

Pulsed Power Systems Group Procedure 8.34.5

C-A PP005

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COLLIDER-ACCELERATOR DEPARTMENT

Title: RHIC Beam Abort Kicker High Voltage Modulator High Voltage Pulse Capacitor
Maintenance and Replacement Procedure

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Group: Pulsed Power

System Engineers concurrence indicate procedure is still current

Name _____ Date _____

Name _____ Date _____

Group Leader concurrence indicates procedure is still current.

Group Leader: _____ Date: _____

**This Procedure Must Be Reviewed By The Technical Supervisor
Prior to use.**

**If This Procedure Does Not Reflect Current Equipment/Processes
Then Immediately Notify The Group Leader**

RHIC BEAM ABORT KICKER HIGH VOLTAGE MODULATOR HIGH VOLTAGE PULSE CAPACITOR MAINTENANCE AND REPLACEMENT PROCEDURE

1. Purpose

To provide guidelines for the Pulsed Power Group and other C-A personnel to conduct RHIC Beam Abort Kicker High Voltage Modulator High Voltage Pulse Capacitor maintenance and replacement work.

2. Prerequisites

- 2.1 Personnel performing the procedure shall have the specific training in this procedure, Lock-out and Tag-out authorized (LOTO), Collider-Accelerator Access Training, Electrical Safety I, and Radiological Worker I, Adult Cardiopulmonary Resuscitation or CPR-Qualified Position (effective June 1, 2005), as well as meeting all job related safety training requirements.
- 2.2 Personnel performing the procedure shall possess a thorough knowledge of the RHIC Beam Abort Kicker Power Supply System.
- 2.3 Personnel performing this procedure shall use appropriate personal protective equipment (PPE) and wear appropriate protective clothing (PPC) (e.g., hardhats, safety shoes, eye and face protection, insulated live-line tools, hot sticks, cotton or fire-resistant clothing, and arc protection). The PPE and PPC should comply with NFPA 70E and BNL standards, see [PPE for Electrical Safety \(Pages 7-13\)](#). Contact BNL ES&H Division Industrial Hygiene Services for regulatory compliance and professional service.
 - 2.3.1 A safety face shield must be worn during initial investigations of problems. A face shield, appropriate safety gloves, and ear protection must be worn when discharging the capacitors with a grounding hook. A resistive grounding hook will always be used first followed by a shorting stick. Before working on the capacitors a ground will be clamped to the appropriate grounding/shorting points.
- 2.4 One person in the team shall act as a Safety Watch.
- 2.5 The qualifications of safety watch include: trained in cardiopulmonary resuscitation (CPR); possessing a thorough knowledge of the locations of emergency-shutdown push buttons and power disconnects of the RHIC Beam Abort Kicker Power Supply System; possessing a thorough knowledge of this procedure and related procedures to be followed and the work to be done.
- 2.6 Safety Watch shall wear appropriate PPE and PPC, and be equipped with high voltage gloves during the capacitor maintenance and replacement process.

- 2.7 The Safety Barricade or barrier shall be placed in work area and clearly posted to warn people of potential danger and hazards.
- 2.8 All other personnel entering the RHIC ring shall maintain a clearance of at least three and one-half (3-1/2) feet from the specific RHIC Beam Abort Kicker equipment at all times during the maintenance and capacitor replacement work.
- 2.9 Enhanced work planning is required for capacitor manipulation and replacement.

3. Responsibilities

- 3.1 The Collider Accelerator Department Pulsed Power Group system engineers and technicians are responsible to maintain the RHIC Beam Abort Kicker Power Supply Systems.
- 3.2 The RHIC Beam Abort Kicker Power Supply System engineers, specialist, technicians are responsible to inspect and keep records of the status of the RHIC Beam Abort Kicker High Voltage Modulator High Voltage Pulse Capacitors by checking operation history, waveforms, system and device integrity etc.
- 3.3 Other Collider-Accelerator personnel, such as cognizant mechanical engineers and mechanical technicians, and operation support technicians can assist the Pulsed Power Group engineers and technicians under supervision when necessary.
- 3.4 The RHIC beam Abort Kicker Power Supply System engineers are responsible to determine the necessary task of capacitor maintenance and replacement.
- 3.5 Personnel performing task on or around energized circuit are responsible to make sure that he/she is in full compliance with all training and qualification requirements listed under section 0 and 0, and to obtain the "Energized Circuit Work Permit" before start the work. Group leader and Supervisor are responsible to verify the training and qualification and the permit be approved by the Chief Electrical Engineer or his delegates.
- 3.6 The RHIC Beam Abort Kicker Power Supply System engineers and Technical Supervisor are responsible to conduct work planning. The work planner shall evaluate all jobs against criteria in [C-A-OPM 2.28](#), "C-A Procedure for Work Planning and Control for Operations". Modify and supplement this and other procedures as necessary, and list all changes/variations in work planning.
- 3.7 The RHIC Beam Abort Kicker Power Supply System engineers and Technical Supervisor or Group leader are responsible to conduct enhanced work planning. Work planning or enhanced work planning must comply with C-A OPM 2.28 "C-A Procedure for Work Planning and Control for Operations". Modify and supplement this and other procedures as necessary, and list all changes/variations in enhanced work planning.

- 3.8 The RHIC Beam Abort Kicker Power Supply System engineers and technicians, cognizant mechanical engineers and technicians are responsible to prepare all necessary tools, devices, hardware, and equipments, etc. for manipulating and replacing high voltage capacitor safely. All electrical equipment, components, and conductors shall be approved for their intended uses. The custom-made or home-made tools, components, devices, and equipment should be built in accordance with a design approved by the Chief Electrical Engineer or his delegates and reviewed and approved in accordance with C-A OPM 9.3.4. They shall be tested or inspected before each use.
- 3.9 The RHIC Beam Abort Kicker Power Supply System engineers are responsible to verify that all instrument used in testing and evaluation has valid inspection and calibration. Record should be maintained for each instrument, by serial number or equivalent method, showing dates of inspection and calibration.
- 3.10 The responsibilities of safety watch include monitoring the work area for unsafe conditions or work practices and taking necessary action to ensure abatement of the unsafe condition or work practice, de-energizing equipment and alerting emergency-rescue personnel as conditions warrant, maintaining visual and audible contact with personnel performing the work, and removal of injured personnel, if possible. The safety watch should have no other duties that preclude observing and rendering aid if necessary.
- 3.11 Personnel performing this procedure are responsible to remove all conductive and loose apparel before conducting the task, and wear appropriate personal protective equipment and personal protective clothing during the work process.

4. Precautions

- 4.1 We should always consider these capacitors to be dangerous and will act accordingly.
- 4.2 All circuits are considered to be energized unless (until) they are positively de-energized to zero energy state.
- 4.3 When capacitors are used to store large amounts of energy, internal failure of one capacitor in a bank frequently results in explosion when all other capacitors in the bank discharge into the fault. Approximately 104 joules is the threshold energy for explosive failure of metal cans. ... A capacitor that develops an internal open circuit may retain substantial charge internally even though the terminals are short-circuited. Such a capacitor can be hazardous to transport, because the damaged internal wiring may reconnect and discharge the capacitor through the short-circuiting wires. Any capacitor that shows a significant change in capacitance after a fault may have this problem. Action should be taken to minimize this hazard when it is discovered”.

5. Policies

- 5.1 This procedure is intended to supplement the details regarding the specific equipment in addition to applicable OSHA, NEC, DOE, BNL, and C-A regulations, standards, and policies. Where this procedure is in conflict with other regulations, standards, or policies, the OSHA, NEC, DOE, BNL, and C-A regulations, standards, and policies shall govern. Any conflicts found shall be reported to system engineers, supervisors, and management.
- 5.2 As directed by DOE, “Where no clear applicable code or standard provides adequate guidance or when questions regarding workmanship, judgment, or conflicting criteria arise, personnel safety protection shall be the primary consideration. Therefore, where there are conflicts between the mandatory requirements of the codes, standards, and regulations, the requirements that address the particular hazard and provide the greater safety shall govern.”

6. Procedure

- 6.1 Hazard and risk evaluation shall be performed before and through the work process.
 - 6.1.1 The known hazards associated with the RHIC Beam Abort Kicker Power Supply Systems and equipment locations may include but not limited to:
 - 6.1.1.1 Ionizing radiation in the area;
 - 6.1.1.2 Oxygen deficiency hazard inside the RHIC tunnel;
 - 6.1.1.3 Fire and smoking;
 - 6.1.1.4 Mechanical: hot fluid, loud sound, oil leak or spill, explosion,
 - 6.1.1.5 cracking and shattering of capacitor case and feed-through,
 - 6.1.1.6 heavy weight;
 - 6.1.1.7 Electrical: high voltage, high current, high energy storage;
 - 6.1.1.8 Slippery surface, and etc.
 - 6.1.2 In emergency, follow C-A OPM 3.0 “Local Emergency Plan for the Collider-Accelerator Department” to notify affected personnel and emergency response unit, and LOTO the equipment accordingly with section 0.
- 6.2 Work planning or enhanced work planning must comply with C-A OPM 2.28 “C-A Procedure for Work Planning and Control for Operations”. Modify and

supplement this and other procedures as necessary, and list all changes/variations in work planning or enhanced work planning.

- 6.3 Diagnose and evaluation: The RHIC Beam Abort Kicker Power Supply System electrical and mechanical engineers, specialist, technicians are responsible to evaluate the status of the RHIC Beam Abort Kicker High Voltage Modulator High Voltage Pulse Capacitors by checking operation history, charging and discharging pulse waveforms, physical appearance, etc. to determine the necessary task of capacitor maintenance and replacement. Any abnormal findings or malfunction of equipment shall be recorded, analyzed, and reported.
 - 6.3.1 Inspecting the external appearance of the RHIC Beam Abort Kicker Modulators, check for signs of physical damage.
 - 6.3.2 In emergency, follow C-A OPM 3.0 “Local Emergency Plan for the Collider-Accelerator Department” to notify affected personnel and emergency response unit, and LOTO the equipment accordingly with section 0.
 - 6.3.3 In situation that abnormal but non-emergency condition presents, barrier or barricade the area with posting and notify affected personnel, the system engineers, supervisor and the management. LOTO the equipment in accordance with section 0. Additional enhanced work planning is required.
 - 6.3.4 In situation that one or more capacitors believed to be physically damaged, evaluating the hazard and estimate the severity of damage, such as possible case rupture, potential fire or smoke, possible oil leaking, etc. LOTO the equipment in accordance with section 0. Barrier or barricade the area with posting, and notify affected personnel, the system engineers, supervisor and the management. Additional enhanced work planning is required.
 - 6.3.5 In situation that the stored energy of the capacitor cannot be fully discharged, estimate the maximum possible trapped energy in the capacitor and possible location of the capacitor inside the high voltage modulator equipment. System engineers and technicians shall check operation history, charging and discharging pulse waveforms, etc., analyze and record all necessary information and report. LOTO the equipment in accordance with section 0. Additional enhanced work planning is required.
 - 6.3.6 In situation that all capacitors are normal but need to be replaced for reasons such as reaching device lifetime, parameter change, etc., LOTO the equipment in accordance with section 0, and follow grounding and discharging procedures to properly discharge all capacitors.

6.4 LOTO

- 6.4.1 Turn the RHIC Beam Abort Kicker power supply system to “Stand By”. Observe and record the high voltage modulator PFN voltage read back. If any one of the high voltage modulator PFN is not properly de-energized, report to supervisor and system engineers. Additional enhanced work planning is required.
- 6.4.2 TURN OFF the RHIC Beam Abort Kicker power supply.
- 6.4.3 LOTO the RHIC Abort Kicker power supply system in accordance with BNL ES&H Standard 1.5.1, C-A OPM 1.5, C-A OPM 2.36 “Lock and Tag Program for Control of Hazardous Energy”, and supplemental procedure/instruction from RHIC Abort Kicker power supply system engineers.
 - 6.4.3.1 Appropriate PPE and PPC comply with NFPA 70E requirement must be used to apply LOTO.
- 6.4.4 Equipment location:
 - 6.4.4.1 There are two RHIC Beam Abort Kicker Systems, one for Blue ring beam dump and one for yellow ring beam dump. The control and auxiliary racks are located in Building 1010A. The high voltage modulators are located inside RHIC tunnel. Each RHIC Beam Abort Kicker Power Supply System has five high voltage modulators attached to the associated kicker magnet vacuum chamber. The circuit breakers of the RHIC Beam Abort Kicker Power Supply Systems are located on the inside wall of the service building 1010a.
 - 6.4.4.2 The main circuit breaker of the Yellow RHIC Beam Abort Kicker Power Supply System is SKK1;
 - 6.4.4.3 The circuit breaker of the Yellow RHIC Beam Abort Kicker High voltage Power Supply is ST1S1;
 - 6.4.4.4 The main circuit breaker of the Blue RHIC Beam Abort Kicker Power Supply System is SKK2;
 - 6.4.4.5 The circuit breaker of the Blue RHIC Beam Abort Kicker High voltage Power Supply is ST1S2.
 - 6.4.4.6 Follow updated PPE procedure to wear required PPE when turn off or turn on the circuit breakers. Check updated PPE procedure in time.

- 6.4.5 Before working on any high voltage modulator or subsystem that requires Lock-out and Tag-out, verify the primary energy source is correctly locked out and tagged out at its corresponding circuit breaker.
 - 6.4.6 Each RHIC Beam Abort Kicker Power Supply System has an Un-interruptible power supply in its control rack. The Un-interruptible power supply has to be drained and positively verified of non-energizing state before working on the system.
 - 6.4.7 All circuits and equipment must be considered energized until opened, tagged, and locked according to an approved procedure and should be proven positively de-energized by testing with an approved testing device known to be in proper working order.
- 6.5 Grounding and shorting
- 6.5.1 Grounding and shorting method should comply with C-A OPM 1.5.2.
 - 6.5.2 Inspect resistive grounding stick and shorting sticks. Ensure they are in good condition, before use them to discharge the Pulse-Forming-Network (PFN) capacitors.
 - 6.5.3 A safety face shield should be worn during initial investigations of problems.
 - 6.5.4 Open and remove high voltage modulator panels carefully. Do not touch any ungrounded terminal of the high voltage modulator.
 - 6.5.5 All conductive panels removed from the equipment shall be safely stored at a distance at least 6 feet away from the equipment being worked on and away from other exposed conductors. The panels shall be restrained and stored against trapping and falling.
 - 6.5.5.1 Inspect high voltage modulator by look, listen and smell for oil leaking capacitors or other problems. If there is any sign of abnormality in the high voltage modulator, evaluate the situation and take appropriate action.
 - 6.5.5.2 If imminent dangerous condition present, follow emergency procedures to notify BNL emergency response unit.
 - 6.5.6 In situation that abnormal but non-emergency condition presents, barrier or barricade the area with posting and notify affected personnel, system engineers, supervisor and the management. Additional enhanced work planning is required.
 - 6.5.7 A face shield, safety glasses, appropriate safety gloves, and ear protection should be worn when discharging the capacitors with a grounding hook.

Inspect PPE and PPC and ensure they are in good condition before each use.

- 6.5.8 A resistive grounding hook will always be used first followed by a shorting stick. Before working on the capacitors a ground will be clamped to the appropriate grounding/shorting points. Discharge capacitor bank in accordance with C-A OPM 1.5.2 and the supplemental Pulse-Forming-Network capacitor discharging procedure posted on the high voltage modulator front panel.
 - 6.5.9 Replace the ground stick with a #2 AWG wire to short the whole PFN. Then put a #2 AWG wire to connect the return to the PFN fame. Always treat these capacitors as potentially dangerous.
- 6.6 In situation that the high voltage modulator must be disconnected from vacuum vessel and pulled into the aisle:
- 6.6.1 A minimal of two people is required to do the following work.
 - 6.6.2 Disconnect the magnet, charging cable and unplug all other cables to the high voltage modulator cabinet.
 - 6.6.3 Disconnect the ground plate and pull the high voltage modulator into the aisle. Secure a #2 AWG ground wire from the high voltage modulator enclosure to the grounding plate to maintain the ground connection.
 - 6.6.4 Do not touch any ungrounded terminal of and within the high voltage modulator enclosure.
- 6.7 In situation that manipulation and/or replacement of one or more high voltage capacitors is required:
- 6.7.1 Do not touch any ungrounded terminal of and within the high voltage modulator enclosure.

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| <p>CAUTION: Check that all grounding wires are connected properly. If not, reconnect them properly.</p> |
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- 6.7.2 Wait enough time to ensure all capacitors are discharged to a safe condition before working in the PFN enclosure.
- 6.7.3 Wear appropriate safety gloves, safety shoes, safety clothes, safety glasses, and face shield when manipulate the high voltage pulse capacitors. Class II type I safety glove is recommended for work under 21 kV DC operating history.

- 6.7.4 Stay alert and evaluated hazard and risk before and through the work process.
- 6.7.5 To remove plastic packaged high voltage pulse capacitor(s):
 - 6.7.5.1 Ground each coil by a multi-branch grounding device. Always keep the PFN grounded and each capacitor shorted, when the coils are being disconnected from PFN.
 - 6.7.5.2 When unscrewing the capacitor, remove the shorting wire and place an approved insulation device on the terminal to prevent contact with the un-grounded and un-shortened capacitor terminal.
 - 6.7.5.3 After removing the capacitor, short the terminals with a #14 AWG wire immediately. Keep the insulator on the capacitor terminals until the capacitor is removed, discharged and shorted.
 - 6.7.5.4 Stay alert and evaluated hazard and risk before and through the work process.
 - 6.7.5.5 Don't use capacitor terminal to hold the capacitor, when assembling or disassembling the capacitor. It will damage the capacitor.
- 6.7.6 To install plastic packaged high voltage pulse capacitor(s):
 - 6.7.6.1 Keep a shorting wire across the capacitor until you are ready to install (screw in) the capacitor. Remove the short, place an insulating nut on the terminal and then screw the capacitor into the return plate.
 - 6.7.6.2 Reconnect the coils to the capacitors and/or short the terminal to ground. Leaving a capacitor ungrounded is not permitted.
 - 6.7.6.3 Don't use capacitor terminal to hold the capacitor, when assembling or disassembling the capacitor. It will damage the capacitor.
- 6.7.7 To remove metal cased high voltage pulse capacitor:
 - 6.7.7.1 Apply braided wires with at least 1/4" width to temporarily short terminals to case and ground.
 - 6.7.7.2 Disconnect the bus connection between the capacitor and the disk resistor stack. After disconnecting both capacitor terminals, put a shorting wire from terminal to terminal and to the ground stud located on the capacitor mounting foot. The shorting wire shall have higher amperage of the capacitor internal wire. For

unmodified capacitors, #6 AWG wire is recommended. For modified capacitors consult factory before work. Remove the temporary braid sated in 6.7.7.1.

- 6.7.7.3 Keep the #6 AWG or larger amperage shorting wire across the capacitor after the capacitor is removed from the high voltage modulator enclosure.
 - 6.7.7.4 Stay alert and evaluate hazard and risk before and during the work process.
 - 6.7.7.5 Because this capacitor is heavy, two people are suggested to move the capacitor, in order to avoid hurt back.
- 2.4.1 To Install metal cased high voltage pulse capacitor(s):
- 2.4.1.1 To install the heavy capacitor safely into the high voltage modulator, two people shall work cooperatively.
 - 2.4.1.2 Always keep the shorting wire tied to the capacitor terminals and metal case until the capacitor is connected to the PFN.
 - 2.4.1.3 Because this capacitor is heavy, two people are suggested to move the capacitor, in order to avoid hurt back.
- 6.8 Push high voltage modulator into position and reconnect to vacuum vessel:
- 6.8.1 Carefully push high voltage modulator into position.
 - 6.8.2 Reconnect all grounds.
 - 6.8.3 Reconnected all cables.
 - 6.8.4 Remove the two #2 AWG grounding wires from PFN and high voltage modulator enclosure.
 - 6.8.5 Install all high voltage modulator panels.
- 6.9 Notify affected personnel and Main control Room before energizing the RHIC Beam Abort System.
- 6.10 The system engineers and technicians are responsible for careful inspection of the equipment and system prior to energizing.
- 6.11 Remove LOTO and re-establish operation condition.
- 6.12 After successful completion of the test, personnel shall exit the ring in accordance with the appropriate access procedures.

- 6.13 Clean the working Area.
- 6.14 Enter a complete description of all work done into the logbook. Report to your supervisor and the system engineers.
- 6.15 Store the removed capacitors in a safe place. Keep all capacitor terminals and metal case shorted with appropriate wires.

7. Documentation

- 7.1 A signed and dated data log (log book) shall be maintained.
- 7.2 Critical waveforms, operation records, analyzing results shall be documented and recorded.
- 7.3 A record should be maintained for each instrument used in testing and evaluation, by serial number or equivalent method, showing dates of inspection and calibration.

8. References

- 8.1 None.

9. Attachments

Note: all requirements from Attachments and links below must be followed. Please pay attention to attachment update.

Management System: Worker Safety and Health

[Subject Area: Electrical Safety](#)

[Management System Description: Work Planning and Control](#)

[C-A Procedure for Work Planning and Control for Operations](#)

[Subject Area: Work Planning and Control for Experiments and Operations](#)

[Subject Area: Lockout/Tagout \(LOTO\)](#)

[Subject Area: Personal Protection Equipment](#)