

Implementation of Electrical Safety Procedures & Techniques for Accelerator Operations



Presented by Martin Murphy (Fermilab) at the
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Fermilab Operations Department Overview

- Five crews of four or five operators
- Five Crew Chiefs
- Eight Operations Specialists
- Upper Managers & Duty Assistant
- Crews & Crew Chiefs work 5-week rotating shift schedules – the schedules are different so that each Crew Chief works with every crew.

Operator's Primary Responsibilities

- Search & Secure of enclosures
- Powering on/off the accelerators
- Establishing and tuning beam as needed
- Monitoring utility and emergency systems
- Preserving the Beam Budget Monitor
- First responders to all failures, fires, and floods

Floods?

Yes, floods.



Search & Secure, Radiation & Electrical Safety

- Search & Secure:
 - A well established training program is in place:
 - Multiple visits, participation and leads for each enclosure prior to qualification
 - Detailed maps & procedures for Ops to use during S&S
- Radiation Safety:
 - Radiation Worker – Retrained every two years
 - Radiation Work Permits (RWP)
 - **ALARA** as a Cultural Norm

Historical Approach to Electrical Safety

- Single course (renewal not required) in Lock-Out Tag-Out (LOTO)
- Singular (renewal not required) training for group LOTO (13.8-KV) procedures
- In terms of day-to-day work there was little direction. Mainly we relied upon “common sense.”
- Lab-wide this led to near misses and the infrequent serious accident.
- Such events served as motivation...

Failure of a 480-V Switch at a Nation Laboratory (not Fermi)

- Undamaged switch
- Damaged switch



NFPA-70E

- In 2005 Fermilab moved to be in-line with the standards set forth by the **N**ational **F**ire **P**revention **A**ssociation.
- Employees undertook a day-long training session that was primarily focused on the power distribution side as opposed to the utilization side.

In Other Words...



The Need for an Operations-Specific NFPA-70E Program

- My bosses felt the Ops Department needed to do more to not only stress electrical safety, but to teach good techniques as well.
- They also felt the Laboratory's NFPA-70E could and should be made more specific for Operations.
- My task was to create and implement such a program

Operations-Specific NFPA-70E

- **Strong Leadership:** Operations & Division management strongly required Ops to follow rules – this was and is a crucial factor!
- Keep it Simple
 - There are many different power supplies and configurations → develop simple categories.
 - Limit unnecessary, but relatively risky activities.
 - e.g. “Hot” jobs are **not** permitted.
 - Provide easy access to personal protective and test Equipment

Arc-flash Hazard Risk Categories

Defined by NFPA-70E

Arc-Flash Hazard/Risk Categories - Required Clothing - Required PPE
Fermilab Summary for NFPA 70E

Calculated Exposure from Prospective Arc-Flash	Hazard/Risk Category	Minimum Required ATPV	Clothing Requirements	Additional PPE
Zero up to 1.2 cal/cm ²	-1	NA	Cotton Tee Shirt and Pants	Safety Glasses
Zero up to 1.2 cal/cm ²	0	NA	Long Sleeve Cotton Shirt and Pants	Safety Glasses
More than 1.2 and up to 4 cal/cm ²	1	4 cal/cm²	FR Coverall	Hard Hat, Safety Glasses
More than 4 and up to 8 cal/cm ²	2	8 cal/cm²	Cotton Clothing Under FR Coverall	Hard Hat, Safety Glasses, Face Shield, Hearing Protection, Leather Gloves, Leather Work Shoes
More than 4 and up to 8 cal/cm ²	2*	8 cal/cm²	Cotton Clothing Under FR Coverall	Hard Hat, Safety Glasses, Double-Layer Switching Hood, Hearing Protection, Leather Gloves, Leather Work Shoes
More than 8 and up to 25 cal/cm ²	3	25 cal/cm²	Cotton Clothing Under 2 x FR Coveralls	Hard Hat, Safety Glasses, Flash Suit Hood, Hearing Protection, Leather Gloves, Leather Work Shoes
More than 25 and up to 40 cal/cm ²	4	40 cal/cm²	Cotton Clothing Under FR Coverall plus Multilayer Flash Suit Jacket & Pants	Hard Hat, Safety Glasses, Flash Suit Hood, Hearing Protection, Leather Gloves, Leather Work Shoes

Breakdown of Hazard/Risk Categories & Personal Protective Equipment (PPE)

- **HRC-0:** Most frequently encountered by Ops – PPE is fairly minimal & comfortable
- **HRC-1:** Almost never encountered by Ops
- **HRC-2:** Occasionally encountered by Ops

Examples will follow...

Hazard/Risk Categorical Criteria as Interpreted by the FNAL Electrical Safety Subcommittee

- **Hazard/Risk Category 0 (HRC-0):**

- Most frequently encountered by Ops:

- Circuit breaker (CB) or fused switch less than 240-V; enclosed (covered) or not
- Enclosed CB or fused switch greater than 240-V and less than 600-V
- Enclosed Motor Controller Center (MCC) up to 600-V

- **PPE Requirements:**

- ✓ Safety glasses
- ✓ Long sleeve shirt & pants both made from untreated natural fiber (e.g. cotton, wool)
- ✓ Leather work gloves are optional (but encouraged)

Examples of HRC-0:

Main Injector Corrector
Bulk Power Supply Disconnect



Linac RF Main Breaker



More Examples of **HRC-0**:

Klystron Solenoid
Panel Breaker



MI Service Building
House Power Safety
Disconnect



Hazard/Risk Categorical Criteria

- **H/R Category 2:**

- Enclosed CB or fused switchgear rated greater than 1-KV
- NFPA-70E details many other combinations of hardware and activities in this H/R category, however, Ops (by order of Mau) **do not** undertake these activities. Instead we call FESS electricians.

- **Required PPE:**

- ✓ Hard hat, hearing protection & arc-rated face shield
- ✓ Fire-retardant Cover-alls over HRC-0 clothing
- ✓ Leather gloves & leather work shoes

Examples of **Category 2:**

Booster Gradient Magnet Power Supply
Utility Yard Disconnects



HRC-2 Activity in Action

(Note the PPE)



FNAL Electrical Safety Sub-committee

Shock/Electrocution Hazard PPE Guidelines

Shock Protection Boundaries and PPE Fermilab Summary for NFPA 70E				
System Voltage Range Phase to Phase	Limited Approach Boundary (Fixed Parts)	Restricted Approach Boundary	Prohibited Approach Boundary	Shock Protection Insulating PPE
50 to 300 Including 120, 277 and 120/208	3 Ft 6 In	Avoid Contact	Avoid Contact	LAB - None RAB - Wear/Use if Contact Likely PAB - Wear/Use if Contact Likely
301 to 750 Including 480/277	3 Ft 6 In	1 Foot	1 Inch	LAB - None RAB - Must Wear PAB - Must Wear
751 to 15K Including 13.8K	5 Feet	2 Ft 2 In	7 Inches	LAB - None RAB - Must Wear PAB - Must Wear
345K to 362K	15 Ft 4 In	8 Ft 6 In	8 Feet	LAB - None RAB - Must Wear PAB - Must Wear
Within the Limited Approach Boundary	Non-Qualified Worker Allowed Within Only if Advised and Escorted. Insulated Equipment/Tools if Contact Likely.			
Within the Restricted Approach Boundary	Only Qualified Worker Allowed Within. May Not Cross Into with Conductive Objects Prohibited. Body Parts Must be Insulated.			
Within the Prohibited Approach Boundary	Consider Activity as Same as Working On.			

Keeping It Simple

- 25 years ago Ops were as likely to be graduates of technical school as University
- Today most Ops have degrees in Physics but minimal or no experience working with high power circuits.
- Given these considerations we **do not** allow Ops to open power supplies with multiple power sources or high stored capacitive energy unless they have equipment specific LOTO.

Configuration Control Lockout List:

LINAC Configuration Control Updated 2/23/2006

LOCKED-OUT name/date/time.....LPSL

UNLOCKED name/date/time

Approved by Safety Officer

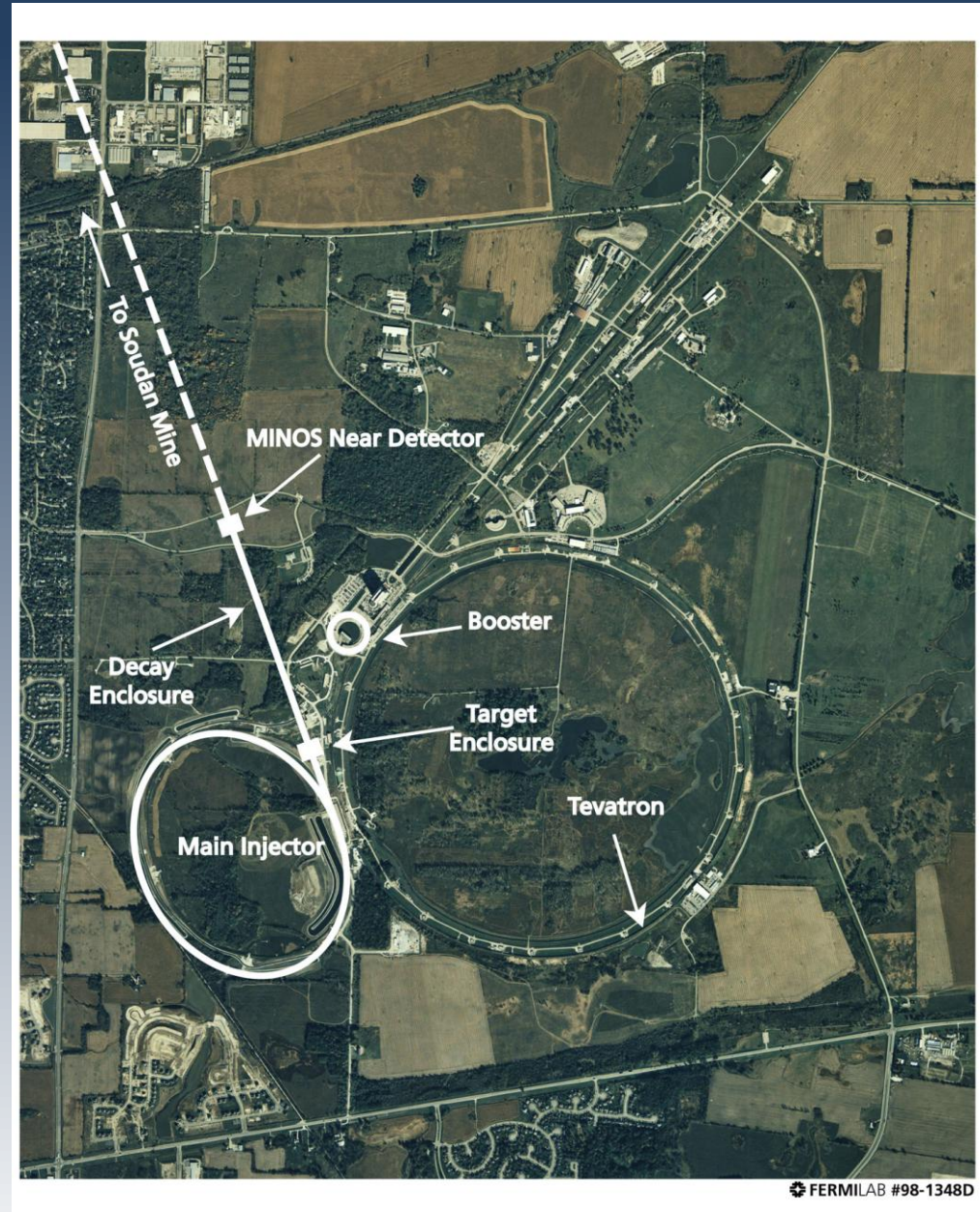
LOCKED-OFF	SUPPLY TYPE	AT ENCLOSURE	CONTROL POINT	NFPA 70E HAZ. CAT.	UN-LOCKED
[] MH1	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] LAM	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] QD4	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] QD3	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] Q2	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] Q5	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] MV1	POWERTEN	LG-1 LINAC	WALL BREAKER	0	[]
[] B:CEP400	FERMILAB	BG24 LINAC/ BOOSTER	WALL BREAKER	0	[]

Developing an Electrical Safety OJT

- Ops have about ~15 different electrical safety procedures
- Some require additional training and some do not
- We felt a need to formalize the process

Group Lock-Out Tag-Out (LOTO)

- Before Access to enclosures Ops perform 13.8-KV LOTO
- Historically:
 - Procedures were read & training was done by a qualified operator
 - No expiration for the training
- Today:
 - Only Crew Chiefs may train
 - New Ops must perform the LOTO three (3) times before being qualified
 - Training must be renewed annually
 - Created Electrical Safety OJT to complete documentation



New Operator Electrical Safety OJT Example

- Ops must complete both FNAL & Departmental NFPA-70E

- Once NFPA-70E is complete Ops may begin training for individual procedures

- The Operations Department Head is only allowed to provide the final signature

Trainer Date

1. **NFPA-70E Training**

_____ Operators must complete the Fermilab NFPA-70E electrical safety training.

_____ Operators must complete the Accelerator Operations Departmental NFPA-70E training.

_____ Once both NFPA-70E training sessions are complete the Deputy Department head will issue the operator fire retardant coveralls.

DH or DDH Date

2. **Master Substation (MSS) 13.8-KV LOTO Procedure**

_____ Operator must read and sign ADSP-05-1211

_____ Introduction to the MSS LOTO field checklist

_____ Operator should understand that Feeder 23 powers all Tevatron bend and quad magnets, low beta power supplies and the C0 shunt

_____ Operator must visit the substation and get a demonstration of the procedure by a Crew Chief. This may be a mock exercise done by the back-up CC if necessary

_____ Operator must then visit the substation with a Crew Chief or his/her designee and lead the procedure; this may be a mock exercise;

_____ Operator must flawlessly perform an actual LOTO procedure with a Crew Chief present

_____ Once these steps and all NFPA-70E training have been complete an operator will be approved by the Department Head (DH) or the Associate DH or the Deputy DH to perform MSS LOTO

LOTO Field Check-List for Trainers

- In order to make training more uniform we provide this checklist to the Crew Chiefs
- Since Crew Chiefs are ultimately responsible for Operations it makes sense for them to be the trainers

Pulsed Power LOTO Practices Checklist for Trainers

Generally speaking each individual is responsible for his/her own LOTO.

Pulsed power LOTO verification for **Booster GMPS, Main Injector, Tevatron, NuMI, and MiniBooNE** are an exception to the previous bullet point. By executing pulsed power LOTO for these locations the lead operator is personally responsible for verifying the 13.8-KV power is de-energized.

Regardless of which system is being manipulated for LOTO the following practices must be followed:

Always bring the appropriate LOTO field form and document each step in real time.

When manipulating a lever for a high voltage cabinet/cubical:

Use the proper personal protective equipment (prescribed by NFPA-70E) when manipulating high voltage switches.

Stand to the side of the cabinet/cubical door to reduce exposure in the event of an arc-flash.

Do not look into the cabinet/cubical window while moving the lever to minimize exposure in the event of an arc-flash.

When another person (e.g. the electrician) is manipulating HV (480-V or greater) breakers or switches stand at least 10 feet away; this will keep you safe in the event of an arc-flash.

Always bring a flashlight to look into the cabinet once the lever has been manipulated. Take your time and verify that each bus connection is OPEN.

Example of LOTO Field Form

- Check lists are used in the field to ensure the written procedure is consistently followed.
- Use of checklist eliminates reliance upon human memory
- A corresponding form is attached to the lockbox in MCR. **The Crew Chief must sign-off that the procedure was followed.**

Kautz Road Substation Feeders 86, 87, & 89 And MI-10 & MI-30 Disconnects LOCKOUT FORM

This form must be used each time MOS 86, 87, and/or 89 is locked out at the Kautz Road Substation in accordance with ADSP-05-1214, or when the safety switches at MI-10 and MI-30 are locked out in accordance with ADSP-05-1210.

Kautz Road Substation Lockout

Remove Manually Operated Switch (Green)(MOS) OPEN keys for MOS 86, 87, and/or 89 from the MCR key tree or Crew Chief cabinet. []

Contact and meet the Duty Electrician at the Kautz Road Substation. The two of you will perform the following operations:

1. Open the Circuit Breakers by turning off 6-1 and 7-1 for MOS86 and 87 lockout and 9-1 for MOS 89 lockout from the KRSS-MMI AB PLC located in the SW rack as you enter the building. []

The Duty Electrician checks that the Circuit Breaker's indicator lights are Green, indicating that the Circuit Breakers are OPEN

2. Duty Electrician inserts (GREEN) MOS keys from the MCR and pulls each MOS handle down. The (RED) MOS CLOSE keys are removed for 86, 87 and/or 89. []

3. Verify the following:

Manually Operated Switch Handle Down	MOS 86	MOS 87	MOS 89
	[]	[]	[]

All Three Switch Blades in each MOS Cabinet must be in the "OPEN" Position (Visually Verify) [] [] []

MI-10 and MI30 Safety Switch Lockout

Operation of the disconnects in these step is an NFPA 70E Class 0 activity.

1. Lead Person locks out the safety switch for the transfer supplies at MI-30. DSPHP-MI30-1A-7 is opened and all three knife switch blades are open. []
2. Turn and remove the Kirk Key from the actuator locking DSPHP-MI30-1A-7 in the open position. []
3. Lead Person locks out the safety switch for the transfer supplies at MI-10. DSPHP-MI10-1A-7 is opened and all three knife switch blades are open. []
4. Turn and remove the Kirk Key from the actuator locking DSPHP-MI10-1A-7 in the open position. []

Return the MOS CLOSE keys and the Safety Switch Kirk keys to the MCR. Place keys in the proper lockout box or Kirk key lock and place Crew Chief lock on associated lockout box.

Date

Signature of Lead Authorized Person

Approved by: _____

April 10, 2008

Continued Training

- Training Videos
 - Ops created several demonstrative videos that exist on a web server and can be reviewed at any time.

- Annual Renewal:
 - Operations NFPA-70E
 - All Group LOTO procedures (High Voltage)

Migration to Electronic Record Keeping

- Historically our procedures were kept in books (three-ring binders).
- Over the past two years these procedures now exist on a secure server.
- Operations has recently implemented an electronic system record keeping.

Summary

- Electrical safety training is much more formal.
- A department specific NFPA-70E program is in place. The Ops Department lead the Accelerator Division in adopting these guidelines.
- Vital LOTO training has been made more uniform and requires annual renewal.
- An electronic database gives CC & Ops quick access to training records and procedures.

Thank You for your Time. Here a
Gratuitous Picture of Lighting at Fermilab.

