ES&H DIVISION
RADIATION CONTROL DEPARTMENT

Radiological Safety Analysis Document

Nominal Operation of the Upgraded Injector Test Facility (UITF)

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Thomas
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Jefferson Lab
Thomas Jefferson National Accelerator Facility

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This Radiological Safety Analysis Document (RSAD) identifies the general conditions associated with running the Upgraded Injector Test Facility (UITF) in a baseline mode which can be used for numerous experiments and accelerator component testing (ES&H Manual Chapter 3130). The document also describes controls with regard to production, movement, and import of radioactive materials to or from the UITF under the described nominal conditions.

1 DESCRIPTION

The UITF operates in the highbay area (classified as a *controlled area*) of the Test Lab.

For purposes of this RSAD, nominal operation of the UITF is here stated to be:

- beam energy no greater than 10 MeV
- effective CW beam current is no more than 100 nA (at 10 MeV)
- beam delivery termination points are
  - the "waist high" beam dumps at IDLM601 and IDLM703
  - HDIce beam dump in the HDIce beamline, IDLMB02
  - Faraday cups 3 and 4 (MeV region Faraday cups)
- maximum beam power from keV energy beams transported through the RF booster without additional acceleration not to exceed 3 mA at 450 keV or 13.4 mA at 225 keV

This configuration covers operation of the UITF for many of the activities currently envisioned for the accelerator. Design of the UITF shielding (see JLAB-TN-18-020) is intended to allow continuous operations with 100 nA, 10 MeV beam, and tolerate full continuous loss or delivery of the beam to an unshielded termination point without exceeding the TJNAF dose design goals for workers and the public.

The beam conditions listed above are enforced only by administrative controls – operator error could result in much higher beam current. The shielding design assessment evaluated a number of accident scenarios, up to 3 kW of 10 MeV beam and 4.2 kW of 5 MeV beam. Worst case beam loss scenarios evaluated under these conditions did not result in doses in excess of the Jefferson Lab Shielding Policy limits. However, since other, less severe off-normal conditions could occur, and such conditions could cause unnecessary dose, the ALARA principle is employed through standard methods such as interlocked area monitors (CARMs) and use of supplemental moveable shielding on dumps and Faraday cups when feasible.

2 SUMMARY and CONCLUSIONS

An approach analogous to the "radiation budget" method used for experiments in CEBAF end stations can be applied to radiation protection goals regarding potential dose to workers in areas around the UITF. As a **controlled area**, the design goal for doses within is 10 mrem/y. In the baseline configuration described above, the UITF is not expected to produce doses exceeding the design goal. However, radiological conditions around the UITF are monitored by the Radiation Control Department (RCD) to ensure that prompt radiation levels remain within expected values.

As specified below, the alteration or reconfiguration of beam line hardware, or modifications to radiation shielding must be reviewed and approved by the RCD. Adherence to this RSAD is vital.

3 CALCULATIONS of RADIATION DOSE in the HIGHBAY

The *TJNAF Radiological Control Manual* (RCD-PMAN-94 #001) contains design goals for annual effective dose applicable to workers and the public. These goals conform to the ALARA standard, establishing prudent limits for designing shielding and engineered controls to limit direct radiation exposure from the UITF accelerator. For radiological workers, the design goal (which applies to areas posted as *radiologically controlled areas* [RCAs]) is 250 mrem/y, equating to an average equivalent dose rate of 0.125 mrem/h by assuming that an individual would not be exposed in excess of 2000 hours in one year. The roof of the UITF Cave 1 is posted as an RCA during beam operations. Calculations and measurements in this area confirm that, except for positions directly above penetrations in the Cave 1 roof, conditions in the RCA are well below the average design goal level. Given the low occupancy in this area, and the limited duration of beam operations to Faraday cup 3 (which is the only condition causing elevated dose rates), expected doses to workers in this area are well bounded by the design goal.

The Jefferson Lab design goal for dose to the public is 10 mrem per year. The same design goal is used for Jefferson Lab workers outside of RCAs. The Test Lab Highbay is designated as a *controlled area* (CA) and has a dose limit of 100 mrem/y, therefore the same design goal – 10% of the DOE annual dose limit – is applied in this area as to public areas.

The shielding design assessment for the UITF indicates that, for an operating duty cycle of 1000 hours per year

- the highest dose to a person outside the RCA boundary is calculated at approximately 10 mrem,
- assuming beam delivery to an unshielded beam dump in the waist high beam line (the limiting condition for dose in the highbay), and
- that a person was present 100% of their work time in the area of highest potential dose.

Measurements in the occupied spaces around the UITF confirm the calculations. Given the supplemental shielding mentioned, and the conservative assumption of 100% occupancy, there is good confidence that actual doses will be much lower.

4 RADIATION HAZARDS

The following controls shall be used to: prevent unnecessary exposure of personnel; comply with federal, state, and local regulations, as well as with TJNAF requirements; and, comply with the experimenter's home institution policies.

4.1 Beam in the UITF Enclosure

Introduction

In any operation involving acceleration of charged particles there are various ways in which beam loss may occur. First, there are continuous routine losses due to particles that do not lie or stay within normal acceptance of the various parts of the machine. These are the most difficult to estimate but can be the cause of a significant part of the prompt radiation experienced because they occur during the entire machine operation period. Second, there are losses that occur due to mis-setting or mis-steering of the beam or due to non-optimal performance of some of the machine equipment. In some cases, these give rise to degradation of specific beam parameters such as energy spread or beam size and can give rise to definable loss points such as maximum dispersive regions or points of large Betatron functions in the transport system. Third, there are losses at the beam termination points (targets, dumps and Faraday cups).

Summary

Beam losses in the UITF enclosure are understood and well mitigated by installed shielding. Hazards from prompt radiation outside the shield are low and well managed by shielding and administrative controls; however, the radiation hazard in the cave during beam operations is high and potentially lethal. Therefore, prior to going to **Run Mode**, several actions will occur.

- Inspections will be made inside and around the cave.
- All magnetic locks on exit doors will be activated.
- Persons trained to sweep the area will enter by keyed access and search all areas of the cave to check for personnel.

After the sweep, the caves status will be changed to **Run Mode** and the Run-Safe boxes will then indicate **OPERATIONAL** and **UNSAFE**.

> *IF YOU ARE IN THE CAVE AT ANY TIME THAT THE RUN-SAFE BOXES INDICATE **UNSAFE**, IMMEDIATELY PRESS THE **PUSH TO SAFE** BUTTON ON THE BOX.*

Controlled area radiation monitors (CARMs) are located in strategic areas around the UITF to ensure that unsafe conditions do not occur in occupied areas. The RCD will monitor the CARMs and conduct surveys as necessary to assess the impact of operations on radiation levels around the UITF.

4.2 Activation of Beamline Components

Activation of materials in the UITF is not expected under normal operating conditions. However, some materials, such as beryllium, may produce neutrons if introduced into the beamline. A neutron detector is positioned in the UITF cave to monitor for inadvertent neutron production. Procedures require surveys be conducted in the event detectable neutron radiation is produced.

No reconfiguration of beam termination points (including installation of vacuum windows) is to be conducted without specific review and permission by the RCD.

4.3 Other Sources

Some of the structural and supplemental shielding components making up the UITF cave contain residual radioactivity (either by their previous use or from their manufacture). The presence of these materials requires permanent posting of a **Radioactive Material Area** in and around Cave 2. To notify personnel of this status, there are postings affixed to the structure. NO drilling, cutting, or other destructive modifications to these components may done without review and approval by the RCD. All radioactive materials brought to Jefferson Lab shall be identified and report to the Radiation Control Department. These materials include, but are not limited to

- radioactive check sources of any activity (exempt or nonexempt),
- previously used targets or radioactive beamline components,
- previously used shielding or collimators, or
- He-3 containers.

The RCD inventories and tracks all radioactive material at Jefferson Lab. Any experimental setup containing radioactive materials must be reviewed and approved by the RCD prior to installation.

5 SHIELDING

5.1 Bulk Shielding

Both empirical and detailed Monte Carlo methods were used to assess the shielding employed at the UITF. The empirical methods represent standard approaches which have been used for many years to define the bulk shielding. Those calculations were followed with detailed Monte Carlo simulations, primarily using the FLUKA radiation transport code. Radiation surveys conducted during UITF commissioning and operations have validated the shielding design. Overall, the bulk shielding requirements are well addressed and additional calculations unnecessary unless the beam configuration (e.g., addition of new beamline) is changed. For purposes of this RSAD, the steel block shield at the north wall of Cave 2 is considered part of the bulk facility shielding. Additionally, though the roof beams on the north end of Cave 2 are designed to be removeable, they are considered structural (bulk) shielding, as they provide part of the enclosure envelope.

5.2 Moveable Shielding

A number of generally small, moveable shielding packages are installed at the UITF. Some of these moveable shields (e.g., steel plates below Cave 1 penetrations) are extremely difficult to move due to their location and size. Others could be relatively easily altered inadvertently if not subject to configuration controls. A subset of these shields are identified specifically as Credited Controls. Though technically not required for baseline operation, shielding on the waist-high beam dumps for 100 nA operations is conservatively assumed to consist of 2" (inches) of lead downstream and laterally around the dumps. This provides about a factor of 10 reduction in the source term for beam delivery to these locations. Temporary reconfiguration of these shields, to include removal of a beam dump to accommodate test configurations, is permitted under the scope of this RSAD, provided RCD reviews the configuration, and the test or experiment is conducted in accordance with EH&S Manual and UITF Operations Directives requirements for such activities.

Movable shielding is configuration-controlled and inspected as part of start-up operations. The configuration of moveable shielding must be verified by the RCD (documented via a written checklist) following scheduled accelerator down periods of one week or more. The specific moveable shielding packages and other controls required for operations are listed on the pre-operations checklist (JLAB, 2020a).

In the event that any of these configurations are modified, the Radiation Control Department Manager (RCM) must approve the deviation in writing, or the reconfiguration must be part of an approved, experiment-specific RSAD.

5.3 Configuration Control

The design and installation of all shielding affecting personnel safety shall be approved by the RCD. Preparation of the design package, configuration control, and periodic inspections shall be controlled by and documented as required by Radiation Control Department procedures. Per the *Shielding Policy for Ionizing Radiation* (JLAB 2020b), all shielding affecting personnel shall be validated by initial radiation surveys and subsequently checked for proper configuration at regular intervals.

All shielding affecting personnel radiation safety shall be subject to configuration controls. All shielding identified in the Accelerator Safety Envelope shall meet configuration management requirements specified for a Level 1 CM (configuration management) system in the *Conduct of Engineering Manual*. The Accelerator Safety Envelope has specific requirements regarding periodic evaluation of shielding integrity.

All shielding affecting personnel radiation safety will be checked as part of the RCD checklist prior to beam operation in the UITF and after accelerator down periods of one week or more.

6 OPERATIONS PROCEDURES

All personnel must comply with UITF Administrative Controls outlined in the UITF Operations Directives (UITF Operations Directives, 2019). There may be additional controls in the form of Operational Safety Procedures (OSP), radiological work permits (RWPs), and other posted instructions from the RCD. A Standing RWP (SRWP [2021-S014 and its sucsessors]) which prescribes the standard posting requirements and governs access to radiological areas produced by the UITF is in place. The original SRWP is on-line as part of TJNAF's web-based training.

> *All designated UITF beam operators must read the SRWP. After which, they shall electronically sign the document signifying that they understand and will comply with the specifications identified in the Standing RWP.*

The UITF is equipped with a **rapid access** monitoring system that provides defense-in-depth protection, allowing verification that prompt radiation production has ceased prior to allowing access. This system also incorporates neutron monitoring as a means to trigger investigation into possible activation of components. Details of the system's operating protocol are delineated in the UITF RWP.

An inspection of the UITF to check for inadvertent modification of radiation protection-related equipment and shielding is conducted prior to every sweep. Additionally, when UITF maintenance involving down periods of one week or more is conducted, a radiation checklist (JLAB 2020a) is completed by the RCD prior to restart, and is used as the basis for approving radiation-related **credited controls**.

Radiological work permits are the standard work authorization documents used to control radiological work. The RCD requires RWPs based on established trigger levels.

Standard RSAD controls apply. The Radiation Control Department shall be contacted for any of the following activities.

- Entry to **Radiation Areas** or **High Radiation Areas**
- Movement of shielding or collimators
- Movement of radioactive components into or out of the UITF
- Any destructive modifications (drilling, cutting, welding, etc.) to activated components or structures

All posted guidance and instructions for shielding configuration & access to radiological areas must be adhered to.

Note: Work planning for all radiological work shall be coordinated through the UITF work coordinator using the *UITFList* work planning tool.

7 DECOMMISSIONING and DECONTAMINATION of RADIOACTIVE COMPONENTS

Experimenters shall be responsible for all experimental equipment brought to Jefferson Lab for temporary use during the experiment. Any radioactive materials brought to Jefferson Lab shall be returned to the experimenter's home institution for final disposition. All M&E transportation shall be carried out in accordance with United States Department of Transportation Regulations (Title 49, Code of Federal Regulations) or International Air Transport Association regulations. In the event that the experimenter's home institution cannot accept the radioactive material due to licensing requirements, the experimenter shall arrange for appropriate transfer of funds for disposal of the material. TJNAF cannot store any radioactive or experimental equipment indefinitely.

The Radiation Control Department may be reached at any time through the Accelerator Crew Chief (269-7050).

8 REFERENCES

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