**SNS-OPM-ATT 2.B-10.a.**
**Unreviewed Safety Issue (USI) Evaluation Form**

## I Title of USI Evaluation:

USI Evaluation for the changes associated with removal of the magnet electrical safety interlock functions and Controlled Access Magnets Energized mode for the Linac, HEBT, Ring, and RTBT PPS systems.

## II Description of Proposed Activity (or discovered condition):

This USI addresses the proposal to remove the non-credited PPS interlock electrical safety functions currently provided to protect individuals from exposure to unprotected energized electrical connectors on magnets in the Linac, HEBT, Ring, and RTBT tunnels. Electrical hazards at SNS, including those associated with tunnel magnets, are safely managed under the provisions of the ORNL Worker Safety and Health SBMS *Electrical Safety* Subject Area. The value of retaining the non-credited PPS electrical safety function is considered low and is potentially confusing to workers. Workers are trained to assume magnets are energized unless de-energized in accordance with the Electrical Safety SBMS (e.g. LOTO). The advantages of the proposed change is that the complexity of the PPS design will be reduced which will allow resources and attention to be focused on the credited mission of the PPS: to mitigate prompt radiation hazards associated with beam.
*Note: It is intended to implement this modification at the same time as the isolation of Linac PPS power supply commons in the Linac klystron gallery (See USID 102030102-ES0084). However, this modification and isolation of PPS power supply commons are considered two separate activities and are not interdependent.*

The PPS design allows each of the accelerator tunnel segments to be in one of six operating modes as defined in Section 3.2.3.3.2 of the FSAD-PF. Four of the operating modes allow personnel to enter the tunnels:

- Restricted Access
- Sweep
- Controlled Access
- Controlled Access Magnets On[1],

At present, the PPS interlocks de-energize magnets for the purpose of electrical safety in the tunnels for three of the four operating modes listed above: 1) Restricted Access mode, 2) Sweep mode, and 3) Controlled Access mode. The proposed change will remove the PPS function of de-energizing magnets for electrical safety purposes in these three operating modes.

The fourth operating mode that allows personnel access in the tunnels is the *Controlled Access Magnets On* mode. Currently, this operating mode is analogous to the Controlled Access Mode except that the PPS does not de-energize the magnets in this mode and an audible warning tone is sounded every thirty seconds in the affected segment to alert personnel in the tunnel that the magnets are energized. Since the PPS will not de-energize any of the magnets for electrical safety purposes with the proposed change, there will be no need for the *Controlled Access Magnets On*; therefore, this operating mode will be eliminated.

It should be noted that a credited function of the PPS is to prevent beam transport by disabling certain magnets defined as *Critical Devices* in Section 3.2.3.5 of the FSAD-PF. This credited function will not be altered by the proposed change. The PPS disables prescribed *Critical Devices* in order to prevent beam transport as required to support the different SNS *Beam Containment Modes* defined Section 3.2.3.5 of the FSAD-PF. The following magnets are defined as Critical Devices:

- First Dipole Magnet in the HEBT (DH11)

[1] Also referred to as Controlled Access – Magnets Energized.

- Second through Eighth Dipole Magnets in the HEBT (DH12-18)
- RTBT DH13 Dipole Magnet
- Extraction Septum Magnet

The PPS disables the Critical Device magnets listed above by de-energizing the associated magnet power supply. The Critical Device magnets are de-energized in an analogous manner as that currently used to de-energize the other magnets for the purpose of electrical safety. It is stressed that the proposed changes do not involve the Critical Device magnets. The proposed changes only affect the other magnets (non-Critical Device magnets).

The proposal to remove the non-credited electrical safety features from the PPS has been reviewed and approved by the SNS Electrical Safety Committee and has been developed as a collaborative effort between the Protection Systems Team and the Electrical and RF Engineering group responsible for the magnet power supplies.

The proposed changes will involve the hardware and software modifications listed below. Drawings associated with the proposed changes are listed on the PCR (SNS-RAD-ICS-CR-0010).

### II.A.1 Summary of Changes to PPS Hardware and Equipment

1) The PPS interface control cable to the non-critical device magnets in the Front End, Linac, HEBT, Ring, and RTBT service buildings will be removed and replaced by a simple jumper wired to enable the magnets.
2) The PPS operator panels in the CCR will be changed to reflect the removal of the PPS control of the non-Critical Device magnets (includes removal of the *Controlled Access Magnets ON* panel controls).
3) PLC Input/Output modules[2] that exclusively interfaced to magnet power supplies will be removed. I/O modules that perform other functions like lights, RF interlocks, and door controls will be retained.

### II.A.2 Summary of Changes to PLC Logic and Other Software

1) The PPS logic software will be modified for the Linac, HEBT, Ring, and RTBT to remove logic related the PPS control of the non-critical device magnets.
2) The EPICS screens will be modified to remove references related the PPS control of the non-Critical Device magnets.

### II.A.3 Changes to Access Control and PPS Certification Procedures and Training

The SNS Protection Systems Team will work in conjunction with the SNS Accelerator Operations Group in revising certification and access control procedures. SNS RAD line management will be responsible for implementing OPM revisions and training associated with the proposed PPS changes as appropriate. Changes to OPM procedures include:

1) Modify PPS procedures referring to Controlled Access Magnets Energized
    - SNS-OPM 3.A-3.1. Access Control Procedures For Primary Beam Enclosures
    - SNS-OPM 3.A-3.1.6. Access Control Procedure (Restricted and Controlled) for the Linac Tunnel - PPS Phase 4.0
    - SNS-OPM 3.A-3.1.7. Access Control Procedure (Restricted and Controlled) for the HEBT Tunnel - PPS Phase 4.0
    - SNS-OPM 3.A-3.1.8. Access Control (Restricted and Controlled) for the Ring, Injection Dump and RTBT - PPS Phase 4.0
2) Modify PPS Certification Procedures 3.A-7.4.12 A-F and I-J to remove references to non critical

2 Input/Output modules (I/O): Inputs convert electrical signals into logical 1's and 0's processed in the PPS logic. Outputs perform the reverse function.

device magnets
3) Modify PPS Certification Procedures 3.A-7.4.12 A-F and I-J to remove test steps referring to "Controlled Access Magnets ON"

**II.B Background**

The Linac, HEBT, Ring, and RTBT Personnel Protection Systems (PPS) perform multiple active safety functions to ensure safe operation of the accelerator segments. The primary safety functions include access controls, radiological interlocks, and beam containment. To date, the PPS also includes a non-credited electrical safety function to shut off all accelerator magnet power supplies when a tunnel segment is open for access. In practice, SNS takes no credit for the electrical safety interlocks of accelerator magnets and instead relies on following the administrative lock-out/tag-out (LOTO) program to protect workers from potential electrical and magnetic hazards in the beam enclosures.

The SNS approach to electrical safety has developed since the original PPS design which included electrical safety interlocks to de-energize magnet power supplies. Most significantly, SNS has fully adopted compliance with the electrical safety program specified in the ORNL SBMS Electrical Safety subject area. Additionally, the ORNL Lock Out Tag Out subject area in SBMS has recently undergone significant revisions to ensure consistency with current electrical safety standards (e.g. 10CFR851, NFPA, NEC, etc.) and practices.

This practice is in accordance with ORNL electrical safety practices prescribed in the SBMS. OSHA explicitly prohibits the exclusive use of interlocks to create an electrically safe condition.
The proposal was reviewed by the SNS Electrical Safety Committee who concluded:

> *Although the PPS system does provide a secondary protection, it is not relied upon for electrical safety. The addition of the secondary PPS interlocks introduces complexity without significant increase in electrical safety.*
> *It is clear from the discussion among the subject matter experts that this proposal will not adversely affect electrical safety. Therefore, the committee agrees that electrical safety is not compromised or diminished by removing PPS control of non-critical magnet power supplies.* (1)

**II.B.1 Critical device magnets**

This proposed change does not impact the four critical device magnet PPS interfaces used for beam containment. There are currently 187 magnet power supply interfaces interlocked through the accelerator PPS systems. Only four of the interfaces provide the credited safety function of preventing beam transport, the other 183 interfaces provide the electrical safety protection of de-energizing magnets when the tunnels are accessible. The four PPS interfaces to Critical Device magnets are listed below and will not be affected by the proposed changes to the PPS:

- First Dipole Magnet in the HEBT (DH11)
- Second through Eighth Dipole Magnets in the HEBT (DH12-18)
- RTBT DH13 Dipole Magnet
- Extraction Septum Dipole Magnet

The FSAD-PF section 3.2.3.5.3 *"Control of Critical Devices"* explains how the credited HEBT, Ring, and RTBT magnets are sufficient to prevent beam transport to an occupied downstream area. Coupled with the facility shielding design and other radiological controls described in the FSAD-PF, personnel in occupied areas are safe during a design-basis beam loss accident.[3]

3 The referenced sections are too involved to replicate in this document. See FSAD-PF sections 4.2-4.4 and 4.6 for a full description of radiological hazards and mitigations for both normal operations and postulated accident scenarios.

### II.B.2 Non critical device magnets

Similarly, either errant operation or failure of a non-critical device magnet cannot create a significant hazard to personnel in occupied areas. The associated magnet failure and beam loss is detected and mitigated through the Machine Protection System (MPS) as described in FSAD-PF section 3.2.2.3 *"Machine Protection System."*

#### II.B.2.1 Electrical Hazard of non critical device magnets

From the Linac to the RTBT there are 468 magnet power supplies interlocked through 187 PPS interfaces (Table 1). Four-hundred fifty-one of the magnets do not rise above the 100 VDC threshold to have special controls for shock or arc flash hazard.[4] These low voltage power supplies were originally incorporated into the PPS interlocks under an abundance of caution. Seventeen magnet power supplies are capable of providing open-circuit voltages above the 100 VDC threshold for evaluation as a shock or arch flash hazard.[5]

**Table 1 Inventory of PPS Interlocked Magnet Power Supplies**

| Open Circuit Voltage[5] | # of Supplies Currently Interlocked | # with PPS Credited Control Function |
|---|---|---|
| ≤ 100 VDC | 451 | 3 |
| 100 < VDC ≤ 300 | 1 | 0 |
| 300 < VDC < 1000 | 16 | 1 |
| > 1000 VDC | 0 | 0 |
| Total | 468 | 4 |

#### II.B.2.2 Magnetic Hazard of tunnel magnets

Magnetic field hazards associated accelerator magnets is mentioned in FSAD-PF Section 4.3.1.3. The FSAD states magnetic hazards are addressed using the same mitigations described in section 4.2.4 *"Electrical Safeguards"* with the additional stipulation that *"non-ferrous tools must be used for work around elements with a high magnetic field…"*. As with electrical hazards, working on or near high magnetic fields requires work planning and mitigations per SBMS requirements (e.g. SBMS Procedure: *Working with Nonionizing Radiation*).

### II.B.3 Control of Electrical Hazards Under ORNL SBMS

The FSAD-PF section 4.3.1.2 addresses electrical hazards in the tunnel due to exposed magnet electrical conductors. FSAD-PF section 4.2.4 *"Electrical Safeguards"* states *"safety of workers is ensured through compliance with the ORNL SBMS requirements, e.g. implementation of NFPA 70E Standard for Electrical Safety in the Workplace."* This section goes on to delineate:

- *"Workers are trained to assume that magnets are powered in all cases and treat them accordingly"* [i.e. regardless of PPS state]

4 See SBMS *Hazard Analysis for Electrical Work* Table 2 (Shock Approach Boundary) and Table 4 *Arc Flash Analysis for Direct Current (DC) Systems.*

5 Magnet power supplies typically operate as a constant current source; they will vary the output voltage to regulate the current. The Open Circuit output voltage is the highest voltage the power supply can produce.

- *"…the* [electrical safety] *limited approach and arc flash boundaries … are clearly marked on the floor*
- *"In cases where workers are required to work on or near a magnet, the magnet power supply is locked out and tagged out"*

Current routine operating practice is to de-energize and LOTO magnet Power Supplies in the HEBT, RING, and RTBT tunnels for any activity which requires personnel to cross the "Approach Boundary" of the magnets. The LOTO is performed in accordance with ORNL *Electrical Safety* subject area in SBMS.

> *Note: All of the Magnet Power Supply conductors within the LINAC tunnel remain covered and labeled in accordance with the ORNL SBMS on Electrical Safety. LOTO on the LINAC Magnet Systems is performed on an as needed basis as determined by its required maintenance. A group LOTO station for each accelerator segment is maintained in the Central Control Room during outages and long maintenance periods.*

FSAD-PF Table 4.3.1-5 *"Qualitative Risk Assessment for the Accelerator Exposed Electrical Conductors"* concludes no credited controls are required and that the *"hazard is adequately addressed through the ORNL SBMS electrical safety requirements."* The electrical safety of high power magnet power supplies is addressed by existing procedures and processes extending from SNS and Engineering & RF group work control procedures. SNS will continue the practice of group lockout of magnet power supplies before general access to an accelerator enclosure.

### II.B.4 Controlled Access Magnets ON PPS Mode

With magnet interlocks tied to the PPS segment access state, it was necessary to have a means to power magnets for special tests with personnel present. Typical examples are polarity checks, field calibrations, and troubleshooting. The *Controlled Access Magnets ON* PPS mode[6] was introduced as a method to allow limited access to powered magnets without having to jumper PPS magnet permits and readbacks. In practice, the Controlled Access Magnets ON mode is rarely used.

The PST System Engineers and Operations management did consider if *Controlled Access Magnets ON* mode should be retained for electrical safety for the four critical device magnets that remain under PPS control. They determined that there was no real benefit and recommended the mode be removed from the PPS.

The FSAD-PF makes several references to *Controlled Access Magnets ON* mode while stressing that personnel must follow all ORNL and SNS requirements for electrical safety and LOTO to work on or near a powered magnet. Suggested modifications to the FSAD-PF are given in Appendix A.

### II.B.5 Controlled Access Magnets ON operator panel key switch

Controlled Access Magnets ON mode is entered by rotating a momentary key switch while simultaneously changing the PPS mode from Power Permit to Controlled Access. The Controlled Access Magnets ON key switch is presently used in three functions:

- Transition into and out of Controlled Access Magnets ON Mode
- Bypass one of two Gamma Blocker OUT position switches (Ring/RTBT Only)
- Reset of PLC output module electronic fuses

The specific action is dependent on the simultaneous operation of another key control. Table 2 lists how the CA Magnets ON switch is used. The table also defines if the function will be removed or modified.

6 The FSAD also refers to this mode as *"Controlled Access - Magnets Energized."*

**Table 2 The "Controlled Access Magnets ON" key switch serves several functions. With removal of the CA Magnets ON PPS mode, other uses will be retained or modified.**

| Action # | CA Magnets ON Key Switch Position: | | Simultaneous Secondary Action | | Result | Keep/Remove/Modify Function? |
|---|---|---|---|---|---|---|
| 1 | Clockwise | + | Mode Switch Transition from Power Permit to Controlled Access | = | Controlled Access Magnets ON Mode | Remove function. Remove key switch in Linac and HEBT. |
| 2 | Counterclockwise | ---- | ---------- | = | Transition to standard Controlled Access Mode (Magnets OFF) | Remove function. Remove key switch in Linac and HEBT. |
| 3 | Clockwise | + | Mode Switch Transition from Power Permit to Beam Permit (Ring/RTBT Only) | = | Bypass Gamma Blocker 'B' Out position switch | Keep (Ring/RTBT Only) |
| 4 | Counterclockwise | + | Mode Switch Transition from Power Permit to Beam Permit (Ring/RTBT Only) | = | Bypass Gamma Blocker 'A' Out position switch | Keep (Ring/RTBT Only) |
| 5 | Clockwise | + | Chipmunk and System Fault Reset Clockwise | = | Reset Output Module Electronic Fuse | Modify: CA Magnets ON key switch no longer used for this function. Reset will be through operation of the Chipmunk/System Fault Reset Key only. |

II.B.5.1 Controlled Access Magnets ON function Removed (Table 2 Actions 1-2)
*Controlled Access Magnets ON* mode is reached by setting the PPS mode to "Power Permit" then switching back to "Controlled Access" while simultaneously holding another panel key in the "Controlled Access Magnets ON" position. When in Controlled Access Magnets ON mode, the PPS allows tunnel entries into a segment without de-energizing the magnets. The PPS provides an audible warning alarm within the tunnel every 30 seconds when in Controlled Access Magnets On mode to remind individuals in the tunnel that the magnets are energized. Special administrative precautions are implemented for tunnel entries under Controlled Access Magnets On mode including a special pre-entry electrical safety briefing.

With the completion of this proposed change, the PPS will no longer tie non critical magnet permits to the PPS state. Therefore, the *Controlled Access Magnets ON* mode will no longer be needed. In accordance with good system safety practices of not retaining unused (dead) functions, the mode will be removed from the PPS PLC logic.

II.B.5.2 Gamma Blocker Position Bypass Retained (Table 2 Actions 3-4)
In the Ring and RTBT tunnel segments, the panel key switch that allows entry into the Controlled Access Magnets On mode has additional features added that allow the same key switch to be placed into the Gamma Blocker Position Bypass position. This feature will be retained.

The Gamma Blockers are shield plugs that are remotely inserted into the beam flight path upstream of the ring injection dump and target as an ALARA measure to reduce local radiation back streaming when personnel enter the tunnels (see Section 3.2.3.10.3 in the FSAD-PF). The PPS provides the non-credited function of monitoring the position of the Gamma Blockers to ensure that the Gamma Blockers are inserted when personnel access the tunnel and to ensure that they are removed prior to beam operations. The PPS provides a non-credited Gamma Blocker Bypass function such that when the key switch is in the Gamma Blocker Bypass position, the operator may transition from Power Permit to Beam Permit mode if either one of the two Gamma Blocker position switches does not indicate "OUT". This feature will be retained for the Ring and RTBT PPS systems. The switches on the Ring and RTBT operator control panels will be renamed to reflect this (see Figure 3).

In the Linac and HEBT, the Controlled Access Magnets ON panel control key is used exclusively for entering/leaving the Controlled Access Magnets ON mode. With the deletion of the "Controlled Access Magnets ON" mode, the key switches (and associated status lights) for the Linac and HEBT will simply be removed (see Figure 4).

II.B.5.3 Reset for PLC Output electronic fuse modified (Table 2 Action 5)
Some PPS PLC output modules have internal electronic fuses to protect against overcurrent. These electronic fuses can be remotely reset using a command within the PLC logic. For convenience, the CA Magnets ON key switch was used in conjunction with the Chipmunk/System Reset key switch to send a signal to reset any tripped electronic fuses. The electronic fuse trip was originally treated differently from other system faults to ensure personnel were aware of the nature of the trip. The PPS logic for all areas now has 'first-out' detection which is displayed through the EPICS control screens. The source for all system faults is displayed and recorded. Therefore, instead of keeping the Linac/HEBT key switch just for this purpose or continuing the complicated multiple function use of the switch in the Ring/RTBT, the electronic fuses will be reset through the dedicated Chipmunk/System Fault reset switch.

**II.C Detailed Description of Changes:**

**II.C.1 Changes to PPS Hardware and Equipment**
The proposed change involves physically removing the wiring to non critical device power supplies and modifying the associated PLC logic for electrical safety interlocks.

1.) Remove non critical magnet PPS control wiring in the Linac, HEBT, Ring, and RTBT service buildings.
    a) Disconnect PPS wiring to non critical device magnet power supplies in the Linac, HEBT, Ring, and RTBT PPS segments. This includes both the PPS Permit outputs to the power supplies and the PPS Magnet Status Readbacks from the power supplies.
    b) Remove PLC input/output hardware modules with no remaining interface to PPS equipment or controlled devices.

As shown in Table 3, there are a total of 187 PPS interfaces distributed among ten racks in the four affected PPS segments. The typical interface wiring between the PPS and a non critical magnet power supply is shown in Figure 1. The PPS provides an ENABLE output command to the supply and receives a status READBACK from the supply. Including power, ground and shield, there are a total of five wires that must be disconnected for each interface.

| PPS Segment | Cabinet, PPS: | # Non Critical Device Power Supply Interfaces |
|---|---|---|
| **Linac** | FE-Cab03 | 4 |
| | Klystron-Cab01 | 25 |
| | Klystron-Cab02 | 22 |
| | Klystron-Cab03 | 11 |
| | Klystron-Cab04 | 16 |
| **HEBT** | HEBT-Cab01 | 23 |
| **Ring** | Ring-Cab01 | 25 |
| | Ring-Cab04 | 10 |
| | Ring-Cab-08 | 30 |
| **RTBT** | RTBT-Cab-01 | 21 |
| | Total | 187 |

**Table 3 PPS Power Supply Interfaces by PPS Cabinet**

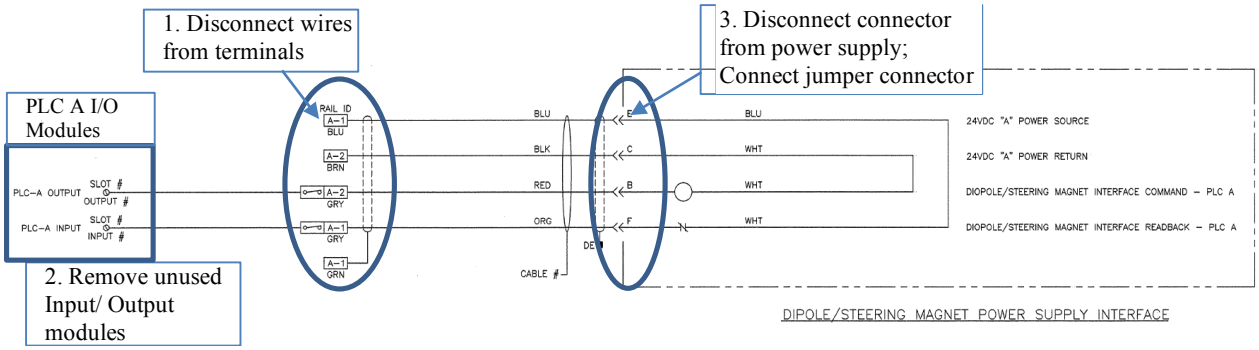


**Figure 1 Typical PPS Interface to non-critical device magnets. The wiring between the circles will be disconnected and removed. PLC I/O modules will be removed if they serve no other purpose. The PPS connection to the power supply will be replaced with a jumper connector originally supplied with the power supply.**

**Figure 2 Typical PPS connection at a non critical device magnet power supply. This connection will be removed and a jumper connector installed.**

2.) Modify the CCR PPS operator panels to reflect the removal of non critical device magnets and the "Controlled Access Magnets ON" panel controls.
   a) Replace CCR PPS operator panels with ones removing references to "Magnets" and "Controlled Access Magnets ON"
   b) Remove the "Controlled Access Magnets ON" key switch and status lamps from the Linac and HEBT CCR operator panels (See Figure 4.)
   c) Re-label the Ring and RTBT "Controlled Access Magnets ON" key switches to "Gamma Blocker Bypass Trigger" (See Figure 3).
   d) Added a panel lamp to indicate Power Permit Mode for System B

**II.C.2 Changes to PLC Logic and Other Software**

1) Modify Linac, HEBT, Ring, and RTBT PPS PLC Logic (Software)
   PLC A Logic Changes:
   a) Modify the System A PPS logic to remove the non critical device magnet Permits, Readbacks, and System checks. *(Note: System B has no interfaces to non-critical device magnets).*
   b) Remove the System A and System B PPS logic associated with "Controlled Access Magnets ON" for the Linac, HEBT, Ring, and RTBT PPS segments.
   c) Modify the System A and System B PLC logic to remove the "Controlled Access Magnets ON" key switch input to reset PLC output module electronic fuses.
   d) Modify the PLC software configuration to remove I/O modules identified in (II.C.1.b) above.
2) Modify or delete EPICS screens to:
   e) Remove references to non-critical device magnet status
   f) Remove references to Controlled Access Magnets ON
3) Modify PPS EPICS alarms relating to non-critical device magnets

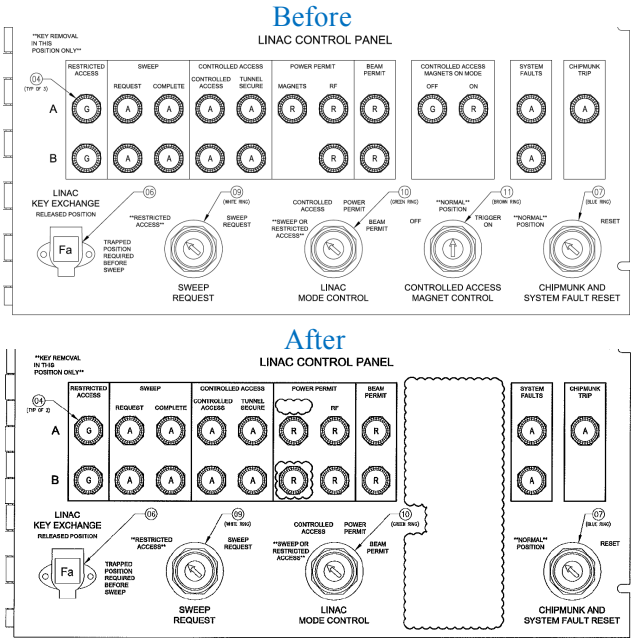


Figure 4 Linac Control Panel Modifications.

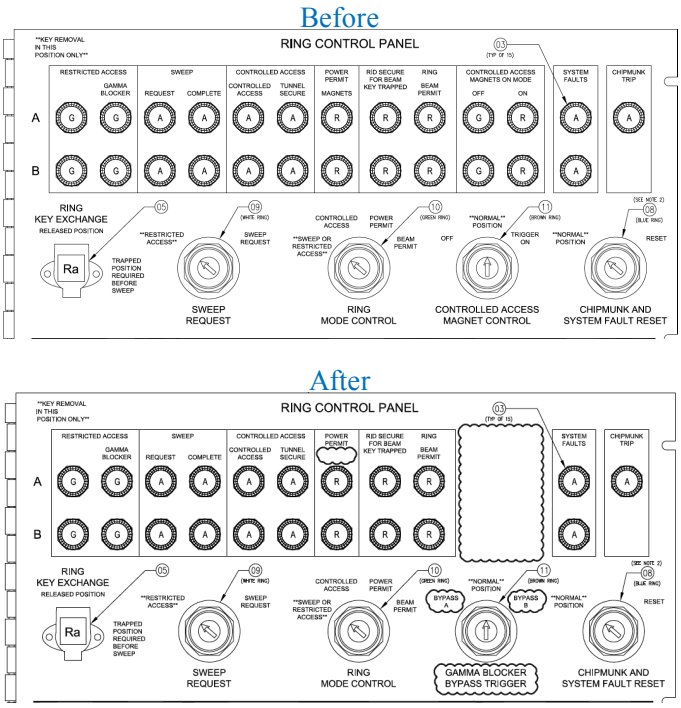


Figure 3 Ring Control Panel Modifications

Table 4 gives the PPS PLC Logic functions to be removed from each PPS segment. Note PLC System B does not contain non-critical magnet interface logic but does contain logic for the *Controlled Access Magnets ON* PPS mode. Section II.B.5 and Table 2 give a detailed description of how the multiple functions performed by the "Controlled Access Magnets ON" key switch will be eliminated in the Linac and HEBT and reduced to one function in the Ring and RTBT.
The logic associated with the CCR operator panel *Controlled Access Magnets ON* mode control key switch will be removed from the Linac and HEBT PPS. In the Ring and RTBT, this switch is also used to allow transition into BEAM PERMIT if one of the two Gamma Blocker position switches is failed. The bypass function will be retained for the Ring and RTBT and the key switch re-labeled on the Ring and RTBT operator panels.
The PPS PLC System A also has two non credited outputs in each segment related to *Controlled Access Magnets ON* operations which will be removed from the logic –

a.) An output to the alphanumeric message display at each entry station that triggers the *"Controlled Access Magnets ON"* message
b.) An output to the public address system that initiates a tone every 30 seconds. This tone was intended to remind personnel in the tunnel that the status was *Controlled Access Magnets ON*.

**Table 4 Logic Functions to be Removed From Linac, HEBT, Ring, and RTBT PPS Logic**

| Logic Function | To be Removed from PPS System A Logic | To be Removed from PPS System B Logic |
|---|---|---|
| **Non-Critical magnet ENABLE** | ✓ | - NA - |
| **Non-Critical magnet Feedback FAULT** | ✓ | - NA - |
| **System FAULT for CA Magnets ON Trigger Switch (Linac and HEBT Only)** | ✓ | ✓ |
| **Controlled Access Magnets ON status** | ✓ | ✓ |
| **Controlled Access Magnets ON Panel Lamps** | ✓ | ✓ |
| **Controlled Access Magnets ON PA System Alarm** | ✓ | - NA - |
| **Use of Controlled Access Magnets ON key switch in PLC Output Electronic Fuse Reset function** | ✓ | ✓ |
| **Entry Station "Controlled Access Magnets ON" display message** | ✓ | - NA - |

## II.D Change Implementation Processes

### II.D.1 QA, Verification, and Validation

There are a set of processes in place to ensure the solution and other modifications are implemented faithfully and correctly. In addition to design and change management processes for CECs defined in the SNS Operations Procedure Manual (OPM), the SNS Protection Systems Team utilizes lifecycle processes defined in ISO/IEC/IEEE 15288 *"Systems and software engineering — System life cycle processes"* to

assure the final product meets the intended performance requirements.

**II.D.2 Design Process:**
The design process encompasses the initial request through the completed and approved design change package. The request and proposal to remove the non critical device magnets was developed jointly between the Protection Systems Team and the Electrical Engineering & RF Group. The proposal was presented to the SNS Electrical Safety Committee to ensure the removal of an electrical safety interlock would not significantly affect how SNS manages electrical safety. The Committee agreed that the SNS relies primarily on the ORNL Lockout/Tagout program as well as SNS maintenance procedures to assure worker safety (1).
The design process first entailed a verification of the as-built documentation and wiring of the existing Linac, HEBT, Ring, and RTBT racks. The verified information was then used as the design basis for the subsequent engineering modifications.

**II.D.3 Implementation Process:**
This change is implemented under Permanent Change Request (PCR) SNS-RAD-ICS-CR-0010.
The SNS Electrical Safety Committee reviewed and endorsed the plan to remove the electrical interlock function from the PPS. The committee agreed that electrical safety is adequately controlled through the ORNL SBMS electrical safety subject area and PPS interlocks do not add value to this practice. (1)

II.D.3.1 Implementation of the Hardware Modifications
Field modifications include:

1. Disconnecting the non critical device wiring at each PPS cabinet
2. Disconnecting the PPS cables at each magnet power supply interface
3. Replacing the PPS connection with a jumper plug
4. Removing the unused PPS-Magnet cables from the cable trays

Planning and safety for field work is covered under the SNS work control process. Field workers will have a work package that includes the work order, safety planning, field documentation, and QA documents.

II.D.3.2 Implementation of the Software Modifications
The PLC logic (software) modifications are implemented by two separate programmers.
SNS-RAD-ICS-QA-0001 addresses the ten SQA criteria under the ORNL SQA SBMS subject area and DOE-O-414.1D and associated guidance 414.1-4A. SNS-RAD-ICS-PR-0014, *"Software for Credited Engineering Controls"* is used to develop and implement PPS PLC modifications. Modifications for each PPS division (A/B) are performed by separate individuals. Engineering personnel performing the software modifications have training and experience in programming the PLC models used in both the existing and new PPS racks.

The PLC software modification process included the following:

- Creation of before/after checklists for modified logic functions
- Verification of hardware/software/firmware compatibility using the PLC vendor compatibility matrix and vendor engineering support
- Modification of copies of the existing certified PLC programs to effect the required changes.
- Simulated operation of each PPS segment
- Verification that only the intended changes were made using inspection and the PLC compare utility.
- Independent inspection of the before and after logic programs as well as the compare report to assure only the intended changes were made.

II.D.3.3 Integration Process
The integration process includes testing the modified CCR panel controls then system level testing with the modified software. For this project, the full integration testing is performed in-situ with all potentially hazardous devices and critical devices locked and tagged OFF. There will be at least two full shifts of preliminary software testing before formal commissioning and certification. Although the software QA process normally identifies implementation errors, the preliminary testing is designed to stress the software to further assure potential errors are addressed before final testing and certification.

II.D.3.4 Operations Documentation Updates and Training
SNS Research Accelerator Division line management will be responsible for implementing processes and training associated with the proposed PPS changes to ensure the appropriate level of training and awareness of electrical safety hazards during tunnel entries.

Procedures listed in Section II.A.3 above will be revised to reflect the proposed modifications. Operations documents referring to "Controlled Access Magnets ON" will be revised to remove reference to this mode. Tunnel Access and Controlled Access training will be modified to remove material related to the PPS electrical safety features and "Controlled Access Magnets Energized" mode.

Tunnel access training to date has informed individuals that the PPS de-energizes magnet connectors for all tunnel entries except "Controlled Access Magnets On" mode. Training has also informed individuals that the PPS de-energizes magnets in the adjacent segment in the event of an emergency gate crash into the adjacent segment. Although individuals are currently trained not to cross the red line unless they have personally affixed a lock per LOTO procedure to ensure devices are de-energized, awareness training of the change in PPS electrical safety functionality will be beneficial in fully informing workers of conditions related to electrical safety of the magnet contactors.

Awareness training for those who already have completed Tunnel Access and Controlled Access training will help effectively communicate the removal of the PPS electrical safety features while reinforcing the importance of compliance with existing electrical safety procedures consistent with SBMS (e.g. red line boundary, LOTO, etc.).

The current practice is to normally LOTO the magnet power supplies out prior to tunnel entries. The Controlled Access Magnets On mode is rarely used. Operations line management will be responsible for updating these processes as appropriate to ensure electrical safety in the absence of the PPS electrical safety related features.

### II.D.4 Testing and Verification Process:

II.D.4.1 Off-Line Testing
Off-line testing includes testing the modified PLC logic to the degree possible. Test and verification tools integrated into the PLC software development environment are used to ensure the intended changes were made and no unintended changes are present. Copies of the old and new PLC programs as well as the results of a compare function between the two are provided to independent software reviewers for verification.

II.D.4.2 Installation Testing
Installation testing includes 100% verification that the non-critical device magnets are disconnected and that the critical magnets function normally. There are three phases to the installation testing for this project:

a.) Dedicated preliminary tests used to verify the field changes and PLC logic changes. During this

phase there may be minor modifications to PLC logic to correct errors not found during the off-line testing.
b.) Formal commissioning tests that validate the specific changes are implemented correctly and that there are no unintended changes to the remaining PPS functions
c.) Completion of a full certification of the Linac, HEBT, Ring, and RTBT PPS segments

All three phases require lockup of the beam enclosures in order to minimize the need to jumper PPS signals to reach a given state or operating condition. During phase a, b, and the first part of c, hazardous devices controlled by the PPS will be locked OFF. The full functionality of the critical device magnets will be verified during this process. Only after the PPS functionality is fully verified during the first part of PPS Certification, will the locks be removed and the hazardous devices powered ON to complete the certification procedures.

**II.E Conclusion of Section II**

The material presented in section II supports the determination of a negative USI. The proposed change removes the magnet electrical safety interlock functions from scope of the Personnel Protection Systems (PPS). As discussed in the FSAD-PF, SNS relies on the administrative function of LOTO to maintain employee safety. This change actually improves the overall safety reliability of the PPS by reducing the complexity of the system and eliminating non-credited functions. The change also has the benefit of improving the overall SNS accelerator availability by reducing the mean time to repair of non credited magnet power supplies. Awareness training will ensure personnel are aware of the PPS changes as appropriate.

**III Does the proposed activity or discovered condition affect information presented in the FSAD-NF or FSAD-PF, e.g. regarding equipment, administrative controls, or safety analyses?**

Yes. The FSAD-PF refers to the PPS electrical safety function including the Controlled Access Magnets On mode in several locations. The FSAD-PF descriptions are clear in specifying that the electrical safety functions of the PPS are not credited. Several sections of the FSAD-PF will need to be revised to reflect the configuration associated with the proposed changes. Suggested FSAD-PF revisions are listed in Appendix A.

**IV Does the proposed activity or discovered condition affect any of the requirements of the ASE?**

No.

The magnet electrical safety interlock function performed by the PPS is not a credited control and not incorporated in the ASE.

**V USI Evaluation Criteria:**

1. Could the change significantly increase the probability of occurrence of an accident previously evaluated in the FSADs? Yes __ No X

   **Justification**:

   The PPS is a Credited Engineered Control credited with protecting workers from potentially injurious prompt radiation produced by accelerator operations. The probability of occurrence of an accident associated with accelerator produced prompt radiation is not affected by the proposed modifications.

   Electrical hazards associated with the exposed magnet conductors are addressed in the FSAD-PF as summarized in the Qualitative Risk Assessment presented in FSAD-PF Table 4.3.1-5 which concludes the "hazard is adequately addressed through the ORNL SBMS electrical safety requirements and that no Credited Controls are required. The qualitative unmitigated probability of occurrence assessed as "Anticipated High" and is unchanged by mitigative measures such as PPS or following ORNL SBMS requirements. The mitigated probability of occurrence listed in FSAD-PF Table 4.3.1-5 is "Extremely Unlikely" and will remain unchanged using the electrical safety protocols required by the ORNL SBMS on Electrical Safety.

   Electrical hazards associated with the exposed magnet conductors fall well within the scope of electrical hazards present across the ORNL site are considered a standard industrial hazard that can be safely managed by ORNL SBMS on Electrical Safety. The ORNL SBMS Electrical Safety Subject Area is consistent with industry best practices and standards and is sufficient to safely manage electrical hazards associated with the magnets.

   SNS Operations line management will ensure that processes and training are in place to ensure electrical safety is implemented per SBMS and to ensure the appropriate level of awareness for changes to the PPS electrical safety functionality.

2. Could the change significantly increase the consequences of an accident previously evaluated in the FSADs? Yes__ No X

**Justification**:

The PPS is a Credited Engineered Control credited with protecting workers from potentially injurious prompt radiation produced by accelerator operations. The consequence of accidents associated with accelerator produced prompt radiation is not affected by the proposed modifications.

Electrical hazards associated with the exposed magnet conductors are addressed in the FSAD-PF as summarized in the Qualitative Risk Assessment presented in FSAD-PF Table 4.3.1-5 which concludes the "hazard is adequately addressed through the ORNL SBMS electrical safety requirements and that no Credited Controls are required. The qualitative unmitigated consequences are assessed as "Medium" and are unchanged by mitigative measures such as PPS or following ORNL SBMS requirements. The consequences of personnel contacting energized connectors are unchanged by the mitigative measures (i.e PPS electrical safety interlocks and/or following ORNL SBMS requirements). The mitigative measures are designed to reduce the frequency that personnel might come in contact with an exposed conductor as addressed in Question 1 above.

Electrical hazards associated with the magnets fall well within the scope electrical hazards present across the ORNL site are considered a standard industrial hazard that can be safely managed by ORNL SBMS on Electrical Safety. The ORNL SBMS Electrical Safety Subject Area is consistent with industry best practices and standards and is sufficient to manage electrical safety hazards associated with the magnets.

SNS Operations line management will ensure that processes and training are in place to ensure electrical safety is implemented per SBMS and to ensure the appropriate level of awareness for changes to the PPS electrical safety functionality.

3. Could the change significantly increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the FSADs?

   Yes__ No X

**Justification**:

When properly implemented, the proposed changes will decrease the probability of a malfunction of the PPS by eliminating functions and equipment that do not perform a credited safety function. The advantage of the proposed change is that the complexity of the PPS design will be reduced which will allow resources and attention to be focused on the credited mission of the PPS which is to mitigate prompt radiation hazards associated with beam.

The probability of inadvertently impacting the credited PPS functions while implementing the proposed modifications is minimized to acceptable levels by implementing the Testing and Verification processes described in Section II.B.4 above.

Once the modifications are complete, proper operability of all safety functionality is verified by the completion of commissioning tests followed by a full PPS system Certification in accordance with approved SNS Procedures. The SNS certification procedures are designed to comprehensively verify detailed system functionality.

4. Could the change significantly increase the consequences of a malfunction of equipment important to safety previously evaluated in the FSADs?

   Yes__ No X

   **Justification**:

   The PPS is a Credited Engineered Control (CEC) credited with protecting workers from potentially injurious prompt radiation produced by accelerator operations. The potential safety consequences of a failure of the PPS system (i.e. excessive prompt radiation exposure) are grave and are unchanged by system modifications.

   Under the proposed change, electrical safety associated with the exposed magnet conductors in the tunnel will be ensured by compliance with the ORNL SBSM Electrical Safety Subject Area. The consequences of a failure to comply with ORNL SBMS Electrical Safety requirements (e.g. LOTO) are unchanged. SNS Operations line management will ensure that processes and training are in place to ensure electrical safety is implemented per SBMS.

5. Could the change create the possibility of a different type of accident than any previously evaluated in the FSADs that would have potentially significant safety consequences?

   Yes__ No X

   **Justification**:

   Removing the electrical safety features of the PPS does not create the possibility for new accidents. Associated accidents will remain those associated with personnel exposure to excessive levels of prompt radiation and personnel inadvertently contacting exposed electrical magnet conductors. SNS Operations line management will ensure that processes and training are in place to ensure electrical safety is implemented per SBMS.

6. Could the change increase the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the FSADs?

   Yes__ No X

   **Justification**:

   No. The proposed modifications will not increase the possibility of a different type of malfunction of equipment important to safety as evaluated in the FSADs. This change simplifies and thus reduces the possible equipment malfunctions of the PPS system credited functions. The possibility of a malfunction associated with implementation of the ORNL Electrical Safety SBMS are deemed acceptably low as addressed in Question 2 above.

DWF 1/14/2016

**VI. USI Determination:** A USI is determined to exist if the answer to any of the 6 questions above (Section V) is "Yes." If the answer to all 6 questions is "No", then no USI exists.

a. Does the proposed activity (or discovered condition) constitute a USI?

__ Yes – DOE approval required prior to implementing

X No – Proposed activity may be implemented with appropriate internal review.

| | |
|---|---|
| Kelly Mahoney, Protection Systems Team Leader, Qualified Preparer | 7-January-2016 Date |
| Aaron Coleman, Protection System Engineer, Reviewer | 1/8/2016 Date |
| David Freeman, SNS Safety Specialist, Qualified Reviewer | 1/7/2016 Date |
| Robert Eason, Electrical Safety Subcommittee Chair | 1/11/16 Date |
| Glen Johns, Accelerator Operations Group Leader, Reviewer | 1-7-16 Date |
| Hans Vogel, NScD Directorate Operations Manager, Reviewer | 1/14/16 Date |

**Approvals:**

| | |
|---|---|
| Kevin Jones, SNS Operations Manager | January 14, 2016 Date |

## VI Appendix A: Proposed FSAD-PF Revisions

FSAD-PF references to PPS magnet electrical interlocks and Controlled Access Magnets ON. The pertinent FSAD information is quoted *in italics*. Recommended changes to the existing text will be highlighted in yellow.

*3.2.3.7 Other PPS Controlled Devices*
*The PPS controls additional devices associated with the accelerator to protect workers from non-beam related hazards ~~or from~~ such as X-rays that could be generated by RF during access to the tunnel. These devices include RF power supplies that provide RF to accelerating cavities located in the LINAC tunnel.*
*~~and~~*
*~~magnet power supplies that may have exposed leads.~~*

3.2.3.3.3 Safety Functions
…
The PPS also performs for the following secondary functions to help enforce safety:
· ~~Prevent energizing of exposed electrical conductors in segments not cleared of personnel except in controlled circumstances.~~
· Shut off RF klystrons ~~and de-energize exposed electrical conductors~~ if personnel enter an operating segment.
· Warn personnel located in segments before beam operations.

*3.2.3.1 … A secondary (non-credited) function is to help protect workers from exposed electrical conductors associated with beam line magnets.*
Delete this sentence.
This description is included in the FSAD to ensure a comprehensive description of all PPS functions. It is not necessary after the proposed change.

*3.2.3.3.2 Operating Modes… The PPS does not go into the Controlled Access-Magnets Energized Mode unless the Power Permit Mode has been reached (ensures no one is in the tunnel when the controlled access-magnets-on mode is selected).*
Delete this sentence. Consider adding description of gamma-blocker.

*Table 3.2.3.3.2-1 PPS Operating Modes*
Delete row describing *"Controlled Access – Magnets Energized"* mode

*3.2.3.7.1.3 Magnet Power Supplies*
*Magnets located throughout the accelerator have exposed electrical connections. To protect workers from the hazards associated with the exposed conductors, the PPS disables power supply operation when the tunnels are accessible ~~(except during "Controlled Access-Magnets On" Mode).~~ Normal lockout/tagout (LO/TO) methods are used to protect workers required to perform "on or near" maintenance on electrical equipment.*
In practice, SNS takes no credit for the PPS interlocks of magnet power supplies and relies exclusively on LOTO when the beam enclosures are open for access.

*Small power supplies for corrector magnets are controlled using a PPS device (small power supply controller) that contains an ac contactor. ~~This contactor is controlled by the PPS and provides a readback signal to indicate when the contactor is open or closed.~~ This contactor controls power to a rack containing several individual power supplies.*
Delete this section.

There is no regulatory driver to have these low-voltage low-current power supplies interlocked through the PPS. They do not qualify as requiring LOTO under NFPA70E. They were included in the PPS interlock under an abundance of caution.

*Medium and large power supplies are controlled using a standard PPS interface. The PPS interfaces with each power supply via a dedicated unique electrical connector. The PPS provides a control signal that enables or disables power supply operation. Two readbacks contact are provided from the power contactor(s) in the power supply to indicate the contactor status (open/closed).*
Delete this section.
Only the four critical device magnets have redundant readbacks to the PPS. These will be maintained unchanged. The remainder of power supplies interlocked for electrical safety only have one Permit and one readback to PPS system A.
There are 18 power supplies that exceed the 100 VDC threshold for a shock hazard. Of those, only one falls into arc flash category 2. The other 17 fall under arc flash category 1.

*3.2.3.8.1… The master key is electrically interlocked to the PPS, such that when the key is removed, hazardous operations are not allowed in the segment ~~(except during "Controlled Access Magnets Energized" when the magnet power supplies are allow to operate)~~.*
As part of this change, operation of non-credited magnet power supplies will not depend on the PPS state.

*4.2.4 Electrical Safeguards…In cases where workers are required to work on or near a magnet, the magnet power supply is locked out and tagged out. In some cases, it is necessary to perform measurements near magnetic elements while powered. ~~A separate Magnet Power On Mode of the PPS is used in these cases.~~ Appropriate control over access during ~~this mode~~* **operations**, *as well as training requirements, addresses these concerns for exposed powered conductors and magnetic fields, and appropriate PPE must be worn for workers who cross the restricted approach and/or arc flash boundaries. A minimum of two workers are assigned to these tasks, with one serving as a safeguard. Additionally, where electrical hazards are present to SNS personnel working in the area, LO/TO procedures are required to be in place and to be part of the SNS Training Program.*
All of the above administrative and PPE requirements remain in place when one must work on or near an energized magnet.

*4.3.1.3 Magnetic Hazards*
*In a few instances, it may be necessary to work near magnetic elements while powered. Appropriate control over access modes and training requirements address these concerns for high magnetic fields (see discussion in Section 4.2.4, "Electrical Safeguards"). In addition, procedures note that nonferrous materials must be used for work around elements with a high magnetic field, both for the protection of the worker and to eliminate the possibility of damage to equipment.*
This section stands as-is.

*3.2.3.10.3 Gamma Blockers*
*The inserted and retracted position of the gamma blocker is monitored by the PPS and MPS using redundant position switches. If the gamma blocker remains in the beam path when commanded to open, both the MPS and PPS would prevent beam operation.*
The function that allows a CCR operator to bypass one of the redundant chains is

*Table 4.3.1-5*
*Qualitative Risk Assessment for the Accelerator*
*Exposed Conductors*
*Does the hazard require a Credited Control per Section 4.1.2?*
*Y/N No—hazard adequately addressed through the- ORNL SBMS electrical safety requirements.*
This statement is accurate as-is.

## VII Appendix B References

1. **Eason, Robert.** *Electrical Safety Committee review of Proposal to remove PPS control of non-critical magnet power supplies.* [e-mail] Oak Ridge, TN : ORNL Electrical Safety Committee, October 28, 2015.
2. **SNS.** Spallation Neutron Source Final Safety Assessment Document for Proton Facilities. *FSAD-PF.* s.l. : Oak Ridge National Laboratory, December 2010. 102030103-ES0018-R02.
3. —. Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities. *FSAD-NF.* s.l. : Oak Ridge National Laboratory, September 2011. 102030102-ES0016-R03.
4. —. SNS Accelerator Safety Envelope (ASE) for Full Power Operations of the Front End, Linac, Ring, Transport Lines, Beam Dumps and Target. *ASE.* s.l. : SNS, May 2007. SNS 102030103-ES0016-R05.