



COURSE MATERIAL FOR LIGHT CLEANING IN POWERED CIRCUITS



Module 1: Fundamentals of Electrical Safety & Regulations

Introduction and Learning Objectives

Welcome to the foundation of electrical safety. Before touching a voltmeter, opening a panel, or using a cleaning solvent, one must understand the invisible danger. This module covers the nature of electricity, the regulatory framework that governs work practices, and how to communicate hazards in the workplace.

****By the end of this module, you will be able to:****

- Identify the primary electrical hazards (Shock, Arc Flash, Arc Blast).
- Define the three approach boundaries and their requirements.
- Locate key safety regulations (OSHA, NFPA 70E).
- Interpret a Safety Data Sheet (SDS) for cleaning chemicals.

Part 1: Introduction to Electrical Hazards

Electricity is a controlled energy source, but when control is lost, it becomes a serious hazard. There are three main ways electricity harms the body:

1. Electric Shock

Electric shock occurs when the body becomes a path for current to flow to the ground or another conductor.

- ****The Physics:**** Voltage (pressure) pushes current (flow) through the body's resistance (skin, tissue).

- ****The Danger:****

- ****0.5 – 3 mA:**** Tingling sensation (Perception threshold).
- ****10 mA:**** Loss of muscle control (Can't let go).
- ****20 – 50 mA:**** Respiratory paralysis (may stop breathing).

- **100 – 200 mA:** Ventricular fibrillation (heart stops pumping, usually fatal).
- **> 200 mA:** Severe burns and cardiac arrest.
- **Severity Factors:** The path of current (hand-to-heart is worst), the duration of contact, and the person's physical condition.

2. Electrical Burns

This is the most common injury related to electrical shock.

- **Cause:** Heat generated by the current flowing through tissue.
- **Types:**
 - **Electrical Burns:** Damage to internal tissues.
 - **Thermal Burns:** Contact with arc flash heat or ignited clothing.
 - **Flash Burns:** UV radiation from an arc flash burning the skin like severe sunburn (can also cause eye damage).

3. Secondary Injuries

Often overlooked, these are injuries caused by the body's reaction to shock.

- **Falls:** A shock can cause muscle spasms, throwing a worker off a ladder or scaffold.
- **Impact Injuries:** Jerking back and striking equipment or structures.

Part 2: Arc Flash and Arc Blast

While shock requires physical contact, arc flash and blast are the "invisible fire" that can injure from several feet away.

What is an Arc Flash?

An arc flash is a dangerous release of energy caused by an electrical arc (a short circuit through the air). It occurs when insulation or isolation between energized conductors is broken (e.g., dropping a tool, dust bridging phases, equipment failure).

The Two Dangers: Flash and Blast

1. Arc Flash (The Fire)

- **Temperature:** Can reach **35,000°F** (19,400°C)—four times hotter than the surface of the sun.

- **Hazards:**

- **Intense Heat:** Ignites standard clothing, causing severe burns.
- **Intense Light:** UV radiation can cause eye damage (arc eye/flash burn) similar to welder's flash.

2. Arc Blast (The Explosion)

- **Cause:** The rapid heating of air and vaporization of metal causes a pressure wave.
- **Hazards:**
 - **Pressure Wave:** Can throw workers across the room, collapse lungs, or rupture eardrums.
 - **Shrapnel:** Molten metal droplets (from vaporized conductors) and debris fly at high speeds.
 - **Sonic Boom:** Loud noise causing hearing damage.

Approach Boundaries (NFPA 70E)

To protect against arc flash and shock, specific boundaries are defined. Only qualified persons with appropriate PPE may cross these lines.

Boundary	Definition	Requirement
Limited Approach	The distance from an exposed energized part where a shock hazard exists.	Only Qualified Persons may cross. Unqualified persons must be constantly escorted.
Restricted Approach	The distance from an exposed energized part where there is an increased risk of shock (inadvertent movement).	Requires an energized work permit, specific training, and appropriate PPE.
Prohibited Approach	The distance from an exposed energized part considered the same as making direct contact.	Entering this zone means you are in direct contact with the live part. Highest level of PPE required.

Part 3: Regulatory Compliance

Safety isn't just a good idea—it's the law. In the United States, the primary regulations are set by OSHA, while the "how-to" standards are set by NFPA.

1. OSHA (Occupational Safety and Health Administration) - 29 CFR 1910.332

OSHA is a government agency that sets and enforces workplace safety standards.

- **Scope:** 29 CFR 1910.332 covers "Training" for electrical safety in general industry.

- **The Rule:** OSHA mandates that employees who face a risk of electric shock must be trained in safety-related work practices.
- **Key Requirement:** Training must be classroom or on-the-job and must be provided to:
 - Qualified Persons (those working on or near exposed energized parts).
 - Unqualified Persons (those whose work brings them near electrical hazards but who do not work on them).

2. NFPA 70E (Standard for Electrical Safety in the Workplace)

While OSHA is the *law*, NFPA 70E is the *consensus standard* that shows employers *how* to comply with the law. It is the "bible" of electrical safety.

- **Purpose:** It provides detailed guidance on practical safety strategies.
- **Key Concepts from NFPA 70E:**
 - **Risk Assessment:** Requires a shock risk assessment and an arc flash risk assessment before any job.
 - **Hierarchy of Risk Control:** Emphasizes eliminating the hazard (putting equipment in an electrically safe work condition) as the first step, rather than just wearing PPE.
 - **Energized Electrical Work Permit:** Requires a formal, written permit for any work performed *within* the Restricted Approach Boundary.

3. Local Ordinances

Always be aware that local municipalities, states, or provinces (e.g., California Title 8, or Canadian provincial regulations) may have **stricter** rules than federal OSHA. When in doubt, the strictest rule applies.

Part 4: Hazard Communication (HAZCOM)

Electrical work often involves cleaning solvents, lubricants, and insulating materials. These have their own chemical hazards that must be understood.

Safety Data Sheets (SDS)

Formerly known as Material Safety Data Sheets (MSDS), the SDS is a document that provides detailed information about a hazardous chemical.

- **The 16-Section Format (Globally Harmonized System - GHS):**
 1. **Identification:** Product identifier, manufacturer details, emergency phone number.
 2. **Hazard(s) Identification:** Signal words (Danger/Warning), pictograms (exploding bomb, flame, health hazard), and hazard statements.

3. **Composition/Ingredients:** Chemical name and concentration.
4. **First-Aid Measures:** What to do if exposed.
5. **Fire-fighting measures:** How to extinguish a chemical fire.
6. **Accidental Release Measures:** How to clean a spill.
7. **Handling and Storage:** Safe storage practices (e.g., flammable cabinet).
8. **Exposure Controls/PPE:** Recommended gloves, respirators, ventilation.

> **Key Takeaway:** Before using any chemical (contact cleaner, degreaser), you must locate and review Section 2 (Hazards) and Section 8 (PPE) of the SDS.

Labeling Requirements (Right-to-Know / WHMIS)

Workers have the "Right-to-Know" what chemicals they are exposed to.

- **Primary Labels:** Containers received from the manufacturer must have a GHS-compliant label including pictograms, signal word, and hazard statements.
- **Secondary Containers:** If you transfer a chemical to a spray bottle or a smaller container, that container **must** be labeled immediately with the product name and the appropriate hazard warning. Unlabeled containers are a major OSHA violation.

Summary & Quiz Review

1. **Three Main Hazards:** Shock (current through body), Arc Flash (extreme heat), Arc Blast (pressure wave).
2. **Boundaries:** Limited (observe only), Restricted (qualified with permit), Prohibited (contact).
3. **Regulations:** OSHA sets the law; NFPA 70E sets the standard for how to follow the law.
4. **Chemicals:** Always check the SDS (Section 2 and 8) and ensure secondary containers are labeled.

Module 2: Contamination Theory and Assessment

Introduction and Learning Objectives

In Module 1, we established the rules of engagement regarding electrical hazards. Now, we must understand the enemy: **Contamination**. The vast majority of electrical failures do not happen because the equipment is "worn out"; they happen because contamination provides a path for electricity to go where it is not supposed to go.

Before we can clean, we must understand **what** we are cleaning, **why** it is dangerous, and **how** to identify the severity of the problem without touching the equipment.

****By the end of this module, you will be able to:****

- Identify common types of industrial contaminants.
- Explain the physical mechanisms (tracking, carbonization) that cause contamination to lead to failure.
- Utilize basic inspection techniques, including thermal imaging principles, to assess contamination levels.

Part 1: Types of Contaminants

Contamination can be defined as any unwanted foreign material on or inside electrical equipment. The type of contaminant often dictates the cleaning method required.

1. Dry Particulates (Dust and Dirt)

- ****Source:**** Normal factory air, construction nearby, grain handling, cement plants, textile fibers.
- ****Characteristics:**** Hygroscopic (attracts moisture). While dry dust may be insulating, once it gets damp, it becomes conductive.
- ****Specific Case:**** ****Carbon Dust**** (from motor brushes or nearby combustion) is particularly dangerous because carbon is electrically conductive even when dry.

2. Carbon Tracking

- ****Source:**** This is not an external contaminant but the **result** of previous small arcs or corona discharge.
- ****Characteristics:**** Thin, hair-like lines of carbonized (burnt) paths across the surface of insulation (like Bakelite or plastic). Once a "track" forms, it acts like a pre-installed wire for electricity to follow.

3. Oil Mist and Grease

- ****Source:**** Leaking hydraulic lines, gearboxes, machining coolant, over-lubrication of nearby bearings.
- ****Characteristics:**** Sticky. Oil acts as a magnet for dust. The combination (oil + dust) creates a "grime" that is difficult to remove and can trap heat. Certain synthetic oils can also attack and soften plastic insulation.

4. Salt Spray (Coastal/Industrial Environments)

- **Source:** Facilities located near oceans or where de-icing salts are used on roads.
- **Characteristics:** Salt (sodium chloride) is highly conductive, especially when combined with humidity. It causes rapid corrosion of bus bars and connectors, leading to increased resistance and heating.

5. Biological Contamination (Bird Nesting/Pest Infestation)

- **Source:** Rodents and birds seeking warmth in electrical cabinets and substations.
- **Characteristics:**
 - **Nesting Materials:** Dry grass and twigs are flammable.
 - **Urine/Feces:** High in moisture and salts. Rodent urine can create a conductive path across insulators, causing "tracking" and flashover.
 - **Corpses:** Can cause short circuits if they bridge phases.

Part 2: Effects of Contamination

How does a little bit of dirt cause a massive explosion? It happens in stages.

The Mechanism of Failure

1. The Contamination Layer

A layer of dust, salt, or oil settles on an insulator or bus bar.

2. Moisture Absorption

When humidity rises (nighttime, fog, rain), the contamination layer absorbs moisture. The dirt becomes damp.

3. Leakage Current Begins

The damp contamination is slightly conductive. A small current starts to "leak" across the surface of the insulator (creepage distance). This current generates heat (I^2R).

4. Dry Band Arcing (Tracking)

The heat from the leakage current starts to dry the contamination in specific spots. These "dry bands" have high resistance. The voltage now jumps *over* these dry spots, creating tiny sparks (micro-arcs). These sparks burn the insulation surface, creating **carbon**.

5. Flashover

Carbon is conductive. The carbon path grows, shortening the distance the electricity has to travel. Eventually, the air gap closes completely, and the full line voltage surges across the surface. This is a **Flashover**—a violent arc that can destroy equipment and cause arc flash injuries.

Other Effects of Contamination

- **Overheating:** A thick layer of dust acts as an insulator (like a blanket). Heat generated by normal current flow cannot escape, causing components to overheat and fail prematurely.
- **Corrosion:** Salt and chemical mists corrode metal connections. Corrosion increases resistance, which increases heat, which accelerates failure.
- **Insulation Degradation:** Certain chemicals can chemically dissolve or embrittle wire insulation, leading to short circuits.

Part 3: Inspection Techniques

Cleaning electrical equipment is inherently risky. Therefore, we must use **Assessment** to determine *if* and *when* cleaning is necessary. The goal is to identify contamination levels while maintaining a safe distance.

1. Visual Inspection

This is the first line of defense. It must be performed by a **Qualified Person** as defined in Module 1, wearing appropriate PPE for the approach boundary.

What to look for:

- **Buildup:** Can you write your name in the dust? Is the color of the equipment obscured?
- **Color Changes:** Are insulators turning brown or black? This indicates carbon tracking from previous arcing.
- **"Cobwebs":** Fine lines of carbon between terminals or from a terminal to ground.
- **Nests/ Debris:** Visible straw, droppings, or insect hives.
- **Oil Leaks:** Puddles or drips at the bottom of cabinets.

****The "Fingernail" Rule (Informal):**** If you can scrape a visible groove in the dust with your fingernail (metaphorically—do not touch energized parts!), it is likely heavy enough to cause problems under humid conditions.

2. Infrared Thermography (Thermal Imaging)

This is the most powerful tool for assessing contamination **without** physical contact. It detects heat.

****Principle:**** All energized components above absolute zero emit infrared energy. A thermal camera shows us the temperature patterns.

****What Contamination Looks Like on a Thermal Camera:****

Condition	Thermal Image Appearance	Interpretation
Clean Connection	Uniform color/temperature across the component.	Normal resistance, normal heat dissipation.
Dirty/Dusty Insulator	The insulator itself may appear **hotter** than expected.	The dust blanket is trapping heat. The equipment is overheating internally.
Tracking/Leakage	"Hot spots" along the surface of an insulator, not just at the connection points.	Leakage current is flowing across the surface, creating friction heat. This is a pre-failure condition.
Corroded Connection	A specific connection point (e.g., a lug) is significantly hotter than the wire leading to it.	Corrosion/dirt at the joint is creating high resistance. This is a fire hazard.

****Important Note on Thermography:****

- ****Load Requirement:**** Thermal scans should ideally be done when the equipment is under at least 40% load. A dirty connection won't heat up if no current is flowing.
- ****Emissivity:**** Clean, shiny metal reflects heat (and the camera's view). Dirty surfaces are better for thermal imaging.

Severity Classification (Example)

Once an issue is found, it is usually categorized for action:

- ****Phase A (Normal):**** No significant temperature difference. No action needed.
- ****Phase B (Intermediate):**** Temperature rise 1°C - 10°C above reference. Monitor during next scheduled outage.

- **Phase C (Serious):** Temperature rise 11°C - 20°C above reference. Schedule repair as soon as possible.
- **Phase D (Critical):** Temperature rise >20°C above reference. Immediate shutdown and repair required.

Summary & Quiz Review

1. **Contaminants:** Dust (insulative dry, conductive wet), Oil (sticky, traps heat), Salt (highly conductive), Biological (flammable, conductive urine).
2. **The Process:** Contamination + Moisture = Leakage Current + Heat = Tracking = Flashover.
3. **Inspection Tools:**
 - **Eyes:** Look for buildup, discoloration (carbon), and nests.
 - **Thermal Camera:** Look for unexpected heat patterns (hot insulators, hot spots on surfaces).

Module 3: Tools, Equipment, and Cleaning Agents

Introduction and Learning Objectives

Using the wrong tool for electrical cleaning is not just ineffective—it is dangerous. A standard vacuum creates static electricity. A wire brush creates conductive dust. A water-based cleaner causes a short circuit. This module covers the specialized arsenal of tools designed to remove contaminants without introducing new hazards (shock, fire, or static discharge).

By the end of this module, you will be able to:

- Select the appropriate non-conductive cleaning agent for a given contaminant.
- Identify safe mechanical tools (brushes, vacuums) for use on electrical equipment.
- Explain the importance of ESD control when working with sensitive electronics.
- Inspect tools for damage that could compromise safety.

Part 1: Non-Conductive Cleaning Agents

The primary rule of electrical cleaning: **The cleaning agent must not conduct electricity.** It must also evaporate quickly and not leave a residue that will attract future dirt.

1. Specialized Electronic Cleaners (Aerosol)

These are the most common agents for general purpose electrical work.

- **Properties:**

- **Dielectric Strength:** They are non-conductive and can often be sprayed on energized components (check the label) without causing a short.

- **Fast Evaporation:** They dry in seconds, leaving no residue.

- **Solvency:** Designed to dissolve grease, oil, and light carbon films.

- **Types:**

- **Plastic Safe:** Formulated to not craze or crack sensitive plastics (polycarbonate, acrylic).

- **Flux Removers:** Specifically for removing soldering flux from circuit boards.

2. De-Ionized (DI) Water

While "water and electricity" is usually a deadly combination, highly purified water can be an exception.

- **Properties:** De-ionized water has had all mineral salts (ions) removed. Without ions, it cannot conduct electricity.

- **Use Case:** Used in high-pressure washing or low-moisture steam cleaning for large insulators and switchgear **only when de-energized** as a precaution, or in very specific live-wash procedures. It is an excellent solvent for dust and salt.

- **Warning:** As soon as DI water hits a dirty surface, it dissolves salts and becomes conductive again. Runoff water is dangerous.

3. Isopropyl Alcohol (IPA)

- **Properties:** A common solvent for cleaning circuit boards and removing light oils. It evaporates quickly and leaves little residue.

- **Concentration:** 99% IPA is preferred. Lower concentrations (70%) contain more water, which can leave moisture and cause corrosion.

- **Safety:** IPA is **HIGHLY FLAMMABLE**. It must never be used near ignition sources (sparks from switches) unless the equipment is de-energized and properly ventilated.

4. Specialty Degreasers

- **Properties:** Heavier solvents (often in gel or liquid form) for removing baked-on grease or carbonized tracking marks.

- **Consideration:** These may require longer drying times and must be verified as non-conductive and non-corrosive.

Part 2: Mechanical Tools

Chemicals dissolve the dirt; mechanical tools physically remove it. The key characteristic of these tools is that they are **non-conductive** and **non-abrasive**.

1. HEPA Vacuums (with Non-Conductive Attachments)

- **Purpose:** To remove loose, dry contaminants (dust, dry tracking debris) without blowing it around.
- **Safety Features:**
 - **Non-Conductive Wands/Hoses:** Must be made of plastic or fiberglass. Never use a metal vacuum wand near live parts.
 - **HEPA Filtration:** High-Efficiency Particulate Air filters trap fine particles (including lead dust or chemical residues) and do not blow them back into the room.
 - **Grounding:** The vacuum body must be grounded to prevent static buildup as air and dust move through the hose.

2. Brushes (The "Horsehair" Rule)

- **Material is Critical:** Never use wire brushes on electrical contacts (unless specifically for battery terminal cleaning). Wire brushes can remove plating, create conductive dust, and leave metal filaments behind.
- **Safe Materials:**
 - **Natural Horsehair:** Soft, non-static, and non-conductive. Ideal for dusting sensitive components.
 - **Nylon/Polyester:** Stiffer for scrubbing stubborn dirt. Ensure they are anti-static grades.
 - **ESD-Safe Brushes:** Have conductive handles to dissipate static (used on circuit boards).

3. Low-Moisture Steam Cleaners

- **Purpose:** To clean where dry methods fail (e.g., caked-on grease, salt spray). They use a tiny amount of DI water heated to steam.
- **Advantage:** The small volume of water (often measured in milliliters) evaporates instantly upon contact with warm equipment, minimizing the risk of water pooling.
- **Usage:** Typically used on *de-energized* equipment or with a very strict safe distance and specialized training.

4. Compressed Air Systems

- **The Danger:** Standard shop air (oil-lubricated compressors) contains moisture and oil, which will contaminate the equipment further.
- **The Safe Tool:**
 - **Canned Air/Duster:** Uses non-conductive, non-flammable propellant (like HFC-152a). Safe for quick dust removal.
 - **Dry Nitrogen:** The gold standard. Nitrogen is inert and bone-dry. It can be used to blow out cabinets and dry components after liquid cleaning without introducing moisture or oxygen (which aids arcing).
- **Warning:** Compressed air (even canned air) can create static electricity if the nozzle is non-conductive. Use "ionized" nozzles when cleaning sensitive electronics.

Part 3: ESD Control Measures (Electrostatic Discharge)

When cleaning circuit boards or sensitive electronic components, the hazard isn't just the *voltage in the wire*; it's the *voltage on your body*. You can carry thousands of static volts without feeling it, which can destroy microchips.

1. Grounding Mats

- **Purpose:** To provide a surface that drains static electricity away from components placed on it.
- **Usage:** Place the circuit board on the mat while cleaning. The mat is connected to ground via a 1-megohm resistor (which protects you if you accidentally touch voltage).

2. Wrist Straps

- **Purpose:** To bond your body to the same ground potential as the equipment.
- **Usage:** Wrap the conductive band snugly around your wrist. Attach the coil cord to the ground point. **Test it** (most workplaces have testers) to ensure the path is intact.

3. Ionizers

- **Purpose:** Used in cleanrooms or for large sensitive assemblies. They blow ionized air that neutralizes static charges on insulated surfaces (like plastic labels) that cannot be grounded.

Part 4: Inspection and Care of Tools

A damaged tool is a hazard. Non-conductive tools that are cracked, dirty, or wet can become conductive.

Pre-Use Inspection Checklist

Before using any cleaning tool on or near electrical equipment, perform this check:

1. ****Insulation Check:**** Look for cracks, cuts, or abrasion on plastic handles, vacuum hoses, and brush handles. If you can see bare conductive material underneath, ****do not use it.****
2. ****Cleanliness:**** The tool itself must be clean. A brush used on a greasy motor will just spread grease to a clean circuit board.
3. ****Wetness:**** Are your tools dry? Are your rags free of moisture?
4. ****Grounding Continuity:****
 - For ESD Wrist Straps: Check the resistance (typically 1 megohm) with a tester.
 - For Vacuum Hoses: Ensure the grounding wire inside the hose is intact.

Storage

- Store brushes in protective covers to keep dust off the bristles.
- Store chemicals in flammable-safe cabinets, away from direct sunlight and heat sources.
- Never store rags soaked in solvents in a pile (risk of spontaneous combustion).

Summary & Quiz Review

1. ****Cleaners:**** Must be non-conductive (high dielectric strength) and fast-evaporating. De-ionized water is an exception but must be used carefully.
2. ****Tools:**** Must be non-conductive (plastic, nylon, horsehair). HEPA vacuums remove dust without spreading it.
3. ****ESD:**** Sensitive electronics require grounding (mats, wrist straps) to prevent invisible static damage.
4. ****Tool Care:**** Inspect for cracks and contamination ***before*** every use. A dirty tool creates a dirty cabinet.

Module 4: Safety Procedures and Risk Assessment

Introduction and Learning Objectives

Knowing what the dirt is (Module 2) and what brush to use (Module 3) is useless if you are electrocuted before you start. This module focuses on the **Procedural Safety Layer**—the rules, permits, and gear that protect you while you work. The central question of this module is: **"Is it safe to do this task, and if so, how?"**

By the end of this module, you will be able to:

- Determine when it is permissible to clean energized equipment versus when it must be de-energized.
- Apply the Lockout/Tagout (LOTO) procedure to create an "Electrically Safe Work Condition."
- Select the appropriate arc flash and shock protection PPE for a given task.
- Complete a Job Safety Analysis (JSA) for a cleaning operation.

Part 1: Establishing an "Electrically Safe Work Condition"

The safest piece of electrical equipment is one that is completely dead. NFPA 70E and OSHA strongly emphasize working de-energized.

De-Energized (The Default State)

Whenever possible, equipment must be placed in an **Electrically Safe Work Condition** before cleaning. This is more than just flipping a switch. It requires:

1. **Identifying all sources** of power (main feed, control power, backup batteries, capacitors).
2. **Interrupting the load** and disconnecting the equipment.
3. **Visually verifying** the disconnect is open (if possible).
4. **Locking and Tagging** the disconnecting means (LOTO).
5. **Testing** *every* phase conductor to verify the absence of voltage with a functioning voltmeter.
6. **Grounding** (if required for high capacitance or high voltage systems).

Energized Work (The Exception)

NFPA 70E states that energized work is only permitted if:

1. **De-energizing introduces additional hazards** (e.g., shutting down a ventilation fan in a hazardous atmosphere, or shutting down life safety equipment).
2. **De-energizing is infeasible** due to equipment design or operational limitations (e.g., testing for voltage requires the equipment to be on).
3. **"Light Cleaning" is specifically permitted** (see below).

The "Light Cleaning" Distinction

NFPA 70E allows for "light cleaning" of energized equipment **if** specific conditions are met. This is a high-risk activity and is strictly defined.

- **Definition:** Cleaning that does not require touching energized parts (e.g., using a non-conductive brush or vacuum to remove loose dust from the exterior of a panel or the interior, but staying clear of live bus bars).

- **Requirements:**

- It must be "light" dusting only—not heavy grinding of carbon tracks.
- The worker must be specifically trained for this task.
- The appropriate Arc Flash PPE (based on the incident energy analysis) must be worn.
- The work must remain outside the Restricted Approach Boundary.
- An energized work permit is typically still required by company policy.

> **Golden Rule:** If you are scrubbing, applying liquid, or getting within inches of live parts, the equipment **must** be de-energized.

Part 2: Lockout/Tagout (LOTO)

When you decide de-energization is required (which should be most of the time), LOTO is the procedure that makes it permanent and safe.

The 6-Step LOTO Process (OSHA 29 CFR 1910.147)

1. **Plan/Shutdown:** Notify affected employees and shut down the equipment using normal operating procedures.
2. **Isolation:** Operate the disconnect switch or breaker to isolate the equipment from its energy source.
3. **Lock and Tag:** Attach your personal lock and tag to the disconnecting device. Only you have the key.
4. **Verify Stored Energy:** Safely release or block any stored energy (check capacitors for voltage, bleed down springs, check air tanks).
5. **Verify Isolation (Test):** Use an approved voltmeter to test **all** phases. Test the meter on a known live source first, test the equipment, then test the meter again on the live source to ensure it is working.
6. **Proceed with Work:** The equipment is now in an "Electrically Safe Work Condition."

> **Critical Note:** If you are part of a crew, *everyone* working on that equipment must apply their own lock. Group LOTO procedures require a designated "primary" worker.

Part 3: Personal Protective Equipment (PPE)

PPE is the last line of defense. If the engineering controls (de-energizing) and procedures (LOTO) fail, PPE is what stands between you and the fire.

1. Rubber Insulating Gloves (with Leather Protectors)

These are not just rubber gloves; they are precision tools rated for specific voltages.

- **Classes:** Gloves are classified by the maximum voltage they can handle.
 - **Class 00:** Rated for 500V AC (Most common for low voltage cleaning).
 - **Class 0:** Rated for 1,000V AC.
 - **Class 1, 2, 4:** For medium and high voltage.
- **Leather Protectors:** Must always be worn *over* the rubber gloves. They protect the thin rubber from cuts, punctures, and abrasion from brushes or vacuum nozzles.
- **Inspection (Air Test):** Before each use, roll the glove from the cuff towards the fingers to trap air and listen for leaks. Hold it close to your face to feel for escaping air.

2. Arc Flash Rated PPE

Cleaning often puts you close to energized parts. If a brush slips, an arc flash can occur. You must wear the correct gear for the potential incident energy level (cal/cm²) found on the equipment's Arc Flash Label.

- **Arc Rated (AR) Face Shield:** Protects face and eyes from the UV light and heat of an arc. Must have a chin protector to prevent the shield from flipping up during blast.
- **Arc Rated Balaclava (Hood):** Worn under the hard hat to protect the neck and head if the face shield doesn't offer full protection.
- **Arc Rated Clothing (FR):** Shirts and pants (or coveralls) made of flame-resistant material (Nomex, Indura, etc.). These will not ignite and continue to burn.
- **Hard Hat:** With arc rating.
- **Safety Glasses:** Always worn under the face shield for impact protection.

3. Basic PPE (Always Required)

- **Safety Glasses:** Even when wearing a face shield, safety glasses protect from falling dust and chemical splashes during cleaning.

- **Hearing Protection:** Vacuums and compressed air can be loud. Also required for arc blast protection.

Key Questions for a Cleaning JSA:

- **Is it energized?** (If yes, a full Energized Work Permit is required).
- **What is the Arc Flash Boundary?**
- **What chemicals am I using?** (Check SDS for PPE and inhalation risks).
- **Can I reach the area?** (Ladder safety vs. Scaffold).
- **What is the debris?** (Is it hazardous waste like lead paint or beryllium?).

Summary & Quiz Review

1. **Default State:** De-energize. Use the 6-step LOTO process to achieve an "Electrically Safe Work Condition."
2. **Exception:** Energized work (including "light cleaning") requires a permit and justification.
3. **PPE Hierarchy:**
 - **Shock:** Rubber gloves (with leathers) of the correct class.
 - **Arc Flash:** AR face shield, AR clothing based on incident energy label.
 - **Always:** Safety glasses.
4. **Planning:** The JSA breaks the job into steps and forces you to identify hazards before they hurt you.

Here is the comprehensive training material for **Module 5: Practical Cleaning Techniques**. This module takes the theory, tools, and safety procedures from the previous modules and applies them to specific real-world scenarios and equipment types.

Module 5: Practical Cleaning Techniques

Introduction and Learning Objectives

Knowing *what* the hazards are and *which* tool to use is only half the battle. You must also know *how* to apply that tool to specific equipment. Cleaning a delicate circuit board requires a completely different technique than cleaning a high-voltage porcelain bushing. Using the wrong technique can push contamination deeper into the equipment or cause physical damage.

****By the end of this module, you will be able to:****

- Apply a systematic cleaning approach to various types of electrical equipment.
- Differentiate between cleaning techniques for low-voltage controls, medium-voltage switchgear, and rotating machinery.
- Execute cleaning tasks without disturbing wiring integrity or creating new hazards.

Part 1: Cleaning Control Panels & Enclosures

Control panels (PLCs, relays, motor control centers) are densely packed with wires and components. The goal here is ****gentle removal of loose contamination without changing anything****.

The "Top-Down" Rule

Always clean from the top of the panel downward. Gravity will cause dislodged dust to fall; if you clean the bottom first, you will just re-contaminate it when you do the top.

Step-by-Step Technique

1. ****Assessment:**** Identify if there are any loose wires, unshielded terminals, or exposed conductors.
2. ****Vacuuming (Primary Method):****
 - Use the ****non-conductive HEPA vacuum**** with a soft brush attachment.
 - Hold the vacuum nozzle ***above*** the component. Do not jam it into wiring.
 - Move systematically: Start at the top, work across, then move down.
 - Pay special attention to wire troughs and cable trays where dust bunnies accumulate.
3. ****Wiping (Secondary Method):****
 - Use a ****lint-free**** cloth (not a rag that leaves fibers).
 - Lightly dampen the cloth with an approved electronic cleaner (if needed). The cloth should be ***damp***, not dripping.
 - Wipe flat surfaces (panel backs, inside of doors) carefully.
4. ****The "No-Tug" Rule:**** Never pull on wires to clean behind them. If you cannot reach behind a wire bundle with a vacuum or brush, leave it. Forcing the issue can loosen termination screws.

Part 2: Circuit Board Cleaning

Circuit boards are the most fragile items. They are susceptible to static discharge, physical breakage, and chemical damage.

Preparation (ESD Setup)

1. **Ground:** Place the board on an ESD-safe mat and wear a grounded wrist strap.
2. **Inspect:** Look for corroded battery terminals, swollen capacitors, or obvious carbon tracks.

Technique

1. **Loose Debris:**
 - Use **canned air/duster** or **dry nitrogen** held at a 45-degree angle.
 - Hold the can upright (tipping it can release liquid propellant which can damage components).
 - Use short bursts to dislodge dust from under chips and connectors.
2. **Stubborn Contamination (Flux, Grease):**
 - Dip an **ESD-safe brush** (horsehair or anti-static nylon) into isopropyl alcohol (99%) or a flux remover.
 - **Scrub Gently:** Lightly brush the affected area. Do not flick solder joints.
 - **Absorb:** Immediately wick away the dissolved contaminant with a lint-free wipe. Do not let it run under chips.
3. **Drying:**
 - Allow the board to air dry completely before reapplying power. Solvents trapped under chips can cause short circuits later.

Part 3: High-Voltage Insulator Cleaning

Insulators (porcelain, polymer, or glass) are designed to provide a long surface path for electricity to travel (creepage distance). Contamination shortens this path. Cleaning them requires restoring that surface.

Dry Wiping

- **Use:** For light dust on accessible, de-energized insulators.
- **Tool:** Dry, lint-free cloth or a tack cloth.
- **Caution:** If the dust is dry, wiping can create static. Ensure the equipment is grounded.

Solvent Application (for Grease or Carbon Tracking)

1. **De-energize:** This is almost always required unless using specialized live-line washing techniques (which are beyond the scope of standard cleaning).
2. **Apply Solvent:** Spray or wipe a non-conductive, plastic-safe cleaner onto the insulator surface.
3. **The "Wrap" Technique:** Wrap a cloth around the insulator petticoats (the ribs) and twist. This cleans the underside of the ribs where contamination hides.
4. **Rinse/Evaporate:** If using a solvent that leaves residue, follow up with a clean dry cloth. If using de-ionized water, ensure it evaporates fully before re-energizing.

Part 4: Motor and Transformer Cleaning

Motors and transformers rely on airflow for cooling. Dust blocks ventilation passages, causing overheating.

The Danger

- **Motors:** Dust acts as insulation, trapping heat. If the motor is TEFC (Totally Enclosed Fan Cooled), the external fan and cooling fins must be clean.
- **Transformers:** Dust on windings blocks airflow. If the dust is carbon-based or conductive, it can cause turn-to-turn shorts.

Technique

1. **Vacuum First:** Use a HEPA vacuum with a crevice tool to remove bulk dust from the cooling fins (motors) and between windings (transformers).
2. **Blow Out (De-energized):**
 - Use **dry nitrogen** or low-pressure compressed air to blow out stubborn dust from winding crevices.
 - **Direction:** Blow from the inside out, or from the top down, to push debris out of the equipment, not further in.
3. **Degreasing (if required):**
 - If the windings are coated in oil, use an electric motor degreaser (specific solvent).
 - **NEVER** use hydrocarbon solvents on energized windings. The solvent vapors are flammable and can be ignited by brushes or starting relays.

Part 5: Substation and Switchgear

This section deals with large enclosures (switchgear lineups) and outdoor substation components.

Exterior Cleaning of Energized Cabinets

This falls under the "light cleaning" rule from Module 4.

- **Scope:** Cleaning the outside of the cabinet doors, tops, and sides.
- **Technique:**
 - Use a damp (non-dripping) cloth with a mild detergent.
 - **DO NOT** spray liquids directly onto the cabinet. Spray the cloth.
 - Keep the cloth away from vents and louvers.
 - Stand on a non-conductive ladder if needed.

Live-Front vs. Dead-Front (Indoor Switchgear)

- **Dead-Front:** The energized parts are behind a metal barrier. You are cleaning the *outside* of the barrier. This is lower risk, but still requires caution around openings.
- **Live-Front:** Older equipment where the front of the panel exposes live terminals and fuses (common on some older motor control centers).
 - **Restriction:** If the equipment is "Live-Front" and energized, **no cleaning is permitted** beyond visual inspection. You are already within the Restricted/Prohibited boundary just by standing in front of it.

Substation Insulators (Outdoor)

Outdoor insulators face rain, salt spray, and pollution.

- **Energized Washing:** Some utilities use high-pressure de-ionized water jets to clean insulators live. This requires **specialized training** and is not for general maintenance staff.
- **De-energized Cleaning (Standard Practice):**
 - Once de-energized and grounded, insulators can be washed with de-ionized water or wiped down with solvents.
 - Inspect for cracks or "chalking" of the porcelain while cleaning.

Module 6: Post-Cleaning Inspection and Quality Assurance

Introduction and Learning Objectives

Cleaning is not complete when the last bit of dust is removed. In fact, the period immediately after cleaning is one of the most critical times for equipment reliability. Tools can be left behind, solvents can pool in low spots, and brushes can accidentally loosen a critical wire. This module covers the essential steps to verify that the equipment is in better shape after cleaning than it was before—and that it is safe to re-energize.

****By the end of this module, you will be able to:****

- Conduct a thorough post-cleaning visual inspection to identify damage or residue.
- Understand the purpose and theory of insulation resistance testing (Megger testing).
- Properly document cleaning activities and report safety observations.

Part 1: Visual Inspection (The "Second Look")

After the tools are down and the solvents are put away, the Qualified Person must perform a deliberate, methodical visual inspection. This is often called a "clean-up walkthrough."

The "Three Cs" of Post-Cleaning Inspection

****1. Contamination (Did we leave any?）****

- Look for smears, streaks, or residue left by cleaning agents.
- Check corners and crevices where dissolved dirt may have run and re-deposited.
- Ensure no cleaning lint or brush bristles are left behind on components.

****2. Connections (Did we disturb any?）****

- This is the most critical check. While cleaning, wires can be accidentally nudged.
- ****Visual Check:**** Look for wires that appear loose, are in a different position than others, or have exposed copper near the termination.
- ****The "Gentle Tug" (Use with Caution):**** On ***de-energized*** equipment only, a qualified person may use a non-conductive tool (like a plastic probe) to very gently verify that wire terminations are still seated. If a wire pulls out easily, it was likely loosened during cleaning and must be re-terminated.

****3. Components (Did we damage any?）****

- Check for cracked plastic housings on breakers or relays that may have been bumped by a vacuum nozzle.
- Ensure that labels and wire markers are still in place and legible (cleaning can sometimes wipe off ink).
- Verify that all safety covers and shields have been reinstalled.

The Moisture Check

If any liquid cleaner (even "fast-dry" solvents) was used:

- ****Feel for Cool Spots:**** Use the back of your hand (near, but not touching) to feel for evaporative cooling, which indicates wet spots.
- ****Look for Pools:**** Tilt your head and look at horizontal surfaces (like the bottom of a cabinet or the top of a bus bar) at a low angle. Look for the shimmer of pooled liquid.
- ****Time:**** If there is any doubt, wait. Allow extra time for evaporation before proceeding to testing or re-energizing.

Part 2: Insulation Resistance Testing (IR Testing)

Cleaning is supposed to improve insulation, but if a solvent damaged a component or left a conductive film, the insulation could be worse. We use an ****Insulation Resistance Tester (Megohmmeter or "Megger")**** to verify.

Theory: Why "Megger"?

A standard multimeter uses a low voltage (9V) to measure resistance. This is not enough voltage to find insulation problems. A Megger applies a high DC voltage (250V, 500V, 1000V, or higher) to "stress" the insulation.

- ****The Test:**** It measures how much current leaks **through** or **across** the insulation.
- ****The Result:**** The reading is in Megohms (MΩ) or Gigaohms (GΩ). Higher is better.

When to Test

- ****After Wet Cleaning:**** If de-ionized water or solvents were used, an IR test is mandatory to ensure everything is dry.
- ****After Heavy Disturbance:**** If you were scrubbing carbon tracks or using stiff brushes, a test verifies you didn't damage the insulation surface.
- ****Before Re-Energizing:**** As a final verification that the equipment is safe to turn back on.

Basic Procedure (De-Energized Only!)

1. ****Verify De-Energized:**** The equipment must be in an Electrically Safe Work Condition (LOTO applied).
2. ****Disconnect Sensitive Electronics:**** Remove or bypass any electronics (VFDs, PLCs, surge suppressors) as the high voltage from the Megger will destroy them.
3. ****Connect Leads:****
 - ****Phase-to-Ground:**** Connect one lead to a phase conductor and one to the ground bus.
 - ****Phase-to-Phase:**** Connect one lead to Phase A and one to Phase B (to test insulation between phases).
4. ****Apply Voltage:**** Press and hold the test button for a standard duration (typically 60 seconds).
5. ****Read and Record:**** Note the reading. Compare it to the manufacturer's minimum value or industry standards (e.g., 1 MΩ per 1000V of operating voltage is a common rule of thumb, though modern standards are often higher).

> ****Safety Warning:**** The Megger charges the equipment with high voltage. After the test, the equipment must be ****discharged**** (allowed to bleed off or shorted to ground with a grounding stick) before touching it.

Part 3: Documentation

If it isn't documented, it didn't happen. Documentation provides a historical record that helps predict future failures and proves compliance with safety and maintenance standards.

What to Document (The Cleaning Log)

For every cleaning task, record the following:

1. ****Equipment ID:**** The specific panel number, motor name, or substation name.
2. ****Date and Time:**** When the cleaning occurred.
3. ****Personnel:**** Names of the qualified persons performing the work.
4. ****Method Used:**** Was it vacuum only? Solvent cleaning? Steam?
5. ****Findings (Before):**** What did you see? (e.g., "Heavy dust buildup on intake vents," "Evidence of rodent nesting," "Carbon tracking on insulator #3.")
6. ****Findings (After):**** What was the result? (e.g., "All vents clear," "Nesting removed," "IR test results: 500 MΩ phase-to-ground.")
7. ****Recommendations:**** (e.g., "Schedule re-cleaning in 6 months," "Replace gasket on door to prevent future dust ingress.")

Reporting Near Misses

A **Near Miss** is an unplanned event that did not result in injury or damage, but had the potential to do so.

- **Examples:**

- You almost dropped a metal tool into a live panel but caught it.
- You found a solvent that was mislabeled and almost used it on a live circuit.
- You discovered that your rubber gloves failed the air test.

- **Why Report?** Reporting near misses allows the company to fix the root cause *before* someone gets hurt. It is a sign of a strong safety culture, not an admission of failure.

Updating Maintenance Records

Cleaning is a maintenance task. The records should be updated in the Computerized Maintenance Management System (CMMS).

- **Closure:** Marks the work order as complete.
- **Trending:** If you consistently note "heavy dust" on a specific panel every 3 months, it might indicate a failing gasket or a new dust source nearby that needs engineering attention.

Summary & Quiz Review

1. **Post-Clean Visual:** Always check for **Contamination** (leftover residue), **Connections** (loose wires), and **Components** (cracks).
2. **Insulation Testing:** Use a Megger (high voltage) to ensure the insulation resistance is still high after cleaning. **De-energize and discharge** before and after.
3. **Documentation:** Record what you did, what you found, and any anomalies. Report near misses to prevent future accidents.

Here is the comprehensive training material for **Module 7: Emergency Response and First Aid**. This module prepares workers for the worst-case scenario. Despite all the planning, risk assessment, and PPE, emergencies can still happen. Knowing how to respond instantly and correctly can mean the difference between life and death.

Module 7: Emergency Response and First Aid

Introduction and Learning Objectives

In the previous modules, we focused on prevention. This module focuses on **reaction**. When an electrical accident or chemical spill occurs, there is no time to read a manual. Your response must be automatic. The primary goal is to prevent further harm and get professional help as quickly as possible.

By the end of this module, you will be able to:

- Execute the correct priority of actions at the scene of an electrical shock.
- Describe the basic steps of CPR and the use of an AED (Automated External Defibrillator).
- Provide initial first aid for electrical burns.
- Safely contain and report a small chemical spill.

Part 1: Electrical Shock Emergency

When someone is being electrocuted, they are part of the electrical circuit. Your first instinct may be to grab them—but **but doing so will make you the second victim.**

The 3-Step Emergency Response (Shock)

Step 1: Assess the Scene and De-energize (Your Safety First)

- **Look:** Is the victim in contact with the source? Is the source still energized?
- **DO NOT TOUCH THE VICTIM** if they are still connected to the electricity.
- **Action:** The absolute best action is to **turn off the power.**
 - If it is a plug-in device, pull the plug.
 - If it is a breaker or switch, turn it off.
 - If it is high voltage and you cannot turn it off quickly, **do not attempt rescue.** Stay back and call emergency services immediately.

Step 2: Remove the Victim (If Safe)

- Only attempt removal if the power **cannot** be shut off quickly AND the voltage is low (residential/industrial control voltage, <600V).
- **Use a Non-Conductive Object:** Use a wooden board, a plastic pipe, a dry rope, or a leather belt to **push or pull** the victim away from the source.
- **Technique:** Stand on a dry surface. Do not use anything metal or wet. Do not touch the victim's skin or wet clothing with your bare hands.

****Step 3: Call for Help****

- In the US/Canada, call ****911**** (or the site emergency number).
- ****Information to give:****
 - "Electrical shock/electrocution."
 - "Victim is unresponsive/not breathing" (if applicable).
 - Exact location.

Part 2: First Aid (CPR/AED and Burns)

Once the scene is safe (power off, victim removed), you must assess the victim's condition.

1. Assessment (Check for Life)

- ****Tap and Shout:**** Tap the victim's shoulder and ask, "Are you OK?"
- ****Check Breathing:**** Look for chest rise and fall for no more than 10 seconds.

2. CPR (Cardiopulmonary Resuscitation)

If the victim is ****unresponsive and not breathing normally (or only gasping)****, they are in cardiac arrest. Their heart has been stopped by the electric shock.

- **C-A-B (Compressions - Airway - Breathing)**

1. **Chest Compressions:**

- Place the heel of one hand on the center of the chest (between the nipples). Place the other hand on top, interlocking fingers.
- Push hard and fast: ****100-120 compressions per minute**** (to the beat of "Stayin' Alive" by the Bee Gees).
- Push down at least ****2 inches**** (5 cm) and allow the chest to fully recoil.

2. **Airway:** Open the airway using the head-tilt, chin-lift method.

- ##### **3. **Breathing:**** Pinch the nose, make a seal over the mouth, and give 2 rescue breaths (each lasting 1 second, watching for chest rise).

- ****Cycle:**** Continue cycles of 30 compressions and 2 breaths until help arrives or the victim shows signs of life.

3. AED (Automated External Defibrillator)

An AED delivers a shock to restart a fibrillating (quivering) heart. These are common in industrial settings.

- **Turn it on** and follow the voice prompts.
- **Attach pads** to the victim's bare chest as pictured on the pads.
- **Stand Clear:** Ensure no one is touching the victim while the AED analyzes the heart rhythm.
- **Shock:** If the AED advises a shock, press the button. Immediately resume CPR starting with compressions.

4. Treatment for Electrical Burns

Electrical burns are unique. There is usually an entry wound and an exit wound. The damage underneath the skin is often much worse than it looks on the surface.

- **DO:**
 - **Cover the burns** with a dry, sterile gauze or a clean cloth. This prevents infection.
 - **Treat for shock:** Lay the victim down, elevate the legs slightly (if no back/neck injury), and keep them warm with a blanket.
- **DO NOT:**
 - **DO NOT** apply ointments, creams, or ice.
 - **DO NOT** remove burnt clothing that is stuck to the skin.
 - **DO NOT** worry about giving the victim water (if they are conscious and thirsty, small sips are okay, but prioritizing EMS arrival is key).

Part 3: Chemical Spills

Cleaning agents are often flammable, toxic, or conductive. A spill during a cleaning task requires immediate action.

The "Three C's" of Spill Response

1. Control (The Source)

- If a bottle tips over, stand it upright.
- If a small container is leaking, place it into a larger, compatible container.

2. Contain (The Spread)

- **Use a Spill Kit:** Most work areas have spill kits containing absorbent socks (booms), pads, and pillows.
- **Sock it in:** Place absorbent socks around the spill to prevent it from spreading or going down a drain.
- **Absorb:** Place pads on the spill to soak it up.

3. Clean Up (and Report)

- **PPE:** Put on the appropriate gloves and eye protection (check the SDS).
- **Scoop:** Use a dustpan and brush to collect the absorbed material.
- **Disposal:** Place the contaminated absorbent in a hazardous waste bag or drum. Do not put solvent-soaked rags in regular trash (fire risk).
- **Report:** Notify your supervisor and fill out any required incident reports, even for small spills.

Emergency Spill Scenarios

- **Flammable Solvent Spill (e.g., IPA):**
 - **Hazard:** Fire/Explosion.
 - **Action:** Eliminate all ignition sources. Ventilate the area. Do not use regular shop vacs (they can spark). Use only explosion-proof vacuums or manual absorption.
- **Contact Cleaner Spill (Aerosol):**
 - **Hazard:** Slipping hazard, fumes.
 - **Action:** Ventilate. Absorb with pads. The propellant evaporates quickly, but the liquid residue remains slippery.