C-AD Unreviewed Safety Issue (USI) Determination Form

Title of USI Determination: Exempt SVTF Accelerator in B912

Description of USI Determination (use attachments): See attached SVTF Exempt Accelerator Safety Analysis, October 2015

Title and Date of Relevant SAD: C-AD Safety Assessment Document, May 2011

Associate Chair for ESSHQ or ESSHQ Division Head must initial all applicable determinations and actions. Write N/A for non-applicable. Leave no blanks.

Determinations and Actions	Initial or Indicate N/A
Determination: The current SAD and/or ASE addresses the hazard associated with the proposed work, event or activity.	[ETL]
Determination: This activity does not constitute a USI.	[ETL]
Action: Use this Form, the USI Checklist and attached description, if any, to document the USI Determination until the next revision of the SAD.	[ETL]
Action: Include this USI Determination as a reference on the ESSHQ Division website "Authorization Bases" after approval by the C-AD Associate Chair for ESSHQ.	[ETL]
Determination: The hazard associated with the proposed work is not analyzed or is not correctly bounded in the C-AD SAD and/or it is not controlled by an ASE.	[N/A]
Action: Submit the USI Determination or a revised SAD and/or ASE to the BNL ESH Committee.	[N/A]
Action: Do not perform activity until BNL has approved.	[N/A]
Action: Do not perform activity until DOE has approved.	[N/A]

Ray Karol — 10-20-2015

Signature of C-AD ESSHQ Division Head — Date

Edward T Lessard — 10-20-2015

Signature of C-AD Associate Chair for ESSHQ — Date

Exempt SVTF Accelerator in B912

The Small Vertical Test Facility (SVTF), formerly operated as a Radiation Generating Device (RGD) has been reviewed and approved by BNL as an exempt accelerator.

The same C-AD staff will be responsible for operating the SVTF, an electron accelerator, in B912. The attached SVTF Safety Analysis concludes that the SVTF can be safely operated as an exempt accelerator. An exempt accelerator is defined by DOE 420.2C, paragraph 3.c. (1), as one whose hazards can be safely managed under the provisions of Title 10, Code of Federal Regulations (CFR), Part 835 and Part 851 that are non-complex in nature and that produce only local work area impacts.

References:

1. Small Vertical Test Facility Exempt Accelerator Safety Analysis (attached).
2. DOE 420.2C, Safety of Accelerator Facilities, paragraph 3.c. (1).
3. BNL SBMS Subject Area, Accelerator Safety, Section 1.1-Authorization Path for Exempt/Equivalent Accelerators.

Collider-Accelerator Department (C-AD)
Small Vertical Test Facility (SVTF)
Exempt Accelerator Safety Analysis

B912, East Experimental Building Addition (EEBA)

Revision 0 **October 2015**

R. Karol, ESSHQ Division, C-AD	10-12-2015 **Date**
E. Lessard, Associate Chair for ESSHQ, C-AD	10-12-15 **Date**
I. Ben-Zvi, Associate Chair for Accelerator R&D, C-AD	10-13-15 **Date**
T. Roser, Department Chair, C-AD	10/13/15 **Date**
B. Mueller, Associate Laboratory Director, Nuclear and Particle Physics	10/13/15 **Date**
G. Mattson, Assistant Laboratory Director for ESH, BNL	10-15-15 **Date**

Title of Facility: B912 Small Vertical Test Facility
Building Number: B912, East Experimental Building Addition (EEBA)

Date of Initial Safety Analysis: Revision 0, October 9, 2015
Subsequent Revision Dates:

Section 1: Introduction

The Small Vertical Test Facility (SVTF) accelerator in the East Experimental Building Addition (EEBA) of B912 is an exempt accelerator, satisfying the criteria for exemption in DOE 420.2C, paragraph 3.c. (1). This accelerator and associated experiment hazards can be safely managed under the provisions of Title 10, Code of Federal Regulations (CFR), Part 835 and Part 851. This safety analysis shows that the SVTF hazards are not complex, and are only capable of producing minor local work area impacts. Thus SVTF operations and maintenance activities can be safely controlled by meeting the requirements in the BNL Radiological Controls Manual for ionizing radiation control, and by complying with the BNL Worker Safety & Health Program through the BNL Standards Based Management System and C-AD Operations Procedures.

The SVTF has safely operated for the last 5 years as a Radiation Generating Device (RGD)[1] for testing RF cavities and small superconducting electron guns. Safety reviews of this facility and test devices have been completed by the C-AD Radiation Safety Committee[2], Accelerator Systems Safety Committee[3] and the BNL ESH Committee[4]. RF cavity testing has been carried out using specific work plans and approved procedures and proposed electron gun[5] testing has had reviews and approvals to proceed. These analyses document the safety of using the SVTF for both RF cavity tests and electron gun tests. Electron gun tests could accelerate electrons and therefore the SVTF is classified as an accelerator. DOE 420.2C allows such exemptions if for example the accelerator is "a room-sized accelerator with a single external/extractable beam, an active safety system, and a single point of entry into the room". The SVTF satisfies this condition. The exemption means that there is no requirement to have a Safety Analysis Document (SAD) and Accelerator Safety Envelope (ASE) and relieves the C-AD from the need to have an Accelerator Readiness Review (ARR).

Description

Conduct of Operations

The operating organization for the SVTF is described in C-AD OPM Chapter 18 and summarized in Figure 1. Specific written procedures for the SVTF accelerator and experimental

[1] BNL Radiation-Generating Device Registration Form for SC RF Block House (SVTF), Model #SCRF BH-1, Serial # SCRF BH-001.
[2] See for example C-AD RSC meeting minutes dated 3/17/09 and 5/20/10 and BNL Memorandum: D. Beavis, *Crab Cavity Test in the SVTF*, dated May 31, 2013.
[3] See for example C-AD ASSRC meeting minutes dated 4/11/11, 4/24/12, 12/19/12 and 5/13/13.
[4] See for example LESHC Committee meeting minutes 10-14 (3/24/11) and 12-01 (5/1/12).
[5] The C-AD had a temporary DOE-BHSO approval for 24 months to conduct SVTF electron gun testing under an exemption. See letter from M. H. Holland (BHSO) to M. J. Bebon (BNL), Department of Energy (DOE) Order 420.2B, *Safety of Accelerator Facilities*, Exemption Request for the Polarized SRF Gun Experiment, dated May 6, 2009.

operations are found in OPM Chapter 18. Other chapters of the C-AD OPM address issues that apply to all of C-AD facilities (e.g., organizational roles, responsibilities, authority, accountability, notifications to management). These procedures and SVTF specific Work Plans state the goals for operations, safety, the means to achieve them, and the controls instituted.

Specific operations procedures and specific Work Plans for the SVTF address

- The organization, responsibilities and authorities including SVTF manning requirements (OPM 18.2.3)
- operation of the SVTF access controls system and sweeping the inside of the facility (OPMs 18.4.4 and 18.4.4.a)
- safe operating limits (OPM 18.10.3)
- Control and status of equipment (Work Plan)

C-AD OPM operations procedures address

- C-AD policies for organization and administration (C-A-OPM Chapters 1and 2)
- C-AD operating practices, e.g., emergency response, work controls (C-A-OPM Chapters 2 and 3)
- Communications and notifications (C-A-OPM Chapter 1)
- Training and qualification of C-AD and SBH/SVTF staff (C-A-OPM Chapter 2)
- Investigation of abnormal events, conditions and trends (C-A-OPM Chapters 1and 10)
- Lockout and tagout of hazardous energy (C-A-OPM Series 2.36)
- Independent verification / assurance practices (C-A-OPM Chapters 9 and 13)
- Operations practices for log-keeping (C-A-OPM Chapter 2)
- Component labeling/identification practices (C-A-OPM Chapter 1)
- Safety committee reviews (C-A-OPM Chapter 9)

Responsibility for the safe and reliable operation of the SVTF resides with the VTF/SVTF[6] Operations Coordinator and the Liaison Physicist. The VTF/SVTF Liaison Physicist is responsible for day-to-day planning of VTF/SVTF test operation, studies, development activities during test periods, and safe, efficient, and effective day-to-day operation of the facility. The VTF/SVTF Liaison Physicist is the focus for all operations-related questions. The VTF/SVTF Operations Coordinator is responsible for managing day-to-day resources and materials for the facility, insuring that the conditions for safe operation are maintained, that staff members are trained in the appropriate safety and administrative procedures for the facility, and that appropriate work planning is conducted. Both the VTF/SVTF Liaison Physicist and the VTF/SVTF Operations Coordinator are responsible for test scheduling to best support and further programmatic and safety goals for the VTF/SVTF facility.

Any change that modifies radiation shielding or that could introduce increased radiation dose, increased oxygen deficiency hazard or new hazards is reviewed and controlled by BNL and C-AD requirements and procedures.

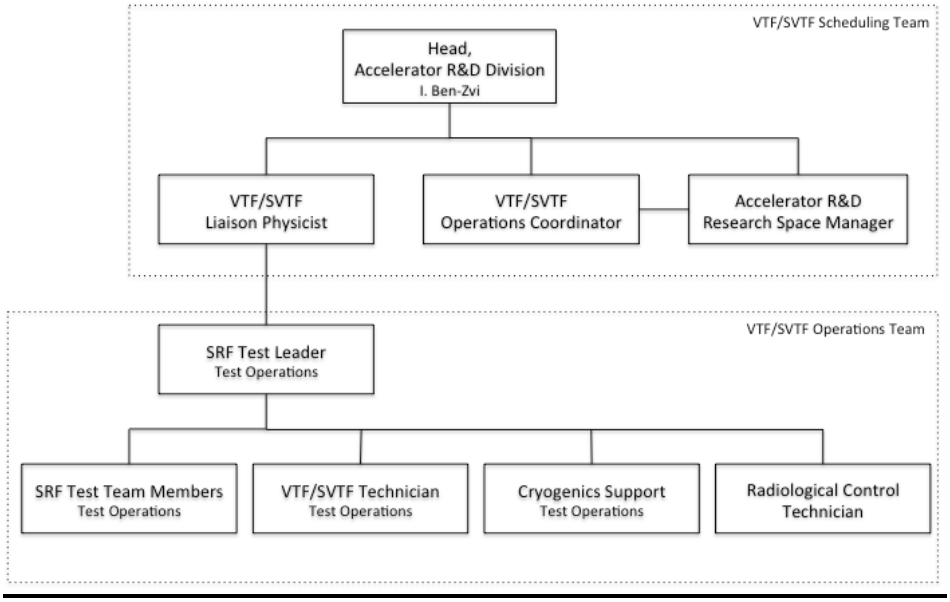
[6] The VTF and SVTF are separate facilities in B912 EEBA. The VTF is a large vertical test facility operated as an RGD that exclusively tests RF cavities. The SVTF is used to test RF cavities and electron guns. The SVTF was safely operated as an RGD and this safety analysis shows that it can be safely operated as an exempt accelerator.

The SVTF is operated remotely from outside the SVTF enclosure during radiation producing activities thus creating little or no radiation hazard to personnel. The SVTF test device controls are located outside the SVTF enclosure. This location has been safely used in the past when the facility was operated as a RGD.

Radiation posting and personal dosimetry requirements are set by the C-AD Radiological Controls Group based upon dose rate measurements. No device testing can be initiated if the potential routine or fault dose rates outside the SVTF enclosure require posting above a Radiation Area.

Each entrant into the SVTF must wear a personal oxygen monitor (POM) when cryogens are in the SVTF to warn of potentially unsafe oxygen levels. Entrants do not need a POM if there is an operable oxygen monitor installed and maintained in the SVTF enclosure.

Figure 1
VTF/SVTF Operating Organization

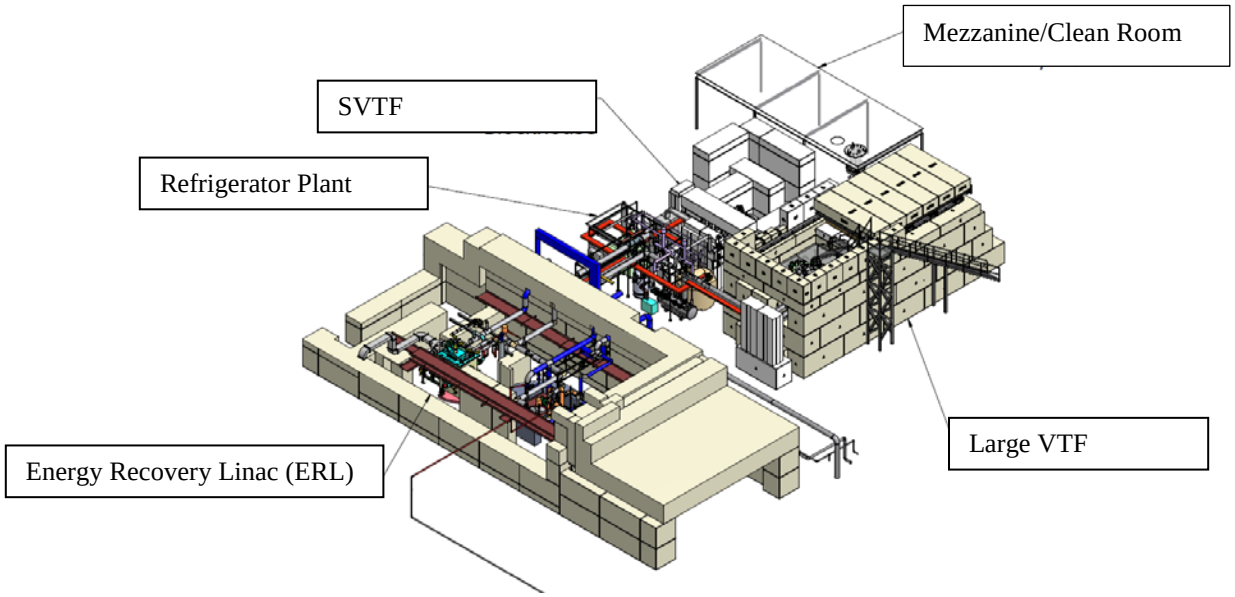


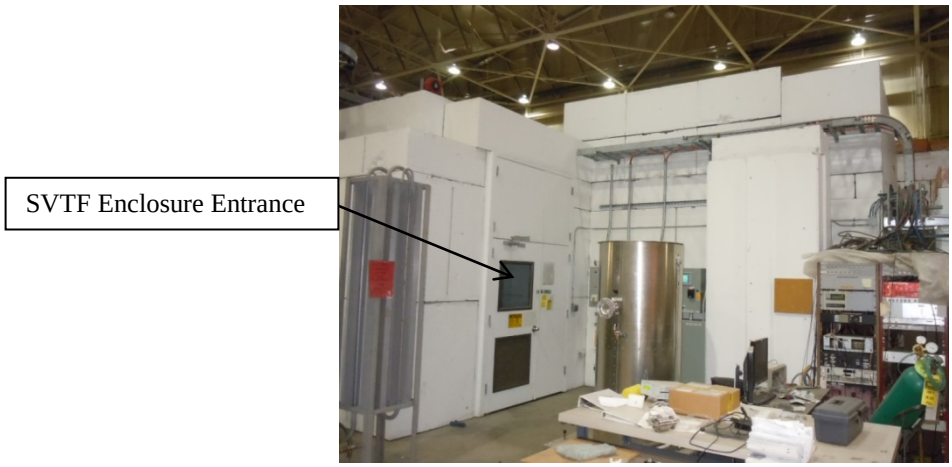
Layout and Equipment Overview

Figures 2, 3 and 4 show the SVTF layout in B912 EEBA. This configuration has been in place over 5 years when the SVTF was safely operated as a RGD. Potential SVTF devices include laser, RF gun, vacuum pipe, vacuum pumps, magnet, power supplies, camera and beamline instrumentation.

The SVTF is enclosed in an above-ground heavy concrete blockhouse. Experimental Dewars[7] are manually rolled through the door. There Dewars contain, for example, the RF cavity test devices. The experiments can be performed either at 4.2 K or at 2 K. Figure 5 shows a typical SRF cavity test device mounted in the 125 L Dewar.

Figure 2
SVTF in B912 EEBA





[7] There are currently two approved Dewars used at the SVTF: 1) 500 liter Cryofab Dewar and 2) 125 liter Dewar, both with a test device RF power limit of 200 W. If additional Dewars are proposed they will be reviewed and approved using C-AD and BNL requirements.

Figure 3
Plan View of SVTF Enclosure

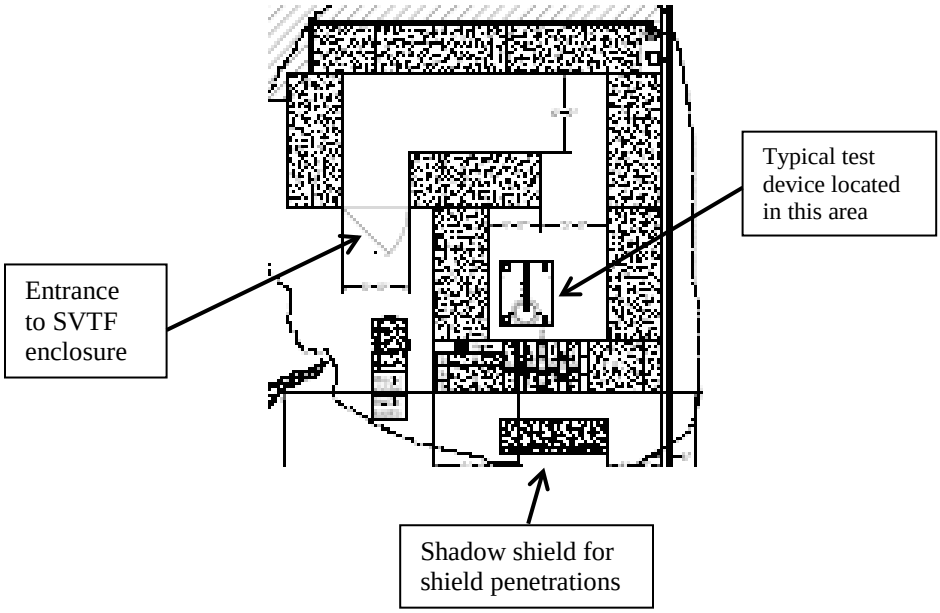


Figure 4
Elevation View of SVTF Enclosure

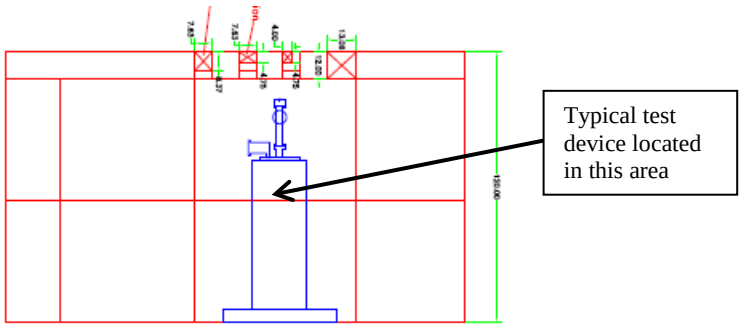
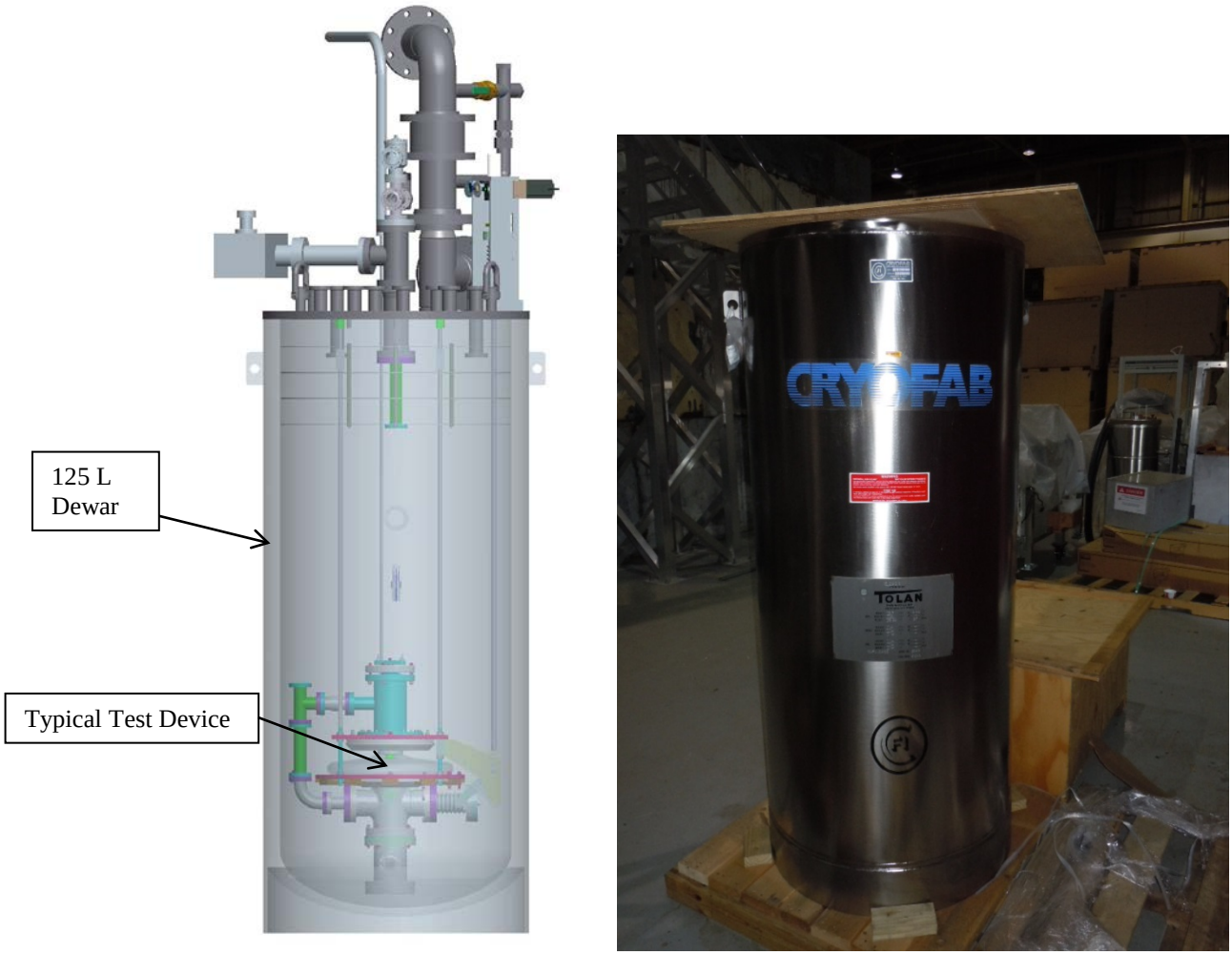


Figure 5
Typical SVTF Test Device in 125 L Dewar



Laser Systems

Lasers may be used if the test device will produce electron beams. The laser design, interlocks, operations and maintenance would always comply with all BNL SBMS laser safety requirements.

The engineered controls for lasers consist of standard commercial machine safety modules or C-AD designed interlocks intended to exclude personnel exposure to physical hazards. Failsafe operation, reset after violation, reach-back upon laser shutter failure, and provision for trained personnel to re-enter the area are incorporated into the design. Dedicated safety shutters are used to remove the hazard when required, and also close upon loss of power or control signal.

During laser commissioning, a large number of optical elements require repositioning and precision alignment. During this period, laser energy is reduced well below normal operational limits to the minimal level necessary for determining beam position and component placement.

Maintenance is limited to replacement and realignment of individual passive optical elements as necessary to provide optimal beam quality. Outside service personnel are always continuously escorted and supervised by C-AD staff during any system maintenance or repair work. Certification of training to vendor laser safety program requirements is obtained for every individual performing service.

Alignment procedures are limited to beam steering through existing optical path, adjustment of transmissive optics such as polarizers/wave plates, and optical path length adjustment of optical delay lines.

Configuration changes occur infrequently and are detailed in system documentation used for operator training. Significant changes require formal operator retraining.

Most laser related accidents occur during alignment. Extra care is taken during alignment. Eyewear is worn during alignment but eyewear is NOT the first level of laser safety. Eyewear protects the wearer only when all other safety procedures and equipment have failed. Primary protection is provided by engineering controls and carefully written and approved procedures and by proper laser beam management.

Power and Electrical Supplies

Power and electrical distribution comply with the NEC and are operated in compliance with NFPA 70E, BNL and C-AD requirements. These hazards are not unique and have the same or less risk as present at other C-AD facilities.

Access Controls System

The installed access control system has safely operated for the last 5 years. This is a PLC system that protects personnel from exposure to RF cavity x-rays and electron gun routine and faulted beam loss. It is a dual interlock system and complies with the design and testing requirements in the BNL Radiological Controls Manual and the BNL SBMS subject area, Interlock Safety. This system is tested by the C-AD Access Controls Group. Only trained and approved personnel may conduct sweeps of the enclosure before device testing.

Section 2: Summary/Conclusions

The SVTF is a room-sized minimum risk accelerator with a single extractible electron beam which stays in the SVTF room, an approved radiation shield configuration and a single entry into the SVTF room. It is a non-complex electron accelerator that is run by trained staff and maintained by the same staff that services the other C-AD accelerators and equipment.

Only local safety impacts are possible, with no life-threatening consequences. Radiation hazards are safely controlled by compliance with the BNL Radiation Controls Manual requirements.

Conventional hazards are safely controlled by compliance with 10CFR851 requirements. All activities are safely controlled by following BNL SBMS and C-AD OPM procedures.

Section 3: Details of the Safety Analysis

This section describes the hazard identification and qualitative hazard analysis for the SVTF accelerator / experimental apparatus in B912 EEBA. The hazard identification process examined the SVTF processes, operations and maintenance that could result in a source of danger with the potential to cause illness, injury or death, damage to operations or environmental damage. The SVTF design documentation, BNL conventional and radiological safety requirements, facility walk downs, C-AD Operating and Emergency Procedures, and discussions with engineering and SVTF staff, experimenters and safety professionals were utilized to conduct the detailed hazard identification and hazard analysis.

A review of all safety- and health-issues related to the SVTF resulted in the need for further safety analyses of 1) radiation from RF cavity or electron beam, and 2) oxygen-deficiency hazards from the use of cryogens to cool test devices.

Standard industrial activities encompass pressure and vacuum, use of small quantities of flammable/inert/cryogenic gases/fluids, electrical, cryogenic fluids, noise, hoisting/rigging, lasers, and magnetic fields. The C-AD controls these risks by complying with the consensus standards and codes, SBMS's Subject Areas, and the C-AD Operations Procedure Manual (OPM). When required, these hazards undergo review by the appropriate BNL or C-AD committee, or by the C-AD's ESSHQ Division specialists during work planning.

Safety Analysis of Non-Standard Industrial Hazards

Ionizing Radiation

The SVTF electron beam and RF cavity test device routine and faulted dose rates outside the SVTF enclosure have been estimated[8] for previously operated test devices and shown to be very low. The estimates show that this is accomplished even assuming a very conservative source term. The goal is to limit the radiation postings outside the SVTF room to no more than a Radiation Area. Previous device testing when SVTF was an RGD shows that this limit is easily satisfied. Because the estimated and measured dose rates are so low, there is no radiation hazard to personnel or the environment. There are no off-site radiological hazards due to general area dose rates or air and liquid emissions from SVTF.

A strict protocol is in place for radiological hazard review of each proposed SVTF test device before operations. This protocol includes evaluating the routine and faulted dose rates for both the bulk shielding and all shield penetrations cracks in the SVTF single layer concrete shielding. The C-AD Radiation Safety Committee (RSC) has been and will continue to conduct documented reviews of the routine and faulted dose rates for each test device. This committee is

[8] See Minutes of RSC Subcommittee Meeting of March 17, 2009 and May 20, 2010 and D. Beavis, *Radiation Issues for the SVTF*, July 17, 2015.

composed of C-AD and BNL experts in radiation safety. The RSC procedures are contained in C-AD OPM Section 9.1 series.

Oxygen Deficiency

Cryogenic liquids are utilized to maintain some SVTF test devices at low temperatures. The exhaust fan for the SVTF enclosure was sized assuming that 25 g/s of helium (330 SCFM) continuously flow into the enclosure following a failure of the LHe Dewar supply line in the enclosure. This calculation[9] assumed that the exhaust fan was on because procedures require that the fan be manually turned on before entering the enclosure. The exhaust fan switch is the same switch used to turn on the SVTF enclosure lights. The SVTF has a volume of 2600 ft^3 with 1000 CFM forced exhaust ventilation. With these conditions, a minimum oxygen concentration of 14.1% would occur ten minutes after leak initiation. To limit the SVTF classification to ODH 0 an allowable leak frequency of P = 0.0016/h would be allowed. This means that the Dewar fill line could fail in the SVTF every 3.6 weeks and still permit the enclosure to be posted ODH 0. This initiator frequency is obviously unrealistically high compared to a credible frequency. Thus, controlling the SVTF as ODH 0 is acceptable and appropriate[10].

Supply Dewars for SVTF test devices must be located outside of the enclosure to preclude the potential release of the entire supply Dewar contents into the SVTF in a short time interval. The Test Dewar in the enclosure is fixed and failure of this Dewar when in use is not considered credible.

In order to set a limit on future SVTF operations with cryogens, a bounding ODH calculation was performed. Because of the small size of the SVTF, the actual egress time is less than 30 seconds. To arrive at a leak rate limit of cryogen into the SVTF, 90 seconds was conservatively assumed for egress time. Calculation shows that after 90 seconds the oxygen concentration would only fall to 16% if the leak rate of cryogen into the SVTF was 40 g/s. This value has been set for the allowable cryogen leak rate limit.

To prevent walking into a hazardous oxygen deficient space in the SVTF room, procedures require that the enclosure exhaust fan must be turned on for 10 minutes before entry and each entrant must have their own portable oxygen monitor (POM) or an alarming, fixed ODH monitor is in place. This delay before entry ensures that the enclosure is adequately purged with fresh air for credible events.

All personnel handing cryogenic liquids and gas must have current cryogenic safety awareness training and must wear the proper PPE as specified in BNL SBMS.

Ozone

To conservatively bound the potential ozone hazard in the SVTF enclosure it is postulated that an electron beam travels totally in air through a distance which is the longest dimension of the

[9] R. Karol, B912 Small VTA House ODH Calculations (Revised), June 20, 2008 (Revised 12-3-08) and email from M. Gaffney, ODH Analysis 912 Blockhouse (LESHC 10-14 Action Item), November 12, 2010.
[10] Email from C. Conrad, LESHC 10-14 Review the Polarized SRF Gun Experiment, 14" Dewar Test Setup, 28" Vertical Test Dewar, and Associated Piping - Status of Open Actions, December 22, 2010, Item 2.2.1.

SVTF (~6 m). The electron beam power is assumed to be at its maximum allowed value of 200 W. Using these values[11], 0.4 L of ozone could be produced if the beam was operated continuously for 8 hours. To enter the 2600 ft^3 SVTF enclosure, the 1000 CFM exhaust fan is always turned on by the entrant for ODH protection. In all cases, entry into the SVTF enclosure is delayed for 10 minutes to reduce the potential oxygen deficiency hazard. This delay also reduces the potential ozone concentration to < 0.1 ppm, the ACGIH TLV, ensuring that ozone is safe upon entry.

Section 4: Controls and Bases:

1. Each test device must have a documented review by the C-AD RSC before the test device is operated. The maximum power and energy of the SVTF RF cavity test device or the electron beam is limited by the primary criterion to maintain an exempt accelerator or accelerator facility status. This primary criterion is that no device x-ray source or beam fault may cause calculated dose rates to exceed 100 mrem/h outside of the SVTF shield[12].
2. If required by the RSC, the alarming SVTF Chipmunks must be operational during RF device or electron gun operations and must be tested annually, not to exceed 15 months. This test interval is consistent with other C-AD Chipmunk testing. SVTF Chipmunk alarm set points are to be specified by the RSC.
3. When cryogens are used in the SVTF enclosure, each entrant must wear their own portable oxygen monitor (POM). In addition, procedures must specify that the enclosure exhaust fan be turned on for 10 minutes (minimum) before entry and remain on for the duration of the entry.
4. If used, all SVTF lasers, laser interlocks for personal safety, and interlock testing must comply with BNL SBMS requirements.
5. ACS interlocks will be checked annually (not to exceed 14 months) or, if the SVTF has not been operated for more than 6 months, before radiation producing activities resume.
6. If installed, the alarming ODH monitor in the SVTF enclosure will be checked annually (not to exceed 15 months) or, if the SVTF has not been operated for more than 12 months, before allowing cryogens to be introduced in the enclosure.
7. Activities involving unreviewed safety issues cannot begin before DOE has provided written approval.
8. If the potential accident flow rate of cryogens into the SVTF enclosure exceeds 40 g/s, the current value assumed in this safety analysis, an analysis of the ODH accident must be completed and approved by the BNL ODH Subject Area SME. The analysis must show that the hazard level is maintained at ODH 0. If the hazard exceeds ODH 0, then the analysis must be reviewed by the BNL ESH Committee before such operations begin.

[11] W. P. Swanson, Radiological Safety Aspects Of The Operation Of Electron Linear Accelerators, Technical Report No. 188, International Atomic Energy Agency (IAEA), Vienna, 1979, Section 2.10, equation 53.

[12] This ensures that there are no High Radiation Areas created from SVTF test device operations. The fault dose rates are routinely expected to remain significantly less than 100 mrem/h in order to maintain ALARA principles.

Section 5: Administrative Controls

1. The VTF/SVTF Operator must remain in the area of the SVTF in B912 EEBA during SVTF beam operations except for emergencies.
2. The ASSRC must conduct a walkthrough of the SVTF whenever significant changes are made to SVTF systems.
3. Modifications to SVTF that are determined to increase the frequency or consequences of known hazards or which introduce new hazards must be documented using the C-AD Unreviewed Safety Issue (USI) process.

Section 6: Assurance Methods for Operations

1. This safety analysis will be reviewed by the BNL LESHC Committee who will be asked to recommend to the BNL ESH ALD that the exempt accelerator status be approved and that the SVTF be added to the BNL list of exempt accelerators. This decision is the responsibility of the BNL ESH ALD.
2. The C-AD RSC and ASSRC will review the radiological and conventional safety of the SVTF accelerator. These reviews will be documented in a set of committee minutes and all recommendations entered into C-AD family ATS.
3. If determined to require a fault study for an SVTF test device, the RSC will specify a fault study plan and the VTF/SVTF Liaison Physicist will write a plan based on these requirements. The RSC Chair will approve the plan.

    3.1 Once each SVTF fault study is completed, the radiation fault study results will be reviewed by the C-AD RSC and corrective actions implemented as needed.
4. SVTF staff training will be documented in the BNL BTMS database
5. The SVTF Liaison Physicist (LP) will generate an RSC Checklist for each test device which will be reviewed by the RSC Chair and approved by the C-AD Department Chair. The VTF/SVTF Operator will verify that all checklist items are complete before start of device testing.

Routine SVTF operations and maintenance will continue to comply with all C-AD requirements and function as all other C-AD facilities.

Acronyms

ACS – Access Control System
ACGIH – American Conference of Governmental Industrial Hygienists
ALD – Associate or Assistant Laboratory Director
ASME - American Society of Mechanical Engineers
ASSRC – Accelerator Systems Safety Review Committee
ATS – Action Tracking System
BTMS – Brookhaven Training Management System
BNL – Brookhaven National Laboratory
C-AD – Collider-Accelerator Department
CFM – Cubic Feet per Minute
CFR – Code of Federal Regulations
EEBA – East Experimental Building Addition
ERL – Energy Recovery Linac
ESH – Environment, Safety and Health
ESRC – Experimental Systems Review Committee
ESSHQ – Environment, Safety, Security, Health and Quality
LHe – Liquid Helium
LN2 – Liquid Nitrogen
LOI – Lines of Inquiry
LP – Liaison Physicist
NEC – National Electrical Code
NFPA – National Fire Protection Association
NPP – Nuclear Particle Physics
OC – Operations Coordinator
ODH – Oxygen Deficiency Hazard
OPM – Operating Procedures Manual
PLC – Programmable Logic Controller
POM – Portable Oxygen Monitor
PPE – Personal Protective Equipment
QA – Quality Assurance
RGD – Radiation Generating Device
RF – Radio Frequency
RSC – Radiation Safety Committee
SBMS – Standards Based Management System
SC – Superconducting
SME – Subject Matter Expert
SRF – Superconducting Radio Frequency
SVTF – Small Vertical Test Facility
TLV – Threshold Limit Value
USI – Unreviewed Safety Issue
VTF – Large Vertical Test Facility