**RSAD for Nominal Operation of the Upgraded Injector Test Facility (UITF)**

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, or import of radioactive materials to/from the UITF under the described nominal conditions.

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# 1. Description

UITF operates in the highbay area of the Test Lab. This area is classified as a Controlled Area.

The 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 nominal configuration covers operation of the UITF for many of the activities currently envisioned for the accelerator. The 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 Jefferson Lab dose design goals for workers and the public.

The nominal beam conditions 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. The 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” approach 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 in the area 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 in the Sections below, the modification/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 Radiological Control Supplement to the ES&H Manual contains design goals for annual effective dose applicable to workers and the public. These goals conform to the ALARA standard and establish prudent limits for designing shielding and engineered controls to limit exposure to direct radiation from the UITF accelerator. For radiological workers, the design goal is 250 mrem/y. This value equates 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 a year. This design goal applies to areas posted as radiologically controlled areas (RCAs). 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 onsite. The Test Lab highbay is designated a Controlled Area 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

## 4.1 From Beam in the UITF Enclosure

4.1.1 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 which do not lie within, or stay within the normal acceptance of the various parts of the machine. These are the most difficult to estimate but they can be the cause of a significant part of the prompt radiation experienced because they occur during the entire machine operations period. Secondly, there are losses which 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. Thirdly, there are losses at the beam termination points (targets, dumps and Faraday cups).

4.1.2 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 are 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 in all areas of the cave to check for personnel.

After the sweep, the cave will be changed to Run mode. The Run-Safe boxes will 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 Radiation Control Department (RCD) will monitor the CARMs and make surveys as necessary to assess the impact of operations on radiation levels around the UITF.

## 4.2 Hazard from Activation of Beamline Components

Activation of materials in the UITF is not expected under normal conditions of operations. However, some materials (e.g. 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 to 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 permission and review 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. The structure has postings affixed to it no notify personnel of this status. No drilling, cutting or other destructive modifications to these components may be conducted without review and approval of the RCD. All radioactive materials brought to Jefferson Lab shall be identified 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 materials onsite. 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 employed 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 (eg. 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” 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 of operations. The configuration of moveable shielding must be verified by RCD (documented by written checklist) following scheduled accelerator down periods of one week or more. The specific moveable shield packages and other controls required for operations are listed on the pre-operations checklist (JLAB, 2020a).

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

## 5.3 Shielding Configuration Control

The design and installation of all shielding affecting personnel safety shall be approved by RCD. Preparation of the design package, configuration control and periodic inspections shall be controlled by and documented as required by written RCD procedures. Per the Jefferson Lab 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 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 RadCon checklist prior to beam operation in the UITF after accelerator down periods of one week or more.

6. Operations Procedures.

All personnel must comply with UITF administrative controls. These controls are outlined in the UITF Operations Directives (UITF Operations Directives, 2019). There may be additional controls in the form of Operational Safety Procedures (OSP), Radiation Work Permits (RWP) and other posted instructions from the RCD. A standing Radiation Work Permit (2021-S014 and its sucsessors) is in place which prescribes the standard posting requirements and governs access to radiological areas produced by the UITF. The original is kept on-line as part of JLAB's web based training. It must be read and signed by all designated beam operators at UITF.

The UITF is equipped with a "rapid access" monitoring system. This system 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 operating protocol for the system are covered 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. In addition, when the UITF conducts maintenance involving down periods of one week or more, a Radiation Checklist (JLAB 2020a) is completed by the RCD prior to restart, and used as the basis for approving radiation-related Credited Controls.

Radiation Work Permits (RWPs) are the standard work authorization documents used to control radiological work. RCD will require RWPs based on established trigger levels.

Standard RSAD controls apply: RCD shall be contacted for any of the following activities:

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

**All posted guidance and instructions for shielding configuration, and 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 delivered to the experimenter's home institution for final disposition. All transportation shall be done 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 funds transfers for disposal of the material. Jefferson Lab cannot store indefinitely any radioactive or experimental equipment.

Approvals:

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Radiation Control Department Head Date

# References

JLAB. (2019a). September 30, 2019. *Final Safety Assesment Document.*

JLAB. (2020c). June, 2020. *Radiation Control Manual,* RCD-PMAN-94 #001 Rev 6. JLAB ES&H Manual. Radiation Control Supplement.

JLAB. (2019b). July, 2019. *UITF Operations Directives*. UTF-AD-01-001.

JLAB. (2020a). Procedure HPP-OPS-002 *Performance of Periodic Routines*

JLAB. (2020b). June, 2020, *Shielding Policy for Ionizing Radiation*, RCD-POL-14 #001, Rev 2.

JLAB. (2019) ES&H Manual, Chapter 3130, *Accelerator Experiment Safety Review Process.*