Subject: Normal Operating, Alignment, and Interlock Test Procedures: NSLS X-ray Generator for Crystal Orientation, Building 535C (Basement)

Prepared By:	Reviewed By:	Approved By:
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Nicholas F. Gmür	Steve Musolino	

*Document must contain approved signatures for validity

NSLS Sample Procedure for Radiation-Generating Devices (RGDs)

Coordination of Crystal Orientation Facility

The Steward of the Crystal Orientation Facility shall coordinate the day-to-day affairs of the Crystal Orientation Facility. These will include design modifications (under the direction of Technical and Scientific Supervision), component replacements, maintenance, interlock tests, radiation surveys, training of new operators, as well as maintaining complete and accurate documentation.

Equipment

Type of Equipment: Transformer for X-ray generator*
Manufacturer: Diffractis 601 ENRAF NONIUS
Model Number: 601004-5-14
kV Range: 15 - 60 kV
mA Range: 4 - 30 mA
Electrical Requirements: 220 V, 50 or 60 Hz single phase
Power consumption: 1800 Watts at full load
PCB Concentration: <2 ppm (~15 gallons of oil; sampled 04/2000)
Location: Bldg. 535C - Room C6A
NSLS Contact: Rick Greene (x3751, Bldg. 725D)
*In use

Type of Equipment: Transformer for X-ray generator*
Manufacturer: Diffractis 601 ENRAF NONIUS
Model Number: 601922-3-2
kV Range: 15 - 60 kV
mA Range: 4 - 30 mA
Electrical Requirements: 220 V, 50 or 60 Hz single phase
Power consumption: 1800 Watts at full load
PCB Concentration: <2 ppm (~15 gallons of oil; sampled 04/2000)
Location: Bldg. 535C
NSLS Contact: Rick Greene (x3751, Bldg. 725D)
*Spare; not currently in use

Type of Equipment: Rigaku enclosure and interlock system

Documentation

a) X-Ray Diffraction Safety Generator, Diffractis 601, Operating Instructions, Enraf Nonius Inc.
- Electronic schematics
- Interface schematics for Rigaku interlock system with Diffractis 601

b) Rigaku Corporation Radiation Shield Instruction Manual, Cat. No. 4621, Manual No. ME410BW4

c) Normal Operating, Alignment, and Interlock Test Procedures: NSLS X-ray Generator for Crystal Orientation, Building 535C (Basement); LS-ES-0001. This procedure will be maintained under the NSLS document control system.

Operational Safety Requirements

1. Operator must be current in NSLS Facility Specific Training as well as General Employee Radiation Training (or NSLS equivalent).

2. Operator must be fully trained in the use of this Radiation Generating Device - RGD (signature/date on Training page of logbook; counter-signed by Steward of the crystal orientation facility).

3. Operator must be wearing a personal radiation badge (TLD).

4. Normal operations involve the presence of at least one operator. Unattended operations are also possible providing:
a) Radiation enclosure is fully closed and interlocked,
b) Door to room is locked, and
c) Unattended Operations for Beamline ("pink") card is properly filled out and displayed on outside of room door (maximum validity = 24 hrs.).

5. There is no need for a formal, check-station search procedure as the X-ray enclosure is table-top sized and fully viewable by the operator.

Off-Normal/Emergency Operation

1. The interlock system protects the operator against inadvertent access to potentially harmful X-rays by closing the X-ray beam shutter and turning off the X-ray generator power supply.

2. If any enclosure panel is opened during normal operation without using the proper interlock by-pass procedure, power to the generator is lost and the X-ray beam shutter locks closed until reset.

3. If any shutter position indicator lamp fails, power to the generator is lost and the X-ray beam shutter locks closed until reset.

4. If the "X-rays On" lamp in the enclosure fails, power to the generator is lost and the X-ray beam shutter locks closed until reset.

5. Should the RGD fail to turn off during any of the above conditions or when the operator attempts the shutdown procedure, then the "Mains" button on power generator itself should be turned off and a diagnosis should take place to determine and correct the source of the problem.

6. If radiation levels >500 cpm are measured inside or outside the radiation enclosure, the electric shutter must be closed and additional shielding must be devised in collaboration with a Radiological Control Technician who may conduct a radiation survey.

7. If any part of an operator's body is directly exposed to the X-ray beam itself, the operator must close the beam shutter and immediately inform Radiological Control Division personnel assigned to the NSLS.

8. If a smoke condition or fire occurs in the power supply or the radiation enclosure:
   - Call x2222 to notify BNL Fire/Rescue;
   - Also, call x2550 to notify the NSLS Control Room personnel to manage the emergency.
   - Unplug generator from electrical socket on adjacent wall;
   - Use a fire extinguisher if you feel competent and it is safe to do so;
   - Evacuate if conditions warrant;

Note:
- Two sprinkler heads cover the crystal alignment room;
- Smoke detectors in adjacent basement area;
- A "B,C" fire extinguisher is located in the room adjacent to the crystal alignment room;
- An "A,B,C" fire extinguisher is located in the hallway leading to the building exit stairs;
- The building exit is located to the left of the doors coming out of the alignment room;
- A fire alarm pull box is located next to the building exit door.

X-ray Generator Normal Operating Procedures:

Start Up:

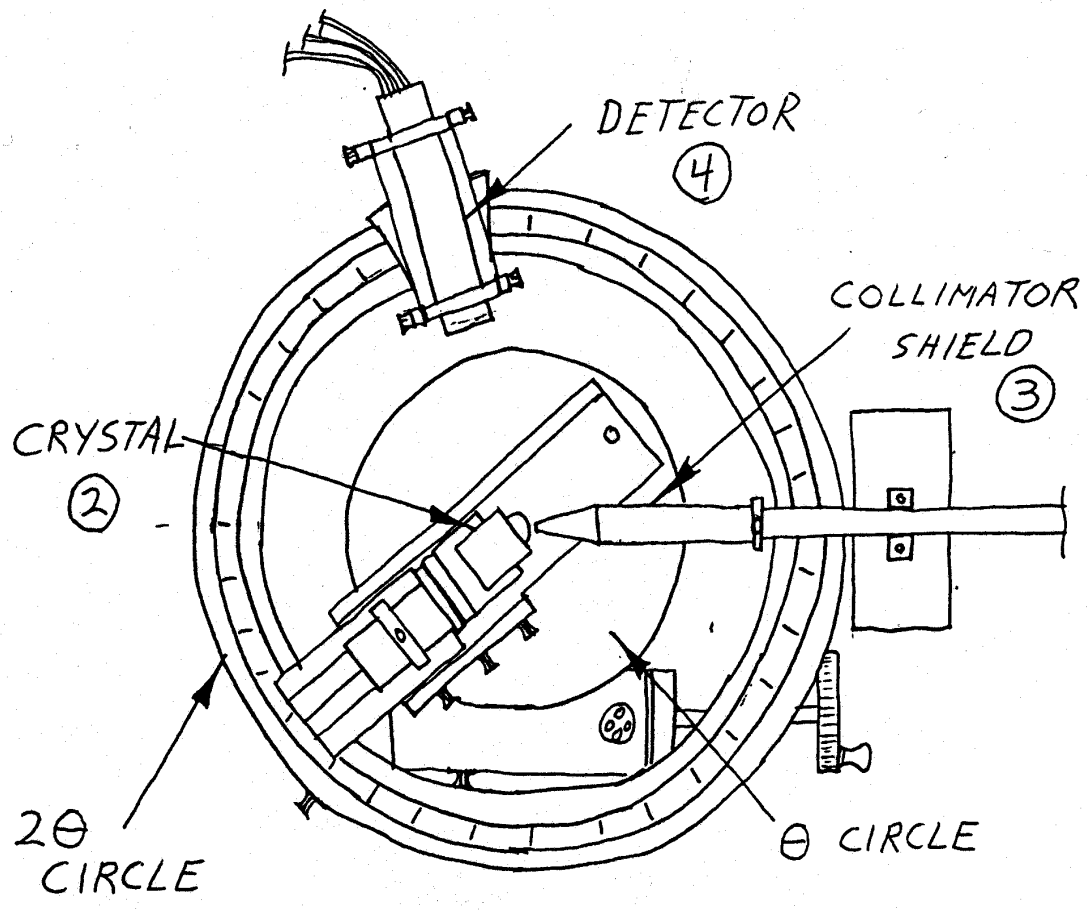
1. Enter date, name, work to be performed in Log Book.
   NOTE: **Sign out and wear a ring dosimeter ONLY IF hands-on manipulation of equipment takes place inside the enclosure with the interlock bypassed, e.g. X-ray beam ON.**

2. With all power off, set up item to be aligned on the "θ Circle".

3. Slide "Collimator Shield" to within 10 mm or less of the crystal surface and tighten the shield clamp screw in order to prevent hand-access.

4. Position "Detector" on "2θ Circle".

Figure 1 (below)



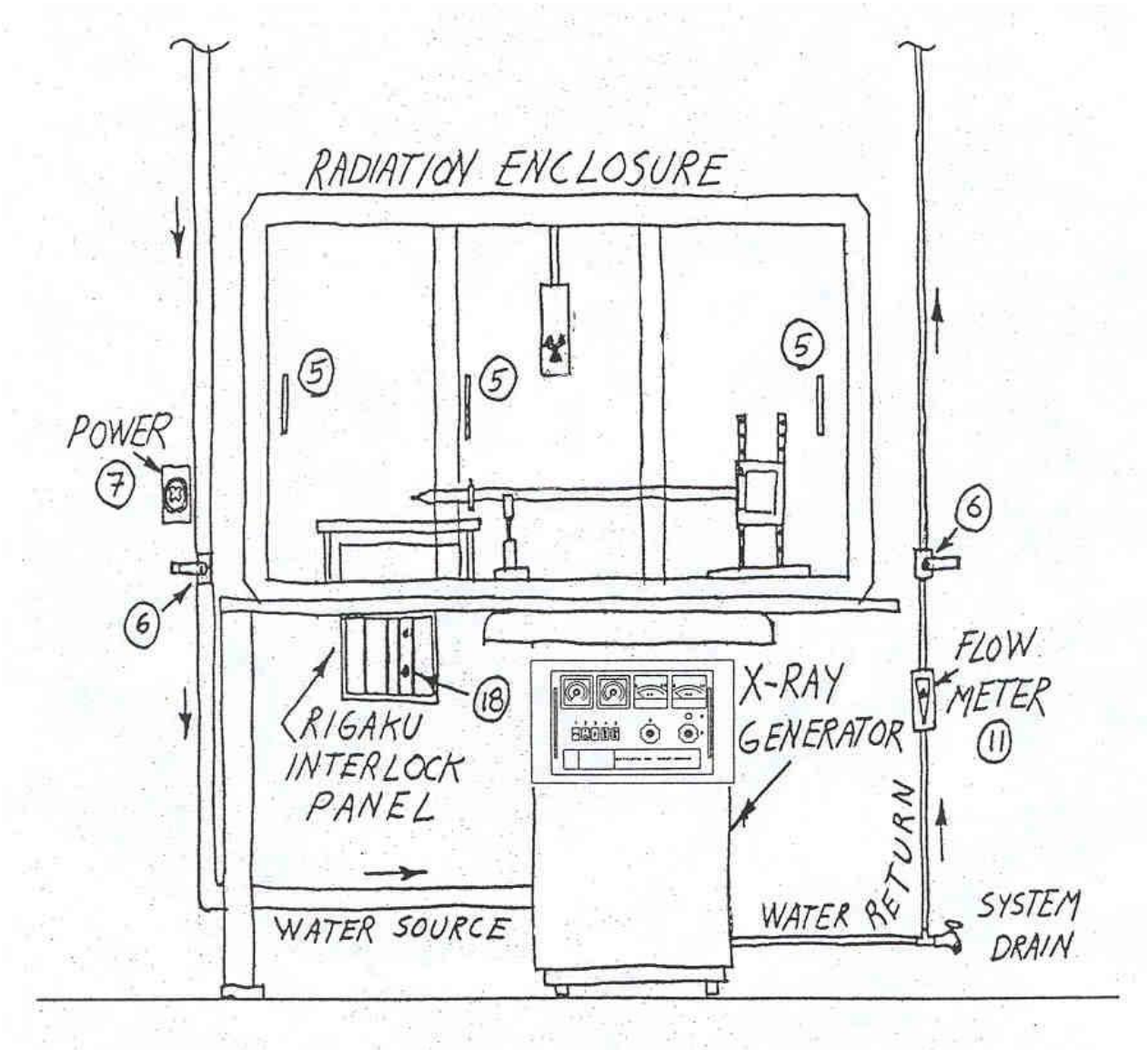


Figure 2 (above)

5. Completely close all seven sliding doors on the enclosure.

6. Open the water tap.

7. Plug X-ray generator power cord into 208V receptacle.

8. Depress the button “Mains” (1).

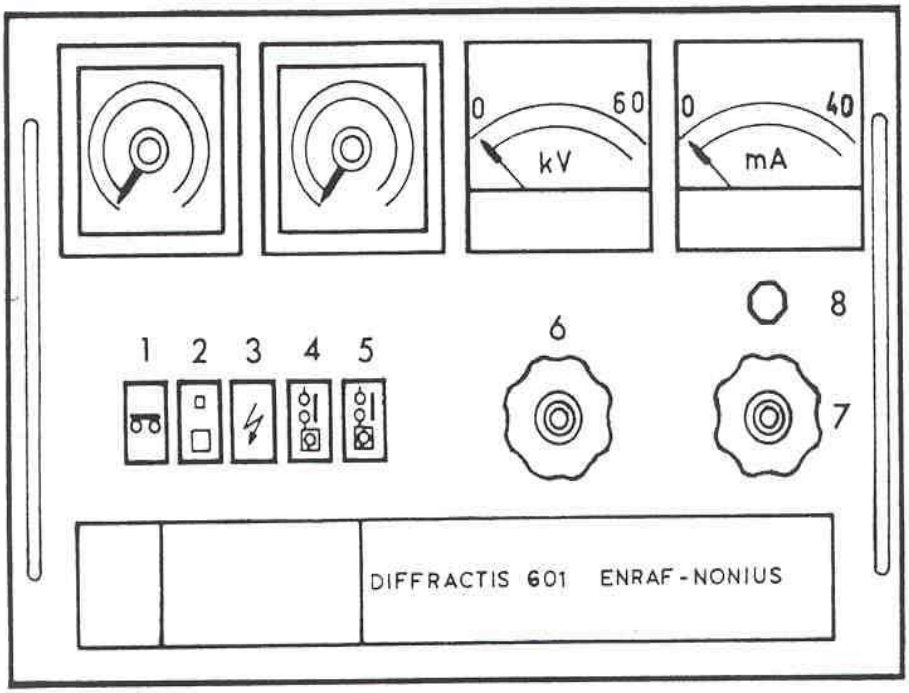


Figure 3 (above)

10. Depress the focus selector switch (2). The red fine focus split display will light up. This is a two position switch – “In” position for fine focus and “Out” position for normal focus tubes (green).
Generator must be started in the fine focus position, even when normal focal tube is used

11. The two timer switches (4 and 5) will be operative if left in the “Out” position. If one or both are pushed in, it is illuminated and indicates that the timer circuit is bypassed.

    The front of the timer has a button marked with an arrow. If this arrow is turned to fully cw (clockwise) position the timer operates on 0-1 hours; in the middle position: 0-10 hours; and in the fully ccw (counter clockwise) position: 0-100 hours.

12. Turn both mA knobs (coarse 7) and (fine 8) to full ccw position.

13. Press the high–voltage switch (3).

14. Turn kV regulator (6) fully ccw (against spring action) and hold till the high voltage switch lights up and stable water flow is established.

15. If necessary, press the fine focus switch (2) for normal focus tube.

16. Check that water flow is greater than 0.8 GPM, as read on the flow meter.

17. If internal relays will not latch, check that all enclosure doors are in their proper tracks and proper positions, then re-try.

1. Select desired Kilovolts and Milliamperes settings:
   - 22 kV and 6 mA are standard settings

   NOTE: The mA circuit can be adjusted by means of the fine and coarse adjustments.

19. Turn on "Power" switch of electric shutter control - yellow "Power" lamp should light. If a timer is used, the shutter will be closed automatically when the selected time has elapsed. If both timers are used, the timer with the longest time setting will switch off the generator as well as the shutter.

20. Press black "On" button of shutter control - two red lamps at the top of the shutter should light, and the red X-ray lamp on the shutter control box should light, - X-rays are now present within the enclosure!

21. Use the radiation survey meter to check for X-ray leakage outside the enclosure - none should be detectable - if radiation >500 cpm is detected, press the "Off" button on the shutter control box. Contact the Facility Support Representative. Devise additional shielding only <u>in collaboration with a Radiological Control Technician</u> who may conduct a radiation survey.

22. If alignment must be performed in an "Open Beam" situation, bypass the enclosure interlock by:

    a) Turning key on the "Rigaku Interlock Panel" and holding it.

    b) Slide open one enclosure panel by ≈30mm - the red "FS Release" lamp on the Rigaku panel should be flashing.

    c) Release key.

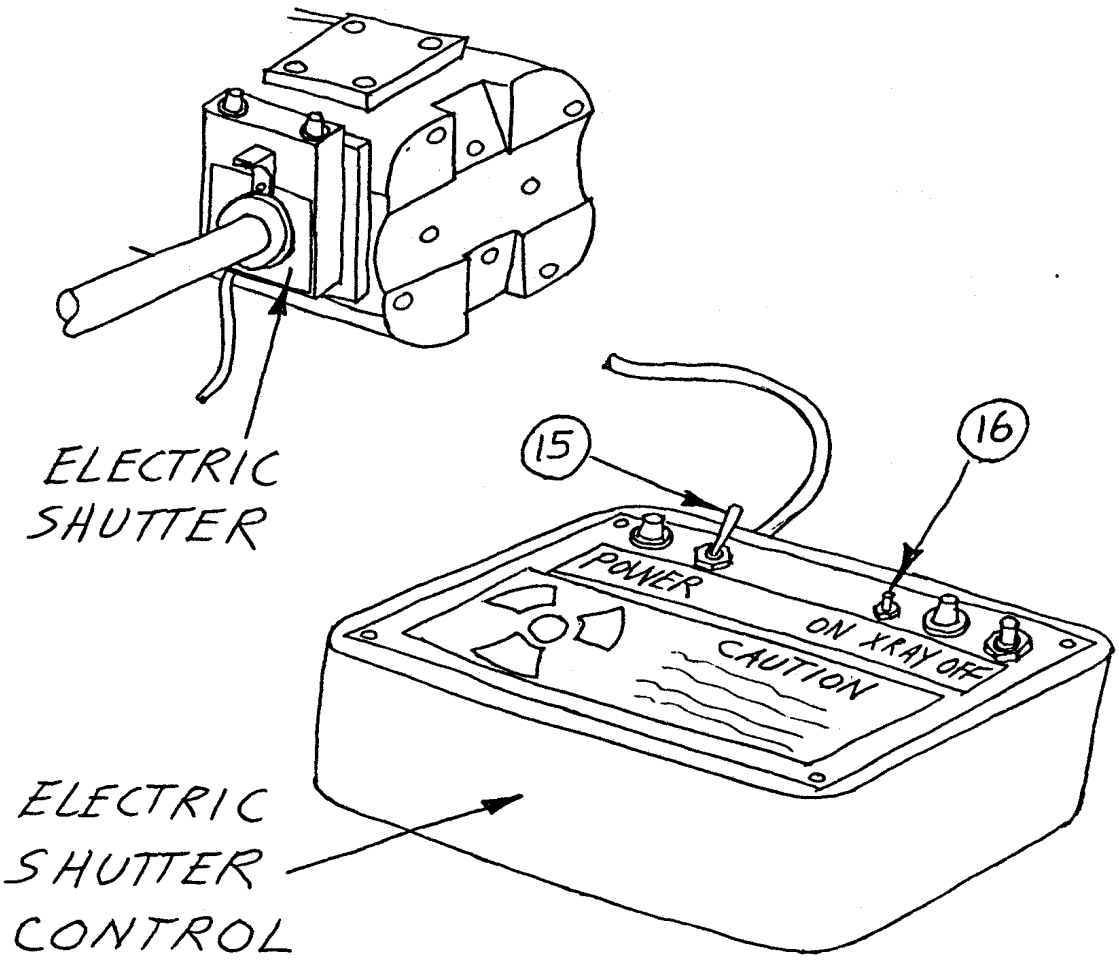


Figure 4 (above)

23. **Assure that operator has signed out and is wearing a ring dosimeter.** Use the radiation survey meter probe in one hand to check the opening produced as the enclosure panel is slid open for the required access – if radiation is detected at a rate >500 cpm, close the panel and the electric shutter, and contact the Facility Support Representative. Devise additional shielding only in collaboration with a Radiological Control Technician who may conduct a radiation survey.

24. Survey the actual region where access will be made to assure that no unusual beam scatter or diffraction is present - in no case shall the survey meter read more than 500 cpm in the region where access will be made, - if it does, close the electric shutter and contact the Facility Support Representative. Devise additional shielding only in collaboration with a Radiological Control Technician who may conduct a radiation survey.

25. Perform the crystal alignment (Note: close the electric shutter whenever X-rays are not actually needed for alignment).

Alignment Notes

Standard Alignment

Crystal alignments typically involve rotating the crystal by hand a number of degrees at a time, adjusting the crystal holder kinematic mount each time to align the planes of the crystal to the position of the incident X-ray beam. The θ ring is then rotated to deliver the maximum signal intensity to the detector making small adjustments, with X-ray beam on, to the crystal holder kinematic mount until the crystal planes are aligned to the same θ reading in 360˚ rotation.

Once the crystal is aligned, the crystal is rotated through 360° to check that all planes are aligned; rotation may be done with the X-ray beam off, checking the crystal at 90° positions.

Note, there are other forms of operation that do not necessarily involve crystal alignment.

Open X-ray Beam Inside Enclosure

The shielding enclosure and X-ray source may be used to test prototype detectors. If the X-ray beam path may be accessible by hand in this configuration, bypassing the interlock for hand access is not allowed. The detector may be aligned in the path of the beam using burn paper, a remote XYZ stage or some other method. If, however, the open beam path is limited "to within 10 mm or less" as cited above under **X-ray Generator Normal Operating Procedures**, then the same requirements as crystal alignment apply. Unattended operation is allowed using the pink card.

X-ray Beam Outside of Enclosure

Certain experiments may require that the X-ray beam be brought out of the shielding enclosure to an external equipment set-up. Such a configuration must be planned and controlled through the use of a Safety Approval Form. In all cases, the path of the X-ray beam must be fully enclosed and a radiation survey must be conducted before the experiment is allowed to commence. No unattended operation is allowed in this configuration.

Shutdown:

If no timer is used, the unit is shut off according to the following procedure:

1. Press the high voltage switch.
2. Press the "Mains" switch.
3. Remove the generator power cord from the wall receptacle.
4. Close the water inlet valve (fully CW).
5. Remove the item aligned.
6. If work is completed for the day, sign out in the logbook, lock room door, and return the key to the Steward.

X-ray Generator Alignment Procedures:

Introduction:

Alignment of the X-ray tube housing, drift tube and collimator, θ (Theta) circle, and 2θ circle in preparation for monochromator crystal orientation is a simple task, which requires open beam use of X-rays in a minimal way. This is because the alignment of these items need not be performed with high accuracy; other portions of the mechanical system govern the accuracy of the crystal orientation, and these parts are machined and assembled to close tolerances.

Four conditions are obtained by alignment:

Condition	Tolerance
a) Intersect center of X-ray beam and rotation axis of sample barrel in "V" block	±3mm
b) Intersect center of X-ray beam and rotation axis of θ (sample) circle	±2mm
c) Place center of detector window in the same plane as the incident and diffracted X-ray beams	±5mm
d) Calibrate angle ring on 2θ (detector) circle	±2°

*Conditions a, b, & c are obtained without use of X-rays. Only condition d requires the use of X-rays.

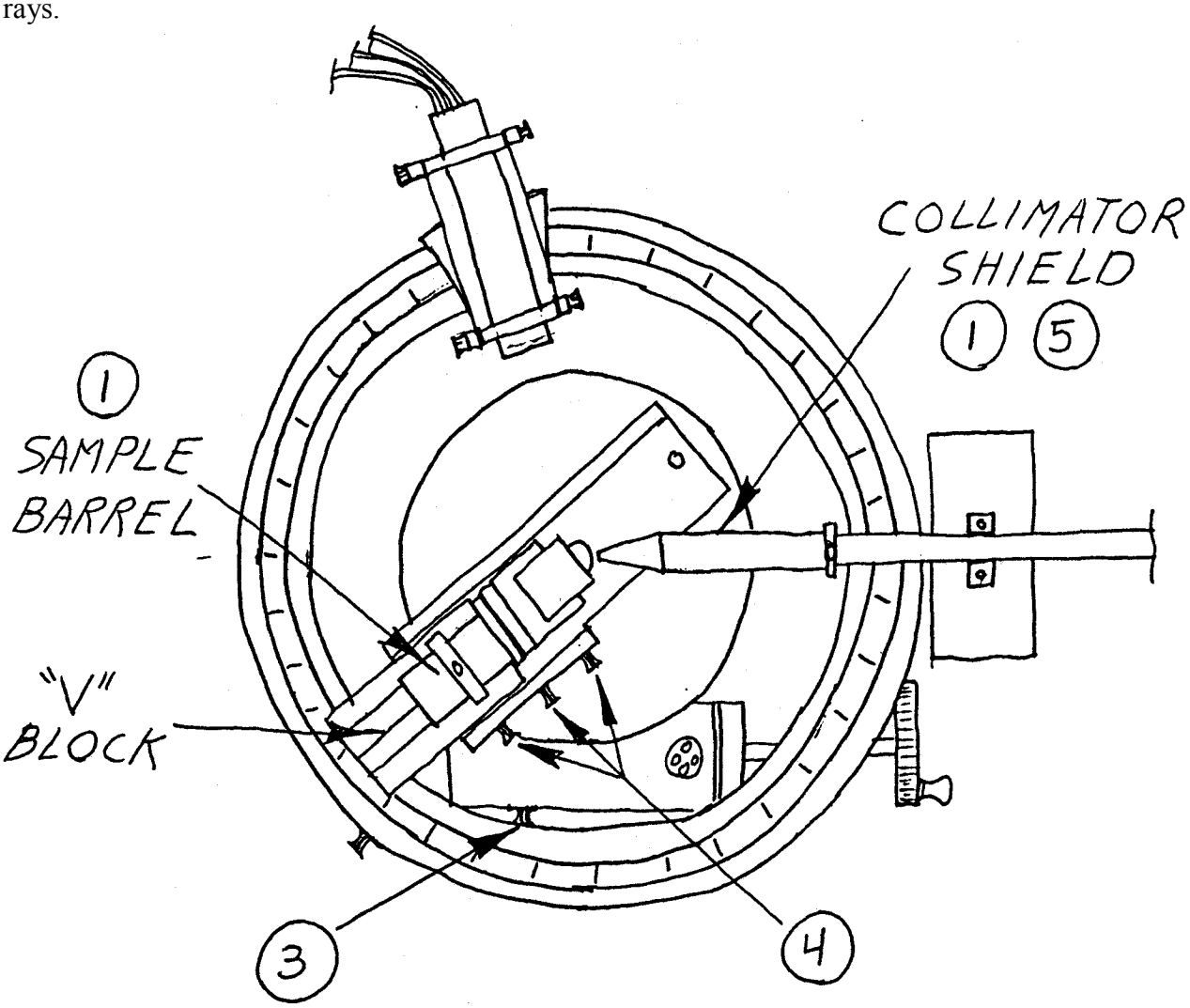


Figure 5 (above)

Procedure:

Intersect center of X-ray beam and rotation axis of sample barrel in "V" block:

1. Fully retract the collimator shield and place the sample barrel in the "V" block.

2. Mark the rotation axis of the sample barrel on its face or use existing machining marks, center-drill holes, etc.

3. Disengage the worm gear drive on the θ circle table and rotate the table so that the collimator axis and the barrel axis are roughly parallel.

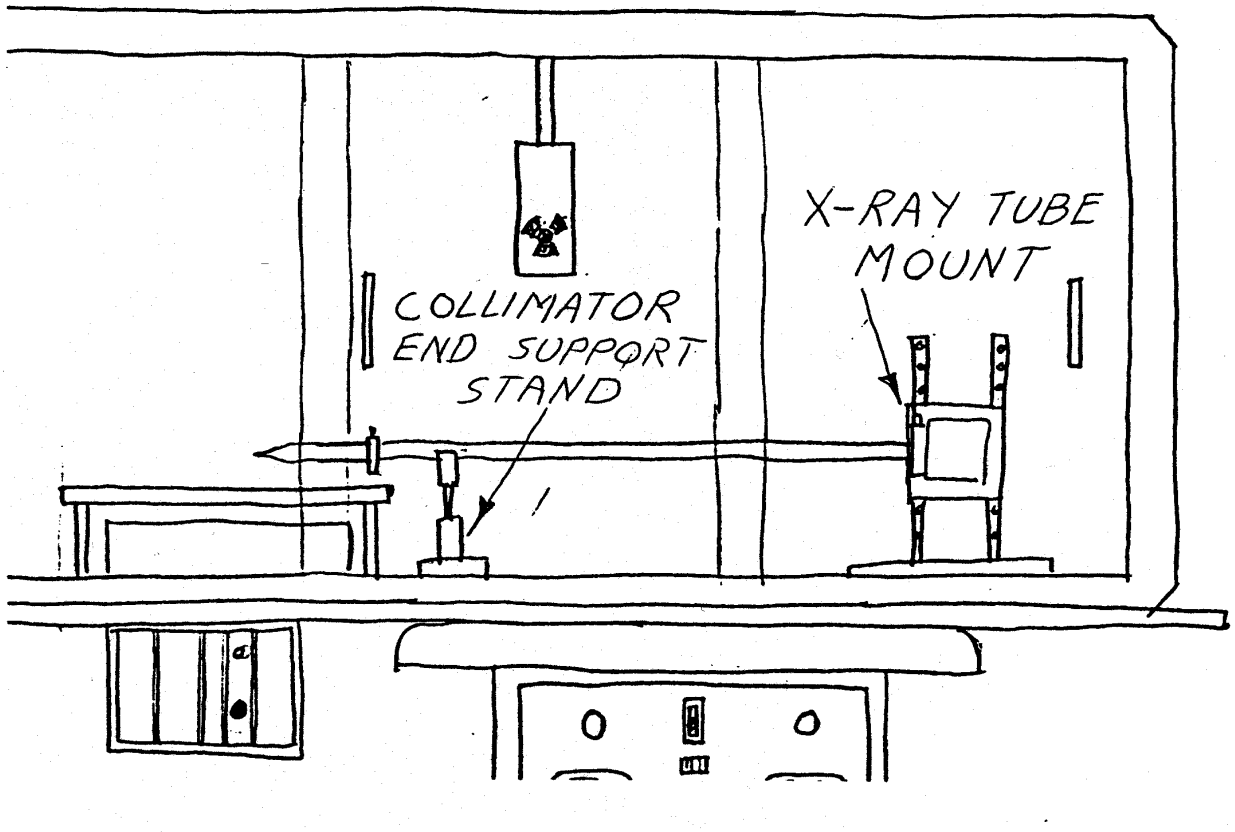


Figure 6 (above)

4. Loosen the brass thumb screws which clamp the "V" block and slide the block so that the face of the barrel is as close as possible to the collimator.

5. Extend the collimator shield to within a few mm of the barrel face and tighten the shield clamp screw.

6. Note whether the end of the collimator shield and the barrel-axis mark lie in a common horizontal plane, within 3mm.

7. If not, retract the collimator shield enough to prevent any collision and carefully raise or lower the X-ray tube mount and collimator end support stand. Before loosening the flange bolts which mount the tube housing to its aluminum right-angle bracket, it is wise to insert a lab jack or other support beneath the flange to support the weight, and help control the motion. Once the tube housing has been moved, readjust the collimator end

support stand to bring the collimator tube ≈horizontal, as measured with a simple spirit level.

8. Repeat steps 5 thru 7, until step 6 is satisfied.

Intersect Center of X-ray Beam and Rotation Axis of θ Circle:

1. Fully retract the collimator shield and remove the "V" block and sample barrel from the θ circle table.

2. Disengage the worm gear drive of the θ circle table and rotate the table so that the steel track runs approximately at right angles to the incident X-ray beam direction, with the end with the brass thumb screws toward the front of the enclosure.

3. Place the centering point fixture (see Figure 7) on the θ circle table track and slide it to its alignment pin.

4. Extend the collimator shield to within a few mm of the centering point and tighten the shield clamp screw.

5. Viewed from above, note whether the end of the centering point lies in the vertical plane passing through the collimator tube axis, within 2mm.

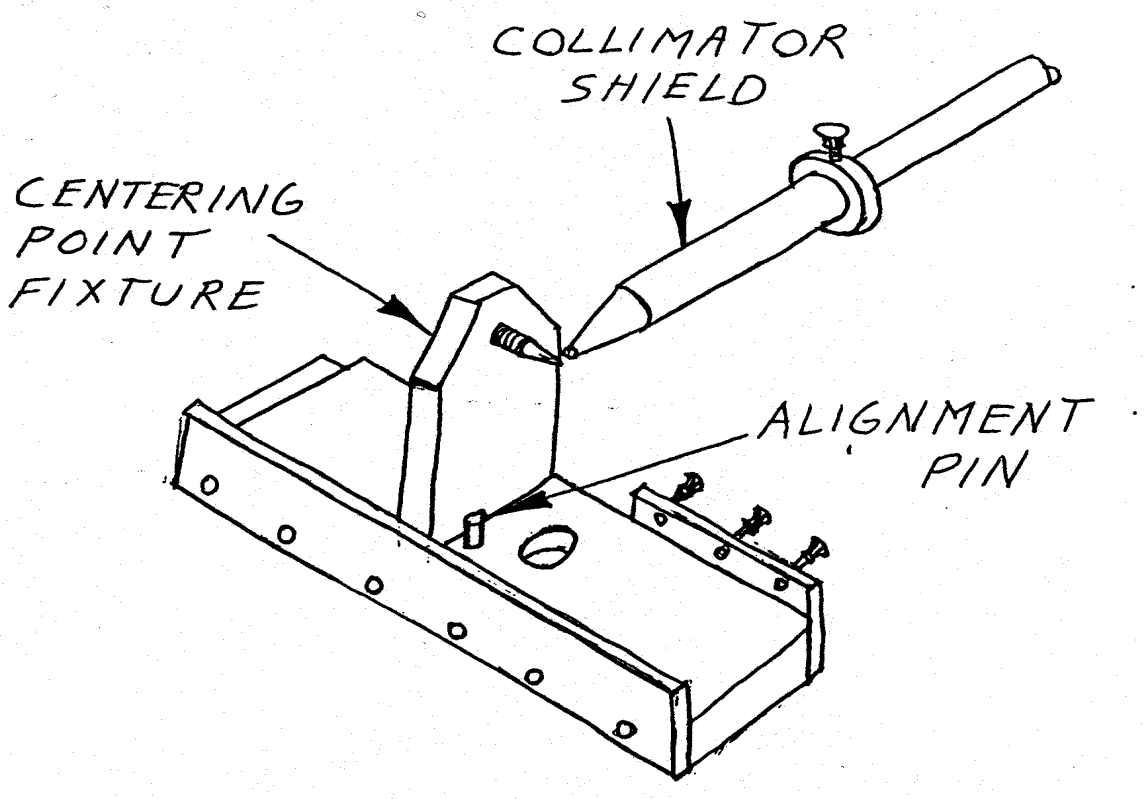


Figure 7 (above)

6. If not, retract the collimator shield 5-10 mm and carefully rotate the tube housing and collimator tube by first lowering the collimator end support stand and removing it from under the collimator tube. Then rotate the X-ray tube housing by gently pushing or pulling on the tube housing near the location of the electric shutter (longest lever arm).

7. Repeat steps 4 thru 6 until step 5 is satisfied.

8. Re-install the collimator end support stand and re-level the collimator tube with a spirit level.

9. Repeat step 5, and move the collimator end support stand slightly if step 5 is not satisfied.

Place Center of Detector Window in the Same Plane as the Incident and Diffracted X-ray Beams:

1. Fully retract the collimator shield.

2. Move the detector on the 2θ circle to about the 140-150° position.

3. As viewed from the 270° mark on the 2θ circle, in a horizontal plane, note whether the center of the collimator shield and the center of the detector window lie in a common horizontal plane, within 5mm.

4. If not, move the detector up or down as required, using the four brass thumbscrews on the detector vertical supports.

Calibrate Angle Ring on 2θ Circle:

1. Remove any crystal holder from the θ circle and rotate the θ circle such that the incident X-ray beam will be unobstructed by anything on the θ circle.

2. Place a temporary horizontal defining slit, 1 mm wide, across the center of the detector. (Pb tape or Pb strips work well).

3. Rotate the detector on the 2θ circle so that it can intercept the incident X-ray beam. (≈0° position)

4. Energize the detector electronics.

5. Perform steps 1-14 of the "Normal Operating Procedures" to start up the X-ray generator.

6. Be certain that the "Kilovolts" and "Milliamperes" controls remain at their minimum positions, 10 kV and 6 mA.

7. Continue with steps 15-23 of the Normal Operating Procedures to get X-rays into the enclosure and override the enclosure interlock.

   Note: operator must be wearing a dosimeter ring to perform the next steps.

8. Perform a radiation survey the base of the detector mount on the 2θ circle to assure that scatter does not exceed 500 counts/min.

9. Loosen the thumb screw on the base of the detector mount and move the detector on the 2θ circle to peak its output reading.

10. Tighten the thumbscrew on the base of the detector mount, and shutdown the X-ray generator.

11. Loosen the thumbscrew which locks the angle ring in the 2θ circle, and rotate the ring so that the 0° mark is under the CCW edge of the brass detector base (as viewed from above).

12. Tighten the thumbscrew on the 2θ angle ring.

Interlock Test Procedure:

Note #1

The Steward of the crystal alignment facility shall conduct this interlock test procedure every 6 months.

Note #2

A Radiological Control Technician shall conduct a radiation survey every 6 months.

Note #3

The NSLS Personnel Protection System (PPS) database administered by the NSLS QA Group shall schedule and track the interlock tests and radiation surveys.

Introduction:

This procedure is designed to test the following subsystems:

a) Rigaku fail-safe enclosure interlocks

b) Fail-safe "X-rays On" lamp in enclosure

c) Blake electric shutter

These procedures do not require that X-rays be present within the enclosure during the tests, however, technically, several tests are performed in "open beam" conditions; the X-ray tube will be running. Therefore a radiation survey meter should be used prior to reaching into the enclosure to assure that scatter does not exceed 500 cpm; **the operator must wear a ring dosimeter.**

Rigaku Fail-Safe Enclosure Interlock:

1. Perform steps 1-14 of the Normal Operating Procedures to start up the generator.

2. Test the door switch for the front-center sliding panel of the enclosure (DOOR NUMBER 4) by sliding that door more than 20 mm in its channel. Latch relay should drop out (i.e. generator trips off), the Kilovolts and Milliamps meter readings should return to zero, and the water solenoid valve should close.

3. Re-energize the generator by sliding the door back to its previous location and momentarily depressing the Start button on the generator front panel.

4. Repeat steps 2 and 3 for each of the additional six (6) enclosure sliding doors.

DOOR NUMBER	1	2	3	5	6	7
STEP 2						
STEP 3						

5. Test the relay contacts in the Rigaku control that prevent latching of the relay, by leaving one enclosure door opened and depressing the generator Start button. Once the Start button is released, the system should immediately turn off.

6. Test the override circuit from power-off state by leaving one or more enclosure panels open and momentarily depressing the Start button on the generator front panel while turning key on the Rigaku panel. Power should come on and latch, but red "FS Release" lamp on the Rigaku front panel should be flashing.

7. Test override reset circuit by now closing the open enclosure panels. Power should remain on, but red FS Release light should go out and remain off.

8. Test that the override circuit is actually off by opening any enclosure panel. Power should immediately be lost from the generator.

9. Re-energize the generator by closing any open enclosure panels and momentarily depressing the Start button on the generator front panel.

10. Test override disable circuit by now by turning key on Rigaku panel. Red FS Release lamp should begin flashing. Release key and red FS Release lamp should go out, and remain off. Power to generator should remain on throughout.

11. Test override circuit from power-on state by now turning key on the Rigaku panel, and while holding, open one enclosure panel. Release the

key. Red FS Release lamp should be flashing and power should remain on in the generator.

Fail-Safe "X-rays On" Lamp in Enclosure:

1. In preparation for later sections of this test, remove the plastic sign from around the red "X-rays On" lamp in the radiation enclosure by loosening the screw on the upper clamp and sliding the sign down and off.

2. Perform steps 1-14 of the Normal Operating Procedures to start up the generator, and set the "Kilovolts" and "Milliamperes" controls to minimum (fully CCW), 10 kV and 7 mA. CAUTION - X-rays are now being generated within the tube!

3. Do not energize the electric shutter and skip ahead to perform steps 22 and 23 of the Normal Operating Procedures to override the enclosure interlock, open the front-center panel enough to allow the red lamp to be unscrewed, and survey the region between the opening created and the red lamp.

4. Unscrew the red "X-rays On" lamp inside the enclosure until the lamp goes out. At that time, all power should be lost from the generator.

5. Screw the lamp back in. The power should remain off.

Blake Electric Shutter:

1. Perform steps 1-12 of the Normal Operating Procedures to start up the generator. (At this stage, with the x-ray tube not operating, the electric shutter can be tested.)

2. Turn on the "Power" switch on the electric shutter control box and momentarily depress the x-ray "On" button on the shutter control box to open the electric shutter. The three red lamps should light as the shutter opens.

3. Switch the "Power" switch off. The shutter should close. Switch it back on, and the shutter should remain closed.

4. Repeat step 2 above and then unplug the power supply for the shutter control box. The shutter should close. Plug it back in. The shutter should remain closed.

5. Repeat step 2 above and then disconnect the gray cable from the shutter control box. The shutter should close, reconnect the gray cable to the shutter control box. The shutter should remain closed.

SIGNED: _____

PRINT NAME: _____

LIFE/GUEST #: _____

DATE: _____

NSLS REVISION & PERIODIC REVIEW LOG

Document Number:	LS-ES-0001
Subject:	Normal Operating Alignment and Interlock Test Procedures: NSLS X-ray Generator for Crystal Orientation, building 535C (Basement)

> See NSLS Quality Control Coordinator for original revision and review signatures <

REVISION TABLE

Rev	Description	Date
B	a) Reformatted document and included new header required b) Incorporated revision and review log.	03/03/2000
C	a) Reformatted document to exclude old generator and include new generator. b) Changed shutdown procedure. c) Deleted door switch access panels on test procedure.	04/18/2000
D	Brought this procedure into conformance with HP-SOP-28, "Radiation Generating Devices" with assistance of SME, Chris Weilandics	04/17/2003

PERIODIC REVIEW TABLE

Complete this table to record the completion of periodic reviews for an existing controlled document. A successful periodic review will reveal the existing document is current, correct, and does not require any revision/change.

Document Review Frequency
3 years

Rev	Date	Reviewed By (Print):	Signature: