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

I Title of USI Evaluation:

Isolate Power Supply Commons in the HEBT PPS Racks and isolate HEBT/Ring Gate Control Power

II Description of Proposed Activity (or discovered condition):

This proposed modification is part of the continuing corrective actions to eliminate potential common failure modes from the accelerator PPS systems. It is tracked under ACTS Issue 16952.1 *"Separate the PPS power supply commons."*

The proposed modifications addressed in this USI evaluation include:
1) Isolate HEBT PPS cabinet power supply commons from earth ground. Specifically for this USI, the HEBT PPS CAB02 PSA, PSB, PSC, PSD, and PSE +24VDC power supply banks will be isolated from earth ground and each other.
2) Replacing semiconductor diodes with relays used to isolate the HEBT and Ring power controlling the magnetic lock on the HEBT/Ring PPS doors.

The associated Permanent Change Request is documented through SNS-RAD-ICS-CR-0017 and Design Change Notice SNS-RAD-ICS-CN-0051.

This change is very similar to the isolation of klystron gallery PPS racks performed in January 2016 under SNS-RAD-ICS-CR-011 and evaluated in USIE 102030102-ES0084.

II.A Summary of Changes to Hardware and Equipment

1) Remove wires that connect PPS DC power supply returns (commons) to earth ground.
2) Remove wires that connect PPS DC power supply returns (commons) between DC power supply banks A-E.
3) Modify the HEBT/Ring tunnel door junction boxes to use relays instead of diodes to electrically isolate the two sources of control power for the door magnetic locks.

II.B Background

The proposed modifications described in this USI evaluation are part of the long-term corrective action plan tracked as ACTS Issue 16952.1. This modification eliminates potential common failure modes by completely isolating the PPS power supplies from each other and from the cabinet earth ground. The proposed changes evaluated in this USI better meets the intent of FSAD-PF 3.2.3.4.1 *PLC Hardware:*

> *"Each redundant PLC in a one-out-of-two configuration is maintained as a separate system to minimize common mode failures."*

Isolation of the 24VDC power for each PPS rack was identified and approved as the appropriate corrective action to eliminate a potential common failure mechanism. A December 2013 design review of proposed interim and long-term modifications identified

> *"The long term modifications, isolating all PLC power supplies from earth ground, maintaining segment and chain power supply isolation and using isolated outputs is a correct solution to the original design shortcomings."*[1]

An independently lead SNS Hazard and Operability Study (HAZOP) team tasked with looking for other potential common failure modes also recommended:

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1 SNS-RAD-ICS-TR-0002 *"Spallation Neutron Source Personnel Protection System Modification Review Committee Report"*

"The long term corrective action to separate PPS power supply commons remains the best way to eliminate the failure mode leading to the July 2013 event. This will be a multi-year effort."[2]

The initial phase, isolation of CCR PPS cabinet power supplies, was reviewed and completed in July 2015 under USI evaluation 102030102-0080. Isolation of the Linac klystron gallery PPS power supplies was completed in January 2016 under USI evaluation 102030102-0084. This modification is scheduled for June 2016. Modification of additional accelerator PPS cabinets to isolate DC power commons will continue through 2018.

II.B.1 Modification of HEBT CAB02 Power Supply Commons

The HEBT PPS rack CAB02 incorporates five banks of 24VDC power supplies used to power various HEBT PPS equipment and field devices. Each bank of power supplies includes two identical power supplies connected through a redundancy module. The redundancy module automatically switches between power supplies in the event of a failure of one of the supplies. Table 1 lists the power supply banks, components, and equipment powered by each bank.

Table 1 HEBT PPS DC Power Supply Banks

Power Supply Bank	Components	Load
A	PS-A1, PS-A2, RED-A	HEBT PPS Chain A Components
B	PS-B1, PS-B2, RED-B	HEBT PPS Chain B Components
C	PS-C1, PS-C2, RED-C	HEBT Chipmunk Radiation Monitoring Systems
D	PS-D1, PS-D2, RED-D	Control Power for HEBT DH-11 and DH12to18 PPS Contactors
E	PS-E1, PS-E2, RED-E	PPS Controlnet fiber-optic repeaters

Banks A, B, and C need to be isolated to minimize potential common mode failures in redundant PPS PLC systems. PPS Chain A and Chain B provide isolated permits that switch the DC power from Bank D to energize the HEBT critical device dipoles. Using a separate supply to operate the contactors minimizes the impact of switching transients on the other PPS equipment. Bank E powers fiber optic repeaters that all of the accelerator PPS systems use to communicate between a central controller and remote I/O in the field. The communication channels are inherently isolated through the use of fiber optic cables.

Presently, each of the DC power supply commons are connected together and to earth ground.
The proposed modifications, shown in Figure 1, will remove the wires connecting the power supply commons to each other and to chassis ground. By removing the wires indicated in figure 1, each of the power supply banks will be isolated from each other and chassis ground.

2 Mahoney, K., et. al. *"Hazard and Operability Study: SNS Personnel Protection Systems."* May 7, 2014

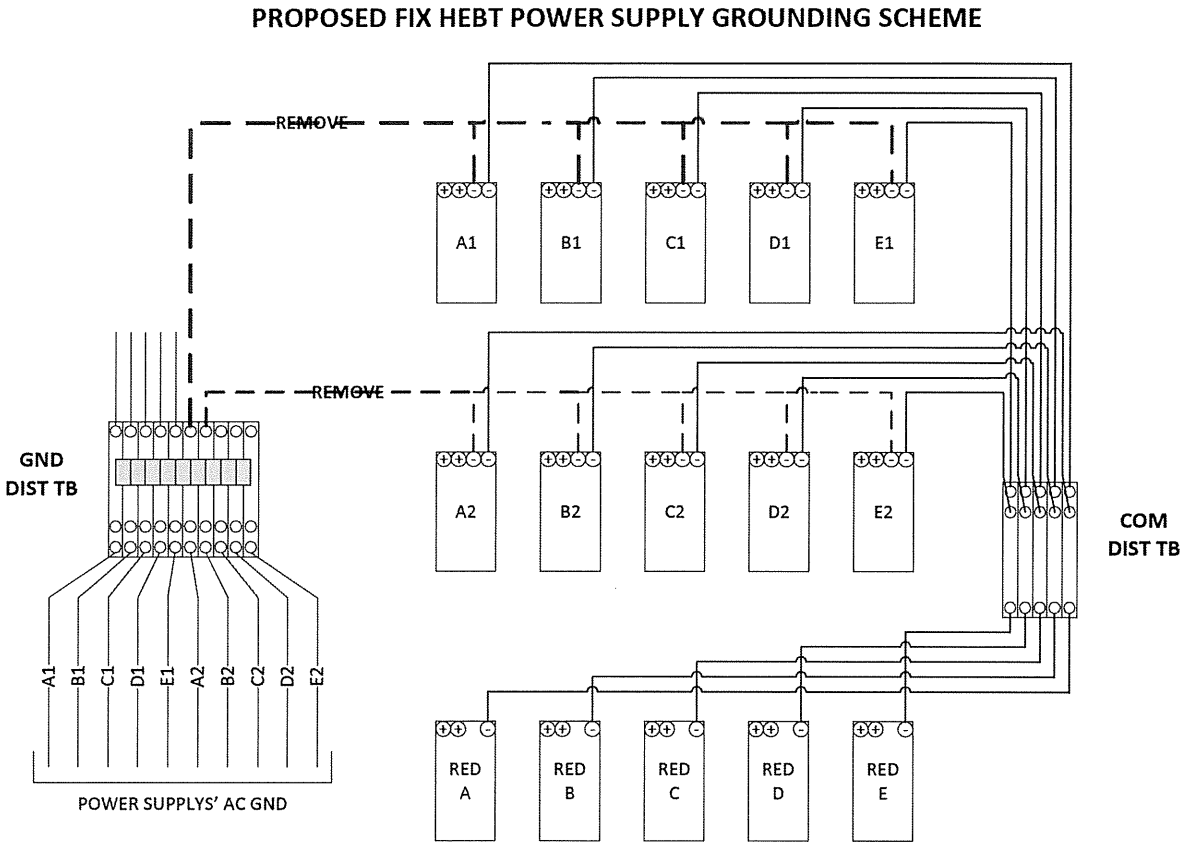


Figure 1 Diagram of HEBT Power Supply Grounding. Dashed lines are wires connecting DC Common to Chassis Ground. These wires will be removed leaving the power supply DC commons isolated.

II.B.2 Modification of HEBT/Ring Gate Maglock Control

The HEBT/Ring tunnel door serves as the primary barrier between the two PPS segments[3]. The door position is independently monitored by the HEBT and Ring PPS systems using separate position switches. However, there is only one magnetic lock for the door that can be energized by either the HEBT or the Ring PPS segment. Presently, steering diodes are used to 'OR' the maglock control power from the two PPS segments. The power supply returns for the HEBT and Ring are also connected together with steering diodes at this junction box. While steering diodes can prevent significant currents from affecting adjacent segment power, they do not truly electrically isolate the two adjacent PPS segments. Also, diodes tend to fail short circuit, which could directly connect the HEBT and Ring PPS power or returns. The preferred method is to galvanically isolate the power and returns of the two PPS segments. In order to completely isolate the HEBT PPS power from the Ring PPS power, the diodes will be removed and two relays will be added to the HEBT gate maglock control signals. The DC power and return for the HEBT will then be fully isolated from the Ring, significantly reducing the potential for failures due to interconnected power and grounds[4]. Although relay contacts can fail open or short circuit, the HEBT and Ring power will remain isolated in both cases. A similar change was successfully implemented for the Linac/HEBT gate in January 2016 (See USI evaluation 102030102-0084).

3 See FSAD-PF section 3.2.3.8.4 "Beam Line Tunnel Gates" for a description of the HEBT/Ring door.
4 Note the door magnetic locks are controlled by PPS Division A only. In the event of a HEBT-Ring PPS A failure due to shorted diodes, credited safety functions performed by PPS Division B are not affected. This failure mode is eliminated with relays.

II.C Detailed Description of Changes:

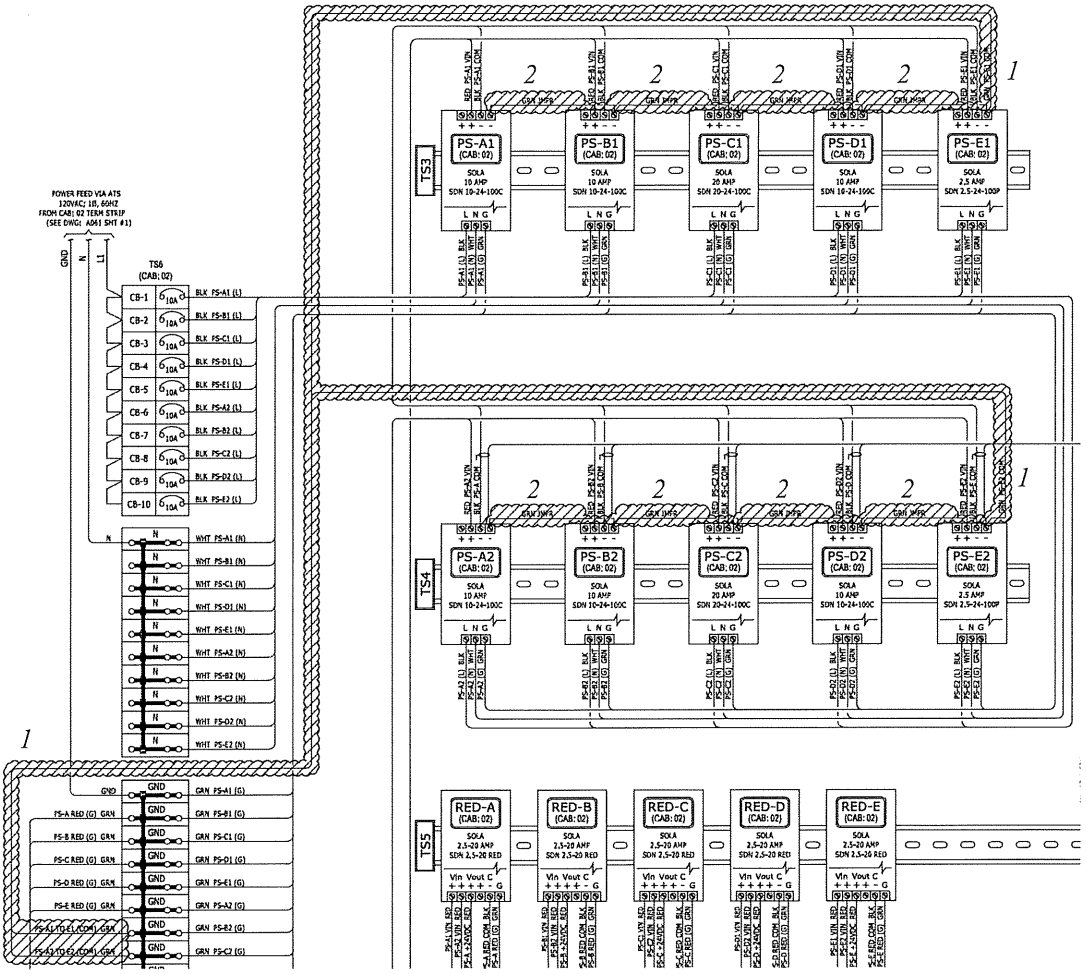
The following section provides more detail on the proposed modifications described in section II.A and II.B

1. *Remove wires that connect PPS DC power returns (commons) to earth ground.*
    a. Removing the wires connecting Power Supplies to earth ground isolates the PPS DC returns from AC ground. (See areas marked '1' Figure 2)
2. *Remove wires that connect Power Supply commons for A1-E1 and A2-E2.*
    a. Removing the wires that connect power supply commons isolates the commons for each power supply bank. (see areas marked '2' Figure 2)

Verification of Items 1&2:

The isolation between each of the PPS PLC power supplies from each other and from earth ground is verified through:

- peer review of the proposed wiring design
- independent inspection of the equipment
- verification against the approved drawings
- electrical measurements on the installed equipment
- 100% verification of HEBT PLC Remote I/O



3. *Re-wire the HEBT/Ring tunnel gate junction boxes using relay logic rather than diodes to electrically isolate the gate magnetic lock control power and returns from each other.*
    a. Remove the steering diodes and associated wiring from the gate interface boxes. (See Figure 3)
    b. Two relays will be installed to isolate the HEBT maglock control power from the Ring maglock control power. The gate control contacts are arranged as a logical 'OR' where either the HEBT or the Ring PPS can lock the gate. Figure 4 shows the modified gate maglock control wiring with relays used for isolation between the HEBT and Ring PPS systems.

Verification of Item 3:
Isolation and proper operation of the Linac and HEBT gate functions will be verified through:

- peer review of the proposed wiring design
- independent inspection of the equipment
- verification against the approved drawings
- electrical measurements on the equipment
- local and remote testing of each gate function to include
    - independent operation of gate position switches
    - independent operation of gate magnetic lock
    - independent operation of emergency exit (ESTOP) pushbuttons
    - proper operation of HEBT/Ring stack lights

EXISTING

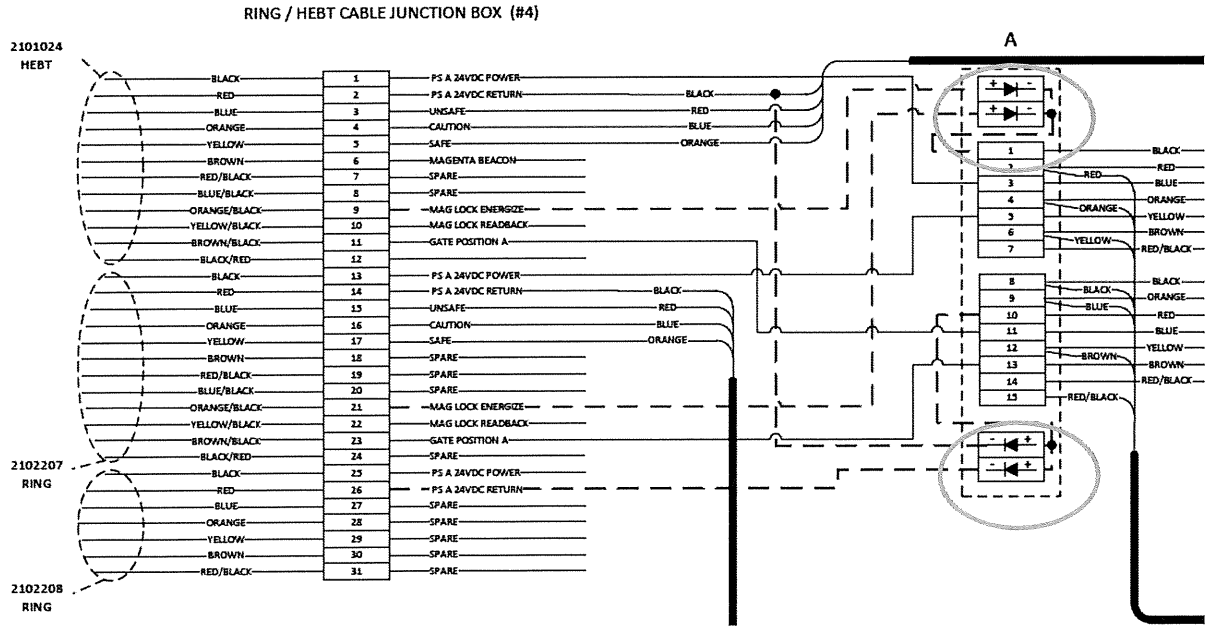


Figure 3 Existing gate maglock control using steering diodes. Diodes and associated wiring (dashed red lines) will be removed.

PROPOSED

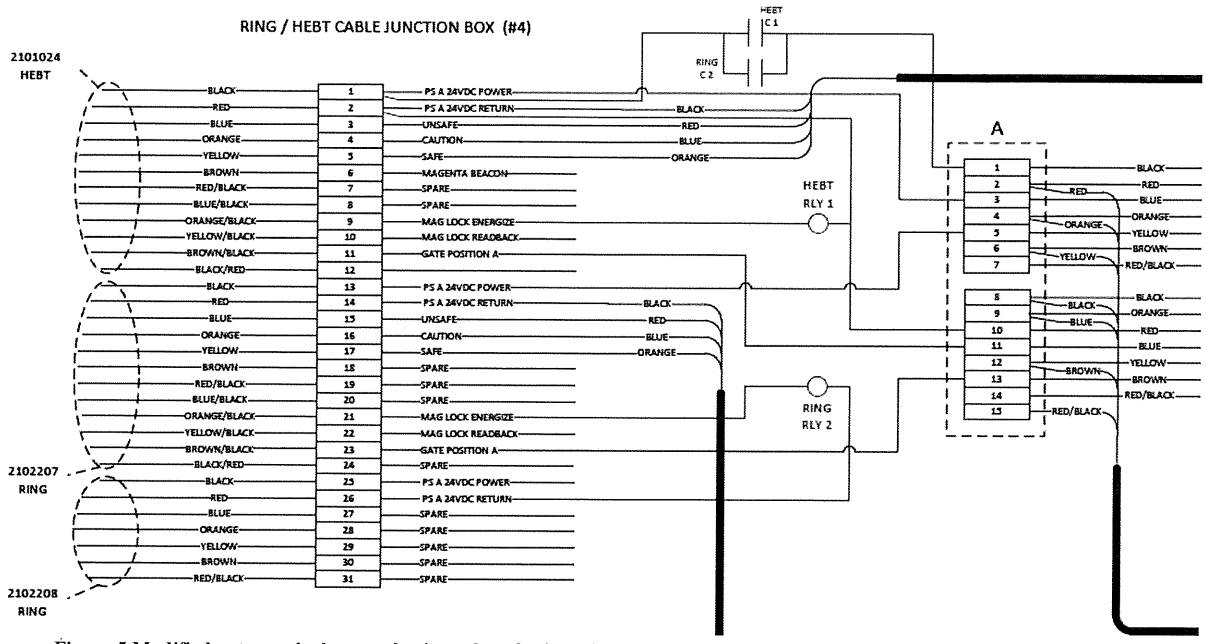


Figure 5 Modified gate maglock control using relays for isolation. Red lines show relays and new wiring. HEBT and Ring magnetic lock control power and returns are now galvanically isolated.

II.D QA, Verification, and Validation

Given the externally reviewed and approved solution to eliminate potential common mode ground errors is to isolate the DC power, 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.1 Design Process:

The design process first entailed a 100% verification of the existing documentation, construction and wiring of the HEBT PPS cabinets and the HEBT/Ring gate wiring[5]. The verified information was then used as the design basis for the subsequent engineering modifications for the revised wiring. New drawings were created where necessary to better document both the existing configuration and design modifications. The new drawings show exactly where power supply common wires are connected.

- The wiring drawings of the junction boxes at the HEBT/Ring tunnel gate were modified to fully isolate HEBT and Ring magnetic lock control power. Drawings are listed in PCR SNS-RAD-ICS-CR-0017 and ECN SNS-RAD-ICS-CN-0051.

5 See, for example, Work Orders 1428758 and 1431394.

II.D.2 Implementation Process:

II.D.2.1 Hardware Modification
There is no new fabrication associated with this change.
The HEBT and Ring PPS will be removed from service during the modification process. During this time an appropriate RS Hold will be applied to the Ion Source and RF modulators. The HEBT and Ring PPS will be returned to service upon completion of the testing and verification process II.D.3.
Modifications to the CAB02 power supply wiring and the PPS gate junction box will make use of work instructions accompanied by drawings highlighting the items to be removed or added. See Figure 4 as an example.

II.D.2.2 Software Modification
There are no software modifications as part of this change.

II.D.2.3 Integration Process
There are no integration requirements for this change.

II.D.2.4 Operations Documentation and Training
There are no changes to Operations Documentation and Training associated with this modification.

II.D.3 Testing and Verification Process:

II.D.3.1 Laboratory Testing (HEBT/Ring Gate Only)
Isolation relays will be tested before installation in the HEBT/Ring gate control junction box.

II.D.3.2 Post Maintenance Testing
The HEBT PPS systems will undergo post maintenance testing using written procedures as part of the verification and validation process[6].
Testing Includes:

a. The power supply grounding modifications will be verified against the modified power distribution drawings.
b. Tests of the modified cabinet wiring include:
   - Verification of isolation between power supplies
   - Verification of isolation between power supplies and earth ground
   - Verification of proper operation of equipment powered by the HEBT power supplies
   - Verification of nominal voltage and current for each power supply
   - Test of each PLC I/O point in HEBT CAB01 to verify proper power/ground connections.

c. The installed HEBT/Ring gate junction boxes will be fully tested along with monitored and controlled devices at the HEBT/Ring Labyrinth. Tests include:
   - Door position switch operation
   - Door magnetic lock operation from both the HEBT and Ring
   - Gate emergency exit switch (ESTOP) operation from both the HEBT and Ring
   - HEBT/Ring stack light operation
   - Electrical isolation of the above items

d. Tests of all HEBT and Ring inter-segment handshaking signals to verify handshaking between segments is not affected by the change.

6 PMT Procedure and Checklist: SNS-RAD-IS-PR-0041

Conclusion of Section II

The material presented in section II supports the determination of a negative USI as documented through the negative answers to the guiding questions in parts III and IV. The changes associated with the isolation of HEBT PPS power supplies and the HEBT/Ring gate controls do not negatively affect the PPS functions described in the FSADs and ASE. Nor are there new failure modes or potential accidents introduced through this change. Rather, the changes described in this document improve the overall safety reliability and reduce potential failure modes of the installed accelerator PPS systems.

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.

No. The proposed modifications to the HEBT PPS do not affect information presented in the FSADs. The PPS system is described in the FSAD-PF Section 3.2.3 and requirements for the PPS CECs are presented in FSAD-PF Section 5.2.1. The proposed modifications do not affect the safety functionality of the PPS as described in the FSADs other than to remove potential vulnerabilities to a common mode failure. Isolating the HEBT PPS DC power supplies decreases the likelihood of a common mode failure similar to that experienced in July 2013. Similarly, replacing diodes with relays for the HEBT/Ring magnetic lock control better isolates the two PPS systems and eliminates the potential for one segment's power to cause an unsafe failure in another.

The proposed changes improve the compliance and performance of the PPS within the FSAD requirements. Specifically, the proposed modification better implements the requirements described in the FSADs.

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

No, the requirements and operational conditions given in the SNS ASE Section 3.2 *Personnel Protection System (PPS)* remain unaffected. The level of detail regarding the proposed modifications (e.g. power supply wiring) is not addressed in the ASE. The proposed modifications do not affect the safety functionality of the PPS other than to remove potential vulnerabilities to common mode failures.

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: No. 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. The proposed modifications do not affect the safety functionality of the PPS other than to remove identified vulnerabilities to common mode failures.

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

Justification: No. The PPS is a Credited Engineered Control credited with protecting workers from potentially injurious prompt radiation produced by accelerator operations. The consequences of accidents addressed in the FSADs (i.e. excessive prompt radiation exposure) are not affected by the proposed modifications associated with this change. The proposed modifications do not affect the safety functionality of the PPS other than to remove potential vulnerabilities to common mode failures.

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: No. The purpose of the proposed modification is to eliminate the potential vulnerability to a common mode failure such that the probability of an unsafe failure of the PPS is reduced. Replacing steering diodes with relays eliminates a potential malfunction due to diode shorts connecting HEBT/Ring DC power.

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: No. 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. The proposed modifications do not affect the safety functionality of the PPS other than to remove potential vulnerabilities to a common mode failure.

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: No. The proposed modifications do not increase the possibility of a different type of accident than those evaluated in the authorization basis that would have potentially significant safety consequences. The type of significant potential accidents associated with the PPS system continues to be excessive personnel exposure to accelerator produced prompt radiation; no new types of accidents are created. The proposed modifications do not affect the safety functionality of the PPS other than to remove potential vulnerabilities to common mode failures.

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. The proposed modifications will reduce the probability of occurrence of a malfunction of the PPS associated with a common mode failure. Using relays slightly increases the likelihood of failure, however the failure mode (short/open circuit) produces the same type of malfunction as a diode failure. This slight decrease in reliability is exceedingly offset by the elimination of failure modes due to diode shorts connecting HEBT/Ring power supplies.

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 — 4/28/2016 Date

Aaron Coleman, Protection System Engineer, Reviewer — 4/28/2016 Date

David Freeman, SNS Safety Specialist, Qualified Reviewer — 4/28/2016 Date

Glen Johns, Accelerator Operations Group Leader, Reviewer — 4-28-16 Date

Hans Vogel, NScD Directorate Operations Manager, Reviewer — 5/13/16 Date

Approvals:

Kevin Jones, SNS Operations Manager or Designee — for KJ — 04/05/16 Date