FERMI NATIONAL ACCELERATOR LABORATORY

ACCELERATOR SAFETY ENVELOPE

Vertical Test Stand (VTS) Accelerator

Revision 10 August 10, 2023

Appendix A of the Safety Assessment Document

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Accelerator Safety Envelope

Vertical Test Stand (VTS) Accelerator

Approval Page

Line Organization Review and Recommendation

This Appendix A Chapter 05 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD), *Accelerator Safety Envelope – Vertical Test Stand (VTS) Accelerator*, was prepared and reviewed by the staff of the Environment, Safety & Health Division (ESH) Accelerator Safety Department in conjunction with the Applied Physics and Superconducting Technology (APS-TD) Directorate staff for the VTS Accelerator.

Signatures below indicate review of this Accelerator Safety Envelope (ASE), and recommendations that it be incorporated into the Appendices of the Fermilab SAD.

☐ _____
APS-TD Associate Lab Director

☐ _____
Accelerator Safety Department Head

☐ _____
SAD Review Subcommittee Chair

Directorate & Fermi Site Office Final Approval

Final approval of this Accelerator Safety Envelope for the Vertical Test Stand (VTS) Accelerator is granted by the Fermilab Director and the DOE Field Element Manager.

_____
Director, Fermi National Accelerator Laboratory

_____
DOE Field Element Manager, Fermi Site Office

Revision History

Author	Rev. No.	Date	Description of Change
Fumio Furuta Maddie Schoell	0	August 10, 2023	Initial issue of this Accelerator Safety Envelope (ASE) for VTS.

Table of Contents

Section 1. Introduction and Scope

This document constitutes the Accelerator Safety Envelope (ASE) for full power operation of the Vertical Test Stand (VTS) Accelerator. It defines the Credited Controls that are established for the VTS Accelerator to assure that the level of risk to all workers, the public, and the environment is maintained at acceptable levels. This ASE is established in accordance with the DOE Order 420.2D, *Safety of Accelerators*, (DOE O 420.2D), and as flowed down through the Fermilab Environment, Safety and Health Manual (FESHM) including the Fermilab Radiological Control Manual (FRCM).

Section 2. Select Definitions and Acronyms

The following terms and/or acronyms are commonly used when discussing operation of the VTS Accelerator. Definitions that come directly from DOE O 420.2D, *Safety of Accelerators*, are noted with an asterisk (*), with further information on the interpretation and application of the definition for use at the VTS Accelerator in italics.

***Accelerator** A device and its components employing electrostatic or electromagnetic fields to impart kinetic energy to molecular, atomic, or sub-atomic particles and capable of creating a radiological area as defined by 10 CFR Part 835, Occupational Radiation Protection. Accelerator components include injectors, targets, beam dumps, detectors, experimental enclosures, accelerator enclosures, experimental areas, and experimental apparatus utilizing the accelerator. The accelerator also includes associated support and test facilities, equipment, systems, and utilities necessary to operate the accelerator or utilize the accelerated beam.

***Accelerator Facility** The accelerator, plant, buildings, structures, and equipment supporting the accelerator and its operations that are under direct control of the contractor

All facilities at Fermilab in some way contain components or conduct activities supporting an accelerator and its operations. As such, all facilities are described in the Safety Assessment Document (SAD).

***Accelerator Operations** Activities within the accelerator facility that, over the lifecycle of the facility, support 1) production or utilization of accelerator beams; 2) research and experimental activities utilizing accelerator beams; 3) handling, storage and analysis of accelerator induced radioactive components and materials within the accelerator facility boundary; 4) receipt, preparation, assembly, inspection, and installation of samples into the accelerator beam; or 5) removal, disassembly, handling, analysis, and storage for radioactive dose minimization to meet the definition of ALARA in 10 CFR Part 835, Occupational Radiation Protection, or transportation requirements, and packaging of samples after use in the accelerator beam. Accelerator Operations excludes radioisotope processing activities that are not required to operate or maintain the accelerator.

***Accelerator Readiness Review (ARR)** A structured method for verifying that hardware, personnel, and procedures associated with commissioning or routine operations are ready to permit the activity to be undertaken safely.

***Accelerator Safety Envelope (ASE)** A documented set of verifiable physical and administrative requirements, bounding conditions, and credited controls that ensure safe operation and address accelerator specific hazards and risks.

Accelerator Safety Envelope Intensity Calculated intensity that, assuming a one (1) hour point source loss would produce a 500 mrem accident condition

Accelerator Specific Hazard Hazards are classified as Accelerator Specific when their nature is uniquely defined by the configuration of the accelerator and they are not fully mitigated by Fermilab standard safety management programs. The passive, active engineered, and administrative mitigations which reduce accelerator specific hazards within Applicable Accelerator Facilities from unacceptable to acceptable risk are the Credited Controls

Applicable Accelerator Facility An Accelerator Facility further posted as an Exclusion Area.

***Commissioning** A phase of an accelerator facility operation that is typically used to conduct initial beam testing and/or verify design specifications. Commissioning periods may be tailored to the needs of each facility and there may be great variations in their duration, breadth, and formality, but in all cases, the activities will be bounded by an ASE and preceded by an ARR and DOE approval.

Compensatory Measure An approved alternative measure that may be used on a case-by-case basis in lieu of a Credited Control, with appropriate and documented approvals.

***Credited Control** Controls determined through the Safety Analysis to be essential for safe operation directly related to the protection of workers, the public, and the environment.

Credited Controls are implemented to mitigate Accelerator Specific Hazards within Applicable Accelerator Facilities to acceptable levels. For other facilities, controls to mitigate similar hazards are managed through programs and requirements specified in FESHM.

***DOE Element** First-tier organizations at DOE/NNSA HQ and in the field as listed in the Correspondence Style Guide, Office of the Executive Secretariat.

***DOE Field Element Manager** The manager having overall responsibility for a DOE field element including execution of oversight policy implementation. The Field Element Manager directs activities of DOE/NNSA field or site offices and has line

accountability for all site program, project execution, and contract management.

The Fermilab Site Office (FSO) Manager is the DOE Field Element Manager.

***DOE Program Secretarial Officer (PSO)** An Assistant Secretary, Office Director, Head of Program Element, or NNSA Deputy Administrator to whom designated field offices directly report and who has overall landlord responsibilities for the assigned direct reporting elements.

Nominal Operating Intensity Intensity identified by the machine and/or Project, analyzed in the Shielding Assessment.

Maximum Operating Intensity The maximum intensity a given segment is allowed to operate at without requiring additional actions/approvals/responses. This value is the Nominal Operating Intensity plus 5%, in order to accommodate potential fluctuation in beam intensity due to changes in efficiency.

***Radiation** Ionizing radiation, including the accelerated particle beam and the radiation produced when the beam interacts with matter or changes direction. Radiation includes alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions.

***Radioisotope Processing** Chemical, thermal, or physical actions taken to separate, isolate, refine, or enrich specific isotopes of a chemical element.

***Residual Radioactivity** Radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from the accelerator or accelerator operations.

***Reviewed Safety Issue** The outcome of the evaluation and determination phase of the USI Process.

***Risk** A quantitative or qualitative expression of possible harm, which considers both the probability that a hazard will cause harm and the amount of harm; or, alternatively, an estimate of the probability of occurrence of a hazard-related incident and the severity of the consequence associated with the incident.

Fermilab utilizes a qualitative risk assessment, following the methodology found in DOE-HDBK-1163-2020, Integration of Hazard Analyses.

***Safety Analysis** A documented process to systematically identify the hazards of a given operation; including a description and analyses of the adequacy of measures taken to eliminate, control, or mitigate the hazards and risks of normal operation; and identification and analyses of potential accidents and their associated risks.

***Safety Assessment Document (SAD)** A document containing the results of a Safety Analysis for an accelerator or accelerator facility pertinent to understanding the risks to workers, the public, and the environment of operating the accelerator.

***Unreviewed Safety Issue (USI)** An activity or discovered condition with accelerator specific hazards that have yet to be evaluated to determine if the activity or discovered condition introduces accelerator specific hazards that are not adequately addressed by the current SAD and approved ASE.

***USI Process** The process or methodology used to evaluate/review USIs to determine if the activity or discovered condition is adequately addressed by the current SAD and approved ASE.

Section 3. Description of Credited Controls

The Credited Controls identified in the ASE are a set of passive, active engineered, and administrative controls in use at the VTS Accelerator that define the bounding conditions and limitations for safe and environmentally sound operations. The Credited Controls listed in the ASE must be in place and functional for all operational areas. During periods of down time or maintenance, Credited Controls may be removed and managed under the Safety Configuration Management program to ensure they are replaced prior to resumption of operations.

For each Credited Control, the following is specified:

- **Applicability** – the condition in which the Credited Control is valid.
- **Basis** – description of the need for the Credited Control.
- **Requirement** – specific elements that must be in place during operation. Operation to the affected area without required elements in place is an ASE violation.
- **Compensatory Measure(s)** – An approved temporary alternative that may be taken to allow for safe operation when a requirement is not in place.
- **Required Surveillance** – management and monitoring practices that must be performed to assure continued effectiveness of the Credited Control. Surveillances are to be carried out at the minimum specified interval. Operation to the affected area without the required surveillance being performed within the minimum specified interval is an ASE violation.
- **Response** – actions to be taken if there is a suspected deficiency, missing control, or other potential ASE violation for that particular Credited Control.

The Credited Controls are divided into three main categories: passive controls, active engineered controls, and administrative controls.

Passive

Passive Credited Controls are elements that are part of the physical design of the facility that require no action to function properly. These are fixed elements that take human intervention to remove. The types of Passive Credited Controls in use for the VTS Accelerator include:

- Shielding (i.e., Permanent/Structural, Labyrinths, Movable, Penetration Shielding)

Acceptable methods for configuration of movable and/or penetration shielding include, but is not limited to: locked chains, Unistrut to block or inhibit movement, cover plates over penetration holes, etc.

Active Engineered

Active Engineered Credited Controls are systems designed to reduce the risks from accelerator operations to an acceptable level. The types of Active Engineered Credited Controls in use for the VTS Accelerator include:

- Radiation Safety Interlock System (RSIS)
- Oxygen Deficiency Hazard (ODH) Safety System

Radiation Safety Interlock System (RSIS)

Radiation Safety Interlock Systems (RSIS) are used to prevent injury, death, or serious over-exposure from beam-on radiation. The principle method employed by the RSIS is to establish and maintain Exclusion Areas surrounding accelerator operating areas. If there is a potential for personnel to inadvertently access the defined Exclusion Area, the RSIS is designed to inhibit accelerator operations in that area.

The RSIS may also include interlocked radiation monitors to supplement passive shielding Credited Controls. If dose rates exceed specified levels analyzed in the Shielding Assessment, the RSIS is designed to inhibit accelerator operations in that area.

The RSIS utilize a modular redundant design where no single component failure will result in a loss of protection. To accomplish this, two separate fail-safe circuits are used to detect specific conditions. All circuits within the RSIS are designed in such a way that if a circuit fails, or specified input is lost, the failure would initiate a system shutdown resulting in a safe condition.

Oxygen Deficiency Hazard (ODH) Safety Systems

ODH Safety Systems are used to prevent injury or death from exposure to oxygen deficient environments. ODH Classifications are determined based on a quantitative risk assessment, further described in FESHM 4240. ODH Classifications are then used to determine required personnel training and qualification and other ODH control measures. ODH Safety Systems utilize various components (e.g., area oxygen monitors, vents, fan, etc.) to maintain the posted ODH Classification.

ODH Safety System component failures are taken into account in the initial ODH analysis, and surveillance requirements are determined based on the analysis. In the event of a known failure of an ODH Safety System component that is necessary to maintain the original ODH Classification, the area is evacuated and ODH Classification is updated as needed based on existing out-of-service policy or updated ODH analysis.

ODH Safety System components that are required to maintain the posted ODH Classification within an interlocked and/or posted Exclusion Areas will be identified as Credited Controls and summarized in this ASE.

Administrative

Administrative Credited Controls encompass the human interactions that define safe operations. These are the accelerator operating policies and procedures that are followed to ensure safe accelerator operations. The types of Administrative Credited Controls in use for the VTS Accelerator include:

- Operation Authorization Document
    - Must include the following information:
        - Issue Date
        - Description of Operation
        - Operating Parameters
        - Credited Controls
            i. Shielding Requirements
            ii. RSIS Required Components and Inputs, including interlocked detectors
            iii. Staffing Requirements
            iv. Accelerator Operating Parameters
    - May also include additional information beneficial to those operating the VTS Accelerator
- Staffing
- Accelerator Operating Parameters

Section 4. ASE Violation Determination and Actions

Determination

Any operation of the VTS Accelerator with a known loss of Credited Control (except ODH Safety System Credited Controls) and/or the safety function of the Credited Control is a violation of the ASE.

> For Credited Controls that have additional overburden or Defense-in-Depth controls, it may not be immediately obvious if a deficiency is in the overburden or in the Credited Controls. In this case, it is not yet known if there even is a deficiency in Credited Controls constituting an ASE Violation. In these circumstances, the appropriate Line Organization and ESH Division Subject Matter Experts (SMEs) will investigate to determine if Credited Controls were impacted. This determination shall be documented following the USI Process, as described in Section 6 of this ASE. If it is determined that Credited Controls were impacted, operations shall be terminated immediately and not resume until the Reviewed Safety Issue (RSI) is finalized. If operations were to resume without the Reviewed Safety Issue (RSI) being finalized, that would constitute an ASE Violation.

For ODH Safety System Credited Controls, in the event of a known failure of an ODH Safety System component that is necessary to maintain the original ODH Classification, and the Cryo

Coordinator/Facility Manager determine that there is a need to reclassify the area (as opposed to replacing components), the area is evacuated and ODH Classification is updated as needed based on existing out-of-service policy or updated ODH analysis. Reentry into the area, before the ODH Classification is updated, is limited to personnel approved by the Cryo Coordinator/Facility Manager to perform work necessary for the ODH reclassification, any other access is a violation of the ASE.

Operation of the VTS Accelerator beyond the specified Operating Parameters is a violation of the ASE.

Operation of the VTS Accelerator with required surveillance of a Credited Control not conducted within specified frequency, as defined in Section 7 of this ASE, is an ASE violation.

Questions regarding determination of an ASE violation shall be addressed to the Environment, Safety & Health (ESH) Division Accelerator Safety Department Head and the Accelerator Division (AD) Associate Lab Director.

Actions

In the event that the ASE is violated, operations of the VTS Accelerator shall be terminated and put in a safe and stable configuration, and not resume until the circumstances of the event are reviewed and approval to resume operations is received. The USI Process, as described in Section 6 of this ASE, will be used to analyze and document the circumstances of the ASE violation. Once the RSI has been finalized for the event causing the ASE violation, approval to resume operations of the VTS Accelerator will be issued by the APS-TD Associate Lab Director and the DOE Field Element Manager.

Events determined to be ASE violations follow FESHM Chapter 3010 *Significant and Reportable Occurrences*, to provide the appropriate DOE notification and reporting.

Section 5. Configuration Management for Credited Controls

To ensure the integrity of the Credited Controls during accelerator operation, several methods of Configuration Management are in place.

- Excavation within the “Excavation Waiver Prohibited Zone” around the accelerator are required to go through the JULIE process. Part of the JULIE process includes ES&H Division Radiation Safety personnel review to determine if required shielding may be impacted.
- Required movable and penetration shielding is posted and locked and/or bolted in place where applicable.
- Components that are part of the Radiation Safety Interlock System (RSIS) are labeled.
- Surveillance is performed, as specified in Section 7.

If shielding or fencing is planned to be removed, the assigned Radiation Safety Officer (RSO) is responsible for ensuring the VTS Accelerator is locked off in a safe state, using RSO Configuration Control locks.

If any Credited Control is not in place, either planned or discovered, the assigned RSO is responsible for ensuring the VTS Accelerator is locked off in a safe state, using RSO Configuration Control locks.

Removal of Credited Controls (i.e., rescinding Operation Authorization Documents, removing shielding or fencing, etc.) during maintenance periods is common, and the assigned RSO is responsible for ensuring the VTS Accelerator is locked off in a safe state, using RSO Configuration Control locks.

The ES&H Division Radiation Physics Operations and Accelerator Safety Departments utilize a Configuration Control Log to track instances of placing the VTS Accelerator in a Configuration Controlled off state. This Log keeps track of reasons why the VTS Accelerator was locked off, what must be done prior to resuming operations, and confirmation that conditions are back in place and confirmed and operations was permitted to resume.

Section 6. Unreviewed Safety Issue (USI) Process

The Unreviewed Safety Issue (USI) Process is used to evaluate proposed activities/modifications and/or discovered conditions to ensure all hazards are adequately addressed in by the current SAD and approved ASE. The USI Process begins with completion of the USI Determination form, which includes multiple questions that will evaluate the proposed activity/modification and/or discovered condition to determine if it is already fully evaluated and included in the SAD and ASE or if and updated evaluation is necessary. At the conclusion of the USI Process, the review of the proposed activity/modification and/or discovered condition is classified as a Reviewed Safety Issue (RSI).

Proposed activities/modifications and/or discovered conditions at the VTS Accelerator are subject to the USI Process.

Compensatory Measures shall be reviewed and approved by the SRSO, and documented using the USI Process, prior to implementation.

Section 7. Summary of Credited Controls for the VTS Accelerator

Passive – Shielding

Applicability Operation of the VTS Accelerator.

Basis Based on the following Shielding Assessments, the shielding is required in the locations listed below.

Shielding Assessment(s):

- C. Ginsburg et al. "Modified radiation shielding of the vertical cavity test facility for VTS2/3 operations" Fermilab-TM-2483-APC-TD, April 2011 https://tiweb.fnal.gov/website/controller/1364
- Yu. Pischalnikov and R. Ruthe, "Fourth Addendum to the Hazard Analysis (Formerly the Safety Assessment Document) for the Vertical Cavity Test Facility", October 2013
- M. Vincent, "Revised Penetration Worksheet for Proposed IB1 VTS Trench", July 2017
- M. Vincent , Revised Exit Effective dose rate for proposed VTS RF Waveguide penetration at IB1, July 2017

Requirement Required shielding specified in the listed Shielding Assessments will be installed in its proper configuration during applicable operations.

The listed Shielding Assessment(s) utilized the incremental shielding assessment methodology, required shielding is summarized here.

Permanent Facility Shielding
none

Permanent Longitudinal Shielding
none

Permanent Transverse Shielding
none

Movable Shielding

Location	Shielding Type	Quantity	Purpose	Preferred Method of Configuration	Comments
Rolling Pit Shielding Cover	Concrete	One	Shield Pit actively in use for high power RF operation	Interlocked in place over Pit actively in use for high power RF operation	

Penetration Shielding

- Trench filled with 11" borated polyethylene

Compensatory Measure(s) In lieu of required shielding, temporary controls, such as guards, fencing, ropes, and/or postings, may be utilized as approved by the SRSO. Each use of a Compensatory Measure shall be documented using the USI Process.

Required Surveillance Required shielding shall be verified annually, not to exceed twelve (12) months.

Response Operation to the VTS Accelerator will be terminated. Operation to the VTS Accelerator will not resume until approval is received from the APS-TD Associate Lab Director and the DOE Field Element Manager.

Passive – Fencing

Applicability Not applicable

Basis Not applicable

Requirement none

Compensatory Measure(s) Not applicable

Required Surveillance none

Response Not applicable

Active Engineered – Radiation Safety Interlock System (RSIS)

Applicability During operation of the VTS Accelerator.

Basis Based on the following Shielding Assessments, the RSIS is established with interlocked barriers around the Exclusion Area, as well as inclusion of required interlocked radiation monitors.

Shielding Assessment(s):

- C. Ginsburg et al. "Modified radiation shielding of the vertical cavity test facility for VTS2/3 operations" Fermilab-TM-2483-APC-TD, April 2011 https://tiweb.fnal.gov/website/controller/1364
- Yu. Pischalnikov and R. Ruthe, "Fourth Addendum to the Hazard Analysis (Formerly the Safety Assessment Document) for the Vertical Cavity Test Facility", October 2013
- M. Vincent, "Revised Penetration Worksheet for Proposed IB1 VTS Trench", July 2017
- M. Vincent , Revised Exit Effective dose rate for proposed VTS RF Waveguide penetration at IB1, July 2017

Requirement The Radiation Safety Interlock System (RSIS) must prevent entry into the following Exclusion Area(s) during appliable operation:

- VTS Pit actively in use

Required components of the RSIS shall be specified in the VTS Accelerator's Operation Authorization Document.

The following components of the Radiation Safety Interlock System (RSIS) shall be in place, with no known loss of safety function, during applicable operations.

<u>Radiation Safety System – Interlocked Radiation Monitors</u>

Required radiation monitors specified in the listed Shielding Assessments, or as required by the assigned Radiation Safety Officer (RSO), must be interlocked to the RSIS.

Type	Location
Chipmunk	VTS Shield Block South
FOX	VTS Shield Block Center
Chipmunk	VTS Shield Block Center
[1]Chipmunk	VTS-1 Pit
[2]Chipmunk	VTS-2 Pit
[3]Chipmunk	VTS-3 Pit

[1] only required when Pit 1 in use for low power RF operation
[2] only required when Pit 2 in use for low power RF operation
[3] only required when Pit 3 in use for low power RF operation

Compensatory Measure(s)	In lieu of required interlocked detectors, temporary controls, such as guards, fencing, ropes, and/or postings, may be utilized as approved by the SRSO. Each use of a Compensatory Measure shall be documented using the USI Process.
Required Surveillance	The RSIS for the VTS Accelerator shall undergo certification annually, not to exceed twelve (12) months.
Response	Operation of the VTS Accelerator will be terminated. Operation of the VTS Accelerator will not resume until approval is received from the APS-TD Associate Lab Director and the DOE Field Element Manager.

Active Engineered – Oxygen Deficiency Hazard (ODH) Safety System

Applicability	Not applicable – Personnel restricted from area while operating
Basis	Based on the ODH Analysis, the ODH Safety System is established with specified required components.
Requirement	The following components of the Oxygen Deficiency Hazard (ODH) Safety System shall be in place, with no known loss of safety function, during personnel access into applicable areas. • N/A
Compensatory Measure(s)	N/A
Required Surveillance	N/A
Response	N/A

Administrative – Operation Authorization Document

Applicability	During operation of the VTS Accelerator.
Basis	To summarize the bounding conditions for safe operation of the VTS Accelerator, and to provide explicit approval for operations of the VTS Accelerator.
Requirement	An approved VTS Radiological Work Permit (RWP) for operation of the VTS accelerator shall be in place during applicable operations.

Compensatory Measure(s)	none
Required Surveillance	The VTS RWP for operation of the VTS accelerator shall be verified annually, not to exceed thirteen (13) months.
Response	Operation of the VTS Accelerator will be terminated. Operation of the VTS Accelerator will not resume until approval is received from the APS-TD Associate Lab Director and the DOE Field Element Manager.

Administrative – Staffing

Applicability	During operation of the VTS Accelerator.
Basis	To ensure operations within bounding conditions specified in RWP for operation of the VTS accelerator, and disable VTS operation and initiate an immediate response in the event of a determined ASE violation.
Requirement	The following staffing shall be in place during applicable operation: • At least one qualified operator present in the VTS Control Room during high power RF operation • No on-site staffing requirement for low power RF operation
Compensatory Measure(s)	none
Required Surveillance	none
Response	Operation of the VTS Accelerator will be terminated. Operation of the VTS Accelerator will not resume until approval is received from the APS-TD Associate Lab Director and the DOE Field Element Manager.

Administrative – Accelerator Operating Parameters

Applicability	During operation of the VTS Accelerator.
Basis	To accommodate necessary cryomodule testing, a wide range of frequency tests are permitted within the VTS Accelerator. The interlocked detectors within the RSIS ensure dose rates in the surrounding areas are maintained within posting limits.

Requirement	The VTS Accelerator will be operated within the following parameters: • Operations permitted within the frequency range of 10 MHz to 20 GHz These parameters are further specified in the VTS Running Condition. Frequency monitoring not required – frequency set by the signal generator.
Compensatory Measure(s)	n/a
Required Surveillance	none
Response	Operation of the VTS Accelerator will be terminated. Operation of the VTS Accelerator will not resume until approval is received from the APS-TD Associate Lab Director and the DOE Field Element Manager.

Section 8. References

[1] ??