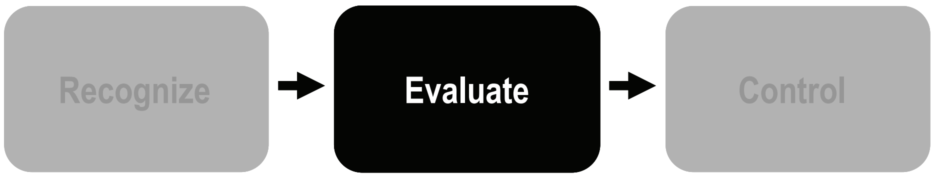
MODULE 3
EVALUATING ELECTRICAL RISK FACTORS



At the end of this module, you will be able to…

- Recognize the purpose and various methods for evaluating arc flash.
- Identify arc flash approach boundaries and their meaning.
- List the steps for conducting a task analysis.
- Recognize how to conduct a fall hazard evaluation.
- Given a case study, analyze the hazards and recommend improvements.

Electrical Hazard Analysis

When electrical components operate at 50 volts nominal and above, workers should de-energize the equipment when they work on it. This means that it should be locked out, tagged out, and then tested to ensure that it is indeed de-energized. The qualified person performing these functions should be outfitted in the appropriate PPE.

If the components cannot be de-energized because of the nature of the work to be performed or because of an increased risk posed by de-energizing, then a Shock Hazard Analysis and a Flash Hazard Analysis need to be performed.

There are three desired outputs for these evaluations.

1. To determine flash protection boundaries
2. To determine incident energy
3. To determine the hazard/risk category for PPE selection

NFPA Evaluations

Evaluation Type: Shock Hazard Analysis

NFPA Definition: A Shock Hazard Analysis shall determine the voltage to which personnel will be exposed, boundary requirements, and the personal protective equipment necessary in order to minimize the possibility of electric shock to personnel. To determine shock hazard, a licensed electrical engineer will perform either a calculation or use Table 130.2(C) of NFPA 70E.

NFPA Reference: 70E 130.2

Who Conducts Evaluation: Licensed Electrical Engineer

Evaluation Type: Flash Hazard Analysis

NFPA Definition: A Flash Hazard Analysis shall be done in order to protect personnel from the possibility of being injured by an arc flash. The analysis shall determine the flash protection boundary and the personal protective equipment that people within the flash protection boundary shall use.

NFPA Reference: 70E 130.3

Who Conducts Evaluation: Licensed Electrical Engineer

Methods for Evaluating Arc Flash

There are many methods for evaluating arc flash. Unless you are a Licensed Electrical Engineer, you will not be making these calculations. However, it may be helpful for you to be familiar with the different methods.

NFPA 70E equations and tables

- Annex D of NFPA provides equations and tables for calculating arc flash.
- These equations are not part of NFPA requirements, but are provided for information.

Institute of Electrical and Electronics Engineers (IEEE) Standard 1584

- Standard 1584 provides definitive calculation steps to support the NFPA standard for arc flash calculations.
- It outlines a method for calculating the anticipated incident energy.

Software programs

- There are numerous software programs that can be used by licensed electrical engineers to calculate arc flash.
- These programs base their calculations on the NFPA equations and the IEEE 1584 standard.

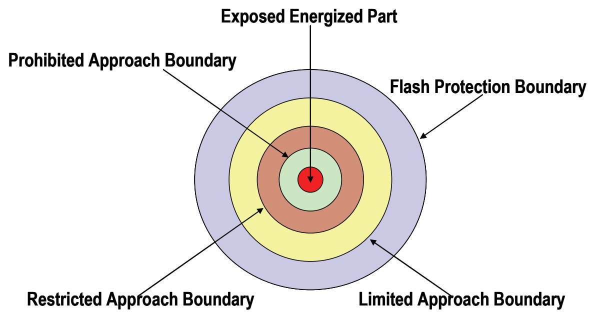
Electrical System Analysis

- This is an electrical system engineering study that is performed by engineers familiar with the power distribution and control equipment and the calculation methods required. The arc flash analysis will determine, among other things, the incident energy potential of each piece of electrical distribution equipment in the facility. This incident energy potential will define the Hazard/Risk Category of PPE that the employee is required to wear while performing any work when energized.

$$Dc = [2.65 \times MVAbf \times t]1/2$$

Limits of Approach

The qualified person will adhere to approach limits based on the type of equipment and the voltage of the system. This diagram illustrates the boundaries *that will be used by the qualified person when working with energized components*. Note that the outermost boundary is for flash protection. All of the inner boundaries are for shock protection.



Boundary	Meaning
Flash protection boundary	This is the outer boundary of the flash protection zone. Employees passing it must wear flash protective equipment.
Limited approach boundary	A person crossing this line must be qualified to do the job/task. They must wear flash protective equipment. Unqualified workers are prohibited from crossing this boundary.
Restricted approach boundary	A person crossing this line enters into restricted space. Only qualified people may cross this boundary. Qualified people must have a written plan that is approved by authorized management. They must use PPE appropriate for working near energized parts. They must ensure no body part crosses the prohibited line and keep as much of their body out of the restricted space as possible.
Prohibited approach boundary	Crossing this line is the same as having contact with the live part. Only qualified people may cross this line. They must have specified training to work on energized parts. They must have a documented plan and a risk hazard analysis that are approved by authorized management. They must wear PPE appropriate for working on live parts.

Using the NFPA Tables

There may be occasions when electrical work must begin before the Flash Hazard and Shock Hazard Analyses are complete. In these instances, the workers must still wear PPE. NFPA has provided tables to help determine which PPE is required when the calculations have not been done. Keep in mind that the data in the NFPA tables tends to be conservative.

Following is a sample of the information provided in the NFPA 70E tables. Please note that this is an excerpt from the tables and only a sample. When these tables are used, **ALL** corresponding notes must be taken into consideration.

Task	Hazard/Risk Category	V-Rated Gloves	V-Rated Tools
Panelboards rated 240v and below			
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
Work on energized parts, including voltage testing	1	Y	Y
Remove or install circuit breakers or fused switches	1	Y	Y
600v Class Motor Control Centers			
Work on energized parts, including voltage testing	2*	Y	Y
Insertion or removal of individual starter "buckets" from the motor control center	3	Y	N
Application of safety grounds, after voltage test	3	Y	N

*A double-layer switching hood and hearing protection are required for this task in addition to other Category 2 requirements.

Table Source: NFPA 70E Table 130.7(C)(9)(a)

Steps for Task Analysis

The most effective way to evaluate the potential risk of a job or project that involves electricity is to perform a task analysis of the job. The task analysis allows you to determine where the electrical hazards are in the job. Here are the steps for performing a task analysis.

1. Involve everyone who will be working on the job/project.

2. Identify every step that must be taken to complete the job/project.

3. For each step, identify the electrical procedures that will be performed.

4. Obtain or create drawings and other documents pertaining to the electrical system(s) that will be involved.

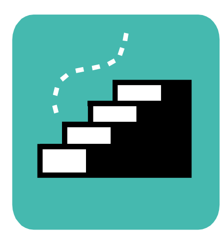
5. Identify the hazards associated with the job/project.
   - Fall
   - Chemical
   - Electric shock
   - Burn
   - Arc flash

6. Agree on safety procedures that everyone will follow.
   - Lockout/tagout
   - Guarding
   - Approach limitations
   - PPE
   - Signage

7. Determine the proper tools that need to be used for the job/project.

8. Determine the PPE that must be used for the job/project.

Note: This list is available on your *Tools and Resources* CD-ROM.



Evaluating Fall Hazards

If electrical work requires working at height (roof or ceiling work, tree trimming), it is important to evaluate the potential hazards that could cause a fall in the event of an electrical incident. Following are some of the items that should be evaluated prior to the job/project.

Item to Evaluate	Yes	No
Is there a proper scaffold or work platform?	☐	☐
Is the scaffold or work platform of a non-conductive material?	☐	☐
Does the work platform have proper guardrailing (top edge height between 39 and 45 inches)?	☐	☐
Does scaffold or work platform have screens or mesh to protect tools from falling into or near the electrical system?	☐	☐
If a ladder is used, is it of non-conductive material?	☐	☐
Does scaffold have toe boards to prevent tools and other loose equipment from falling?	☐	☐
On a suspension or scissor scaffold, are electrical wires properly insulated and free of damage?	☐	☐
Is there adequate clearance between the scaffold or ladder and power lines?	☐	☐
Is the scaffold free of dust and debris?	☐	☐
Are fall arrest systems used?	☐	☐
Is the scaffold or ladder free of moisture, snow and ice?	☐	☐

Note: This checklist is available on your *Tools and Resources* CD-ROM.

Activity: Case Study

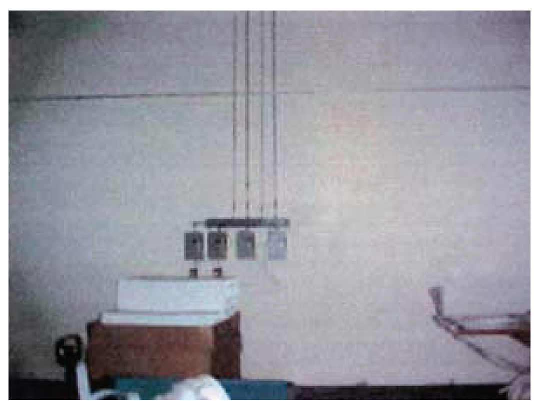
Directions: Read the case study, then complete the following worksheet. This is a summary of an incident that actually happened

Background of the Incident

The incident occurred at a large, cosmetic packaging plant in an urban-industrial area. The plant specialized in manufacturing plastic inserts for protecting and displaying the products. Most of this manufacturing was done in the thermoforming department, a large room with 13 industrial thermoforming machines. Sheets of plastic were fed into the machine and pressed between two large, heated dies. The dies created multiple impressions of the form in the plastic, each of which were cut out in the next production step. Cosmetics or other items were placed into the plastic insert, which was then placed into the box to make the final package.

The residual heat created by the thermoforming machines caused the room to become uncomfortably warm for employees, so management decided to install large exhaust fans in the walls. The fans would redistribute the heat from the thermoforming room into the plant's adjoining warehouse. Plant employees were to install most of the non-live wiring, and an electrical contractor was hired to do the actual electrical connections. Management assigned the plant's mechanic to do the non-live wiring. The mechanic was a 21-year-old Hispanic male who was responsible for performing maintenance and minor repairs on the thermoforming machines. Assisting him was a laborer (the victim) who was being trained as a mechanic's assistant. Both workers had been hired on the same day in November, 2002.

The wiring project required the installation of metal conduit from four switching/breaker boxes mounted on the wall underneath the fans. The conduit ran up the wall to the fans (see photo at right), then extended up to the ceiling joists of the room where it was to terminate near a three-phase, 480-volt electrical bus bar that supplied power to the thermoforming machines. The mechanic was to mount the conduit and run the electrical wires through it. The two workers were instructed not to do any electrical connections, which were to be done later by a contracted licensed electrician. The electrical bus bar was an enclosed system made of four copper conducting plates mounted in a steel enclosure measuring approximately 14 inches wide by five inches high. The bus bar was mounted on the bottom of the roof joists, approximately five feet beneath the ceiling and 20 feet above the floor. Switched electrical junction boxes were mounted to the side of the bus to transfer power to the machines. The bus bar had been installed by a contractor hired by the new company management in April, 2003.



Conduit leading to switches at floor level

Activity: Case Study—continued

Background of the Incident—continued

Scissor Lift

The incident occurred the afternoon of Wednesday, May 5, 2004. The two-man crew started the project, which was expected to take two to three days, during their usual 7:00 a.m. to 4:00 p.m. shift. They used a powered scissor-lift (see photo at right) to raise them to the ceiling joists of the thermoforming room. Work proceeded uneventfully through the morning and into the early afternoon.

About 3:00 p.m., the two workers were on the lift, installing conduit near the electrical bus bar. The end of the bus enclosure was open due to a missing end-cap, exposing four electrical conducting plates. While the mechanic had his back turned, the victim, who was not trained to test circuits, picked up a voltmeter from the lift and connected the two testing probes across the copper plates. The mechanic reportedly saw this and shouted "No!" but the connection caused an electrical arc and overloaded the voltmeter, which exploded near the victim.

Burned "V" Shape in Bus Bar Plates

The arc burned a deep "V" into the four metal bus plates (see photo at right), caused the power to go out, and set off the fire alarm. Sparks from the arc and/or exploding voltmeter set the victim's clothing on fire. The mechanic tried to extinguish them, setting his own clothes on fire. The mechanic lowered the lift to ground level, where a plant employee used a fire extinguisher to put out the fires. The mechanic then lost consciousness. The darkness and fire caused a panic among the employees in the area, and everyone was evacuated. The police received a 911 call from the plant and dispatched a unit. Officers reported finding the area dark and smoke filled, with the two workers unconscious on the platform of the scissor lift. The two workers were transported to the emergency room where they were treated for burns. Attending physicians did not find evidence of electrical injuries to either worker, and determined that the mechanic, who was treated and released, had 10% total body burns to his hands and chest. The victim suffered more extensive injury with 35% total body burns and smoke inhalation. Fourteen days after the incident, the victim succumbed to his injuries.

Following the incident, plant management brought in a crisis counselor to help the employees who witnessed the incident. Investigations by company management and OSHA found that the electrical contractor who installed the electrical bus bar apparently neglected to place an end-cap on the bus enclosure, leaving the electrical conductors exposed.

Activity: Case Study—continued

Background of the Company

The employer was a contract manufacturer for the personal-care products industry, specializing in manufacturing packaging materials, packaging, and product distribution. The company owned six plants in two states, and employed around 1,400 permanent employees, not including staff hired through a temporary agency. The plant where the incident occurred was purchased by the company about 18 months prior to the incident. This plant employed 170 permanent employees, and 200 to 300 temporary employees, most of whom worked on the assembly lines during busy season. The employer stated that most of the employees were from the Dominican Republic. The employees at this plant were not unionized.

Background and Experience of the Victim

The victim was a 19-year-old Hispanic male who had worked for the company about a year and a half. Hired as a laborer-helper, he was being trained as a mechanic's assistant. Most of his training was on-the-job, and included a 45-minute machinery awareness training course. He did not have any training on electrical safety. He was born in the US and was bilingual in English and Spanish.

Notes:

Activity: Case Study—continued

Directions: In your group, analyze the case on the previous pages, then answer the following questions.

1. What hazards were present in this situation?

2. What did the management and employees do wrong?

3. How could an incident like this have been prevented?

Planning for Your Small Business

Directions: Based on what you've learned in this module, what will you do back on the job?

1. Identify two or three actions you will take when you return to your worksite.
2. In addition, identify the potential barriers you might encounter in taking these actions.
3. Next, list ideas for overcoming the barriers identified.

Action Plan

Action	Potential Barriers	Overcoming the Barriers