July 29, 2005

To: ES&H

From: Gerald C. Brown

Subject: Energized Electrical Work Review Report Recommendations

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Please take the appropriate actions by the dates indicated on the attached memo, and coordinate with other Lab organizations, particularly the Electrical Safety Committee.

Department of Energy
Fermi Area Office
Post Office Box 2000
Batavia, Illinois 60510

DIRECTOR'S OFFICE

JUL 28 2005

JUL 27 2005

Mr. Gerald C. Brown, Associate
Director for Operations Support
Fermilab
P.O. Box 500
Batavia, IL 60510

7/29/2005

Dear Mr. Brown:

SUBJECT: ENERGIZED ELECTRICAL WORK REVIEW - FINAL REPORT

Reference: Memorandum, D. Erbschloe to J. Livengood, dated 7/20/05, Subject: Same As Above

Enclosed for your information and usage is the final report for the Fermilab Energized Electrical Work Review, conducted on June 13-17, 2005.

The review team made several recommendations for improvement. My expectation is that the Laboratory will prepare a Corrective Action Plan to address these recommendations. Please submit the plan to this office for my review and approval by August 16, 2005. Corrective actions are expected to be completed no later than six months from July 20, 2005. My office expects a bi-monthly status report on plan activities starting September 15, 2005.

Should you require additional information, please contact Jon Cooper at extension 4288, Ed Bucki at extension 4891, or John Scott at extension 2250.

Sincerely,

Jonathan P. Cooper

for Dr. Joanna M. Livengood
Site Manager

Enclosure:
As Stated

cc: P. Oddone, w/o encl.
K. Stanfield, w/o encl.
B. Chrisman, w/o encl.
W. Griffing, w/encl.

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

July 20, 2005

MEMORANDUM FOR JOANNA M. LIVENGOOD
MANAGER
FERMI SITE OFFICE

FROM: DONALD R. ERBSCHLOE
ACTING CHIEF OPERATING OFFICER

SUBJECT: Energized Electrical Work Review

Please find attached the final report of the Energized Electrical Work Review at Fermi National Accelerator Laboratory (FNAL), conducted on June 13-17, 2005. The review team agreed that there were "islands of excellence" at Fermilab, and also that there was much work remaining to accomplish. The review team noted that Fermilab uses an innovative device to operate switchgear circuit breakers, which keeps the worker at a safe distance in the event the circuit breaker fails catastrophically. Also, the team recognized the value of a comprehensive method developed by the Technical Division to aid in the performance of arc flash incident energy calculations.

The review team concluded that the Laboratory does not specifically identify National Fire Protection Association (NFPA), *Standard for Electrical Safety Requirements in the Workplace*, (NFPA 70E) in its Work Smart Standards Set, and it has not been included in all subcontracts. Fermilab policy allows manipulative energized electrical work, but the review team did not agree with the justifications used by one Fermilab Division. Fermilab does not have a corporate training program for NFPA 70E requirements. The Laboratory makes subcontractors responsible for training their own employees, but does not verify subcontractor training. The Laboratory does not have an effective program for periodically testing, inspecting and maintaining personal protective equipment (PPE).

The review team made several recommendations for improvement. Our expectation is that the laboratory will prepare a Corrective Action Plan to address these recommendations, which should be approved by you and transmitted to this office. Corrective actions are expected to be completed within six months from the date of this letter and monitored by the Site Office. A follow-up visit may be scheduled as appropriate.

Printed with soy ink on recycled paper

If you have any questions about this, please contact Barry Parks of my staff at (301) 903-9649 or by email at barry.parks@science.doe.gov.

Attachment

cc w/attachment:
R. Orbach, SC-1
R. Rosner, FNAL
R. Staffin, SC-25
L. Dever, SC-31
J. Zamirowski, CH

Office of Science
U.S. DEPARTMENT OF ENERGY

Energized Electrical Work Review

Fermi National Accelerator Laboratory

June 13-17, 2005

Energized Electrical Work Review

Fermi National Accelerator Laboratory
June 13-17, 2005

Executive Summary

This review is one of nine reviews of the Office of Science (SC) Laboratories that Dr. Raymond Orbach, Director, requested be performed to provide an independent assessment of the planning and performance of energized electrical work (electrical hot work). The purpose of the review is to provide an overview of the status of work on energized electrical equipment across the SC Laboratory complex and to provide assistance to the SC Laboratories in the area of electrical safety. The review looked at the Laboratory's systems and processes for handling work on energized electrical equipment, as well as the Fermi Site Office (FSO) oversight of electrical work.

This review was conducted at the Fermi National Accelerator Laboratory (Fermilab) during the period June 13-17, 2005. Topics evaluated during the review were processes for working on energized equipment, implementation of those processes, training for Laboratory and subcontractors who perform work on energized equipment, flowdown of Department of Energy (DOE)/Fermilab requirements to subcontractors, and contractor oversight methods.

The Fermilab Electrical Safety Program does not list National Fire Protection Association (NFPA), *Standard for Electrical Safety Requirements in the Workplace*, (NFPA 70E) as a required standard. The program permits energized manipulative work and Directorate approval is required when the voltage exceeds 250-Volts, phase-to-phase. Fermilab procedures do not specify appropriate justifications for energized electrical work required by NFPA 70E. The review team did not agree with the justifications used by one of the Divisions for manipulative energized electrical work performed over the last six months. The Energized Hazard Analysis/Work Permit (EHAWP) has been applied inconsistently and with varying degrees of completeness by the various Fermilab Divisions/Sections. However, the most recent Fermilab procedure incorporates NFPA 70E requirements.

Fermilab does not currently have a corporate level training course for designating qualified persons as recognized by NFPA 70E. Efforts are currently underway for acquiring a vendor to provide this training to the Laboratory. Fermilab line organizations have taken it upon themselves to interpret NFPA 70E requirements, which have led to inconsistent implementation across the facility.

Formal oversight programs consist of Division/Section Head documented inspections which are required to be conducted at least quarterly in industrial and technical areas. The Tripartite Environment, Safety and Health (ES&H) Assessment process is another portion of ES&H oversight activities at Fermilab. These assessments are planned and

performed jointly by the Divisions/Sections, the ES&H Section, and the Fermi Site Office (FSO).

FSO oversight program consists of Facility Representatives responsible for oversight of the accelerator and experimental operations and the support and service activities. In addition to participation in the Tripartite Assessment, FSO also carries out focused assessments of specific ES&H programs across Fermilab to determine the effectiveness of the program and to identify weaknesses. Currently, FSO does not have a multi-year schedule to assure adequate coverage of the entire ES&H Program.

Fermilab subcontracts do not make any specific mention of NFPA 70E, or any laboratory-specific requirements for energized electrical work. Flowdown of requirements for energized electrical work is documented with an EHAWP. Fermilab does not offer formal training for their subcontractors on NFPA 70E requirements. The review team could not find any subcontractor electrical worker who had been formally trained in NFPA 70E requirements.

As of June 2005, Fermilab requires that the subcontractor provide all required personal protective equipment (PPE), and specifies that the PPE "must be in accordance with Occupational Safety and Health Administration and NFPA." Although PPE was readily available, personnel were not trained in the appropriate use, care and testing of the equipment. The absence of training was also revealed by a lack of understanding of approach boundaries and barriers.

Subcontractor electrical workers were observed to be wearing all-cotton clothing, but there is no specific policy in place for that requirement. The review team did not find any explicit documentation which explained that subcontractors could also "stop work;" however, subcontractors told the review team that they understood that they did have "stop work authority." During the course of the review team interviews, employees indicated that Fermilab disseminates lessons learned to subcontractors via toolbox safety meetings.

Any activity that penetrates the soil requires an excavation permit. Procedures for conducting concrete cuts or coring must also be followed. There is a single point of contact for the organization or project that intends to conduct the work. For concrete cuts and coring an EHAWP must be developed which assumes that the energized circuit will be cut and therefore the EHAWP must include shock and electrocution as an associated hazard of the work activity.

Conclusion

The Laboratory does not specifically identify NFPA 70E in its Work Smart Standards Set, and it has not been included in all subcontracts. Fermilab policy allows manipulative energized electrical work, but the review team did not agree with the justifications used by one Fermilab Division.

Fermilab does not have a corporate training program for NFPA 70E requirements. The Laboratory makes subcontractors responsible for training their own employees, but does not verify subcontractor training. The Laboratory does not have an effective program for periodically testing, inspecting, and maintaining PPE.

Acronyms and Abbreviations

AC	Alternating Current
CAD	Computer-aided Design
CFR	Code of Federal Regulations
CY	Calendar Year
DOE	Department of Energy
EHAWP	Electrical Hazard Analysis/Work Permit
ESS	Electrical Safety Subcommittee
ES&H	Environment Safety and Health
ESHTRK	ES&H Tracking System
FAO	Fermi Area Office
FESHM	Fermilab ES&H Manual
FESS	Facilities Engineering Services Section
Fermilab	Fermi National Accelerator Laboratory
FPN	Fine Print Note
FR	Flame-Resistant
FSO	Fermi Site Office
IEC	International Electrotechnical Commission
ITNA	Individual Training Needs Assessment
kV	Kilovolts
LOTO	Lockout/Tagout
LSC	Laboratory Safety Committee
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PPE	Personnel Protective Equipment
SC	Office of Science
SLAC	Stanford Linear Accelerator Center
T&M	Time and Materials
TD	Technical Division
V	Volts
VAC	Volts Alternating Current
WSS	Work Smart Standards Set

Energized Electrical Work Review

Fermi National Accelerator Laboratory
June 13-17, 2005

1. Purpose

The purpose of this review is to provide assistance to the Office of Science (SC) and SC Laboratories in the area of electrical safety. The review assessed the Laboratory systems and processes for handling electrical work with a focus on processes for conducting work while equipment is energized (electrical hot work).

2. Scope

This review concentrated on the planning and execution of work conducted on energized equipment at the Fermi National Accelerator Laboratory (Fermilab). It included reviewing and evaluating the Laboratory's policies, processes, and procedures that plan and execute work on energized electrical equipment. The following topics were evaluated during the review:

- The process for working on energized electrical equipment.
- The implementation of the process for working on energized electrical equipment.
- Training program for Laboratory and subcontractors personnel.
- The flowdown of Department of Energy (DOE) and Fermilab requirements to subcontractors.
- The methods used for oversight of work on energized electrical equipment by Fermilab and the Fermi Site Office (FSO).

3. Observations

3.1 Energized Electrical Work Program

Contractual environment, safety and health (ES&H) requirements for Fermilab are defined in the Work Smart Standards Set (WSS). The current WSS lists the National Fire Protection Association (NFPA) Codes and Standards "as applicable", but does not specifically identify NFPA 70E, *Standard for Electrical Safety in the Workplace*, (NFPA 70E). However, NFPA 70E has been accepted by Fermilab as applicable to their operations.

Energized Work Policy

The Fermilab Electrical Safety Program is implemented primarily by the Fermilab Environment, Safety and Health Manual (FESHM) Chapter 5040 and by the oversight responsibility of the Electrical Safety Subcommittee (ESS) of the Laboratory Safety

Committee (LSC). FESHM Chapters 5041 through 5048, and FESHM Chapter 5120, *Fermilab Energy Control Program (Lockout/Tagout)* contain detailed elements of the safety program. It is the responsibility of the Fermilab Divisions/Sections to implement these chapters.

The requirements for energized work on the AC electrical power distribution systems for voltage levels less than 600-VAC are contained in FESHM Chapter 5042, *AC Electrical Power Distribution Safety – for Systems Operating at 600-VAC Nominal or Less*. The requirements for energized work above 600-VAC are contained in Facilities Engineering Services Section (FESS) Standard Policy and Procedures No. 5303. The requirements for low and high power utilization equipment are contained in FESHM Chapter 5041.

FESHM Chapter 5040 does not include NFPA 70E in the list of applicable standards; however, the last sentence of the section "Electrical Work Activities" does include a limited reference to the 2000 edition.

> *Recommendation 1: Fermilab should ensure its electrical safety program includes NFPA 70E as a mandatory standard.*

FESHM Chapter 5042 states "except for metering, and testing, working on the exposed energized conductors of distribution equipment is generally prohibited." With appropriate justification the Division/Section Electrical Coordinator(s) can authorize work on energized system at 130-VAC or less (terminal-to-ground) or 250-VAC (terminal-to-terminal). Energized work on systems exceeding these limits requires approval from the Fermilab Directorate.

> *Recommendation 2: Establish 50-VAC as the threshold for identifying systems that are required to be de-energized in order to work safely.*

> *Recommendation 3: Avoid using ambiguous words like "generally" in defining policy on energized work.*

The use of the term "hot work" is very common throughout the Laboratory and is used in FESHM Chapter 5040. In existing NFPA and Occupational Safety and Health Administration (OSHA) standards the term "hot work" is not used when applicable to electrical work.

> *Recommendation 4: Use the more appropriate description of "energized [electrical] work" in place of the phrase "hot work."*

3.2 Energized Electrical Work Program Implementation

Energized Work

Fermilab has a policy that while "...working on exposed energized conductors is generally prohibited, it is recognized that occasionally operational necessity requires

work on energized power distribution systems. These circumstances are expected to be rare exceptions, requiring special precautions and utmost care to prevent accident and injury" (FESHM Chapter 5042, Section 4). The use of the term "rare" does not communicate useful criteria for performing energized work. The Accelerator Division has been performing manipulative energized electrical work, e.g., removing and replacing a circuit breaker, conduit entry and wire pulling into an energized 120/208-VAC power distribution board, and installing circuit breakers in an energized Square D, I-Line 480-VAC power distribution panel. Over the last six months this Division issued thirteen work permits authorizing electrical work on energized systems at 130-VAC or less. The justification cited to perform this work energized was NFPA 70E, Article 130.1, FPN No. 2, "circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment." The review team believes that this justification is not applicable to the Fermilab situation because a single circuit may be shutdown without requiring shutting down all the other circuits of the accelerator.

Recommendation 5: Discontinue the practice of energized manipulative work.

During the FESS morning briefing, jobs for the day were reviewed by the group supervisor, the group coordinator and the manager. The discussions were detailed and appropriate for coordination of the activities. One of the jobs discussed was a switching activity.

The worker who would operate the cutoff switch had the correct personal protective equipment (PPE) for the activity and it was clear that he understood the PPE requirements. The Electrical Hazard Analysis/Work Permit (EHAWP) for this activity was not available at the time the switching activity took place. Subsequently, a review of the EHAWP found it lacked important information required by NFPA 70E, e.g., arc flash distance and shock approach boundaries.

Inspection of FESS electricians' PPE and equipment revealed out-of-date voltage-rated gloves and a hot stick with no test date.

Recommendation 6: Implement a program to ensure voltage-rated gloves and live line tool (hot stick) testing is current.

In a discussion with a FESS electrical engineer on the safe operation of medium voltage switchgear, the engineer indicated that they use a control circuit extension device that allows an individual to stand to the side when operating switchgear circuit breakers. This reduces the exposure of the worker in the event the circuit breaker fails catastrophically. The review team recognizes the value of this innovative device for protecting workers.

Noteworthy Practice 1: Fermilab has developed a control circuit extension device to move the worker further from the hazard.

Energized Electrical Work Permit

FESHM Chapter 5042, states that, "The completed Electrical Hazard Analysis/Work Permit for work on an energized power distribution system shall conform to NFPA 70E, Article 130.1(A)(2)." The majority of the work permits examined did not meet the requirements of NFPA 70E, nor FESHM Chapter 5042, e.g., they lacked a description of the required PPE, the arc flash boundary, and the shock protection boundaries. On June 5, 2005, FESHM Chapter 5042 was reissued and included a revision of the EHAWP to include the NFPA 70E, Article 130.1(A)(2) requirements.

FESHM Chapter 5042 does not require an EHAWP for diagnostics, testing or zero voltage checks. NFPA 70E requires all the analysis necessary to complete an EHAWP for these activities, but gives an exemption to documenting the process.

> *Recommendation 7: Use an EHAWP for diagnostics, testing or zero voltage checks.*

The Technical Division (TD) has developed a comprehensive method to aid in the performance of arc flash incident energy calculations that involves the creation of computer-aided design (CAD) generated one-line diagrams that include all the information necessary to perform short circuit and arc flash analysis. In addition, a second set of CAD one-line diagrams have been developed, as a second level drawing, which includes the short circuit current data at all key buses. A trial version of short circuit and arc flash calculation software is under evaluation. This software will eventually be used to automatically perform these calculations.

> *Noteworthy Practice 2: TD has developed a comprehensive method to aid in the performance of arc flash incident energy calculations.*

> *Recommendation 8: Implement the use of the comprehensive method developed by the TD to aid in the performance of arc flash incident energy calculations throughout the Laboratory.*

Some workers complained about wearing a double-layered switching hood in hot weather and indicated that the reduction in visibility increases the difficulty of performing some diagnostic tasks. They use a 45 calorie hood for all their work. (NFPA 70E only requires a face shield for categories "1" and "2" and a 25 calorie hood for hazard category "2*"). Using flame-resistant (FR) apparel and PPE with a rating significantly higher than is needed for the activity unnecessarily increases "PPE related" hazards such as reduced vision and hearing.

> *Recommendation 9: Review the application of FR apparel and PPE to make sure that it is appropriate to the hazard level.*

The Laboratory currently permits the use of a solenoid voltage tester. Because of a history of catastrophic failure in industry, many organizations have banned the use of this kind of tester.

> *Recommendation 10: Consider prohibiting the use of the solenoid voltage tester by subcontractor and in-house personnel.*

Non-contact voltage testers are permitted to be used to perform zero voltage checks when performing lockout/tagout (LOTO) by FESHM Chapter 5048. This is a violation of both 29 Code of Federal Regulations (CFR) 1910.333(b)(2)(iv)(B) and NFPA 70E, Article 120.1, item (5).

> *Recommendation 11: Discontinue the practice of using non-contact voltage testers for zero voltage checks if meters are commercially available that are "IEC CAT-III" rated for the voltages and conditions to be tested.*

3.3 Energized Electrical Work Training

Fermilab does not have a corporate level training course for implementing the requirements of NFPA 70E. As such, there is no formal mechanism at Fermilab for designating a "Qualified Person" as recognized by NFPA 70E, Article 110(D)(1). The ESS Chairperson has been tasked by the Associate Director for Operations Support (in his capacity as the LSC Chairperson) to identify a vendor to provide this training. It is anticipated that this vendor will be identified and hired by the end of this summer. Due to the absence of a corporate level training course for implementing the requirements of NFPA 70E, Fermilab line organizations have individually taken actions for communicating selective information to their respective employees. The depth of this communication varies by organization from minimal to extensive. Furthermore, this has led to varying interpretations and conflicting methods of implementation. For example, some persons interviewed feel that testing, troubleshooting and inspection is not energized work. A desire was expressed by those responsible for employee safety that this corporate level training be made available as soon as possible to establish consistent implementation of NFPA 70E. No formal schedule has been established for how and when this training will be accomplished.

> *Recommendation 12: Establish a schedule for completing Fermilab corporate level NFPA 70E training.*

Fermilab provides electrical safety training for its employees who face risk from electrical hazards. This training is accomplished through classroom and computer-based presentations, and on-the-job by means of toolbox safety sessions, mentoring, mass e-mail distribution, printed bulletins, preparation of work planning documentation, pre-job briefings, and daily employee interactions.

Formal training requirements are established through the Fermilab Individual Training Needs Assessment (ITNA). ITNA is a web-based process by which each supervisor will,

for each subordinate employee, identify necessary safety training. Supervisors are responsible for identifying the hazard exposures for the employee, that the employee is trained to recognize those hazards, and that the employee is fully prepared to respond appropriately to those hazards. Through a series of questions, ITNA maps a set of required training courses for each employee. This set is generated as an *Individual Training Summary* which lists and tracks those courses the employee must complete.

NFPA 70E, Article 110.6(D)(2) calls for unqualified persons to be trained in and be familiar with any of the electrical safety-related practices necessary for their safety. ITNA raises the question of whether an individual will work near exposed conductors of energized electrical equipment, or design/service electrical equipment and/or transmission distribution systems. Answering yes to this question establishes *Electrical Safety for Qualified Workers* as a mandatory training course. ITNA does not take into consideration the fundamental electrical hazard training required for the balance of Laboratory employees, i.e., ITNA does not map to any mandatory electrical safety training course for unqualified persons.

> *Recommendation 13: Establish unqualified person training requirements and revise ITNA so as to allow supervisors to map any required training for the applicable employees.*

Fermilab training courses specific to the hazards associated with energized electrical work include:

New Employee ES&H Orientation

All new employees, and selected visitors and subcontractors who will be on-site for more than three months are required to attend this training which covers general ES&H information. Though specific direct reference to the performance of energized electrical work is not made, all employees are introduced to the concept of establishing an electrically safe working condition through what is described at Fermilab as LOTO Level 1 training. This is core information intended to introduce "affected employees" to the Laboratory's hazardous energy control requirements as found in FESHM Chapter 5120.

Subcontractor Safety Orientation

This mandatory course for subcontractors provides an overview of the Laboratory's expectations for the performance of safe work. Though the video presentation for this course included some discussion on electrical safety, there is no specific mention of energized electrical work. The *Fermilab Subcontractor Safety* booklet handed out during the course notes that work on electrical distribution systems is performed only by qualified workers and requires an approved Electrical Work Permit. The course notes that the subcontractor is responsible for providing its employees with necessary training and equipment, and for complying with the requirements of OSHA. See section 3.5,

Subcontractor Safety, of this report concerning verification of subcontractor completion of required safety training. This course has a two-year qualification term.

Basic Electrical Safety

This optional course provides information that covers electrical theory, electrical hazards (shock, burns, arc-blast, explosions, and fire), and effects of electricity on the body, common workplace circuits, electrical protective devices, grounding, ground-fault circuit-interrupters, and wiring for proper polarity. This course does not cover current Laboratory policy on the performance of energized electrical work.

LOTO Level 2

This course is the continuation of the LOTO Level 1 course and prepares "authorized employees" for the actual placement of locks and or tags for the control of hazardous energy as prescribed by FESHM Chapter 5120. This is currently a one-time requirement. Fermilab is currently developing a LOTO Level 2 prequalification course. The course under development will conclude with an examination which requires a passing score of 80 percent. Training requirements established through ITNA also identify job-specific LOTO procedures established by the associated line organization.

Electrical Safety for Qualified Workers

This course was described as having originally been established as a result of a DOE Tiger Team finding on the need for Fermilab employees to be trained on electrical hazards per OSHA. Successful completion of this one-time required course concludes with an examination which requires a passing score of 80 percent. This results in each participant being designated as a "Qualified Person" as defined by OSHA. The OSHA definition is similar, but not identical to the definition of qualified person as is used by NFPA 70E. The number of employees reported to have been designated as qualified persons through completion of this course is reported to be between 400-500.

In late 2003, the Fermilab ES&H Section took ownership of the course and revised the original content. These changes brought the training into better alignment with NFPA 70E, but the training still lacks all of the required elements sought by NFPA 70E, Article 110.6(D)(1) for designating a qualified person. This includes the Laboratory's own policy regarding the performance of energized electrical work and the decision-making process associated with the EHAWP. Likewise, those changes which were made do not satisfy the required elements of NFPA 70E, Article 110.6(D)(1).

Two Tripartite Assessments of NFPA 70E implementation in FESS and Technical Division have identified that improvements are needed in NFPA 70E-related training. No recent changes have been made. However, the immediate need for making these changes may not be necessary, pending the selection of a vendor for the presentation of NFPA 70E training for designating Fermilab employees as qualified persons.

During interviews, concerns were expressed regarding the adequacy of guidance made available in the training as it relates to emergency response. NFPA 70E, Article 110.6(C) calls for training to address methods of release of victims, and for persons to be regularly instructed in methods of first-aid and emergency procedures if their duties warrant such training. The issue of summoning emergency assistance is said to be well understood. However, suggestions for obtaining a "2x4" to knock a coworker free, or to wear a rope around the waist to get pulled from an energized circuit are viewed as impractical or impossible solutions. Without preparation for such an occurrence, a desperate desire to grab and pull a coworker free could lead to multiple fatalities. The objective of NFPA 70E to first establish an electrically safe work condition should be the primary means of avoiding an electrical contact incident. If energized work must be performed, employees should be trained to know that their first action in responding to an electrical contact incident must be to remove the source of electricity.

> *Recommendation 14: Modify the Fermilab's training as it relates to responding to electrical contact incidents by first promoting working de-energized; and if work must be performed energized, that during work planning and pre-job briefings workers be trained on how and where to remove the source of electricity.*

Other ES&H Training Courses

Time did not permit review of the balance of Fermilab training courses to ensure that associated electrical safety issues receive adequate consideration, e.g., does mobile crane training address approach distances for avoiding contact with overhead lines. Because of the safety-related work practices for the use of lasers found in NFPA 70E, Article 330.3, the electrical safety content of the laser safety training course was briefly discussed. It was learned from that discussion that information presented on electrical safety might be minimal.

> *Recommendation 15: Ensure that all ES&H training courses with electrical safety considerations appropriately reflect Laboratory policy on the performance of energized electrical work and/or the requirements of NFPA 70E.*

3.4 Oversight

Formal oversight programs at Fermilab are identified in the FESHM Chapter 1040, *ES&H Self Assessment Program.* They consist of Division/Section Head documented inspections which are required to be conducted at least quarterly in industrial and technical areas. The Tripartite ES&H Assessment process is another portion of ES&H oversight activities at Fermilab. These assessments are planned and performed jointly by the Divisions/Sections, the ES&H Section, and the FSO. Recent Tripartite Assessments which have evaluated the implementation of NFPA 70E have been performed in the TD and FESS.

An electrical safety review was performed in CY04 in the Particle Physics Division. A planning meeting is conducted annually that identifies the ES&H area to be covered in a Tripartite ES&H Assessment. The areas which are reviewed are based on historical knowledge of the ES&H program of the Division/Section in which the assessment will be performed.

The results of assessments are tracked on the Fermilab ES&H Tracking System (ESHTRK) system. This database system automatically sends reminders to responsible persons when actions are due or past due. It also informs management of overdue actions and actions which have been reported as complete. FSO has read only access to this tracking system. FSO requests corrective action plans from Fermilab on FSO review findings and recommendations. Those actions are entered into the Fermilab ESHTRK system. FSO findings from walkthroughs of the site are entered into an FSO tracking system.

FSO has two Facility Representatives. One Facility Representative is responsible for the accelerator and experimental operations while the other is responsible for support and service activities. The FSO Facility Representative Program is documented in FAO Procedure 2.7 Rev. 2, dated April 2002. The Facility Representatives are responsible to conduct surveillances to observe, evaluate and report on the effectiveness of the Fermilab ES&H Programs. They accomplish this by providing reports to the FSO Site Manager on their activities as well as participating in Tripartite and program reviews in their assigned Fermilab organizations.

FSO Program reviews are focused assessments of a specific ES&H program across Fermilab to determine the effectiveness of that program and identify any weaknesses. These program reviews are scheduled on a calendar year basis. The current year's schedule has five reviews identified, including this energized electrical work review. The schedule is developed based on discussions among the staff of the ES&H and Program Support Team. Currently FSO does not have a multi-year schedule which assures adequate coverage of the Fermilab ES&H Program.

> *Recommendation 16: FSO should evaluate the need to develop a master schedule for the evaluation of the complete Fermilab ES&H Program.*

The ESS is an advisory group to the LSC, and is responsible for recommending guidelines for the operation and maintenance of electrical systems that include building and experimental equipment. It is composed of no more than eleven members from the sections and divisions. The subcommittee currently meets on a monthly basis and includes an observer from the site office. The Associate Director for Operations Support has used this subcommittee to assist in the oversight of electrical activities at Fermilab. The ESS had been used to assist in the development of the *Action Plan for DOE Improved Performance of Electrical Safety at Fermilab*. The action plan has resulted in six tasks. The EES has been working on these tasks, but their original due dates have been extended. Currently two of the six tasks still remain open. This may be partially due to additional actions which the Associate Laboratory Director for Operations Support

as the LSC Chairperson assigned to the ESS after the accident at Stanford Linear Accelerator Center (SLAC).

Fermilab and Argonne National Laboratory have recently partnered in a joint review of their energized electrical work policies and procedures. This evaluation has not as of yet been presented to Fermilab management for assignment of action items and evaluation of its results.

3.5 Subcontractor Safety

Most of the electrical work at Fermilab is done by subcontractors. Fermilab subcontracts do not make any specific mention of NFPA 70E, or any Laboratory-specific requirements for energized electrical work. Fermilab requires subcontractors to have an ES&H program which encompasses "applicable aspects" of "29 CFR 1910, *Safety and Health Regulations for General Industry*" and "29 CRF [sic] 1926, *Safety and Health Regulations for Construction.*" For contracts over $100,000, subcontractors are required to submit a copy of their company ES&H program to the Laboratory, which is reviewed for acceptance by the ES&H Section. For contracts valued under $100,000, the subcontractor is required to submit a Safety Questionnaire for acceptance, instead of a complete program.

The review team examined one subcontractor safety program, and found that it did not provide for NFPA 70E-specific training or PPE. Some PPE requirements evaluated were found to be out-of-date; for example, hard hats required for electrical work are to be Class B, which the American National Standards Institute has changed to Class E.

> *Recommendation 17: Confirm the implementation of NFPA 70E by subcontractors.*

Flowdown of requirements for energized electrical work is documented with an EHAWP. All electrical work by subcontractors requires a hazard analysis and a work permit. This requirement is explicitly explained in a "Subcontractor Orientation" videotape, which must be viewed by all subcontractors before coming to work at Fermilab for the first time.

Fermilab manages subcontractors with Task Managers and Construction Coordinators, who work in the field and are responsible for contractor safety. According to FESHM Chapters 7010 and 7011, Task Managers are responsible for preparing the Hazard Analysis and Electrical Work Permit for T&M subcontractors, while Construction Coordinators approve documents prepared by the fixed-price subcontractors. Neither is required to attend the Electrical Safety for Qualified Workers course. Anyone with minimal National Electrical Code training or with degrees, such as Electrical Engineering, is assumed to be knowledgeable and qualified.

> *Recommendation 18: More clearly define the training and experience requirements for approval of Task Managers and Construction Coordinators.*

Persons with oversight of electrical work should be trained in electrical safety and NFPA 70E. Training should be recurring.

Fermilab does not offer any formal training for their subcontractors on NFPA 70E requirements, although they do offer training for radiation safety and oxygen deficiency hazards. The review team was told by Laboratory staff that subcontractors are expected to provide training for their workers, in keeping with their contractual commitment to comply with applicable regulations. However, the Laboratory does not appear to make any attempt to formally verify or document such training. Fermilab requires the time and materials (T&M) subcontractor to use only journeymen electricians. However, this has not ensured that subcontractor personnel are trained to minimum standards. T&M subcontractors interviewed by the review team had minimal knowledge and familiarity with NFPA 70E requirements, were not familiar with the Approach Boundaries of NFPA 70E, and have not received training on the proper use, care and testing of PPE. Copies of NFPA 70E were available to T&M subcontractors through the site supervisor.

Recommendation 19: Make sure subcontractor electricians are formally trained in NFPA 70E requirements. The training should include appropriate use, care, and testing of PPE.

The review team found inconsistencies with the PPE contractors are required to have, and how it will be supplied. Depending on who was interviewed, the review team was told that the Laboratory does not (and never has) supplied PPE to contractors, or the Laboratory does currently and always has supplied the PPE for contractors, and the Laboratory no longer (as of June 1st) supplies PPE to contractors. According to contracts, as of June 2005, Fermilab requires that the subcontractor provide all required PPE, and specifies that the PPE "must be in accordance with OSHA and NFPA."

Subcontractors interviewed by the review team were not aware of any program for periodic testing or inspection, such as American Society for Testing and Materials, D120 specifications for testing rubber insulating gloves every six months. During interviews, the contractor site supervisor said he was aware that gloves should be sent for testing every six months, but that requirement is not being maintained. The review team spot-checked two sets of rubber insulating gloves, and neither had been recently tested - one pair was marked as last tested in 1993 and the other pair in 1984.

Subcontractor electrical workers were observed to be wearing all-cotton clothing, but there is no specific policy in place with that requirement. Subcontractors do not have any specific requirements in either the contract or their own safety manual for 100 percent natural fiber clothing or long sleeve shirts and long pants. Although use of natural fiber clothing is emphasized in toolbox meetings, it is not required. Furthermore, electricians interviewed were unaware of requirements for persons working on electrical equipment to wear long sleeve shirts and long pants. Subcontractors checked had available flame resistant coveralls, a rated hardhat with face shield, and rubber mats. One full set of 1000-Volts insulated tools was available for use. Rubber insulating gloves were found stored inside leather protectors in canvas glove bags. Per manufacturer instructions,

gloves should be stored outside the leather protectors, cuff down, in the canvas bags to eliminate the possibility of bacterial growth that can damage the rubber when moisture is trapped between the rubber and leather. Leather protectors must be of the appropriate length for the rubber insulating glove length. The Class 2 gloves also had the wrong leather protectors. The gloves available are for any subcontractor personnel, using a "one size (11) fits all" concept.

While it was indicated by subcontractor supervision that PPE is worn for all energized work, including voltage testing for zero energy verification, subcontractor personnel indicated that the PPE is only used a few times per month, but that lockout/tagout is typically performed daily.

Recommendation 20: Require subcontractor electricians to wear appropriate all-cotton clothing, with long sleeve shirts and long pants as a minimum, when performing energized electrical work.

Recommendation 21: Make certain that contractors wear appropriate PPE for all tasks.

Recommendation 22: Verify that:

- *personal protective equipment used by subcontractors is properly maintained, inspected, and tested.*
- *each electrician is issued a personal pair of rubber insulating gloves properly sized for their hands. Properly sized gloves will result in improved dexterity and appropriate protection.*
- *appropriate gloves for the voltage are utilized to improve dexterity. Persons working on 480-Volt maximum equipment do not require Class 2 gloves suitable for 17kVolt.*

Contracting documents specify that any Fermilab employee can "stop work" being performed by subcontractors. The review team did not find any explicit documentation which explained that subcontractors could also "stop work;" however, subcontractors told the review team that they understood that they did have "stop work authority."

Recommendation 23: Document that subcontractors have "stop work" authority.

Additional on-the-job training and lessons learned are communicated through required weekly 15-minute toolbox sessions and required monthly safety meetings, which are also required to be recorded with topics and attendance. In addition to lessons learned, these topics include lockout/tagout, confined space, cardio-pulmonary resuscitation, and shock hazards, as some examples. Urgent topics for safety are communicated in morning meetings or special sessions. For instance, lessons learned on the SLAC accident were communicated not only through multiple toolbox sessions, but through a review provided

to Arlington Electrical Construction on October 18, 2004. All T&M subcontractor electricians were given a copy of the SLAC report. The one-hour monthly safety meetings are used to discuss subjects as described above in more detail and review the important points of the contractor safety program.

Electrical subcontractors establish work zones when performing electrical work through the use of cones, ropes, barrier tape, fences, plastic chain, and other available methods. However, contractors are not aware of the flash protection, limited, restricted, and prohibited approach boundaries. When asked how they establish the work zone, the review team was told that it is typically a six to eight foot boundary unless more is required. High energy systems could have flash protection boundaries greater than the six to eight foot zones currently established. Also, subcontractors told the review team that Laboratory personnel often do not respect work zone barriers.

> *Recommendation 24: Confirm that subcontractor employees are trained to recognize flash and approach boundaries in order to establish appropriate work zones.*

> *Recommendation 25: Ensure that all personnel respect established work zone boundaries. Subcontract employees should be trained to recognize that attendants may be necessary when work zones are established in high-traffic areas.*

Subcontractors are not following the process outlined in NFPA 70E, Article 120.1 for zero voltage verification; specifically, meters are not being tested after the zero voltage verification.

> *Recommendation 26: Subcontractor oversight personnel should ensure appropriate training and implementation of NFPA 70E lockout procedures.*

3.6 Blind Penetrations and Excavations

The ESS was charged to study recent concrete coring incidents which have resulted in the cutting of conduits. The two incidents which occurred were the cutting of a 480-Volt conduit while coring an 8" hole in a 4' concrete floor in the D0 area of the Tevatron enclosure, and the coring of a 2" diameter hole in a 3" floor in the Industrial Center Building. This has led to revision of FESHM Chapter 7030, *Rule for Excavating*, and the development of FESHM Chapter 7040, *Concrete Cutting and Coring Activities.*

FESHM Chapter 7030 identifies the guidance for the actions needed for obtaining an excavation permit prior to any activity that penetrates the soil. FESHM Chapter 7040 identifies the procedures to be used when concrete cuts or coring must be conducted. In both procedures the FERMI-JULIE (utility locator) serves as the single point of contact for the organization or project that intends to conduct the work. In the case of excavations, the JULIE office, using a map of the area in which the work will be conducted, contacts the appropriate onsite utility point of contact to have buried utilities

identified through use of various methods. The utility locator uses color-coded spray paint as well as flags to identify the location of the buried utility. An Excavation Permit is used to assure that all utilities are appropriately located and identified in the location of the excavation. The permit cannot be issued until all utility contacts have either identified the buried utility and noted any restrictions (such as hand digging or other precautions) and have signed off on the permit. Once all the utilities are verified in the field the permit is issued for a period of seven calendar days, which may be extended based on the verification that no changes to buried utilities has occurred. The final approval is by the FERMI-JULIE Coordinator. Currently Fermilab is developing a computerized JULIE process in which a requestor can identify the location of an excavation on a site map and the computer system will electronically notify the appropriate utility coordinator for field identification of buried utilities. When the program is in operation the utility coordinator will send an electronic message to the JULIE system so a permit can be issued. The purpose is to free up the time of the JULIE coordinator to allow that person to use a global positioning system to map the location of utilities found in the field and have them mapped on an AutoCAD site map. Additional precautions are required to be taken when an excavation is required to be performed near an accelerator enclosure.

The concrete cutting and coring procedure also uses the FERMI-JULIE coordinator to serve as the point of contact for this type of work. The FERMI-JULIE Coordinator secures the services of a commercial locating service to identify utilities which are in the identified work area. In the case of concrete coring or cutting, an EHAWP is required to be prepared. The EHAWP assumes that the energized circuit will be cut and therefore must include shock and electrocution as an associated hazard of the work activity. The concrete coring procedure requires that the cutting/coring machine must be adequately grounded and be powered through a ground-fault circuit-interrupter even though the equipment may be double-insulated. It further requires that the operator wear properly rated rubber insulated gloves and provide additional protection against voltage step potential at the tool. If a credible flash hazard exists, the operator must be provided appropriate PPE for the hazard. The procedure indicates that "every effort will be made to plan the work during times when de-energizing circuits or turning off utilities will cause the least disruption of operations." When unknown utilities are identified in the process of locating or core/cutting activities, the FERMI-JULIE Coordinator and the area Electrical Coordinator are required to provide the information on the location of the utility for updating of the appropriate drawings.

4. Conclusions

The Laboratory does not specifically identify NFPA 70E in its Work Smart Standards Set, and it has not been included in all subcontracts. Fermilab policy allows manipulative energized electrical work, but the review team did not agree with the justifications used by one Fermilab Division.

Fermilab does not have a corporate training program for NFPA 70E requirements. The Laboratory makes subcontractors responsible for training their own employees, but does

not verify subcontractor training. The Laboratory does not have an effective program for periodically testing, inspecting and maintaining PPE.

The following recommendations are made to enhance the existing electrical safety program at Fermilab.

Program

Recommendation 1: Fermilab should ensure that its electrical safety program includes NFPA 70E as a mandatory standard.

Recommendation 2: Establish 50-VAC as the threshold for identifying systems that are required to be de-energized in order to work safely.

Recommendation 3: Avoid using ambiguous words like "generally" in defining policy on energized work.

Recommendation 4: Use the more appropriate description of "energized [electrical] work" in place of the phrase "hot work."

Implementation

Recommendation 5: Discontinue the practice of energized manipulative work.

Recommendation 6: Implement a program to ensure voltage-rated gloves and live line tool (hot stick) testing is current.

Recommendation 7: Use an EHAWP for diagnostics, testing or zero voltage checks.

Recommendation 8: Implement the use of the comprehensive method developed by the TD to aid in the performance of arc flash incident energy calculations throughout the Laboratory.

Recommendation 9: Review the application of FR apparel and PPE to make sure that it is appropriate to the hazard level.

Recommendation 10: Consider prohibiting the use of the solenoid voltage tester by subcontractor and in-house personnel.

Recommendation 11: Discontinue the practice of using non-contact voltage testers for zero voltage checks if meters are commercially available that are "IEC CAT-III" rated for the voltages and conditions to be tested.

Training

Recommendation 12: Establish a schedule for completing its corporate level NFPA 70E training.

Recommendation 13: Establish unqualified person training requirements and revise ITNA so as to allow supervisors to map any required training for the applicable employees.

Recommendation 14: Modify the Fermilab's training as it relates to responding to electrical contact incidents by first promoting working de-energized; and if work must be performed energized, that during work planning and pre-job briefings workers be trained on how and where to remove the source of electricity.

Recommendation 15: Ensure that all ES&H training courses with electrical safety considerations appropriately reflect Laboratory policy on the performance of energized electrical work and/or the requirements of NFPA 70E.

Oversight

Recommendation 16: FSO should evaluate the need to develop a master schedule for the evaluation of the complete Fermilab ES&H Program.

Subcontractor Safety

Recommendation 17: Confirm the implementation of NFPA 70E by subcontractors.

Recommendation 18: More clearly define the training and experience requirements for approval of Task Managers and Construction Coordinators. Persons with oversight of electrical work should be trained in electrical safety and NFPA 70E. Training should be recurring.

Recommendation 19: Make sure subcontractor electricians are formally trained in NFPA 70E requirements. The training should include appropriate use, care, and testing of PPE.

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Recommendation 22: Verify that:

- *personal protective equipment used by subcontractors is properly maintained, inspected, and tested.*

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- *appropriate gloves for the voltage are utilized to improve dexterity. Persons working on 480-Volt maximum equipment do not require Class 2 gloves suitable for 17kVolts.*

Recommendation 23: Document that subcontractors have "stop work" authority.

Recommendation 24: Confirm that subcontractor employees are trained to recognize flash and approach boundaries in order to establish appropriate work zones.

Recommendation 25: Ensure that all personnel respect established work zone boundaries. Subcontract employees should be trained to recognize that attendants may be necessary when work zones are established in high-traffic areas.

Recommendation 26: Subcontractor oversight personnel should ensure appropriate training and implementation of NFPA 70E lockout procedures.

Blind Penetrations and Excavations

None

The following noteworthy practices were identified during this review:

Noteworthy Practice 1: Fermilab has developed a control circuit extension device to move the worker further from the hazard.

Noteworthy Practice 2: TD has developed a comprehensive method to aid in the performance of arc flash incident energy calculations.

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