



OAK RIDGE
NATIONAL
LABORATORY

**Assessment of ORNL Radiation
Generating Device Safety Features and
Programmatic Compliance**

**Nuclear and Radiological Protection
Division**

**Oak Ridge National Laboratory
Oak Ridge, TN 37831**

August 14, 2007

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**Assessment of ORNL Radiation Generating Device Safety Features and
Programmatic Compliance**

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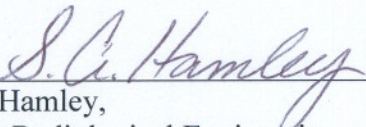


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8-14-07

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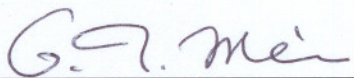
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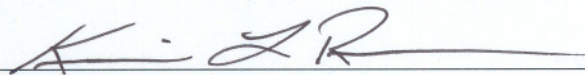
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Assessment of ORNL Radiation Generating Device Safety Features and Programmatic Compliance

Executive Summary

In September of 2006, a researcher in the Alloying Behavior and Design Group of the Materials Science and Technology Division was performing an experiment using an X-ray powder diffractometer when he noted that the mechanical shutter position indicator indicated that the shutter was open, even though the instrument had been commanded to close the shutter. Other shutter position indicators incorrectly indicated that the shutter was closed. The researcher was concerned that the shutter was also open when he placed the sample in the sample chamber which may have resulted in an inadvertent exposure to the X-ray beam.

An investigation was chartered that concluded that the shutter had stuck in the open position and that the instrument safety features were not fault-tolerant for a stuck shutter fault and as such, did not operate as expected. The investigation also concluded that the researcher likely did not receive an inadvertent exposure. As a result of the investigation, an assessment was ordered of all active Radiation Generating Devices (RGDs) in use at the Oak Ridge National Laboratory.

Forty-four RGDs were assessed for both procedural compliance and safety feature function. One finding, fourteen opportunities for improvement, and four proficiencies were identified. Of the 44 RGDs assessed, 38 were found to have robust safety features that would likely prevent any inadvertent exposure to radiation. Five RGDs were found to lack robust safety features, but had sufficient administrative controls in place to ensure safe operation. One RGD was removed from service. No significant procedural deficiencies were identified by this assessment.

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1.0 Purpose and Scope

This assessment was performed as a follow-on action resulting from the October 2006 investigation of a stuck x-ray powder diffractometer shutter. The investigation revealed that the safety features for the x-ray powder diffractometer operated in an unexpected manner that was neither “fail-safe” nor tolerant of a stuck shutter fault. Additionally, the investigation found that the device shutter failure was due in part to cooling problems that resulted in a deformed lead shield. The purpose of this assessment was to evaluate all operating and operable Radiation Generating Devices (RGDs) currently in inventory for similar issues and to demonstrate compliance with the Standards Based Management System (SBMS) requirements and to verify that safety features are effective and operate as expected, where possible.

This assessment reviewed the requirements contained within the SBMS Subject Area: *Radiation Generating Devices* for each operable RGD. A checklist for these requirements was prepared for the investigation cited above, and was used in this assessment. Additionally, an evaluation matrix was developed to assess the design and functionality of shutter position indicators and safety features. This matrix, in combination with the manufacturer’s documentation and/or drawings, if available, was used to assess the operation of shutter indicators and safety features and understand the risk of failure of these features. This assessment also reviewed available documentation for previous incidents, occurrences and lessons learned involving RGDs. Finally, the assessment teams performed a lab-wide evaluation of devices capable of producing radiation areas or intense beams of radiation, but are not registered as RGDs. For these devices, the safety features matrix were applied as applicable to assess safety features.

This assessment placed initial priority on RGDs that are listed as active in-use or are out-of-service but could readily be placed back into service, since these instruments represent the greatest risk. Once the higher risk devices were assessed, the assessment team evaluated, on a case-by-case basis, the out-of-service instruments that are not likely to be returned to service to determine if assessment is necessary. Similarly, special case RGDs, such as electron microscopes, were evaluated on a case-by-case basis to determine if assessment was necessary.

2.0 Description of Initiating Event

On September 1, 2006, a researcher in the Alloying Behavior and Design Group of the Materials Science and Technology Division was performing an experiment using an X-ray powder diffractometer. While preparing to remove a sample that he had inserted a short time earlier, the researcher noted that a mechanical shutter position indicator flag indicated that the shutter was open, though the control panel and the “Shutter Open” lamps on the tube tower indicated a shutter-closed condition. Typically, the X-ray tube tower remains energized and continues to produce X-rays, with the shutter providing shielding while samples are manipulated in the sample chamber.

Because the mechanical shutter position indicator flag is physically attached to the shutter, the researcher concluded that the shutter was indeed open, and immediately

contacted the custodian of the instrument. Since the tube tower was energized, the researcher became concerned that the shutter may also have been stuck in the open position when he placed the sample in the chamber possibly resulting in an inadvertent exposure. It is not unusual for X-ray diffractometers to produce exposure rates of tens of thousands of rad per second within the small, highly collimated beam. An investigation later concluded that there was no inadvertent exposure.

The investigation also found that the safety features did not function as expected for the condition in which the shutter is stuck in the open position and the control panel is in a shutter-closed state. The instrument is equipped with several features designed to prevent inadvertent beam exposure and alert operators to the status of the X-ray beam and the shutter position. Some of these features were found to be fault-intolerant to a stuck shutter, and as such, did not function as expected. The critical fault-intolerant safety features all operate correctly when the instrument is operating correctly. These features operate primarily by either sensing the status of the shutter by way of its energizing circuit, or in the case of interlocks, de-energizing the shutter circuit when breached. The shutter is operated by a solenoid that opens the shutter when energized and closes the shutter when de-energized.

If the shutter circuit is energized, the safety features operate correctly and are able to correctly sense shutter position. However, the design of the safety features apparently did not contemplate a stuck shutter fault. When the shutter energizing circuit is de-energized, the critical fault-intolerant safety features were ineffective. The safety features appear to be designed with the assumption that a de-energized shutter mechanism would invariably result in a closed shutter. In the case of this event, the shutter circuit was de-energized when the researcher initiated the routine to close the shutter. However, the shutter became lodged in its tracks and did not close. The fault-intolerant safety features failed to either indicate that the shutter was open, or prevent access to the beam. The following describes the critical fault-intolerant safety features in more detail:

Interlocked Sample Chamber: The instrument's goniometer is equipped with an electro-mechanical interlock on the sample chamber that senses the position of the sample chamber cover and de-energizes the shutter circuit if the sample chamber is opened. However, the interlock does not directly sense the shutter position. Rather, it is simply a trip switch. In the event of a stuck shutter, the interlock would de-energize the shutter circuit, yet the shutter would remain open.

Shutter Position Indicator Lamp: The instrument is equipped with a shutter position indicator lamp that is located atop the tube tower. The lamp circuit is wired in series with the shutter solenoid and senses the state of the shutter circuit. When the shutter circuit is energized, the lamp illuminates. When the shutter circuit is de-energized, the lamp is extinguished. In the event of a stuck shutter, the lamp does not indicate that the shutter is open.

Interlocked Enclosure: In 1989, an interlocked enclosure was installed on the instrument. The intent of the interlock was to initiate shutter closure by de-energizing the

shutter circuit in the event the enclosure was opened while the shutter was open. However, in the case of a stuck shutter, de-energizing the shutter circuit had no effect on shutter position. As such, this feature was intolerant of a stuck shutter fault.

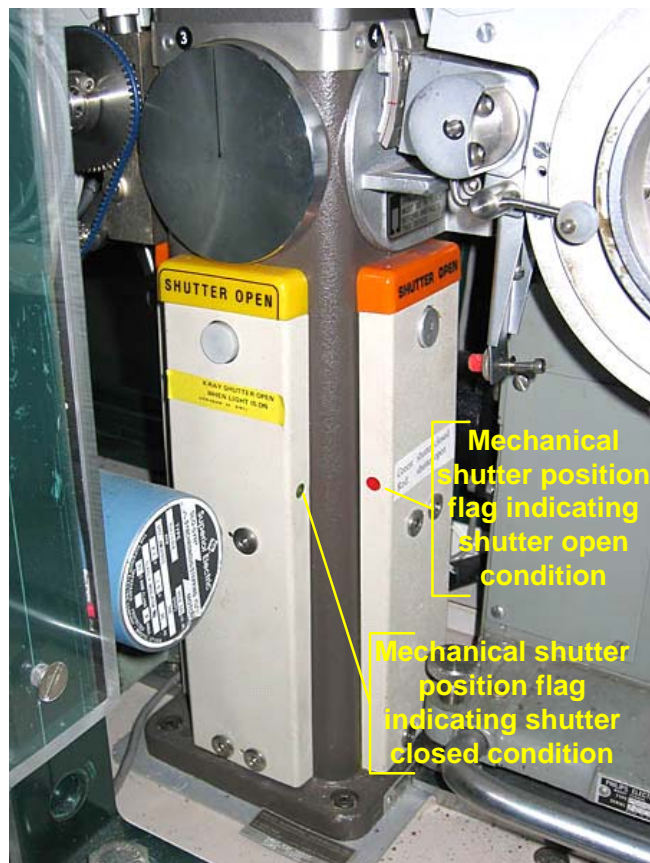
Audible Alarm: In 1995, an audible alarm was fitted to the instrument for the purpose of alerting operators to an open-shutter condition if the enclosure were to be opened when the shutter was open. The investigation found that the alarm circuit is triggered based upon the shutter circuit. As such, when the shutter circuit is de-energized, the alarm circuit is de-energized as well. The alarm, therefore, is not operable when the shutter is stuck open and the shutter circuit is de-energized.

Two safety features were found to function correctly and as expected. The instrument is equipped with an “X-rays On” lamp that indicates the status of the instrument’s X-ray tube. This feature is failsafe in that the X-ray tube generator is wired in series with the lamp and as such, will not function if the lamp is not illuminated. Additionally, the tube tower is equipped with a small mechanical flag that is physically linked to the shutter and provides a failsafe indication of shutter position. This was the safety feature that alerted the researcher to the open-shutter condition.

It should be noted, however, that the two safety features that functioned correctly and as expected are both passive features. That is, they offer only a visual indication of conditions and rely on the operator to notice them. They do not offer any active means of intervention as, for example, an interlock may offer. The “X-rays On” lamp remains illuminated when the instrument is in use, regardless of the shutter position. Samples are routinely placed in the sample chamber when the lamp is illuminated, with the operator depending upon the shutter mechanism to prevent radiation exposure.

The sole reliable indicator of shutter condition was the mechanical flag. However, the mechanical flag is small and easy to overlook. Figure 1 shows a photograph of the tube tower with the mechanical flags identified. If the shutter is open, the flag displays a red color. Likewise, if the shutter is closed, the flag displays green.

Figure 1



3.0 Assessment Method

A primary focus of this assessment was to identify those safety features that provide both passive and active actions to protect the users from exposure; to understand the limitations of such features and to recommend compensatory actions if necessary.

3.1 Team

A multidisciplinary panel consisting of Nuclear and Radiological Protection Division (NRPD) and Instrumentation and Controls (I&C) personnel was assembled to perform this assessment. The panel was divided into two teams with each team consisting of NRPD and I&C subject matter experts. The review teams met periodically to review the assessment plan, review progress and provide technical assistance as needed.

3.2 Compliance Checklist

The compliance checklist was developed based primarily on the applicable Standards-based Management System (SBMS) subject areas and procedures. The checklist template is provided in Appendix C and includes references to the applicable requirements. Before performing an assessment, the assessment team provided the custodian with the Appendix C checklist template so the custodian could assemble the necessary documents, procedures, drawing, etc. required for the assessment. In the interest of brevity, the completed checklists are not included in this report. A summary of the results of the compliance assessment is contained in section 4.1 Compliance.

3.3 Instrument Data Sheet

The instrument data sheet contains detailed information regarding the configuration and safety features for each instrument. Completed data sheets for each RGD assessed are contained in Appendix B.

3.4 Shutter Position Indicator Verification Matrix

The shutter position indicator verification matrix (Appendix D) was designed to test the shutter position indicator(s) as well as safety features for each possible configuration of beam power, shutter position, shutter switch position and sample chamber. It was not expected that each configuration would be physically tested, since this may require overriding of safety features and interlocks, intentional jamming of shutters, or physical damage to the instrument. As such, each configuration was physically tested only if it could be done so safely and without damage to the instrument. If a configuration could not be directly tested, every effort was made to infer the operational characteristics of shutter indicators and safety features from the manufacturer's literature, drawings or schematics. In the interest of brevity, the verification matrices are not included in this report. A summary of the operational aspects of key safety features is contained in Appendix A.

3.5 Other Devices

The assessment team contacted Division Radiological Control Officers (DRCOs) to identify other devices that are capable of producing radiation areas or high dose-rate beams but that are not currently identified as RGDs and are not tracked in the ORNL Radiation Source Inventory (RASIN) database. Examples include source devices containing radiation sources, interlocks and shutters; particle accelerating devices capable of producing radiation areas with or without shielding, etc. These other devices were evaluated by the assessment team on a case-by-case basis to determine if they should be assessed to the criteria in this plan.

3.6 Review of Previous Incidents

The assessment team reviewed available documentation for previous incidents involving RGDs, from both ORNL activities as well as other facilities. The review included ORNL Radiological Event Reports, DOE Occurrences and DOE Lessons Learned. The team evaluated corrective actions for these related incidents to ensure that previous actions are considered.

4.0 Results Summary

At the time of the assessment, there were 49 RGDs categorized as active-in-use (5 were taken out of service before the assessment was concluded, but were assessed), 22 RGDs categorized as out-of-service and 39 RGDs categorized as special case. Special case RGDs include instruments and equipment that do not fall into the “shielded room”, “enclosed beam”, “open beam” and “source device” categories as defined in the Standards Based Management System (SBMS) descriptions. Special case RGDs are typically electron microscopes or devices that operate in a vacuum and produce potentials of less than 16 kV.

Of the 49 active-in-use RGDs, 44 were evaluated as part of this assessment. Of the remaining five, two are located within hot cells, and as such could not be readily assessed; one was in the process of significant upgrades to safety features and will be assessed once the upgrades are completed; one is a hand-held X-ray fluorescence unit that does not have safety features as contemplated by this assessment, and one is a baggage scanner that similarly does not have applicable safety features. The X-ray fluorescence unit is operated under the control of a radiological work permit (RWP) with coverage by a Radiological Control Technician (RCT). Two other X-ray fluorescence units that are operated without RCT coverage were evaluated. The baggage scanner had been previously evaluated for radiological safety, and is operated under strict procedural control.

The inventory records for the 22 RGDs categorized as out-of-service were reviewed to determine if any of the instruments were likely to be returned to service in the near future. None were identified. It was concluded by the assessment teams that a similar assessment would be performed prior to returning any out-of-service RGDs to service.

The inventory records for the 39 RGDs categorized as special case were reviewed to determine if this assessment approach would be applicable to the specific instruments. The primary population in this category consists of electron microscopes which operate under vacuum, and as such, cannot be operate in such a way as to expose the operator to electron or X-ray beams. The remaining RGDs in this category have similar limitations. It was concluded by the assessment teams that this assessment was not applicable to the special case RGDs and that they presented only minimal exposure risk. Therefore, none were assessed.

4.1 Compliance

Regulatory and procedural compliance was assessed using the procedure compliance checklist (Appendix C). This checklist was derived primarily from the requirements contained within SBMS for the procurement, design, pre-operational review, training, routine operations, periodic safety features test and maintenance of safety features for RGDs. Additionally, the checklist included a section for beam alignment procedures. While there are no SBMS requirements for beam alignment procedures, the process of aligning an X-ray or radiation beam often requires that safety features be defeated or overridden. The assessment panel agreed that the beam alignment process for RGDs that require beam alignment should be evaluated for safety.

4.1.1 Findings

There were no findings identified by the compliance assessment.

4.1.2 Opportunities for Improvement

Six opportunities for improvement (OFIs) were identified by the compliance assessment. Four of these were related to a lack of proceduralized approach to beam alignment (XG-3109, XG-3130, XG-3153, XG-3166). One OFI identified an opportunity to use the ORNL SAP baseline training notification process to ensure training for RGD users remains current (XG-3133). One OFI identified a lack of an official RGD maintenance logbook (XG-3167).

4.1.3 Proficiencies

Four proficiencies were identified by the compliance assessment. All were related to excellent machine-specific training and training record-keeping (XG-3097, XG-3157, XG-3215, XG-3216).

4.2 Safety Features

Safety features were evaluated using the instrument data sheets (Appendix B) and the shutter position verification matrix (Appendix D). A summary results table was

developed (Appendix A) that lists key safety features as well as issues or proficiencies for each RGD. The summary results table is color coded to indicate:

- Instruments that have active safety features, such as interlocks linked to beam power, that serve to actively prevent inadvertent access to radiation beams (green). These instruments are deemed to have the most robust safety features and require no additional controls.
- Instruments that have active features, *e.g.* audible radiation alarms, that clearly indicate to the user that the instrument is producing radiation in a potentially unsafe configuration such as an open enclosure or sample chamber (yellow). These are deemed to have robust active safety features, but do not actively prevent inadvertent exposures. These instruments typically do not require additional administrative controls.
- Instruments that have only passive indicators of radiation status such as shutter position or beam power (magenta). These instruments may have also demonstrated fault-intolerance for a stuck shutter condition and are deemed to have vulnerable passive safety features. As such, these instruments may require additional administrative controls.
- Instruments that have insufficient safety features for safe operation (red). Only one instrument was identified in this category and was removed from service.

More detailed descriptions of the instruments and associated safety features are contained in the instrument data sheets.

The assessment teams found it difficult to evaluate the safety features behavior using the shutter position verification matrix, particularly for the state in which the shutter is ordered closed yet remains stuck open. This state is difficult to recreate without mechanically jamming the shutter, damaging the instrument or creating a radiation exposure hazard for the assessment team. Where possible, the behavior of the safety features was inferred from drawings or instrument literature.

4.2.1 Findings

One instrument (XG-3175) was found to have a shutter position indicator light that appeared to incorrectly indicate shutter position under normal conditions. This instrument was removed from service.

4.2.2 Opportunities for Improvement

Eight OFIs were identified during the safety features assessment. Four of the OFIs were related to shutter composition (XG-3020, XG-3022, XG-3119, XG-3187). Lead has been demonstrated to degrade and corrode under intense radiation beams. This has resulted in sticking shutters in previous incidents. These four OFIs identified lead or other materials

with a history of sticking problems in shutter composition. Two OFIs identified indicator lights that were not clearly labeled as to their function (XG-3168, XG-3169). Two OFI suggest installation of an alarming radiation detector (XG-3201, XG-3098). One OFI suggests that shielding curtains be checked prior to operation (XG-3214).

4.2.3 Proficiencies

No proficiencies were identified in the safety features assessment.

5.0 Conclusion

Forty-four RGDs were evaluated in this assessment. Thirty-eight of those were found to have robust, active safety features that would likely prevent inadvertent radiation exposure under predictable fault conditions that include a stuck shutter. Five RGDs were found to lack robust, active safety features, though the operation of these RGDs includes administrative controls sufficient to ensure safe operation. One RGD was removed from service. No substantial procedural deficiencies were identified. It is concluded that no significant vulnerabilities similar to the initiating event exist.

The ORNL RGD program appears to be robust and effective. However, the safety feature evaluation approach in this assessment was found to have value for routine use in the RGD program. Certain elements, therefore, will be incorporated into the RGD registration and inspection programs.

6.0 References

Investigation of a Stuck X-ray Powder Diffractometer Shutter and Potential Exposure, October 13, 2006

RGD Assessment Plan, January 19, 2007

SBMS Subject Area: *Radiation Generating Devices*

Appendix A: Results Summary Table

| RASIN Number | Description | Mfr. Date | Key Safety Features | Issues or Proficiencies |
|---------------------|---|------------------|--|---|
| XG-2677 | Large Specimen Stress Analyzer | 1986 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3008 | Cabinet X-ray Machine | 1981 | Redundant door interlocks de-energize X-ray beam if challenged. Interlocks were tested at low power and found to function properly | |
| XG-3020 | X-ray Diffractometer | 1948 | Redundant door interlocks activate shutter closure but do not de-energize X-ray beam. All shutter indicators are fail-safe and will correctly indicate a stuck shutter. | Custodian is the only operator of this unit. Contains lead shutter parts (OFI) |
| XG-3022 | X-ray Diffractometer | 1952 | Redundant door interlocks de-energize X-ray beam if challenged. | Lead Shutter (OFI) |
| XG-3089 | Radiography Unit | 1989 | Unit contains no shutter and is contained in a vault with redundant door interlocks that de-energize X-ray beam if challenged. Vault contains redundant radiation detectors. This unit is currently out of service pending a move to a new facility. | |
| XG-3094 | Rotating Anode Diffractometer | 1976 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3097 | X-ray Diffractometer | 1987 | An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | Effective mechanism for machine specific training and excellent training record for each user (P) |
| XG-3098 | X-Ray Diffractometer | Unk | Door interlocks activate shutter closure but do not de-energize X-ray beam. | Consider installing radiation detector with alarm (OFI) |
| XG-3100 | Radiography Unit | 1985 | Unit contains no shutter and is contained in a vault with redundant door interlocks that de-energize X-ray beam if challenged. Vault contains redundant radiation detectors. This unit is currently out of service pending a move to a new facility. | |
| XG-3109 | X-ray Diffractometer and Four-circle Diffractometer | 1988 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | No beam alignment procedure (OFI) |

| RASIN Number | Description | Mfr. Date | Key Safety Features | Issues or Proficiencies |
|--------------|----------------------------------|-----------|--|--|
| XG-3110 | Radiography Unit | Unk. | Unit contains no shutter and is contained in a vault with redundant door interlocks that de-energize X-ray beam if challenged. Vault contains redundant radiation detectors. This unit is currently out of service pending a move to a new facility. | |
| XG-3119 | Irradiator | 1987 | Shield door interlocks de-energize X-ray beam if challenged. | Contains lead shutter parts (OFI) |
| XG-3124 | X-ray Diffractometer | 1990 | Redundant door interlocks de-energize X-ray beam if challenged. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3125 | X-ray Diffractometer | 1992 | Redundant door interlocks de-energize X-ray beam if challenged. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3126 | X-ray Diffractometer | 1990 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3129 | X-ray Diffractometer | 1994 | Redundant door interlocks de-energize X-ray beam if challenged. An audible alarm activates if enclosure is opened with beam on and shutter open. | |
| XG-3130 | X-ray Diffractometer | 1964 | Redundant door interlocks de-energize X-ray beam if challenged. | No beam alignment procedure (OFI) |
| XG-3131 | X-ray Diffractometer | 1996 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3132 | Electron-beam Welder | 1996 | Instrument can only create beam under vacuum. Shielding is interlocked to beam power. Unit has no shutter. | |
| XG-3133 | Electron-beam Welder | Unk. | Instrument can only create beam under vacuum. Shielding is interlocked to beam power. Unit has no shutter. | Use SAP baseline training notices to ensure training remains current (OFI) |
| XG-3153 | Four-circle X-ray Diffractometer | 1997 | Redundant door interlocks activate shutter closure and de-energize X-ray beam if challenged. | No beam alignment procedure (OFI) |
| XG-3155 | X-ray Diffractometer | 1995 | Redundant door interlocks de-energize X-ray beam if challenged. | |

| RASIN Number | Description | Mfr. Date | Key Safety Features | Issues or Proficiencies |
|--------------|-------------------------------------|-----------|---|---|
| XG-3157 | | 1991 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | Training records are well maintained for each user. Retraining is required every two years. Excellent recording mechanism and practice (P). |
| XG-3161 | X-ray Diffractometer | 2000 | Door interlocks activate shutter closure but do not de-energize X-ray beam. An independent radiation detector with alarm will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3164 | X-ray Diffractometer | 2002 | Redundant door interlocks de-energize X-ray beam if challenged. | |
| XG-3165 | Vacuum Chamber X-ray Diffractometer | 1997 | Instrument can only create beam under vacuum. Beam power is interlocked to redundant vacuum switches. Chamber flange is interlocked to beam power. Unit has no shutter. | |
| XG-3166 | X-ray Diffractometer | 2002 | Redundant door interlocks activate shutter closure and de-energize X-ray beam if challenged. | No beam alignment procedure (OFI) |
| XG-3167 | Profiler | 2002 | Door interlocks activate shutter closure and de-energize X-ray beam if challenged. | No maintenance logbook (OFI) |
| XG-3168 | Radiography Camera | 2007 | Unit is used within a shielded vault with audible radiation detectors. No other physical fail-safe features are in use. Vault access is controlled by door locks and administrative access control. This unit is currently out of service pending a move to a new facility. | Indicator lights outside vault could be more clearly labeled as to function (OFI) |
| XG-3169 | Radiography Camera | 2007 | Unit is used within a shielded vault with audible radiation detectors. No other physical fail-safe features are in use. Vault access is controlled by door locks and administrative access control. This unit is currently out of service pending a move to a new facility. | Indicator lights outside vault could be more clearly labeled as to function (OFI) |
| XG-3175 | Tomography Unit | 2003 | Enclosure and sample chamber interlocks were found to not be fail-safe. Shutter position indicator lights did not appear to function as expected. | Unit was removed from service by the custodian. |
| XG-3186 | X-ray Diffractometer | 2003 | Redundant door interlocks activate shutter closure and de-energize X-ray beam if challenged. | |

| RASIN Number | Description | Mfr. Date | Key Safety Features | Issues or Proficiencies |
|--------------|------------------------------------|-----------|--|---|
| XG-3187 | X-ray Diffractometer | 2003 | Redundant door interlocks de-energize X-ray beam if challenged | Shutter has a history of sticking due to corrosion of shutter material. Custodian is working with the vendor to install new shutter if different composition. (OFI) |
| XG-3190 | Electron Microscope | 1990 | Gun shielding switch, dark field detector switch and viewing window are all interlocked to beam power. | |
| XG-3201 | X-ray Diffractometer | 2004 | Redundant door locks activate shutter closure only. | Consider installing radiation detector with alarm (OFI) Custodian is the only operator. |
| XG-3204 | Radiography Unit | Unk. | Redundant door interlocks de-energize X-ray beam if challenged. Unit has no shutter. | |
| XG-3205 | Cabinet X-ray Tomography Unit | 2005 | Redundant door interlocks de-energize X-ray beam if challenged Unit has no shutter. | |
| XG-3213 | Open-beam X-ray Inspection Station | 2005 | Unit is "open-beam" and has no shutter. The only safety feature is an "X-ray On" lamp and a foot pedal switch that activates X-ray beam. | No active safety features exist to prevent exposure. However, custodian has good procedures, and operators are well trained. |
| XG-3214 | Hand-held X-ray Fluorescence | 2005 | Unit is "open-beam" and has no shutter. The only safety features are three "X-ray On" lamps. | No active safety features exist to prevent exposure. However, custodian has good procedures, and operators are well trained. Shielding curtains should be checked prior to each use to ensure proper shielding (OFI). |
| XG-3215 | Four-axis X-ray Diffractometer | 2006 | Redundant door interlocks activate shutter closure and de-energize X-ray beam if challenged. | Effective mechanism for machine specific training and excellent training record for each user (P). |
| XG-3216 | Four-axis X-ray Diffractometer | 2006 | Redundant door interlocks activate shutter closure and de-energize X-ray beam if challenged. | Effective mechanism for machine specific training and excellent training record for each user (P). |

| RASIN Number | Description | Mfr. Date | Key Safety Features | Issues or Proficiencies |
|--------------|---------------------------------|-----------|---|--|
| XG-3217 | X-ray Fluorescence Spectrometer | 2006 | Door interlock de-energizes X-ray beam if challenged. | Instrument is equipped with a lamp that indicates when shutter is closed rather than the more intuitive configuration of indicating shutter is open. |
| XG-3224 | X-ray Diffractometer | 2006 | Redundant door interlocks activate shutter closure but do not de-energize X-ray beam. Shutter-linked solenoids lock enclosure when shutter is open. Custodian intends to add an independent radiation detector with alarm that will activate if sample chamber is opened with beam on and shutter open. | |
| XG-3225 | X-ray Diffractometer | 1996 | Door is mechanically linked to shutter such that door cannot be opened with shutter open. | |

Legend:

Green: Indicates that the instrument has active features, such as interlocks linked to beam power, that actively **prevent** access to radiation beams.


Yellow: Indicates that the instrument has active features, such as audible radiation alarms, that clearly indicate to the user that the instrument is producing radiation in a potentially unsafe configuration (such as open enclosure of sample chamber)

Magenta: Indicates that the instrument has only passive indicators of instrument radiation status such as shutter position or beam on.

Red: Indicates that the instrument is either unsafe to operate, or requires strict administrative controls.

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Appendix B: Instrument Data Sheets

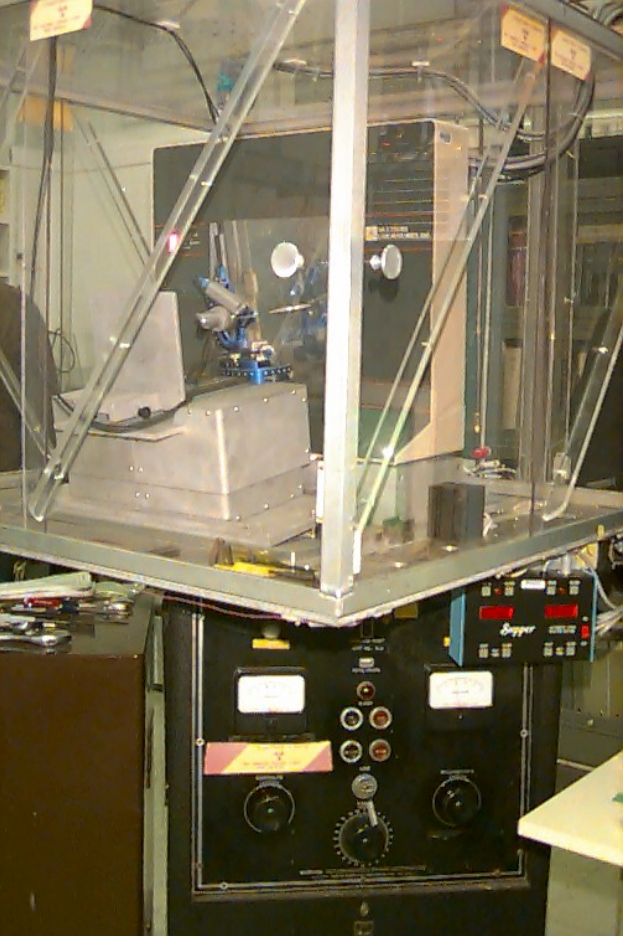
| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-2677 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | TEC | Model Number | 1630 |
| Date of Manufacture | 1986 | | |
| Assessment date | 03/07/2007 | | |
| Description | Large specimen stress analyzer | | |
| Modifications | Bypass switch, shutter added, enclosure added, shutter light added, shielding added, ORNL Annunciator Q6598 audible x-ray monitor/alarm added | | |
| Drawings | yes | | |
| Shutter Composition | 1.9mm WCu 70/30 wt% | | |
| Shutter Indicator #1 Description | Yellow light in enclosure (failsafe) | | |
| Shutter Indicator #2 Description | Red dome light in enclosure tied to shutter (failsafe) | | |
| Shutter Indicator #3 Description | LED on 641 control panel | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | X-ray on, over ride light (modular) | | |
| Safety Feature #2 Description | Door interlocks | | |
| Safety Feature #3 Description | ORNL Annunciator Q6598 audible x-ray monitor/alarm (not failsafe) | | |
| Safety Feature #4 Description | Shielding/enclosure | | |
| Safety Feature #5 Description | Audible and visual bypass indicator (failsafe unknown) | | |
| Notes: Rotary shutter |  | | |


| Table 1 | Instrument Data Sheet | | |
|---|--|---------------------|---|
| RASIN ID # | XG-3008 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Field Emission Corp. | Model Number | Faxitron 805 |
| Date of Manufacture | 1981 | | |
| Assessment date | 2/1/2007 | | |
| Description | Cabinet X-ray machine, output exposure ~ 60 R/h | | |
| Modifications | None | | |
| Drawings | Schematic diagram included in the Operating Procedure | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "EXPOSE" light/switch indicator on the cabinet door. | | |
| Safety Feature #2 Description | Redundent door interlocks for deenergizing X-ray tube. | | |
| Safety Feature #3 Description | Timer | | |
| Safety Feature #4 Description | NA | | |

Notes:

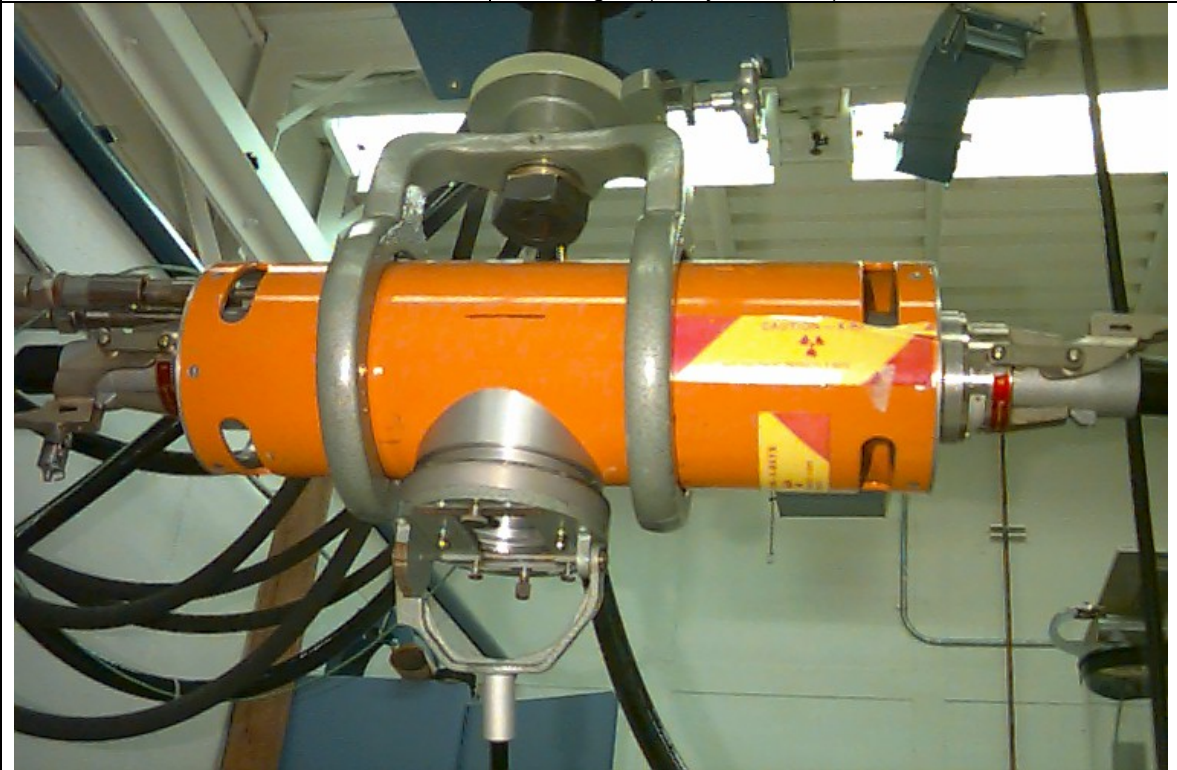
Operating procedure stated that the timer should be turned to zero before opening the cabinet door. Do not depend on interlocks to turn X-rays off. Discussed with the custodian and this procedure steps were well followed.



| Table 1 | | Instrument Data Sheet | |
|---|--|---|---|
| RASIN ID # | XG-3020 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Norelo/Philips | Model Number | Type 12045B-2 |
| Date of Manufacture | 1948 Approx | | |
| Assessment date | 5/24/07 | | |
| Description | X-ray diffractometer | | |
| Modifications | Enclosure and safety systems added | | |
| Drawings | Yes, on file. | | |
| Shutter Composition | Brass (CuZn) slide with bare lead plate affixed | | |
| Shutter Indicator #1 Description | Mechanical port indicator (both ports) | | |
| Shutter Indicator #2 Description | LED port indicator (both ports) | | |
| Shutter Indicator #3 Description | Real-time Laue light (one port only) | | |
| Shutter Indicator #4 Description | Charles Supper brand indicator (both ports) | | |
| Safety Feature #1 Description | X-ray On Light, overhead | | |
| Safety Feature #2 Description | X-ray On Light, panel | | |
| Safety Feature #3 Description | Door Interlocks (2 each, 8 doors) | | |
| Safety Feature #4 Description | Shutter switches, both ends of shutter travel have interlocks. That is, a switch for when the shutter is fully open and another for fully closed | | |
| <p>Notes: All shutter indicators are fail-safe. Tube tower has added lead shielding. Lead plate on shutter has 0.5 mm clearance; no sticking reported since installation in 2000 (approx).</p> | |  | |

| Table 1 | Instrument Data Sheet | | |
|--|---|---------------------|---|
| RASIN ID # | XG-3022 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | North America Philips | Model Number | 2045/1 |
| Date of Manufacture | ~ 1952 | | |
| Assessment date | 2/15/2007 | | |
| Description | X-ray diffraction unit, sealed tube with a back-reflection camera. | | |
| Modifications | Modified enclosure door interlock. Added Blake Industries shutter mechanism. | | |
| Drawings | Interlock circuit. | | |
| Shutter Composition | Lead. | | |
| Shutter Indicator #1 Description | Lamp on the control panel. | | |
| Shutter Indicator #2 Description | Small lamp on the shutter. | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray Hazard" lamp | | |
| Safety Feature #2 Description | door interlocks* | | |
| Safety Feature #3 Description | X-ray ON lamp on panel | | |
| Safety Feature #4 Description | | | |
| Notes: |  | | |
| All shutter indicators are fail-safe. Tube tower has added lead shielding. Lead plate on shutter has 0.5 mm clearance; no sticking reported since installation in 2000 (approx). | | | |

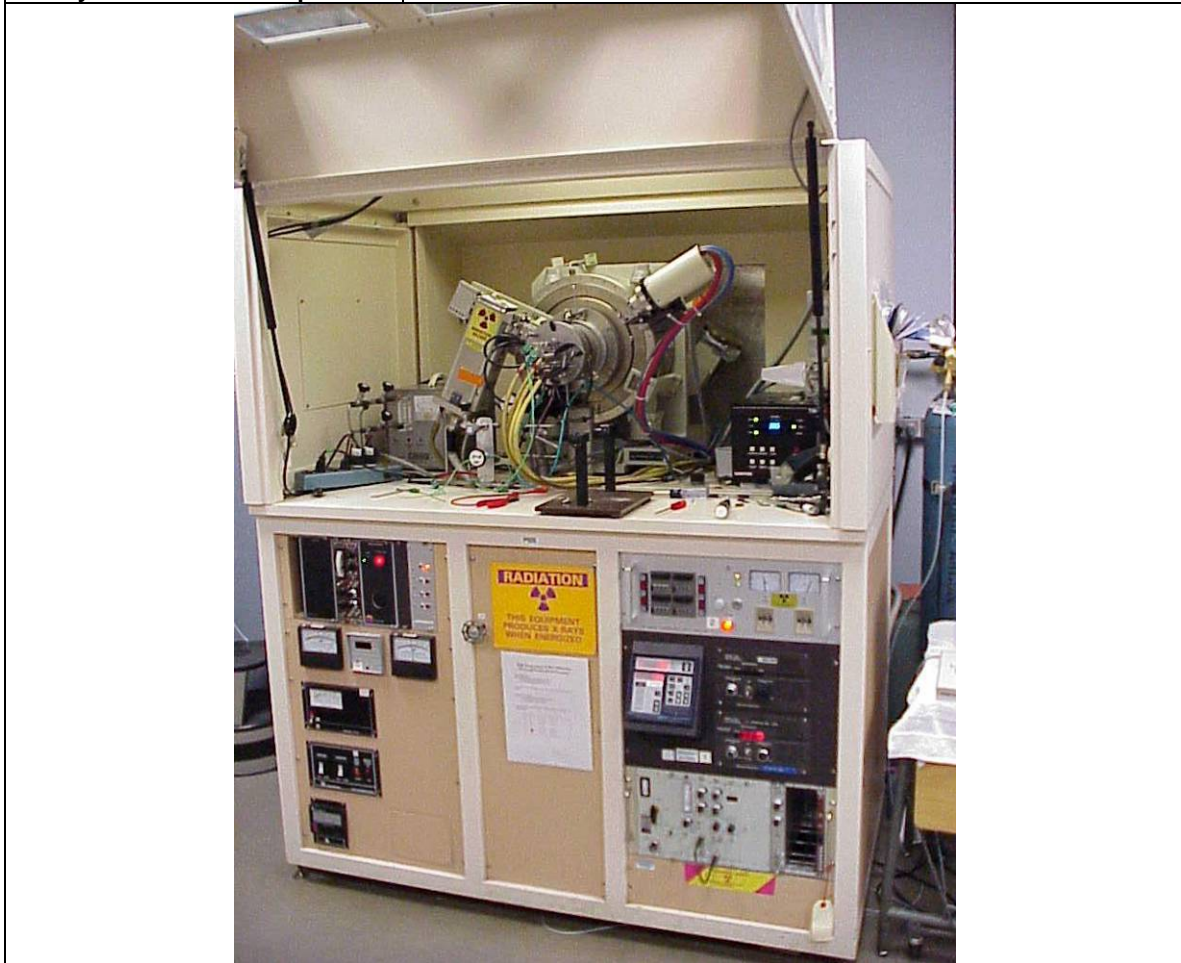
| Table 1 | Instrument Data Sheet | | |
|---|--|---------------------|---|
| RASIN ID # | 3089 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Seifert | Model Number | ISP Volt 320 |
| Date of Manufacture | 1989 | | |
| Assessment date | 01/29/2007 | | |
| Description | Seifert radiography unit, in vault, 320 kV | | |
| Modifications | None, but vault is ORNL-designed and provided, as is one indicator panel. | | |
| Drawings | Drawings of safety circuits are available per AJB | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | Not applicable | | |
| Shutter Indicator #2 Description | Not applicable | | |
| Shutter Indicator #3 Description | Not applicable | | |
| Shutter Indicator #4 Description | Not applicable | | |
| Safety Feature #1 Description | Shielded vault | | |
| Safety Feature #2 Description | Door lock magnet | | |
| Safety Feature #3 Description | Door interlock switches | | |
| Safety Feature #4 Description | Scram button with lights | | |
| Safety Feature #5 Description | Lights and bell | | |
| Safety Feature #6 Description | Dual radiation detectors, inside vault, to panel ratemeters | | |
| Safety Feature #7 Description | Padlock (used when not in use) | | |
| Safety Feature #8 Description | External Geiger counter | | |
| Safety Feature #9 Description | Scram button, kills X-rays (but not source radiation), unlocks door magnet (safety feature #2) | | |



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3094 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Rigaku | Model Number | Rotaflex Ru 200 |
| Date of Manufacture | | | |
| Assessment date | 2/15/2007 | | |
| Description | Rotating anode X-ray Diffraction Unit. The unit has two beam lines but only one is active. | | |
| Modifications | Added enclosure door interlock. Replaced lead shutter and added X-ray area monitor/alarm. | | |
| Drawings | Interlock circuit. | | |
| Shutter Composition | Contains no lead. | | |
| Shutter Indicator #1 Description | Shutter indicator on the control panel. | | |
| Shutter Indicator #2 Description | Lamp on the shutter. | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | X-ray monitor and audible alarm* | | |
| Safety Feature #2 Description | door interlock | | |
| Safety Feature #3 Description | X-ray ON lamp | | |
| Safety Feature #4 Description | window interlock** | | |
| Notes: | | | |
| *The monitor/alarm is activated only when the door is open and shutter is open and bypass switch is active. | | | |
| ** The window interlock was never used. | | | |



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3097 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | PAD X |
| Date of Manufacture | 1987 | | |
| Assessment date | 2/22/2007 | | |
| Description | X-ray diffraction unit | | |
| Modifications | Added mechanical shutter position flag. Added detector annunciator/alarm. | | |
| Drawings | | | |
| Shutter Composition | Tantalum | | |
| Shutter Indicator #1 Description | LED on tube housing | | |
| Shutter Indicator #2 Description | Shutter position flag | | |
| Shutter Indicator #3 Description | Shutter OPEN lamp (failsafe) | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Enclosure door lock. | | |
| Safety Feature #2 Description | Detector annunciator/alarm | | |
| Safety Feature #3 Description | NA | | |
| Safety Feature #4 Description | NA | | |



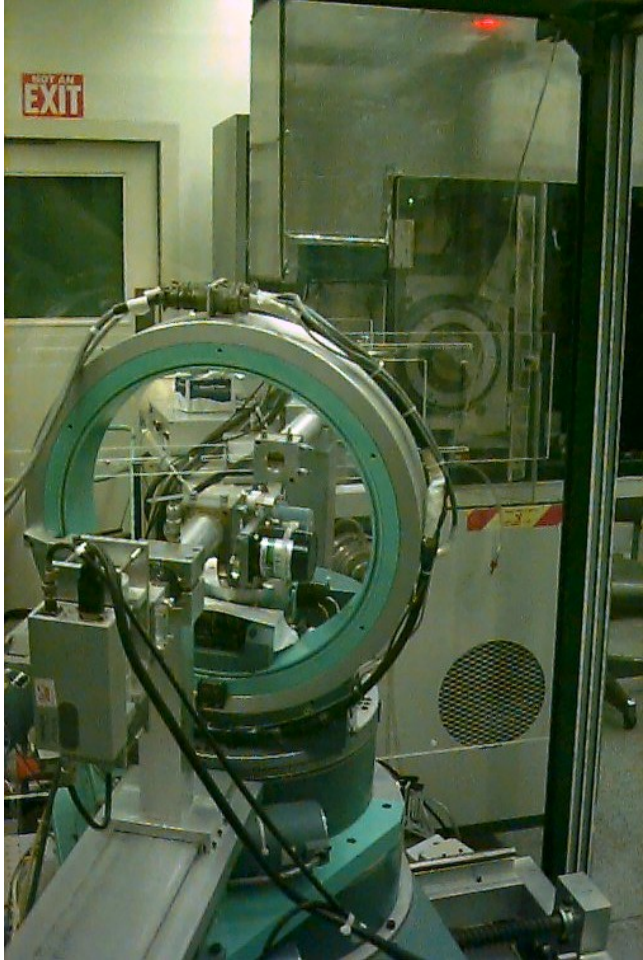
| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3098 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | PAD V |
| Date of Manufacture | 1987 | | |
| Assessment date | 1/11/2007 | | |
| Description | Single-head X-ray diffraction unit operating at max 40 kV | | |
| Modifications | Enclosure interlock, by-pass controller, "X-ray ON" lamp, shielding added to the bottom of the tube housing. | | |
| Drawings | Some interlock drawings on file at I&C | | |
| Shutter Composition | Unknown | | |
| Shutter Indicator #1 Description | Multiple LEDs – primary indicator | | |
| Shutter Indicator #2 Description | Multiple LEDs | | |
| Shutter Indicator #3 Description | Mechanical indicator | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON/OFF" LEDs (failsafe) | | |
| Safety Feature #2 Description | Independent enclosure interlock with redundant indicators | | |
| Safety Feature #3 Description | Manufacturer provided X-ray ON/OFF switch | | |
| Safety Feature #4 Description | By-pass indicator inside the indicator | | |

Notes:
 Custodian noted that Shutter Indicator #1 is failsafe based on I&C evaluation; Shutter Indicator #2 is not failsafe re shutter position. Custodian masked Shutter Indicator #2 with a cardboard. He instructed the uses to rely on Shutter Indicator #1 LEDs and the mechanical indicator.

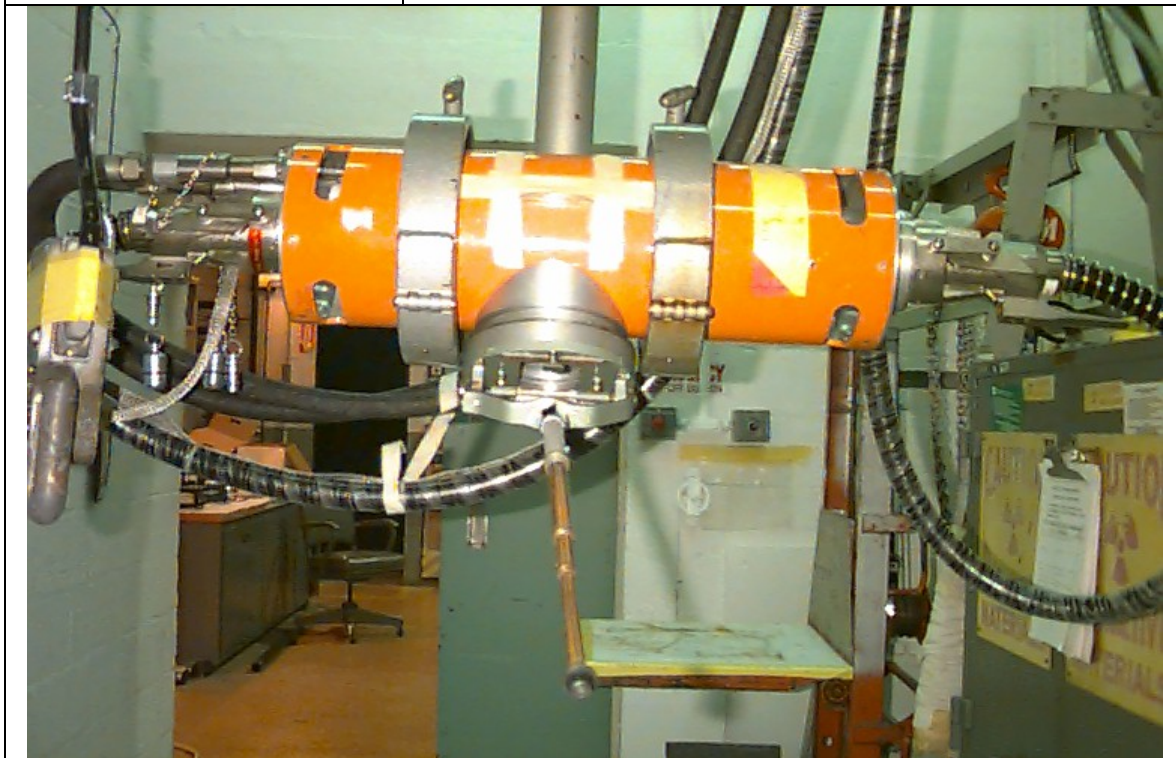


| Table 1 | Instrument Data Sheet | | |
|---|--|---------------------|---|
| RASIN ID # | 3100 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Philips | Model Number | 942117039612 |
| Date of Manufacture | 1985 | | |
| Assessment date | 01/29/2007 | | |
| Description | Low Power Philips radiography unit, in vault, 50 kV | | |
| Modifications | None, but vault is ORNL-designed and provided, as is one indicator panel. | | |
| Drawings | Drawings of safety circuits are available per AJB | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | Not applicable | | |
| Shutter Indicator #2 Description | Not applicable | | |
| Shutter Indicator #3 Description | Not applicable | | |
| Shutter Indicator #4 Description | Not applicable | | |
| Safety Feature #1 Description | Shielded vault | | |
| Safety Feature #2 Description | Door lock magnet | | |
| Safety Feature #3 Description | Door interlock switches | | |
| Safety Feature #4 Description | Scram button with lights | | |
| Safety Feature #5 Description | Lights and bell | | |
| Safety Feature #6 Description | Dual radiation detectors, inside vault, to panel ratemeters | | |
| Safety Feature #7 Description | Padlock (used when not in use) | | |
| Safety Feature #8 Description | External Geiger counter | | |
| Safety Feature #9 Description | Scram button, kills X-rays (but not source radiation), unlocks door magnet (safety feature #2) | | |



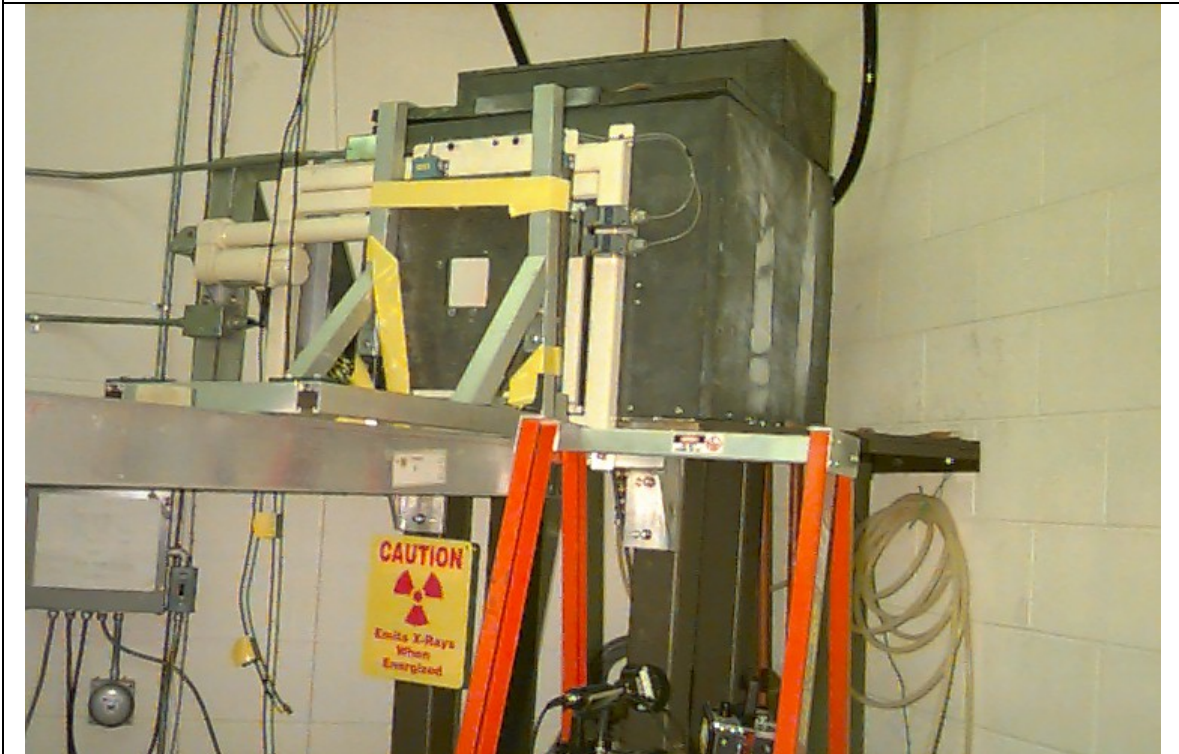
| Table 1 | | Instrument Data Sheet | |
|---|--|---|---|
| RASIN ID # | XG-3109 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Rigaku | Model Number | Ru-300 |
| Date of Manufacture | January 2006 | | |
| Assessment date | 3/8/2007 | | |
| Description | Diffraction unit, 100 mA @ 50 kV | | |
| Modifications | Enclosure interlock on both sides | | |
| Drawings | Door interlock drawing on file | | |
| Shutter Composition | Change to tantalum in 2003 (originally was lead shutter) | | |
| Shutter Indicator #1 Description | Shutter indicator on the panel | | |
| Shutter Indicator #2 Description | Lamp in the enclosure for the powder unit and on top and two sides of the enclosure for the 4 circle unit. | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" lamp on the panel | | |
| Safety Feature #2 Description | "X-ray On" lamp on top of the machine | | |
| Safety Feature #3 Description | Door interlock for the powder unit; shutter interlock switch for the 4-circle unit | | |
| Safety Feature #4 Description | Detector annunciator and audible alarm for the powder unit; the audible alarm for the 4-circle unit | | |
| <p>Notes: This device contains two X-ray units – a powder diffractometer and a four-circle diffractometer</p> | |  | |

| Table 1 | Instrument Data Sheet | | |
|---|--|---------------------|---|
| RASIN ID # | 3110 | In Use? | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No |
| Manufacturer | Seifert | Model Number | |
| Date of Manufacture | | | |
| Assessment date | 01/29/2007 | | |
| Description | Seifert radiography unit, in vault, 320 kV | | |
| Modifications | None, but vault is ORNL-designed and provided, as is one indicator panel. | | |
| Drawings | Drawings of safety circuits are available per AJB | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | Not applicable | | |
| Shutter Indicator #2 Description | Not applicable | | |
| Shutter Indicator #3 Description | Not applicable | | |
| Shutter Indicator #4 Description | Not applicable | | |
| Safety Feature #1 Description | Shielded vault | | |
| Safety Feature #2 Description | Door lock magnet | | |
| Safety Feature #3 Description | Door interlock switches | | |
| Safety Feature #4 Description | Scram button with lights | | |
| Safety Feature #5 Description | Lights and bell | | |
| Safety Feature #6 Description | Dual radiation detectors, inside vault, to panel ratemeters | | |
| Safety Feature #7 Description | Padlock (used when not in use) | | |
| Safety Feature #8 Description | External Geiger counter | | |
| Safety Feature #9 Description | Scram button, kills X-rays (but not source radiation), unlocks door magnet (safety feature #2) | | |



| Table 1 | Instrument Data Sheet | | |
|----------------------------------|--|--------------|---|
| RASIN ID # | XG-3119 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Pantak | Model Number | HF-320 |
| Date of Manufacture | 1987 | | |
| Assessment date | 5/22/07 | | |
| Description | Irradiator | | |
| Modifications | None to safety features. Did replace oil filter cooler. | | |
| Drawings | Yes, on file. | | |
| Shutter Composition | Two: High speed LEAD shutter for exposures-NOT INTERLOCKED; Steel encased lead Biological shutter-interlocked | | |
| Shutter Indicator #1 Description | Biological Shutter-Red indicator light | | |
| Shutter Indicator #2 Description | | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | Shield Door Interlocks | | |
| Safety Feature #2 Description | Biological Shield Interlocks | | |
| Safety Feature #3 Description | Area Monitor | | |
| Safety Feature #4 Description | X-ray on lights (2) | | |
| Safety Feature #5 Description | Warning Bell and delay | | |
| Safety Feature #6 Description | Generator key switch | | |

Notes:
 "Beam On" lights indicate status of High speed shutter.



| Table 1 | Instrument Data Sheet | | |
|---|--|---------------------|---|
| RASIN ID # | XG-3124 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Philips | Model Number | MCG-30 |
| Date of Manufacture | Early 1990s | | |
| Assessment date | 05/09/2007 | | |
| Description | 320 kV constant potential, 20 mA | | |
| Modifications | Pre-warn timer extended to 20 seconds warning | | |
| Drawings | Yes | | |
| Shutter Composition | High speed (not safety), lead Safety shutter, lead, steel encased | | |
| Shutter Indicator #1 Description | Red light on generator | | |
| Shutter Indicator #2 Description | Red light on wall | | |
| Shutter Indicator #3 Description | Red light outside door | | |
| Shutter Indicator #4 Description | Console light | | |
| Safety Feature #1 Description | Safety shutter, CDRH switches (2) to power supply, in parallel | | |
| Safety Feature #2 Description | Door interlocks | | |
| Safety Feature #3 Description | Scram switches (3) | | |
| Safety Feature #4 Description | "Run/Safe" switch | | |
| Safety Feature #5 Description | "X-Ray On" light on generator and door | | |
| Notes: 2 CDRH switches wired in parallel, on door and safety shutter. "Run/safe" switch prevents energizing device during maintenance. | | | |
| | | | |

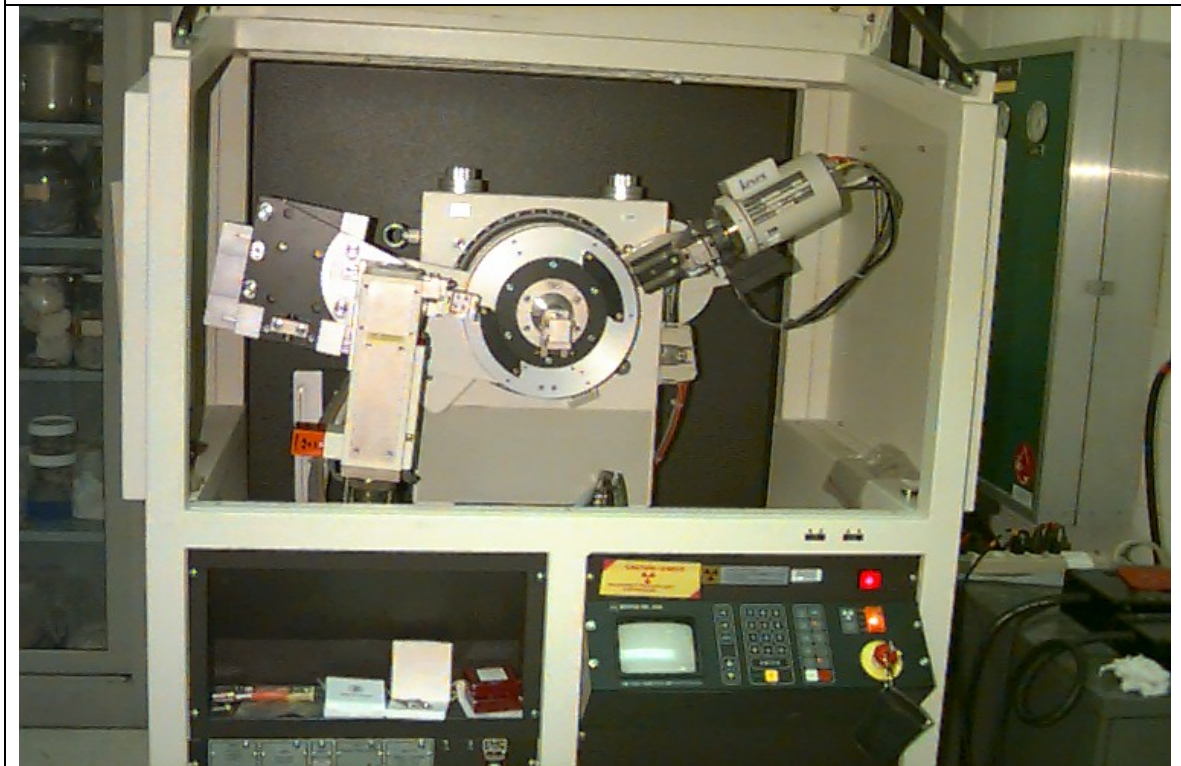
| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3125 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | XDS-2000 |
| Date of Manufacture | March 1992 | | |
| Assessment date | 03/07/2007 | | |
| Description | Rotating anode diffraction unit | | |
| Modifications | ORNI audible indicator Modified shutters – tantalum Shutter open light made failsafe Brass, lead tube tower parts replaced with 304L stainless steel (1 copper shim remaining) | | |
| Drawings | Yes | | |
| Shutter Composition | 4.5mm tantalum | | |
| Shutter Indicator #1 Description | Shutter open light inside enclosure (failsafe) | | |
| Shutter Indicator #2 Description | Console LED (failsafe unknown) | | |
| Shutter Indicator #3 Description | Manual shutter position lever (failsafe) | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | X-ray on light (failsafe) | | |
| Safety Feature #2 Description | ORNL audible annunciator (not failsafe) | | |
| Safety Feature #3 Description | Audible and visual bypass indicator (failsafe unknown) | | |
| Safety Feature #4 Description | Door interlocks | | |

Notes:

There are two shutters, manual and electronically operated. Both are 4.5mm tantalum.

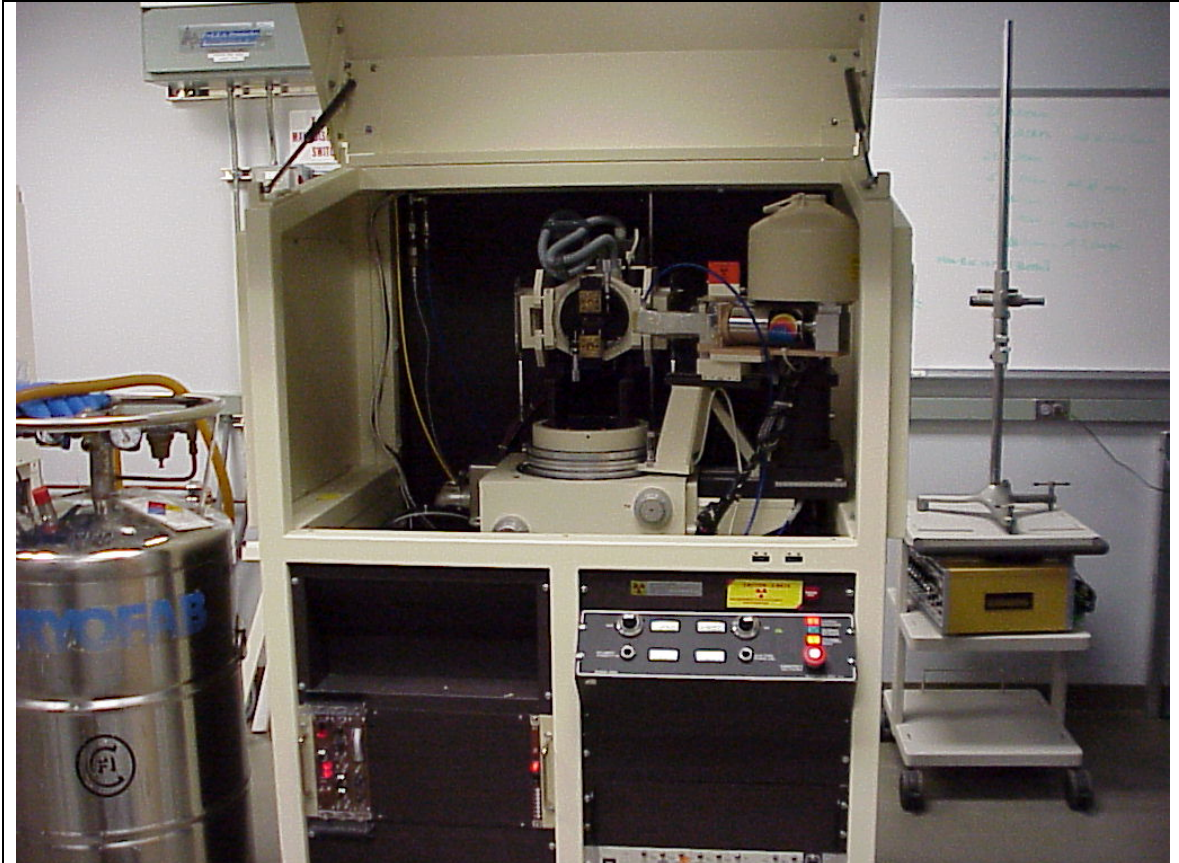


| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3126 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | XDS 2000 |
| Date of Manufacture | | | |
| Assessment date | 3/28/2007 | | |
| Description | Automated X-ray Powder Diffractometer system. | | |
| Modifications | Added the ORNL Q6598 X-ray Area Monitor & Alarm . | | |
| Drawings | In I&C file. | | |
| Shutter Composition | Not known. | | |
| Shutter Indicator #1 Description | LED on the shutter | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-Ray ON" indicator on the tube | | |
| Safety Feature #2 Description | "X-Ray ON" indicator on the panel | | |
| Safety Feature #3 Description | Enclosure interlock | | |
| Safety Feature #4 Description | Area Monitor and Alarm | | |
| Notes: | | | |



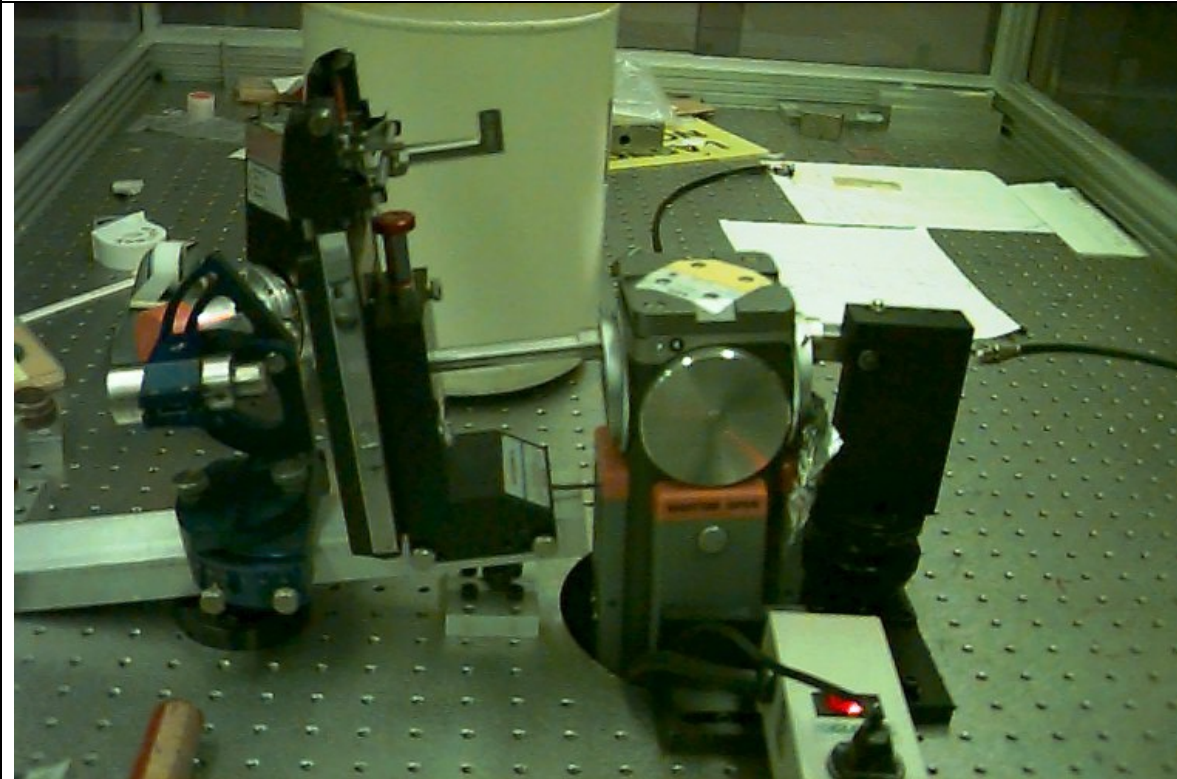
| Table 1 | Instrument Data Sheet | | |
|---|---|---------------------|---|
| RASIN ID # | XG-3129 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | XDS 2000 |
| Date of Manufacture | July 1994 | | |
| Assessment date | 03/07/2007 | | |
| Description | X-ray diffraction unit | | |
| Modifications | ORNL Annunciator Q6598 audible x-ray monitor/alarm Moved "X-ray On" light to more prominent location | | |
| Drawings | Yes, to include ORNL Q6598 | | |
| Shutter Composition | 3mm steel | | |
| Shutter Indicator #1 Description | Shutter open light #1 in enclosure (not failsafe) | | |
| Shutter Indicator #2 Description | Shutter open light #2 in enclosure, 6 LED, position-sensitive. Status unknown for burned-out LED(s) | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | X-ray On light (failsafe status unknown) | | |
| Safety Feature #2 Description | Key switch | | |
| Safety Feature #3 Description | Door interlocks | | |
| Safety Feature #4 Description | ORNL Annunciator Q6598 audible x-ray monitor/alarm (not failsafe) | | |


Notes:



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3130 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | General Electric | Model Number | SRG-5 |
| Date of Manufacture | Around 1964 | | |
| Assessment date | 3/8/2007 | | |
| Description | The device has two X-ray tube heads with shutters. | | |
| Modifications | Added enclosure in 1996 | | |
| Drawings | | | |
| Shutter Composition | Tungsten alloy | | |
| Shutter Indicator #1 Description | Shutter indicator on the control box | | |
| Shutter Indicator #2 Description | Shutter indicator above the shutter (fail safe) | | |
| Shutter Indicator #3 Description | Mechanical shutter | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" lamp on the panel (not fail safe) | | |
| Safety Feature #2 Description | "X-ray ON" lamp above the enclosure (fail safe) | | |
| Safety Feature #3 Description | Door interlock to the X-ray power | | |
| Safety Feature #4 Description | NA | | |

Notes:



| Table 1 | Instrument Data Sheet | | |
|---|---|---------------------|---|
| RASIN ID # | XG-3131 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | X-1 (ID-3000) |
| Date of Manufacture | | | |
| Assessment date | 1/25/2007 | | |
| Description | X-ray Diffraction Unit | | |
| Modifications | Added X-ray Area Monitor and Alarm (ORNL Q6598). | | |
| Drawings | In the manufacturer's technical manual (X-1) | | |
| Shutter Composition | lead | | |
| Shutter Indicator #1 Description | Red indicator LED | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" lamp on the machine | | |
| Safety Feature #2 Description | X-ray monitor alarm (audible) | | |
| Safety Feature #3 Description | X-ray monitor lamp | | |
| Safety Feature #4 Description | Door interlock | | |
| Safety Feature #5 Description | Door interlock reset | | |
| Notes: |  | | |

| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3132 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Leybold-Heraeus Vacuum System | Model Number | EBW (15) 523640 |
| Date of Manufacture | Was installed in 1996 | | |
| Assessment date | 4/12/2007 | | |
| Description | Electron Beam Welder | | |
| Modifications | Upgrade of the computerized control panel was planned for 2007. | | |
| Drawings | Available at I&C | | |
| Shutter Composition | The device has no shutter. | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Vacuum Ready light | | |
| Safety Feature #2 Description | Five emergency stop buttons | | |
| Safety Feature #3 Description | Beam-On indicator/beam current meter | | |
| Safety Feature #4 Description | Shielding interlock | | |

Notes:

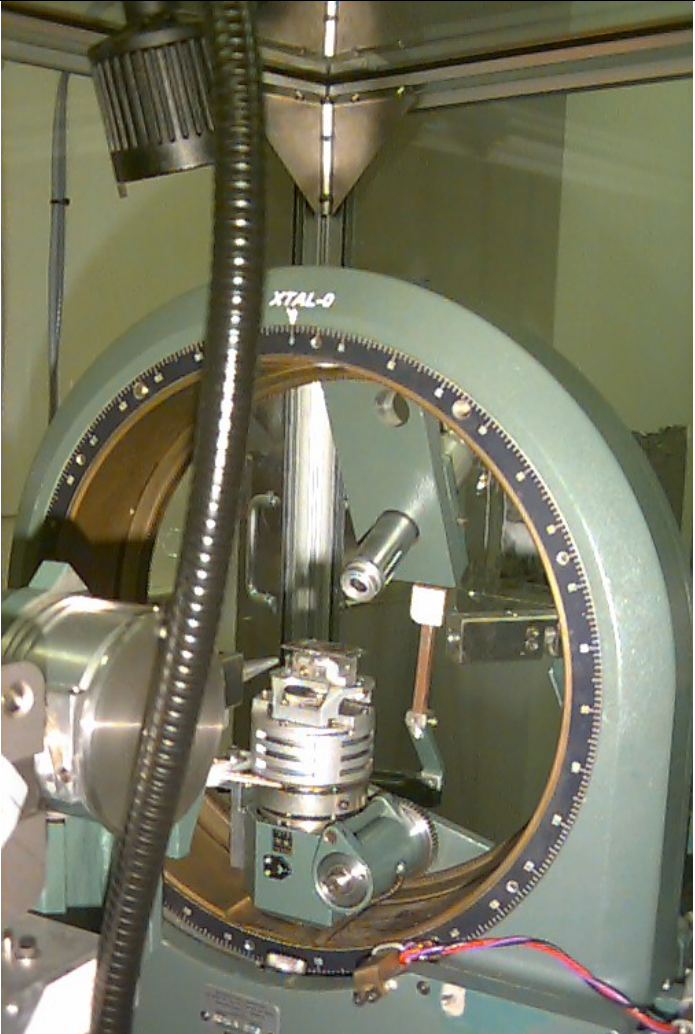
The beam current meter functions as a redundant "Beam On" indicator.



| Table 1 | Instrument Data Sheet | | |
|---|---|---------------------|---|
| RASIN ID # | XG-3133 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | PTR Precision Technologies | Model Number | S/N 698 |
| Date of Manufacture | | | |
| Assessment date | 3/28/2007 | | |
| Description | Electron beam welder; max power 150 kV and 100 mA; only tungsten is used as target. | | |
| Modifications | None | | |
| Drawings | In I&C file. | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "Vacuum Ready" light on the panel | | |
| Safety Feature #2 Description | Emergency Stop buttons (5 total) | | |
| Safety Feature #3 Description | "Beam ON" indicator/beam current meter | | |
| Safety Feature #4 Description | Shield Interlock | | |

Notes:
 Emergency Stop buttons cut off tube HV when activated.
 The beam current meter functions as a redundant "Beam ON" indicator.
 Shield interlock cut down the HV when activated.



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3153 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Spellman | Model Number | DF3 |
| Date of Manufacture | 1997 | | |
| Assessment date | 3/8/2007 | | |
| Description | Diffraction unit, 50 mA @ 60 kV. There are four diffractometers in the device but only one is in use which has shutter installed. | | |
| Modifications | Door switches interlocked to the X-ray generator and lead shutter replaced with tungsten.. | | |
| Drawings | | | |
| Shutter Composition | Change to tungsten in 2002 (originally was lead shutter) | | |
| Shutter Indicator #1 Description | Shutter indicator on the panel | | |
| Shutter Indicator #2 Description | Shutter indicator above the shutter | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" lamp on the panel | | |
| Safety Feature #2 Description | "X-ray On" lamp on top of the RGD | | |
| Safety Feature #3 Description | Door interlocks (mechanical, connect to the X-ray power) | | |
| Safety Feature #4 Description | Door interlocks (magnetic, connected to the shutter) | | |
| Notes: |  | | |

| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3155 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Siemens/Bruker | Model Number | D5005 |
| Date of Manufacture | 1995/1996 | | |
| Assessment date | 5/16/07 | | |
| Description | X-ray diffractometer | | |
| Modifications | None | | |
| Drawings | Yes, on file. | | |
| Shutter Composition | Brass (CuZn) | | |
| Shutter Indicator #1 Description | Tube Tower-2 lights; Light filaments are in series with shutter switch | | |
| Shutter Indicator #2 Description | | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | X-ray On Light, on top of cabinet; tied to generator in series with enclosure switch. | | |
| Safety Feature #2 Description | Door Interlock, 3 switches | | |
| Safety Feature #3 Description | Service Door Interlock | | |
| Safety Feature #4 Description | Computer signal to Shutter Switch | | |
| Safety Feature #5 Description | Shutter interlock switches, both ends of shutter travel have interlocks. That is, a switch for when the shutter is fully open and another for fully closed | | |



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3157 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Scintag | Model Number | XDS 2000 |
| Date of Manufacture | ~ 1991 | | |
| Assessment date | 2/22/2007 | | |
| Description | X-ray diffraction unit | | |
| Modifications | Replaced back enclosure (metal) with plastic. Added detector annunciator/alarm. | | |
| Drawings | | | |
| Shutter Composition | Tantalum | | |
| Shutter Indicator #1 Description | Orange LED on tube housing | | |
| Shutter Indicator #2 Description | Big "Shutter OPEN" lamp | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Enclosure door lock. | | |
| Safety Feature #2 Description | Detector annunciator/alarm | | |
| Safety Feature #3 Description | NA | | |
| Safety Feature #4 Description | NA | | |
| Notes: | | | |



| Table 1 | Instrument Data Sheet | | |
|---|---|---------------------|---|
| RASIN ID # | XG-3161 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Panalytical | Model Number | XPert Pro MPD |
| Date of Manufacture | 11/2000 | | |
| Assessment date | 03/07/07 | | |
| Description | X-Ray diffractometer | | |
| Modifications | ORNL Annunciator Q6598 audible x-ray monitor/alarm | | |
| Drawings | ORNL I&C | | |
| Shutter Composition | Gold coated WCu alloy, 78/22 wt%, 4.4mm thick | | |
| Shutter Indicator #1 Description | Panel indicator (failsafe) | | |
| Shutter Indicator #2 Description | LED indicator, not part of safety circuit, not failsafe | | |
| Shutter Indicator #3 Description | Doors will lock (failsafe) | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | ORNL Annunciator Q6598 audible x-ray monitor/alarm (not failsafe) | | |
| Safety Feature #2 Description | X-ray On light (failsafe) | | |
| Safety Feature #3 Description | Key switch | | |
| Safety Feature #4 Description | Panel HV and mA indicator | | |
| Safety Feature #5 Description | Front and rear door interlocks (failsafe) | | |



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3164 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | YXLON | Model Number | MGC41 |
| Date of Manufacture | 6/2002 | | |
| Assessment date | 5/17/07 | | |
| Description | Cabinet, enclosed beam | | |
| Modifications | None | | |
| Drawings | Yes, on file. | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | X-ray On Light, on top of cabinet | | |
| Safety Feature #2 Description | Door Interlock | | |
| Safety Feature #3 Description | X-ray On Light, on control panel | | |
| Safety Feature #4 Description | Safety circuit light (door), green light on control panel | | |
| Notes: | | | |



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3165 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Omni Instruments | Model Number | Spellman DF3 (generator) |
| Date of Manufacture | 1997 | | |
| Assessment date | 3/8/2007 | | |
| Description | Vacuum chamber x-ray diffractometer., operated at 30 mA @ 50 kV (max) | | |
| Modifications | Lead tape added as shielding and shutter material modified. | | |
| Drawings | On file | | |
| Shutter Composition | Changed from lead to tungsten in 2003 | | |
| Shutter Indicator #1 Description | "Shutter Open" indicator on the stand | | |
| Shutter Indicator #2 Description | "Shutter Closed" indicator on the stand | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Yellow "X-ray ON" indicator on the tower (fail-safe) | | |
| Safety Feature #2 Description | Red "X-ray ON" push button on lamp on the panel (redundant and fail-safe) | | |
| Safety Feature #3 Description | Vacuum switches interlocked to the tube HV | | |
| Safety Feature #4 Description | Flange switches interlocked to both the tube HV and shutter | | |

Notes:

Vacuum switches activate at less than 10 mill torr (shut down HV).



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3166 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Omni Instruments | Model Number | Spellman DF3 (generator) |
| Date of Manufacture | 2002 | | |
| Assessment date | 4/4/2007 | | |
| Description | Reel-to-reel X-ray Diffraction unit, 30 mA @ 50 kV. | | |
| Modifications | Lead shutter was replaced with tungsten in 2003. Shutter controller motor replaced in 2006. | | |
| Drawings | | | |
| Shutter Composition | Tungsten | | |
| Shutter Indicator #1 Description | Red "Shutter Open" indicator on tower | | |
| Shutter Indicator #2 Description | Green "Shutter Closed" indicator on tower | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Yellow "X-ray ON" lamp on tube tower | | |
| Safety Feature #2 Description | Red "X-ray ON" lamp on the panel | | |
| Safety Feature #3 Description | Door interlocks (to HV and shutter) on the primary door. | | |
| Safety Feature #4 Description | Door interlocks (HV) on two other doors. | | |
| Notes: The RGD enclosure has three doors. The front door (primary door) is used during normal operation. Two side doors are padlocked. | | | |



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3167 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Quintek Measuring Systems | Model Number | QDP-01X |
| Date of Manufacture | 2002 | | |
| Assessment date | 05/21/07 | | |
| Description | Profiler | | |
| Modifications | Shutter logic modified during commissioning to dump generator power if shutter and door are both open. | | |
| Drawings | Yes | | |
| Shutter Composition | Unknown | | |
| Shutter Indicator #1 Description | Shutter open lights, 2 | | |
| Shutter Indicator #2 Description | Shutter closed lights, 2 | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | Door position (software) | | |
| Safety Feature #2 Description | X-ray on light | | |
| Safety Feature #3 Description | | | |
| Safety Feature #4 Description | | | |

Notes:



| Table 1 | Instrument Data Sheet | | |
|----------------------------------|---|--------------|---|
| RASIN ID # | XG-3168 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Amersham | Model Number | 660 B |
| Date of Manufacture | | | |
| Assessment date | 1/29/2007 | | |
| Description | Iridium-192 Radiography Camera | | |
| Modifications | None | | |
| Drawings | None – independent of vault | | |
| Shutter Composition | NA | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Camera shielding | | |
| Safety Feature #2 Description | Vault shielding | | |
| Safety Feature #3 Description | Crank cable padlock | | |
| Safety Feature #4 Description | Count rate meters (GM's inside vault) and external warning lights (outside vault) | | |
| Safety Feature #5 Description | Entrance door magnet | | |
| Safety Feature #6 Description | Count rate meter (GM) and audible indicator (both outside vault) | | |
| Safety Feature #7 Description | Vault door padlock | | |
| Safety Feature #8 Description | Lights inside vault and entrance door scram switch (button) | | |
| Safety Feature #9 Description | Camera tray interlock switch | | |
| Safety Feature #10 Description | Arming mechanism and key | | |
| Safety Feature #11 Description | Source armed interlock switch | | |



| Table 1 | Instrument Data Sheet | | |
|----------------------------------|---|--------------|---|
| RASIN ID # | XG-3169 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Amersham | Model Number | 660 B |
| Date of Manufacture | | | |
| Assessment date | 1/29/2007 | | |
| Description | Iridium Radiography Camera | | |
| Modifications | None | | |
| Drawings | None – independent of vault | | |
| Shutter Composition | NA | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Camera shielding | | |
| Safety Feature #2 Description | Vault shielding | | |
| Safety Feature #3 Description | Crank cable padlock | | |
| Safety Feature #4 Description | Count rate meters (GM's inside vault) and external warning lights (outside vault) | | |
| Safety Feature #5 Description | Entrance door magnet | | |
| Safety Feature #6 Description | Count rate meter (GM) and audible indicator (both outside vault) | | |
| Safety Feature #7 Description | Vault door padlock | | |
| Safety Feature #8 Description | Lights inside vault and entrance door scram switch (button) | | |
| Safety Feature #9 Description | Camera tray interlock switch | | |
| Safety Feature #10 Description | Arming mechanism and key | | |
| Safety Feature #11 Description | Source armed interlock switch | | |
| Safety Feature #12 Description | Door safety audible alarm at control panel | | |



| | |
|---------|-----------------------|
| Table 1 | Instrument Data Sheet |
|---------|-----------------------|

| | | | |
|---|--------------------------|---------------------|---|
| RASIN ID # | XG-3175 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Source Ray | Model Number | SB-80-500 (source), Imtek (enclosure) |
| Date of Manufacture | 6/2003 | | |
| Assessment date | 05/25/07 | | |
| Description | MicroCat Tomography unit | | |
| Modifications | See notes | | |
| Drawings | Yes, See notes | | |
| Shutter Composition | Unknown | | |
| Shutter Indicator #1 Description | Software indicator | | |
| Shutter Indicator #2 Description | | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | X-Ray On light, panel | | |
| Safety Feature #2 Description | Sample chamber interlock | | |
| Safety Feature #3 Description | | | |
| Safety Feature #4 Description | | | |

Notes:

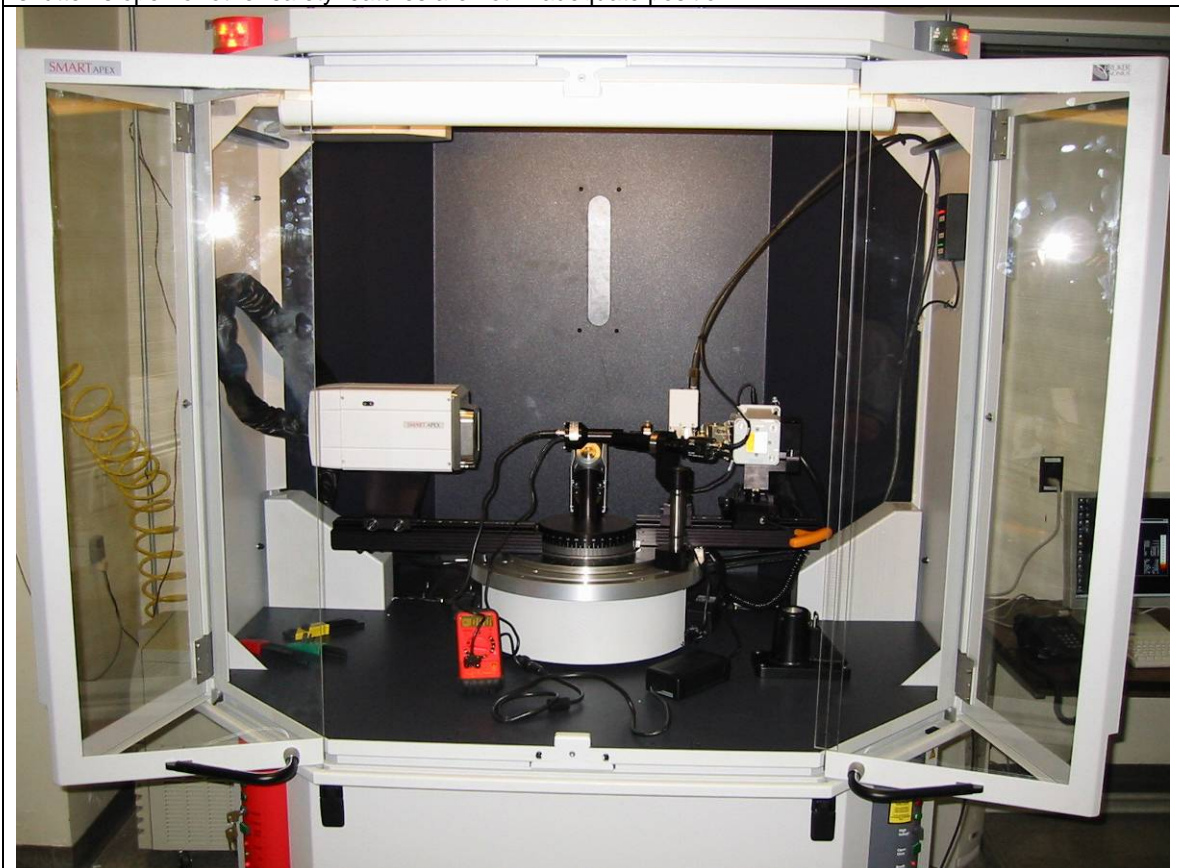
There are 9 interlocks on the Imtek enclosure. 8 would not be tripped under normal operation, only if covers were removed as for maintenance. The device is a custom-built micro tomography unit. Unit has been removed from service.



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3186 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Bruker AXS | Model Number | Smart APEX |
| Date of Manufacture | 2003 | | |
| Assessment date | 4/11/2007 | | |
| Description | X-ray diffraction device operated at 40 mA and 50 kV (max) | | |
| Modifications | Door switches interlocked to the X-ray generator and lead shutter replaced with tungsten.. | | |
| Drawings | | | |
| Shutter Composition | unknown (may be zinc coded based on custodian) | | |
| Shutter Indicator #1 Description | LEDs on the tube housing | | |
| Shutter Indicator #2 Description | LEDs on the enclosure interior wall | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Door lock | | |
| Safety Feature #2 Description | Door interlock switches* | | |
| Safety Feature #3 Description | Emergency STOP button | | |
| Safety Feature #4 Description | NA | | |

Notes:

* The interlock switches are on the top and bottom of each door. The interlock shuts off tube HV if the shutter is open or other safety features are not in adequate position.



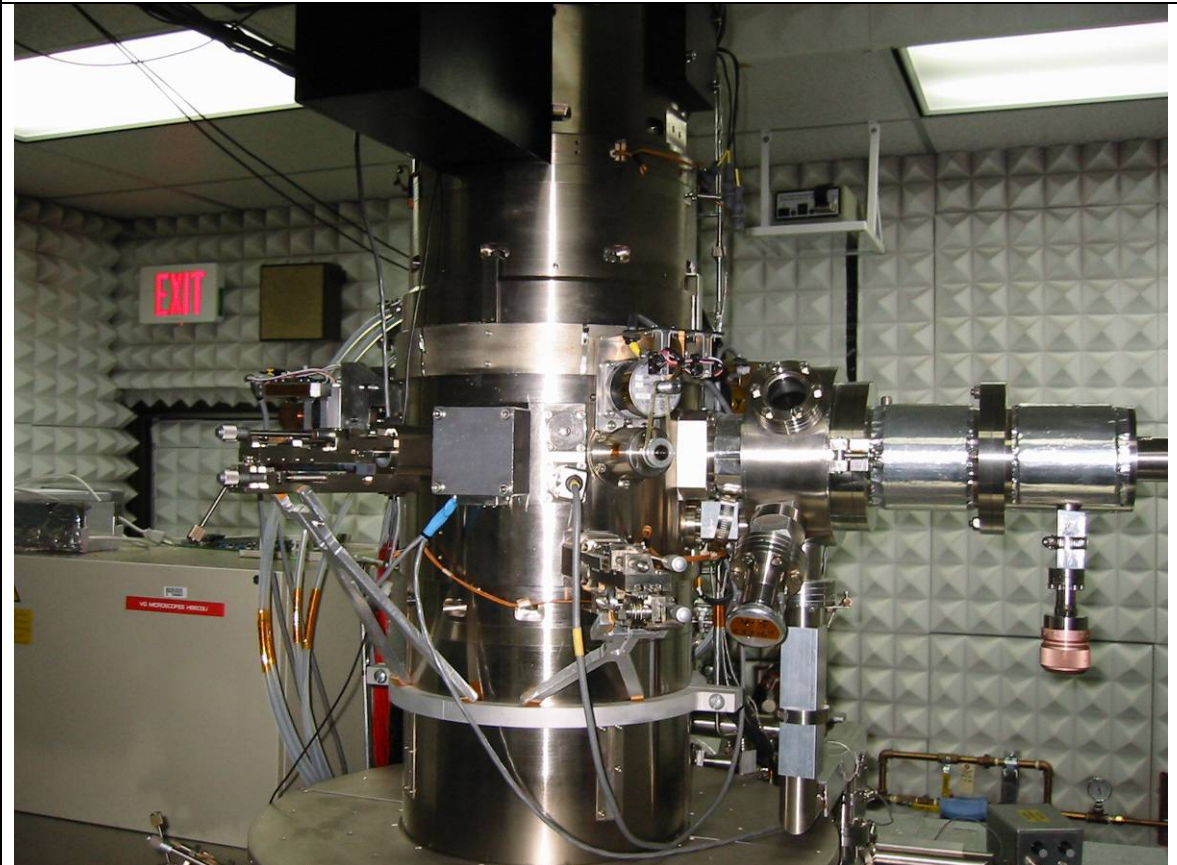
| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3187 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | PANalytical | Model Number | MRD |
| Date of Manufacture | 10/2003 | | |
| Assessment date | 5/24/07 | | |
| Description | X-ray diffractometer | | |
| Modifications | None | | |
| Drawings | Yes, on file. | | |
| Shutter Composition | Gold coated WCu (78/22 wt%) alloy | | |
| Shutter Indicator #1 Description | Green LED on Tube Tower (not fail-safe) | | |
| Shutter Indicator #2 Description | Shutter Open indicated by "1" appearing on control panel | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | Yellow Taxi Cab X-ray On Light, on top of cabinet. | | |
| Safety Feature #2 Description | 4 light bars on control panel | | |
| Safety Feature #3 Description | Door Lock/Interlock | | |
| Safety Feature #4 Description | | | |

Notes:
When the shutter opens, the door locks.



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3190 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | VG Scientific | Model Number | HB-603 |
| Date of Manufacture | 1990 | | |
| Assessment date | 5/24/07 | | |
| Description | Electron microscope | | |
| Modifications | Various upgrades | | |
| Drawings | Yes, by custodian. | | |
| Shutter Composition | NA/No shutter | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | Gun shielding switch (vessel) Interlock | | |
| Safety Feature #2 Description | Dark field detector switch Interlock | | |
| Safety Feature #3 Description | Viewing window Interlock | | |
| Safety Feature #4 Description | | | |

Notes:



| Table 1 | | Instrument Data Sheet | |
|---|--------------------------------------|-----------------------|---|
| RASIN ID # | XG-3201 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | INEL | Model Number | XRG 3000 |
| Date of Manufacture | 2004 | | |
| Assessment date | 4/19/2007 | | |
| Description | Powder diffraction X-ray unit. . | | |
| Modifications | | | |
| Drawings | | | |
| Shutter Composition | Either SS or nickel; no lead | | |
| Shutter Indicator #1 Description | Electronic LEDs on tube head | | |
| Shutter Indicator #2 Description | Mechanical shutter switch | | |
| Shutter Indicator #3 Description | Switch/lamp on the panel | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" lamp inside the enclosure | | |
| Safety Feature #2 Description | Door interlocked to shutter | | |
| Safety Feature #3 Description | Camera interlock | | |
| Safety Feature #4 Description | NA | | |

Notes:



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3204 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | SRNL | Model Number | CC-420-WSRS |
| Date of Manufacture | | | |
| Assessment date | 05/31/07 | | |
| Description | SRNL Maximus Radiography unit, fixed. No shutter | | |
| Modifications | No | | |
| Drawings | Yes | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | X-ray on light, panel | | |
| Safety Feature #2 Description | X-ray on light, cabinet | | |
| Safety Feature #3 Description | Door interlock switches (HV and LV contacts, dual) | | |
| Safety Feature #4 Description | Cover interlock switches, single (requires tools to remove) | | |
| Notes: | | | |
| X-ray source is Marietta X-ray, Inc. | | | |



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3205 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Hamamatsu | Model Number | L 8031-01 |
| Date of Manufacture | 2005 | | |
| Assessment date | 4/4/2007 | | |
| Description | Cabinet X-ray tomography unit operated at max 0.1 mA @ 100 kV. The beam is very close to the sample. | | |
| Modifications | | | |
| Drawings | | | |
| Shutter Composition | No shutter | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" lamp on the stand (failsafe and redundant) | | |
| Safety Feature #2 Description | "X-ray ON" lamp on the panel (failsafe) | | |
| Safety Feature #3 Description | Door interlocks (one magnetic switch on each 4 doors, interlocked to X-ray tube HV) | | |
| Safety Feature #4 Description | | | |

Notes:



| Table 1 | Instrument Data Sheet | | |
|---|-----------------------|---------------------|---|
| RASIN ID # | XG-3213 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | PACE | Model Number | XR3000 |
| Date of Manufacture | Nov. 2005 | | |
| Assessment date | 4/26/2007 | | |
| Description | Open-beam RGD. | | |
| Modifications | None | | |
| Drawings | In I&C file. | | |
| Shutter Composition | NA | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | "X-ray ON" indicator | | |
| Safety Feature #2 Description | NA | | |
| Safety Feature #3 Description | NA | | |
| Safety Feature #4 Description | NA | | |

Notes:

* I&C records showed that the "X-ray ON" indicator is not fail-safe. However, by design, if the "X-ray ON" light burns out, the X-ray power won't be turned on when the foot pedal is depressed. The foot pedal serves as the redundant indicator.



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3214 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Niton | Model Number | XLt 898SWY |
| Date of Manufacture | December 2005 | | |
| Assessment date | 5/2/2007 | | |
| Description | Handheld XRF, used inside a shielded stand. | | |
| Modifications | None | | |
| Drawings | NA | | |
| Shutter Composition | NA | | |
| Shutter Indicator #1 Description | NA | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | NA | | |
| Safety Feature #2 Description | NA | | |
| Safety Feature #3 Description | NA | | |
| Safety Feature #4 Description | NA | | |

Notes:



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3215 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | PANalytical | Model Number | X'Pert PRO |
| Date of Manufacture | January 2006 | | |
| Assessment date | 5/10/2007 | | |
| Description | Four-axis diffraction unit | | |
| Modifications | None | | |
| Drawings | Schematic diagram on file in the Facility Management Division (I&C group). | | |
| Shutter Composition | Gold plated SS; no lead | | |
| Shutter Indicator #1 Description | Indicator on the panel (fail-safe) | | |
| Shutter Indicator #2 Description | Yellow LED on tube tower | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Door lock. | | |
| Safety Feature #2 Description | Door interlock | | |
| Safety Feature #3 Description | "X-Ray ON" lamp (fail-safe) | | |
| Safety Feature #4 Description | NA | | |

Notes:



| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3216 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | PANalytical | Model Number | X'Pert PRO |
| Date of Manufacture | January 2006 | | |
| Assessment date | 5/10/2007 | | |
| Description | Four-axis diffraction unit | | |
| Modifications | None | | |
| Drawings | Schematic diagram on file in the Facility Management Division (I&C group). | | |
| Shutter Composition | Gold plated SS; no lead | | |
| Shutter Indicator #1 Description | Indicator on the panel (fail-safe) | | |
| Shutter Indicator #2 Description | Yellow LED on tube tower | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Door lock. | | |
| Safety Feature #2 Description | Door interlock | | |
| Safety Feature #3 Description | "X-Ray ON" lamp (fail-safe) | | |
| Safety Feature #4 Description | NA | | |

Notes:



| Table 1 | | Instrument Data Sheet | |
|---|---|-----------------------|---|
| RASIN ID # | XG-3217 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Kratos/Shimadzu | Model Number | uEDX-1300 |
| Date of Manufacture | January 2006 | | |
| Assessment date | 5/10/2007 | | |
| Description | X-ray Fluorescence Spectrometer; X-ray emitted at higher energy than XG-3215 or XG-3216 | | |
| Modifications | None | | |
| Drawings | Schematic diagram on file in the Facility Management Division (I&C group). | | |
| Shutter Composition | Gold plated SS; no lead | | |
| Shutter Indicator #1 Description | Shutter CLOSE IED on the panel | | |
| Shutter Indicator #2 Description | NA | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Door lock. | | |
| Safety Feature #2 Description | Door interlock (microswitch on either side of the door) | | |
| Safety Feature #3 Description | NA | | |
| Safety Feature #4 Description | NA | | |
| Notes: | | | |

| Table 1 | | Instrument Data Sheet | |
|---|--|-----------------------|---|
| RASIN ID # | XG-3224 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | PANalytical | Model Number | MPD X'Pert |
| Date of Manufacture | 2006 | | |
| Assessment date | 2/22/2007 | | |
| Description | X-ray diffraction unit operating @ max. power of 45 kV and 40 mA | | |
| Modifications | Brand new machine, no modifications. Customer will soon add a detector annunciator/alarm. | | |
| Drawings | | | |
| Shutter Composition | Gold plated SS. | | |
| Shutter Indicator #1 Description | Lamp on the panel | | |
| Shutter Indicator #2 Description | Yellow LED on the tube. | | |
| Shutter Indicator #3 Description | NA | | |
| Shutter Indicator #4 Description | NA | | |
| Safety Feature #1 Description | Enclosure door lock and interlock. | | |
| Safety Feature #2 Description | Microswitch solenoid on top of the door. | | |
| Safety Feature #3 Description | NA | | |
| Safety Feature #4 Description | NA | | |

Notes:



| Table 1 | Instrument Data Sheet | | |
|---|---------------------------------------|---------------------|---|
| RASIN ID # | XG-3225 | In Use? | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Manufacturer | Rigaku | Model Number | Miniflex |
| Date of Manufacture | 1995/1996 | | |
| Assessment date | 5/14/07 | | |
| Description | X-ray diffractometer | | |
| Modifications | None | | |
| Drawings | Yes, on file. | | |
| Shutter Composition | TBD. Manufacturer has been contacted. | | |
| Shutter Indicator #1 Description | Shutter LED on Panel | | |
| Shutter Indicator #2 Description | | | |
| Shutter Indicator #3 Description | | | |
| Shutter Indicator #4 Description | | | |
| Safety Feature #1 Description | X-ray On Light | | |
| Safety Feature #2 Description | X-ray On LED | | |
| Safety Feature #3 Description | Emergency off | | |
| Safety Feature #4 Description | | | |
| Notes: Door is MECHANICALLY linked to the shutter, such that the door cannot be opened with the shutter open. | | | |



Appendix C
Radiation Generating Device SBMS Procedure Compliance Checklist

RASIN ID #: _____ Personnel Interviewed: _____

Assessed by: _____ Date: _____

For each area reviewed, compare the information with each requirement below. Indicate whether the area met the requirement (Yes), did not meet the requirement (No), or the requirement did not apply (NA). If the area did not meet the requirement, then provide a brief explanation in the space provided. If this is an Opportunity for Improvement, check the OI box; if this is a proficiency, check the P box; then provide an explanation in the Comments field. In addition to assessing procedural compliance, assessors should evaluate the overall effectiveness of both the requirement, and the method to demonstrate compliance.

| Requirement | | Meets Requirement | Comments |
|-------------|--|--|----------|
| 1.0 | Procuring or Designing an RGD | | |
| 1.1 | RGD Custodian notifies RGD Program before acquisition. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 1.2 | RGD Program and RGD Custodian categorize RGD and determine safety features (Safety Feature Checklist/Safety Features Deviation Request) | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 1.3 | RGD Program reviews procurement specification/engineering drawings which include applicable safety features. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 1.4 | Custodian performs or procures services to determine unique safety features such as shielding and submits them to the RGD Program for review and approval. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |

| 1.5 | The Custodian is responsible for written procedures to ensure radiological safety during operation and maintenance. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
|----------------------------------|--|--|----------|
| Requirement | | Meets Requirement | Comments |
| 2.0 Preoperational Review | | | |
| 2.1 | RGD Program performs the preoperational reviews and approves RGD for operation by signing the Safety Features Checklist, Safety Features Deviation Request, and Safety Features Inspection Report. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 2.2 | Pre-operational radiation survey is performed at maximum power and under all possible sources/orientations and is documented with the RGD Survey Form. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 2.3 | RGD Program conducts RGD registration, posting, and labeling. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 2.4 | Custodian maintains a file of operators authorized to use the RGD. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 2.5 | Custodian develops and provides device-specific instruction to all operators. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 2.6 | Custodian corrects any deficiencies identified by RGD surveys within 6 weeks or applies for a variance | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |

| Requirement | | Meets Requirement | Comments |
|-------------|--|--|----------|
| 3.0 | Training | | |
| 3.1 | Custodian maintains current in compliance training (Radiological Safety Training for RGD Custodians) | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 3.2 | Custodian ensures authorized operators are current in RGD compliance training (Radiological Safety Training for RGD Custodians or Operators) | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 3.3 | ORNL field radiographers complete RW I or II training. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 3.4 | Custodian provides device-specific instruction to operators or anyone who may be exposed to radiation from the device. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 3.5 | Authorized operators escort RGD users who have not completed the compliance training. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 3.6 | As needed, Custodian submits training waivers request to RGD Program. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |

| Requirement | | Meets Requirement | Comments |
|-------------|---|--|----------|
| 4.0 | Routine Operations | | |
| 4.1 | Custodian notifies RGD Program of any modifications that may affect personnel exposure. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 4.2 | Custodian notifies RGD Program of the change in status of an RGD, for example, removing it from or returning it to service. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 4.3 | Custodian or Operator removes the RGD from service, if any safety feature fails or is determined to be degraded, until repairs can be made. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 4.4 | With the concurrence of the RGD Program, a radiation work permit may be used to allow operation until the safety feature is repaired. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 4.5 | Custodian provides a logbook for recording the dates and results of safety feature tests, inspections and maintenance, and radiation surveys, and the dates of findings and corrective actions. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 4.6 | RGD Program performs annual survey using the RGD Survey Form and maintains a file of review, registration, categorization, inspection, and survey information of RGDs. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |

| Requirement | | Meets Requirement | Comments |
|-------------|---|--|----------|
| 5.0 | RGD Safety Feature Periodic Test | | |
| 5.1 | Periodic tests were performed every 6 months for shielding, interlocks, personnel and area radiation monitoring equipment, warning devices, signs, and other safety features that were determined to be needed. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 5.2 | RGD Program reminds Custodian prior to the test due date. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 5.3 | Custodian notifies RGD Program that the test is performed satisfactorily. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 5.4 | RGD Program performs annual survey and documents the completion of periodic tests on the RGD Survey Form and maintains a file for each RGD. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |

| Requirement | | Meets Requirement | Comments |
|-------------|--|--|----------|
| 6.0 | Maintenance of RGD Safety Features | | |
| 6.1 | Custodian notifies RGD Program before maintenance is performed on an energized RGD. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 6.2 | Custodian notifies the RGD Program after maintenance of safety features (such as shielding, interlocks, displays or warning devices) before operation; a radiation survey/evaluation is required after maintenance of safety features. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 6.3 | Custodian maintains access to maintenance procedures and records and records the date, purpose, and results of maintenance in the operational log book. | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 7.0 | Beam Alignment Procedures | | |
| 7.1 | Does custodian have a beam alignment procedure? | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 7.2 | Are safety features disabled or overridden to perform beam alignment? | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 7.3 | Are there sufficient safeguards to ensure that overridden safety features are identified as being disabled? | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |
| 7.4 | Are there sufficient safeguards to ensure that overridden safeguards are returned to the normal state following beam alignment? | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA <input type="checkbox"/> OI <input type="checkbox"/> P | |

Appendix D: Shutter Position Verification Matrix

| Table 2 | Shutter Position Indicator Verification | | | | | | | |
|--|--|--------|--------|--|--------|--------|--------|------|
| | Actual Condition | | | | | | | |
| Beam Power | On | On | On | On | On | On | On | On |
| Shutter Position | Closed | Closed | Closed | Closed | Open | Open | Open | Open |
| Shutter Switch Position | Closed | Closed | Open | Open | Closed | Closed | Open | Open |
| Sample Chamber | Closed | Open | Closed | Open | Closed | Open | Closed | Open |
| Shutter Indicator #1 | | | | | | | | |
| Shutter Indicator #2 | | | | | | | | |
| Shutter Indicator #3 | | | | | | | | |
| Shutter Indicator #4 | | | | | | | | |
| Safety Feature #1 Action | | | | | | | | |
| Safety Feature #2 Action | | | | | | | | |
| Safety Feature #3 Action | | | | | | | | |
| Safety Feature #4 Action | | | | | | | | |
| Notes: | | | | | | | | |
| Conclusions/Recommendations: | | | | | | | | |
| Noteworthy Practices: | | | | | | | | |
| <u>Shutter Indicator</u> OO – Open by observation CO – Closed by observation OS – Open by schematic CS – Closed by schematic NA – Not observable | | | | <u>Safety Feature Action</u> AO – Activated by observation NO – Not activated by observation AS – Activated by schematic NS – Not activated by schematic NA – Not observable | | | | |