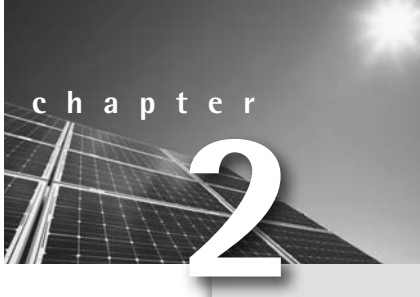
PV Systems Safety



FIVE WORKERS, ON AVERAGE, ARE ELECTROCUTED in the United States every week. A typical PV module can produce about 3 amps of current in full sunlight. It takes only a fraction of that amount to kill a person. More modules wired together to produce ever higher voltages, especially in today's PV systems, pose even more of a safety hazard. And, as this chapter will also point out, it's not only electricity that PV system installers have to worry about. Various safety hazards result from PV systems being installed on roofs, or other high places, and in environments that can be remote and inhospitable.

Given the very real dangers that can result from working with PV systems, it's crucial that those in the industry approach their work with safety always in mind.

Topics & Concepts

This chapter covers the following topics and concepts:

- The building blocks of basic PV safety
- General site safety
- Personal protective equipment (PPE)
- Hazards, prevention, safety equipment, and emergency response
- The importance of body position and awareness
- Working space: for PV systems and installers
- Safety regulations, OSHA, and beyond
- A PV safety checklist

Goals

When you complete this chapter, you will be able to:

- Understand the importance of safety on a PV systems site
- Cite the hazards related to working with PV systems and how to avoid them, know how to use safety equipment, and know how to respond to emergencies
- Implement general and electrical site safety measures
- Understand the nature of electrical hazards and their prevention
- Understand the nature of all PV hazards and how they relate to one another
- Understand battery safety
- Be familiar with personal protective equipment
- Understand the importance of body position and awareness
- Ensure proper personal and PV systems workspace
- Know general OSHA regulations related to PV systems, and their limitations
- Develop a PV safety checklist

Perhaps at the top of any safety checklist is attitude. Those who approach safety as a constant priority are far more likely to be safe than those who don't. Those who take the steps needed to ensure safe working practices are far less likely to encounter accidents than those who are careless or flip. Half the battle is wanting to be safe and acting accordingly. The rest is about learning how to act safely. That is what this chapter is about.

The Building Blocks of Basic PV Safety

Safety Culture

Perhaps the most important rule to remember regarding safety at a PV site is this: It can happen to you! Taking the proper attitude is one of the first steps toward creating a safe working environment. On a broader scale, the attitude that any one person may have about safety is probably most influenced by the culture at the workplace. As important as the bottom line is in any business, including PV systems installation, money won't matter much if someone gets hurt or killed on the job. That is why it is important to make safety a number one priority.

Yet the establishment of a safety culture on the job involves more than just attitude. Wanting to do the right thing

NOTE

A PV safety checklist is provided near the end of this chapter. As you are reading, see if you can create your own safety checklist and try to match it with the one provided here.

is important. Taking the steps to do so, especially in relation to safety, is just as important. That path to comprehensive safety at work involves various factors. From knowledge and planning, to establishing good habits and regular reviews, a safe work environment doesn't just happen. It takes dedication and vigilance to make sure everyone working on an installation site is safe.

The Human Factor

Even the best-intentioned employers and employees can get it wrong. Sometimes they lack the knowledge. Other times they may allow other goals, such as productivity, to cloud decisions related to safety. In the end, we're all human beings, which is why errors and accidents can happen in the first place. If we always got things right, there wouldn't be any need for safety measures at all. Of course, we do get things wrong, which is why a safety regimen needs to be in place and constantly worked at.

Knowledge

One can never have too much knowledge in the PV industry. This applies not only to safety, but also to every aspect of a PV system. The more you know about the various components of any system, the more you know about the various hazards that accompany them. Knowledge about the installation site is important, too, as is how the PV design applies to the site, what installation measures are needed, what safety equipment is needed, and so on. Yes, knowledge can be power, but it takes action so that knowledge can lead to a safe work environment.

In some ways, the path to safety is much like the building of a PV system. One step leads to another **FIGURE 2–1**. The right attitude toward safety can lead to a safety culture. This leads to the pursuit of knowledge. Knowledge, in turn, is essential in planning for a safe work environment and for effective communication.

Planning and Communication

You must not underestimate the importance of planning and communication to establishing safe working conditions. You are not really safe on the job unless you plan for safety. The safety plan is useless if you cannot communicate it to everyone involved. Planning and communication are also important in the event of an accident or injury. Installers should plan for these incidents in advance. They must also communicate these plans effectively. During accidents the plan must be executed properly. Communication is paramount throughout the process. When communication is good, everyone works from the same page. This not only leads to fewer accidents and injuries; it also leads to a work environment where confidence and security replace fear and worry.

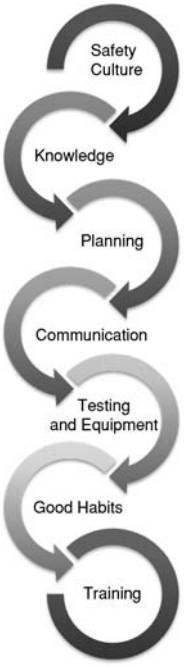
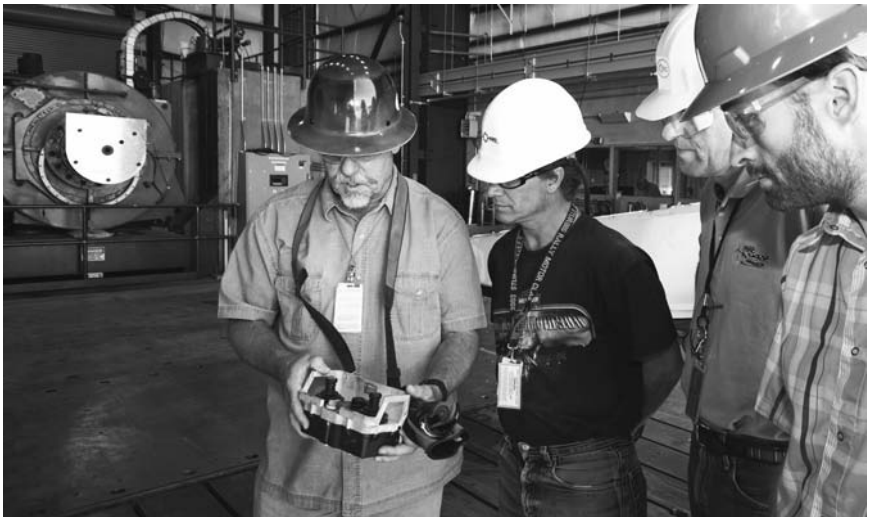


FIGURE 2–1 Basic safety

Every situation and work task is unique. In other words, no plan can anticipate every event. There is an old military saying: Every plan becomes obsolete the moment a campaign starts. The same goes for safety planning. You should continuously review the safety plan and revise as needed. Even with preparation, the plan might not be very good. Circumstances may also change. If a plan does change, you should communicate these changes to the team.



NREL hoisting and rigging safety training at the Dynamometer Test Facility (DTF) located at the NWTC

Courtesy of DOE/NREL

It's not a plan unless you can communicate it. If even two people interpret the same plan differently, then you have at least two plans. That can spell disaster in an emergency. Welcome and encourage any questions. An environment of open communication is essential to planning. It is a good practice for all PV installation teams to conduct a daily briefing that includes ongoing safety issues.

Testing and Equipment

Another basic requirement for a safe PV installation work environment is having proper equipment and testing. This involves knowledge and a safety-focused culture.

You will read about the specific equipment and testing involved in safe PV systems installation later in this chapter. You will also read about regulations on the need for proper safety training. PV systems come with specific hazards that require the right equipment and the proper testing of that equipment.

Good Habits

Many of the building blocks for basic safety don't amount to much without effective execution. Such execution comes with the development of good work habits

and practices. Such habits cover a wide range of behaviors. PV installers should never work alone. Having an extra set of hands and eyes can avoid tragedy. Always keep the work area clear of clutter, especially on rooftops where one trip can lead to a lethal fall. Workers should always be alert, skeptical, and patient.

Good habits produce predictable environments. Good habits must also include expecting the unexpected. Workers must never simply assume that everything will be OK. Never assume anything. Ultimately, you are responsible for your own health and safety. If something goes wrong, you can't blame others for what happens to you. It's a simple reality to remember when planning and working. You have to ensure your own safety on the job as well as the safety of those who work with you.

To summarize, these are the steps to take to develop safety habits on a job site:

- Don't work alone
- Keep workspace clear of clutter
- Be alert, skeptical, and patient
- Expect the unexpected
- Never assume anything

Regular Review

An overlooked aspect of safety on the job involves regular review. This, again, builds upon other aspects of safety, such as good habits, the right attitude—you get the idea. Perhaps most important, regular review builds on the idea of expecting the unexpected. You can't just make a one-time determination that everything is safe and expect to avoid accidents from there on. You may overlook some things unless you conduct regular reviews. This can help ensure that all comprehensive safety measures are in place.

First-Aid Training

Finally, another safety measure to address on all job sites is instruction in first aid. Emergency response is often overlooked but is essential in a PV systems environment. As you will learn shortly, some serious hazards await workers on a site. Even the best planning and foresight can still lead to accident and injury. In such circumstances, first-aid training that includes CPR (cardiopulmonary resuscitation) can literally be a lifesaver. You will learn about some of these emergency response measures shortly in the context of various PV-related safety hazards.

General Site Safety

Installers should apply the safety principles learned so far in this chapter to every work site. For each safety principle learned in this chapter, there is a specific precaution to consider. Let's take a look at some examples.

Before working on a specific site, find out what medical and emergency facilities are available nearby, or what measures would need to be taken in case of an injury. You should also inspect the site for hazards. You must mitigate or remove all hazards before work starts. For example, it might be a smart move at some point to check the junction box for snakes—while using the appropriate safety gloves and equipment.

When checking the site for possible hazards, also check for any available safety equipment such as a fire extinguisher or a first-aid kit. Industrial settings often have their own emergency facilities. Examine these, too. Remove any clutter or potential obstacles during the site inspection. Conduct these inspections with as many members of the team as possible. Again, a safety plan is that much better if it is communicated to everyone who will be working on site and will be depending on one another to get the job done safely.

A later section of this chapter will deal with site safety as it specifically relates to electrical hazards.

Personal Protective Equipment

Before learning about the specific hazards associated with working with PV systems, it is important to understand what **personal protective equipment (PPE)** is and how to use it to safeguard against unexpected events or accidents. The use of PPE by installers helps combat the hazards. No amount of preparation and planning can prevent all untoward events from happening. In those rare cases when something unforeseen does happen, the proper backup is the use of PPE. Proper planning and preparation ensures that installers are using the correct PPE for protection against any specific hazard.

PPE includes any equipment designed to minimize injury resulting from one or more hazards. It can also refer to equipment designed to detect the threat of such hazards. Installers should choose PPE that is designed for the specific hazards of the job. Some forms of PPE are designed for one specific hazard, such as fire, while other forms of PPE have multiple uses, such as protecting against chemical exposure and electrical shock. As the following section on hazards shows, various forms of PPE exist to combat specific PV systems hazards installers commonly face.

Hazards, Prevention, Safety Equipment, and Emergency Response

Given the fact that a variety of hazards are associated with working with PV systems, it is important to learn about these hazards and know how to deal with them. As with most aspects of safety, a focus on one aspect to the exclusion of others is undesirable. A comprehensive approach will involve knowledge,

preparation, and implementation. Perhaps most important, safety must be about constant vigilance. Simply assuming everything is safe is how accidents occur and injuries happen.

What follows is a checklist of the hazards involved in working with PV systems, the strategies used to avoid them, the equipment that may be used to protect oneself should anything go wrong, and the emergency response required in the event of an accident. Study this list and apply it wisely to the various situations you may encounter.

NOTE

PV professionals should remember that job hazards don't necessarily exist in isolated categories. For the purpose of simplicity and instruction, they are separated in this chapter and analyzed individually. However, sometimes more than one hazard can result from the same act, or the same injuries can occur from different hazards. For example, dropping a battery can result in a chemical leak and burn, electric shock, and fire. Similarly, a person can fall either from an electric shock or from tripping over a cable.

Electrical Hazards

Electricity is an obvious hazard related to working with PV systems. Whether the job is in a household or an industrial setting, everyone needs to be aware of the hazards involved working with electricity, and the measures used to minimize them. This is especially true of people who work with electricity for a living and manipulate the various devices involved in its production, storage, and usage.

Perhaps the easiest mistake to make when considering electrical hazards is to assume that only one type exists: electric shock. That is not the case. Various other hazards exist as a result of working with electricity and must be examined

ELECTRICAL SAFETY HAS COME A LONG WAY, BABY

Even though our understanding of electricity is very scientific, the ability to predict the impact of electric hazards isn't as precise. The earliest methods of testing a circuit for current involved tasting. A wire with a live current would produce a salty taste on the tip of researchers' tongues. When the taste turned into shock, a voltage hazard had been discovered. By then, of course, it was too late!

Similarly, much of the work performed by electricians in the early twentieth century was done by trial and error. Each practitioner would determine for himself or herself the safety measures to use when dealing with potential electrical hazards. Of course, because there was little shared knowledge or pooled experiences, the numbers of accidents and injuries at the time were unacceptably high.

Fortunately, the development of safe working procedures surrounding electrical professions, including PV systems installers, has improved. Advanced instruments are now used to detect the existence and strengths of current. Knowledge today about electrical hazards is extensive, and safety regulations and standards are now commonplace.

individually by PV professionals. Electricity can cause other behaviors to occur, such as muscle contractions, which in turn can lead to falls. The fall can be worse than the original shock. It is therefore necessary to know all the dangers associated with working with electricity, and how to avoid them.

Electric Shock

The Hazard Electric shock occurs when a person makes contact with an open and uninsulated source of electrical energy. The amount of current needed to pass through the body and cause shock can vary. It can depend on factors such as perspiration or the amount of conductive material in a person's shoes. The body itself is filled with conductive material, such as oxygenated blood. The nervous system carries electrical impulses to and from the brain, so the body's nerves can serve as vessels for electric shock.

At only 0.001 amps (.001A), a person will feel a simple tingling sensation. It only takes 0.02A of current to freeze muscles. Muscle freeze creates the additional hazard of making a person unable to let go and break the circuit. At 0.1A, ventricular fibrillation can occur. This is an uncontrollable contraction of the heart muscle that can be stopped only through medical intervention. At 0.5A, the heart can cease to function. At 1.5A, the skin can start burning, which further lowers the body's resistance and can lead to instant death.

Prevention There are various measures you can take to prevent electric shock from occurring on the job. In general, knowledge about electricity and wiring related to PV systems is a must. The more an installer knows about electricity, the more he or she knows about how to control shock and avoid it. Educating PV systems installers about various facets of electricity is an important goal of this book. Yet education must not start and stop here. Even before you go to a site, you must become familiar with the project. This includes understanding hazards and precautionary steps.

Additionally, any work site must contain the appropriate barriers, warning signs, and tags related to electrical hazards. For example, there must be barriers to prevent anyone from entering exposed areas without warning. Clearly mark all potential electric hazards with warning signs and labels. A **tag** is a common measure used to warn people not to turn certain electrical switches on during installation, repair, or maintenance. These tags are often accompanied by a **lockout**, which physically prevents a device from being turned on when workers are at risk.

Another basic safety strategy is to always assume that a PV system or its wiring is "hot," or electrically energized. Installers must avoid simply throwing a blanket over a module.

TECH TIPS

Lockout and tagging are common safety measures used when working with electrical components. A lockout is essentially a lock that is placed on the power source disconnect in order to physically prevent a closed circuit from forming. Tagging is a more subtle safety tactic but a necessary precaution. It involves putting tags on locations that can energize a circuit that is off and being worked on. Tags serve as a reminder to anyone working around the system that contact could put someone in serious danger.

Light could still pass through and generate electricity. Check the current and voltage of all wiring with the appropriate instrumentation. Do this very carefully, since many systems have modules connected in series. This means that, although the amperage can remain low, the voltage can increase dramatically and serve as a serious hazard.

Applicable Safety Equipment High voltage gloves can provide the body greater electrical resistance when exposed to a current. Appropriate measuring and testing equipment can help ensure that devices are safe to handle. Nonconductive footwear can further prevent a current from running through a person's body.

First-Aid and Emergency Response People suffering from electric shock can also suffer from muscle freeze, which leaves them holding onto the live conductor. All efforts must be made to separate the person from the conductor. To do this, turn the power off. If this isn't possible, then use an available grounding stick, or anything made of nonconductive material, such as wood, in order to free the person.

Once the victim is separated from the hazard, perform CPR on him or her. If the victim is breathing, has a pulse, and is conscious, then implement standard procedures for shock victims, such as laying the person down, raising his or her feet, and covering him or her with a blanket until medical personnel arrive. If the victim is in need of defibrillation, trained medical personnel should have the necessary equipment and expertise to perform the procedure.

There is a general approach to first aid that you should take regardless of the hazard or injury involved. Here are the steps you should take:

- **Maintain composure**—It's not every day that you are confronted with emergencies or life-threatening situations. Keep your cool, for yourself and the victim. Panic will only make a bad situation worse.
- **Scan the scene for continuing hazards**—If someone has been injured as a result of a hazard, anyone showing up on the scene to help could be at risk, too. Assess the area for ongoing risks, and address any hazards.
- **Separate the injured person from the hazard**—If the injured person is still in contact with the hazard, such as an exposed conductor, or even a swarm of wasps, make every effort to remove him or her from the hazard before starting first aid.
- **Assess the victim's status**—After you clear the victim from the hazard, check to see whether the pulse is breathing and has a pulse. What is the specific injury?
- **Know CPR**—This is a chapter on safety. It can provide you with only some general information about how to deal with emergency procedures. Ideally, *everyone* working on a PV systems site should know CPR and be able to apply it to accident victims.

- **Get help**—Attracting as much attention as possible to the scene of the accident can only help. You may be able to find someone able to call 911. It can also help in assisting the victim in other ways, including the providing of more first-aid knowledge, bringing needed supplies, or just providing an extra set of hands.
- **Know the shortest path to emergency care**—Finding out the location of and best route to the closest hospital emergency room or other facility should be part of your standard procedure every time you start work at a new job site. Delivering an injured person to a known health facility might save a life.
- **Keep a cell phone**—Always keep a cell phone nearby. You can use a phone to call emergency personnel to the scene and get immediate medical advice before they arrive.

Arc Flashes, Fires, and Related Burns

The Hazard An **arc flash** is an explosion that occurs as a result of an arc fault, which occurs when a short circuit has been opened but the fuse has not blown or the circuit breaker has not been tripped. A spark, or arc flash, occurs between connections, which can result in fires or even ultraviolet eye damage. Arc faults are more likely to occur between corroded or loose connections. As with electric shock, another danger with an arc flash relates to the reaction of the mind and body to the incident. The explosion may cause a worker to fall or jump into an even more dangerous position.

Arc faults are far more likely to occur with high voltage electrical systems. Since many of today's PV systems can produce up to 600V, the possibility of an arc flash is very real.

Burns can occur in varying degrees when working with PV systems. At one end of the spectrum, thermal burns are caused by metal and glass components exposed to the sun. Such components can reach temperatures of over 200 degrees Fahrenheit and cause burns if prolonged contact is involved. At the other end of the spectrum are severe burns caused by arc flashes, which contain plasma that can reach temperatures of at least 16,000 degrees Fahrenheit. In between these extremes, exposed electrical conductors, in conjunction with battery leaks and hot temperatures, can cause fires that result in serious burns in need of immediate treatment.

Prevention Arc flashes weren't recognized as a specific hazard until the 1990s. Knowledge of the phenomenon itself is the first step toward prevention. Although faulty equipment can cause an arc fault, arc faults are also often caused by human behavior. Standing too close to an electrical system, especially without protective gear, can be unwise. Additionally, arc faults are sometimes caused by loose

conductors coming into contact with one another. This is a result of parts not fastened properly or loose metallic tools creating a short.

Applicable Safety Equipment The kind of fire that can be produced by an arc flash is different from other types of fires. For that reason, the kind of PPE that should be used in protection needs to be different, too. Clothing specifically rated for arc flashes is available. The key to any protective clothing is that it not ignite, even if it allows thermal burns, which are far less dangerous than clothes that are on fire. Clothing must also provide the necessary protection without being too uncomfortable to wear. Uncomfortable clothing is less likely to be worn.

PPE related to arc flashes must include appropriate safety goggles that also protect from the extreme light emitted. Falls are also a risk stemming from arc flashes. That is why hard hats, harnesses, and other related safety gear must be used when arc flashes are a potential hazard.

First-Aid and Emergency Response The severity of any burns suffered differs in proportion to the nature of the hazard. Relatively minor burns where no blistering has occurred can be flushed with water and dressed with loose bandaging. You must treat more severe burns such as those often associated with arc flashes differently. If blistering or charring of the skin has occurred, the affected areas should only be cleaned of any large pieces of debris and bandaging applied loosely. You should not use water. You must notify emergency personnel immediately if an arc flash explosion results in an accident.

Testing for Voltage

Now that you have learned about electrical hazards you are ready to learn about additional preventive measures. One such measure involves the use of a voltmeter. As the name suggests, a voltmeter measures the amount of voltage that exists at any given point within an electrical system. This is important because anyone working with circuits must know if any voltage exists, and if so, what its strength is. This not only allows for safe working conditions, but it also helps assess if the system is working properly. If the system isn't testing as desired, PV workers should take steps to troubleshoot the problem.

Testing voltage is particularly important for some of today's PV systems. These use grid-tied inverters that handle high voltages at any point in time. Given that modules are wired together in series in order to produce ever-increasing amounts of voltage, relying on an ammeter alone can be dangerously deceiving. Adding more modules in series will keep the current at the same low reading, while significantly

NOTE

WARNING Testing for voltage can itself be a hazardous activity. Improper training in the use of testing equipment, or use of the wrong equipment, can lead to short circuits, arc flashes, or other electrical hazards. Always use equipment with the proper safety rating, including a DC voltage rating if using a voltmeter, or DC amperage rating if using an ammeter. Voltmeters that are available at some hardware stores, for example, do not meet industry recommended safety ratings.

increasing the voltage. An installer can be caught by surprise if he or she does not use a voltmeter to measure voltage. A surprise is the last thing you need when working with a high voltage system—or any electrical system.

A **digital multimeter (DMM)**, which can measure voltage, amperage, and resistance, is also used to test PV systems components. However, you must be careful when using a DMM. For high voltage systems, it may be safer to use a clamp-on ammeter to measure amperage. A DMM, which shorts a circuit to take the reading, can result in a large electrical arc. Use a clamp-on voltmeter when working with a system that contains high amperage levels.

Grounding

Grounding is another basic safety measure you can take to prevent unnecessary exposure to electrical hazards. Excessively high voltages or currents can have a variety of causes, including lightning or human error. To mitigate the effects of such electrical buildups, electrical workers can ground an electrical system in a way that allows the current to have a safe route to the ground. PV workers should ground individual components and the entire system. Proper grounding is simply another precaution to take that ensures the safety of any electrical environment and the people who encounter it.

Insulated Tools

Yet one more basic safety measure in preventing exposure to electrical hazards is **insulated tools**. An insulating material is anything that prevents the passing of an electric current through it. Insulation is the exact opposite of conduction. It follows that the tools that PV systems installers use should be made of insulating materials. Use rated insulated tools and never use them beyond their rating. For example, if a tool is rated at 1000V (AC), it must never be used for voltages higher than that. Insulated tools essentially provide an extra barrier between a person and an exposed conductor, but they are just tools. Also use insulated PPE beyond insulated tools, such as safety rated gloves and goggles.

Electricity-Related Site Safety

A previous section of this chapter dealt with steps involved in general site safety and inspection. This section will deal with those issues specifically as they relate to electricity. PV systems and installations must be approached step by step so that there are no surprises and so that risks and hazards can be minimized.

TECH TIPS

There is a distinction between an insulated tool and an **insulating tool**. An insulated tool is a normal tool that is insulated to protect a worker from electric shock. For example, a screwdriver with an insulated handle is an insulated tool. An insulating tool has a specific design that insulates a worker from an exposed electrical conductor. For example, place a hot stick on a live wire in order to further protect the worker from electrical exposure. A **hot stick** is essentially an insulated pole, usually made of fiberglass, used by electricians and others working on energized high-voltage electric power lines.

Today's hot sticks are not only for insulating use, however. They can have attachments at the end that allow for the testing of voltage, the tightening of bolts, the turning on and off of switches, or one of many other helpful functions. Just remember to use properly rated multipurpose hot sticks that perform their primary function well. That function is to insulate workers from electrical hazards. What is the point of being able to test for voltage if such voltage ends up injuring the tester?

Perhaps the first step to take in site electrical safety is to become familiar with the PV system design even before coming to the site. What is the configuration of the system? How many modules does it have? How are the circuits configured? What are the system's voltage and current? Does the system have any batteries?

Once on site, check the drawings against the actual system configuration. Do this with the installation team and the property owner. Make sure to note any differences. Review any possible changes with the client. Having this kind of knowledge of the system can help in avoiding the unexpected and expensive conflicts. Inspect all components of the PV system and be familiar with them. Check how to disconnect or turn the system off, including all switches and fuses.

To maintain proper site practices, never disconnect wires before measuring voltage. Do not leave disconnected wires exposed. Cover their ends with a wire nut or tape. Someone else must be close to a switch while disconnecting wires. Always keep hands dry and wear safety-rated gloves. Avoid clutter, since it might create confusion. Clutter can also increase the risk of distraction or physical mishaps. Inspect the site for any emergency equipment, such as fire extinguishers or first-aid kits. A first-aid kit must always be brought to a site and left at an agreed location. Familiarity with nearby emergency facilities is also a site priority. Any review prior to the beginning of work will increase safety and productivity.

Batteries

The Hazard Batteries are perhaps the most potentially dangerous hazard related to working with PV systems. Batteries constitute a triple threat to anyone who works with them. They can produce high voltage shock; the electricity and leaks of chemicals and acids can produce severe burns; the hydrogen gas that most PV systems batteries emit can be the source of serious explosions or fires. In addition, batteries are heavy to lift and can cause injury if dropped. You must use extreme caution when working near a battery.

Prevention Fortunately, there are numerous preventive steps that you can take when working with batteries. Always keep open flames, or anything that ignites, away from batteries. Do not use hats made of metal. Metal hats are conductive. Also, avoid using non-insulated tools. Ensure that the battery box is properly vented. Do not wear jewelry when working with a battery. Have baking soda handy to neutralize acid from spills. Have fresh water handy to flush any chemical splashes.

When dealing with batteries that have a base electrolyte, provide the proper neutralization equipment and chemicals to neutralize spills or leaks. Always take the time to thoroughly understand the batteries you are working with, including their installation, maintenance, and safety requirements.

Always keep batteries at level temperatures, and connect them to a PV system last in order to avoid unwanted electrical surges, chemical leaks, or splashes during installation.

Applicable Safety Equipment Safety equipment related to electric shock was covered earlier in this chapter. Regarding the chemical hazards related to batteries, workers must always wear PPE that physically protects the body from splashes and leaks. Such PPE includes any clothing made out of rubber, including gloves, boots, and an apron. Neoprene is a material that can specifically provide protection when you are dealing with open batteries. Also use carrying straps to lift batteries properly in order to avoid drops, spills, and explosions.

First-Aid and Emergency Response Having fresh water around when working with batteries is essential. Any chemical burn ought to be flushed with water, including any burn around the eyes, for up to 30 minutes after initial exposure. If the chemical in question is acid, then baking powder can also be used to neutralize the effects. You should apply a dry and clean bandage to any burns. This should be applied as loosely as possible. If someone has been internally exposed, have the victim consume water, milk, or other smooth liquids such as milk of magnesia or vegetable oil before getting immediate medical attention.

THE ENERGY DOCTOR'S BATTERY SAFETY GUIDELINE

Always test the battery voltage, configuration, and polarity three times before any circuit connections are completed and the battery circuit is closed. This accomplishes a number of goals:

1. It provides three opportunities to confirm voltage, configuration, and polarity.
2. It provides the time to determine if anything was overlooked in the installation that may result in serious electrical problems, such as direct shorts, improper wiring, loose connections, and damage to the battery or batteries. It also provides time to review the series parallel configuration.
3. It slows the review process down enough to see the battery array from a number of visual positions, which provides a further safety margin.
4. It may save your life, avoid serious debilitating injury to you, your coworkers, and the owner, and avoid a serious explosion or fire.

If you have ever seen a dead short in a battery system, or seen the aftermath of a battery explosion, you will find the guideline a reasonable method of improving safety practices around the thousands of amps stored in those batteries.

Falls

The Hazard PV system installers are exposed to falls in various ways. First, as has already been mentioned, falls can result from electric shocks that either freeze muscle reaction or cause workers to jump back and fall. Second, any job done at dangerous heights involves the risk of falling. Since PV systems are often installed on rooftops and other high locations the hazard of falling is a serious concern. Various other hazards can cause workers to engage in unwanted movements that cause falls, such as avoiding an arc blast or being swarmed by wasps.

Prevention A basic preventive measure in avoiding falls on the job is to ensure stable footing at all times. If using a ladder, plant it firmly on the ground and secure it properly. If working on a rooftop, remove all clutter and place extension cords so that nobody trips over them. Erect barriers on the edges of rooftops and cover any holes and fortify any vulnerable areas. Always working with someone else helps for the purpose of communication and help, if needed. Awareness is also a key to working safely in high places. After a while, a person can forget that he or she is working at a location five stories high. Such complacency must be avoided. You should always take steps to make sure that falls are unlikely. Any work that does not have to be done at a high location should be done on the ground.

Another important step in preventing falls is the choice of proper equipment. For example, ladders with insulated side rails can help protect workers from electric shock and, as a result, help prevent unnecessary falls. Always use the right ladder for the right job. If an extension ladder is needed, do not use a stepladder. Wait until the proper ladder is available for the job. Never use ladders on scaffolding. If you have to go higher, then build the scaffolding to the needed height. Always avoid shortcuts.

Applicable Safety Equipment Always use harnesses to avoid falls, especially at heights that can lead to serious injury or death. Safety nets are an additional piece of equipment that can provide not only added safety, but peace of mind. Use ropes at the top of extension ladders for fastening. Make sure to tie off the ladder to a stable surface. Hard hats and safety glasses, although meant more for protection against flying objects, can also provide protection against hitting other surfaces, or even tree branches, during falls. It also might not hurt—literally speaking—to wear some padding or extra clothing that can provide extra protection in case of a fall.

First-Aid and Emergency Response The most likely fall-related injuries include sprains, dislocations, and fractures. If the person is conscious and in serious pain, err on the side of caution and treat the situation as if a fracture has occurred. For fractures, you should move the victim into the shade. You should

also place him or her in a comfortable position. You can use a splint for an injury to the arm or leg, but only if the splint does not cause more pain. Any response must be quick in order to prevent shock or a worsening of the condition.

Other Hazards: Exposure, Bites, and Cuts

The Hazard There are a few basic concerns when it comes to PV installation sites. PV systems require ample access to sunlight during the day, which means that PV installers will be heavily exposed to the sun. Additionally, PV systems are often located in remote areas separated from utility grids. This doesn't mean that other locations aren't suitable or frequently used. It just means that PV systems installers will encounter certain unique environments in addition to more typical hazards.

As a result, PV systems installers must be on the lookout for hazards such as exposure, bites, and cuts. Exposure comes from being situated in areas without shading for extended periods—in both hot and cold weather. Being in either situation without proper preparation can be dangerous. Bites from various animals, including snakes and wasps, can be a danger. This is especially true since animals are likely to use junction boxes and other PV systems components for nesting. PV systems also involve components that can have sharp edges or hard surfaces. This can lead to cuts or bumps. These are sometimes very serious and require medical attention.

Prevention PV pros can take various measures to help prevent some of the unique hazards related to PV systems installation. To protect against exposure to sun or wind, and heat or cold, proper clothing is of paramount importance. Hats and sunscreen can help prevent sunburn or worse. Drinking fluids is also important. In the cold, ample clothing is important. Layering is often essential to maintaining correct body temperature as conditions change throughout the day. Workers must always be careful when working in areas that can conceal wasp or snake nests, in order to avoid bites. To avoid cuts and bruises, always use extreme caution when handling PV components. Using shortcuts is a recipe for having devices fall on people accidentally and cause unnecessary injury.

Applicable Safety Equipment Proper PPE protects against exposure, bites, or cuts essentially by providing appropriate covering of the skin or body. Thick gloves can provide some protection from cuts and bites. Hats can provide protection from the sun, and hard hats and safety shoes can provide protection from falling objects. Often the best form of protection from the hazards that Mother Nature has to offer is wisdom—wisdom to know what kinds of hazards exist in the air and underground, and what precautions against them you need.

First-Aid and Emergency Response If symptoms of heat exposure become apparent—such as cool and pale skin, dilated pupils, headaches, nausea, or

cramps—then the person should be taken to shade, made to lie down with feet raised, be given water to drink, and be covered with wet towels. If a victim suffers from cold exposure and symptoms include shivering, numbness, and dizziness, then take the person to a warm location. Provide warm liquids and remove any wet clothing immediately. Hypothermia, a condition involving dangerously low body temperatures, is a serious risk associated with cold exposure. You must have it treated by trained medical personnel immediately.

At least two types of dangers are associated with animal bites. First, allergic reactions can be serious, or even life-threatening. They need to be treated properly. Snakebites involve the injection of poison into a person's bloodstream. Snakebites are rarely deadly, as long as a person receives proper medical attention in a timely fashion. Trying to suck the venom out or tamper with the wound in any way only increases the chances of infection. Inform medical personnel about the kind of snakebite if possible. If a stinger from an insect is in the skin, remove it, wash the skin, and apply ice to the affected area.

Deal with cuts by applying direct pressure with sterilized or clean dressing. If bleeding continues, elevate the wound, find nearby pressure points, and then apply pressure. Apply additional pressure by using overlapping roller bandage to completely cover the wound. Pressure and clean dressing are crucial in preventing cuts from becoming more severe or life-threatening.

The Importance of Body Position and Awareness

Perhaps one of the more often overlooked aspects in any physical activity, and not just PV systems installations, is the importance of body position. Whether it be taking a swing with a golf club, or lifting a heavy box, one can make a task that much more efficient, and safer, by doing it with the proper body positioning.

Of course, safety and efficiency become all the more important when dealing with electrical systems. This is why body positioning also becomes more important. Although PPE can help in avoiding electrical hazards, as can testing for voltage or properly grounding a system, sometimes the most basic step involves knowledge and awareness about how one's body should be positioned in certain situations. Just knowing that a slight change can make all the difference is enough. Body positioning can help with nonelectrical hazards, such as falling.

Always survey the area where a task will be accomplished, and visually determine how to complete the task. Consider the space that is available, where to stand or otherwise position yourself, and what options are available before initiating the task. Always have at least one exit strategy.

Working with Electricity

Regarding electricity, all it takes is simple contact for any conductive material to become part of a circuit. This principle unfortunately also applies to the

human body. That is why body position is so important whenever a person is within the vicinity of an electrical system in any way. Just touching something that is touching a hot circuit will expose you to electric shock. This is particularly true when objects are moving. For example, if a ladder comes into contact with a wire, and you happen to be holding the ladder, then you risk becoming a part of the circuit themselves. This can result in severe electric shock. This is why it's a great idea to use nonconductive ladder.

Arc Flashes

The goal of body positioning is slightly different in regards to arc flashes. Not only must you be aware of what you are touching, but you must also be aware of where you are in relation to possible arc flash points. The danger with arc flashes isn't just touching them. You can suffer serious injury if you are merely relatively close to them. The risk with arc flashes is that much greater because human contact is often what causes them in the first place. Recognize where and when an arc flash may occur. It is also a wise practice to build a barrier or use existing natural or workspace barriers to prevent exposure.

Tools/Power Tools

Another aspect of body positioning and awareness you should consider is the handling of tools. Just as touching something can expose you to electric shock, so can holding a tool that is touching something. Similarly, something as seemingly innocent as dropping a tool on an exposed or vulnerable circuit can cause an arc flash, explosion, or fire. That is why it is important to handle all tools carefully. Never rush the job. Perhaps more important is having the awareness of body position to know where a tool should be positioned so that, if it falls, it falls in a relatively safe spot.

PV system installers also use power tools, which can create dust and even flying objects. You need the right body awareness to protect against this type of hazard, too. You need proper alertness, positioning, and PPE. Use all necessary safety precautions when handling power tools. This includes the use of guards and other protective measures that come with the equipment. You must be aware of the tools you are using and also have training in their proper use.

When Some Injuries Are Better Than Others

Although avoiding injury is the goal of job safety, and body positioning is important to reaching that goal, sometimes you need to consider which is the lesser of two evils when you react to a hazard. If moving a person's hand out of the way of a severe electric shock means you cut your hand, then take the cut on the hand. It's only human nature to want to avoid injuries of any kind. That is where awareness comes into play. If you are always alert and aware of the situation, then a split-second decision might result in an acceptable injury instead of a deadly one.

General Body Awareness

Also, remember that body positioning and awareness do not apply only to electrical hazards. Given that PV systems workers often work in elevated locations, the need for awareness can be that much more acute. Workers must not get complacent in any working condition. It can sometimes be easy to develop a sense of security if accidents have not occurred recently. Always maintain extra awareness in any situation where potential hazards exist. These activities can involve working with electricity or simply lifting objects from the ground.

Working Space: For PV Systems and Installers

There are two factors to keep in mind when considering workspace for installing PV systems.

First, there needs to be enough space and clearance for the PV system itself. In general, the workspace to install a PV system needs to be greater in width and height than the PV system. Additionally, greater voltages generally require greater clearances. These basic clearance provisions allow a worker to make his or her way around a system without being trapped, enclosed, or unduly exposed to hazards.

Second, there needs to be adequate space for the PV installer to do the work safely. Some jobs require the work to be done in confined spaces where access is limited. An attic is a good example of a confined space for installing a PV system. The PV system itself doesn't occupy an attic, but an installer might have to in order to complete some portion of the overall installation.

PV installers must take certain precautions when using a workspace. First, study the area carefully and plan extraction procedures in case of an emergency. Second, if you work in potentially difficult spaces, you should have at least one other person to help. Additionally, ensure proper ventilation and oxygen. This may mean bringing in special oxygen equipment. Wear additional protective equipment. This can include goggles and clothing that protects from particles that could fall, float, or fly through the air as the work is completed.

Safety Regulations, OSHA, and Beyond

Of course, safety is not simply of concern to PV systems practitioners. Safe working conditions have been an integral part of workers' rights for centuries, especially in potentially dangerous jobs. The United States government created the Occupational Safety and Health Administration Agency (OSHA) in 1970 to further regulate working conditions for people in industries ranging from commercial fishing to agriculture. Many of the provisions established by OSHA apply to construction and deal with issues such as electrical safety, fall prevention, tool use, and installation procedures. Many of these provisions apply specifically to work performed by PV installers.

There are certain rights and obligations that apply to workers under OSHA regulations. There are also certain standards that employers must follow. For example, OSHA consists of general provisions that ensure health and safety for all workers, including the requirement that all workers follow the employer's safety rules and use proper equipment and safety gear. Workers must also report certain violations and cooperate with on-site OSHA inspectors. Employers, for their part, are required to provide safe and healthy work environments, provide training, maintain safety records, and report accidents and fatalities. OSHA standards must be made accessible to workers. Today, they are also available on the Internet at www.osha.gov.

The OSHA regulations most relevant to those in the photovoltaics industry are those that apply to the construction industry. PV systems installers are construction workers, as far as OSHA is concerned.

OSHA regulations fall under Section 29 of the US Code of Federal Regulations (CFR). Part 1926 of Section 29 specifically applies to the construction industry. They are listed in the following manner: 29 CFR Part 1926, with specific subparts listed afterward. Some of these subparts are included in the following list, along with some of their specific applications:

- **Subpart C–General Safety and Health Provisions**—Requires employers to ensure that workers wear the proper protective equipment when dealing with hazardous devices or materials.
- **Subpart I–Tools: Hand and Power**—Requires the use of safe hand tools, including a provision that wooden handles be free of cracks and splinters.
- **Subpart K–Electrical**—Includes regulations that cover wiring methods, temporary wiring, proper coverings, extension cords, and so on.
- **Subpart N–Cranes, Derricks, Hoists, Elevators, and Conveyors**—Requires that any crane or lifting device used during an installation be operated by someone who is qualified.

However, Part 1926 isn't the only set of OSHA regulations applicable to PV systems. For example, Part 1910, dealing with general occupational safety and health standards, includes the following regulations that PV systems installers must consider:

- **Subpart I–Personal Protective Equipment**—Provides regulations surrounding insulating blankets, matting, covers, line hoses, gloves, and rubber sleeves.
- **Subpart J–General Environmental Controls**—Refers to "lockout/tagout" or the control of hazardous energy. In other words, any energy, including that derived from photovoltaic sources, must be controlled and provision made for possible surges.

- **Subpart K–Medical and First Aid**—Establishes regulations that employers must follow concerning the provision of needed medical personnel and facilities.

Although OSHA and other various safety codes and regulations are an important part of any safety arsenal, you must remember that they are only regulations. They come with the advantage of establishing rules that employers and workers follow. They are not perfect. They cannot possibly cover every single safety measure needed for every job. Additionally, they are not always updated quickly or even enforced consistently. Regulations and codes can help to keep employers honest, and employees safe, but they don't watch over you like a guardian angel. The right attitude, instilled work habits, and continued diligence are also needed.

A PV Safety Checklist

The following list is not a comprehensive checklist of all the issues involved in ensuring safety on the job. However, it does provide a basic summary of the safety measures discussed in this chapter. It can serve as an outline of the tasks to perform to ensure a safe working environment when working with a PV system.

- Know about the types of hazards associated with installing PV systems.
- Know CPR and first aid.
- Instill a culture of safety throughout the work environment.
- Hold daily briefings that include safety issues.
- Ensure workers always use good habits on the site.
- Do not work alone.
- Study the PV system design and schematic.
- Inspect the installation site and check for potential hazards.
- Check the area for emergency response facilities.
- Develop an installation and safety plan.
- Communicate the plan to the entire team.
- Test all equipment used on the site, including testing equipment.
- Implement prevention measures specific to the hazards involved.
- Ensure use of proper PPE for the job at hand.
- Test for voltage, implement proper grounding procedures, and use insulated tools.
- Always be aware of body positioning on the job.
- Ensure ample workspace for yourself and the PV system.
- Be familiar with applicable safety regulations, including OSHA.
- Ensure regular review of all issues related to safety—from knowledge and planning to implementation and emergency response.

Chapter 2 Summary

This chapter has provided an overview of the safety issues PV systems installers must be familiar with to do the job. Such safety issues start with establishing a basic safety culture at the workplace. This will then be a foundation on which other building blocks can be placed. Other basic safety measures include site safety and personal protective equipment (PPE). Safety regulations such as those found in OSHA are also important and useful, but only one part of a comprehensive approach to safety.

Electricity-related hazards, including electrical shock, are obviously important when dealing with PV systems. Yet they are not the only hazards involved. All hazards relate to one another in some fashion. Any approach to PV systems hazards must involve knowing the hazard, knowing how to prevent it, using the proper safety equipment, as well as the appropriate emergency response. Electrical hazards can be avoided through voltage testing, grounding, and using insulated tools. Body position and awareness also help maintain safety, as does ensuring space for the PV system and the people who will work around it.

Key Concepts and Terms

Arc flash
Digital multimeter (DMM)
Grounding
Hot stick
Insulated tool
Insulating tool
Lockout
Personal protective equipment (PPE)
Tag

Chapter 2 Assessment

PV Systems Safety

1. First aid training is one of the building blocks of basic safety.
   - ❑ **A.** True
   - ❑ **B.** False
2. You should avoid multipurpose personal protective equipment.
   - ❑ **A.** True
   - ❑ **B.** False
3. Which of the following is not safety equipment directly related to preventing electric shock?
   - ❑ **A.** Gloves
   - ❑ **B.** Footwear
   - ❑ **C.** Thermal clothing
   - ❑ **D.** Goggles
   - ❑ **E.** Hard hat

4. Why check a circuit for voltage? (*Select two.*)
- ❑ **A.** To test a voltmeter
- ❑ **B.** To determine if any voltage exists
- ❑ **C.** To calculate the amount of voltage that exists
- ❑ **D.** To test a digital multimeter (DMM)

5. You use an ammeter to verify the existence of voltage in a PV system.
- ❑ **A.** True
- ❑ **B.** False

6. What kinds of hazards are related to working with batteries? (*Select three.*)
- ❑ **A.** Ultraviolet light
- ❑ **B.** Electric shock
- ❑ **C.** Chemical leak
- ❑ **D.** Infrared light
- ❑ **E.** Fire

7. Which of the following liquids should you always have on hand when dealing with batteries?
- ❑ **A.** Water
- ❑ **B.** Acid
- ❑ **C.** Gasoline
- ❑ **D.** Liquid hydrogen

8. Which of the following substances should you have on hand when dealing with batteries?
- ❑ **A.** Baking powder
- ❑ **B.** Baking soda
- ❑ **C.** Salt
- ❑ **D.** Fiberglass

9. Victims should take which of the following liquids if chemicals have been ingested? (*Select three.*)
- ❑ **A.** Soda
- ❑ **B.** Water
- ❑ **C.** Milk
- ❑ **D.** Medicinal alcohol
- ❑ **E.** Vegetable oil

10. Use a _____ at the top of a ladder to secure it.
- ❑ **A.** rope
- ❑ **B.** harness
- ❑ **C.** nail
- ❑ **D.** hammer

11. Always assume it is a fracture if a person is in pain after a fall.
- ❑ **A.** True
- ❑ **B.** False

12. Snakebites are rarely deadly.
- ❑ **A.** True
- ❑ **B.** False

13. Which of the following must be applied to a cut? (*Select two.*)
- ❑ **A.** Cream
- ❑ **B.** Pressure
- ❑ **C.** Dressing
- ❑ **D.** Venom

14. The acronym for the government safety agency established in 1970 is:
- ❑ **A.** OSHA.
- ❑ **B.** OHSA.
- ❑ **C.** ASHA.
- ❑ **D.** AHSA.