Jefferson Lab
Thomas Jefferson National Accelerator Facility

Notable Event Report
(See ES&H Manual Chapter 5200 Appendix T1 Event Investigation and Causal Analysis for Instructions)

Click For Word Doc

Notable Event Report

Title of Event			
Event Title:	Shock Incident at the ARC1 Box Power Supply in the LERF		
Date and Time of Occurrence:	07/26/2016 at approximately 11:00 am	**Notable Event Number:**	ACC-16-0726
Event Location:	LERF /Building 18	**Date Notable Event Report is Due*:**	08/25/2016

*The Notable Event Report is due to the ESH&Q Reporting Officer with 30 days of the Initial Fact Finding Meeting unless an extension is requested.

Summary of Event and / or Injuries, including Initial Fact Finding Meeting information: determine the chain of events and timeline. Use attachment as necessary.

Summary of Event:

On July 26, 2016, two technicians were working under an approved work package to diagnose a magnet problem within the Low Energy Recirculating Accelerator Facility (LERF). The ARC 1 power supply for the magnet is in a top-side gallery, while the magnet/magnet string is located in the LERF vault. After applying a lock and tag to the 480 volt input on this particular magnet power supply, the voltage verification unit showed the power supply to be de-energized. One of the technicians was in the process of removing a direct current output conductor from the power supply cabinet when they received an electrical shock as their elbow brushed against the grounded cabinet frame. The work was promptly stopped and their Supervisor informed. The technician that received the shock was not injured, which was confirmed after evaluation by the onsite medical clinic. The technician has been medically released without restrictions. Based on post-event measurements, the unexpected voltage was measured to be 87 volts alternating current between the positive side output conductor and the power supply cabinet. The uncontrolled electrical power originated from an induced/coupled voltage from a trim card supply on a magnet coil which is embedded in the ARC1 dipole magnet. The trim card was a 30volt/10amp direct current (DC) output card. The cause of the trim card going into oscillation, producing an alternating current voltage at its output, was later determined to be the load impedance falling outside of the specification for the normally configured compensation loop. The standard practice for the CEBAF equipment is that the power supply and the magnet load are properly matched during the design and then this matching is followed up with an analysis of the magnet string. Work was halted until an amended work plan eliminating the risk of a repeated shock, was developed and implemented. Soon after the investigation process began, a short term action plan (see below) was put into to place and the suspension of the specific work activities was lifted.
From post event measurements that were made and further evaluation of the system configuration, the electrical characteristics of the shock event are best summarized as follows:

- The worst possible case shock level scenario is approximately 48 volts AC at 1.6 amps (76.8 watts) with a short circuit load (current and voltage are not in phase on the inductive load).
- The estimated shock level at the time of the event is approximately 87 volts AC (measured) and 0.88 amps (which is 76.8 watts divided by the measured 87 volts or I=P/E).

Short Term Action Plan: (as communicated in an email from Todd Kujawa to Arne Freyberg on 7/27/2016.

Following today's initial fact finding meeting, for the LERF shock event that took place on 7/26, the following short term action is being proposed to allow safe work on magnet systems that have multiple coils driven by separate power supplies. This action is to be implemented in addition to a groups' normal documented process

Summary of Event and / or Injuries, including Initial Fact Finding Meeting information: determine the chain of events and timeline. Use attachment as necessary.

for working on power supplies or magnets. When working on a magnet system that fits the criteria above one must additionally:
1) Determine what other power supplies are involved with powering the magnet configuration (other coils) to be worked on.
2) Complete a Lock, Tag, & Try (LTT) Multiple Energy Form (ESH manual chapter 6110T1); one is attached to this email.
3) Execute the steps on the LTT form (to remove sources of energy capable of inducing/coupling an unwanted voltage).
4) Perform work as documented in the work plan (ATLIS).
Meanwhile the Notable Event Investigation team will continue with the labs reporting process and this short term action will be observed for continuous improvement.

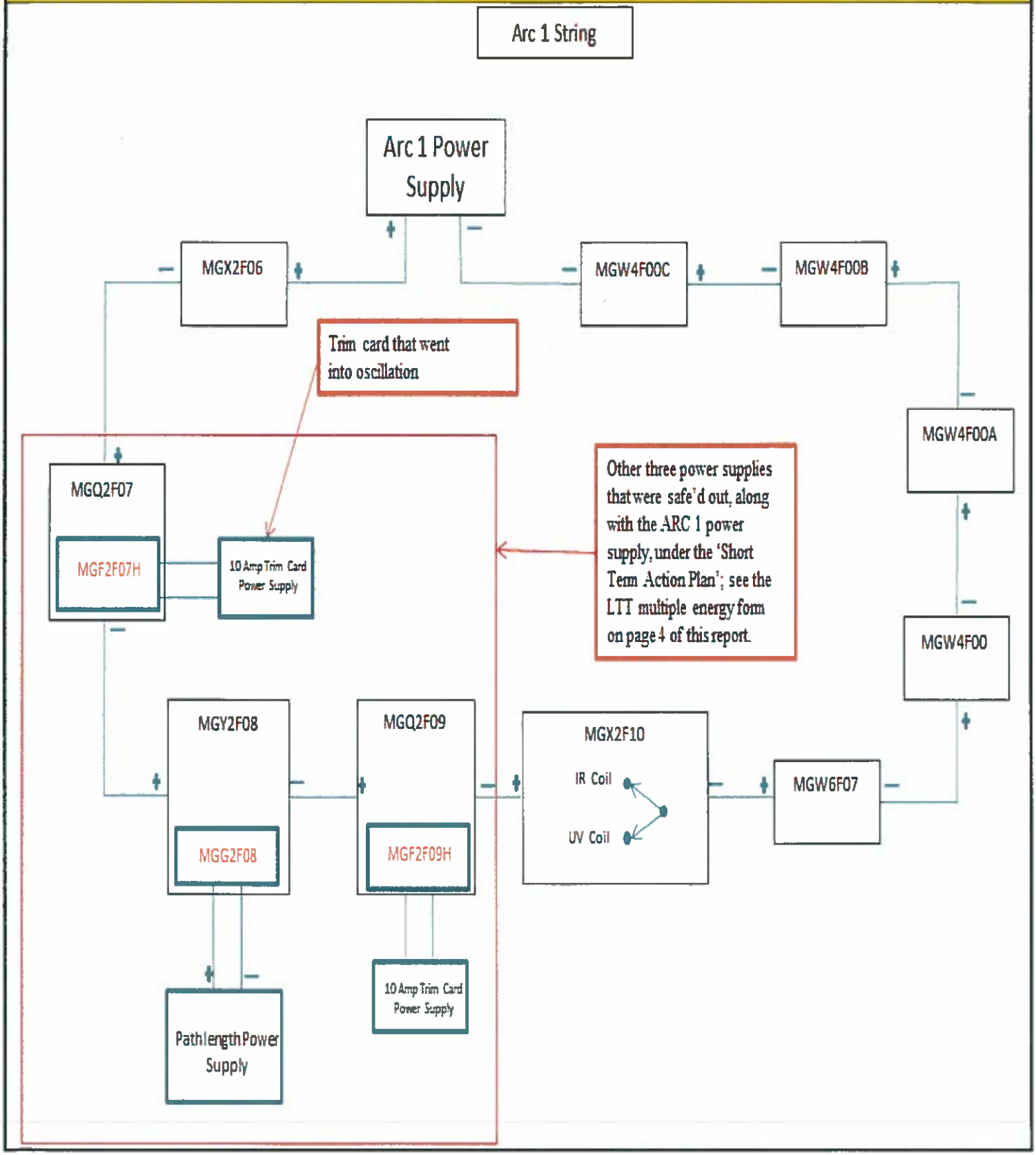
Timeline of Events:

7/26 – event occurred
7/26 – system safe'd out
7/26 – unexpected voltage source troubleshooting/discovered
7/26 – notifications made to ESH and Reporting Manager
7/26 – employee visited Occupational Medicine for routine checkup
7/26 – post event measurements taken to further understand the event scenario
7/26 – suspend work put on all magnet configurations that have multiple coils driven by separate power supplies
7/27 – Fact Finding meeting
7/27 – extent of condition being looked into
7/27 – short term action proposed to allow safe work on magnet configurations that have multiple coils driven by separate power supplies / suspend work lifted
7/28 – follow up Notable Event Team meeting
7/29 – initial ORPS released
7/29 – benchmarking notifications sent out to other labs through the Electrical EFCOG group
8/1 – investigation process started
8/11 – took second set of post event measurements to re-verify first set taken (period of time in between the two sets of measurements do to the commissioning run of the LERF Dark Light experiment)
8/15 – Notable Event Team meeting to discuss second set of measurements and the causal analysis
8/17 – draft report sent out for a two day review
8/22 – final report sent to Reporting Manager

Attachments:

1) Block Diagram LERF ARC 1 Magnet String (page 3)
2) ARC 1 Box Supply String Lock, Tag, & Try (LTT) Multiple Energy Form (page 4)
3) LERF ARC1 dipole and magnetically coupled trim coil (pages 5-12)

Summary of Event and / or Injuries, including Initial Fact Finding Meeting information: determine the chain of events and timeline. Use attachment as necessary.



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Summary of Event and / or Injuries, including Initial Fact Finding Meeting information: determine the chain of events and timeline. Use attachment as necessary.

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Lock, Tag, & Try (LTT) Multiple Energy Form (See ES&H Manual Chapter 6110 Appendix T1 Lock, Tag, Try (LTT) Procedure)

This procedure is for securing and controlling the hazardous energy and/or unexpected start-up of the equipment/system listed below.

Arc 1 box Supply String

Before beginning service or maintenance work, the following steps must be completed, by all qualified taggers, in sequence and in accordance to ESH manual chapter 6110T1-3.0 ('Process Steps'). Include sufficient detail to allow for a safe and orderly shutdown and isolation of the equipment/system to be worked on.

Step #	Energy Isolating/Draining Device	Device Location	Method used to determine De-energized State
1.	Arc 1 Box Supply	FL05B04	BAS Box Supply Safe Out Procedure
2.	MPATH Box Supply (Pathlength)	FL05B06	SAS Box Supply Safe Out Procedure
3.	Trim Card MGF2F07H	FL05B10 CHAN. 20	Power down and remove trim card from rack
4.	Trim Card MGF2F09H	FL05B09 CHAN. 2	Power down and remove trim card from rack

Reviewed and Signed by all Qualified Taggers			Date:
Mark A. Todd	Print Name:	Mark A. Todd	7/28/16
J Delk	Print Name:	Jason C. Delk	7/28/16
	Print Name:		
	Print Name:		
	Print Name:		

Signature of Author to this Form			Date:
Jim Coleman	Print Name:	JIM COLEMAN	7/28/16

THIS FORM MUST BE POSTED NEAR THE WORK AREA UNTIL WORK IS COMPLETE

NOTES:

1. DO NOT PROCEED until this form has been completed and signed by an authorized employee.
2. Authorized employees are current in SAF104 (LTT training) and have equipment specific training for the equipment/system to be worked on.
3. This form satisfies the requirements of ESH Manual Chapter 6110T1-3.0 Process Steps – (Step 2: Determine the Need for a Written Procedure).

Form Revision Summary

Revision 0.0 – 03/09/15 – New form corresponding to ESH Manual Chapter 6110T1

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.

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EES DC

LERF ARC1 dipole and magnetically coupled trim coil:

Acronyms:

BPS -- Box Power Supply

TC -- Trim Card

O.C. -- Open Circuit

S.C. -- Short Circuit

Gnd -- Earth ground potential

All amperage measurements are with 1Amp = 10 mV on the blue trace

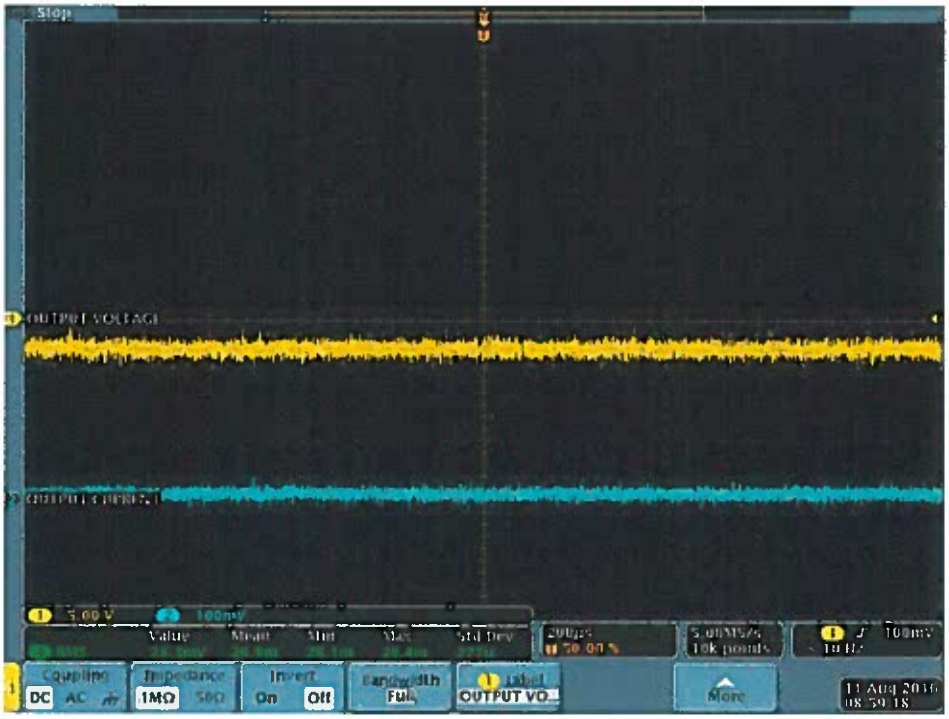

Figure 1. Voltage at BPS terminals with leads O.C. and non-oscillating trim card

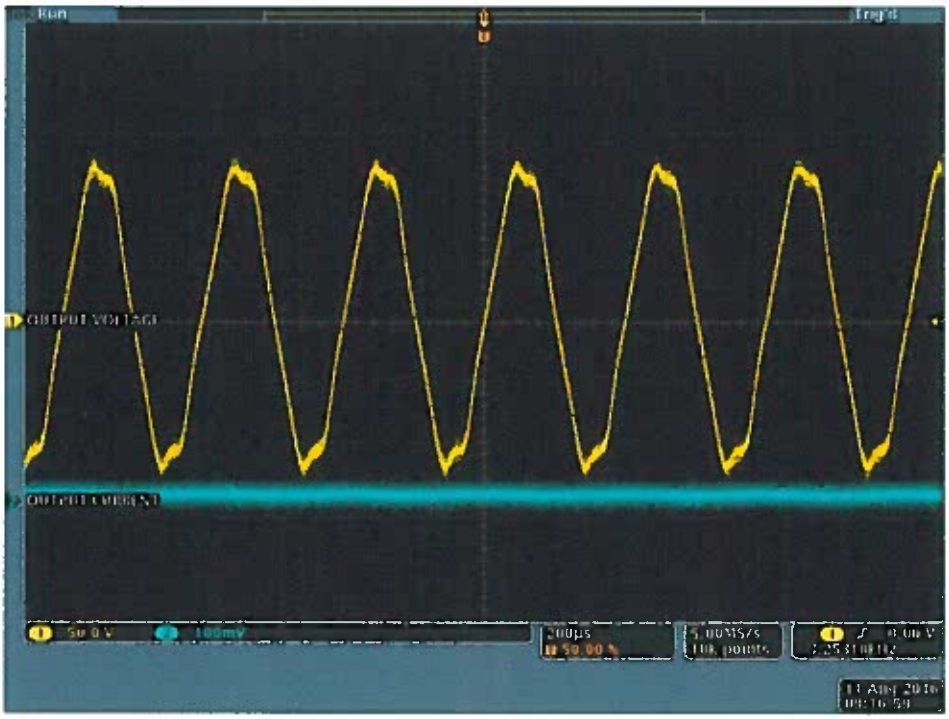

Figure 2: Voltage at positive BPS terminal to Gnd, with leads O.C. and oscillating trim card

Note: The voltage is about 125 Volts peak, corresponding to ~87Vrms that was measured using a handheld Fluke DVM. The frequency of oscillation is around 3.2 kHz

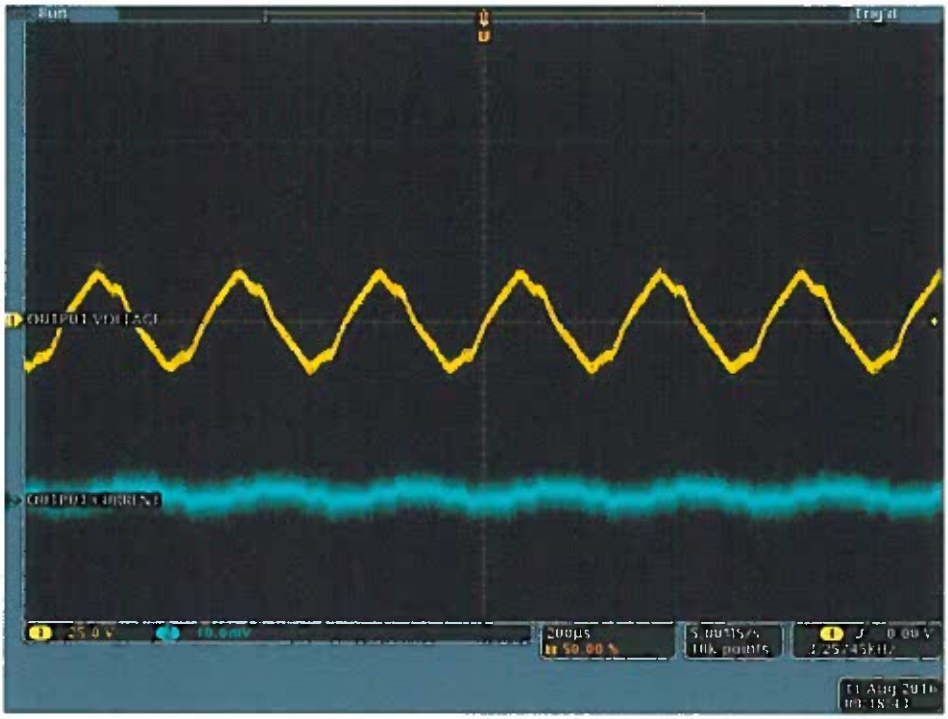

Figure 3: Voltage at negative BPS terminal to Gnd, with leads O.C. and oscillating trim card

Note: The voltage is about 24Volts peak, which is around 16 Vrms

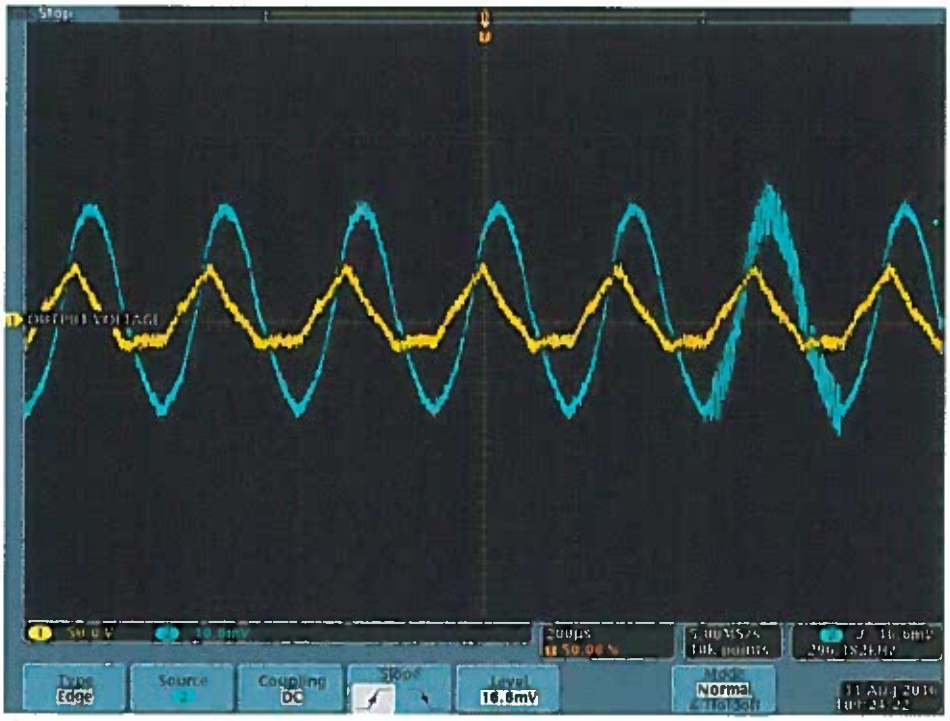

Figure 4. Voltage and current on BPS buss with leads S.C. This worst case scenario shows the voltage is less than 50 Volts and less than 4 Amps peak.

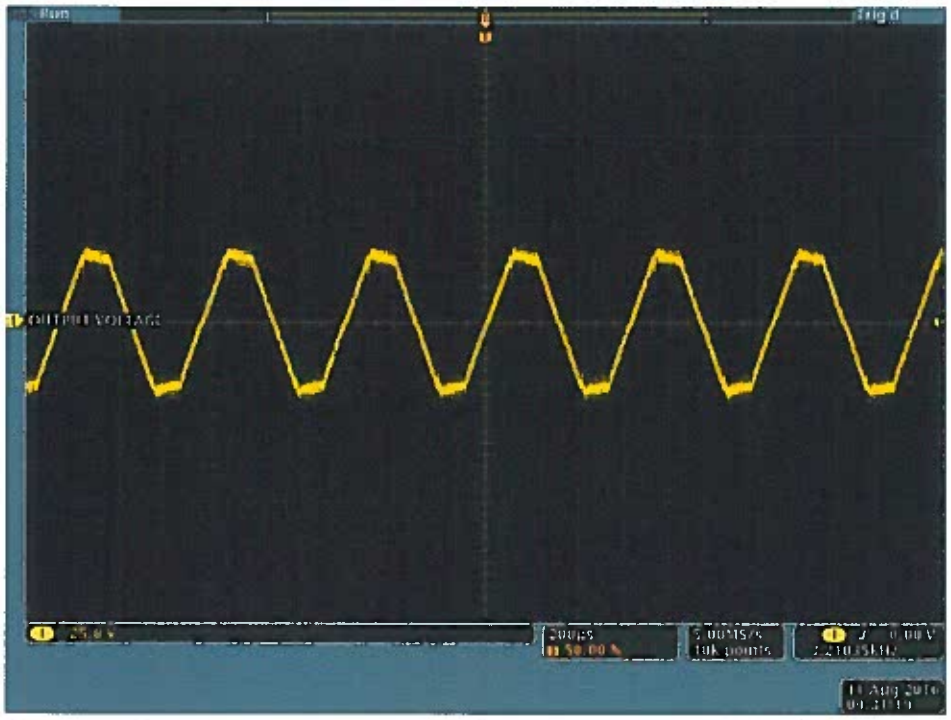

Figure 5. Trim Card output voltage when oscillating. Output current swing is about 9 .5 Amps peak. This is regardless of BPS leads open or short circuited.

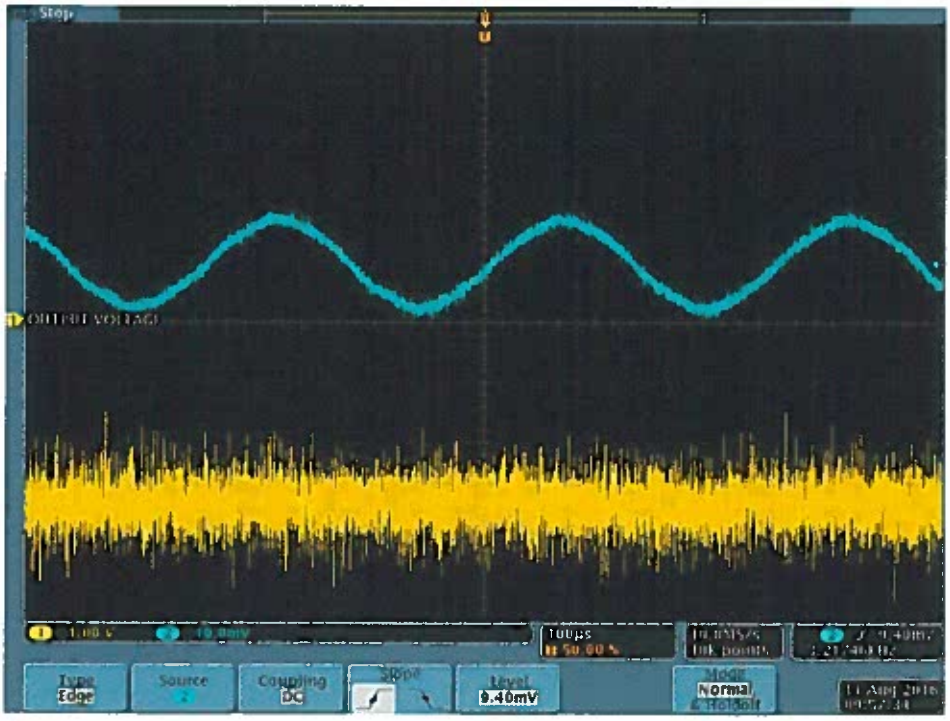

Figure 6. Voltage at BPS across leads when attached to BPS output terminal.

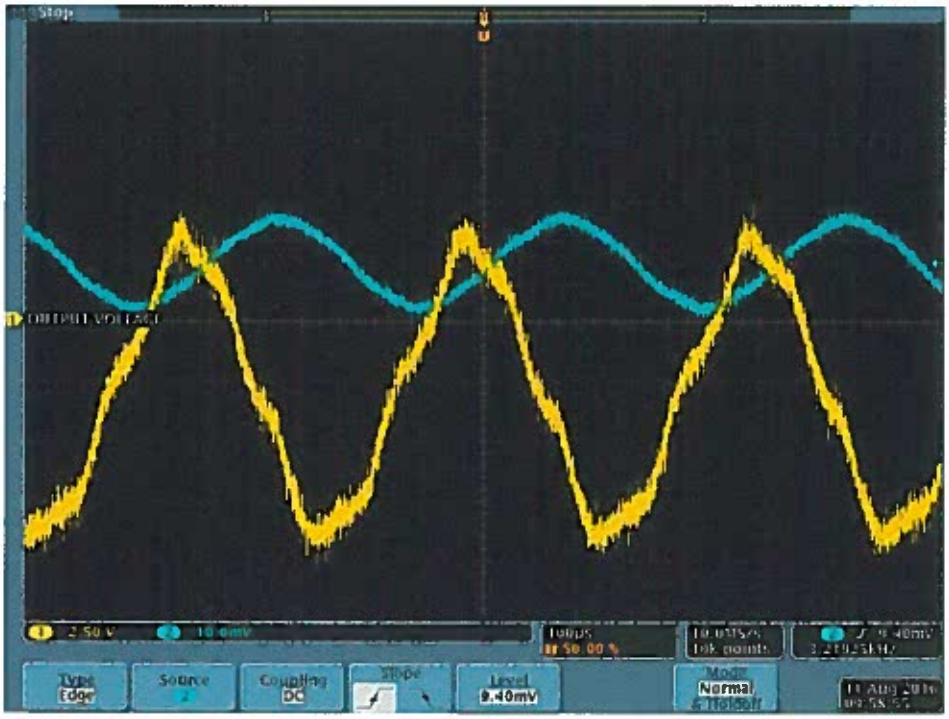

Figure 7. Voltage measured BPS positive/negative lead to ground when leads connected to power supply

Note: When attached to the power supply, the voltage measured across the leads will be zero as surmised during the initial investigation.

Note: Measured voltage from positive lead to Gnd was about 3.68Vrms. The resistance to Gnd changed from the expected 100 Ohms to 45 Ohms, which should have been a clue about the unusual circumstance.

Note: The resistance value of 45 ohms was measured during the initial stage of troubleshooting the earth leakage fault; which is significantly less than the expected 100 ohms

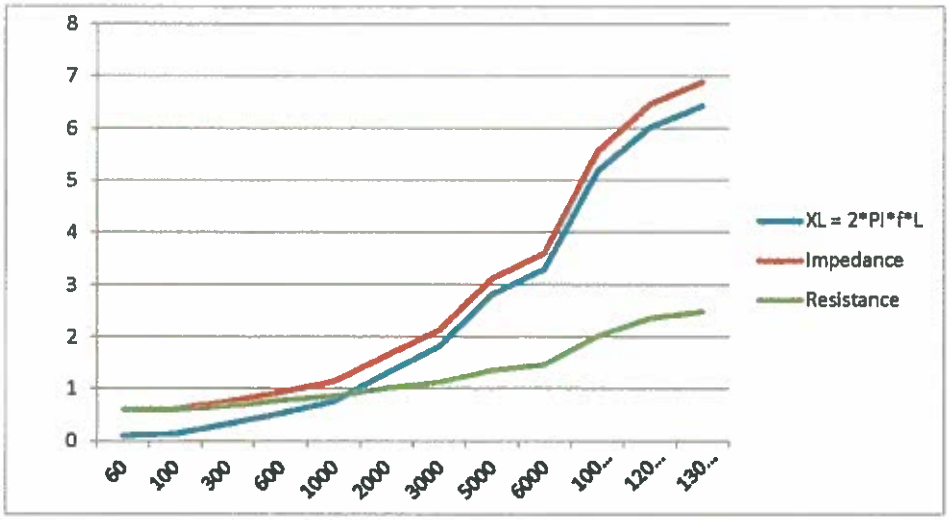

Figure 8. Impedance of Trim Cad Driven Coil, Channel 20 MGF

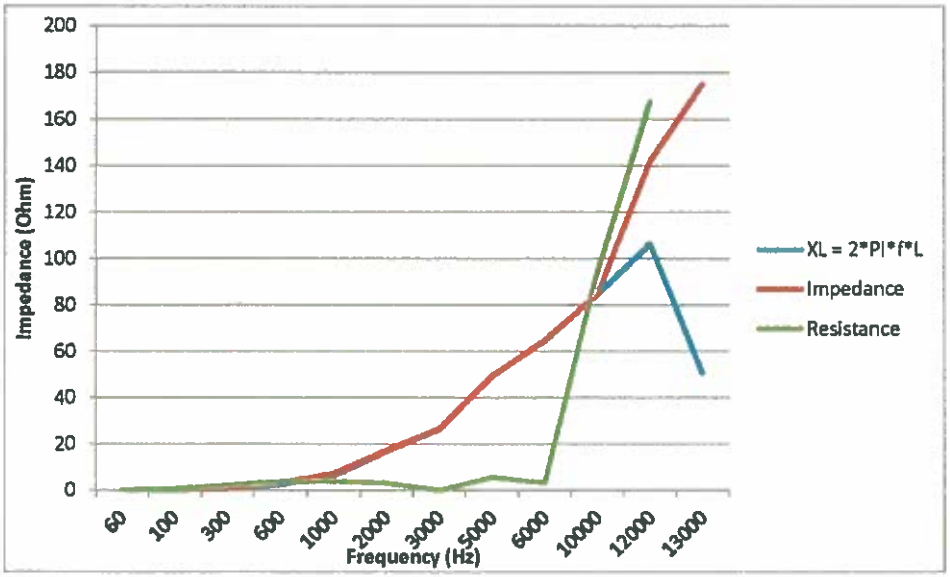

Figure 9. Impedance of LERF ARC1 string

Note: The oscillating Trim Card was found to be stable and well behaved into a nominal JLab corrector/quad in its intended configuration

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Notable Event Worksheet

Causal Analysis: (Use attachment as necessary)	
Root Cause:	The problem (incident event scenario) was not anticipated and therefore analysis of the systems hazards were not performed and mitigated. The cause of the trim card going into oscillation, producing an alternating current voltage at its output, was later determined to be the load impedance falling outside of the specification for the normally configured compensation loop.
Contributing Causes: (List as many as apply.)	C1 - Lack of sufficient operational/design review; review of a system as individual components and not as a whole complete operating system. C2 - Lack of single point ownership/responsibility when it comes to a system that involves multiple interests from different groups. Each group has their own agenda and the optimization between the power supply and the magnet load is not always considered or looked at.

Extent of Condition Check	JLab CATS Number	Target Date	Action Owner
Check: All equipment/system owners will review their magnet configurations and determine if they have magnets that have multiple coils driven by separate power supplies and label the magnets and corresponding power supplies. Evidence of completion: List of results from extent of condition sent to the Electrical Safety Engineer (ESE of EHS). The list shall include what power supplies are involved in the scenario of 'magnets that have multiple coils driven by separate power supplies' and label the magnets and corresponding power supplies.	NE-2016-13-01	12/1/2016	Ed Folts - (Physics – Halls A-D) Harry Fanning - (Accelerator – Injector & Test Lab) Paul Collins - (Engineering CEBAF & LERF)

Does this event involve failed equipment?	No	Is there similar equipment in other areas?	Yes	** If yes, assign extent of condition check to the appropriate DSO(s).

Corrective Action(s)	JLab CATS Number	Target Date	Action Owner
Evaluate the effectiveness of the 'short term action plan' and implement any continuous improvements. Determine the final corrective action to prevent a recurrence of this type of incident. Implement improvements to work procedures and equipment specific training as deemed necessary. Evidence of Completion: Action plan submitted to Electrical Safety Engineer; final approval will be voted on by the Electrical Safety Committee.	NE-2016-13-01	12/1/2016	Andrew Kimber / Jack Segal
Evaluate the need to improve on the process of an operational/design review when an end user makes a	NE-2016-13-01	12/1/2016	Andrew Kimber /

Corrective Action(s)	JLab CATS Number	Target Date	Action Owner
request for a power supply to be connected to their magnet/coil loads. This process should consider identifying a single system owner point of contact for analyzing any hazards. To ensure optimization of the system and control/updating of documentation related to the system the desktop instruction should include a process to access and control the trim card spares. Evidence of completion: A desktop instruction developed by the DC Power Group.			Jack Segal
Evaluate the need to update the magnet configuration documentation at the LERF. Include in this opportunity the analysis of the magnet loads so as to best match a power supply to each load for better optimization of the whole system. Evidence of completion: Block diagrams and documented analysis of the LERF's different magnet strings. Use the CEBAF main machine process as the standard model.	NE-2016-13-01	12/1/2016	Andrew Kimber
Engineering Division Management should evaluate the possible need and make a recommendation for rolling replacements of Trim Cards based on the Trim Card II design to areas where the Trim Card I designs are utilized. Evidence of completion: Written determination	NE-2016-13-01	12/1/2016	Andrew Kimber

Lessons Learned (Confer with Lessons Learned Coordinator) (Use attachment as necessary)	Lessons Learned Number
When an unexpected result/scenario is encountered; take time to stop the work and re-analyze the path forward.	
When performing a design/operational review, made up of different components, make sure the system is reviewed as a whole.	

Witness Accounts: (Use attachments as necessary. Box will expand as necessary)

Shock Incident at the ARC1 Box Power Supply in the LERF on 7/26/16

(witness statement from Technician II)

On Tuesday, July 27th 2016 at approximately 08:30am, Technician I and Technician II began work on the ARC1 Box Power Supply in the LERF. The previous day the box supply tripped off due to an earth leakage fault.

We utilized our well established Lock, Tag and Try procedure for the box power supply. Technician I donned the appropriate PPE (long sleeves, gloves and safety glasses), checked the VVU, turned the supply off at the top mounted barrel switch and then re-checked the VVU. We applied our locks and Technician I, still in PPE, used the ground stick to discharge any stored energy still present at output of the supply.

We then took resistance measurements of the earth leakage circuitry and its connections to the output of the supply and the magnet string (same point at this time). At this time a resistance check from both the positive and negative output

Corrective Action(s)	JLab CATS Number	Target Date	Action Owner

connections to ground indicated only 40 ohms when it should have indicated 100 ohms. In hindsight this diminished resistance measurement, over 50% lower than what was expected should probably have led to other AC and DC voltage measurements but none were taken.

Next, we disconnected the control power transformer and attached an external control power transformer which allows us to test interlock and other functions of the box power supply while the 3 phase, 480vac input power is locked out. We then attached another small DC power supply from the positive output point to ground in order to verify the operation of the earth leakage fault detection circuitry. All checks verified normal and consistent operation of the earth leakage circuitry.

Since the testing of the earth leakage circuitry indicated satisfactory operation, we then decided to remove the magnet string leads from the output of the power supply. While handling the positive magnet lead, Technician II received a slight shock. We immediately stopped work and took DC and AC voltage measurements across both leads and with each lead to ground and found that the positive lead measured approximately 87vac RMS to ground and the negative lead was approximately 20vac RMS to ground. We then notified our supervisors, who in turn notified the Electrical Safety Engineer in ES&H. Together, a supervisor, Technician I & II, and the Electrical Safety Engineer determined that the extraneous AC voltage was coming from a trim card located in rack FL05B10, channel 20 which, under normal conditions, supplies a DC current to magnet MGF2F07H the coil of which is embedded in the ARC1 dipole magnet MGQ2F07.

Records, Documents, Pictures, and Other References: (Copy and paste, use attachments or document links as necessary)

Emergency Notifications Made (Subsequent to the Event):	Date	Time
Fire, Rescue & Emergency Medical: (9-911)		
Guard Post: x5822; 269-5822		
Occupational Medicine 269-7539	07/26/2016	1:00pm
ESH&Q Reporting Officer: 876-1750	07/26/2016	11:00am
Crew Chief 630-7050		
Industrial Hygiene: 269-7863:		
Other: Electrical Safety Engineer (ESH)	07/26/2016	10:00am

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Notable Event Worksheet

Confirmation Review Distribution: Investigation Team Members Affected Division Managers ESH&Q Reporting Officer	It is asked that you review and provide comments to this document to the Lead Investigator (denoted on Page 1) within TWO (2) days. Your comments will be reviewed and incorporated as appropriate. Thank you for your consideration in this matter.

Investigation Team Confirmation:
The below signees, confirm to the best of their knowledge, that the information presented in this document is accurate and complete.

Role	Print	Signature	Date
Lead Investigator (ESE-ESH)	Todd Kujawa	Todd Kujawa	9/13/16
SME (EESDCP Leader)	Sarin Philip	Sari Philip	9/14/16
SME (EESDCP Deputy)	Jim Coleman	Jim Coleman	9/14/16
DSO-ENG	Paul Collins	Paul A. Collins	9/13/16

Acceptance/Acknowledgement of Facts

	Print	Signature	Date:
Associate Director/ Department Manger	Will Oren	Will Oren	9/14/16

Upon confirmation submit document to the ES&H Reporting Officer for completion and distribution.

Documentation of Findings: (To be Completed by ESH&Q Reporting Officer)

Notable Event Number:	ACC-16-0726
CATS Number:	NE-2016-13-01
Lessons Learned Number:	964
ORPS Number:	SC--TJSO-JSA-TJNAF-2016-0004
NTS Number:	N/A
CAIRS Entry:	N/A
DOE Cause Code:	A4, B3 Work Org & Planning LTA, C08 Job Scoping did not identify special condition or circumstances
ISM Code:	Develop and Implement Hazard Controls

Unless otherwise specified the following is to be completed by the Lead Investigator.

Step 1 Initial Fact-Finding Meeting (To be held as soon as reasonably possible following event(within 24 hours))					
Date:	07/27/2016	**Time:**	9:00 am	**Location:**	LERF / Building 18

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Notable Event Worksheet

Required Attendees: (Print Name)		Optional Attendees: (Print Name) Present	
Lead Investigator:	Todd Kujawa	**Associate Director:**	Andrew Kimber / EES Dept Head
ESH&Q Representative:	Todd Kujawa	**TJSO Observer:**	Patty Hunt
Supervisor of involved persons(s):	Jim Coleman	**Subject Matter Expert(s), Facility/Equipment Owner as applicable:**	
Involved or impacted person(s):	Mark Todd		Paul Collins / DSO ENG
			Sarin Philip / EESDCP Leader
			Tina Johnson / Reporting Officer
Witness(es):	Eric Diggs		Harry Fanning / DSO ACC (observer)

Agenda *(Ensure the pace of the meeting allows time for accurate note taking.)*	**√ if Complete**
1. Introduction – Provide Event Title, Date and Time of Occurrence, and Location:	✓
2. Attendance - Are Required Attendees present.	✓
3. Purpose of Initial Fact-Finding meeting.	✓
4. Event Reconstruction – Use information to complete Section 3. Summary of Event and/or Injuries below.	✓
a. Personnel and organizations involved in the event.	✓
b. Conditions and actions preceding the event.	✓
c. Chronology (timeline) of the event; and	✓
d. Immediate actions taken in response to the event.	✓
5. Clarify information – Subject-Matter Expert (SME) confirms work conditions.	✓
6. Stop Work or the Tag Out Required? If "Yes" – establish the restart criteria and inform the affected Management chain.	Yes
7. Compensatory Actions Required? If "Yes" determine responsibility and include confirmation documentation.	Yes
8. Records or documentation required to confirm, clarify, or complete information (i.e., work plans, work control documents, photos, etc.).	✓
9. Other Questions or Concerns: Ask attendees if there are any other questions, concerns, or information that they wish to provide.	✓
10. Obtain TJSO Observer feedback on conduct of fact finding meeting and potential improvements.	✓

Step 2 Investigation Team:	**Date Convened:** (Within 24 hours of Fact Finding Meeting.)	07/28/2016 at 9:00am

Role	Name	Department/Group	Phone
Lead Investigator (ESH)	Todd Kujawa	EHSQ/IND	x7006

DSO-ENG	Paul Collins	ENG/DSO	x5981
SME	Jim Coleman	ENG/EESDCP	x7312
SME	Sarin Philip	ENG/EESDCP	x7117
ESHQ Reporting Officer	Tina Johnson	EHSQ	x7611
EES Dept. Head (observer)	Andrew Kimber	ENG	X5145
TJSO Observer	Steve Neilson	TJSO	x7215

Environmental Aspects [NA]

Type of Material Released:		**Quantity:**
Source:		**Time Flow was Halted or Controlled:**

For Investigation Team (√ All That Apply):

☐	**Reportable Quantity**	☐	**Impact Ground/Soil**	☐	**Storm Water Channel/Drain**	☐	**Sanitary Sewer**

Categorization and Reporting
(To be completed by ESH&Q Reporting Officer within two hours – unless essential information is still pending)

ORPS Determination:	Date:	07/27/2016	Time:	2155

ORPS/NTS/CAIRS Determination: Minor Shock in LERF Jul 27

From: Tina Johnson
To: Steve Neilson
Cc: Patty Hunt, Todd Kujawa, Bill Rainey

Steve,

As you know on July 26, 2016, two technicians were working under ATLIS task ID#16543 "LERF: Repair of ARC1 and ARC2 Box Power Supplies." Around 11:00, Todd Kujawa was notified that a technician received 87 volts AC shock while disconnecting the positive terminal of the ARC1 power supply. The output DC power leads were being disconnected from the power supply so that the power supply and the output circuitry would be isolated so that the earth leakage fault could be better investigated/understood. Before manipulating any of the output cables, the power supply 480 volts AC input was locked and tagged.

The shock occurred when the DC lead was being brought up out of the power supply enclosure; the technician stated that one hand on the lead while an elbow brushed up on the grounded enclosure.

When the voltage was discovered the leads were then covered and locked out with a protective locking device. As a precautionary measure, the technician was evaluated by Occupational Medicine and returned to work without restrictions.

Follow up troubleshooting led to the discovery of a deficient magnet trim cable card that was producing the unwanted voltage. This event is under investigation as a notable event and the Lab has also determined that this event is ORPS Reportable:

Subgroup E Hazardous Electrical Energy.
SC Criterion
2 Any unexpected or unintended personal contact (burn, shock, etc.) with an electrical hazardous energy source (e.g., live electrical power circuit, etc.).

If you have any questions or concerns, feel free to contact me.

10 CFR 851 Screen:	Date:	07/27/2016	Time:	2155

Categorization and Reporting
(To be completed by ESH&Q Reporting Officer within two hours – unless essential information is still pending)

ORPS Determination:	Date:	07/27/2016	Time:	2155

Negative: This event does not meet the voluntary criteria as a discreet programmatic weakness.

Final Distribution:

ES&H Reporting Officer (Original)
Associate Director/Department Manager
Division Safety Officer
Investigation Team Members
ESH&Q Liaisons

Form Revision Summary

Revision 1.6 – 02/22/16 – Updated form to reflect extent of condition ensuring it covers failed equipment per MOA
Revision 1.5 – 10/04/13 – Changed COE to Lessons Learned; updated links.
Revision 1.4 – 09/06/12 – Qualifying Periodic Review. Clarification of content only.
Revision 1.3 – 01/31/12 – Updated ESH&Q Reporting Officer assignment from S.Smith to C.Johnson per M.Logue Edited to clarify process steps.
Revision 1.2 – 10/20/11 – Updated ESH&Q Reporting Officer assignment from J.Kelly to S.Smith per M.Logue.
Revision 1.1 – 05/24/11 – Edited to clarify process steps.
Revision 1.0 – 11/23/10 – Updated to reflect current laboratory operations.

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Tina Johnson	02/22/16	02/22/19	1.6

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