Fermi National Accelerator Laboratory

ESE Department / Computing Division

Personnel Safety & Training

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I. Introduction To The ESE Department

Environment, safety and health (ES&H) in the Electronic Systems Engineering (ESE) Department and at Fermilab is of utmost importance. On August 2, 1999 the new Fermilab Director, Dr. Michael Witherell, issued his first memorandum to all Fermilab employees, visiting users, guest scientists and contractors stating the importance of ES&H matters at Fermilab. Dr. Witherell urged us to continue "to identify environment, safety and health issues at the Laboratory and to plan our work so as to avoid unnecessary risks".

In the same memo, Dr. Witherell then described specific goals for the maximum total of lost workdays and stated that the Laboratory is very committed to achieve these goals. He then stated: "I think you all understand that although the numbers are important, it is the people at the Laboratory who really matter. We owe it to each other to keep our Laboratory a safe place to work." We in the ESE Department share the same point of view as expressed by the Director. ESE Department personnel have to proceed with our duties in a safe manner, identifying the risks and taking precautions to avoid or minimize these risks. We must help our peers where possible to identify ES&H hazards, attend appropriate training classes and read appropriate ES&H documentation including hazard analysis information. Safety is a collective commitment, and everybody in our department has to do their best to improve his/her own personal safety and that of their colleagues. Quoting Amy Pavnica, the Computing Division Senior Safety Officer, "Safety is part of our every day activity; it is everybody's responsibility."

Following a Department of Energy mandate, Fermilab implemented its Integrated Safety Management Plan[1] (ISMP) in April 1997. All ESE Department personnel have to be familiar with and to abide by this plan. Section 2.5 of the ISMP defines worker participation stating that "It is understood at Fermilab that safety can not be imposed from above. The work will be safe only if workers are involved in the process of developing safe work procedures." The section then describes the mechanisms in place to provide for worker involvement.

The seven principles of the ISMP at Fermilab are:

1) Line management responsible for safety
2) Clear roles and responsibilities
3) Competence commensurate with responsibility
4) Balanced priorities
5) Identification of standards and requirements,
6) Hazard controls tailored to work
7) Operations authorization

Regarding Line Management of responsibility the ISMP states: "Line responsibility has been the cornerstone for the development of the ES&H program at Fermilab. Within the Laboratory, responsibility for safety at all levels is explicitly defined in Chapter 1030 of the Fermilab ES&H Manual[2] (FESHM)." The ISMP also defines five core functions to safely execute a task. Their implementation vary based on Fermilab organizational levels. For example, the implementation of the core functions at the institutional (Laboratory) level is different than the implementation of the core functions for a person that is executing some specific task. Following these five core functions throughout all the levels of the organization will translate into achieving a safe working place. The five core functions are:

1) Define work
2) Analyze hazards
3) Establish controls
4) Perform work
5) Provide feedback & improvements

It is the responsibility of each of us to understand the meaning and to implement the principles of the core functions described in the ISMP manual.

This document addresses several issues related to ES&H issues within the ESE Department. It describes the hazards most commonly found in areas where ESE personnel work and describes documents containing information about

these hazards. This document also contains information regarding specific training required or recommended for ESE personnel to perform their job in a safe and proper manner.

Another very important section in Chapter 2060 of the Fermilab's ES&H Manual can be found at URL:

http://www-esh.fnal.gov/FESHM/2000/2060.html

This chapter contains a 'Hazard Analysis for Fermilab Employees' which defines procedures for insuring employee safety at the laboratory.

A. Department Activities

The ESE Department is composed of engineers, physicists, technicians, co-op students, guest scientists, guest engineers and summer students. The organization chart of the Computing Division including that of the ESE Department is available on the web at URL:

http://www.fnal.gov/cd/main/cdorg.html

The organization chart of the ESE Department can be accessed via this web page. Quite often several people not in the ESE Department can be found working in ESE work areas. These people work with ESE personnel on joint projects. These personnel are also made aware of and must follow ES&H practices within our work areas.

The ESE Department of Fermilab's Computing Division works on various electronics systems primarily for colliding beam and fixed-target experiments at Fermilab. These systems include front-end electronics systems such as silicon strip and pixel detector readout electronics, trigger systems such as the pixel and global triggers for the BTeV R&D project, and data acquisition systems such as DART for fixed-target experiments and systems for CMS and the BTeV R&D project. ESE expertise is considered a laboratory-wide resource, and is available to the High Energy Physics community on a prioritized request basis. In addition, the ESE Department is responsible for the ACPMAPS system, an in-house-designed computer system for the Theoretical Physics Department for doing lattice-gauge calculations. Almost all electronics involves only low-voltage, high-current electronics, using definitions specified in the Fermilab Environment, Safety and Health (ES&H) Manual. Front-end instrumentation systems such as silicon strip and pixel readout electronics additionally and only occasionally involve high-voltage, low-current electronics to bias detectors and also involve the occasional use of radiation sources. Recently, the department has started doing R&D with VCSELs (Vertical Cavity Surface Emitting Lasers). These low-power, Class 3b lasers will be used to transmit data from pixel and other detectors serially at high-speeds.

B. Additional ES&H Information

The following are two additional sources of ES&H information available to Fermilab employees and others working at Fermilab.

1) **Right to Know Center** – These areas are located throughout Fermilab. They contain safety information including copies of MSDS forms (see #2 below) for various hazardous materials at the laboratory. For ESE Department personnel they are located at the East and West wings of the third floor of Feynman Computing Center.
2) **MSDS** (Material Safety Data Sheet) – These notes contain information on various hazardous materials and can be found at the 'Right to Know' centers. MSDS information for various hazardous materials can also be accessed via the web at URL:

http://www-esh.fnal.gov/owa_user/owa/msds_search.html

II. ES&H Within The ESE Department

The Electronic Systems Engineering Department of Fermilab's Computing Division works on a broad range of electronics systems, from front end-electronics to data acquisition systems and in-house-design of computer systems.

ESE expertise is considered a laboratory-wide resource and is available to the High Energy Physics community on a prioritized request basis.

ESE Personnel working with hazards may be required to attend training courses, read hazard analysis information, go to medical examinations, etc. It is the responsibility of the ESE Department Head and Associate Department Heads to make sure that each individual has completed appropriate training and has been informed of the proper safety procedures before that individual can begin his/her work. This pertains to ESE Department personnel or any other person working on a potentially unsafe task in an ESE Department work area.

The ESE Department maintains various ES&H information documents in an unlocked and easily accessible cabinet in two areas, Room 335 and Room 328. These cabinets contain copies of hazard analysis forms and various other documents pertaining to ES&H issues at Fermilab. All ESE Personnel are encouraged to read this material.

On July 14, 1999, Gerry Bellendir sent a memorandum to all Computing Division employees entitled "Hazard Analysis for Fermilab Employees" (FESHM2060). This updated version of the original document incorporates relevant material regarding all aspects of dealing with hazardous materials. This document can be accessed at URL:

http://www-esh.fnal.gov/FESHM/2000/2060.html

When an employee needs to work with potentially hazardous materials and/or equipment, the employee and his/her supervisor or task manager must discuss and understand the information contained in the appropriate hazard analysis form prior to the employee beginning his/her new work. Both must also sign a copy of the hazard analysis form prior to that employee beginning his/her new work to ensure that everyone is aware of the potential hazards of this work.

All the signed originals of hazard analysis and other safety review forms are kept in a locked cabinet with restricted access. This locked cabinet contains all signed originals of hazard analysis forms, system and/or test stand reviews, electronic design reviews, etc. Only the ESE Department Head and ESE Associate Department Heads have keys to open this cabinet.

A. Web Pointers To General Fermilab ES&H Information

ESE Department safety information will be based on and derived from information from the Division office, ES&H department and other sources beyond the department. Much of this information is accessible over the World Wide Web and Web links are used extensively within this document. For maximum usability, this ESE safety document is also web-accessible.

As background, the Fermilab Directorate[3] page links to the Fermilab Directorate Documents[4] page, including links to the Fermilab Director's Policy Manual[5], the Fermilab Engineering Standards Manual[6], a Procedures for Experimenters[7] note, and other documents of site-wide interest.

A link to the Fermilab Integrated Safety Management Plan[8] (FISMP) is also found on this directorate page. The laboratory's plan for safety management including the seven guiding principles and the five core functions of ES&H at the Laboratory can be found in this document.

Fermilab's ES&H Section web home page can be accessed at URL:

http://www-esh.fnal.gov/home/owa/esh_home_page.html

The MANUALS link provides access to several useful documents:

1) The **ES&H Handbook**, a quick overview to the Laboratory's ES&H program. This document includes practical safety tips and reviews general emergency procedures and actions.
2) The **Fermilab Environment, Safety and Health Manual** (FESHM). The safety and environmental protection programs and procedures are specified in this document.

3) The **Fermilab Radiological Control Manual** containing the program description and the detailed information applying to radiation safety at Fermilab.
4) The **Fermilab Engineering Standards Manual** with mandatory requirements and recommended practices for civil, mechanical and electrical (including electronics) engineering activities at Fermilab.
5) The **Industrial Hygiene Manual** for the monitoring of potentially hazardous environments.

The ES&H section home page has several very useful programs. Use TRAIN for all aspects of training needs assessment and classes. Use ESHTRK for department safety audits and forms, active findings and many reports about the findings.

The Department Of Energy is on the web. The Laboratory's safety guidelines come from the DOE through the DOE Office of Laboratory Operations and ES&H. The guidance document for the Environment, Safety, Health, and Infrastructure Management Plan can be accessed at URL:

http://www.er.doe.gov/production/er-80/pdf_file/eshiguid.pdf

Directly applicable to our work is the DOE Handbook of Electrical Safety.

B. ES&H Chain Of Command

The following two subsections give the ESE Department and the Fermilab ES&H chains of command. Laboratory personnel should follow this chain of command in all ES&H matters. Occasionally a worker at Fermilab becomes concerned his or her immediate ES&H chain of command hasn't taken adequate or proper steps in an ES&H matter. In such cases the worker is strongly encouraged to bring any such concern(s) to whatever level of this chain of command is necessary to get an ES&H issue satisfactorily and/or completely resolved.

1. Within The ESE Department

The chain of command or responsibility for handling ES&H issues within the ESE Department is currently as follows:

- Each individual is responsible for maintaining awareness of and for following all relevant ES&H procedures.
  - An ESE Associate Department Head is tasked to be the principal department contact regarding ES&H issues. This task includes performing periodic ES&H audits, addressing subsequent findings either directly or by referring them to the appropriate organization and/or person, and following up on all such issues. Also includes assuring proper training is completed. Currently Bob Forster[9] is assigned this task, with Vince Pavlicek[10] serving as alternate.
    - The ESE Department Head is ultimately responsible for all department matters, ES&H and otherwise. The current ESE Department Head is Ed Barsotti[11].

2. Fermilab's ES&H Organization

The Chain of Command for ES&H issues extends beyond the ESE department itself, and is as follows:

- The Computing Division Senior Safety Officer, currently Amy Pavnica[12].
  - The Computing Division Head, currently Dr. Matthias Kasemann[13],
    - The Fermilab ES&H Section[14], currently headed by Bill Griffing
      - The Laboratory Safety Committee[15], currently headed by Associate Director George Robertson
        - The Fermilab Director, currently Prof Michael Witherell[16],
          - Universities Research Association (URA)[17], which operates Fermilab under contract with the United States Department of Energy (DOE)[18]. The current Secretary of Energy is Bill Richardson[19].
            - The DOE operates its Office of the Inspector General[20] (IG). The Inspector General operates a Hot Line, at (202) 586-4073. The DOE IG also operates a web accessible version of the Hot Line[21].

C. ES&H Updates & Procedures For Informing People

1. Within The ESE Department

ES&H additions, updates, or changes are disseminated throughout the ESE Department primarily via email containing either the information itself or web pointers to the information. Information is also disseminated via department meetings or bulletin board postings.

ESE Department members, as well as ESE Department guests working within ESE geographic areas of responsibility, are required to stay current with ESE Department, Computing Division and Laboratory ES&H procedures, and are included in all such updates.

2. Fermilab's ES&H Organization

The Computing Division Senior Safety Officer (CD/SSO), is responsible for disseminating Computing Division ES&H additions, updates, or changes in ES&H documents to relevant organizations within the Computing Division. Each computing division organization is responsible for propagating the information through at least the relevant members of the organization. This information includes information addressing specific ESE Department work environment issues, and also general division or Lab-wide issues.

3. Fermilab's Personnel Policy Guide

Another useful Laboratory document is Fermilab's Personnel Policy Guide[22]. Although it is not intended as an ES&H manual, it does list several Laboratory policies pertaining to its personnel.

D. ESE Work & Potential Safety Hazards

ESE Department personnel work on electronics and other equipment that presents potential safety hazards to them. This section highlights some of these potential hazards. Some work assignments in the ESE Department may require specific training and work procedures not discussed in this document. It is the job of all ESE personnel to identify risks in both their work assignments and the work assignments of others. Once potential safety hazards are identified, we must all see that effected people receive proper training conforming to the Laboratory's ES&H requirements.

1. Low-Voltage, High-Current Electronics

This section outlines the ESE Department safety procedures for handling low-voltage, high-current electronics. These procedures are detailed and implemented in the Fermilab ES&H Manual. The Fermilab ES&H Manual is therefore considered part of this ESE Department safety manual.

The safety requirements for low-voltage, high-current power distribution systems are detailed in the Fermilab ES&H Manual, Occupational Safety And Health section on Electrical Safety and can be accessed at URL:

http://www-esh.fnal.gov/FESHM/5000/5046.html

Additional information is in the ES&H Section's on-line version of the Fermilab Engineering Standards Manual, Section 3.3 Low Voltage, High Current Power Distribution which can be accessed at URL:

http://www-esh.fnal.gov:8001/FESM/FESM.html#Heading76

For safety purposes within the ESE department, a hazard analysis sheet must be completed and signed by any person who'll be working on any low-voltage (less than 50 volts), high-current (greater than 10 amps operating or 50 amps rated current) system, PC board, module or other electronic device. The internal wiring of a commercially-manufactured piece of equipment is exempt as detailed in the FESHM section 5046 reference above. The reference provides guidance on load connections, ribbon cables, multiple conductors and mechanical components. Test stands within the department frequently contain power supplies that fall within these parameters. The department will supply a guidance sheet containing a list of items to check on a new test stand as it is assembled. These sheets

should be filled out, signed and filed with the department safety hazard analysis forms before the stand is powered for the first time.

2. High-Voltage, Low-Current Electronics

This section outlines the ESE Department safety procedures for handling high-voltage, low-current electronics. These procedures are detailed and implemented in the Fermilab ES&H Manual[23]. The Fermilab ES&H Manual is therefore considered part of this ESE Department safety manual. The Fermilab ES&H Handbook[24] is similarly considered part of this ESE Department safety manual and is best viewed using the link on the ES&H Manuals web page[25].

Quoting the Electrical Safety[26] section of the Industrial Safety[27] section of the Fermilab ES&H Handbook[28]:

> "Electrical and electronic installations at the Laboratory must conform to the intent of the current edition of the National Electric Code. The standards of nationally recognized testing agencies, such as Underwriters Laboratory, must be observed in the selection of electric wiring, electrical/electronic devices and equipment. When no existing code or standard applies, the design of electrical and electronic installations must give prime consideration to the safety of personnel.
>
> "If you work on or around equipment with the potential of electrical shock, you should attend training about the hazards involved and actions which you should follow to prevent injury. Whenever possible, electrical equipment must not be worked on until it has been reliably de-energized. "

Additional information is available in the Fermilab ES&H Manual[29], 5000 Occupational Safety And Health[30], 5040 Electrical Safety section[31], 5040 Fermilab Electrical Safety Program Rev. 4/99[32]. Quoting from the 2nd paragraph, titled 'Policy':

1) "Electrical systems and equipment and all design, construction, installation, inspection, testing, and operations activities shall be in accordance with DOE mandatory electrical safety standards to the extent that these standards apply. These standards are:

   a) "29 CFR 1910, Subpart S, OSHA General Industry Standards, Electrical Subpart[33]
   b) "29 CFR 1910.137, OSHA General Industry Standards, Electrical Protective Devices[34]
   c) "29 CFR 1926, Subpart K, OSHA Construction Standards, Electrical Subpart[35]
   d) "Electrical Standard for Industrial Machinery, NFPA 79[36]
   e) "National Electrical Code, NFPA 70[37], ANSI C1
      [Note: High Voltage is defined as greater than 600 Volts AC or DC]
   f) "National Electrical Safety Code, ANSI C2"

   [Acronyms: ANSI[38], the American National Standards Institute,
   NFPA[39], the National Fire Protection Association
   NFPA 70 is the National Electrical Code.
   OSHA[40], the Occupational Safety & Health Administration]

2) "Where systems or equipment lie outside the scope of the mandatory standards, specially developed Laboratory or Division/Section policies and procedures, prudent engineering judgment, peer review, and available industry guidance shall be employed to ensure safety of personnel and property.

3) "The Fermilab Electrical Safety Program shall promote an electrically safe workplace free from unauthorized exposure to electrical hazards. If not eliminated, exposures to electrical hazards shall present the lowest risks to workers as reasonably possible."

OSHA classifies 50 Volts and above as "high voltage" and introduces a plethora of rules, regulations, and guidelines covering those working with "high voltage". Some OSHA documentation is available on the ESE safety resource shelf. Not quite as well known is that current is more dangerous than voltage. The National Safety Council[41] Technical Resources, Books & Manuals[42] page lists "Supervisors Safety Manual". The 6th edition includes Table 13A titled 'Current and its effect on the Human Body' on page 345. Symptoms described as 'Shock - painful and severe, muscular contractions, breathing difficult' can be caused by 60 cycle, alternating currents as low as 23 milliamps for men and 15 milliamps for women. Care is mandatory.

The ESE Department has some need to work with high voltage, using OSHA's definition. Two examples current at the time of this writing are the pixel detector bias voltages, and the AC line voltage to the FASTBUS power supplies connected to FASTBUS crates and VME64 subracks.

Engineering and electronic technician training addresses handling this high voltage, but others (notably physicists and computer professionals) usually have not had the benefit of the same training. All ESE Department employees are tasked with watching out for the safety of our guests. We expect those same guests to act responsibly and request help when appropriate. Guests abusing these responsibilities will lose access privileges to the ESE Department lab space and equipment.

Fermilab Employees and Users are held responsible for following the recommendations of the various safety resources at Fermilab. Particularly relevant to ESE staff and guests are section 5040 Fermilab Electrical Safety Program Rev. 4/99[43] and section 5045 High Voltage Coaxial Connectors[44] in section 5040 on Electrical Safety[45] in section 5000 on Occupational Safety And Health[46] in the Fermilab ES&H Manual[47].

Section 3.2.1 High Voltage Coaxial Connectors[48] and section 3.2.2 Considerations for Control Systems Utilizing 100 Volts[49] in section 3.2 High Voltage Low Current Power Distribution[50] of the Fermilab Engineering Standards Manual[51] (also available in a PDF version[52]) are also relevant.

Other useful information on high-voltage, low-current safety issues is available here[53] and in the DOE Handbook of Electrical Safety (DOE-HDBK-1092-98) (PDF version)[54].

The US Department of Labor[55] Occupational Safety and Health Administration is much better known simply as OSHA[56]. A host of OSHA[57] regulations become applicable when working with voltages of 50 volts and over. Please refer to sections 1910.301[58] through 1910.309[59], 1910.333[60], and 1910.335[61] of section 1910 Subpart S - Electrical (1910.301 to 1910.399)[62] from PART 1910 Occupational Safety and Health Standards[63] from the OSHA Regulations (Standards - 29 CFR)[64]. For instance, OSHA Regulation 1910.304[65] is titled 'Wiring Design and Protection'.

For safety purposes, a hazard analysis sheet must be completed and signed by any person who will be working on any PC board, module or other electronics on which any components operate at high-voltage ($\geq$ 50 Volts) levels. Current levels on such equipment is most always limited to well below 10 Amps on ESE Department's high-voltage circuitry.

3. Radiation Sources & Radiation Area Access

This section outlines the ESE Department safety procedures for handling Radiation Sources and accessing Radiation Areas. These procedures are detailed and implemented in the Fermilab Radiological Control Manual[66]. The Fermilab Radiological Control Manual[67] is therefore considered part of this ESE Department safety manual.

a) Radiation Sources

Both Radioactive Source training (course #FN000048 or equivalent) and the appropriate level of Radiation Worker training (course #FN000301/CE/01 or course #FN000301/CR/01 or the equivalent) shall be provided to, and completed by, employees and experimenters prior to their use of radiation sources. This training must be documented on the Individual Training Plan[68] network accessible on the Fermilab ES&H section[69] TRAINing[70] page. In addition, the Fermilab ES&H section[71] publishes the Fermilab Radiological Control Manual[72], which details the Responsibilities of Persons Using Radioactive Sources at Fermilab[73].

The ESE Department has occasional need of using a radiation source in its Feynmann Computing Center (FCC3) lab area in conjunction with detector development research. Towards that end, the Computing Division Senior Safety Officer helped obtain a low level source for ESE lab use in FCC328. Quoting from a clarifying e-mail:

> Date sent: Thu, 24 Jun 1999 14:26:20 -0500
> From: pavnica@fnal.gov (Pavnica, Amy)
> Subject: Re: Use of Rad Sources in FCC
> To: forster@fnal.gov (Bob Forster)
>
> Bob,
>
> Yes, it can be left unattended as long as a sign indicating the source, the owner of the source and where they can be reached is located near it. If the source is going to be left out for an extended period of time, i.e. overnight or over several days, Kathy Graden from ES&H needs to be notified before it's left out.
>
> Hope this helps.
>
> Amy

The training required by the Fermilab ES&H section obviates the need for local hazard analysis procedures.

b) Radiation Access

Support of ESE Department products deployed to experimental areas can require ESE staff to enter radiation areas. Other Fermilab divisions operate these areas so ESE personnel requiring such access must qualify with the level of Radiation Worker training appropriate to the specific location of interest. The Fermilab ES&H section[74] publishes the Fermilab Radiological Control Manual[75], which was previously assumed into this document and which includes various sections on controlling access to radiation areas.

4. Lasers

This section outlines the ESE Department safety procedures for handling lasers. These procedures are defined in the Fermilab ES&H Manual, therefore the Fermilab ES&H Manual is considered part of this ESE safety manual.
The safety requirements for Laser Systems are in the Occupational Safety and Health section on Physical Factors accessible at URL:

http://www-esh.fnal.gov/FESHM/5000/5062_1.htm

Detailed there are the classification criterion for lasers, the hazards of each class, and the procedure for safely using each class of lasers. All laser use in the ESE Department must be examined to determine the class of the hazard. All laser systems above class 1 must undergo a hazard analysis, be labeled according to the FESHM, and users must follow the prescribed controls according to the FESHM. If the laser light is not accessible or is protected by failsafe interlocks, then it is exempt from this section. An example of this is the department laser printers.

The following two charts from the FESHM contain the summary of laser classes and precautions for accessible laser radiation and the prescribed controls for each class.

LASER CLASSIFICATION AND PRIMARY PRECAUTIONS

HAZARD CLASS	DESCRIPTION OF HAZARD	PRIMARY PRECAUTION
1	Radiation cannot cause injury in exposures 30,000 seconds	None
2	Visible wavelength radiation which requires >0.25 seconds to cause retinal injury	Do not stare into beam
3a[1]	Visible wavelength radiation which can cause retinal eye injury in exposures >0.25 seconds because of large beam diameter	Do not stare into beam or view directly with optical instruments
3a[1]	Visible wavelength radiation can cause eye injuries in exposures <0.25 seconds OR UV/IR radiation can cause injury in exposures <30,000 seconds	Avoid direct eye exposure
3b[1]	Radiation can cause eye injuries in exposures <0.25 seconds	Avoid direct exposure to beam
4	Diffuse reflection of radiation can cause eye injury in exposures <0.25 seconds OR Radiation can cause skin injury OR Radiation can cause material damage/fire	Avoid eye or skin exposure to direct or scattered radiation

Controls for laser systems **Hazard Class of Laser Radiation**	**1**	**2**	**3a**	**3b**	**4**
1. Classify/Inventory/Label	E	M	M	M	M
2. LSO approval to operate			R	M	M
3. Precautions for maintenance, repair or modification	M	M	M	M	M
4. Primary Beam Precautions		M	M	M	M
5. Precautions for public displays		M	M	M	M
6. Training for laser workers		R	R	M	M
7. Eye exam for laser workers				M	M
8. Beam precautions			M	M	M
9. Warning signs			R	M	M
10. Area directly supervised by qualified laser operator				M	M
11. Precautions for spectators				R	M
12. Lock up laser when not in use				R	M
13. Protective eyewear				R	M
14. Startup warning				R	M
15. Standard operating procedures				R	M
16. Locks/Interlocks				M	M
M = Mandatory, R = Recommended, E = exempt unless laser system is modified					

Note 1: Class 3a visible wavelength lasers have outputs 1-5x that of the maximum associated Class 2 output. Class 3a UV/IR lasers have outputs 1-5x that of the maximum associated Class 1 output.

Although laser training is only recommended for some classes of lasers, users of any laser equipment within the ESE Department will be strongly urged to take the ES&H laser safety course. The ES&H Laboratory Laser Safety Officer (LSO):

1) Provides technical guidance on laser safety, reviews
2) Approves purchase requisitions for non-exempt laser systems
3) Maintains a site-wide database of laser systems
4) Classifies the radiation hazard of laser systems
5) Provides training in laser safety
6) Provides laser radiation hazard warning signs
7) Determines appropriate protective laser eyewear

8) Reviews and approves written operating procedures

The LSO may be contacted by calling the ES&H Section, Ext. 4646.

5. Beryllia (Beryllium Oxide) Printed Circuit Boards

Inhalation or handling of beryllium-containing materials (e.g., beryllia {beryllium oxide}) can cause health problems. ESE Department personnel and others working in ESE Department work areas with these materials should refer to the Fermilab ES&H Manual, Section titled 'Special Toxic Hazards - Beryllium and Beryllium Alloys, Chronic Beryllium Disease Prevention Program' for the description of these hazards. This information can be accessed at URL:

http://www-esh.fnal.gov/FESHM/5000/5052_5.html

Another source of information about beryllia hazards is contained in the appropriate MSDS information sheet available in the Right to Know centers.

All beryllia circuit boards handled by ESE Department personnel or others working in ESE Department work areas have a surface concentration level below 0.025 micrograms per squared centimeter ($\mu g/cm^2$). This concentration level is below the threshold which requires the full implementation of the Beryllium Work Control Permit, as described in the Fermilab ES&H Manual, Section 5052.5 entitled 'Special Toxic Hazards - Beryllium and Beryllium Alloys, Chronic Beryllium Disease Prevention Program'. The actions that ESE Department personnel or others working in ESE Department work areas shall take are described in the hazard analysis form for beryllia circuit boards.

Wipe tests can be conducted by the Computing Division Senior Safety Officer (SSO) to determine the surface concentration levels of beryllia circuit boards. Section 5052.5 of the ES&H manual authorizes the use of data from similar previous work which documents exposures below the $0.025\mu g/cm^2$. ESE Department management requires that the Computing Division SSO authorize the use of this previous data to make a determination whether the board in question has surface concentration levels below 0.025 $\mu g/cm^2$.

Before any ESE Department personnel or another person working in ESE Department work areas can be authorized to handle beryllia circuit boards, he/she is required to read and review the beryllia circuit board hazard analysis form and to complete the Beryllium Handling training course. Reading the appropriate MSDS information is also recommended.

6. Soldering Stations

Soldering Stations are a routine component in most ESE Department projects. Soldering Stations generally consist of a soldering iron, soldering iron holder, and a base unit. The soldering end of the iron is the tip, which applies heat to melt, or liquefy, raw solder. Liquefied solder "flows" onto non-solder-masked metallic areas of printed circuit boards and the metallic "legs" of components. When the soldering iron tip heat source is removed, the liquid solder solidifies and forms an electrically conductive bond between the printed circuit board and the component. When the soldering iron is not being used, it rests in the soldering iron holder such that the heated tip is not in direct contact with anything. Since the soldering iron tip gets hot, potential safety issues arise (Please refer to the Hazard Analysis sheet).

It is ESE Department's policy that soldering stations are not to be left on while unattended, both for safety and to extend tip life. Realistically, there will be occasions when such soldering stations are inadvertently left on while unattended. The hazard stems from the possibility of hot soldering iron tips igniting a flammable material such as paper, or lab tissue wipes, while not being used. The ESE Department has addressed the issue in the following three ways:

a) Attending to Clutter in the Vicinity of Soldering Stations

ESE promotes situational safety awareness, which in this case means eliminating flammable and other clutter in the work area prior to beginning the task. Eliminating combustible material eliminates the fire hazard.

b) Touch Sensitive Soldering Stations

ESE has purchased soldering stations with touch sensitive irons, such that the iron tip is not heated unless the iron is actually being touched, which normally means the iron is in somebody's hand. Since the tip is off and unheated when the iron is at rest in its holder, there is no inadvertent fire danger.

c) Older or Larger Soldering Stations

Older soldering stations, or soldering stations with greater heat output at the tip, typically do not have touch sensitive irons. ESE addressed the problem of these irons being left on by installing manually operated timers limiting the length of time the AC power line is active to the soldering station. Even though the soldering station may be turned on, users must reset the timer to provide AC power to operate the soldering station.

The use of heat in this way also leads to effects such as fumes and skin burns (please refer to the Hazard Analysis sheet for further details). In general, ESE requires the use of adequate ventilation and optical magnification while soldering.

7. Safety Grounding Of Electrical Equipment

The work of ESE department personnel puts them in daily contact with a variety of electrical systems and a common element of all those systems is the need for proper grounding. The main purposes of grounding are personnel safety and equipment protection. Systems or test stands that are improperly grounded increase the risks of shock, fire and equipment damage. Properly grounded systems or test stands reduce those risks and minimize danger from lightening. A good understanding of grounding is important so some introduction will be supplied here. Additional references and web links follow these paragraphs.

There are two basic categories of safety ground connections. The system grounding category is where one of the conductors that carry load current is connected to earth ground. The residential mains neutral wire is an example of a grounded conductor. The equipment grounding category is where the equipment frames, boxes and pipes are connected by conductors that do not carry current unless there is a fault condition. The first case provides the voltage reference connection to allow different systems to interconnect without voltage differences causing problems. The second case provides a conductive barrier protecting personnel from hazardous voltages and a conductive path for fault currents through which the currents can flow to the earth and away from users. Both of these categories of grounding must be applied correctly to ensure the safety of the personnel operating the equipment. The system must be analyzed both for normal operation and for all reasonable modes of failure to be sure that normal operation and fault conditions will not endanger the users or the equipment. That analysis should include providing safe paths for fault currents to allow the circuit protection devices to operate correctly.

Equipment grounding is sometimes incorrectly called shielding. This word is more appropriate in the areas of Electromagnetic Interference and Radio Frequency Interference. However, the same pieces of metal can perform double duty as both an equipment-grounding conductor and as shielding.

References:

DOE Handbook of Electrical Safety DOE-HDBK-1092-98. An online version is available here. Section 4 has information and references to several standards organizations.
National Electrical Code, 1993, National Fire Protection Association, available on the Safety bookshelf.
Supervisors Safety Manual, The National Safety Council, 1985. Chapter 13 has a good explanation of shock and electrocution hazards and covers grounding well.
Practical Electrical Wiring, 15th edition, H. P. Richter, and W.C. Schwan, 1990, McGraw-Hill Publishing, available on the Safety bookshelf. The chapter on grounding is excellent.

E. Electronics, Systems & Test Stands – Grounding, Electrical & Personnel Safety

ESE Department personnel or others working in ESE Department work areas need to operate systems and test stands to test hardware and software. These systems and test stands need to be powered and, oftentimes, they need to be left unattended while powered. Some of these systems and test stands contain custom-made electronic designs and assemblies and they may not have been reviewed for personnel safety and potential fire hazards. Also, the equipment's personnel safety ground may not be properly connected presenting a potential electrical shock hazard to personnel. In order to minimize the safety risks described above, the ESE Department has organized a review process which includes a newly organized System and Test Stand Review Committee.

Since safety is everybody's responsibility, it is extremely important that ESE Department personnel and others working in the ESE Department work areas use their best judgement as to whether a review is necessary before the equipment is powered. When some member of the ESE Department or another person working in an ESE Department work area identify a system or test stand that is a potential safety hazard, he/she must request to ESE Department management that a review be conducted. This should occur even if that person only suspects that a potential safety hazard may exist.

All systems or test stand safety reviews are conducted by the ESE Department's System and Test Stand Review Committee. Members of this committee are chosen by the ESE Department Head or one of its Associate Department Heads. Members can be ESE Department personnel and/or other appropriate laboratory personnel.

This committee reviews both pertinent material related to such systems and test stands and recommendations of other similar safety committees. They make a written recommendation to the ESE Department Head or Associate Department Heads. The ESE Department Head or Associate Department Heads will then act based on the recommendations of the committee possibly overriding the recommendations of the committee. The ESE Department Head or Associate Department Heads reports his/her decision on an Operation Readiness Clearance form as shown in Appendix A.

The subjects reviewed include, but are not limited to, the following items:

1) Design of the printed circuit boards
2) Power supplies
3) Electrical and personal safety grounding

The ESE Department has a long history of thoroughly reviewing each new electronics printed circuit board design for both safety and functionality before it is manufactured. An Associate Department Head (currently Vince Pavlicek) arranges for these printed circuit board reviews and assigns a committee to conduct the review. Potential voltage arching on the boards and over-voltage and over-current protection are some safety issues addressed by the review committee. Potential safety concerns can be greatly minimized by fusing all electronic designs, using transient suppressors and following the recommendations described in the 'Low-Voltage, High-Current Electronics' and 'High-Voltage, Low-Current Electronics' sections of this document. Special attention has and will always be given to the Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies, standard IPC-D-2221 and 2222 published by the Institute for Interconnecting and Packaging Electronic Circuits (IPC). This document is locally available. Other pertinent rules and recommendations may be required as deemed important by the review committee. After each review, the printed circuit board review committee is required to document their findings in written form. This information is later used by the 'System and Test Stand Review Committee' during their reviews.

The power supply connections to subracks or printed circuit boards have to include fusing (if applicable). All power supply current conductors and connectors have to support the maximum current provided by the power supplies. There has to be safe connections to the 110/208V electrical outlets as described in the FESHM and Section 3.2 of this document. All reasonable steps have to be taken to avoid personnel exposure to high-voltage carrying wires or connectors. If work being performed requires that some high-voltage wires or connections be exposed or easily accessible, the system or test stand should preferably not be left unattended. If it has to be left unattended, signs must be posted on the system or test stand and, if applicable, some form of barrier (as, for example, some yellow plastic rope) should be build.

Sound electrical grounding practices must be employed at each test stand or system to avoid any electrical shock hazards. For guidance on grounding refer to the Section II.D.7 of this document.

Any other concern associated with some hazard of a system or test stand not discussed here can and should be brought to the attention of the ESE Department Head or any Associate Department Head by anyone at any time.

1. System Or Test Stand – Safety Check Out List

The present list describes the most common points reviewed by the 'System and Test Stand Review Committee' or by the Department Head or Associate Department Heads prior to allowing a system or test stand to be initially powered or left unattended and powered. This list can be changed or augmented as deem necessary.

1) Safety ground connections
2) Wire gage sufficient to carry maximum power supply current
3) High-voltage exposure
4) Printed circuit board safety review recommendations
5) Over-current (fusing) and over-voltage protection
6) Connections from the 110 VAC and/or 208 VAC electrical outlets

2. System Or Test Stands – Authorization Procedures Prior To Use

ESE Department personnel use a wide variety of test stands. It is difficult to define which test stands require the review and clearance for operation. Some systems may need operation clearance just to be left powered and unattended. For example, a test assembled around UL-approved instrumentation and current-limited, low-current power supplies can be powered without any clearance. However, the same system may need clearance if it is left working unattended in evenings and night hours. In general, all systems and test stands need review before they can be left powered and unattended. The ESE Department management will make the best effort to identify these situations on a case by case basis and arrange appropriate reviews. ESE Department personnel or others working in ESE Department work areas should, as a rule, ask department management whether a review is necessary. All systems that need review prior to initial powering or prior to being left unattended and powered must have the written Operation Readiness Clearance from the ESE Department Heads on a form similar to the one shown in the Appendix A.

3. System Or Test Stands – Periodic Review Procedures

Systems and test stands undergo a formal safety inspection every three months. Less formally, but more importantly, all ESE Department systems and test stands are subject to an safety review whenever anybody notices or questions anything potentially unsafe. Monitoring for safety hazards and responding to perceived hazards is required of everyone all the time, not just on certain calendar days. The review procedures for system or test stand periodic inspections is the same as described in Section III.G.2.

F. ES&H & Electronic Designs

1. Electronic Designs & ESE Department Review Procedures

ESE Department electronic designs can be divided into two categories, designs for outside users and designs that will only be used within the ESE Department. The safety procedures vary depending on the category. All electronic designs undergo departmental peer review at the point where the design makes the transition from schematics and layout to actual boards that will be assembled and operated. Besides checking that the design meets the electronic requirement, the review ensures that the design has no safety issues or that they have been identified and addressed.

Designs for outside use have additional review requirements. There can be safety and usability requirements applied by the ultimate user. These can be satisfied by a separate design review conducted by the user or they can become additional issues addressed during the ESE Department's review. Depending on the size and complexity of the design, there may be additional reviews scheduled during the design process. The object is to divide the design process into sections that can be dealt with in reviews lasting less than three hours. Future users and maintainers are

welcome to be part of any design reviews conducted by the ESE Department. Any major change to a design requiring physical modifications must be examined by both the project engineer and ESE Department management. This examination is used to determine if safety issues were also changed and whether a new design review is needed.

2. Formal Review By CDF Experiment

ESE Department designs for the CDF experiment are an example of a designs for outside users. These module and system designs are reviewed by both the ESE Department and a CDF review committee at multiple points in the design process. Some of the areas examined were printed circuit requirements, cable requirements, grounding and shielding, subrack specification, and test stands. These items are URLs pointing to the CDF/PPD documents applied to hardware built for the CDF Run II upgrade.

G. ESE Department Self-Audits

1. Self-Audits – Schedules

A formal inspection process is in place requiring a detailed inspection of all department lab areas quarterly and all department office areas every six months. The results of these inspections are entered into the ESHTRK[76] database. Less formally, but more importantly, all ESE Department areas are subject to an audit whenever anybody notices or questions anything potentially unsafe. Monitoring for hazards and responding to perceived hazards is required of everyone all the time, not just on certain calendar days.

2. Self-Audits – Procedures

The ESE Department manager responsible for ES&H inspections and follow-up is currently Bob Forster[77]. His alternate is currently Vince Pavlicek. The responsible manager volunteers other department members in these inspection and follow-up procedures in order to involve everyone in the ES&H process. The responsible manager assures audit findings are followed-up to completion. The responsible manager monitors the dynamic ESE Department environment, monitoring personnel changes and hazards as they come and go.

III. Personnel Training Courses

The Fermilab ES&H Section monitors ESE Department personnel training needs and accomplishments. The current list of department personnel training records including needed training is available from the ES&H TRAIN ITNA database accessible at URL:

http://www-esh.fnal.gov/owa_user/owa/itna.log

To see this information, select CD, then CD/ESE. This is the list of CD/ESE members with completed Individual Training Needs Assessment (ITNA) forms on file.

The current list of department personnel training plans is available from the ES&H database and can be accessed at URL:

http://www-esh.fnal.gov/train/owa/itp.group_rpt

To see this information, select CD and Submit, then CD/ESE and Submit. This is the Individual Training Summary for all ESE members listed in the ITNA Log.

As the department tasks vary, members of the department will change their ITNA forms to reflect changes in their needed skills. ES&H training and skills assessments will assist the ESE Department in maintaining the skills of the department members. The current list of specific skills need and department members requiring those skills can be accessed at URL:

http//:www-ese.fnal.gov/safety/skill_list.html

ESE department heads will periodically review the department tasks, training needs and personnel training summaries to oversee department safety and recommend training based on planned work. However, it is the responsibility of department members to ensure that his or her individual training matches their current needs.

New employees to the ESE department will be introduced to ESE specific safety information during their first week on the job. A modified version of the ES&H New Employee Orientation Checklist (Appendix B) will be used to provide a framework for this introduction. This introduction should be done promptly to support, reinforce and expand on the laboratory safety indoctrination that the employee will have just received.

IV. Appendix A – Operation Readiness Clearance Form

OPERATION READINESS CLEARANCE

Date: _____

Authorization For System Or Test Stand Operation

Date(s) of safety review(s): _____

_____

_____

Location of the system or test stand: _____

System or test stand name and/or description: _____

Has system or test stand been cleared for unattended operation while powered? _____

_____
Department Head or Associated Department Head

_____
Requested by

V. Appendix B – New Employee Orientation Checklist

The Fermilab ES&H Home Page78 includes a link to a Guidance79 page, on which is found a link to a general Fermilab New/Transferring Employee Orientation Checklist80. The following is a version of that document customized for use in the CD/ESE department. It is expected that this document will continue to evolve to meet the dynamic needs of the ESE department.

Fermilab New/Transferring Employee Orientation Checklist

(Page 1 of 3)

_____ _____ Employee's Name Fermi ID#
_____ _____ Supervisor's Name Fermi ID#
GENERAL The supervisor must review the following information with the new/transferring employee or ensure that each applicable item is demonstrated/reviewed. The new/transferring employee should initial each item after the item has been reviewed or demonstrated and feels that they have a good grasp of the item. Questions or uncertainties should be cleared up before initiating the item. Upon completing the checklist, both the employee and the supervisor should sign and date the checklist.

TOPICS	INITIALS	
General Administrative Information	**Emp**	**Supv**
1. Review Fermilab ES&H Manual		
2. Safety Responsibility Employee (Include reporting of "near misses", dangerous condition, accidents, etc.) Line Management Laboratory ES&H Policy and Goals		
3. Employee Access to Medical, Monitoring, and Personnel Records		
4. Absence from Fermilab Vacation Business Trips Sick		
5. Responsibility For Property Security Key Boxes Reporting Lost or Stolen Property Removal of Property from Fermilab Assignment of Keys		
6. Use of Telephones Phone Directory Personal Calls Use of Pager		
7. Computer E-mail Software Security Licensing Policy, etc. Training (MS Word, Excel, File Maker Pro, etc.)		
8. Creation and Maintenance of Records		
9. ID card		
10. Vehicle Safety and Vehicle Sticker		
11. Mail Station Number and Location		
12. Introduction to Staff (Include location of ES&H and Health Physics representatives)		
13. Section Personnel Policy Guide		

Fermilab New/Transferring Employee Orientation Checklist

TOPICS	INITIALS	
Emergency Procedures/Equipment	**Emp**	**Supv**
1. Building, Laboratory and Wilson Hall Emergency Alarms		
2. Fire Evacuation Routes		
3. Assembly Areas		
4. Tornado Shelter		
5. Area Emergency Wardens		
6. Reporting of Emergencies (x3131) Spills Threats Injury Environmental Incident		
7. Exits, Safety Showers, Eyewash Fountains		
Safe Work Practices		
1. Compressed Gas Cylinders		
2. Lockout/Tagout		
3. Pressure Safety		
4. Housekeeping		
5. Safe Lifting Techniques		
6. ODH Areas		
7. Radiation Personnel Dosimetry Program Radiation Worker Training Source Training Material Move Training		
8. Hazardous Materials Material Safety Data Sheets Labeling NFPA Review/Stamp		
9. Electrical Safety		
10.Material Handling Crane Operation Forktruck Operation		
11.Bloodborne Pathogens		
12.Fire Extinguishers		
13.Lasers		

Fermilab New/Transferring Employee Orientation Checklist

(Page 3 of 3)

TOPICS	INITIALS	
Personal Protective Equipment (Care, Repair and Replacement)	**Emp**	**Supv**
1. Eye (Safety Glasses)		
2. Foot (Safety Shoes)		
3. Head (Hard Hats)		
4. Hand (Work Gloves)		
5. Respirators Training Medical Surveillance Fit-Testing		
Miscellaneous Items		
1. Building access Lock down procedures After hours access Parking locations and restrictions		
2. Prohibited Articles from being brought onto site Alcoholic Beverages Illegal Drugs Hazardous Materials Explosives and Incendiary Devices Firearms/Weapons Radioactive Sources		
3. Smoking Regulations		
4. Location of Medical Department		
5. Visitor Procedures and Responsibilities		
Supervisor's Briefing		
1. Expectations		
2. Roles and Responsibilities		
3. Authority		
4. Housekeeping		
5. Requisitioning Supplies and Equipment		
6. Time Off		
7. Other _____		
I have completed all activities associated with each item which is applicable to my position within the _____ Division/Section and have discussed all issues/concerns with my supervisor. _____ _____ Employee Signature Date		
I have discussed all applicable items with the above named employee. I am satisfied that he/she has completed all items appropriate for their position. All items that are not applicable have been marked, "NA". _____ _____ Supervisor Signature Date		

VI. Appendix C – Document Style Comments & URLs

This document has been written in a style intended for easy online use, using imbedded hotlinks to refer to World Wide Web resources. A potential deficiency of this style is that the imbedded hotlinks are useless from printed copies of this document. This appendix addresses this issue by including the raw Universal Resource Locators (URL's) for each numbered hotlink used throughout the document.

[1] http://www-esh.fnal.gov/FISMP/
[2] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=800
[3] http://www.fnal.gov/directorate/Policy_Manual.html
[4] http://www.fnal.gov/directorate/documents.html
[5] http://www.fnal.gov/directorate/Policy_Manual.html
[6] http://www-esh.fnal.gov:8001/FESM
[7] http://www.fnal.gov/directorate/documents
[8] http://www-esh.fnal.gov/FISMP
[9] http://fncduh.fnal.gov:8080/fnalonly/cd_photos/BForster.gif
[10] http://fncduh.fnal.gov:8080/fnalonly/cd_photos/VPavlicek.gif
[11] http://fncduh.fnal.gov:8080/fnalonly/cd_photos/EBarsotti.gif
[12] http://fncduh.fnal.gov:8080/fnalonly/cd_photos/APavnica.gif
[13] http://fncduh.fnal.gov:8080/fnalonly/cd_photos/MKasemann.gif
[14] http://www-esh.fnal.gov/home/owa/esh_home_page.html
[15] http://www-esh.fnal.gov/owa_user/owa/lsc.html
[16] http://www.fnal.gov/directorate/profiles/witherell.html
[17] http://www.fnal.gov/directorate/ura/ura.html
[18] http://www.doe.gov/
[19] http://home.doe.gov/glance/secbio.htm
[20] http://www.hr.doe.gov/ig/mainhome.htm
[21] http://www.hr.doe.gov/ig/hotline.htm
[22] http://fnalpubs.fnal.gov/policyguide/cover.html
[23] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=800
[24] http://www-esh.fnal.gov/FESHM/Handbook/TOC.html
[25] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=10
[26] http://www-esh.fnal.gov/FESHM/Handbook/Handbook.html
[27] http://www-esh.fnal.gov/FESHM/Handbook/Handbook.html
[28] http://www-esh.fnal.gov/FESHM/Handbook/TOC.html
[29] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=800
[30] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=5000
[31] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=5040
[32] http://www-esh.fnal.gov/FESHM/5000/5040.html
[33] http://www.osha-slc.gov/OshStd_toc/OSHA_Std_toc_1910_SUBPART_S.html
[34] http://www.osha-slc.gov/OshStd_data/1910_0137.html
[35] http://www.osha-slc.gov/OshStd_toc/OSHA_Std_toc_1926_SUBPART_K.html
[36] http://catalog.nfpa.org/cgi-bin/SoftCart.exe/STORE/PAGES/79-97.htm?L+nfpanonmembers+vbnw8053+936380727
[37] http://catalog.nfpa.org/cgi-bin/SoftCart.exe/STORE/TopSellingProducts.htm?L+nfpanonmembers+vbnw8053+936380698
[38] http://www.ansi.org
[39] http://roproc.nfpa.org
[40] http://www.osha.gov
[41] http://www.nsc.org
[42] http://www.nsc.org/product/pubs/techpubs.htm
[43] http://www-esh.fnal.gov/FESHM/5000/5040.html
[44] http://www-esh.fnal.gov/FESHM/5000/5045.html
[45] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=5040

[46] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=5000
[47] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=800
[48] http://www-esh.fnal.gov:8001/FESM/FESM.html#Heading74
[49] http://www-esh.fnal.gov:8001/FESM/FESM.html
[50] http://www-esh.fnal.gov:8001/FESM/FESM.html#Heading73
[51] http://www-esh.fnal.gov:8001/FESM
[52] http://www-esh.fnal.gov:8001/FESM/fesm.pdf
[53] http://pchem.scs.uiuc.edu/pchemlab/electric.htm
[54] http://tis.eh.doe.gov/techstds/standard/hdbk1092/hdbk1092.pdf
[55] http://www.dol.gov
[56] http://www.osha.gov
[57] http://www.osha.gov
[58] http://www.osha-slc.gov/OshStd_data/1910_0301.html
[59] http://www.osha-slc.gov/OshStd_data/1910_0309.html
[60] http://www.osha-slc.gov/OshStd_data/1910_0333.html
[61] http://www.osha-slc.gov/OshStd_data/1910_0335.html
[62] http://www.osha-slc.gov/OshStd_toc/OSHA_Std_toc_1910_SUBPART_S.html
[63] http://www.osha-slc.gov/OshStd_toc/OSHA_Std_toc_1910.html
[64] http://www.osha-slc.gov/OshStd_toc/OSHA_Std_toc.html
[65] http://www.osha-slc.gov/OshStd_data/1910_0301.html
[66] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=900
[67] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=900
[68] http://www-esh.fnal.gov/train/owa/itp.indiv_rpt
[69] http://www-esh.fnal.gov/home/owa/esh_home_page.html
[70] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=100
[71] http://www-esh.fnal.gov/home/owa/esh_home_page.html
[72] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=900
[73] http://www-esh.fnal.gov/FRCM/Ch04/Ch04.html#Heading31
[74] http://www-esh.fnal.gov/home/owa/esh_home_page.html
[75] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=900
[76] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=200
[77] http://fncduh.fnal.gov:8080/fnalonly/cd_photos/BForster.gif
[78] http://www-esh.fnal.gov/home/owa/esh_home_page.html
[79] http://www-esh.fnal.gov/home/owa/esh_home_page.page?this_page=30
[80] http://www-esh.fnal.gov:8001/Guidance/FermiEmpOrienCL.htm