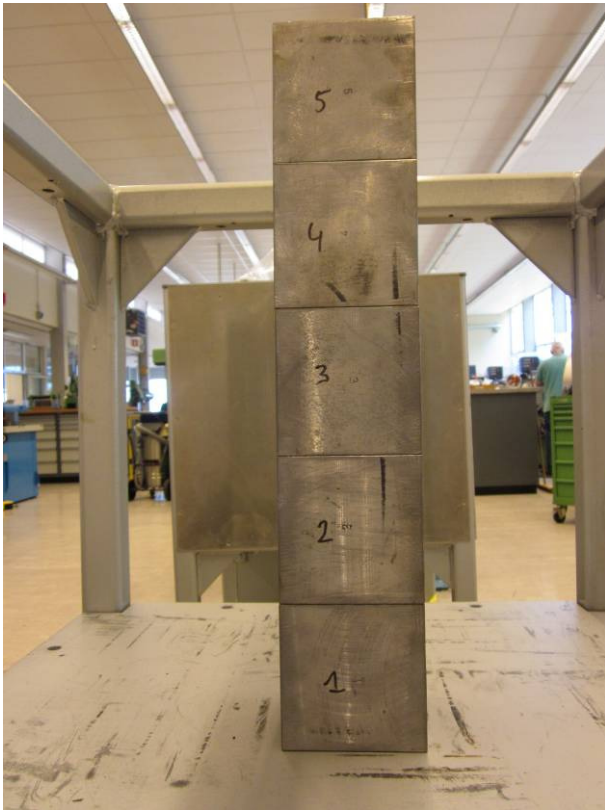


Figure 6: Central lead bricks.

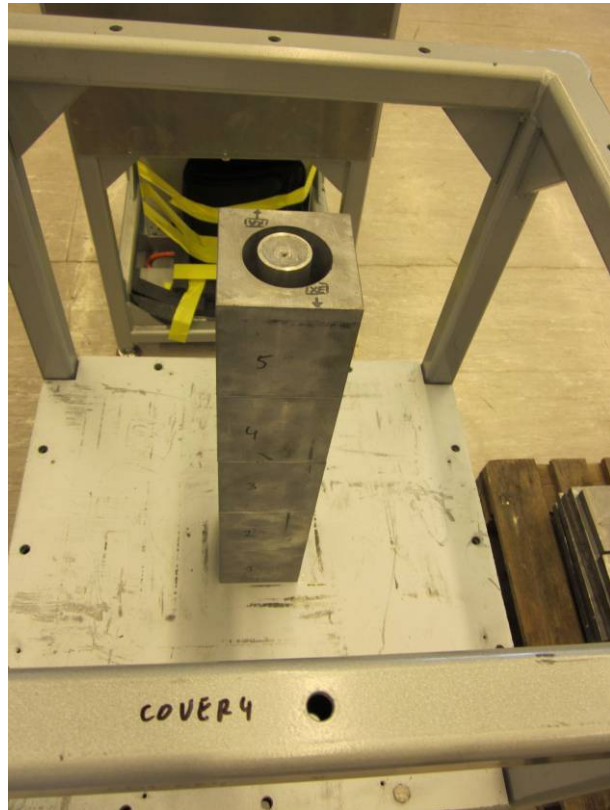


Figure 7: Pay attention to the orientation of the bricks (markings cover4-XE).

2. Place small plates A, B, C, D, E, F, G and H as in Figure 8 using screws provided. The length of the screws is written on the plates. Again, pay attention to the orientation of the plates with respect to each other and to the frame.
3. Place big plates 1, 7, 13 and 19 as in Figure 9.

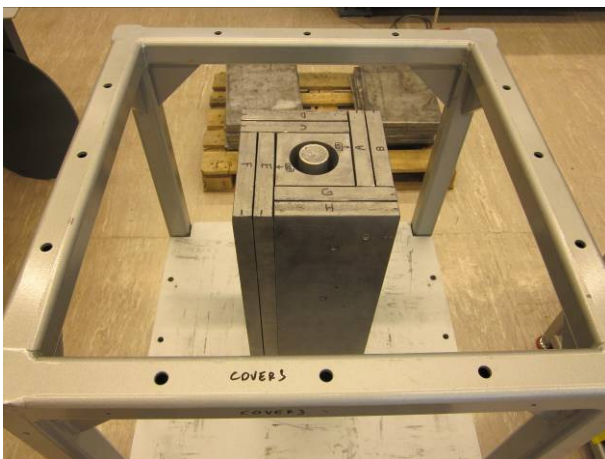


Figure 8: Positioning small lead plates.

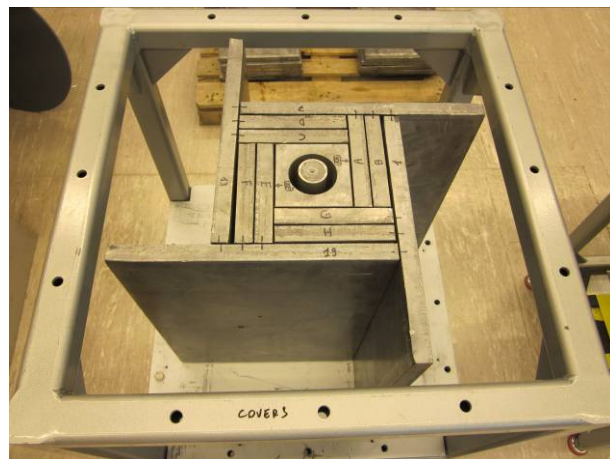


Figure 9: Placement of big plates 1, 7, 13 and 19.

4. Continue fixing plates using screws as in Figure 10 and Figure 11. When one side is finished, install the aluminium supports at the bottom and top (Figure 12). The supports are labelled. Check that all bolts (M10x80) are installed with washers and nuts (Figure 13).

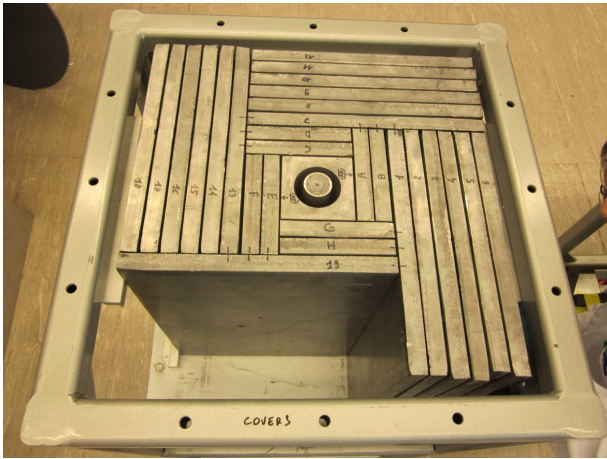


Figure 10: Building up the shield.



Figure 11: Complete shield.

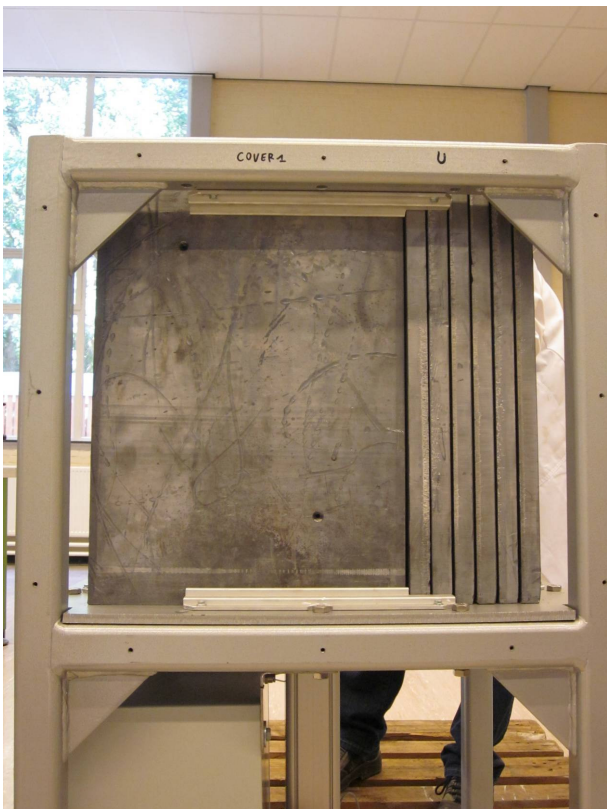


Figure 12: Supports at top and bottom.



Figure 13: Nuts and bolts to fix the base plate.

5. Install the top cover using M10x80 bolts, washers and nuts. Connect the guard switch connector X18. Verify the alignment of the shield with respect to the frame and top cover.
6. Install the guiding tube and side covers.

4.5.2 Installation procedure shield NIR – neutron

1. With the source holder down, place the cadmium plate around it (at the bottom there is no aluminium plate), and stack all 10 central HDPE blocks. Align using the guiding tube. Place blocks 1, 2, 3 and 4 and fix with screws (Figure 14). Then, add blocks 5, 6, 7 and 8 (Figure 15).

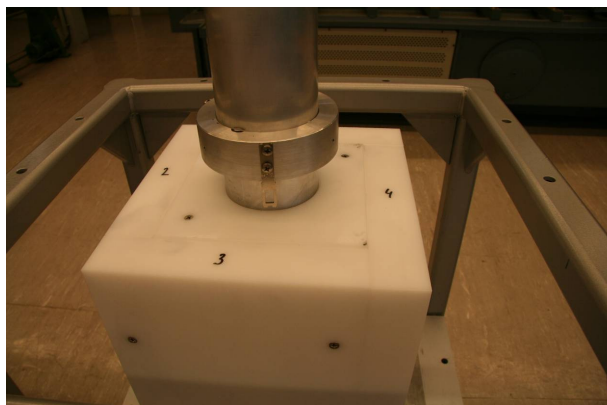


Figure 14: Central HDPE blocks, and blocks 1 to 4.

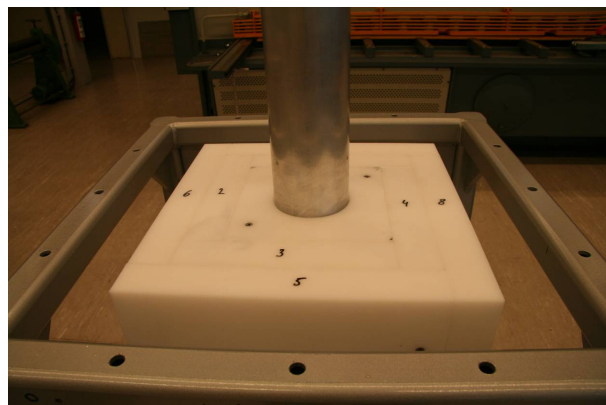


Figure 15: HDPE blocks 5 to 8 added.

2. Add blocks 9, 10, 11 and 12 and fix using screws (Figure 16).
3. Add Al/Cd/Al panels to all sides, and on top. Remove the guiding tube and verify that the shield is properly centred (Figure 17).

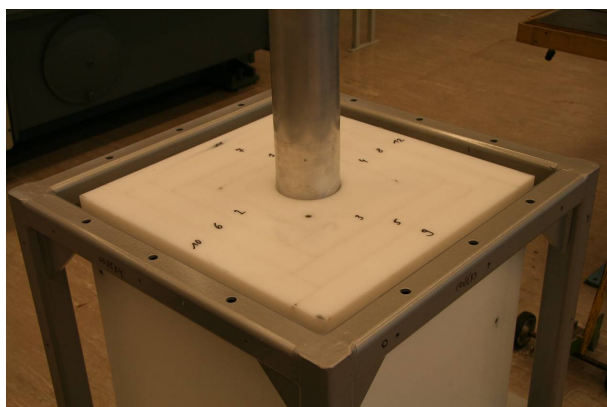


Figure 16: HDPE blocks 9 to 12 added.

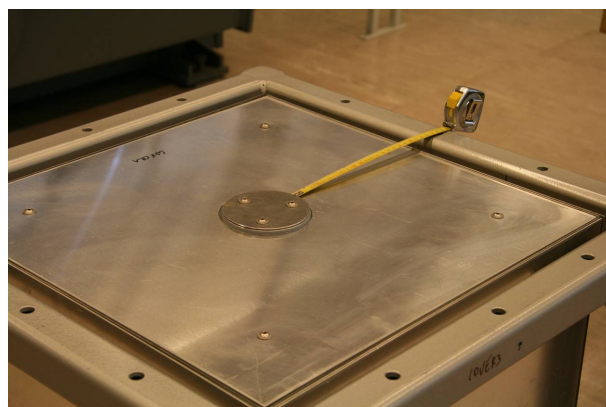


Figure 17: Al/Cd/Al sandwich panels installed and verifying centring.

4. Install L-shaped supports at the bottom using M10x80 bolts (Figure 18).

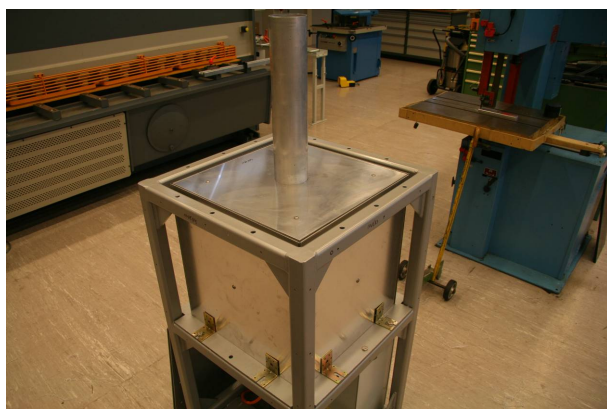


Figure 18: L-shaped supports added.

5. Install the top cover and remaining L-shaped supports with bolts M10x80.
6. Install guard switch connector X18.
7. Verify the centring using the guiding tube.
8. Install the guiding tube and the side covers.

5 Operating instructions

5.1 Controls and indicators

On the control panel and the beacon a number of controls (switches and push buttons) and indicators are placed (Figure 19 and Figure 20).



Figure 19: NIR control panel.

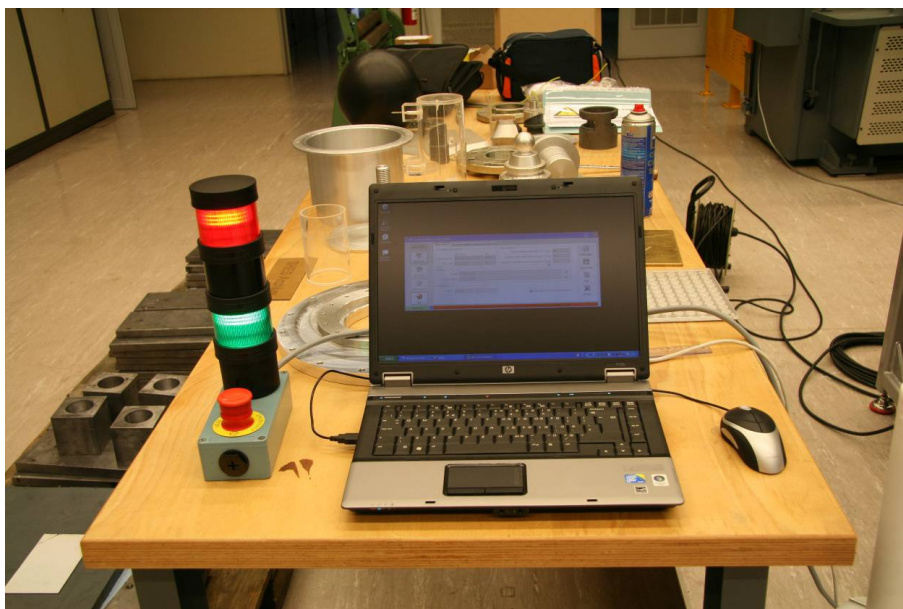


Figure 20: NIR beacon and PC.

An overview of the controls and indicators is presented in Table 2, followed by a detailed description.






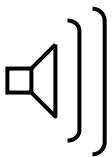
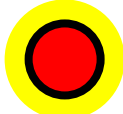
Control / Indicator	Colour	Place	Function of the control	Meaning of the indicator	
POWER Main switch	 Black	Control panel	Switch device on/off.  Use X15 to completely remove tension.		
POWER Indicator	 Green	Control panel Beacon		ON Device is powered-on.	
				OFF Device is powered-off.	
RESET Indicator <u>and</u> button	 Blue	Control panel		FLASHING ON/OFF Device is in safe standstill, waiting for connection with NIR Control Software.	
				When RESET button is pushed, device will go to normal operation. Only effective when the indicator is ON.	ON Device is in safe standstill. Connection with NIR Control Software established.
					OFF Device in normal operation. (Or powered-off)
RADIATION EXPOSURE Indicator (Warning signal)	 Red	Control panel Beacon		ON Source holder is in exposed position.	
				OFF Source holder is in shielded position.	
Acoustic indicator		Beacon		Acoustic signal that indicates the start and end of the exposure. Intended use is only to facilitate the execution of the test procedure.	
EMERGENCY STOP Button	 Red on yellow	Control panel Beacon	Pushing this button will stop the movement of the source holder and bring the device to safe standstill state.		

Table 2: Controls and indicators.

5.1.1 POWER main switch

The POWER main switch is used to switch the device on and off. Switching it off will not completely remove the supply voltage from the device. Use the mains plug X15 and wait for 5 minutes to completely remove all tensions from the device. The switch can be locked in the off position using a padlock.

5.1.2 Green POWER indicator

The green POWER indicators on the beacon and the control panel are lit when the device is powered.

5.1.3 Blue RESET indicator / push button

The blue RESET indicator is also a push button. When the device is powered-on, the blue RESET indicator displays the state of the device. When the indicator is continuously lit or blinking, the device is in safe standstill state. In this state, the device can not be controlled by the software and it is safe to change the source. When the RESET indicator is off, the device is in normal operation and the software can be used to move the source holder.

The indicator blinks when the connection with the software is not established. Pushing the RESET button will not have any effect. The connection with the software has to be established first, before the RESET button is pressed.

When continuously lit and then pushed, the device will leave the safe standstill state on the condition that all the emergency stop buttons are released and the guiding tube is properly installed. The motor controller will power-up and the device will go to normal operation.

5.1.4 Red RADIATION EXPOSURE indicator

The exposure indicator is lit when the source holder is out of the shield. There is an exposure indicator on the control panel and on the beacon. The exposure indicator signal warns the operator for the presence of ionising radiation that could lead to an increased exposure.

5.1.5 Acoustic signal

The purpose of the acoustic signal (on the beacon) is to indicate the start and the end of an exposure in an audible way. A single beep is heard when the source holder leaves the shield two short beeps are heard when the exposure has stopped (see Figure 21). The beeps have a duration of 100 ms. Refer to heading 7.10 to adjust the power of the acoustic signal. The acoustic signal can be switched on and off using the control software.

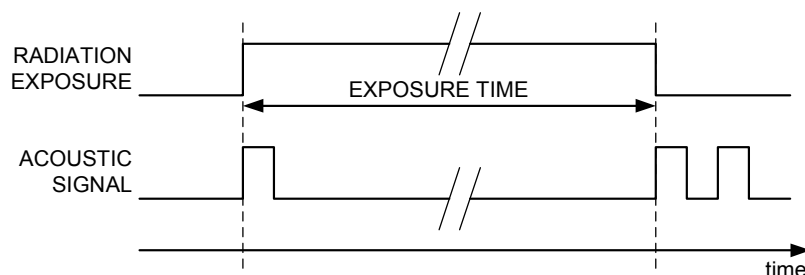


Figure 21: Timing of the acoustic signal with respect to the exposure of the source.



Note

The acoustic signal is not active during the complete exposure. Therefore, it can not be used as a radiation exposure indicator. The intended use is to indicate the start and end of the exposure.

5.1.6 EMERGENCY STOP button

For this device, it was judged that the risks and implications of injury by the moving parts in case of malfunctioning of the safety components is higher than the risk related to the exposure to ionising radiation. As a consequence, when the red emergency stop button is pushed, the device will immediately stop the movement of the source holder and go to the safe standstill state. The source will *not* be moved inside the radiation shield.



Warning
 Risk of exposure to ionising radiation
 The only goal of an emergency stop is to stop the moving parts of the device as quickly as possible by bringing the device to the safe standstill state. It is not the aim to stop the exposure. An emergency stop will not move the source back into the radiation shield.

After an emergency stop, controlling the device with the control software is no longer possible. The emergency stop condition has to be resolved first, and the operator has to reset the safety relay by pressing the RESET button.

5.2 Operational states

The device can be in different operational states. In each state only specific actions are possible and the transition to any other state is well-defined. The green POWER and the blue RESET indicator represent the state of the device (see Table 2).

The transition between the states is depicted in Figure 22. Some main states have "sub-states", shown in *italic* on the figure. In a sub-state the conditions of the main state are valid, but with specific limitations.

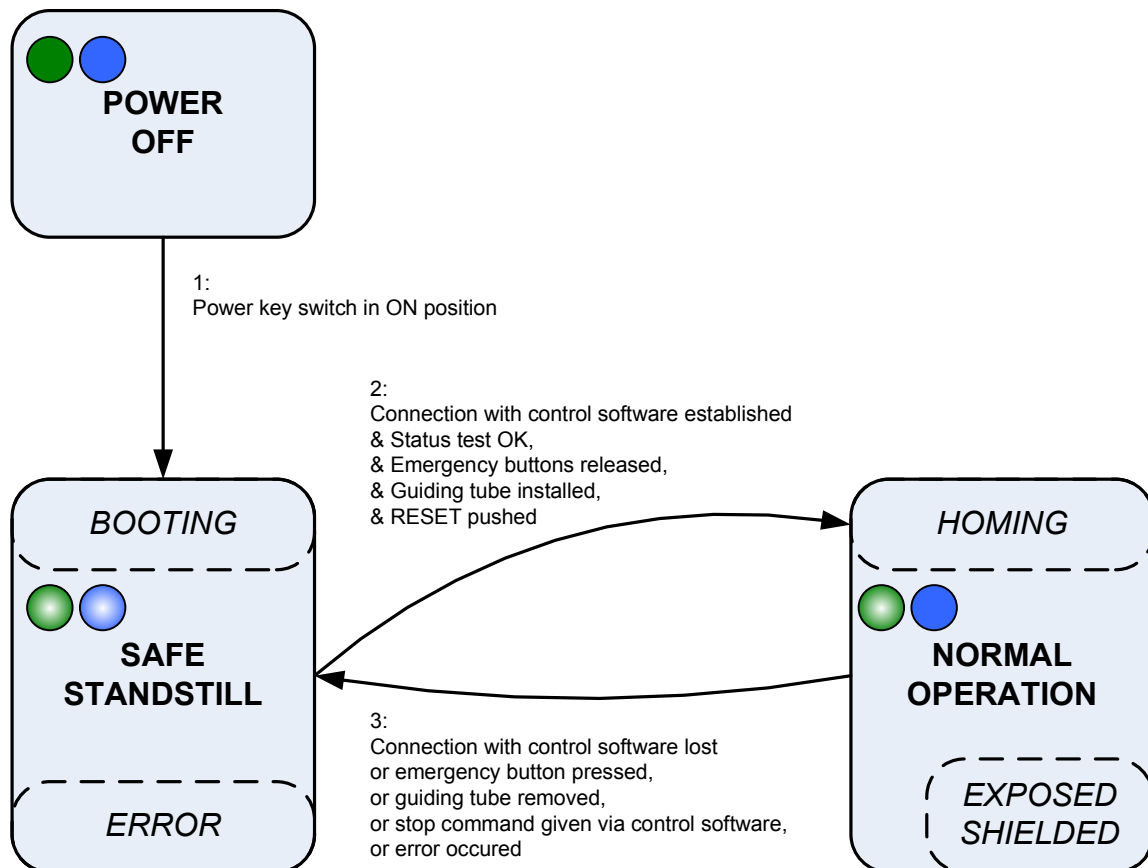


Figure 22: State diagram of NIR.

5.2.1 Power-off state

In the power-off state, all indicators are off and operation is not possible.

5.2.2 Safe standstill state

In safe standstill, the motor brake is activated and the motor controller output stage is powerless. In this state it is safe to remove the guiding tube and to open the source holder to change the source.



Note

The safety features of the device bring it automatically to the safe standstill state when the guiding tube is removed. Nevertheless, one should always use the control software to start the procedure to change the source.



Warning

Dangerous voltage.

The safe standstill refers to the motion of the device only. It is not safe to work on the electrical connections in safe standstill state.



Warning

Risk of exposure to ionising radiation in safe standstill state.

The only goal of the emergency stops is to stop the moving parts of the device as quickly as possible by bringing the device to the safe standstill state. It is not the aim to stop the exposure of a source by moving it back into the shield.

After powering on, the PLC will boot. Booting will take about 25 seconds. Relay K6 is open and forces the device to stay in safe standstill. Also, power contactor K5 is open and so the motor controller is disconnected from the mains, until the connection with the control software has been established. The blue RESET indicator will flash on and off.

When the control software is running and the user commands the control software to "connect", the blue RESET indicator will stop flashing and will light up continuously. Then, the operator has to push the RESET button, to acknowledge the connection with the software. This push will only have effect when all emergency stop buttons are released and when the guiding tube is properly installed. Only then, the safety relay will close and the PLC will power-up the motor controller. The device can now leave the safe standstill state and go to the normal operation state (transition 2 in Figure 22).

5.2.3 Normal operation state

In the normal operation state, K5 and K6 are closed, and the safety relay is activated (K1, K2, K3 and K4 in relay K7 are closed). The motor controller is powered and the output stage is active.

When leaving the safe standstill state, a homing procedure is required before the commands to expose or shield a source can be given. The homing procedure establishes the reference point (zero) of the position encoder. Homing is a command given from within the control software.

The normal operation state can be left in one of the following ways:

- The connection with the control software running on the PC is lost. The PLC will open relay K6, putting the device to a safe standstill.
- One of the emergency buttons is pressed.
- The guiding tube has been removed.
- A stop command has been given using the control software.
- An error occurred.

5.3 Operating the device using the control software

5.3.1 Powering-up

Follow the procedure in the table below to power-up the device.

1. Verify that the device is installed properly and connect all cables as explained in heading 4.
2. Power-up the PC. Verify that "suspend" or "hibernation" mode is switched off.
3. Start the irradiator by turning the main switch S1 to the ON position. On the irradiator control panel, the green POWER indicator will light, and after about 25 seconds the blue RESET button/indicator will start to blink.
4. Start the NIR Control Software, select the proper configuration file and verify that the System settings are properly set. Check that the "ADS Connection properties" correspond to the "Network identification tag" on the device. Refer to heading 7 for the procedure to change the system settings. The window looks like Figure 23.

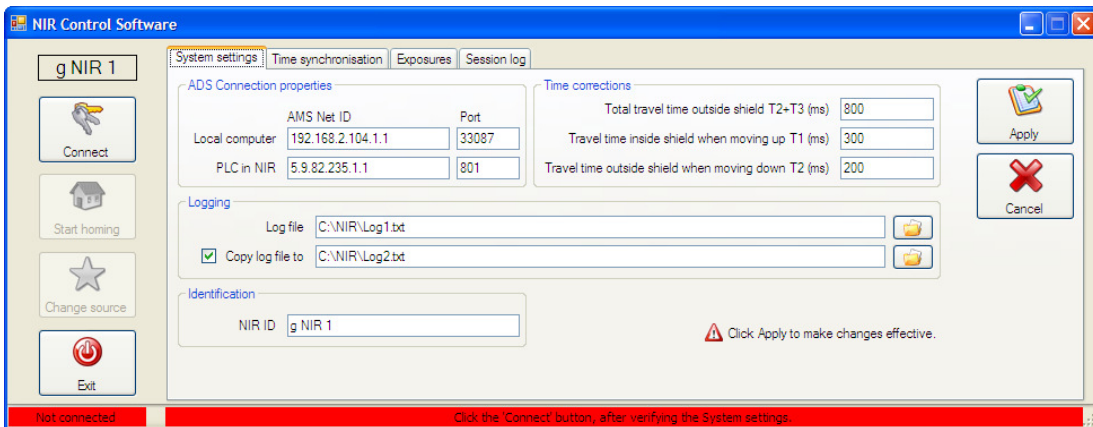


Figure 23: Starting the NIR control software.

5. When the PC has obtained an IP address, click the Connect button. When connected, the blue RESET button/indicator will illuminate continuously and the NIR Control Software will show "Connected" in the lower left corner of the window (Figure 24).

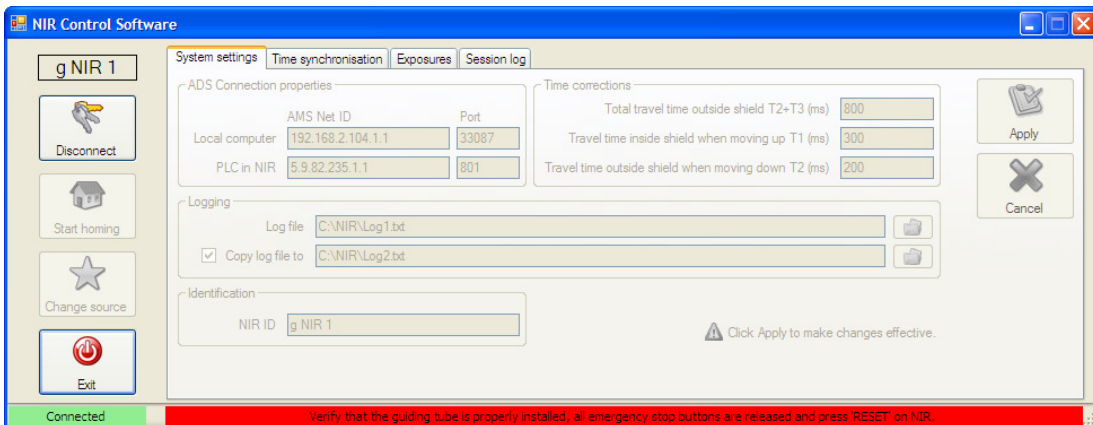


Figure 24: Connecting with the irradiator.

6. Check that both emergency stop buttons are released. If not, turn the buttons clockwise until they unlock. Verify that the source holder and the guiding tube are installed properly. Check the proper state of both guard switch pins. Both guard switches shall be engaged. The X18 bypass connector shall be removed.
7. Press the blue RESET switch to bring the device to the normal operation state. The motor controller will power-up (Figure 25), and the blue RESET indicator will go off.

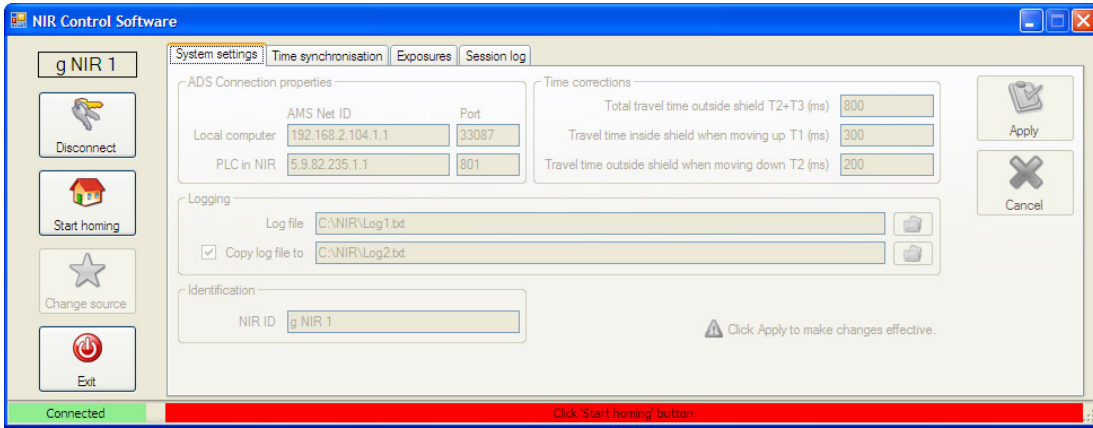


Figure 25: Ready to start the homing procedure.

8. Perform a homing operation by clicking the "Start homing" button. The cylinder will slowly move down until it reaches the homing limit switch. The NIR Control Software will switch to the "Exposures" tab automatically (Figure 26). The irradiator is now ready to expose the source or to change the source.



Note

After an emergency stop, the start-up procedure has to be followed again from step 7.

5.3.2 Changing or removing the source

Changing a source is always performed in safe standstill state. Follow this procedure to change or remove the source.



Note

Changing a source is only possible from the normal operation state. The NIR Control Software indicates "Ready" at the bottom of the window (Figure 26).



Danger

Ionising radiation

There is an increased risk of exposure to ionising radiation when the source is changed. Proper measures need to be taken to limit the exposure to ionising radiation to men, and to prevent loss of the source.

1. Click the "Change source" button in the NIR Control Software (Figure 26)

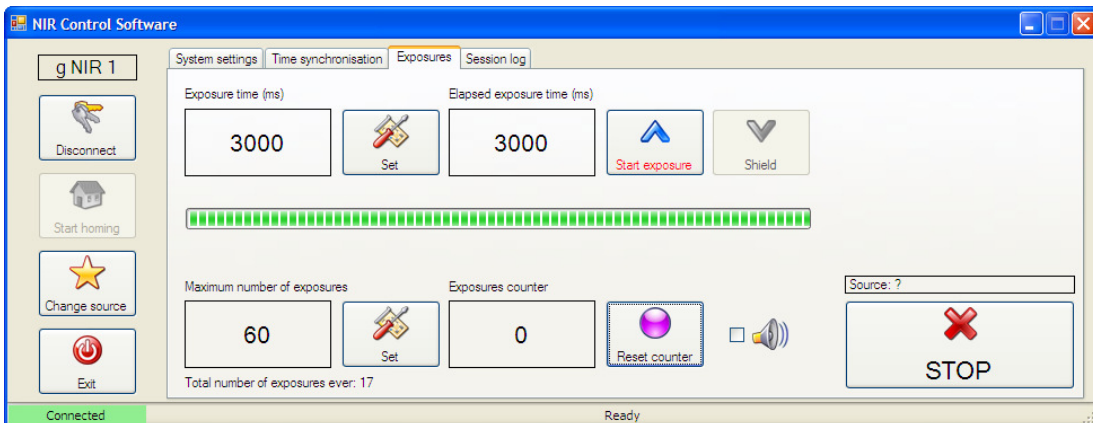


Figure 26: NIR Control Software ready to start an exposure.

- The software will ask for the ID of the new source. This ID will be written to the log file. Click "Cancel" to cancel the procedure or click "OK" to confirm (Figure 27). After clicking "OK", the radiation exposure indicator will go on and the source holder will slowly move out the shield. After that, the irradiator will be brought to the safe standstill state. On the control panel, all three indicators will be on.

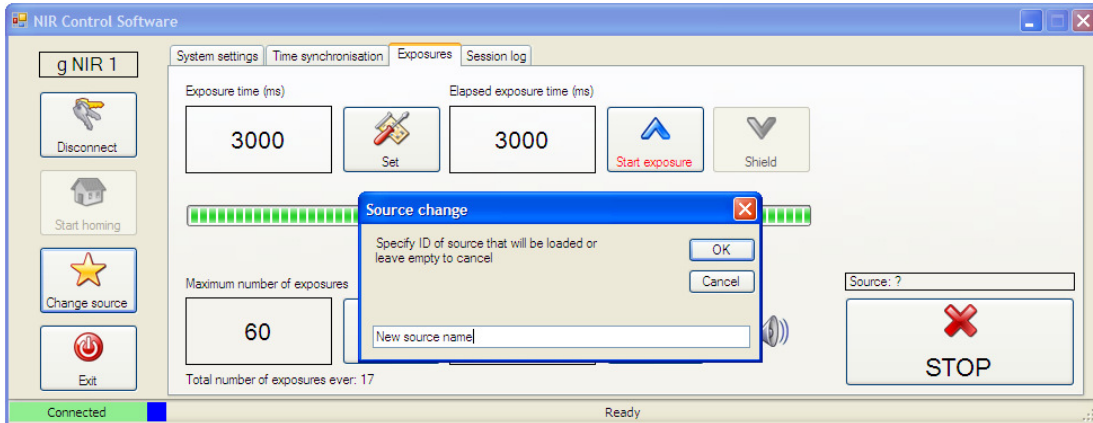


Figure 27: The NIR Control Software asks for the ID of the new source.

- Remove the guiding tube by first removing the wing screw and then vertically pulling the tube out of the shield (Figure 28 and Figure 29).

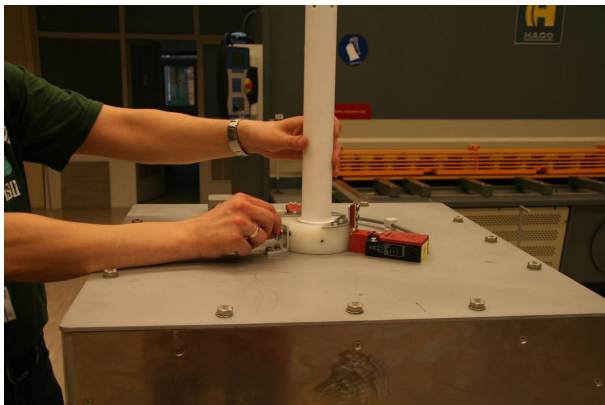


Figure 28: Remove wing screw.

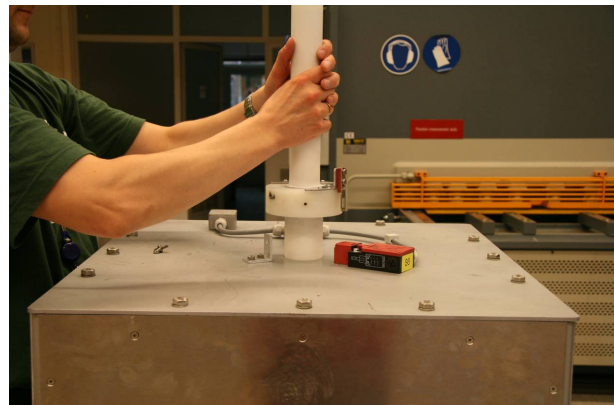


Figure 29: Pull guiding tube vertically out.

- Unscrew top of the source holder and load/unload the source (Figure 30 and Figure 31).



Figure 30: Unscrew top of source holder



Figure 31: Source can be loaded.

- Make sure that the source can not move inside the source holder.

6. Screw the top shield of the source holder completely back on. Do not tighten it too hard in order not to damage the source holder.
7. Reinstall the guiding tube by sliding it back into the device.
8. Verify that the two safety pins are properly inserted into the guard switches.
9. Screw in the wing screw.
10. Verify that both emergency stop buttons are released.
11. Push the blue RESET button to put the device in normal operation.
12. Perform a homing operation by clicking the "Start homing" button in the NIR Control Software. The source holder will slowly move down until it reaches the homing limit switch. The irradiator is now ready to expose the source.

5.3.3 Exposing a source

If the required source is not in the source holder, first change the source using the procedure above.

The exposure sequence starts by moving the source out of the shield. After the exposure time has elapsed, the source moves back into the shield. The exposure time is set using the control software. This time is corrected for the actual time that the source moves inside the shield.

A resettable counter keeps track of the number of exposures. After the number of exposures has been reached, it is no longer possible to expose the source without resetting the counter.

A total exposures counter is kept in the configuration file and shown on the bottom of the window.



Danger

Ionising radiation

The risk of exposure to ionising radiation is inherent to the intended use of the device. Proper measures need to be taken to limit the exposure to ionising radiation to men.

The "Exposures" tab in the NIR Control Software provides control over the exposures and the counters.

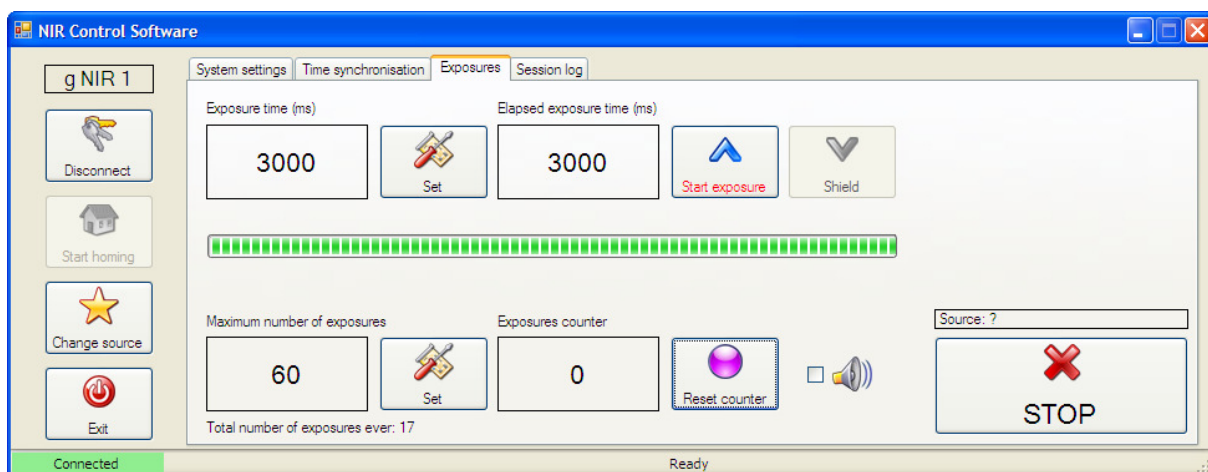


Figure 32: Controls and indicators on the "Exposures" tab in the control software.

You will see the following controls and indicators on the "Exposures" tab (Figure 32):

- The exposure time, specified in milliseconds. The exposure time can be changed by clicking the "Set" button next to the indicator.
- The elapsed exposure time, specified in milliseconds.
- The "Start exposure" button.

- The button to shield the source. Pressing this button interrupts the exposure of the source before the exposure time has elapsed, and moves the source back into the shield.
- A progress indicator for the exposure time.
- The maximum number of exposures. This maximum can be changed by clicking the "Set" button next to the indicator.
- An indicator showing the number of exposures, and a button to reset the counter.
- A check box to enable an acoustic signal indicating the start and the end of an exposure. When the source leaves the shield, one beep is generated, when it moves back into the shield, two beeps are generated (see Figure 21).
- A box indicating the ID of the source.
- A "Stop" button to immediately stop the movement of the actuator.



Note

The stop button in the NIR Control Software should not be used as an emergency stop. Use the mushroom pushbutton on the beacon instead.

To expose the source, simply set the correct exposure time and click the "Start exposure" button. When the source is being exposed, the window looks like Figure 33.

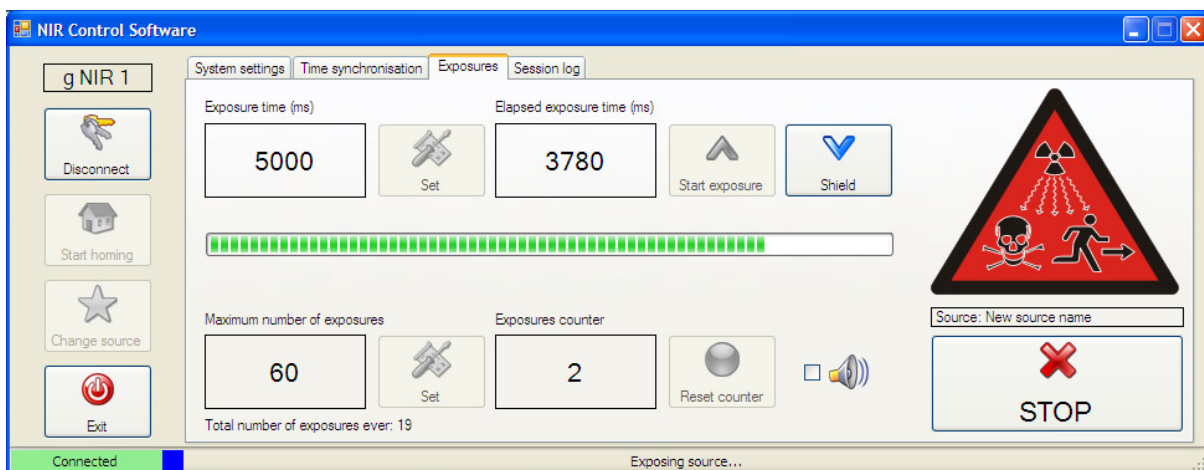


Figure 33: The control software during exposure.

5.3.4 Power-down

To power down the irradiator:

- Remove the source and store it in an appropriate way.
- Perform a homing.
- Click the "Disconnect" button. The device will go to a safe standstill.
- Click the "Exit" button to close the NIR Control Software.
- Switch off the PC.
- Switch off the irradiator using the main switch on the control panel.
- Unplug the mains plug X15

5.3.5 Log files

The NIR Control Software keeps a file in which following events are logged:

- The start and duration of an exposure.
- The changing of a source.
- Clicking "Shield". This will add the sentence "Previous exposure was incomplete" to the log.
- Comments added.



Note

Emergency stops or clicks on the stop button are not logged. The message "incomplete exposure" will not be logged to the file!

The log file can be specified in the "System settings" tab. The software can automatically copy the log file to another folder when required. A copy is made every time a line is appended to the log file.

The log file is a tab delimited text file, structured as in the example below:

```
NIR Log file

NIR ID:      gNIR1

Total#      Exp.# Start date/time  Exp.time (ms)
4           1      2010/12/03 12:52:00.564 3000
5           2      2010/12/03 12:52:06.964 3000
Source loaded: SRC1
6           3      2010/12/03 12:53:09.264 3000
7           4      2010/12/03 12:53:18.364 800
8           5      2010/12/03 12:53:20.964 800
9           6      2010/12/03 12:53:24.064 800
10          7      2010/12/03 12:53:27.264 800
11          8      2010/12/03 12:53:35.464 800
12          9      2010/12/03 12:53:55.764 3000
Previous exposure was incomplete.
13         10      2010/12/03 12:54:03.664 3000
14         11      2010/12/03 12:54:15.864 3000
15         12      2010/12/03 13:03:07.784 3000
Comment:    Changing to procedure ...
16         13      2010/12/03 13:04:24.414 3000
```

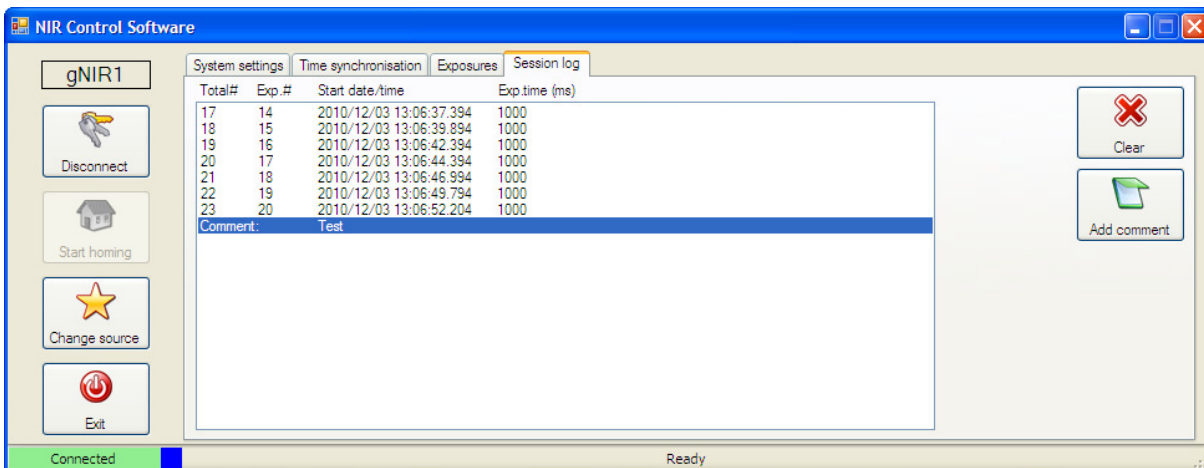


Figure 34: Events logged.

In the "Session log" tab, you will see a log of the events during the last session. It is possible to add comments to the log file, by clicking the "Add comment" button (Figure 34).

6 Safety performance

6.1 Risk assessment

The risk category was determined according to EN 951-1:

- S2: Serious (irreversible) injury is possible taken into account the high power of the electrical cylinder.
- F1: The frequency of exposure is small: only when the source needs to be changed, the operator accesses the moving parts of the machinery. The exposure time is short due to the quick movement of the cylinder.
- P2: There barely is the possibility to avoid impact of the moving parts when parts of the body of the operator are exposed because of the high speed of operation of the cylinder (0.4 m in 0.6 s).

Based on this assessment, it is judged that the device is in category 3 according to EN 951-1. This implies the following requirements:

The requirements of category B and the use of well-tried safety principles shall apply. Safety related parts shall be designed such that:

1. *A single fault in any of these parts does not lead to the loss of the safety function, and*
2. *The single fault is detected whenever reasonably practicable.*

Requirements for category B:

Safety-related parts of control systems and/or their safety devices and their components must be designed, constructed, selected, assembled and combined in accordance with the relevant standards such that they can withstand the expected influence.

For the design of the safety function this means that:

- The proper components shall be selected;
- If a single fault occurs, the safety function is still maintained;
- Some, but not all faults are detected;
- Accumulation of undetected faults can lead to the loss of the safety function.

6.2 Safety circuit and safety related parts



Important

The device is designed to shield a radioactive source far below natural background levels, so that when shielded it is completely invisible to the radiation detector being tested. For this reason, shielding is over-dimensioned. However, the maximum activity of the source that can be used is limited.

It was judged that the risk for injury due to the fast movement of the source holder is larger than the risk for exposure to ionising radiation. As a consequence, an emergency stop will stop the movement of the actuator as soon as possible. It will not put the source back into the radiation shield.

A safety circuit is a redundant circuit built with the following components:

- Emergency stop buttons S3 on the control panel and S4 on the beacon. The emergency stop buttons have redundant contacts.
- Guard switches S5 and S6. The interlocks detect the presence of the guiding tube. When the guiding tube is removed, the contacts of S5 and S6 open. These interlocks do not have

redundant contacts, but two interlocks are used of which the actuators are mechanically connected via the guiding tube.

- The relay K6, installed to enable the breaking of the safety circuit:
 - By the PC via the PLC: used in the procedure to change the source;
 - By the PLC alone: used in case of failure of communication between PC and PLC.

Because the safety circuit runs through the beacon cable, it will be impossible to start the motor controller when the beacon is not connected. Also, when the beacon cable breaks, an emergency stop will be triggered.

Important: relay K6 is not a safety component. Failure in its operation (contacts stay closed) will not lead to an unsafe situation because:

- In case it was triggered by the PC (procedure to change the source), the user will have to remove the guiding tube anyhow in order to access the source. Removing the guiding tube will trigger the emergency stop procedure with the safety components S5 and S6.
- In case of loss of communication with the PC, the operator can not give the command to expose the source; so no movement of the actuator will take place.

The safety circuit is monitored with the safety relay K7. Breaking it will trigger the emergency stop procedure. The circuit is built following specifications of the manufacturer of the motor controller. In case of emergency stop, following actions will occur:

- The safety relay K7 immediately disables the motor controller by opening K1 and K2. This breaks the controller enable signal to the motor controller. The motor controller brings the actuator to a stop and engages the brake. EN 954-1 category 3 is integrated in the motor controller.
- After a delay of 1 s, the safety relay K7 disables the output stage of the motor controller by opening delayed contacts K3 and K4 (signal output stage enable). Also, driver supply is disabled and brake activated by breaking the connection from X3.1 to X3.2 on the motor controller U2.

After an emergency stop, the device will be in safe standstill. Safe standstill is indicated by an illuminated RESET button (continuously or blinking if the connection with the control software on the PC is lost). In safe standstill, the PLC and software can not control the instrument.

Note: power contactor K5 has no safety function. Its only use is to power-up the motor controller by command of the control software. The PLC will only close K5 when the safety relay K7 is engaged (monitored by signal SAFREL). Failure of K5 (contacts remain closed) will not lead to an unsafe situation since the safety circuit described here is not affected.

6.3 Recovery after emergency stop or power-up (RESET)

When an emergency stop condition was present (or immediately after the device was powered-up), the safety relay K7 needs to be reset to take the device from safe standstill to normal operation. This is done by pressing the RESET button on the control panel.

When there is a radioactive source in the source holder when the emergency stop was triggered, it might be necessary to remove it before resetting the device. Care should be taken when removing the source in order to limit exposure to radiation and to contain possible contamination in case the source broke. Remove the guiding tube and access the source in the normal procedure (5.3.2). If the source can not be accessed since it is at the level of the shield, manually operating the motor controller can be an option (as described in 7.8 and using the bypass connector X18). In rare cases, partly disassembling the shield in order to access the source is the only possibility to recover it.

Safety relay K7 is wired as specified by the manufacturer, in the scheme “two channel emergency stop / start button monitored”. The start button is the RESET button on NIR. Pressing the RESET button only has effect when there is no emergency stop condition and when the motor controller is in a safe operating mode. That is when all the emergency stop buttons are released and the guiding tube is properly installed. After pressing the RESET button, its light goes off. Then homing needs to be performed and normal operation can continue.

6.4 Feedback

Category 3 of EN 954-1 requires the use of a feedback system. This is realised with the contacts NC1 and NC2 on the motor controller. When driver supply is present, the contact is open. Adding this contact to the RESET circuit of the safety relay K7 will have the effect that it is impossible to reset K7 in case the motor controller fails.

6.5 Essential health and safety requirements

The following requirements apply. In short, an explanation is given to demonstrate compliance.

Ref.	Description
Q1	<p>Machinery shall withstand anticipated operating stress:</p> <ul style="list-style-type: none"> - The actuator system was selected in accordance with the mechanical load (total mass and speed of operation of the source holder). Maximum mass of the source is listed in Table 1. - The servo motor is equipped with a mechanical brake that can hold the source holder and prevent it from falling in case of power loss of the motor.
Q2	<p>Machinery stops safely in case of power interruption.</p> <ul style="list-style-type: none"> - In case the mains power is interrupted during the actual move of the actuator, the motor brake is engaged automatically. The brake is designed to release only when the 24 V control voltage is present. The brake has sufficient power to hold the load on the actuator and prevents it from falling.
Q3	<p>Machinery stops safely in case of loss of communication with control software.</p> <ul style="list-style-type: none"> - The communication between the irradiator and the control software is monitored continuously by the PLC. In case of loss, an emergency stop is triggered, bringing the device to a safe standstill.
Q4	<p>Use of safety components, redundant motor contacts, feedback loop.</p> <ul style="list-style-type: none"> - The servo motor controller is compliant to cat.3 of EN 951-1. - NIR is equipped with a safety relay. In case of an emergency stop, this relay breaks the "controller enable" and "output stage enable" connection between the PLC and the motor controller. When "controller enable" is low, the motor controller does not react on positioning commands sent to it, and the motor brake is activated. When "output stage enable" is low, the electrical power to the output stage of the driver is cut. Feedback is realised in the RESET circuit of safety relay K7. See heading 6.2.
Q5	<p>Risk for injury shall be reduced as much as reasonably achievable.</p> <ul style="list-style-type: none"> - The moving parts of the device are not accessible when the guiding tube is installed. When the guiding tube is removed, the device will come to a safe standstill and the motor controller will be disabled. This safety function is implemented using the guard switches S5 and S6 and safety relay R1.
Q6	<p>Emergency stop.</p> <ul style="list-style-type: none"> - The machinery has two emergency stop buttons. One is placed within reach of the operator, the other on the control panel of the machine. Also, two guard switches that guard the presence of the guiding tube are connected to the emergency stop circuitry. The emergency stop circuitry is installed with redundant contacts. See heading 6.2.
Q7	<p>Risk for exposure to ionising radiation shall be reduced.</p> <ul style="list-style-type: none"> - The source type and activity shall be chosen by the user in compliance with local safety standards and the shielding provided.

Q8	<p>Risk for electrocution shall be reduced.</p> <ul style="list-style-type: none"> - The electrical cabinet and cables are wired in accordance with directive 2006/95/EC (low voltage directive) and harmonised standard EN 60204-1 (Safety of machinery - Electrical equipment of machines - General requirements).
Q9	<p>Risk for exposure to hazardous materials shall be reduced.</p> <ul style="list-style-type: none"> - Hazardous materials (lead, cadmium) are not accessible without disassembling at least part of the device. If during disassembly of NIR – neutron, small metal particles are found close to the source holder, they shall be cleaned with appropriate care as they could contain cadmium.

Table 3: Essential health and safety requirements.

6.6 Residual risks

Table 4 summarises the residual risks related to the transport, installation and use of the device. It provides actions to reduce these risks as much as reasonably achievable.

Ref.	Description
R1	<p>Risk for exposure to ionising radiation.</p> <ul style="list-style-type: none"> - Always use appropriate sources with respect to local regulations and shielding provided. - Always store sources in an appropriate way when they are not in use. - Always obey general ALARA principles. - The operator shall always have a visual contact with the irradiator so that he can verify that there is nobody present in the zone with elevated radiation level during exposure. This especially applies when the remote interface to the control software is used. In that case, the PC running the control software shall be locked and the beacon placed to the operator that actually controls the start of an exposure.
R2	<p>Risk for tipping over when lifting.</p> <ul style="list-style-type: none"> - Use a belt to fix the device to the forklift. - Always insert the forks of the forklift or manual pallet jack completely into the slots. - Ensure that the device is kept levelled during lifting.
R3	<p>Risk for tipping over during transport.</p> <ul style="list-style-type: none"> - Remove the radiation shield and transport it separately.
R4	<p>Risk that emergency stop is not within reach of operator.</p> <ul style="list-style-type: none"> - Always place the beacon next to the operator that controls the device.
R5	<p>Risk for damage to the source.</p> <ul style="list-style-type: none"> - The source shall always be well-fixed to the source holder using the proper materials.
R6	<p>Risk for injury in case both guard switch pins break.</p> <ul style="list-style-type: none"> - Before installing the guiding tube, verify that the guard switch pins are in good condition.
R7	<p>Risk for exposure to hazardous materials: wear of cadmium.</p> <ul style="list-style-type: none"> - The source holder of NIR – neutron contains two cadmium disks. The disks move up and down with the source holder. To prevent wearing-off, the disks are a little smaller than the source holder so that it does not come into contact with the guiding tube. After long use and excessive wear of the source holder, cadmium could come into contact with the guiding tube, resulting in release of dust particles. Inspect the position of the cadmium disks above and below the neutron source holder regularly to prevent wearing-off.
R8	<p>Risk that belt breaks.</p> <ul style="list-style-type: none"> - When the belt breaks during motion of the source holder or when the source holder is in exposed position, the source holder might fall down. In normal conditions, the guiding tube will prevent access to the falling holder, thereby reducing risk for injury. - If there is a source present when the belt breaks, care should be taken when removing it in order to reduce exposure. It might be required that part of the radiation shield is removed in order to access the source.

R9	<p>Risk that X18 BYPASS still on, thereby disabling the guard switches.</p> <ul style="list-style-type: none"> - Make sure that the bypass X18 is removed in normal operation. - Store the bypass in a safe place.
R10	<p>Risk that user modifies electrical connections.</p> <ul style="list-style-type: none"> - Modifications to the electrical system are strictly prohibited and shall be performed by the manufacturer only. - Keep the electrical cabinet closed and locked. Store the key in a safe place.
R11	<p>Risk that the user does not follow the instructions in this manual.</p> <ul style="list-style-type: none"> - With the guiding tube and guard switches, the risk for injury is very much reduced. - The user is responsible for understanding user manual and the risks associated with the use of the device. If not clear, the user should contact the manufacturer.
R12	<p>Risk for fire.</p> <ul style="list-style-type: none"> - In case of serious malfunctioning of electrical components, there is a residual risk that the control cabinet catches fire. - The device should not be left unattended, and shall be switched off when not in use.

Table 4: Residual risks.

6.7 EC declarations of conformity for electrical and safety components

All electrical and safety components used in this device are declared by their manufacturer to conform to EC regulations 2006/95/EC (low voltage directive) and 2004/108/EC (EMC directive). All the EC declarations of conformity are available on the NIR Installation and Documentation DVD. A copy is available on the PC delivered with the devices.

6.8 Use of the main switch and mains plug

The main switch S1 will not completely remove the power from the device. Use the mains plug X15 to remove power. Observe the instructions in heading 9 “Maintenance and repairs”.

6.9 External influences

The irradiator was designed to operate in and withstand to the environmental conditions listed in Table 5 (according to IEC 60364-5-51).

External influence	Code	Remark
Category A (environment)		
Ambient temperature	AA5	+5 °C to +40 °C (Normal)
Atmospheric humidity	AB5	5 to 85% RH (Normal)
Altitude	AC1	≤ 2000 m (Normal)
Presence of water	AD1	Negligible
Presence of foreign solid bodies	AE1	Negligible
Corrosion	AF2	Atmospheric conditions
Mechanical stress impact	AG1	Low severity
Vibration	AH2	Medium severity – usual industrial conditions
Flora	AK1	Negligible – no hazard
Fauna	AL1	Negligible – no hazard
Radiation	AM41	Designed to be used in an environment with presence of ionising radiation.
Sun	AN1	Negligible
Seismic effect	AP	Needs to be evaluated by the user with respect to the risks present at the place of installation.

Lightning	AQ1	Needs to be evaluated by the user with respect to the risks present at the place of installation.
Movement of air	AR1	Low
Wind	AS1	Low
Category B (use)		
Qualification of persons	BA5	Skilled/authorised personnel only
Electrical resistance of human body	BB1	Condition of human body: dry
Contact of persons with earth potential	BC3	Frequent
Condition of evacuation in case of emergency	BD1	Low density / easy exit
Nature of processed or stored materials	BE4	There is a risk for contamination of the irradiator since due to its nature; it is most likely to be used/installed in controlled areas with presence of radioactive sources.
Category C (construction)		
Construction materials	CA1	Non combustible
Building design	CB1	Negligible risks

Table 5: External influences.

6.10 Regular inspections and functional tests

6.10.1 Inspections at each use

At the beginning of each use, the operation of the indicators shall be tested. Put the device in normal operation and verify that both green power indicators are on, and that the red exposure indicators are off. Switch on the acoustic exposure indicator. Perform an exposure and verify that both exposure indicators are lit during the exposure time, and that an acoustic signal is heard at the start and the end of the exposure.

6.10.2 Functional tests

To ensure safe long-term operation, the inspections and functional tests listed here shall be performed:

- Once per year when the device is in continuous use;
- After transport;
- Before putting in operation after a period of standstill of more than 3 months.

The template below (NIR Inspection Sheet) describes the tests/inspections to be performed and the required outcome. If the outcome is not as specified, the user shall inform the manufacturer before resolving the issue. Records of these tests shall be kept by the user and made available to the manufacturer upon request.

NIR Inspection Sheet		Serial number	Date of inspection
This inspection concerns: <input type="checkbox"/> A yearly inspection <input type="checkbox"/> Inspection after transport from: to: <input type="checkbox"/> After standstill <input type="checkbox"/> Other:		Operator name + signature	
Test	Procedure	Required outcome	OK / NOK
T1	<u>Quality of cables in emergency stop circuit</u> With device powered down, X15 removed and after 5 minutes of waiting time, verify that all cables and connectors in the emergency stop circuit are not damaged: <ul style="list-style-type: none"> • the cable to the beacon • connector X13 • the cable from the cabinet to the guard switches S5 and S6 • connector X18. Measure resistance with emergency stop buttons released and guiding tube installed: <ul style="list-style-type: none"> • On X13 (beacon cable) between pin 1 and 4 • On X13 (beacon cable) between pin 2 and 3 • On X18 (cable to S5/S6) between pin 2 and 4 • On X13 (cable to S5/S6) between pin 1 and 3 	<ul style="list-style-type: none"> • Cable not damaged • No indications of squeeze • Cable firmly attached to connectors • Connectors lock • No loose contacts in connectors • All measured resistances lower than 1 Ohm. 	
T2	<u>Quality of power cable</u> With device powered down, X15 removed and after 5 minutes of waiting time, measure resistance between L1, N and PE from X15 to X14. Verify that the cable is not damaged.	<ul style="list-style-type: none"> • Cable not damaged • No indications of squeeze • Cable firmly attached to connectors • Connectors lock • No loose contacts in connectors • All measured resistances lower than 1 Ohm. 	
T3	<u>Guard switches</u> <ul style="list-style-type: none"> • Verify that the guard switches S5 and S6 are firmly attached to the NIR frame. • Verify that the guard switch pins of S5 and S6 are firmly attached to the ring around the guiding tube. • Verify that the ring around the guiding tube is firmly attached to the guiding tube. • Inspect glue area between ring and tube (NIR – gamma). 	<ul style="list-style-type: none"> • Both guard switches can not be moved with respect to NIR frame. • Both guard switch pins can not be moved with respect to ring. • Ring can not be moved with respect to tube. • Glue shows no cracks. 	
T4	<u>Guiding tube</u> <ul style="list-style-type: none"> • Verify that there is no excessive wear on the guiding tube that could influence proper operation. 	<ul style="list-style-type: none"> • Guiding tube in good shape. 	
T5	<u>Source holder</u> <ul style="list-style-type: none"> • Use the procedure to change the source, inspect that the lower part of the source holder is firmly fixed to the actuator cylinder. • Check that central part of source holder is firmly fixed to lower part. • Check for damage of thread between central part and top part. 	<ul style="list-style-type: none"> • Lower part of source holder can not move from cylinder. • Central part can not move with respect to lower part. • Thread between central and top part not damaged. 	
T6	<u>Emergency stops during normal operation</u> <ul style="list-style-type: none"> • With device in normal operation state, press emergency stop button S3. Observe indicators on control panel. Try to reset by pressing the button. Release the button S3, press the reset button and redo homing (follow instructions on NIR control software). • Repeat for S4 on beacon. • Repeat by removing the guiding tube. 	<ul style="list-style-type: none"> • After every test, the device shall go to safe standstill: Power indicator is lit; blue Reset button/indicator is lit continuously. • It shall not be possible to reset when the emergency stop button is still activated. • After releasing the emergency buttons and pressing the reset button, device goes back to normal operation (reset indicator off). 	

T7	<u>Emergency stop during move of cylinder</u> <ul style="list-style-type: none"> • Unscrew the wing screw from the guiding tube. • With device in normal operation state, start the procedure to change the source. • During move up of the source holder, firmly pull out the guiding tube. • Verify that device is in safe standstill state. • Verify that the brake is activated by trying to push down the source holder. • Reinstall the guiding tube and reset, redo homing. 	<ul style="list-style-type: none"> • Motion shall stop immediately after the guard switch pins leave the switches. • Device is in safe standstill. • It shall not be possible to push down the source holder. • After reset, device is in normal operation. 	
T8	<u>Emergency stop by cable break</u> <ul style="list-style-type: none"> • With the device in normal operation, disconnect connector X12. • Wait and observe control panel indicators. • Press reset. • Reconnect and reset. • Repeat with X13. 	<ul style="list-style-type: none"> • After disconnecting X12 or X13, device shall go to safe standstill. • Reset impossible when cable not connected. • Reconnecting X12 or X13 shall make reset possible. 	
T9	<u>Test of motor controller</u> <ul style="list-style-type: none"> • With the device in normal operation, start a trace recording with minimum exposure time, as described in 7.6 	<ul style="list-style-type: none"> • In FCT trace view, actual position should closely follow the setpoint, as indicated in Figure 46. 	

7 System configuration

System configuration includes the installation of software and its configuration, and the programming of the programmable components inside the irradiator.

Some settings have to be made in the operating system of the PLC inside the irradiator. The CERHOST program is used to make a remote connection to the Windows CE operating system. It can be found on the NIR Installation and Documentation DVD.

7.1 *Installing the TwinCAT PLC software*

TwinCAT PLC is a commercial software package that can be purchased from Beckhoff. However, the part of TwinCAT PLC that the NIR Control Software actually uses is free of charge. After installation, TwinCAT PLC will run with full functionality for 30 days. After the trial period, the TwinCAT run time engine will stop working on the PC where it was installed, but the other functionalities will continue to work, including the programming of the PLC and the communication between the PLC and the NIR Control Software, which uses the TwinCAT ADS-OCX. The installation of the OCX is included in the TwinCAT PLC installation.

The operating system shall be a 32-bit Windows system. In the \TwinCAT folder on the NIR Installation and Documentation DVD, you will find the TwinCAT installer. Follow the instructions from the manufacturer of the software (Beckhoff).

7.2 *Installing the NIR Control Software*

There is no installation program for the NIR Control Software. The source code of the software is available. The program was developed in Microsoft Visual Basic Express 2010, which can be downloaded free of charge. The manufacturer of NIR is not responsible for changes that the user made to the control software.

7.3 *Operating the device in a network*

Communication between the PC and the irradiator takes place over the TCP/IP protocol. The user may wish to communicate directly with the device, or over a network. Communicating over a network has the advantage that time synchronisation with a SNTP server is possible, and that two or more irradiators can be controlled from the same PC simultaneously (Figure 35).

In any configuration, both the PC and the irradiator need an IP address before any communication takes place. As with any network, they also need to have the same subnet mask. For performance reasons, it is recommended to assign fixed IP addresses to both the PC and the irradiator, although it is also possible to use DHCP.

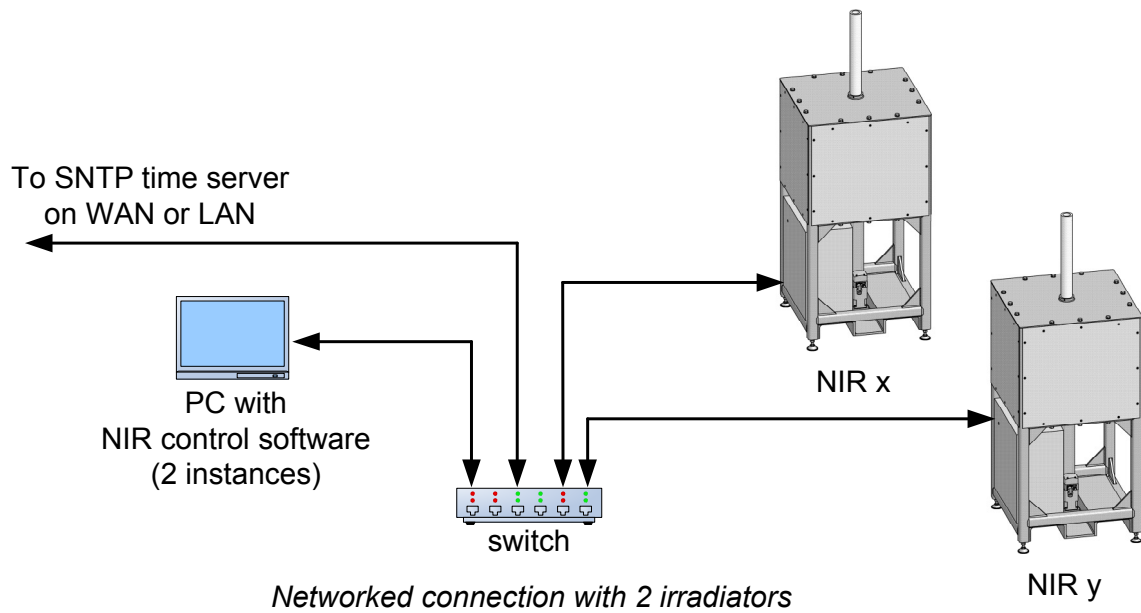
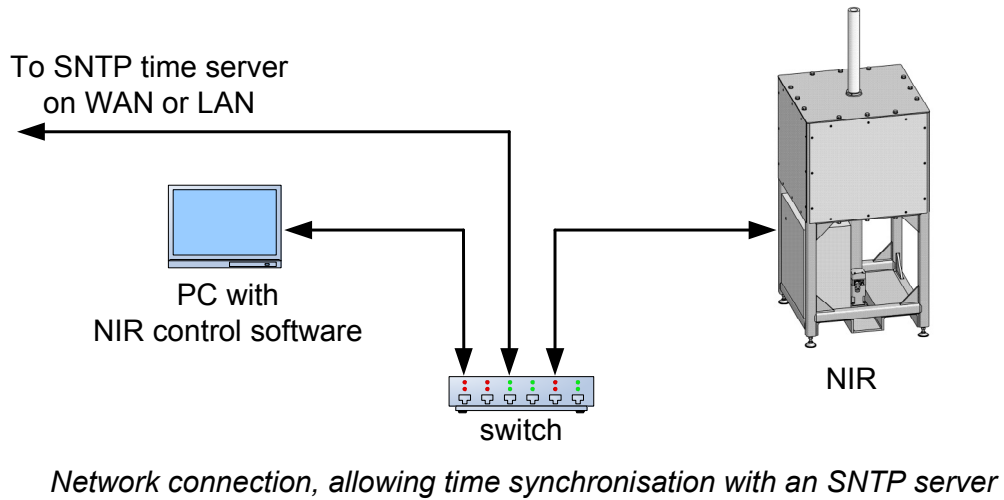
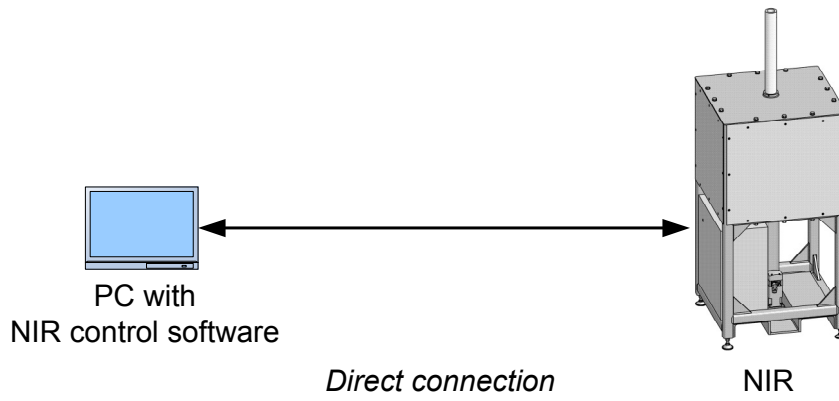


Figure 35: Different network configurations of one or more irradiators.

7.3.1 Configuration of "routes"

For the communication to work properly, two "Routes" have to be created:

- One route from the PC to the irradiator;
- The other route from the irradiator to the PC.

If the PC will control more than one irradiator, there will be routes from the PC to all of the irradiators and back.

The TwinCAT System Manager is used to configure the routes. To start the TwinCAT System Manager, right-click the TwinCAT symbol in the Windows Taskbar, and select System Manager (Figure 36).

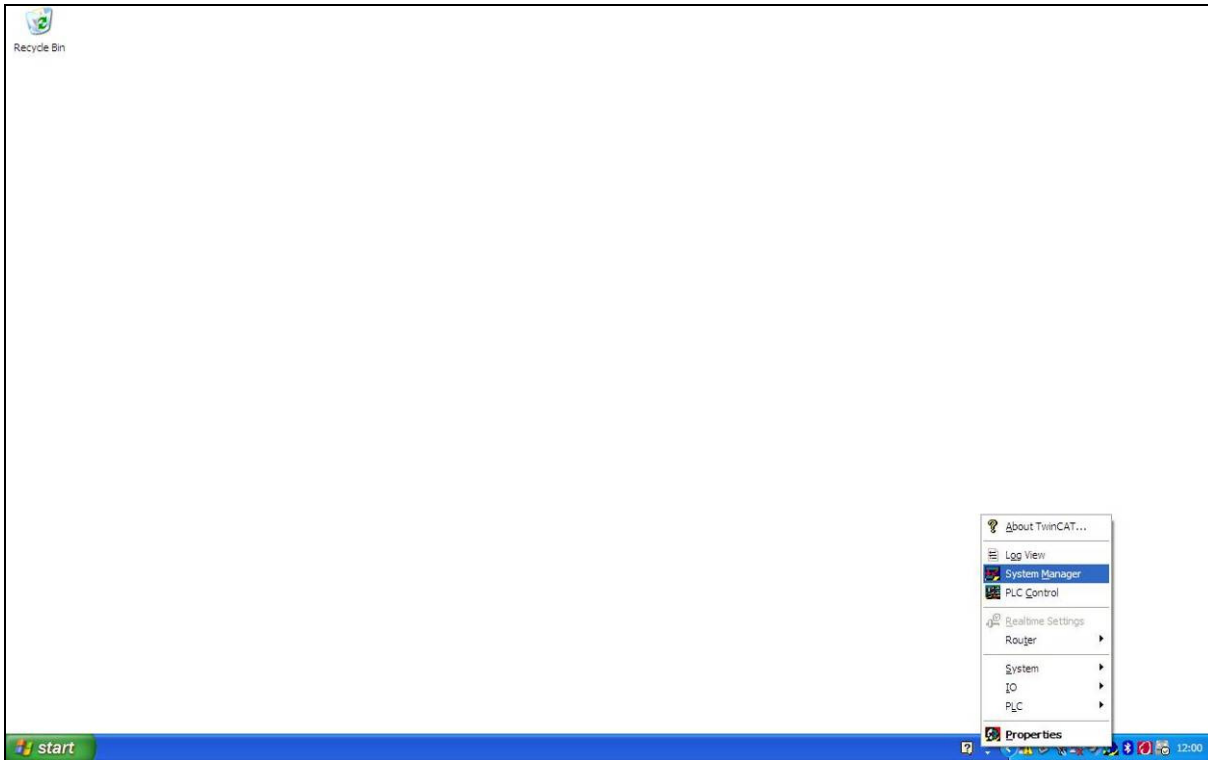


Figure 36: Starting the TwinCAT System Manager.

In the TwinCAT System Manager, click File, Open from the menu and browse for the NIR1.tsm file in the \System configuration\PLC folder on the NIR Installation and Documentation DVD.

First, the local system (the PC) needs to be configured. Select the local PC as the Target System. This is done with F8, and then selecting ---Local--- and clicking OK. On the left side of the window, select Route Settings under SYSTEM – Configuration. Select the tab "Current Routes" on the right side of the window. A list of currently available routes is displayed. To add a new route to an irradiator, click the Add button. (See Figure 37)

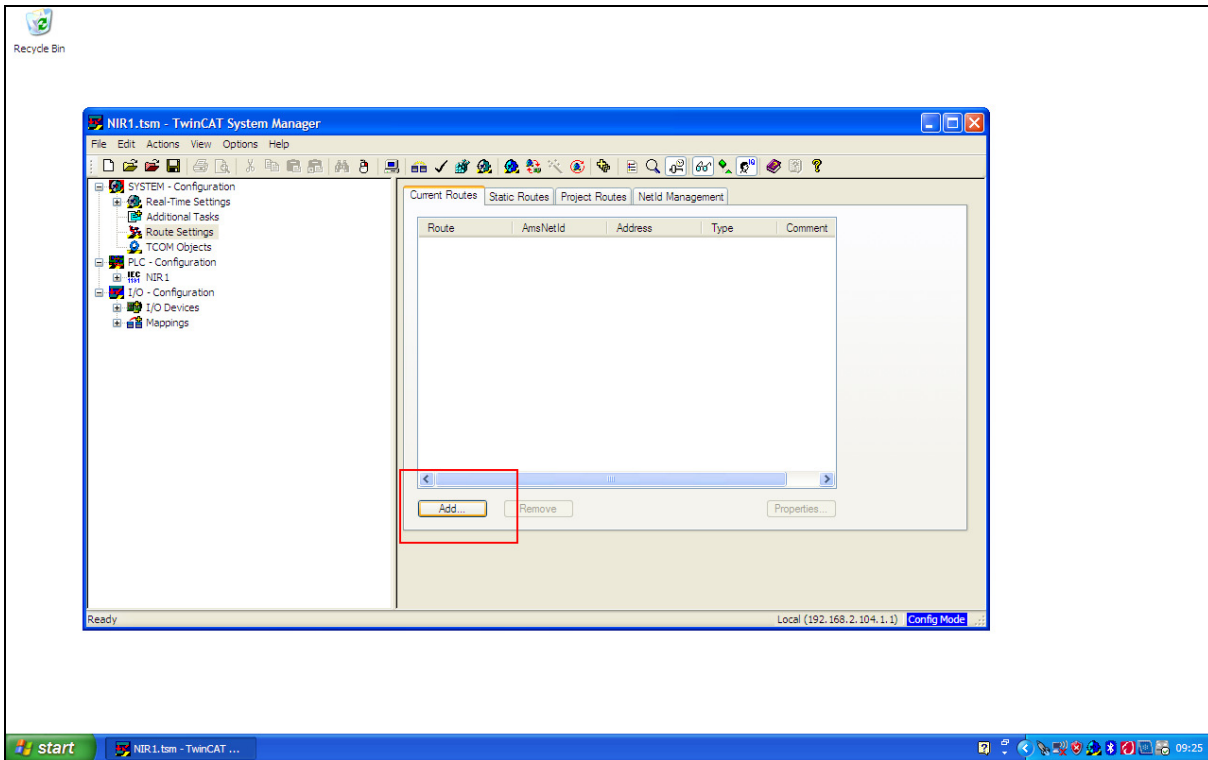


Figure 37: Adding routes.

In the Add Route Dialog, click the button "Broadcast Search". You will see a list of Routes to different PLCs connected to the network (Figure 38).

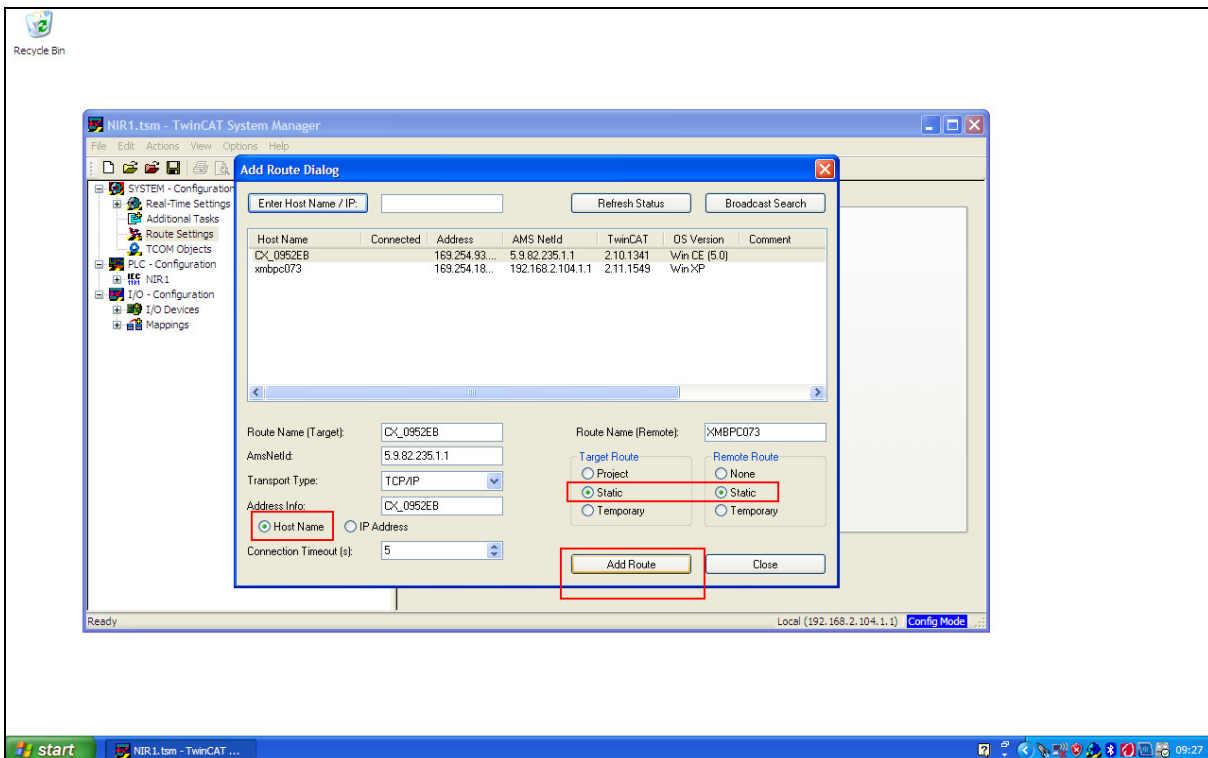


Figure 38: Configuration of routes on the local system.

Select the proper route and write down the Host Name, IP Address and AMS NetId for further reference. At the bottom of the screen, select Host Name, and Static for Target Route and Remote Route (Figure 38). Then, click the "Add Route" button. When the system asks for logon information, enter "Administrator" as user name and leave the password blank. Click OK and then Close. The screen now looks as in Figure 39.

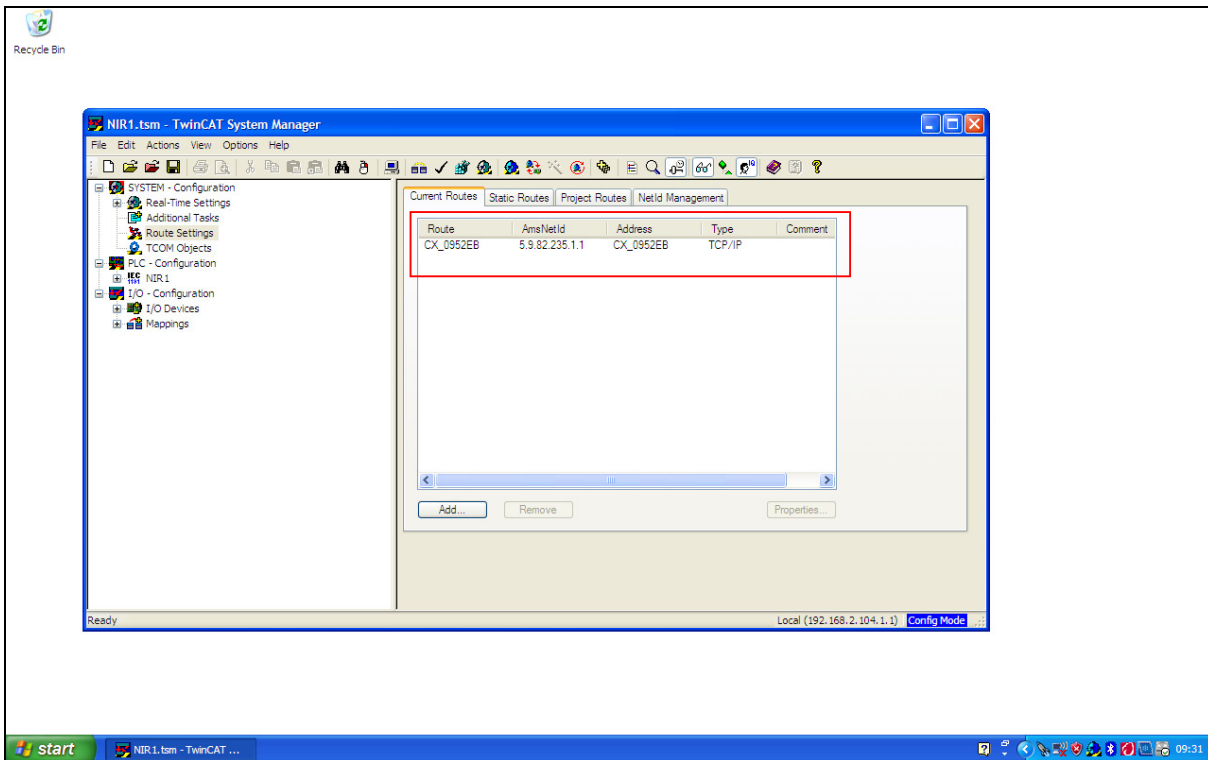


Figure 39: List of available routes on the local system.

Now the route needs to be activated. From the menu, click Actions, Generate Mappings. Then, Actions, Check Configuration, and finally, Actions, Activate Configuration. Confirm with OK. Click Cancel when the system asks to start TwinCAT in Run Mode. After the 30 day trial period, TwinCAT will only run in Config Mode, which has no further implications for the irradiator.

Secondly, a route to the PC has to be created from the irradiator. Change the Target System by clicking F8 and selecting the irradiator's Host Name from the list. If the host name is not there, perform a Search and add the route in the same way as described above. After selecting the Host Name, click OK. Verify that there is a route to the PC, as in Figure 40. Write down the AMS Net Id of the PC. In Figure 40, the PC has the Host Name "XMBPC073".

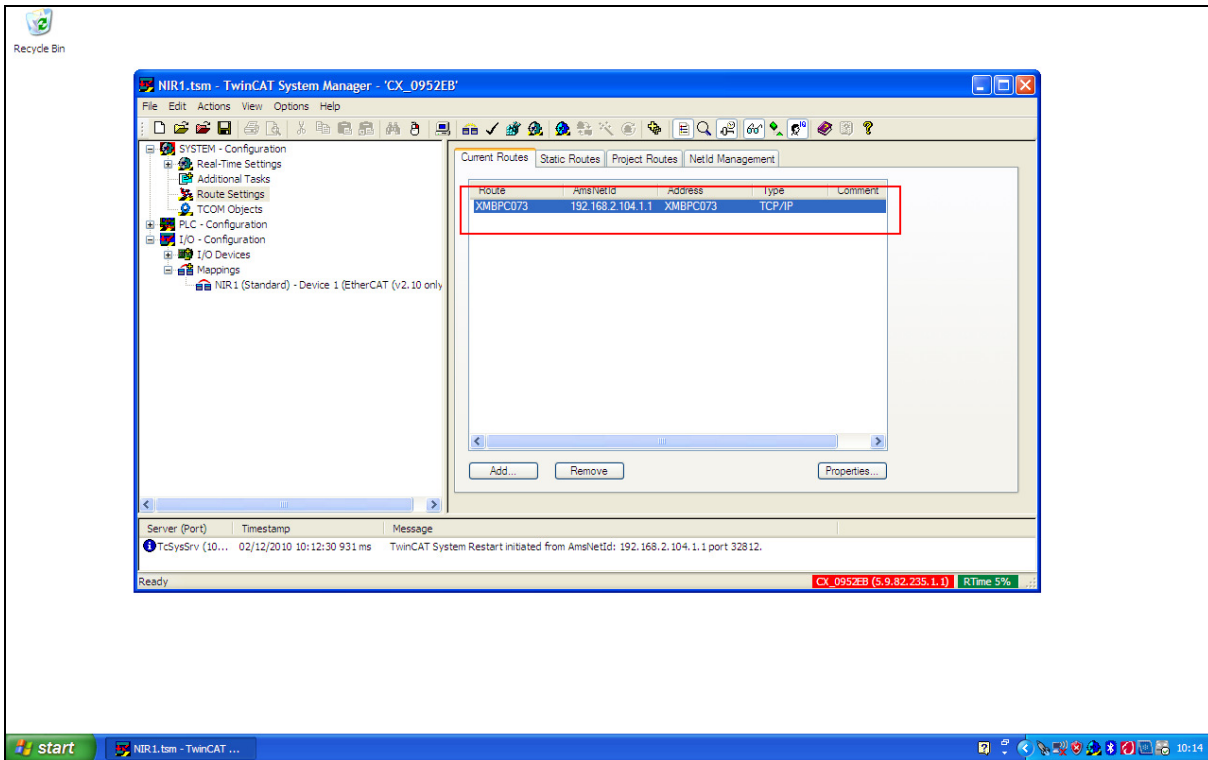


Figure 40: Configuration of routes from the remote system (PLC) to the PC.

Finally, also this route needs to be activated. From the menu, click Actions, Generate Mappings. Then, Actions, Check Configuration, and finally, Actions, Activate Configuration. Confirm with OK. This time, click OK to restart the TwinCAT System in Run Mode. (Now, the TwinCAT system refers to the irradiator.) Close the System Manager.

7.3.2 System settings in the NIR Control Software

Once the routes are configured and activated, the System settings in the NIR Control Software have to be changed to reflect the correct AMS Net Id and port numbers for the local computer and the irradiator.

The NIR Control Software reads and stores all settings in a configuration file. The file is located in the same folder as the program executable. See heading 7.7 for a description of the configuration file.

7.4 Changing the IP address of the irradiator and the PC

By default, the PC and the irradiator have a fixed IP address. This has the advantage of a faster establishment of the connection between the PC and the irradiator after power-up. If required, the IP addresses can be changed. Make sure that PC and irradiator are on the same subnet. Also, write down the IP addresses for later reference, and update the "Network identification tag" when the IP address or the subnet mask of the irradiator has been changed. An Excel sheet is available on the NIR Installation and Documentation DVD that can be used to generate a new Network identification tag.

7.4.1 IP address of irradiator

When the irradiator and the PC are not on the same subnet, they can not talk to each other and you can not change the IP address of the irradiator. If this is the case, first set the IP address of the PC to the same subnet as the irradiator, allowing communication. Then, set the IP address of the irradiator to the new value, and finally set the PC's IP address.

The manufacturer has setup the irradiator to use a fixed IP address. The address can be found on the "Network identification tag", attached to the irradiator cabinet.

Start CERHOST and click File, Connect. Enter the IP address of NIR (see inside the cabinet door).

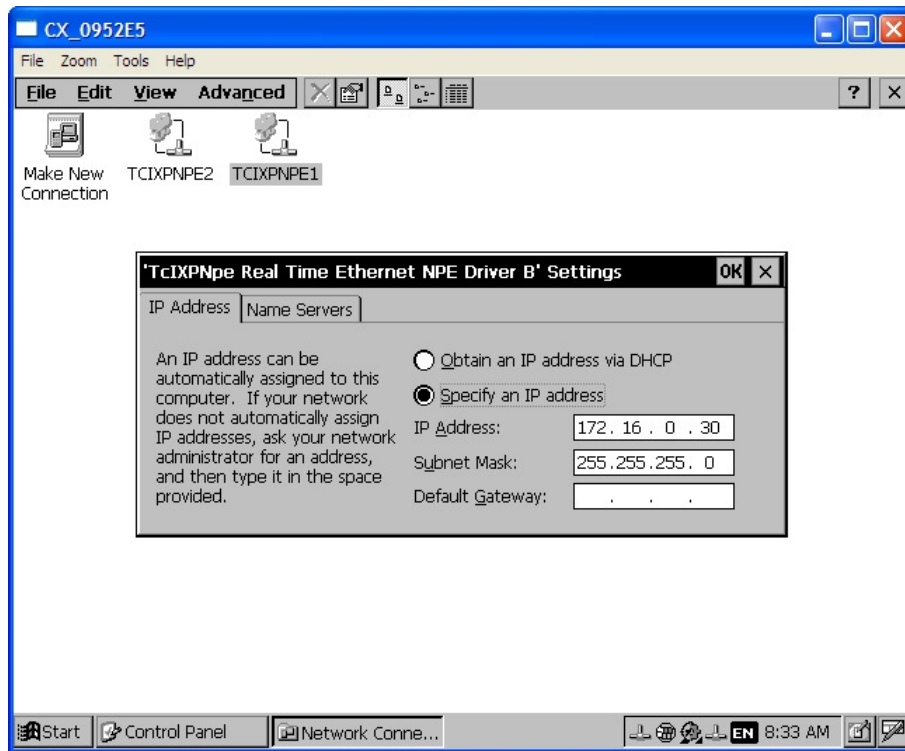


Figure 41: Setting the IP address of the irradiator

Click Start, Settings, Control Panel. Double click Network and Dial-up Connections, and open the TCIXPNPE1 connection. Specify the new IP address and subnet mask, and click OK. Update the Network identification tag accordingly. When the new address is applied, the connection will be lost.

7.4.2 IP address of PC

From the Start menu, go to the Control Panel and open Network Connections. Right click Local Area Connections, and select the Internet Protocol (TCP/IP). Click the Properties button. Specify an IP address and click OK and then Close. Verify that the PC has the new IP address using "ipconfig" in the command prompt.

7.4.3 Checking TCP/IP communication with the irradiator

As with any device connected to the Ethernet, the "ping" command can be used to check TCP/IP communication between two devices. On the PC, open the command prompt, by e.g. clicking Run from the Start menu and then using the command "cmd". In the command prompt, type ping, followed by the IP address of the irradiator, or the Host name. Both can be found on the irradiator's "Network identification tag", attached to the cabinet. When communication is not successful, check the IP addresses and subnet masks of the PC and the irradiator.

7.5 Time synchronisation

The NIR Control Software automatically generates a log file with the precise start and duration of every exposure. The start time is taken from the PLC clock inside the irradiator, not from the PC that runs the control software. The PLC clock should be set to synchronise automatically with an SNTP server accessible on the network (Figure 35). The procedure below explains how to setup the irradiator to enable SNTP time synchronisation.

Start CERHOST and click File, Connect from the menu. Type the Host name as it is printed on the "Network identification tag". After connecting, you will see the Windows CE environment of the PLC inside the irradiator.

7.5.1 Setting the time zone

First, set the time zone. Double click on the clock on the task bar and select the proper time zone. Typically, this would be UTC (Figure 42). Click the Apply button and close the window.



Figure 42: Setting the time zone in the irradiator PLC.

7.5.2 Specifying an SNTP time server

From the Start menu in Windows CE, click on My Device, choose Control Panel and open the Beckhoff CX Configuration Tool. On the Miscellaneous tab, you can specify an SNTP Server and a refresh rate (Figure 43). Click the Apply button. Click yes to accept a system reset. After reset, switch off the power of the irradiator using the main switch, wait a few seconds and switch the irradiator on again. The PLC should boot and the blue reset indicator will start to blink. Connect again using CERHOST and verify that settings are correctly applied.

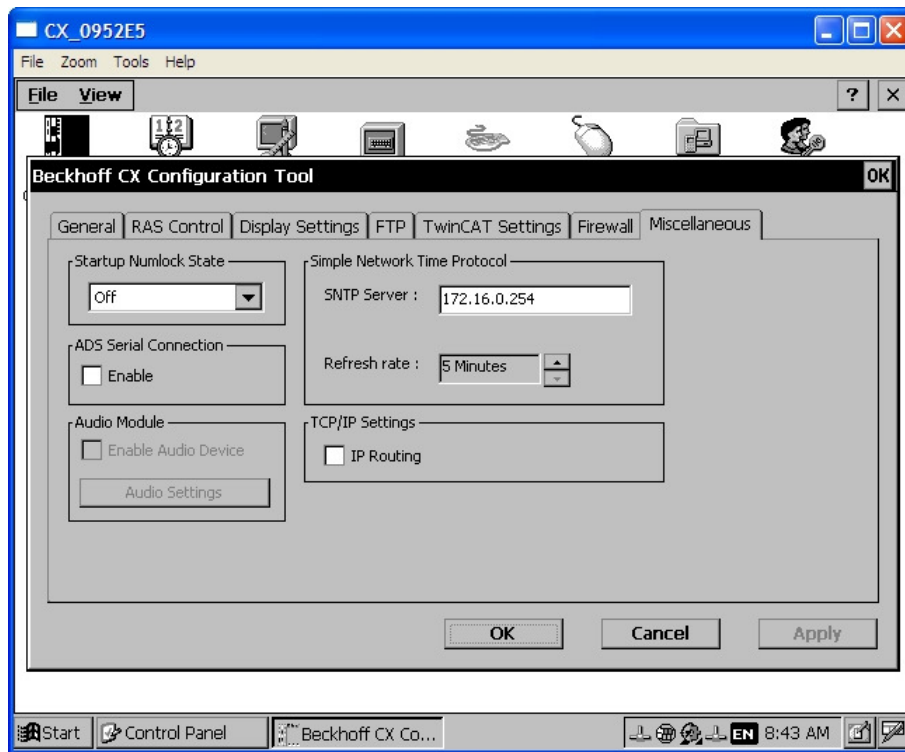


Figure 43: SNTP server configuration on the PLC.

7.6 Correction of exposure time

The motor controller very precisely controls the motion profile of the actuator (Figure 44). At point a, the command to move the actuator out is sent. At point b, the source leaves the radiation shield and at point c the upward motion is complete. At point c, a timer T^* is started. When the time T^* has elapsed (d) the command to move the actuator back down is sent. At e, the source moves into the shield again, and at point f the motion is complete. The effective exposure time T_{EXP} is longer than the time T^* . In order to correct the exposure time for the time that the source is moving inside the shield, the travel times T_2 and T_3 have to be subtracted from the exposure time to obtain T^* :

$$T^* = T_{EXP} - (T_2 + T_3)$$

The times T_2 and T_3 can be measured using the Festo Configuration Tool. Then, the values can be introduced in the NIR Control Software. T_1 determines the precise start of the exposure. To obtain the proper time for the acoustic stop signal also time T_2 has to be introduced. The next paragraphs explain how to measure the correction parameters and enter them into the NIR Control Software.

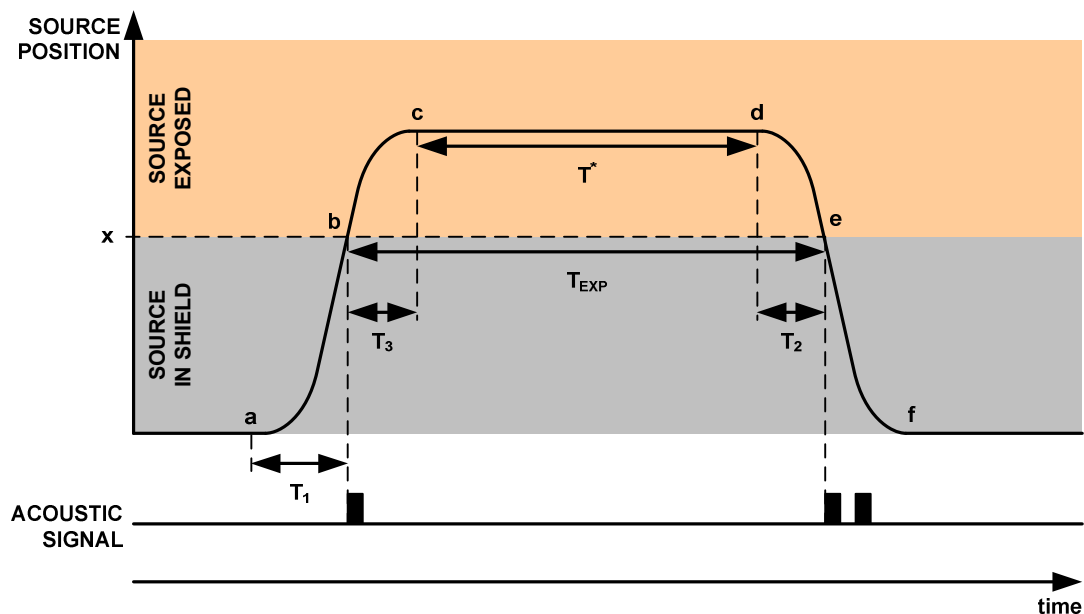


Figure 44: Correction parameters for the exposure time.

7.6.1 Determining reference positions on the source holder and the irradiator

For a precise correction of the exposure time, two reference positions should be defined:

- On the source holder;
- On the irradiator.

It is convenient to mark a position on the source holder as the reference position and then align the source vertically so that it corresponds with the reference position. As an example, we place the reference position 50 mm above the bottom of the gamma source holder, and the top of the lead shield as reference position on the irradiator. The exposure time will start and stop when both reference positions correspond with each other.

7.6.2 Preparing the irradiator



Warning

During some parts of the configuration process, control of the actuator is necessary without the guard switches installed. A special connector named X18 BYPASS should be placed to replace the guard switches. Otherwise, operating the device will not be possible.

Be sure to remove the connector X18 BYPASS and reconnect the connector X18 to the guard switches after the work.

Remove the guiding tube and the cover panel on the right hand side of the irradiator; install the X18 BYPASS connector.

7.6.3 Setting the exposure time

Power-up the irradiator and start the NIR Control Software, connect, click the blue RESET button on the NIR and perform a homing. Set the exposure time to the desired value, e.g. 5000 ms.

7.6.4 Recording the motion profile using the Festo Configuration Tool

Connect a serial cable between the motor controller (U2) and the PC. Start the Festo Configuration Tool (FCT), load the NIR1 project and establish the serial connection with the motor controller. In the Workspace, click Trace Configuration and set the Controller tab precisely as in Figure 45. Take care that the Trace Control Duration is longer than the exposure time.

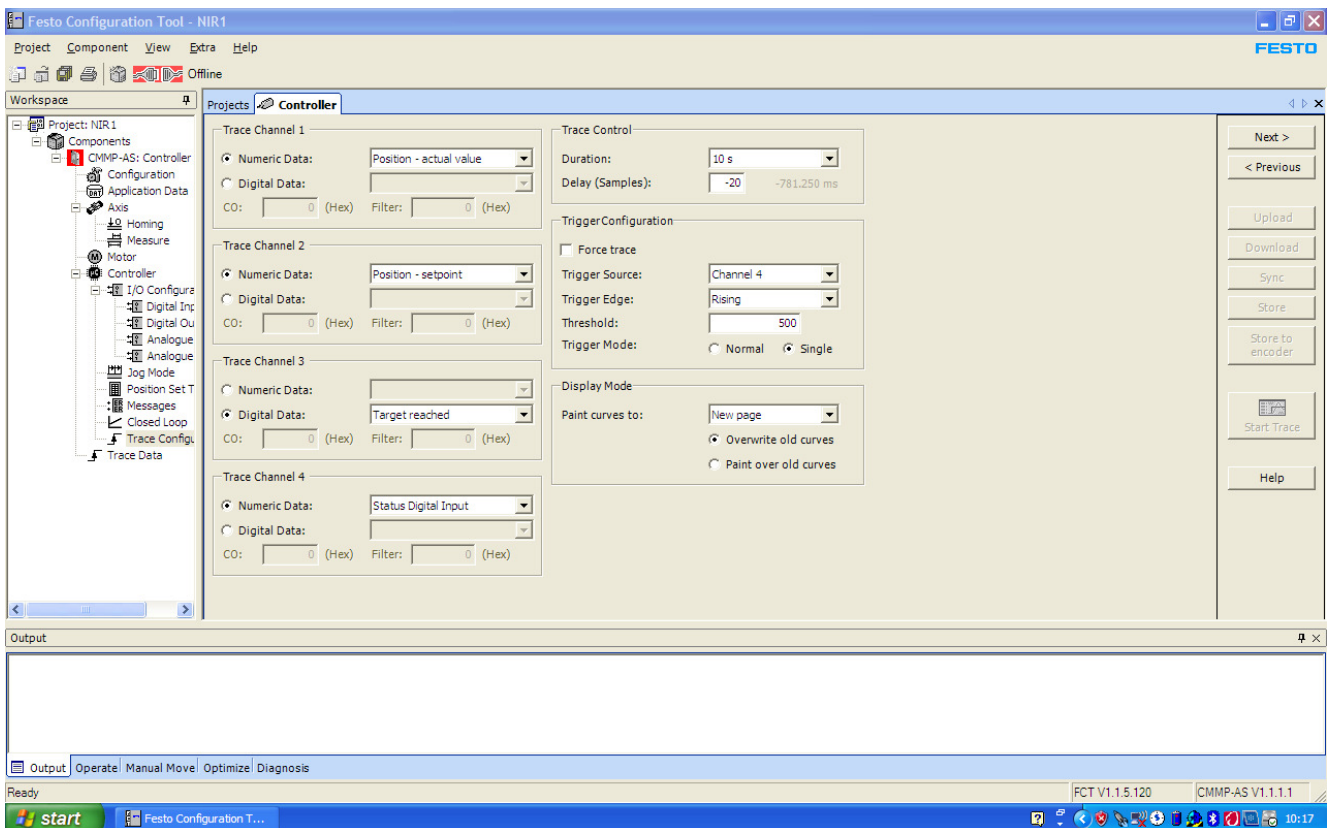


Figure 45: Trace configuration in FCT.

Click the Start Trace button. In the NIR control soft, do one exposure with minimal exposure time. After the exposure, in FCT, click Trace Data in the Workspace. You will see a screen like Figure 46. For info: BIT 9 of the "Status Digital Input" is the start positioning signal that is sent by the PLC to the motor controller. This signal can be used to verify exposure times.

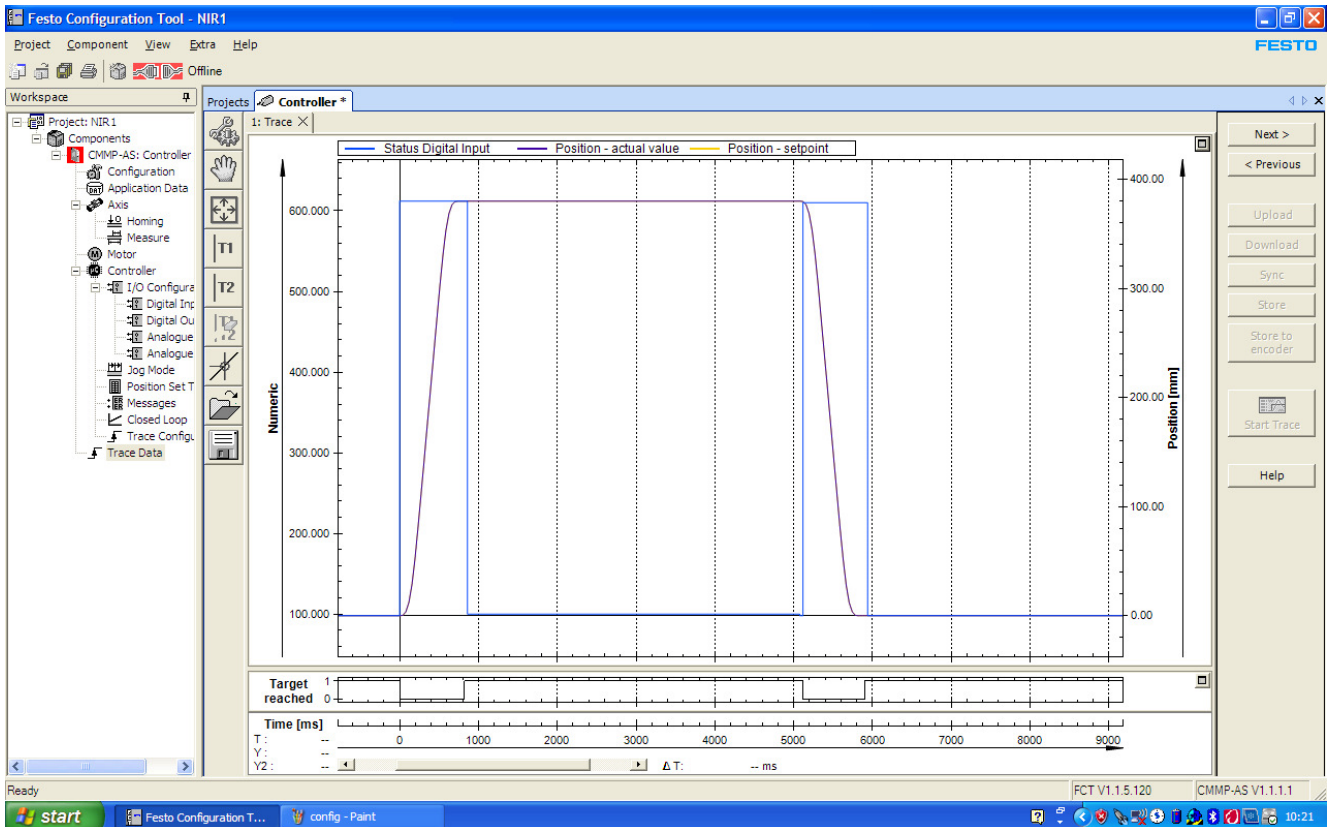


Figure 46: Trace data in FCT with 5000 ms exposure time.

7.6.5 Determining the position at which the source leaves the shield.

In FCT, take control and move the cylinder manually until the reference position of the holder corresponds to the reference position on irradiator. In the example, this is at $x = 221.28$ mm.

7.6.6 Calculating the correction times

Right click on the graph and select Export, copy values to clipboard. Open the Excel sheet "NIR Exposure time correction.xls" (from the NIR Installation and Documentation DVD) and paste the values in cell A9. (Go to cell A9, select Paste Special, Text). Click the Update button and enter the value x in the sheet and read the calculated values $T1$, $T2$ and $T2+T3$.

7.6.7 Entering the correction times in the NIR Control Software

Copy the calculated values $T1$, $T2$ and $T2+T3$ from the Excel sheet to the System settings tab in the NIR Control Software and click the Apply & save button.

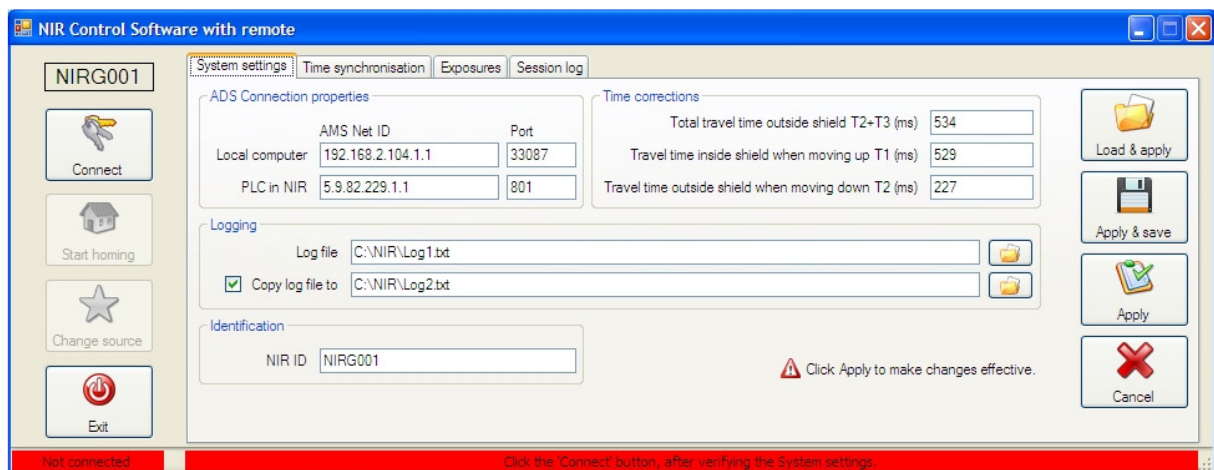


Figure 47: NIR Control software - System settings.

7.6.8 Fine-tuning / verification

The trace option of FCT can be used to verify the exposure time. Repeat recording the trace and adjust T_2+T_3 until the actual exposure time corresponds with the exposure time set, taking into account the 10 ms resolution.

7.6.9 Finishing

Make sure to remove X18 BYPASS and re-install the guiding tube and side cover. Power-down the irradiator completely.

7.7 Configuration file

The configuration file is unique for every irradiator. It contains the NIR ID (serial number), the total exposures counter, the AMS addresses, the correction times for the exposure and the location of the log files. An example is given below. Do not edit the file while the NIR Control Software is running.

```
NIR ID:      NIRG001
TotalExposures: 63
AMSLocalNetID: 192.168.2.103.1.1
AMSLocalPort: 33087
AMSRemoteNetID: 5.9.82.229.1.1
AMSRemotePort: 801
TraveltimeT2T3_ms: 795
TraveltimeT1_ms: 431
TraveltimeT2_ms: 327
Logfile:     C:\NIR\NIRG001Log1.txt
LogfileCopy: C:\NIR\NIRG001Log2.txt
Copy: True
```

7.8 Configuring the motor controller



Warning

During some parts of the configuration process, control of the actuator is necessary without the guard switches installed. A special connector named X18 BYPASS should be placed to replace the guard switches. Otherwise, operating the device will not be possible.

Be sure to remove the connector X18 BYPASS and reconnect the connector X18 to the guard switches after the work.

The motor controller (U2) is a programmable component. When it is replaced, it needs to be properly configured. When the mass of the source holder changed, new parameters for the motor controller have to be generated, downloaded and stored.



Warning

Danger for injury or damage to the device

The correct operation of the device depends on the correct configuration of the programmable components. The (re)programming shall only be done with the settings/programs provided by the manufacturer. If in any doubt, contact the manufacturer for assistance.

7.8.1 Installing the Festo Configuration Tool

The Festo Configuration Tool (FCT) is used to configure the motor controller. When it is not yet installed, install it first from the NIR Installation and Documentation DVD, and copy the FCT project "NIR1" from the installation DVD to the FCT project folder on the PC.

7.8.2 Positioning the limit switch

The correct position of the limit switch is essential for the proper operation of the irradiator. The limit switch determines the "home" position of the cylinder. The home position corresponds to a vertical position of the cylinder of 0 mm. Every time the irradiator is powered-on, homing has to be performed before exposures can be started. The limit switch is a normally open switch. This means that the switch is open when the magnet in the cylinder is not in the close vicinity of the switch. During homing, the cylinder will slowly move down to find the switch. When the switch is found, it will move up until the switch is opened again. This position will be the home or 0 mm position.



Warning

Risk for damage to the actuator.

When the limit switch is not positioned properly, the actuator will bump into the end of its range. Permanent damage of the actuator can occur.

Position the limit switch using the NIR limit switch gauge block, as shown on Figure 48. Take care that the switch is in the same groove of the cylinder housing as on the picture, and that the cable is in the same direction. Insert the gauge block in the groove and fix the switch using a screwdriver. Remove the gauge block. The length of the gauge block is 87.8 mm.

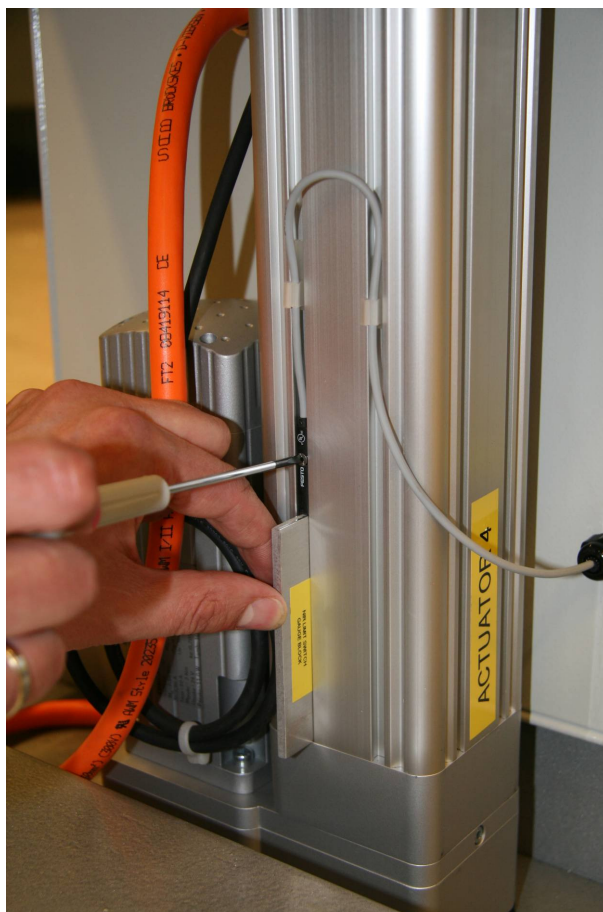


Figure 48: Place where the limit switch shall be installed.

When the limit switch is positioned, following checks have to be performed to ensure proper operation of the irradiator:

- Verify that the cylinder can move freely to the shielded and exposed positions (see 7.8.3).
- Verify that the source holder assembly does not touch the base plate during homing (see 7.8.4).

7.8.3 Verification of the free movement of the cylinder

After positioning the limit switch, verify that the cylinder can perform homing and can reach the exposed position without bumping into the end of the range. During these tests, the Festo Configuration Tool will be used to control the cylinder, and X18 BYPASS is installed. A connection between the irradiator and the NIR Control Software is required to close the safety relay K7.

Power down the irradiator, remove the radiation shield and remove the source holder assembly from the cylinder.

Power-up the irradiator using the main switch S1. Start the NIR Control Software and select the proper configuration file for NIR (see inside the electrical cabinet door). Click the Connect button and press the blue RESET button on NIR. Do NOT start homing using the NIR Control Software! At the bottom of the screen, the NIR Control Software shows that it is connected to the irradiator (Figure 49).

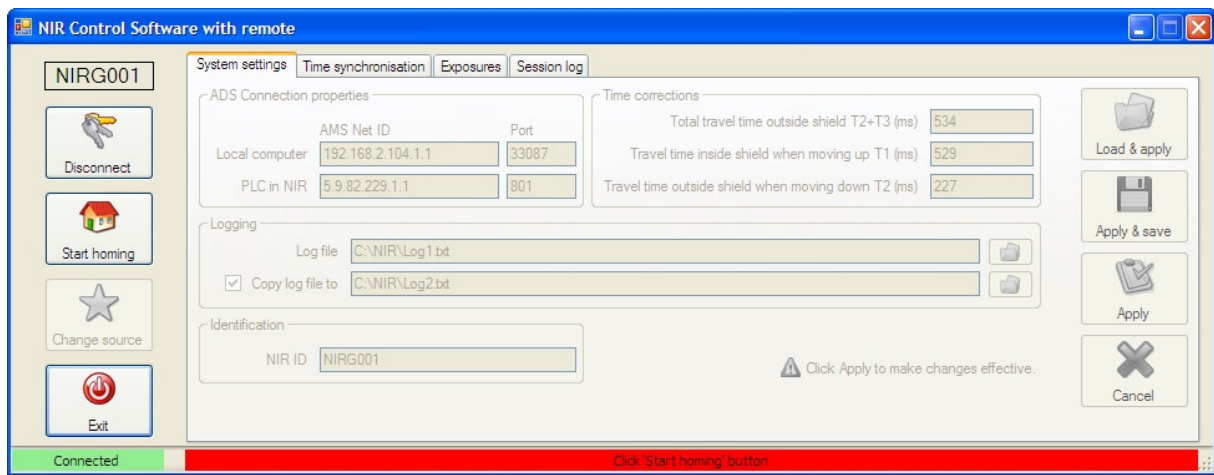


Figure 49: Connecting with NIR.

Start the Festo Configuration Tool and open the project NIR1. Select the tab Manual Move at the bottom, and select Homing in the Workspace. Take control over the motor controller by checking FCT in Device Control. Check the Enable box to power the motor controller output stage (Figure 50).

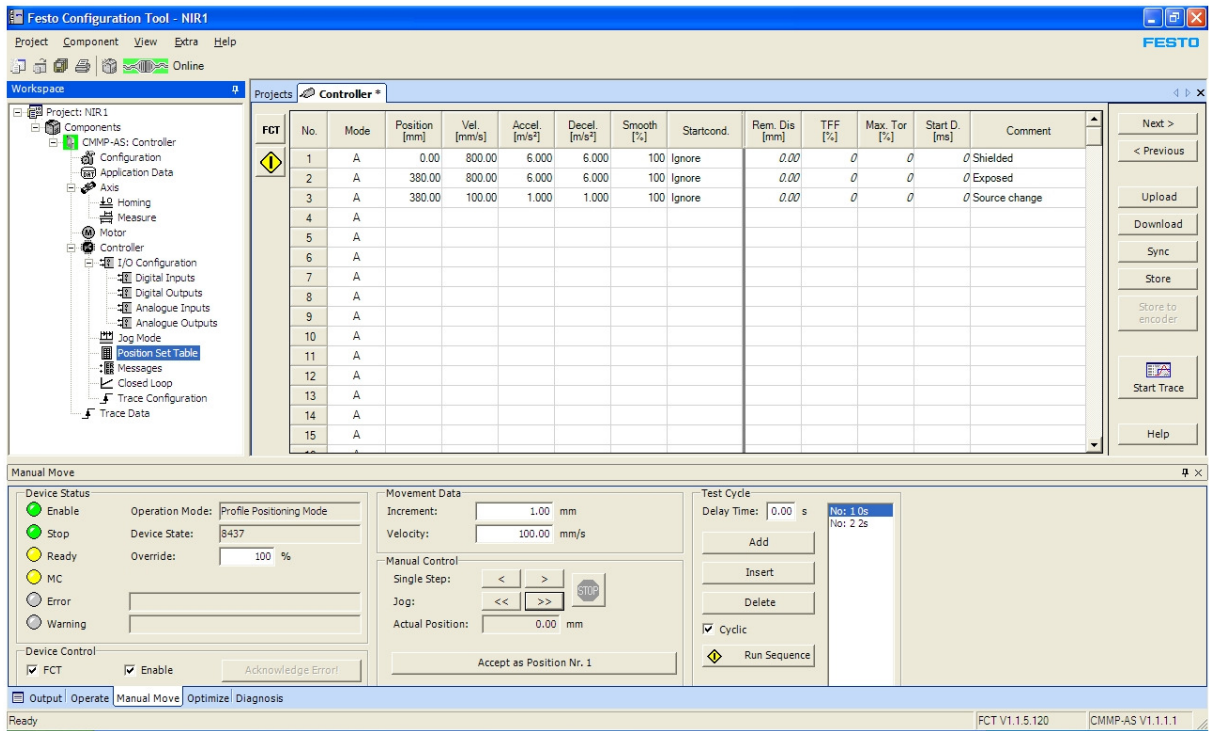


Figure 51: The position set table in the Festo Configuration Tool.

Move the cylinder up manually, using the buttons << and >> or < and >, step by step until the Actual Position shows 380. In Movement Data, Increment, you can set the steps that are applied when you click the < or > button. When the position is close to 380, take small steps of 1 mm to go beyond 380 to find the end of the range. When the cylinder reaches the end of the range, FCT will generate a "Motor i²t" warning, indicating large but short power consumption by the motor (Figure 52).

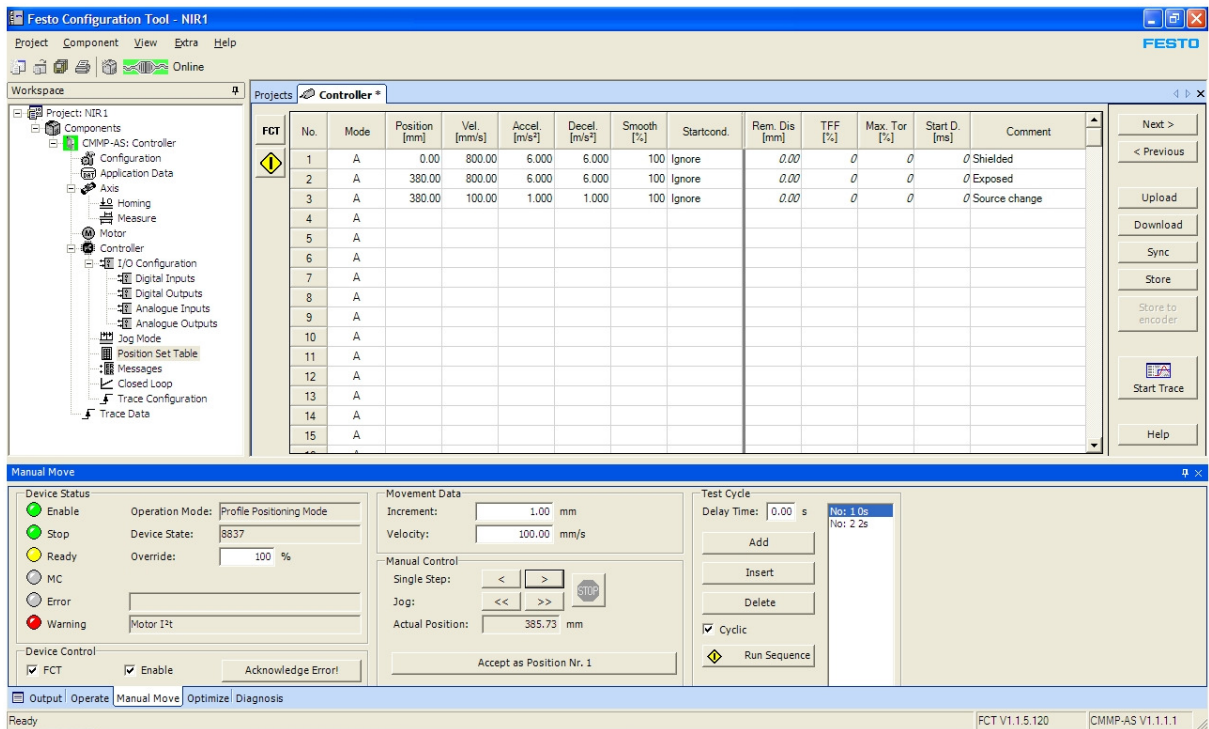


Figure 52: FCT generates a warning at the end of the cylinder's range.

There should be at least 3 mm extra, beyond the exposed position. In other words, the end of range should be at a position greater than 383 mm. In this figure, the end is at 385.73 mm. If there is less

extra space, move the limit switch a bit down to correct. Then, first redo homing and then try to reach position 383. Measure the new position of the limit switch and write down.

When the homing can be done without bumping into the end of range, and when exposed position can be reached with at least 3 mm of extra range, a fast move can be done by selecting a position (n° 1, 2 or 3) in the Position Set Table, and clicking the yellow button on the left of the table. Repeat a few times. At the end, move the cylinder to position n° 1. The source holder assembly can now be mounted on the cylinder (see 7.8.4).

7.8.4 Mounting the source holder assembly on the cylinder

First, verify the free movement of the cylinder, as described in 7.8.3.



Warning

Risk for damage to the source holder assembly.

When the source holder assembly is not positioned properly, the holder will bump onto the irradiator during homing. Permanent damage of the holder can occur.

With the shielding removed from the irradiator and the cylinder in the homing position, mount the source holder assembly onto the cylinder. First, screw the nut (M16x1.5) completely onto the threaded end of the cylinder, then install the Al/Cd/Al shield (only for NIR-neutron) and finally screw on the source holder (Figure 53 and Figure 54).



Figure 53: Source holder in homing position (NIR – neutron).

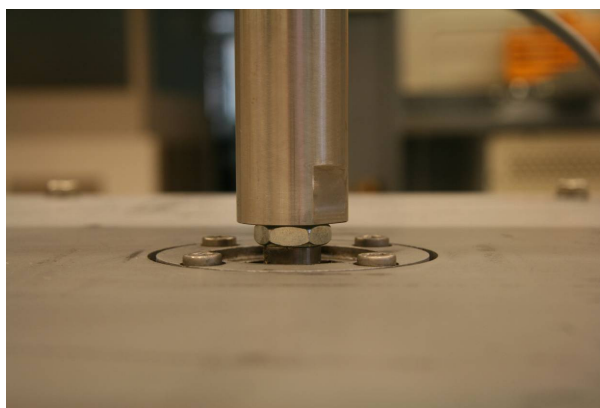


Figure 54: Source holder in homing position (NIR - gamma).

Perform a homing as described above, and check that the holder does not touch the load plate during homing. When homing is possible without touching, disable the controller and uncheck FCT control. Take FCT offline and remove the serial cable. Then, in the NIR Control Software, click Disconnect. Then click Connect again, press the RESET button on NIR and start homing. Try a few exposures. After that, reinstall the shield, remove X18 BYPASS and reconnect X18 and close the covers.

7.8.5 Changing the mass of the source holder

The control loop for the servo motor controller is optimized for the load of the actuator. For the irradiators, the load of the actuator corresponds to the total mass of the source holder. In principle, this includes the mass of the source. When the mass of the source holder changes by more than 0.5 kg, a new set of optimized parameters should to be determined, and those parameters have to be downloaded to and stored in the motor controller. The default mass of the empty source holders for the gamma and neutron irradiator are shown in Table 1.

To change the mass, open the Festo Configuration Tool and open the project NIR1 (Figure 55).

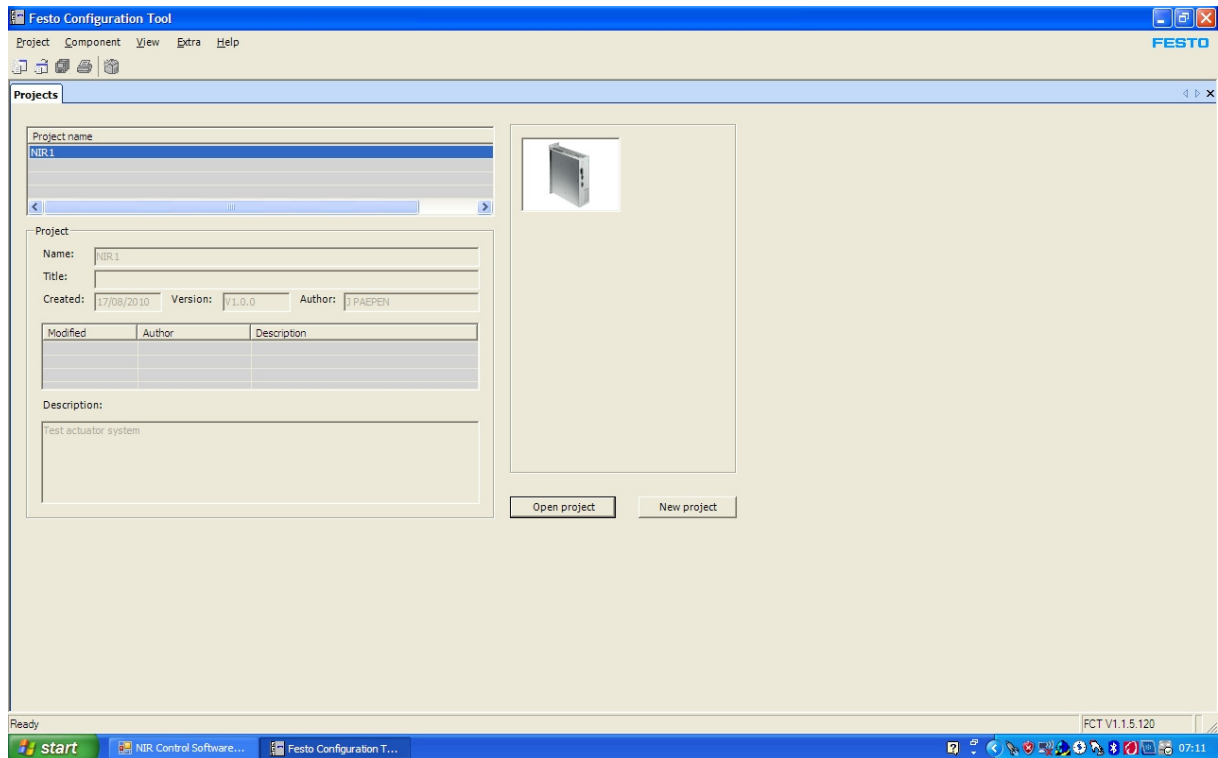


Figure 55: Festo Configuration Tool projects.

In the Workspace on the left of the screen, select Application Data. In the Controller tab on the right, select Environment. Enter the total mass of the source holder in the box Application Data, Total Load (Figure 56).

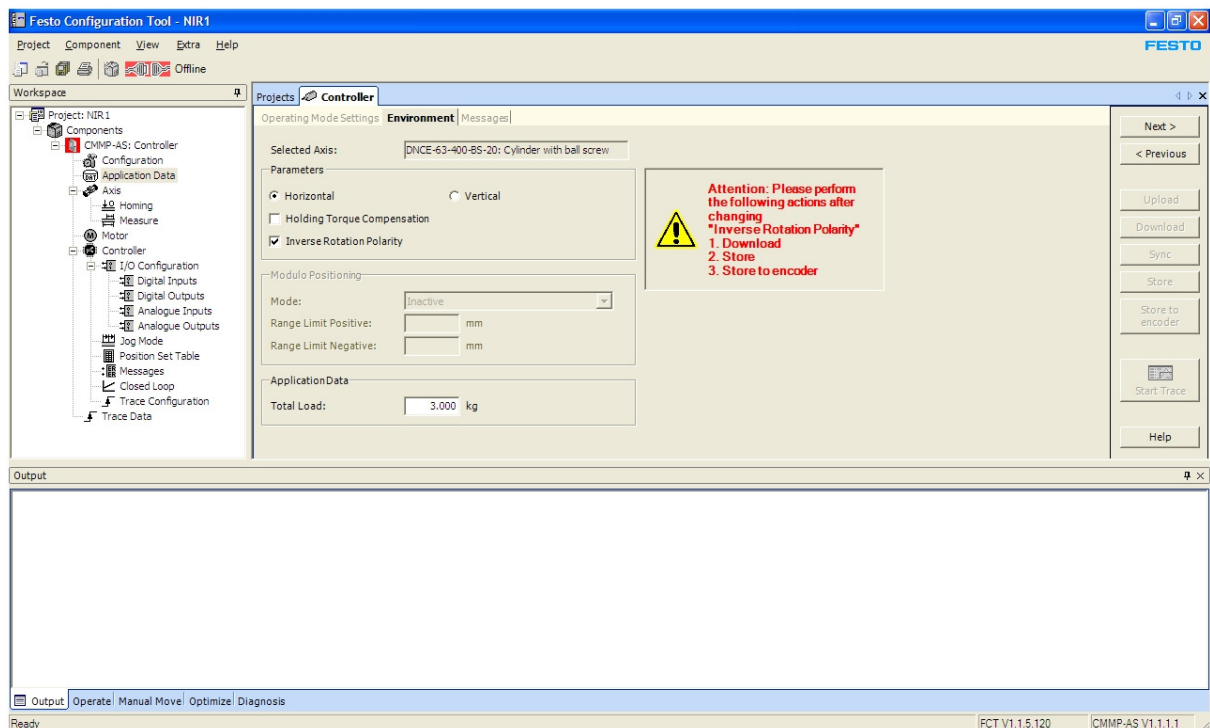


Figure 56: Setting the total load in the Festo Configuration Tool

Then, in the Workspace, select Closed Loop and click the Calculate button on the right (Figure 57). FCT will then recalculate the parameters for the motor controller control loop.

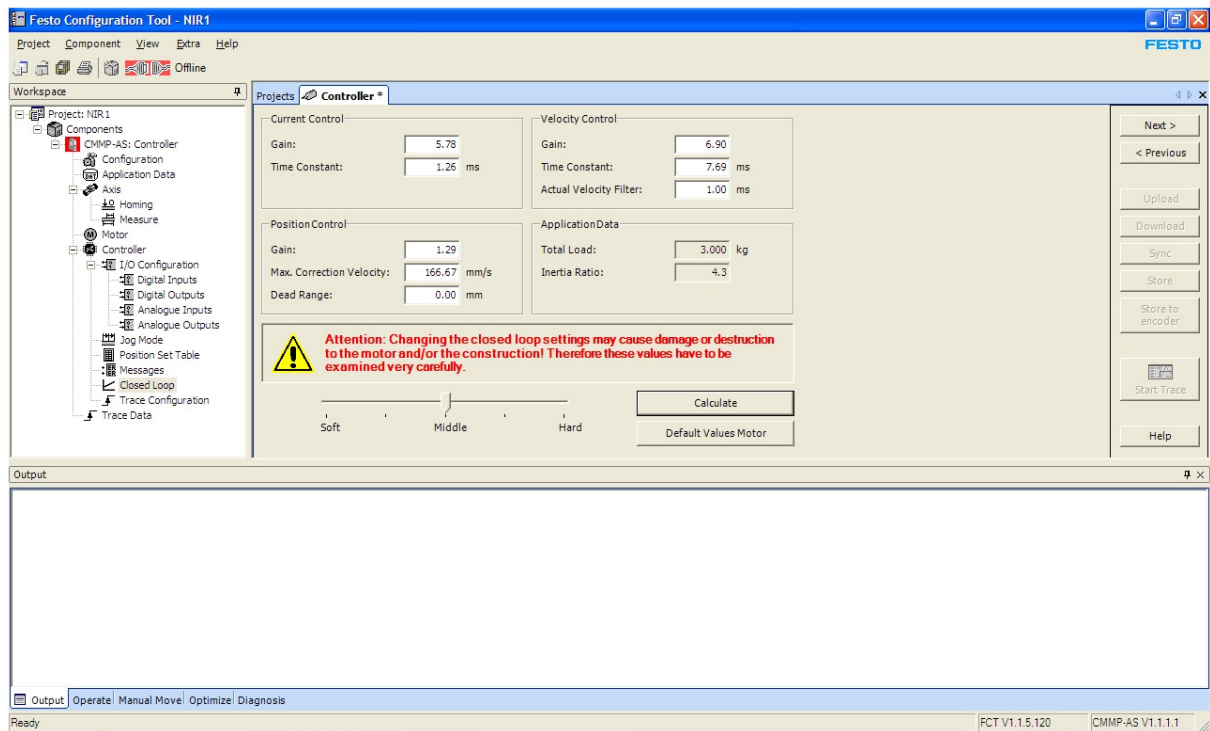


Figure 57: Recalculating the control loop parameters in the Festo Configuration Tool.

Save the new settings. When this has been done, the new parameters need to be downloaded to the motor controller and stored. Refer to heading 7.8.6.

7.8.6 Downloading the configuration to the motor controller

Downloading the configuration of the motor controller is done using the Festo Configuration Tool. First, switch off the device using the main switch (S1). Open the electrical cabinet of the irradiator and make a connection from a serial port on the PC to the motor controller (U2), connector X5, labelled "Serial". Use the cable provided.



Warning

High electrical voltage and high working current.
Danger of death or serious injury due to electrical shock.

Do not touch the electrical connections when the device is switched on.

Switch on the irradiator with the main switch (S1) and wait until the blue RESET indicator starts to blink. Start the Festo Configuration Tool, open the NIR1 project and click on the red "Offline" button at the top of the screen to establish the connection. When online, click the Operate tab at the bottom of the screen and in the box Device Control, check the box FCT. On the right of the screen, click the Download button to transfer the configuration to the motor controller. Then, click the Store button to make the changes permanent (Figure 58).

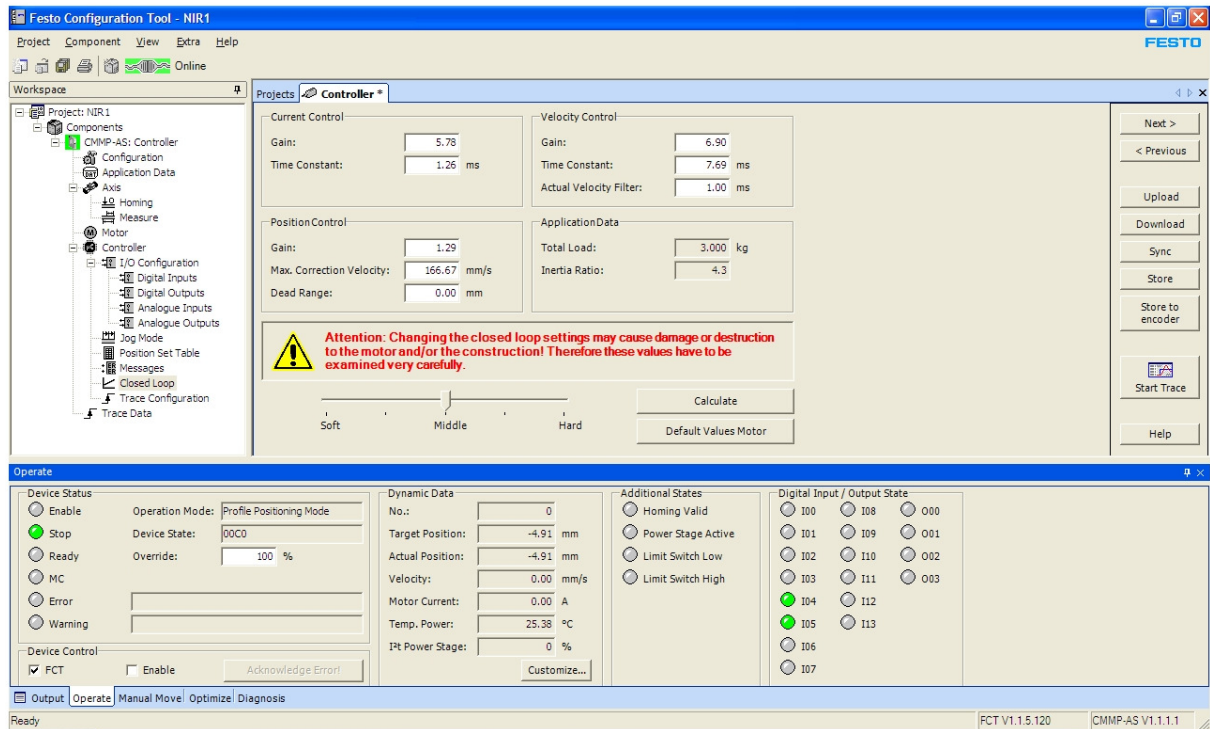


Figure 58: Downloading the configuration to the motor controller using the Festo Configuration Tool.

After downloading and storing, disconnect the serial cable and close the electrical cabinet of the irradiator.

7.9 Configuring the PLC

The device contains two programmable components: the motor controller U2 and the PLC (U3). When delivered, those components are properly configured, but it is necessary to program new components after they have been replaced. The PLC U3 consists of one base module (CX9000) and 4 additional I/O modules (1x EL1004 and 3x EL2004). The I/O modules can be replaced with modules of the same type without the need for reprogramming. The base module CX9000 is programmable and shall be reconfigured after replacement.

Beckhoff TwinCAT PLC shall be installed first. See "7.1 Installing the TwinCAT PLC".

- Configure the PC for a fixed IP address within the same subnet as the PLC.
- Start the TwinCAT System Manager.
- From the menu, select File, Open and browse for NIR1.tsm. Click Open.
- In PLC-Configuration, select NIR1.
- In the right panel, click the Change button and browse for NIR1.tpy. Confirm to rescan the project.
- From the menu, select Actions, Choose Target System. Click the Search(Ethernet) button. Click the Broadcast Search button. The PLC Host name should appear in the list. Select it, and select Host name, Static Target Route and Static Remote Route. Click Add Route. When the software asks the password for the Administrator account, leave it blank. There should be an X now in the Connected column. Click Close.
- The PLC name now appears in the list of target systems. Select it, and click OK.
- From the menu, select Actions, Generate Mappings.
- Then, select Actions, Check Configuration.
- Select Actions, Activate Configuration. Click OK to confirm. Wait. Click OK to restart TwinCAT in Run Mode.
- Start TwinCAT PLC Control, and open the file NIR1.pro.

- From the menu, click Online, Choose Run Time System.
- Find the name of the PLC in the list (not the Local system) and select Run-Time 1 (Port 801). Then click OK.
- From the menu, click Online, Login. Confirm to download the new program.
- Click Online, Create Bootproject.
- Click Online, Reset All. Confirm with Yes.
- Click Online, Run. The blue RESET indicator will start flashing after a while.
- Close TwinCAT PLC Control.
- Close TwinCAT System Manager.

7.10 Changing the power of the acoustic signal

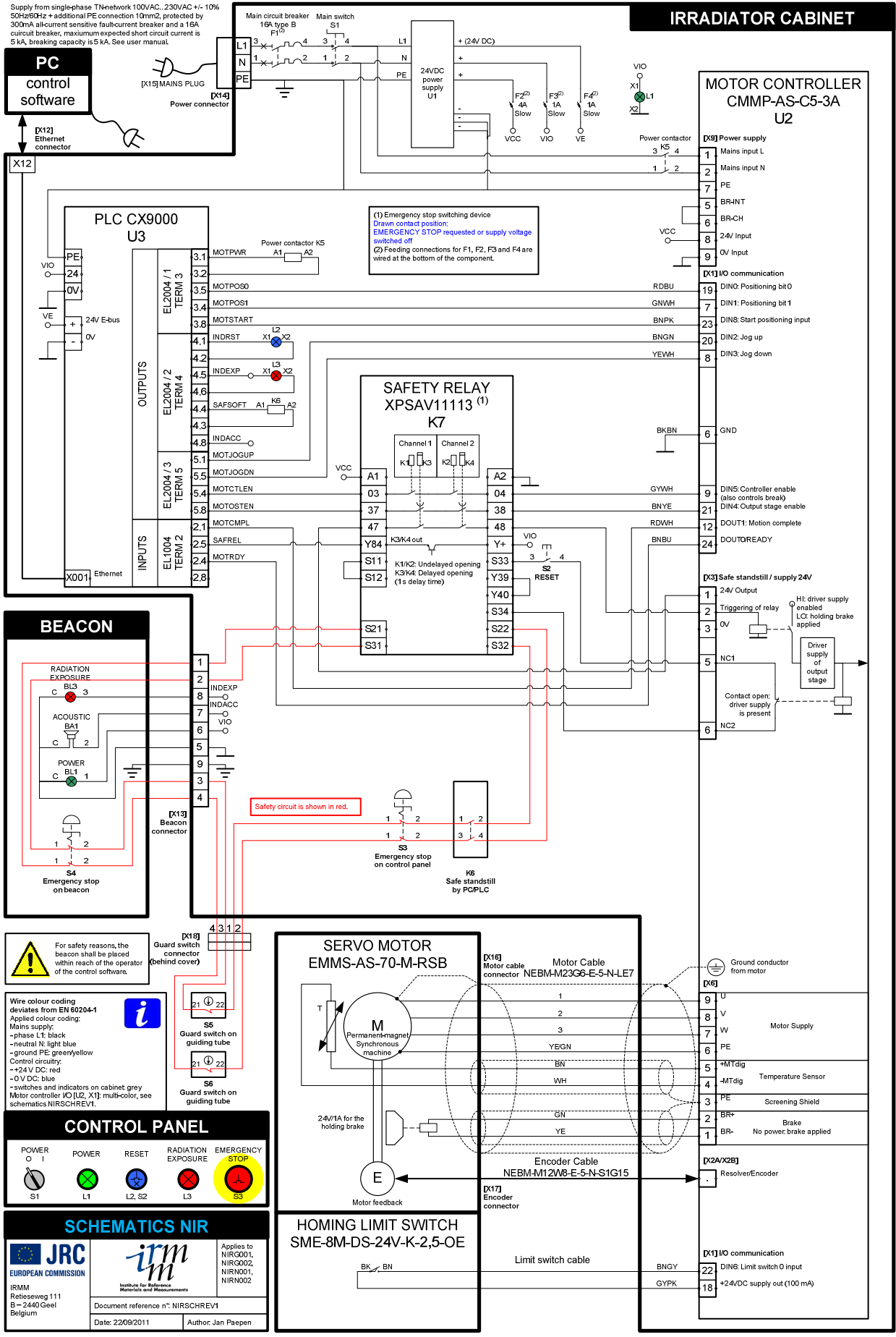
The power of the acoustic signal on the beacon can be changed by means of 2 microswitches inside the buzzer. To access the switches, the buzzer has to be removed from the beacon by turning the black ring at the base in the direction of the arrow. Table 6 represents the switch positions and the corresponding power.

Switch 3	Switch 4	Power
ON	ON	90 dB
OFF	ON	85 dB
ON	OFF	80 dB
OFF	OFF	70 dB

Table 6: Acoustic signal power adjustment.

Switch 1 shall remain ON, and switch 2 shall remain OFF. After changing the switches, reinstall the buzzer and lock the black ring.

8 Schematics NIR controller



9 Maintenance and repairs



Warning

Dangerous voltage

High electrical voltage and high working current
Danger of death or serious injury due to electrical shock

Before performing maintenance on the device, switch off the power using the main switch. Disconnect the mains plug X15 and wait for 5 minutes until all residual charge has disappeared. During maintenance, put mains plug X15 in the sight of the operator.



Warning

Replacement of components

Use only accessories and spare parts which are approved of by the manufacturer. Safety components should only be replaced with identical models from the same manufacturer. If not available, contact the manufacturer of NIR.



Warning

Use of programmable components

The following components have to be configured or programmed before they can be used. When one of these components needs to be replaced, the configuration shall be performed according to the instructions in this manual, or by the manufacturer.

The programmable components are:

- The safety relay K7
- The motor controller U2
- The PLC U3



Warning

Qualification of personnel

Only skilled / authorised personnel shall be allowed to work on the irradiator's electrical system.



Warning

Sufficient light shall be foreseen at the work place during maintenance.

9.1 Maintenance

There are no particular components that need regular maintenance. Normal household cleaning using a damp cloth is sufficient. Switch off power and unplug the mains plug X15 before cleaning.

9.2 Replacing electrical components

For assembling and maintaining the system, the relevant EN and IEC regulations, as well as all national and local safety and accident prevention regulations must always be observed.

Most of the wires of the irradiator are uniquely identified by colour. If in doubt or when identification is missing, make sure to identify all wires that are connected to the component that needs to be replaced, before removing the wires. Refer to the user manual of the component for instructions.

9.3 Replacing the PLC U3 or the motor controller U2

When PLC U3 or motor controller U2 needs to be replaced, they have to be reprogrammed. Refer to headings 7.8 and 7.9 for details.

9.4 Replacing and configuring the safety relay K7

The safety relay K7 needs to be configured after replacement and before they can be used. In case of malfunctioning, diagnosis can be performed using the indicators showing its status. In the XPS-AV Instruction sheet (03/2010), the meaning of the indicators is explained. Since this is a safety component, it shall be replaced with identical models from the same manufacturer. This safety relay has delayed contacts. It is important to set the delay time to 1 s before commissioning a new part. Refer to the XPS-AV Instruction sheet (03/2010) for the procedure. The configuration needs to be done only once.

9.5 List of components

The list of components can be found on the NIR Installation and Documentation DVD. If relevant, user manual and installation instructions are provided.

9.6 Regular inspections and functional tests

To ensure safe long-term operation, a series of inspections and functional tests needs to be performed. See heading 6.10 Regular inspections and functional tests.

10 List of hazardous materials - Material Safety Data Sheets (MSDS)

10.1 Lead

Used in	Shielding NIR – gamma (GNIR)
Quantity	1403 kg
Reason for use	Gamma radiation shield

10.1.1 Section 1: Chemical Product and Company Identification

Product name: lead	Contact information:
CAS#: 7439-92-1	European Commission
RTECS: OF7525000	Joint Research Centre
TSCA: TSCA 8(b) inventory: Lead	Institute for Reference Materials and
CI#: Not applicable.	Measurements
Chemical Name: Lead	Retieseweg 111
Chemical Formula: Pb	B – 2440 Geel
	Belgium

10.1.2 Section 2: Composition and Information on Ingredients

Material	% by Wt	CAS #	OSHA EXPOSURE LIMIT
Lead (Pb)	91 – 99.99	7439-92-1	0.05 mg/cubic meter
Antimony (Sb)	0.5 – 9.0	7440-36-0	0.50 mg/cubic mete

Toxicological Data on Ingredients: Lead LD50: Not available. LC50: Not available.

10.1.3 Section 3: Hazards Identification

Potential Acute Health Effects: Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.

Potential Chronic Health Effects: Slightly hazardous in case of skin contact (permeator).

CARCINOGENIC EFFECTS: Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC. **MUTAGENIC EFFECTS:** Not available. **TERATOGENIC EFFECTS:** Not available. **DEVELOPMENTAL TOXICITY:** Not available. The substance may be toxic to blood, kidneys, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organs damage.

10.1.4 Section 4: First Aid Measures

Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.

Skin Contact: Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops.

Serious Skin Contact: Not available.

Inhalation:

If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Not available.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

10.1.5 Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances: Non-flammable in presence of open flames and sparks, of shocks, of heat.

Explosion Hazards in Presence of Various Substances: Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions: SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards: When heated to decomposition it emits highly toxic fumes of lead.

Special Remarks on Explosion Hazards: Not available.

10.1.6 Section 6: Accidental Release Measures

Small Spill: Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill: Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

10.1.7 Section 7: Handling and Storage

Precautions: Keep locked up. Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not ingest. Do not breathe dust. Wear suitable protective clothing. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents.

Storage: Keep container tightly closed. Keep container in a cool, well-ventilated area.

10.1.8 Section 8: Exposure Controls/Personal Protection

Engineering Controls: Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill: Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits: TWA: 0.05 (mg/m³) from ACGIH (TLV) [United States] TWA: 0.05 (mg/m³) from OSHA (PEL) [United States] TWA: 0.03 (mg/m³) from NIOSH [United States] TWA: 0.05 (mg/m³) [Canada] Consult local authorities for acceptable exposure limits.

10.1.9 Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Metal solid.)

Odor: Not available.

Taste: Not available.

Molecular Weight: 207.21 g/mole

Colour: Bluish-white. Silvery. Gray
pH (1% soln/water): Not applicable.
Boiling Point: 1740°C (3164°F)
Melting Point: 327.43°C (621.4°F)
Critical Temperature: Not available.
Specific Gravity: 11.3 (Water = 1)
Vapour Pressure: Not applicable.
Vapour Density: Not available.
Volatility: Not available.
Oder Threshold: Not available.
Water/Oil Dist. Coeff.: Not available.
Ionicity (in Water): Not available.
Dispersion Properties: Not available.
Solubility: Insoluble in cold water.

10.1.10 Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Incompatible materials, excess heat

Incompatibility with various substances: Reactive with oxidizing agents.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Can react vigorously with oxidizing materials. Incompatible with sodium carbide, chlorine trifluoride, trioxane + hydrogen peroxide, ammonium nitrate, sodium azide, disodium acetylide, sodium acetylide, hot concentrated nitric acid, hot concentrated hydrochloric acid, hot concentrated sulfuric acid, zirconium.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

10.1.11 Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Inhalation. Ingestion.

Toxicity to Animals: LD50: Not available. LC50: Not available.

Chronic Effects on Humans: CARCINOGENIC EFFECTS: Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC. May cause damage to the following organs: blood, kidneys, central nervous system (CNS).

Other Toxic Effects on Humans: Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Acute Potential: Skin: Lead metal granules or dust: May cause skin irritation by mechanical action. Lead metal foil, shot or sheets: Not likely to cause skin irritation Eyes: Lead metal granules or dust: Can irritate eyes by mechanical action. Lead metal foil, shot or sheets: No hazard. Will not cause eye irritation. Inhalation: In an industrial setting, exposure to lead mainly occurs from inhalation of dust or fumes. Lead dust or fumes: Can irritate the upper respiratory tract (nose, throat) as well as the bronchi and lungs by mechanical action. Lead dust can be absorbed through the respiratory system. However, inhaled lead does not accumulate in the lungs. All of an inhaled dose is eventually absorbed or transferred to the gastrointestinal tract. Inhalation effects of exposure to fumes or dust of inorganic lead may not develop quickly. Symptoms may include metallic taste, chest pain, decreased physical fitness, fatigue, sleep disturbance, headache, irritability, reduces memory, mood and personality changes, aching bones and muscles, constipation, abdominal pains, decreasing appetite. Inhalation of large amounts may lead to ataxia, delirium, convulsions/seizures, coma, and death. Lead metal foil, shot, or sheets: Not an inhalation hazard unless metal is heated. If metal is heated, fumes will be released. Inhalation of these fumes may cause "fume metal fever", which is characterized by flu-like symptoms. Symptoms may include metallic taste,

fever, nausea, vomiting, chills, cough, weakness, chest pain, generalized muscle pain/aches, and increased white blood cell count. Ingestion: Lead metal granules or dust: The symptoms of lead poisoning include abdominal pain or cramps (lead colic), spasms, nausea, vomiting, headache, muscle weakness, hallucinations, distorted perceptions, "lead line" on the gums, metallic taste, loss of appetite, insomnia, dizziness and other symptoms similar to that of inhalation. Acute poisoning may result in high lead levels in the blood and urine, shock, coma and death in extreme cases. Lead metal foil, shot or sheets: Not an ingestion hazard for usual industrial handling.

10.1.12 Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are less toxic than the product itself.

Special Remarks on the Products of Biodegradation: Not available.

10.1.13 Section 13: Disposal Considerations

Waste Disposal: Waste must be disposed of in accordance with federal, state and local environmental control regulations.

10.1.14 Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

10.1.15 Section 15: Other Regulatory Information

Federal and State Regulations: California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Lead California prop. 65: This product contains the following ingredients for which the State of California has found to cause reproductive harm (female) which would require a warning under the statute: Lead California prop. 65: This product contains the following ingredients for which the State of California has found to cause reproductive harm (male) which would require a warning under the statute: Lead California prop. 65 (no significant risk level): Lead: 0.0005 mg/day (value) California prop. 65: This product contains the following ingredients for which the State of California has found to cause birth defects which would require a warning under the statute: Lead California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: Lead Connecticut hazardous material survey.: Lead Illinois toxic substances disclosure to employee act: Lead Illinois chemical safety act: Lead New York release reporting list: Lead Rhode Island RTK hazardous substances: Lead Pennsylvania RTK: Lead

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

DSCL (EEC):

R20/22- Harmful by inhalation and if swallowed. R33- Danger of cumulative effects. R61- May cause harm to the unborn child. R62- Possible risk of impaired fertility. S36/37- Wear suitable protective clothing and gloves. S44- If you feel unwell, seek medical advice (show the label when possible). S53- Avoid exposure - obtain special instructions before use.

HMIS (U.S.A.):**Health Hazard:** 1**Fire Hazard:** 0**Reactivity:** 0**Personal Protection:** E**National Fire Protection Association (U.S.A.):****Health:** 1**Flammability:** 0**Reactivity:** 0**Specific hazard:****Protective Equipment:**

Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Safety glasses.

10.1.16 Section 16: Other Information**References:** Not available.**Other Special Considerations:** Not available.**Created:** 10/10/2005**Last Updated:** 11/01/2010

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10.2 Cadmium

Used in	Shielding NIR – neutron (NNIR)
Quantity	13.2 kg
Reason for use	Absorption of thermalised neutrons

10.2.1 Section 1: Chemical Product and Company Identification

Product name: cadmium	Contact information:
CAS#: 7440-43-9	European Commission
RTECS: EU9800000	Joint Research Centre
TSCA: TSCA 8(b) inventory: Cadmium	Institute for Reference Materials and
CI#: Not applicable.	Measurements
Chemical Name: Cadmium	Retieseweg 111
Chemical Formula: Cd	B – 2440 Geel
	Belgium

10.2.2 Section 2: Composition and Information on Ingredients

Name	CAS#	% by Weight
Cadmium	7440-43-9	100

Toxicological Data on Ingredients: Cadmium: ORAL (LD50): Acute: 2330 mg/kg [Rat]. 890 mg/kg [Mouse]. DUST (LC50): Acute: 50 ppm 4 hour(s) [Rat].

10.2.3 Section 3: Hazards Identification**Potential Acute Health Effects:**

Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer), of eye contact (irritant). Severe over-exposure can result in death.

Potential Chronic Health Effects:

CARCINOGENIC EFFECTS: Classified A2 (Suspected for human.) by ACGIH, 2 (Reasonably anticipated.) by NTP. **MUTAGENIC EFFECTS:** Not available. **TERATOGENIC EFFECTS:** Not available. **DEVELOPMENTAL TOXICITY:** Not available. The substance is toxic to kidneys, lungs, liver. Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure to a highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

10.2.4 Section 4: First Aid Measures

Eye Contact: No known effect on eye contact, rinse with water for a few minutes.

Skin Contact: After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cover the irritated skin with an emollient. If irritation persists, seek medical attention. Wash contaminated clothing before reusing.

Serious Skin Contact: Not available.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation: Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. **WARNING:** It may be hazardous to the person providing aid to give mouth-to-mouth resuscitation when the inhaled material is toxic, infectious or corrosive. Seek immediate medical attention.

Ingestion: Do not induce vomiting. Examine the lips and mouth to ascertain whether the tissues are damaged, a possible indication that the toxic material was ingested; the absence of such signs, however, is not conclusive. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

10.2.5 Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: 570°C (1058°F)

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances: Non-flammable in presence of open flames and sparks, of heat, of oxidizing materials, of reducing materials, of combustible materials, of moisture.

Explosion Hazards in Presence of Various Substances: Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions: **SMALL FIRE:** Use DRY chemical powder. **LARGE FIRE:** Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards: Material in powder form, capable of creating a dust explosion. When heated to decomposition it emits toxic fumes.

Special Remarks on Explosion Hazards: Not available.

10.2.6 Section 6: Accidental Release Measures

Small Spill: Use appropriate tools to put the spilled solid in a convenient waste disposal container.

Large Spill: Use a shovel to put the material into a convenient waste disposal container. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

10.2.7 Section 7: Handling and Storage

Precautions: Keep locked up Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing

material. Do not ingest. Do not breathe dust. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents.

Storage: Keep container dry. Keep in a cool place. Ground all equipment containing material. Keep container tightly closed. Keep in a cool, well-ventilated place. Highly toxic or infectious materials should be stored in a separate locked safety storage cabinet or room.

10.2.8 Section 8: Exposure Controls/Personal Protection

Engineering Controls: Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill: Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits: TWA: 0.01 (ppm) Consult local authorities for acceptable exposure limits.

10.2.9 Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Lustrous solid.)

Order: Not available.

Taste: Not available.

Molecular Weight: 112.4 g/mole

Colour: Silvery.

pH (1% soln/water): Not applicable.

Boiling Point: 765°C (1409°F)

Melting Point: 320.9°C (609.6°F)

Critical Temperature: Not available.

Specific Gravity: 8.64 (Water = 1)

Vapour Pressure: Not applicable.

Vapour Density: Not available.

Volatility: Not available.

Order Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility: Insoluble in cold water, hot water, methanol, diethyl ether, n-octanol.

10.2.10 Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Reactive with oxidizing agents.

Corrosivity: Not considered to be corrosive for metals and glass.

Special Remarks on Reactivity: Reacts violently with potassium.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

10.2.11 Section 11: Toxicological Information

Routes of Entry: Inhalation. Ingestion.

Toxicity to Animals: WARNING: THE LC50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 890 mg/kg [Mouse]. Acute toxicity of the dust (LC50): 229.9 mg/m³ 4 hour(s) [Rat].

Chronic Effects on Humans: CARCINOGENIC EFFECTS: Classified A2 (Suspected for human.) by ACGIH, 2 (Reasonably anticipated.) by NTP. The substance is toxic to kidneys, lungs, liver.

Other Toxic Effects on Humans: Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: An allergen. 0047 Animal: embryotoxic, passes through the placental barrier.

Special Remarks on other Toxic Effects on Humans: May cause allergic reactions, exzema and/or dehydration of the skin.

10.2.12 Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are as toxic as the original product.

Special Remarks on the Products of Biodegradation: Not available.

10.2.13 Section 13: Disposal Considerations

Waste Disposal:

10.2.14 Section 14: Transport Information

DOT Classification:

Identification:

Special Provisions for Transport:

10.2.15 Section 15: Other Regulatory Information

Federal and State Regulations: California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Cadmium California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: Cadmium Pennsylvania RTK: Cadmium Massachusetts RTK: Cadmium TSCA 8(b) inventory: Cadmium SARA 313 toxic chemical notification and release reporting: Cadmium CERCLA: Hazardous substances.: Cadmium

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada): CLASS D-1A: Material causing immediate and serious toxic effects (VERY TOXIC). CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

DSCL (EEC): R26- Very toxic by inhalation. R45- May cause cancer.

HMIS (U.S.A.):

Health Hazard: 3

Fire Hazard: 1

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 3

Flammability: 1

Reactivity: 0

Specific hazard:**Protective Equipment:**

Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Safety glasses.

10.2.16 Section 16: Other Information**References:**

- Hawley, G.G.. The Condensed Chemical Dictionary, 11e ed., New York N.Y., Van Nostrand Reinold, 1987.
- Liste des produits purs tératogènes, mutagènes, cancérogènes. Répertoire toxicologique de la Commission de la Santé et de la Sécurité du Travail du Québec.
- Material safety data sheet emitted by: la Commission de la Santé et de la Sécurité du Travail du Québec.
- SAX, N.I. Dangerous Properties of Industrial Materials. Toronto, Van Nostrand Reinold, 6e ed. 1984.
- The Sigma-Aldrich Library of Chemical Safety Data, Edition II.
- Guide de la loi et du règlement sur le transport des marchandises dangereuses au Canada. Centre de conformité international Ltée. 1986.

Other Special Considerations: Not available.

Created: 10/09/2005

Last Updated: 11/01/2010

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Abstract

Radiation detectors are used in nuclear security in an attempt to intercept illicit trafficking of radioactive or nuclear materials. In this field, several types of detectors are used to detect the presence of a source, to measure the exposure rate to men, to locate and to identify it. To test the performance of such detectors, many exposures with a radioactive source are required (typically 60), and the exposures need to be repeated with sources with different gamma-energies, and with neutron-emitting sources. For some tests, combinations of sources are used. IRMM and ITU jointly designed and built an instrument, named "NIR" that can expose a radioactive source for a defined amount of time. The instrument consists of a source holder, mounted on an electrically controlled cylinder. The cylinder pushes the source holder out of a radiation shield, and retracts the holder after the exposure time has elapsed. Unique about this instrument is the fact that it does not contain a fixed source. Instead, the user can choose any source available and mount it in the source holder. The motion of the source holder is very precisely controlled using a servo motor. It will always come to the same position, following the same motion profile. The instrument can be controlled from a distance using software running on a computer, thereby reducing exposure to operators, as compared to manually executed exposures. The instrument allows to test of several radiation detectors at the same time. The high speed of operation and precision results in a reduced total test time and an increased confidence in the test result. This document is the user manual of the instrument NIR, it contains the original instructions for transport, installation and operation.

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