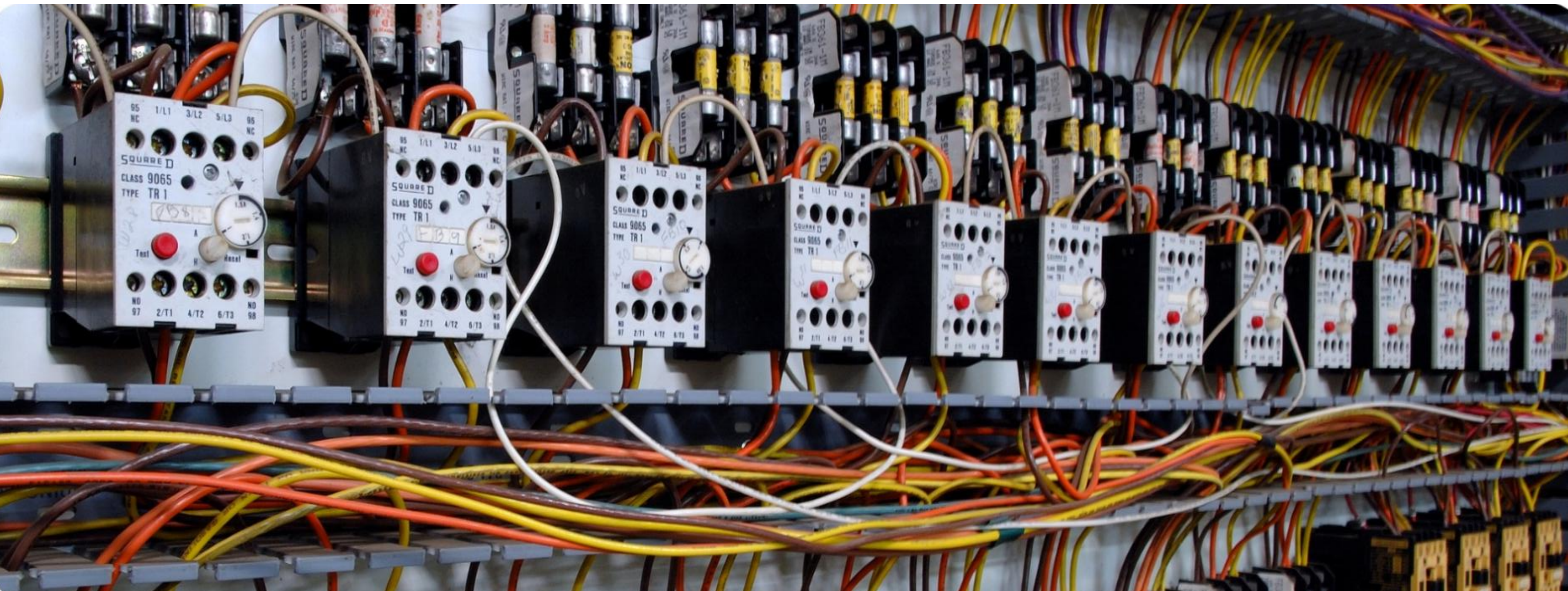
Transit Core Competencies Curriculum

Participant Resource Guide

Electrical Foundations

May 2026



Course Outline

- Module 1: Introduction to Electricity
- Module 2: Basic Electrical Principles
- Module 3: AC and DC Electricity
- Module 4: Circuit Components & Architecture
- Module 5: Magnetism and Electromagnetism
- **Module 6: Electrical Tools**
- Module 7: Safety and PPE

TWC Transit Workforce Center

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Course: Electrical Foundations
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Module 6 – Electrical Tools

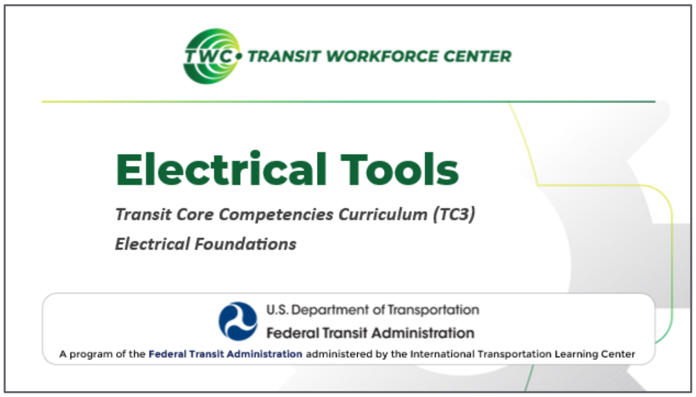
Objectives

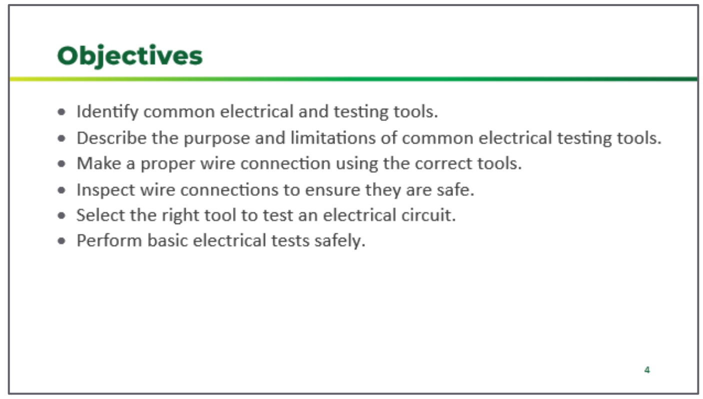
- Identify common electrical and testing tools.
- Describe the purpose and limitations of common electrical testing tools.
- Make a proper wire connection using the correct tools.
- Inspect wire connections to ensure they are safe.
- Select the right tool to test an electrical circuit.
- Perform basic electrical tests safely.

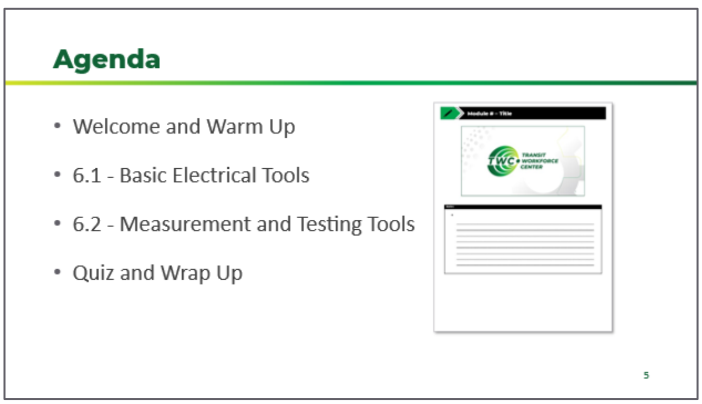
Key Terms

- Clamp Ammeter
- Electrical Tools
- Megohmmeter
- Multimeter
- Shrink Tubing
- Test Light
- Wire Connector
- Wire Crimper
- Wire Cutter
- Wire Gauge
- Wire Stripper
- Wire Terminal

Electrical Tools







Notes:

- Before we get into today's topic, let your instructor know if you have experience with these tools.
    - What they are and how you have used them?
- If you have never used theses tools below, that's OK too. You'll learn all about them in this module.

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Notes:

- Before we get into individual tools, it's important to understand what we're trying to accomplish.
- Electrical tools aren't used in isolation; they work together to create one reliable connection.
- A good electrical connection must be:
    1. **Mechanically secure** (won't pull apart or loosen)
    2. **Electrically reliable** (low resistance, consistent current flow)
    3. **Protected** from damage, vibration, and the environment

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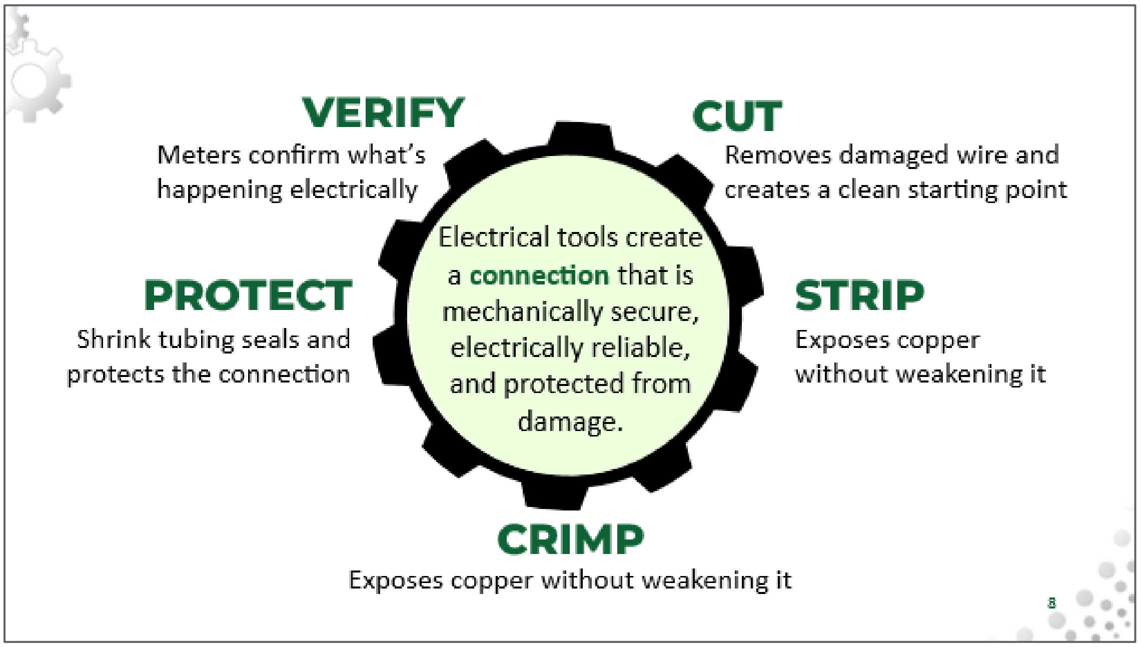

Notes:

- To achieve this connection, electrical tools work together to…
  - a) Cut – Removes damaged wire and creates a clean starting point
  - b) Strip – Exposes copper without weakening it
  - c) Crimp – Secures the wire to a connector so current can flow
  - d) Protect – Shrink tubing seals and protects the connection
  - e) Verify – Meters confirm what's happening electrically
- If any one of these steps is done poorly; the entire connection is at risk.
- Most electrical problems are not caused by bad components. They start at poor connections, often due to small mistakes early in the process. Now that we understand the goal, let's talk about wire thickness and the parts we're attaching wires to; connectors and terminals.

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Notes:

- This section covers the important basic electrical tools every mechanic should master.
- Errors made during cutting, stripping, and crimping cause many real-world electrical failures on buses and rail cars.

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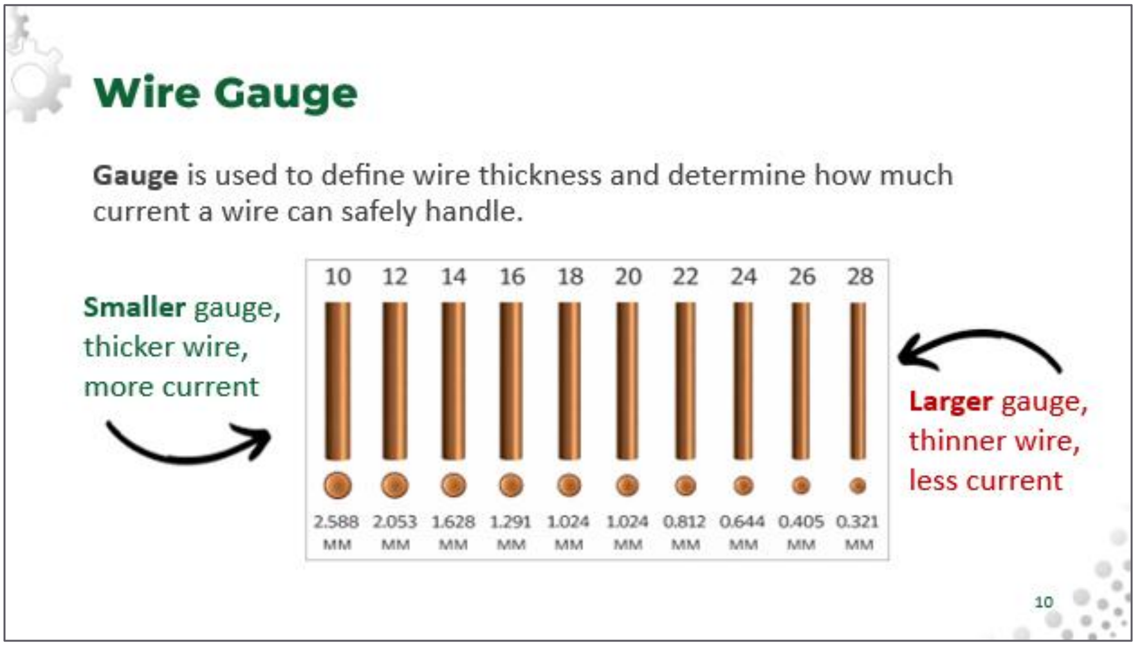

Notes:

- Gauge defines wire **thickness**, not length, and determines how much current a wire can safely handle. Wire thickness directly affects tool selection and connection quality.
- **AWG** stands for American Wire Gauge. It's the standard system used in the U.S. to identify the diameter (thickness) of an electrical wire. The AWG number will be printed on the wire.
  - The smaller the AWG gauge number, the thicker the wire, the more current it can handle.
  - The larger the AWG gauge number, the thinner the wire, the less current it can handle.
- In addition to current, wire thickness will also determine wire **stripper notch** to use and which **crimper and terminal size** are appropriate
- Take a look at the graphic. As the gauge number increases (10 → 28), the wire **gets thinner.**
- Thinner wire is easier to damage if the wrong tool or setting is used

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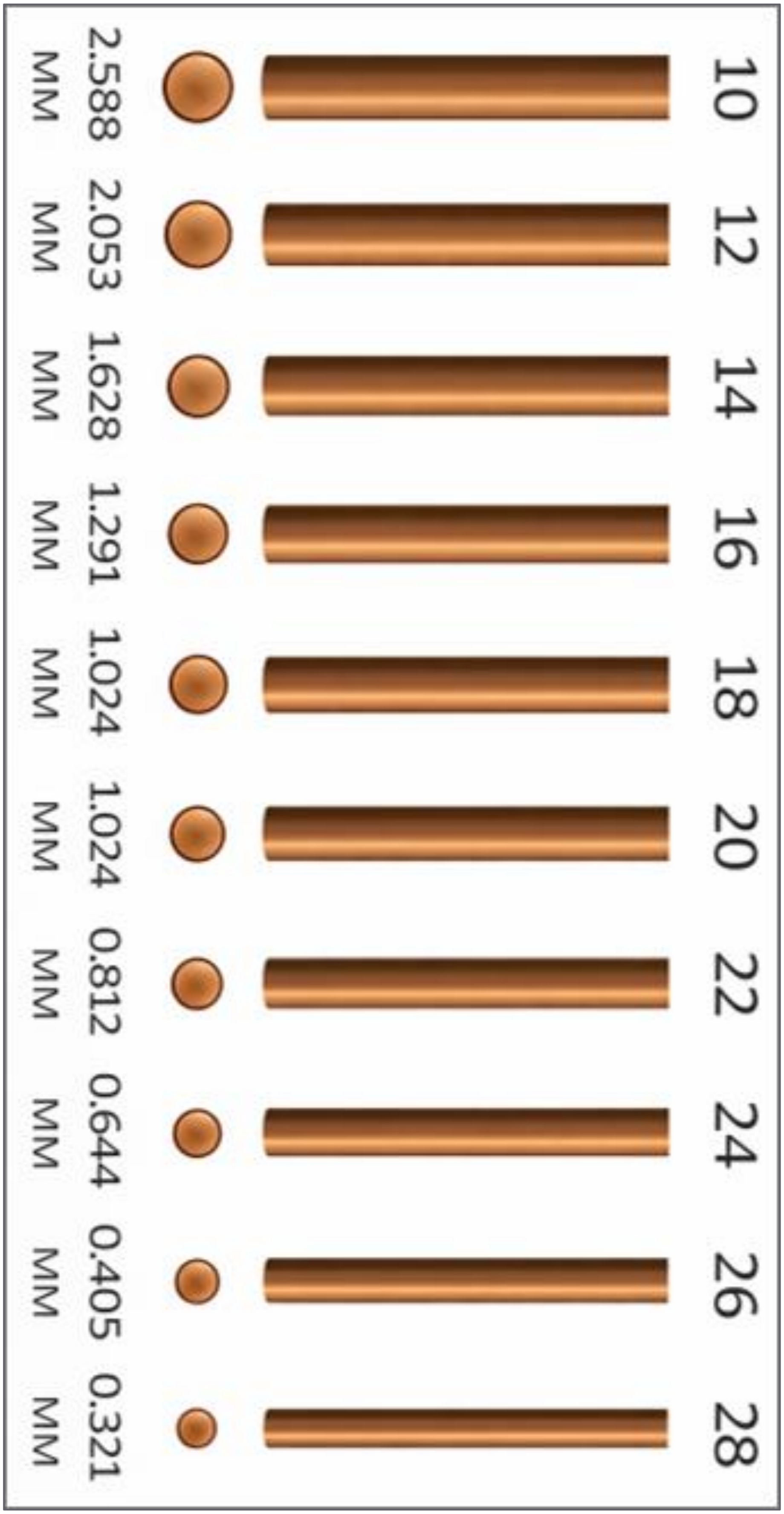
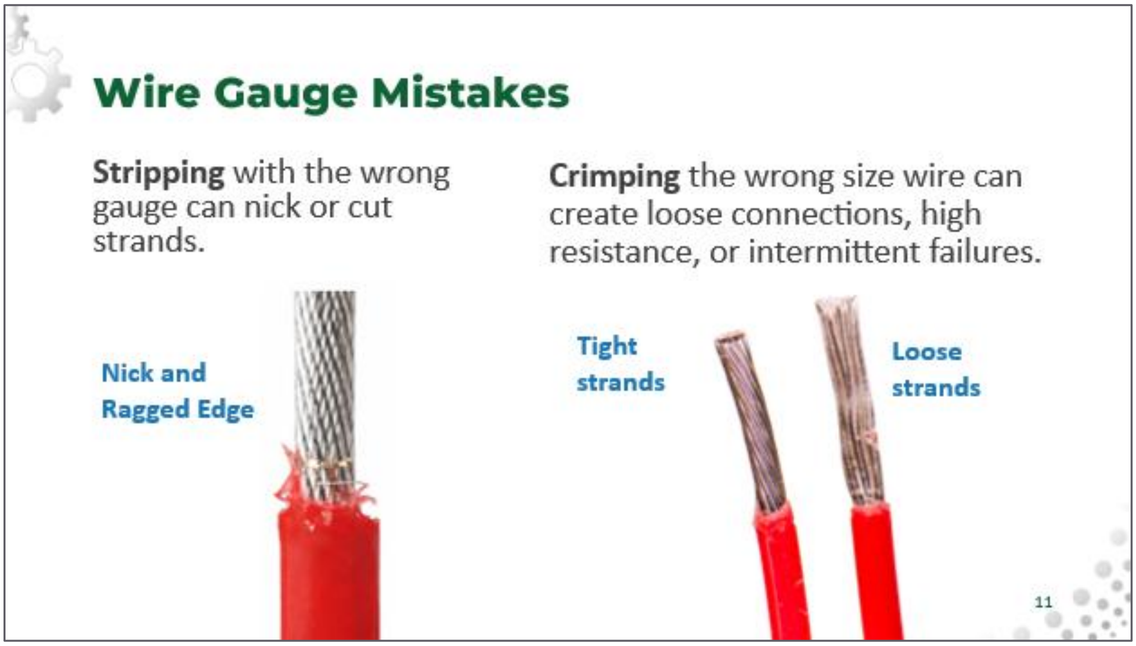
Wire Gauge Chart





Notes:

- Most wiring mistakes start with using the wrong gauge setting on a tool.
    a) **Stripping** with the wrong gauge can **nick or cut strands**
    b) **Crimping** the wrong size wire can create loose connections, high resistance, or intermittent failures.
- This is why you should never guess the wire size. Verify it by checking the markings, documentation, or by using a gauge tool.
- Wire thickness affects what kind of tools we use including wire cutters, strippers, and crimpers which we'll learn more about shortly.

1. Where do you usually find the wire gauge?
2. What should you do if you're not sure of the gauge?

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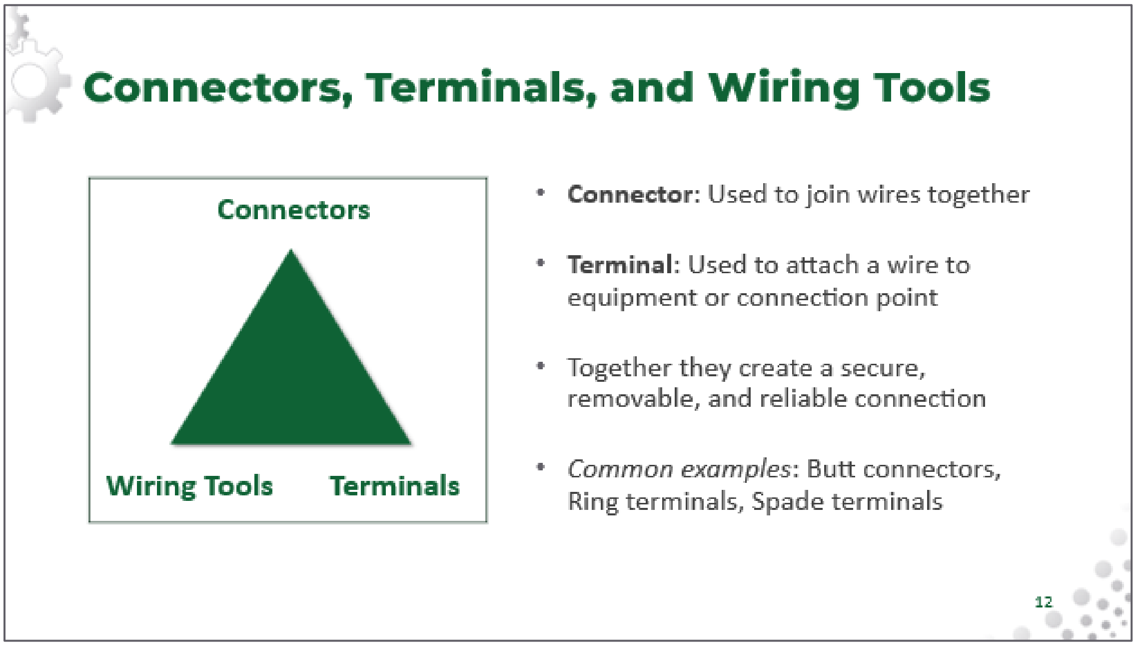

Notes:

- Recall what was said at the beginning of the lesson - electrical tools create a **connection** that is mechanically secure, electrically reliable, and protected from damage.
- Connectors, terminals, and wiring tools all play an important role in making that connection happen.
  - **Connectors** are used to join wires together.
  - **Terminals** are used to attach a wire to a piece of equipment or a connection point.
  - **Wiring tools** such as cutters, strippers, and crimpers are used to properly prepare and secure those connections.
- We use connectors and terminals to attach a wire to something. That "something" might be another wire, a component, or a connection point such as a stud, screw, or terminal block.
- When installed correctly, connectors and terminals provide a consistent, reliable contact point.
- They create a connection that can safely handle **current flow**, **withstand vibration**, and allow for **maintenance** or **replacement** when needed.
- **Common examples** you will see include butt connectors, which join two wires end-to-end; ring terminals, which attach a wire to a stud or bolt; and spade terminals, which slide under a screw or terminal block.
- It's important to remember that connectors themselves do not carry current independently.
- The quality of the wire-to-connector connection is what determines whether the circuit performs safely and reliably.

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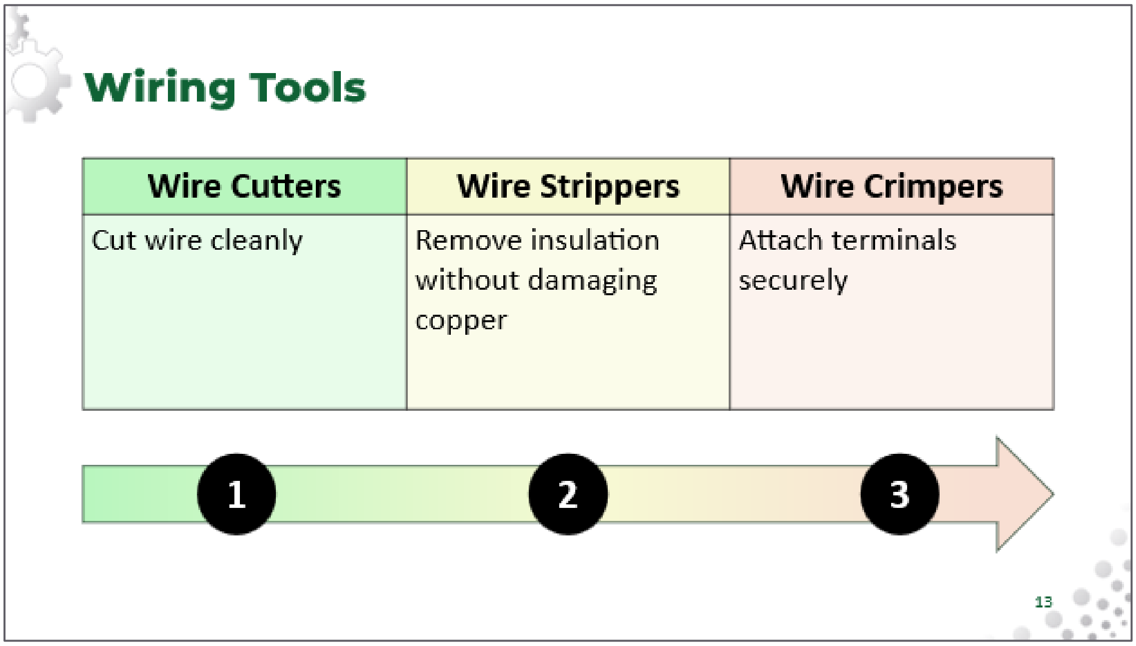

Notes:

- Electrical tools are not just for cutting and shaping wire. They are used to properly prepare and secure those connections.
- They protect current flow, system reliability, and worker safety.
- Three core tools to master include:
  1. **Wire cutters** which cut wire cleanly
  2. **Wire strippers** which remove insulation without damaging copper
  3. **Crimpers** which attach terminals securely
- You will always follow the same order. **Cut** – **strip** - **crimp**

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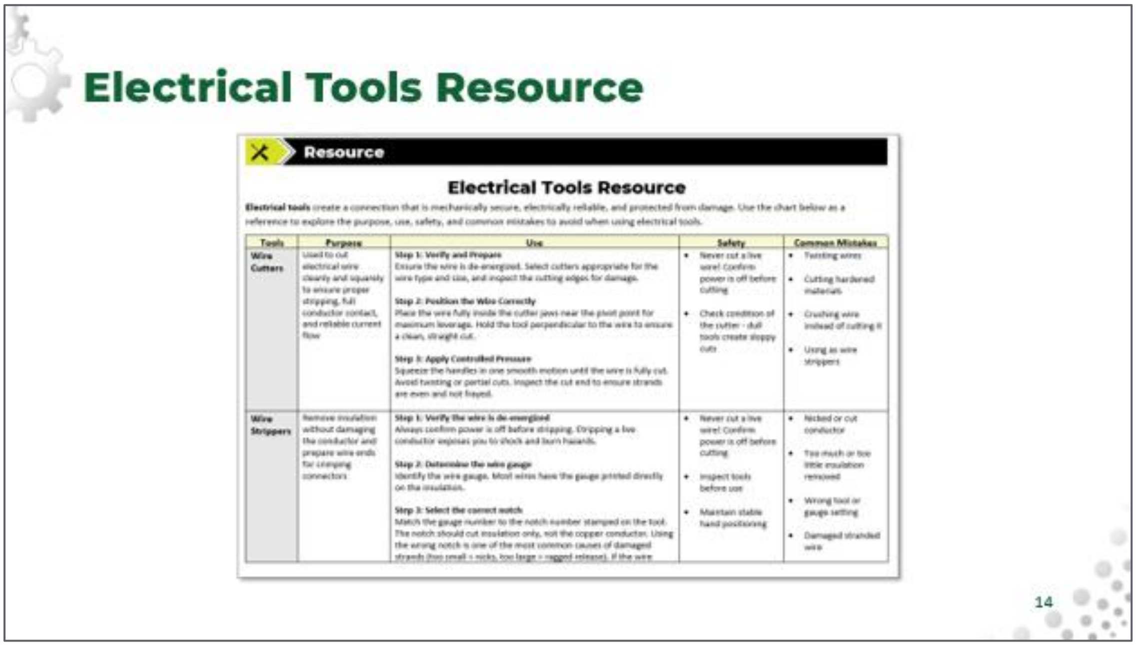

Notes:

- In this Participant Guide you'll find an "Electrical Tools Resource."
- Use this handout as a guide as we review the purpose and use of electrical tools along with safety best practices and common mistakes.

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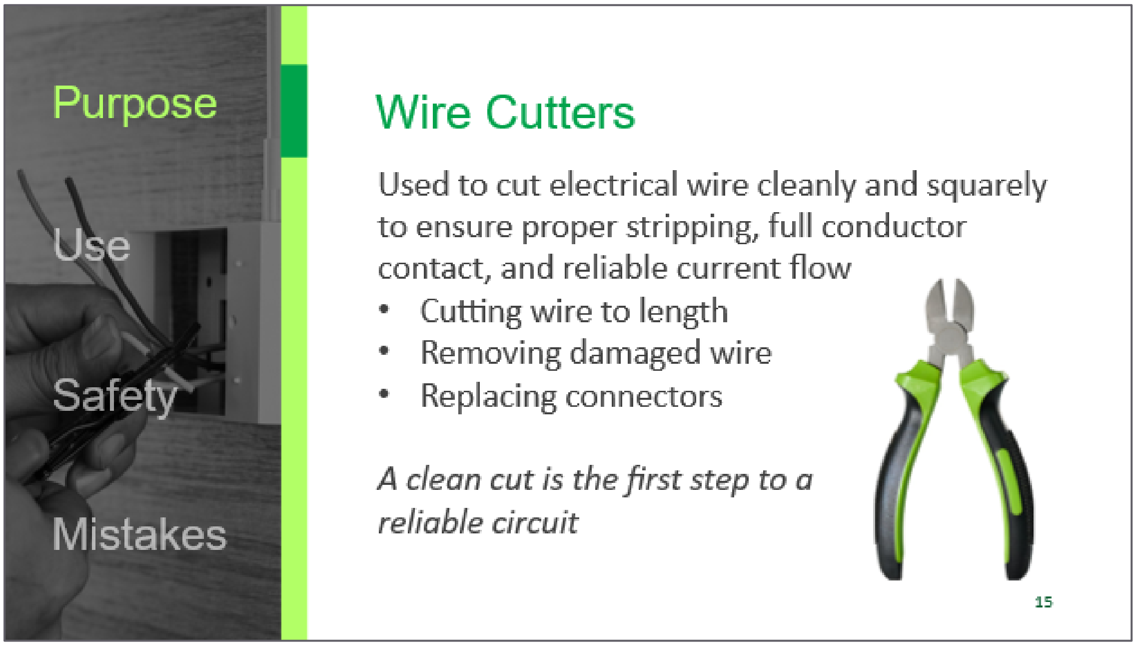
Resource

Electrical Tools Resource

Electrical tools create a connection that is mechanically secure, electrically reliable, and protected from damage. Use the chart below as a reference to explore the purpose, use, safety, and common mistakes to avoid when using electrical tools.

Tools	Purpose	Use	Safety	Common Mistakes
Wire Cutters	Used to cut electrical wire cleanly and squarely to ensure proper stripping, full conductor contact, and reliable current flow 	**Step 1: Verify and Prepare -** Ensure the wire is de-energized. Select cutters appropriate for the wire type and size, and inspect the cutting edges for damage. **Step 2: Position the Wire Correctly -** Place the wire fully inside the cutter jaws near the pivot point for maximum leverage. Hold the tool perpendicular to the wire to ensure a clean, straight cut. **Step 3: Apply Controlled Pressure -** Squeeze the handles in one smooth motion until the wire is fully cut. Avoid twisting or partial cuts. Inspect the cut end to ensure strands are even and not frayed.	• Verify the circuit is de-energized • Check condition of the cutter - dull tools create sloppy cuts	• Twisting wires • Cutting hardened materials • Crushing wire instead of cutting it • Using as wire strippers
Wire Strippers	Remove insulation without damaging the conductor and prepare wire ends for crimping connectors 	**Step 1: Verify the wire is de-energized -** Always confirm power is off to avoid shock and burn hazards. **Step 2: Determine the wire gauge -** Identify the wire gauge. Most wires have the gauge printed directly on the insulation. **Step 3: Select the correct notch -** Match the gauge number to the notch number stamped on the tool. The notch should cut insulation only, not the copper conductor. If the wire gauge is between sizes, start with the larger notch. Then check the results and adjust if needed. **Step 4: Remove the insulation -** Apply steady, controlled pressure and pull the insulation straight off. Do not twist or jerk the tool, as this can nick or stretch the copper. If the insulation does not release easily, stop and recheck the notch size before trying again.	• Verify the circuit is de-energized • Inspect tools before use • Maintain stable hand positioning	• Nicked or cut conductor • Too much or too little insulation removed • Wrong tool or gauge setting • Damaged stranded wire

Wire Crimpers	Attaches connectors or terminals to wires by compressing the conductor and terminal barrel together to create a secure mechanical and reliable electrical connection. 	**Step 1: Inspect the prepared wire -** Before crimping, inspect the strands, strip length, and insulation edge. The quality of the crimp depends on a clean cut, proper stripping, and correct tool selection. If the crimp isn't mechanically secure, it won't be electrically reliable. **Step 2: Select the correct terminal and die -** Select a connector or terminal that matches the wire size. Then choose the correct crimping die. Confirm whether the terminal is insulated or non-insulated. Always use the correct die (slot) size - Crimper dies are designed for specific wire gauges. Remember the sequence: wire gauge determines terminal type, and terminal type determines crimper selection. **Step 3: Insert the wire fully -** Insert the wire completely into the connector so all exposed strands are inside the barrel. The conductor should be fully seated before crimping. **Step 4: Complete the crimp -** Squeeze the tool firmly with steady pressure until the the barrel is fully compressed and crimp is complete. **Step 5: Inspect and test -** Every crimp should be followed by a visual inspection and a gentle tug test. If it pulls out, it fails. A proper crimp should hold under normal force	• Verify the circuit is de-energized • Inspect tool condition and die selection • Keep fingers clear of crimping jaws • Perform a visual inspection and pull test	• Connector too small • Too much insulation stripped • Excess wire not trimmed • Crushed crimp
Shrinking Tube	Contracts tightly around the wire or connection to form a snug barrier to protect crimps, splices, and exposed conductors. 	**Step 1: Slide Tubing Onto the Wire -** Place shrink tubing on the wire before installing the connector. **Step 2: Complete the Connection -** Crimp the connector onto the wire. **Step 3: Position the Tubing -** Slide tubing over the completed connection. **Step 4: Apply Heat Evenly -** Using a heat gun, evenly heat the wire until the tubing fully contracts. **Step 5: Inspect the Seal -** Confirm tubing has fully shrunk and verify adhesive has begun to flow at the ends.	• Verify the circuit is de-energized • Use controlled heat (heat gun) • Apply heat evenly and keep it moving • Avoid overheating • Allow connection to cool before handling	• Forgetting to slide tubing on *before* crimping • Using the wrong tubing size • Overheating the tubing • Uneven shrink or soft spots • Tubing too short to cover the full connection



Notes:

- Wire cutting is usually the first step before stripping and crimping. They are used to cut electrical wire cleanly and squarely to ensure proper stripping, full conductor contact, and reliable current flow.
- They are also useful for:
  - Cutting wire to the correct length
  - Removing damaged, corroded, or overheated sections of wire
  - And cutting off old connectors before installing new ones
- A clean cut is the first step to a reliable circuit.
- Crushed or frayed ends make stripping harder and lead to weak crimps.
- Wire cutters aren't just about length. They protect the conductor for everything that comes next.
- If you damage the conductor here, you won't see the problem immediately. It shows up later as heat, voltage drop, or intermittent issues.

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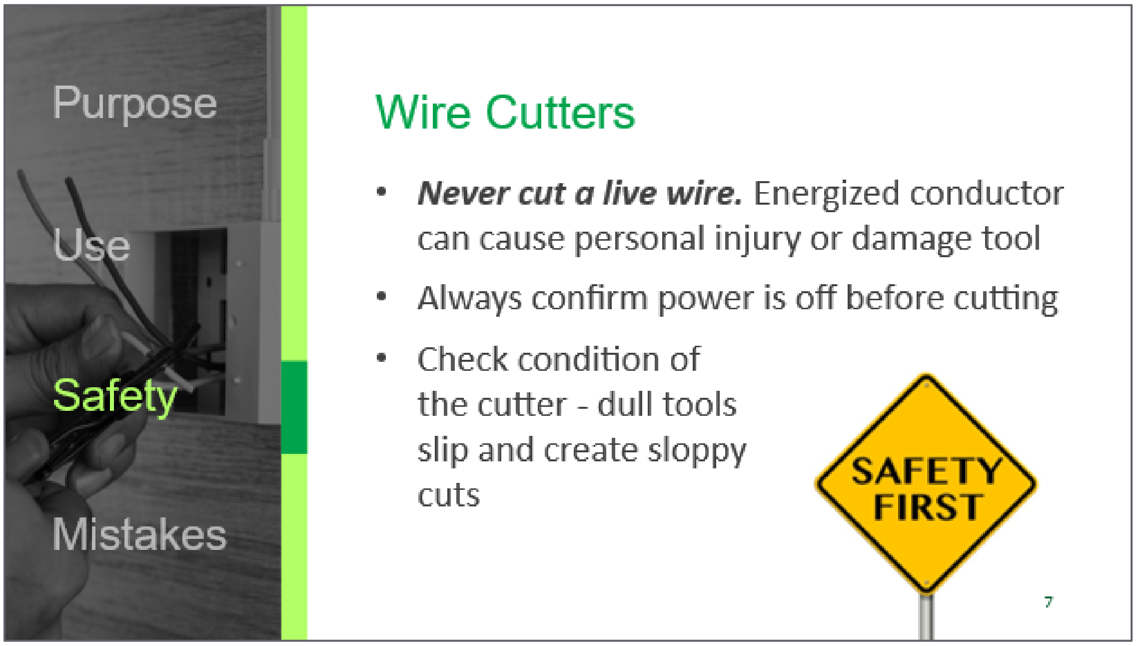
Notes:

- Using wire cutters take a little preparation and a steady hand.

1. **Verify and Prepare** - Ensure the wire is de-energized. Select cutters appropriate for the wire type and size and inspect the cutting edges for damage.
2. **Position the Wire Correctly** - Place the wire fully inside the cutter jaws near the pivot point for maximum leverage. Hold the tool perpendicular to the wire to ensure a clean, straight cut.
3. **Apply Controlled Pressure** - Squeeze the handles in one smooth motion until the wire is fully cut. Avoid twisting or partial cuts. Inspect the cut end to ensure strands are even and not frayed.



Notes:

- Wire cutters are simple tools, but can still cause injury or damage if used incorrectly
- ***Never cut a live wire****!* Cutting a live wire can cause arcing, tool damage, or injury. Even low-voltage DC can arc.
- Always verify the circuit is de-energized and confirm power is off.
  - Don't rely on labels or assumptions
  - Follow proper lockout/tagout and verification steps
- Inspect the cutter
  - Check for dull or chipped edges, misaligned jaws, or damaged handles
  - Dull cutters are more likely to slip or crush wire
- **Key takeaway**: Safe cuts start with power off and a tool in good condition.

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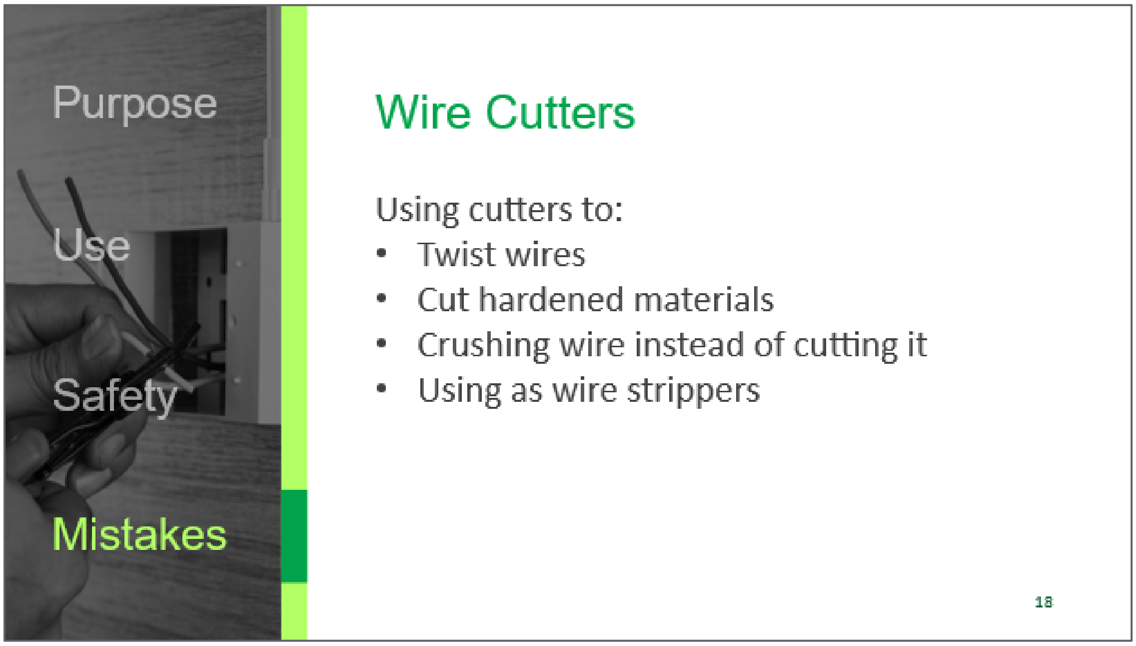
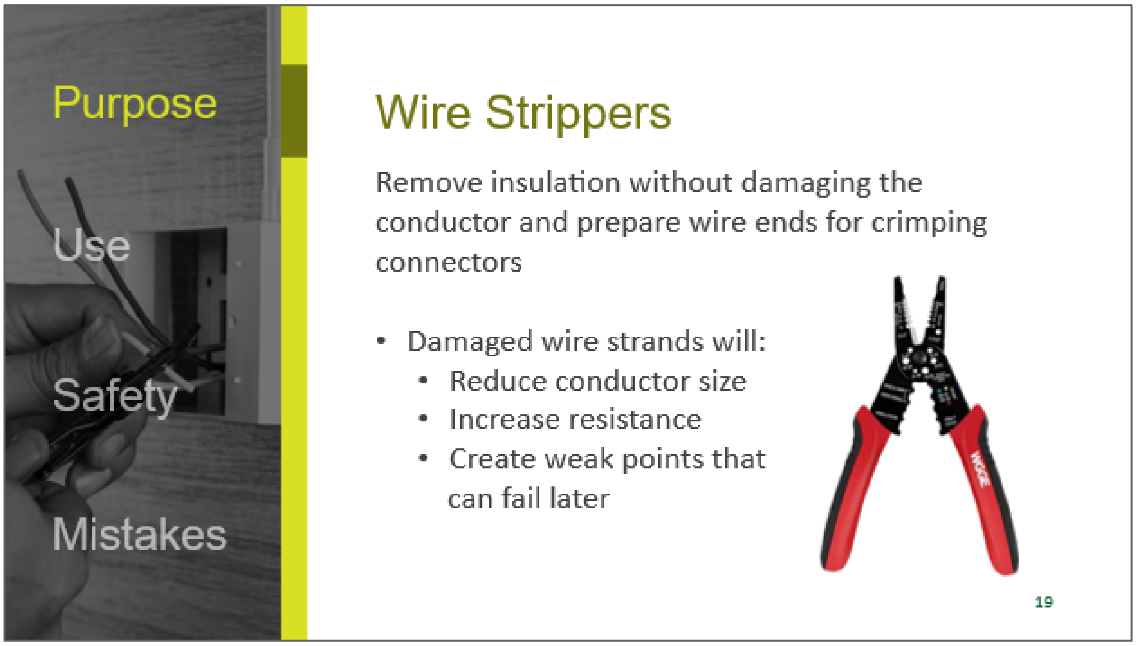


Notes:

- These mistakes damage the wire, the tool, or both. Small shortcuts here cause problems later.
- **Using cutters to twist wires**
  - Cutters are not made for twisting. Twisting can break strands and deform the wire.
  - Twist by hand if needed, not with cutters.
- **Cutting hardened materials**
  - Cutters are designed for copper wire only.
  - Cutting hardened materials dulls or chips the blades.
  - Damaged cutters lead to poor cuts on future wires.
- **Crushing wire instead of cutting**
  - Crushing flattens and damages the conductor.
  - Damaged wire is harder to strip and crimp properly.
  - If it won't cut cleanly, stop and inspect the tool.
- **Key takeaway:** A clean cut sets up everything that follows.



Notes:

- Stripping is where most electrical failures begin. If you nick strands while stripping, that weakens the connection.
- Wire strippers remove insulation without damaging the copper underneath, <u>but only if you use the correct notch for the wire gauge</u>.
- When strands are damaged:
  - The effective conductor size is reduced
  - Resistance increases
  - The connection becomes a **weak point** that can fail over time
- These failures often show up later as:
  - Intermittent issues
  - Heat at the connection
  - Vibration-related problems
- **Key reminder**: Stripping is about protecting the conductor, not just exposing copper.

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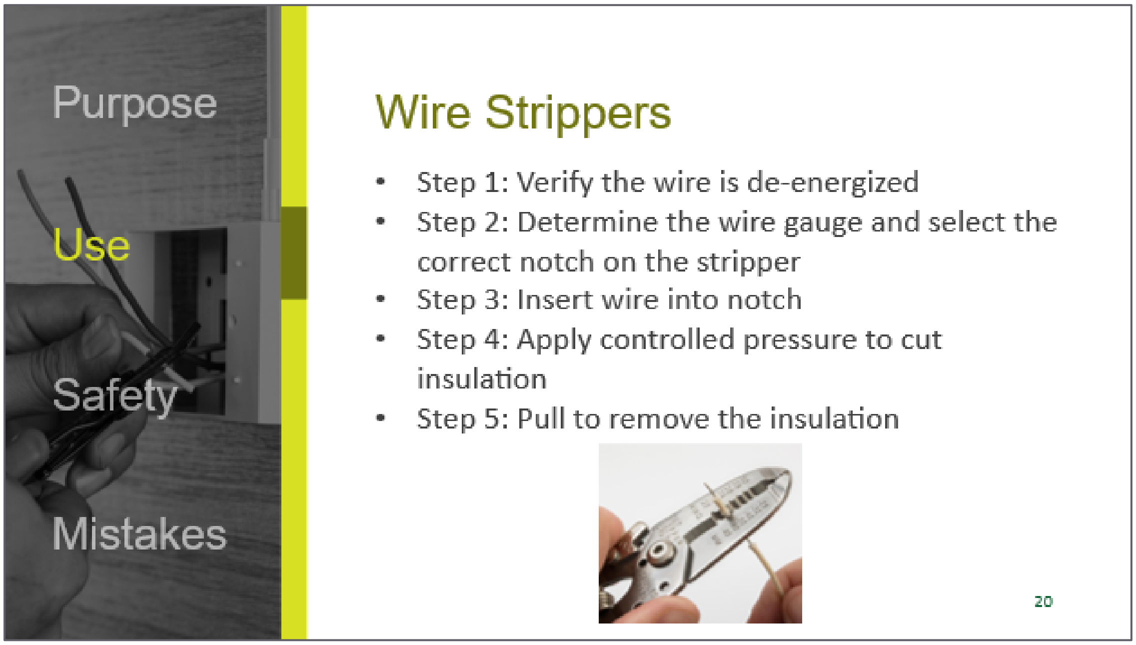

Notes:

- Using wire strippers is relatively simple, but each step is important.
- Before using wire strippers, always verify the wire or circuit is de-energized and safe to handle.
- Wire strippers are designed to remove insulation without damaging the conductor underneath.
- Wire strippers have multiple notches for different wire gauges. Using the correct notch is important to avoid nicking or weakening the wire.
- Insert the wire into the correct notch at the desired strip length.
- Apply controlled pressure to cut only the insulation layer. Too much force can damage the conductor.
- Pull the insulation off the wire to expose the bare conductor.
- If the conductor appears nicked, cut, or damaged after stripping, the wire should be restripped.
- Clean wire stripping is important for creating safe and reliable electrical connections.

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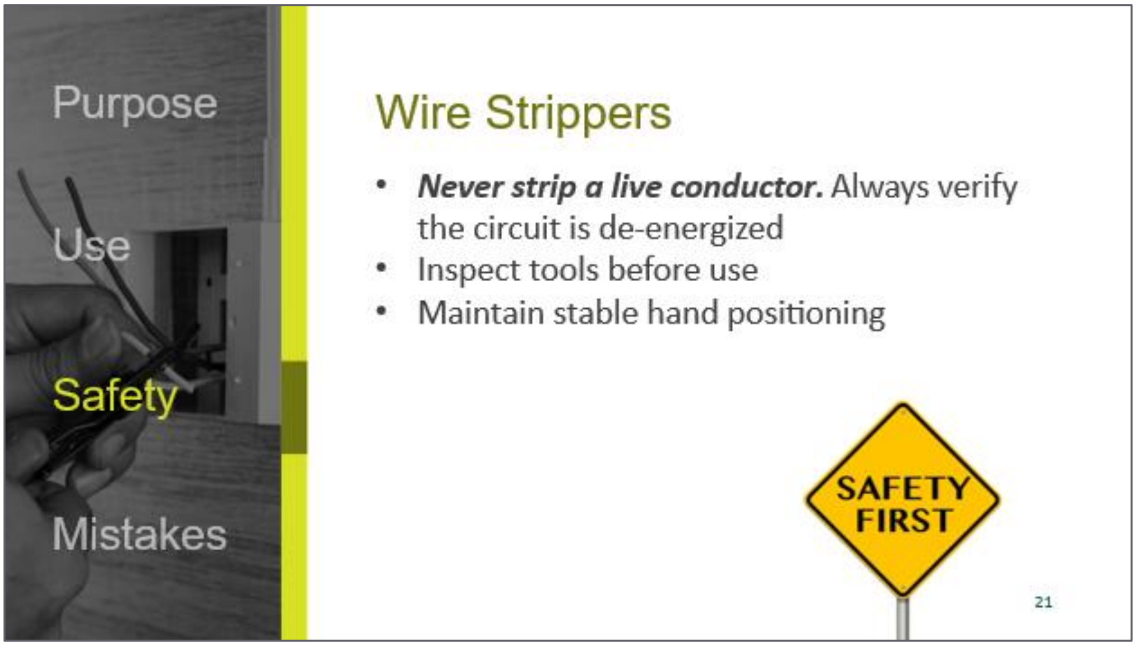

Notes:

- Stripping a live conductor exposes you to shock, burns, or arc hazards. Always verify the circuit is de-energized before stripping.
- Inspect your tools before use. If the insulated handles are cracked or damaged, your protection is reduced.
- Jerking the tool or using poor hand positioning can cause it to slip, leading to cuts or puncture injuries.
- Dull or misaligned blades require more force. More force increases the chance of losing control of the tool.
- Most of these injuries are preventable with inspection, proper technique, and verifying de-energization first.

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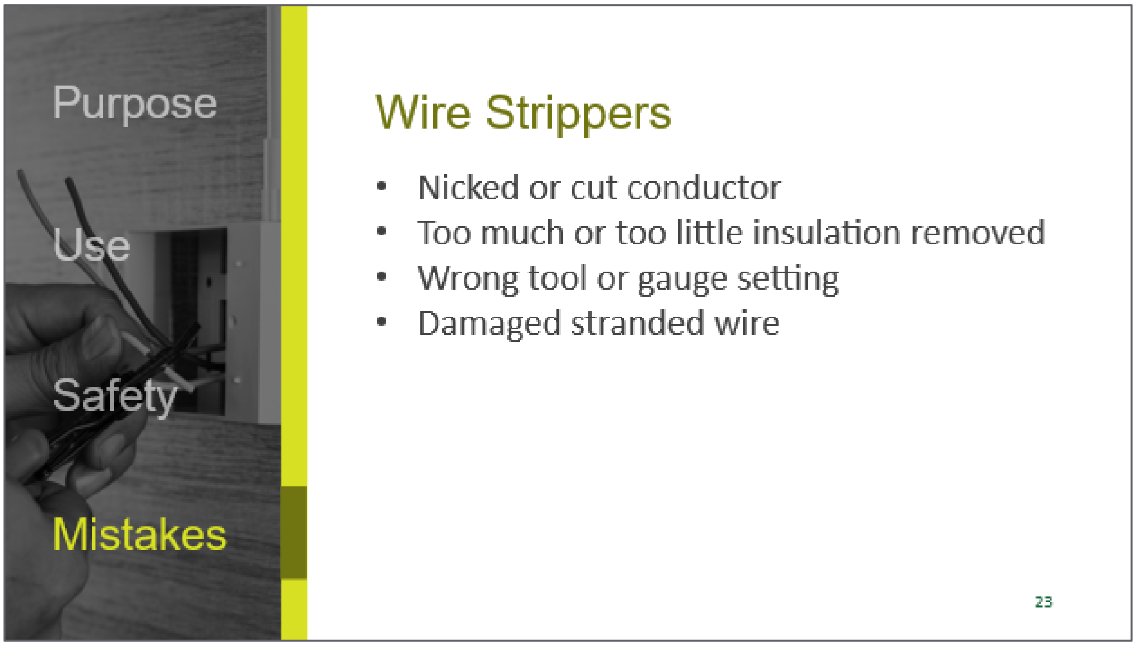
Notes:

- Most terminals used in transit require about a quarter inch of stripped wire.
  a) If it's too short, it will lead to a poor contact.
  b) If it's too long, it will lead to exposed conductor.
- The goal is for the copper to be fully inside the terminal barrel with insulation right up to the edge.
- **The insulation should be removed cleanly.**
  - The insulation edge should be smooth and even.
  - No torn or ragged insulation left behind.
- **All strands should be intact.**
  - Every strand carries current. Missing strands reduce capacity and weaken the connection.
- **There should be no nicks or cuts.**
  - Even small nicks increase resistance. Damaged strands are failure points over time.
- **Correct strip length**
  - Have enough bare copper to fully seat in the connector.
  - Be sure there is no exposed copper outside the terminal once crimped.
  - Inspect before you crimp because fixing it later takes longer.



Notes:

- These are some common reasons electrical connections fail after installation
- Many of these issues are hard to see once the connector is installed
- **Nicked or cut conductor**
  - Even small nicks weaken the wire.
  - Reduced conductor size increases resistance which can lead to heat buildup and eventual failure.
- **Too much or too little insulation removed**
  - **Too much** insulation removed leaves excess copper exposed.
    - This can increase the list of shorts and create a shock hazard.
    - This is especially dangerous in tight or vibrating spaces.
  - If **too little** insulation removed, it can prevent the terminal from making full contact.
    - This can result in a loose or high-resistance connection and causes intermittent problems.
- **Wrong tool or gauge setting**
  - Using the wrong notch crushes or cuts strands.
  - Sometime the damage may not be obvious until the wire is under load.
  - This reinforces the need to verify the gauge before stripping.
- **Damaged stranded wire**
  - Missing strands reduce current-carrying capacity.
  - This makes the connection more sensitive to vibration.
- If the wire isn't right after stripping, the connection won't be right later.

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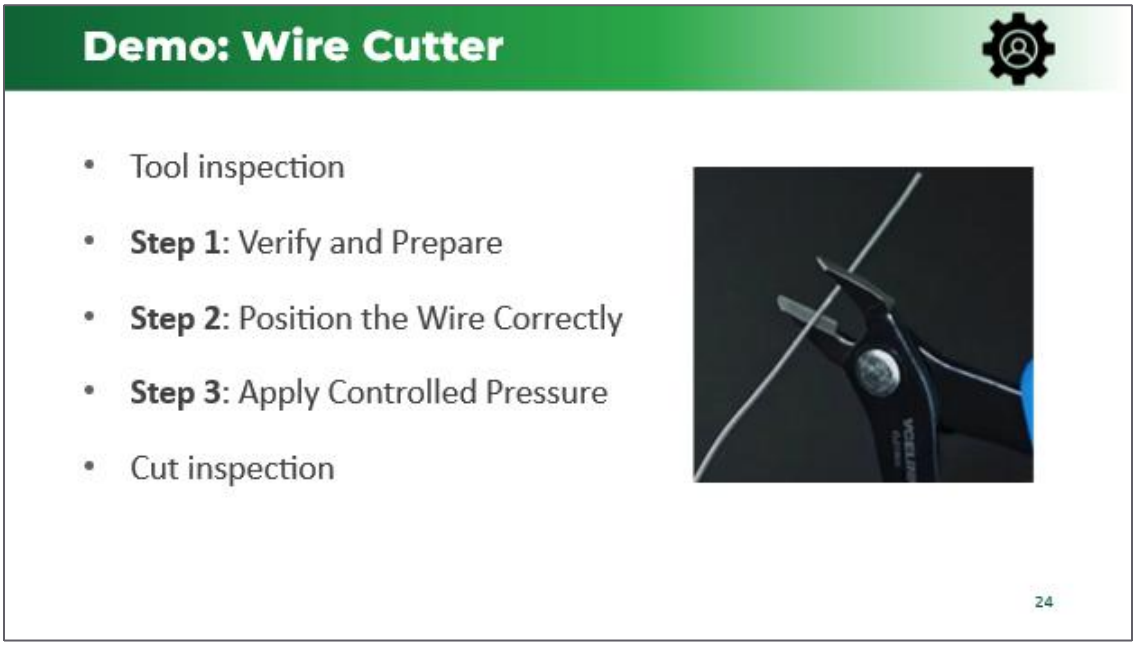
Demo: Wire Cutter
Tool inspection
Step 1: Verify and Prepare
Step 2: Position the Wire Correctly
Step 3: Apply Controlled Pressure
Cut inspection
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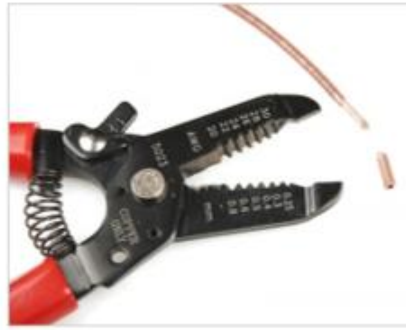
Demo: Wire Stripper

- Tool inspection
- **Step 1:** Verify wire is de-energized
- **Step 2:** Determine wire gauge
- **Step 3:** Select the correct notch
- **Step 4:** Remove the insulation
- Cut inspection



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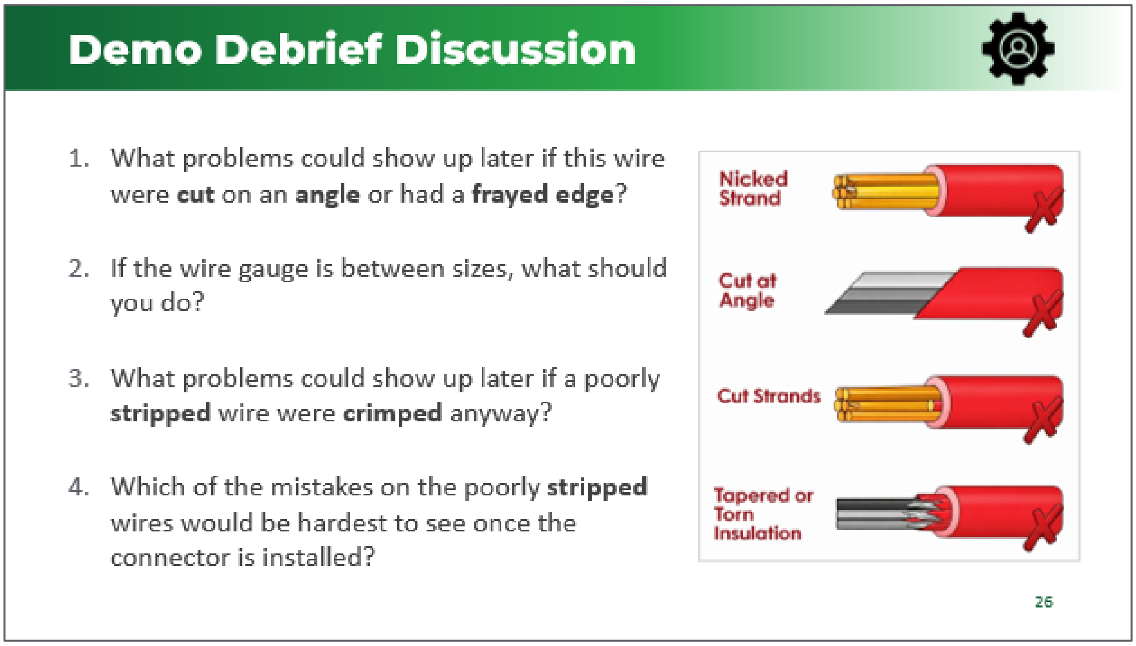

Notes:

- **Now a debrief discussion** using these questions:
    1. What problems could show up later if this wire were cut on an angle or frayed edge?
    2. If the wire gauge is between sizes, what should you do?
    3. What problems could show up later if a poorly stripped wire were crimped anyway?
    4. Which of the mistakes on the poorly stripped wires would be hardest to see once the connector is installed?

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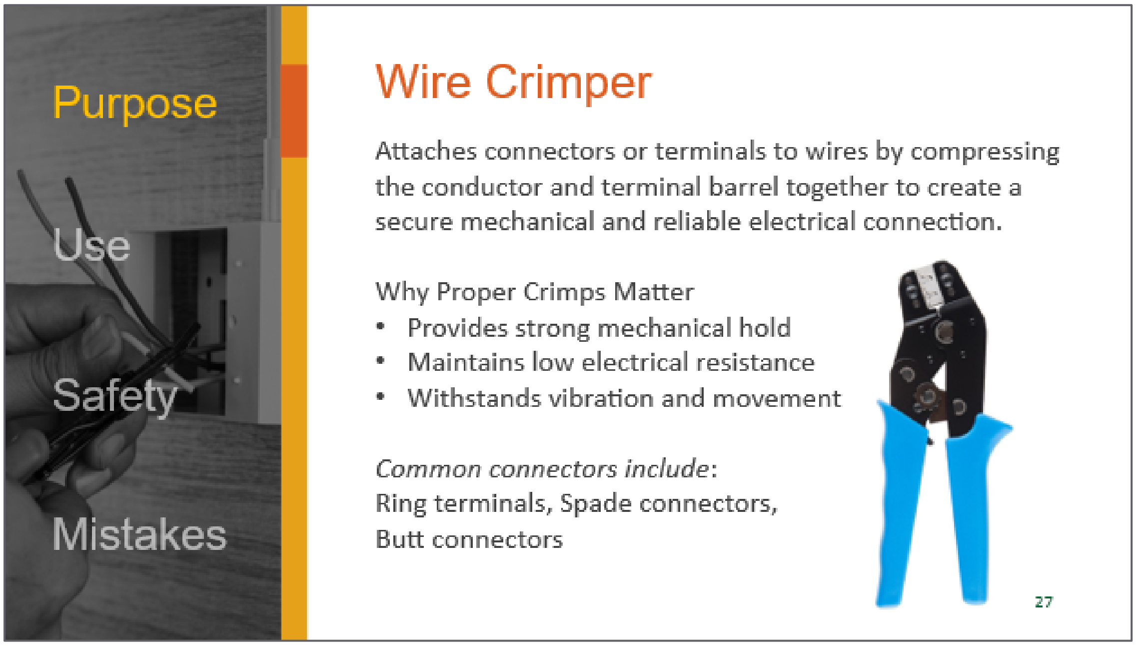

Notes:

- Crimpers are one of the most common and important tools in electrical work. Their purpose is simple: they attach connectors or terminals to prepared wires.
- This step turns a stripped wire into a usable electrical connection. A solid crimp is what makes these connections reliable.
- Crimping squeezes the copper conductor and the terminal barrel together. The goal is two things:
    1. A strong mechanical hold and
    2. A solid electrical path for current.
- A crimp isn't just holding the wire in place, it's carrying current.
- A proper crimp won't pull off under normal force, maintains low resistance, and survives vibration and movement. A poor crimp, on the other hand, is one of the most common causes of electrical failures.
- You'll commonly see connectors like ring terminals, spade connectors, and butt connectors. Each has a different job, but they all depend on one thing — a solid crimp.

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Notes:

1. **Inspect the prepared wire**
   - Before crimping, inspect the strands, strip length, and insulation edge. The quality of the crimp depends on earlier steps — a clean cut, proper stripping, and correct tool selection. If the crimp isn't mechanically secure, it won't be electrically reliable.
2. **Select the correct terminal and die.**
   - Select a connector or terminal that matches the wire size. Then choose a correct crimping die.
   - Confirm whether the terminal is insulated or non-insulated.
   - Always use the correct die (slot) size - Crimper dies are designed for specific wire gauges. If the die is too small, strands can be crushed or cut. If it's too large, the wire won't be held securely. Either mistake leads to loose connections, high resistance, and intermittent failures.
   - Remember the sequence: wire gauge determines terminal type, and terminal type determines crimper selection.
3. **Insert the wire fully.**
   - Insert the wire completely into the connector so all exposed strands are inside the barrel. The conductor should be fully seated before crimping.
4. **Complete the crimp.**
   - Squeeze the tool firmly until the crimp is complete. Use steady pressure and ensure the barrel is fully compressed.
5. **Inspect and test.**
   - Every crimp should be followed by a visual inspection and a gentle tug test. If it pulls out, it fails. A proper crimp should hold under normal force

Let's check in on how to use a crimper.

1. What happens electrically when a connection is loose?
2. If a crimp looks tight but used the wrong die, would you trust it? Why or why not?

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Notes:

- These are the minimum standards a crimp must meet. If it doesn't meet these criteria, it should be redone.
  a) **Connector tightly secured -** The connector should feel solid on the wire with no movement between the wire and the terminal. Any looseness means poor mechanical hold and poor electrical contact.
  b) **No wire pull-out -** Perform a gentle tug test. The wire should not slide or pull out of the connector. If it moves, the crimp has failed — even if it looks acceptable.
  c) **Correct crimp location used -** The crimp must be made on the metal barrel, not on the insulation alone. Using the wrong section of the tool can crush the barrel or leave the wire loose. This reinforces matching the wire gauge, terminal type, and crimper selection.
  d) **Insulation and conductor properly compressed -** The copper strands should be compressed inside the barrel without being cut. There should be no exposed copper outside the connector.

Notes:

- Crimping may seem low-risk, but there are both immediate and long-term safety considerations.
- First, always verify the circuit is de-energized.
  - Even though you're not cutting insulation at this step, you're still working on a conductor.
- Inspect the crimper before use. Check that the die is appropriate for the wire gauge and terminal type. Using the wrong die doesn't just affect quality — it can crush strands, create high resistance, and lead to overheating later.
- Keep your fingers clear of the crimping jaws.
  - Ratcheting crimpers apply significant force, and pinched fingers are a common shop injury.
- Apply steady pressure and let the tool complete the crimp cycle. Don't try to stop midway.
- After every crimp, perform a visual inspection and a gentle pull test. A crimp that isn't mechanically secure isn't electrically reliable.
- Remember — poor crimps are one of the most common causes of electrical failures. In transit environments, vibration amplifies small mistakes. A bad crimp today can become an equipment failure tomorrow.

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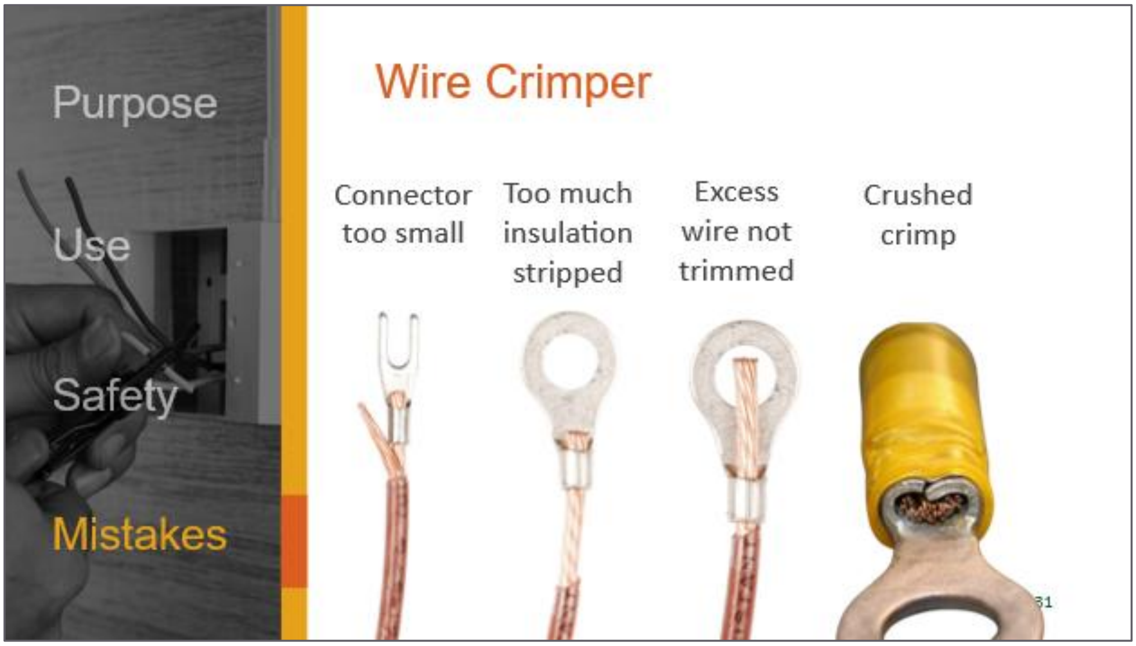

Notes:

- These examples look almost correct — and that's what makes them dangerous. These are common causes of intermittent electrical failures.
- **Connector too small**
  - If the connector is undersized, the wire won't seat fully in the barrel and strands may flare or bunch up.
  - An undersized connector creates high resistance and weak mechanical hold, which can lead to overheating, arcing, and potential fire hazards under vibration.
- **Too much insulation stripped**
  - Excess bare copper increases the risk of shorts and shock hazards. It also reduces insulation support inside the terminal, weakening the connection.
- **Excess wire not trimmed**
  - If copper extends past the terminal barrel, this usually means the strip length was incorrect. Copper extending past the terminal can contact nearby metal parts, creating hidden short circuits that may only appear after movement or installation.
- **Crushed crimp**
  - A crushed crimp happens when the wrong die size is used (usually too small) or when excessive force is applied, causing the terminal barrel to over-compress. This can flatten or deform the barrel and cut or severely compress the copper strands inside.
  - A crushed crimp reduces current-carrying capacity and can overheat or fail under load, creating dangerous intermittent or high-resistance faults.
  - If you see exposed copper or any looseness, reject the crimp and redo it.

1. Which of these would be hardest to catch without close inspection?
2. Which mistake is most likely to cause problems under vibration?

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Notes:

- There are three common types of crimpers you'll encounter, and selecting the correct one determines connection quality.
- An **insulated crimper** is used only with insulated terminals.
- The crimping areas are **color-coded** — red, blue, and yellow — to match common wire sizes.
- These tools are designed to crimp the metal barrel while also supporting the insulation for strain relief.

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Types of Crimpers

Non-Insulated Crimper

- For non-insulated terminals only
- Sized by wire gauge (no color coding)
- Creates tight metal-to-metal crimp
- Insulation added after (e.g., heat shrink)

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Notes:

- A **non-insulated crimper** is used with bare terminals.
- It creates a tight metal-to-metal crimp, but insulation or heat shrink must be added afterward.
- Because there's no built-in insulation support, technique and inspection are critical.

Notes:

- **Combination tools** are common in the field because they combine cutting, stripping, and crimping in one tool. However, each section has a specific purpose. Convenience does not replace correct selection.
- *One mistake shows up repeatedly* — mixing insulated and non-insulated crimpers. That leads to loose crimps, crushed barrels, and poor electrical contact.
- The decision rule is simple: wire gauge determines terminal size; terminal type determines the correct crimper.

Demo: Proper Wire Crimp

Goal: Distinguish between a **proper** crimp and a poor crimp

- Step 1: Inspect the prepared wire
- Step 2: Select the correct terminal and die
- Step 3: Insert the wire fully
- Step 4: Complete the crimp
- Step 5: Inspect and test

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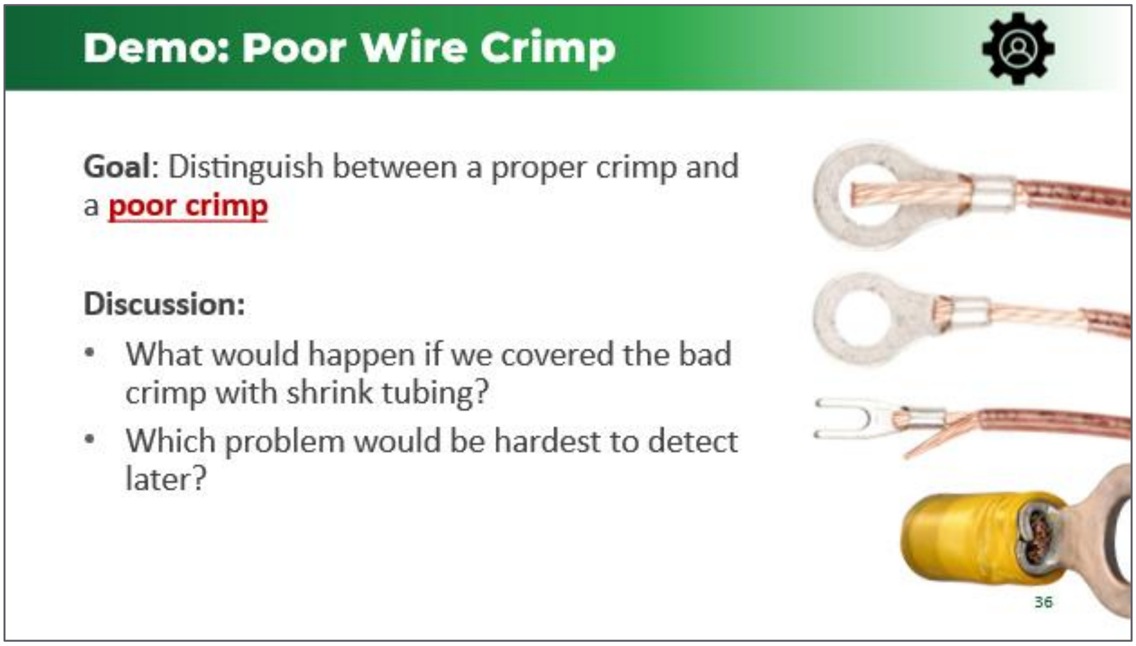

Notes:

- Key questions for after the demo:
  1. What would happen if we covered the bad crimp with shrink tubing?
  2. Which problem would be hardest to detect later?

Notes:

- Shrink tubing is used after the electrical connection is complete.
- When heat is applied, shrink tubing contracts tightly around the wire or connection to form a snug barrier to protect crimps, splices, and exposed conductors.
- It does not carry current, and it does not improve a bad crimp. Its job is to protect good work.
- Electrically, this matters because shrink tubing provides insulation protection. It helps prevent shorts to ground, moisture intrusion, and corrosion at the connection.
  - This is especially important in environments with vibration, moisture, and temperature changes.
- It's critical to reinforce the sequence: shrink tubing protects a good connection but won't fix a bad one.
- Always inspect the crimp *before* applying shrink tubing. Once the tubing is applied, problems underneath are much harder to see.

1. What problems could show up if we skip shrink tubing?
2. What happens if we cover a loose crimp with shrink tubing?

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Notes:

1. Slide Tubing Onto the Wire - Place shrink tubing on the wire before installing the connector.
2. Complete the Connection - Crimp the connector onto the wire.
3. Position the Tubing - Slide tubing over the completed connection.
4. Apply Heat Evenly - Using a heat gun, evenly heat the wire until the tubing fully contracts.
5. Inspect the Seal - Confirm tubing has fully shrunk and verify adhesive has begun to flow at the ends.

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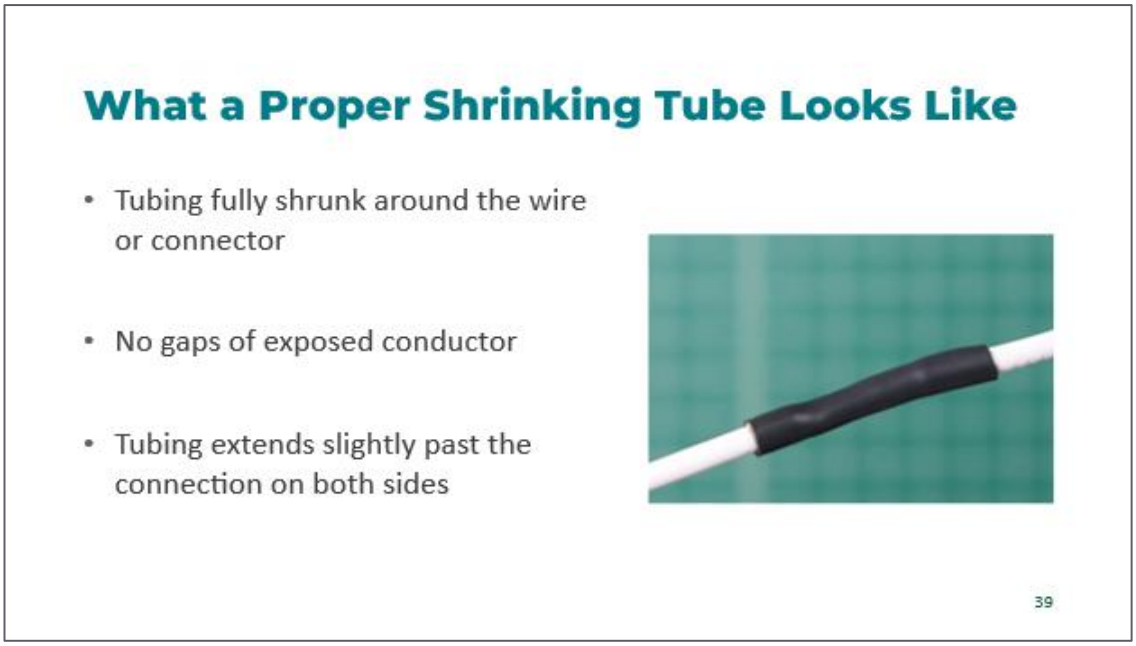

Notes:

- This slide shows what an acceptable, finished connection should look like. Shrink tubing is the final protection step.
- First, the **tubing should be fully shrunk** around the wire or connector.
  - It should fit snug and uniform with no loose sections or soft spots. An even shrink pattern tells you heat was applied in a controlled way, not overheated in one spot.
- Second, there should be **no exposed conductor**. All copper and metal should be completely covered.
  - Any exposed copper creates both a shock risk and a short-to-ground risk. If copper is visible, the tubing should be redone.
- Third, the **tubing should extend slightly past the connection** on both sides.
  - This provides insulation, strain relief, and helps keep moisture and contaminants out. It also shows that the tubing was sized and positioned correctly before heating.
- Shrink tubing protects the connection after the electrical work is complete, but only if it's installed correctly.

1. What could happen if shrink tubing stops right at the connector?
2. Why is it important that we don't see any copper here?

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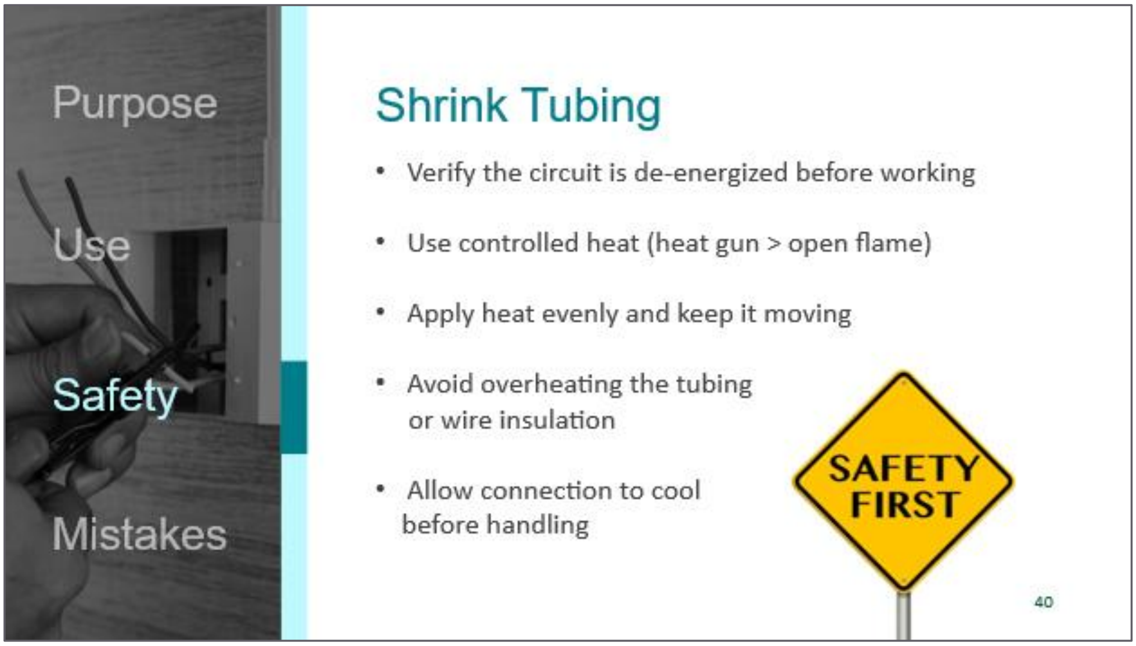

Notes:

- When it comes to safety, we start as we always do, by verifying the circuit is de-energized before applying shrink tubing. Even though you're in the protection phase, you're still working on a conductor.
- Use controlled heat such as a heat gun, never an open flame. Open flames can damage insulation, overheat connectors, and create fire hazards.
- Apply heat evenly and keep the heat source moving. Concentrating heat in one area can scorch the tubing, melt insulation, or damage the connection underneath.
- Avoid overheating. If tubing bubbles, burns, or splits, it has been overheated and should be replaced.
- After shrinking, allow the connection to cool before touching it. Recently heated connectors and conductors can cause burns.

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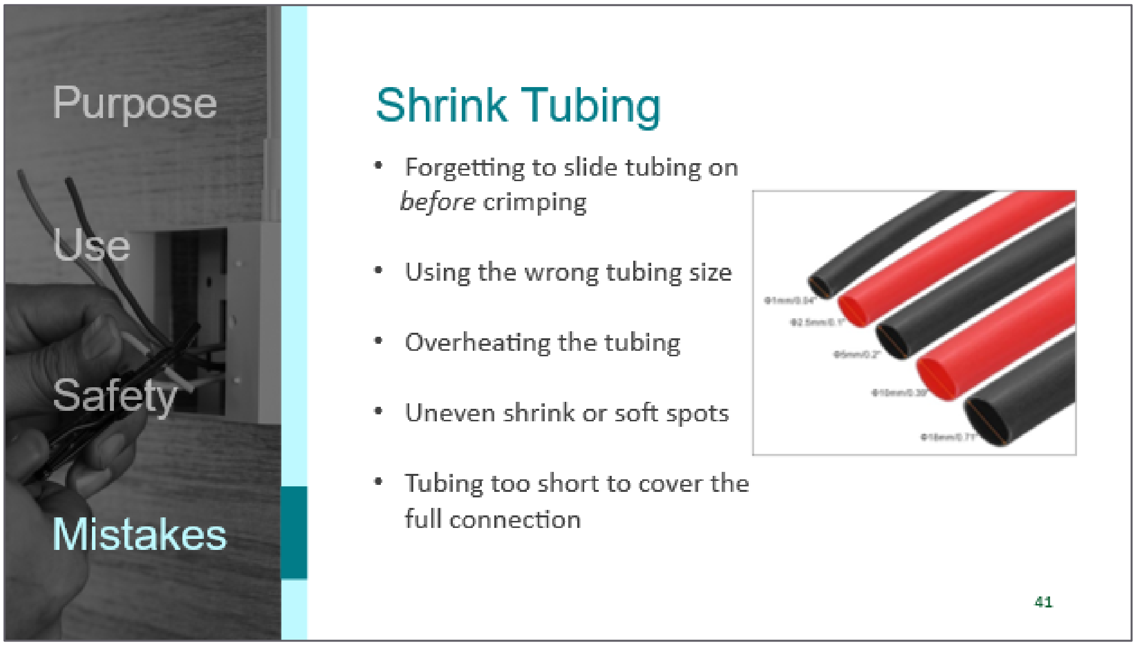


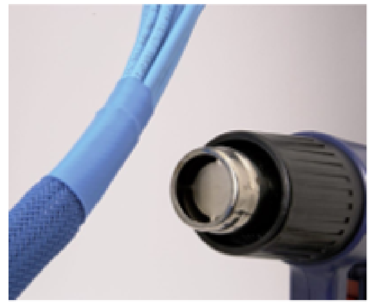
Notes:

- One of the most common mistakes is forgetting to slide the tubing onto the wire ***before*** crimping. Once the connector is installed, you must cut it off to fix it.
- Using the wrong tubing size causes problems. If it's too large, it won't seal properly. If it's too small, it may split during heating.
- Overheating is another common issue. Burned or brittle tubing reduces insulation protection and may damage the wire underneath.
- Uneven shrink or soft spots indicate inconsistent heat application and may leave weak areas. Shrink from the center outward for even coverage.
- Tubing that stops right at the connector instead of extending past it reduces strain relief and moisture protection.
- Most importantly, shrink tubing does not fix a bad crimp. It protects good work — it does not repair poor workmanship.

Demo: Proper Shrinking Tube

Goal: Recognize what properly applied shrink tubing looks like and what should be rejected

- **Step 1**: Slide Tubing Onto the Wire
- **Step 2**: Complete the Connection
- **Step 3**: Position the Tubing
- **Step 4**: Apply Heat Evenly
- **Step 5**: Inspect the Seal



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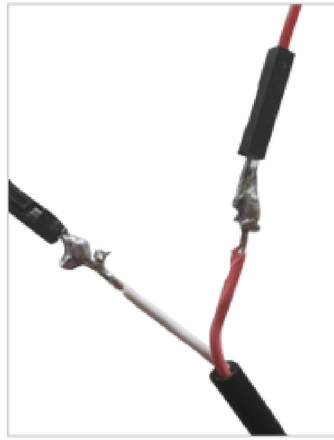
Demo: Poor Shrinking Tube

Goal: Recognize what properly applied shrink tubing looks like and what should be rejected

Discussion:

- What problems could show up if shrink tubing doesn't fully cover the connection?
- Can shrink tubing fix a bad crimp? Why or why not?



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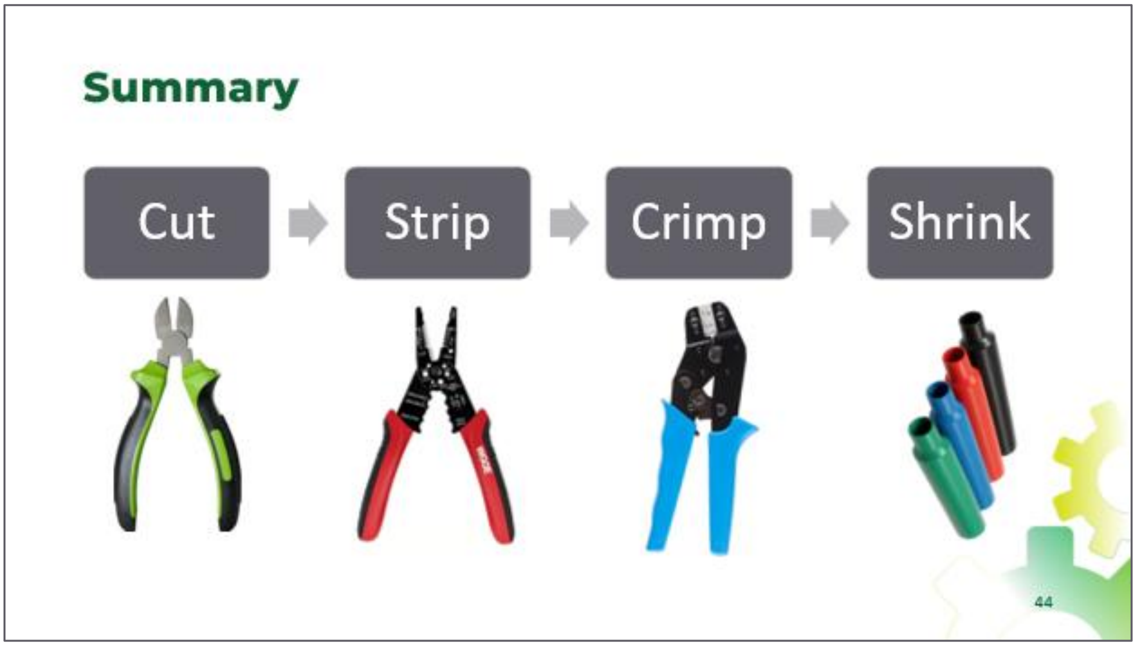
Notes:

- Debrief questions for after the demo:
    1. What problems could show up if shrink tubing doesn't fully cover the connection?
    2. Can shrink tubing fix a bad crimp? Why or why not?



Notes:

- Before we move into hands-on practice, let's review the process. Everything we've covered fits into this three-step sequence. If you follow this order every time, you prevent most wiring problems.

1. Step one is **Cut**.
   - Start with a clean, square cut and remove any damaged or corroded wire. A bad cut makes stripping harder and crimping less reliable. A clean cut sets up everything that follows.
2. Step two is **Strip**.
   - Remove the insulation without damaging the strands. Use the correct gauge on the stripper and remove only as much insulation as needed. This is a pass/fail step. If the wire isn't right here, stop and redo it before moving on.
3. Step three is **Crimp**.
   - Attach the connector to create a strong mechanical hold and a reliable electrical path. Use the correct wire gauge, terminal, and crimper. Always inspect the crimp and perform a gentle tug test. Low resistance equals reliable current flow.
4. Step four is **Shrink**.
   - Protect and seal the connection after crimping. Shrink tubing provides insulation, strain relief, and protection from moisture and vibration. Remember, it protects good work — it does not fix a bad crimp.

- The **key takeaway**: most electrical failures don't come from bad parts — they come from poor connections.
- Following this sequence — **Cut** → **Strip** → **Crimp** → **Shrink** — protects you from that.

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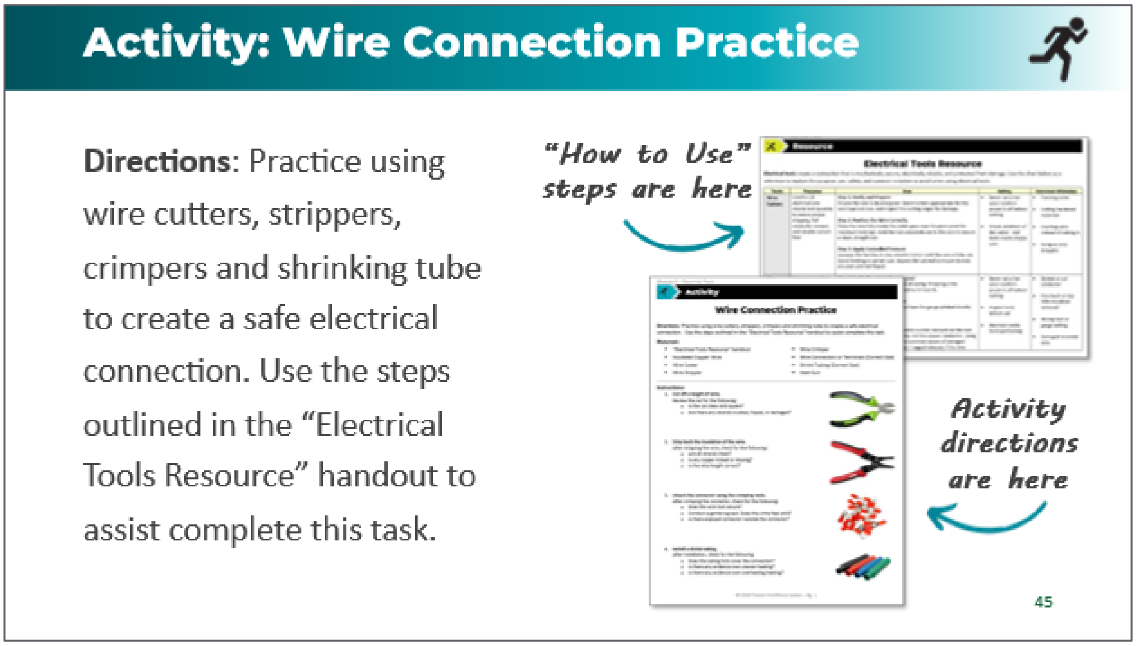


Notes:

- Once you complete the activity, move to the next pages to answer the following debrief questions.

Activity

Wire Connection Practice

Directions: Practice using wire cutters, strippers, crimpers and shrinking tube to create a safe electrical connection. Use the steps outlined in the "**Electrical Tools Resource**" handout to assist complete this task.

Materials:

- "Electrical Tools Resource" handout
- Insulated Copper Wire
- Wire Cutter
- Wire Stripper
- Wire Crimper
- Wire Connectors or Terminals (Correct Size)
- Shrink Tubing (Correct Size)
- Heat Gun

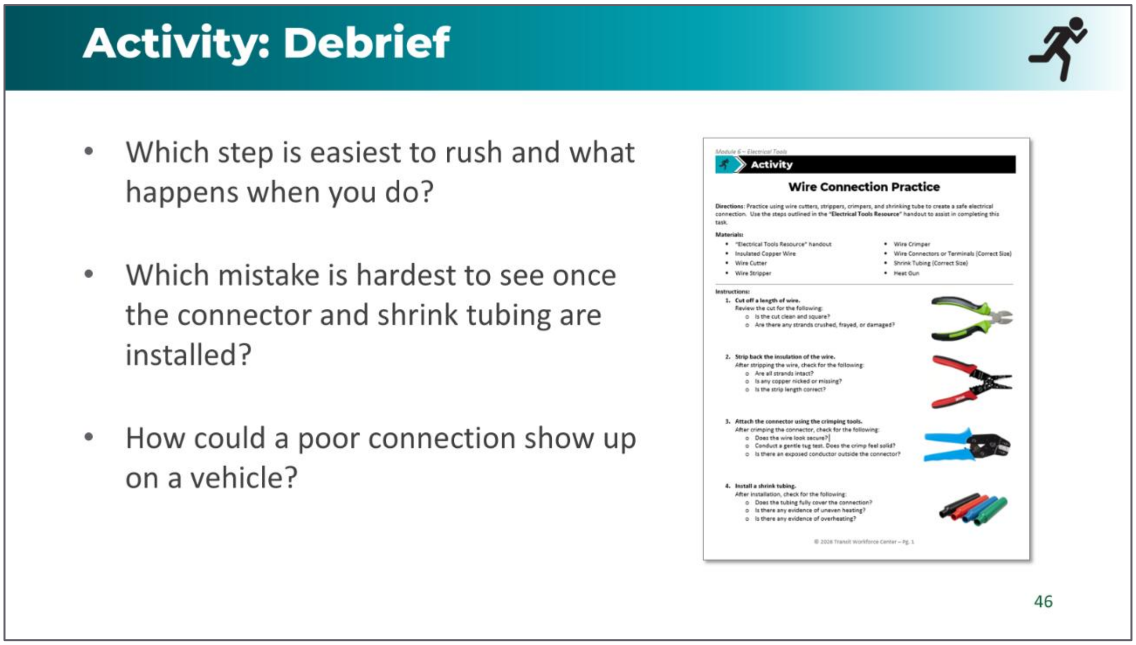
Instructions:

1. **Cut off a length of wire.**
   Review the cut for the following:
   - Is the cut clean and square?
   - Are there any strands crushed, frayed, or damaged?

2. **Strip back the insulation of the wire.**
   After stripping the wire, check for the following:
   - Are all strands intact?
   - Is any copper nicked or missing?
   - Is the strip length correct?

3. **Attach the connector using the crimping tools.**
   After crimping the connector, check for the following:
   - Does the wire look secure?
   - Conduct a gentle tug test. Does the crimp feel solid?
   - Is there exposed conductor outside the connector?

4. **Install a shrink tubing.**
   After installation, check for the following:
   - Does the tubing fully cover the connection?
   - Is there any evidence over uneven heating?
   - Is there any evidence over overheating heating?



Notes:

- Now that you've completed the hands-on portion, let's reflect on where mistakes tend to happen and how that connects to what you might see on a vehicle.

1. **First question**: <u>Which step is easiest to rush — and what happens when you do</u>?
   a) Many people rush stripping or crimping because they look like simple tasks. But the step that looks easiest is often where the most damage happens.
   b) Rushing stripping can nick strands. Rushing crimping can create a loose or crushed connection. Small shortcuts here lead to bigger failures later.
2. **Second question**: <u>Which mistake is hardest to see once the connector and shrink tubing are installed</u>?
   a) Common answers here include nicked strands under the insulation, a loose crimp hidden by shrink tubing, or insulation caught under the terminal barrel.
   b) The key point is that some mistakes become invisible once they're covered.
   c) That's why inspection must happen at three critical points — after stripping, after crimping, and before shrink tubing is applied.
3. **Third question**: <u>How could a poor connection show up on a vehicle</u>?
   a) A poor connection might cause intermittent operation, failures after vibration or movement, heat at the connection, or components that work sometimes but not always. These are the kinds of problems technicians spend hours chasing — and many of them start with a small connection issue.

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Recall and Review

- ✓ Why do clean cuts matter?
- ✓ How do you choose the correct stripper gauge?
- ✓ Why is too much or too little stripped insulation is a problem?
- ✓ Perform a pull test after crimping without being prompted.
- ✓ What makes a crimp mechanically strong and electrically reliable?
- ✓ What does shrink tubing protects against?

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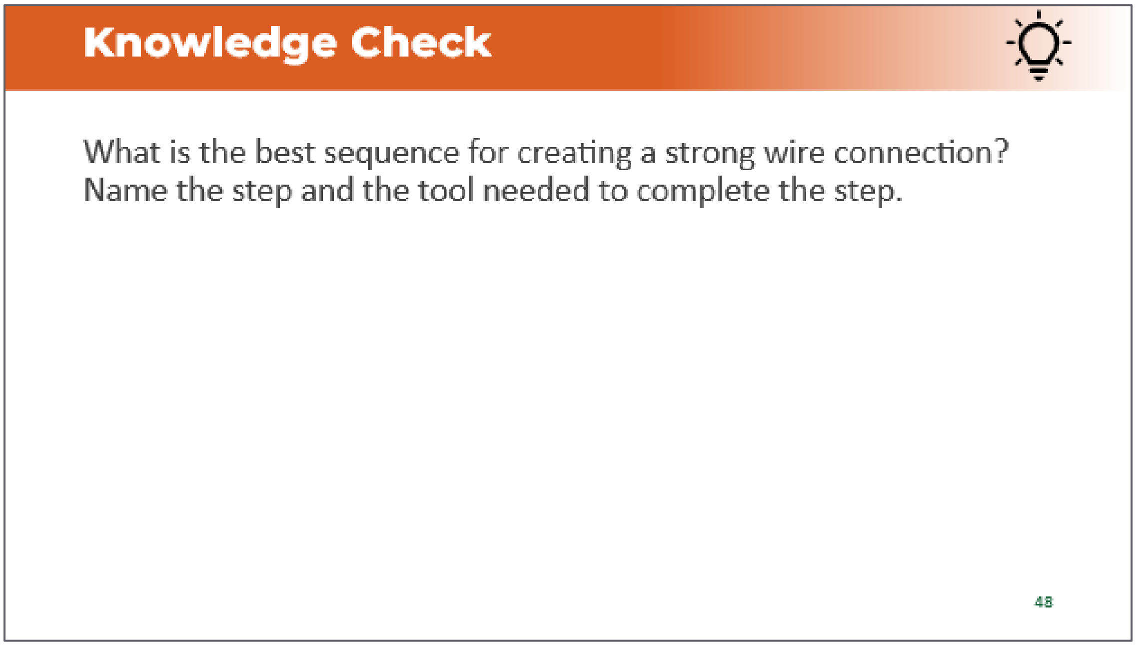
Knowledge Check
What is the best sequence for creating a strong wire connection? Name the step and the tool needed to complete the step.
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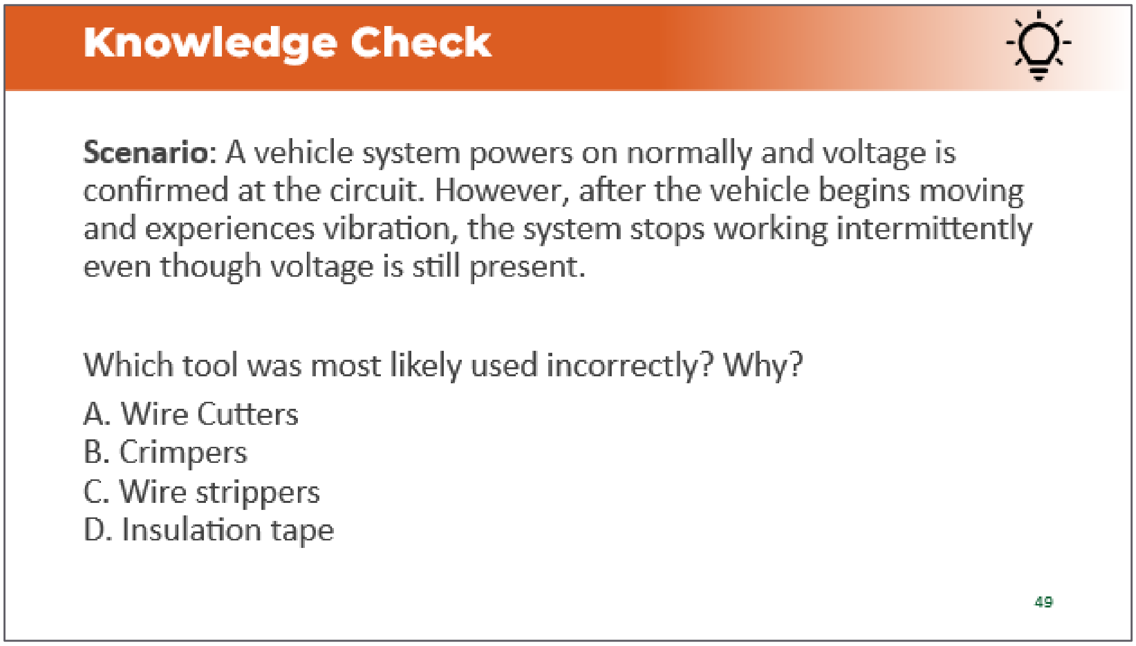
Knowledge Check
Scenario: A vehicle system powers on normally and voltage is confirmed at the circuit. However, after the vehicle begins moving and experiences vibration, the system stops working intermittently even though voltage is still present.
Which tool was most likely used incorrectly? Why?
A. Wire Cutters
B. Crimpers
C. Wire strippers
D. Insulation tape
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Knowledge Check

Scenario: Safety Focus. A wire connection looks secure, but the insulation is stripped back too far leaving the conductor exposed.

Why is this a safety concern?

A. It can short to ground or create a shock hazard
B. It reduces voltage
C. It blocks current
D. It improves conductivity

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Knowledge Check

Inspect the wire crimp connections below:

1. Identify the issue
2. Explain the impact of this issue.

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Summary and What's Next

- Wire cutters create clean starting points by removing damaged wire.
- Wire strippers remove insulation without damaging the conductor.
- Crimpers secure wires to connectors for reliable current flow.
- Shrink tubing protects connections from shorts, moisture, and damage.
- Using the right tool, in the right order, creates safe and dependable connections.

Next, we'll learn how to test and verify those connections using electrical measurement tools.

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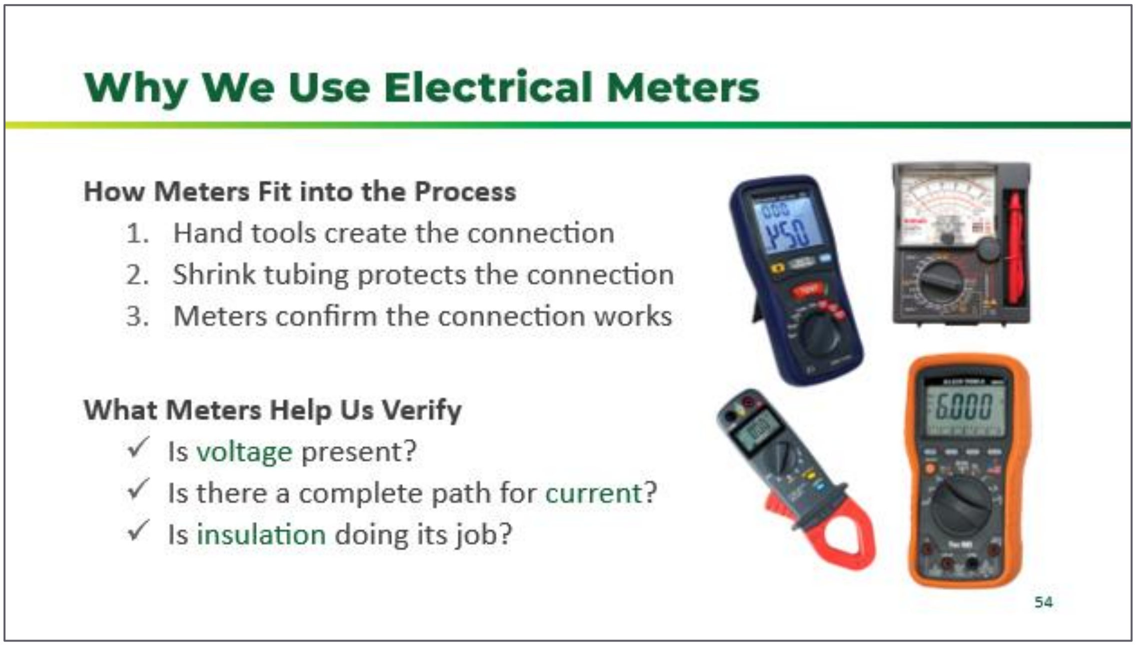
Notes:

- In this section, you earn how to safely use common tools to measure and test electrical circuits.



Notes:

- Up to this point, we've focused on making the connection — cutting, stripping, crimping, and protecting it. Now we're shifting to *verifying* the connection.
- Meters don't repair wiring. They tell us what's happening electrically.
- Think about the sequence we've built:
  - Hand tools create the connection.
  - Shrink tubing protects the connection.
  - Meters confirm whether the connection is actually working as intended.
- When we use a meter, we're typically verifying three things:
  1. Is voltage present? In other words, is power available at this point?
  2. Is there a complete path for current? Can electricity actually flow through the connection?
  3. And is insulation doing its job? Is electricity staying where it's supposed to be?
- One important misconception to address: Seeing voltage does *not* automatically mean that the system will work.
- A poor connection can still show voltage — but it may overheat, fail under load, or act intermittently.
- If a system shows voltage but doesn't work, what might that tell us?

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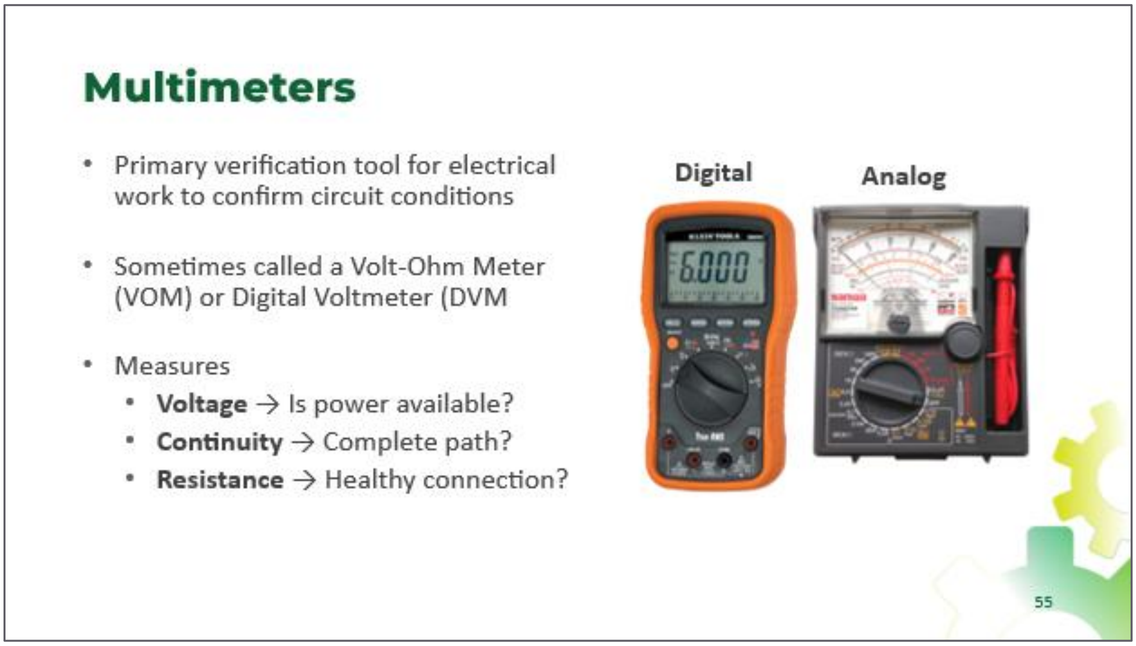

Notes:

- Now that we've talked about verifying connections, let's introduce the primary tool we use to do that — the **multimeter**.
- You may also hear multimeters called volt-ohm meters, VOMs, sometimes digital voltmeters, or DVMs.
- A multimeter is our main verification tool in electrical work.
    - After we cut, strip, crimp, and shrink, this is what tells us whether the connection is actually functioning properly.
- A multimeter helps us verify three core things.
    1. First, **voltage** — is power available at this point in the circuit?
    2. Second, continuity — is there a complete path for **current** to flow?
    3. Third, **resistance** — is the connection healthy, or is resistance higher than it should be?
- It's important to remember: a multimeter does not fix problems. It confirms the condition of the circuit. It tells you what's happening electrically, but it doesn't automatically tell you why.
- Most of what is used today are digital multimeters. They're easier to read and more common in the field. Analog meters are older and less common, but you may still see them in some settings.
- If a system isn't working, which test would you use first — voltage or continuity?

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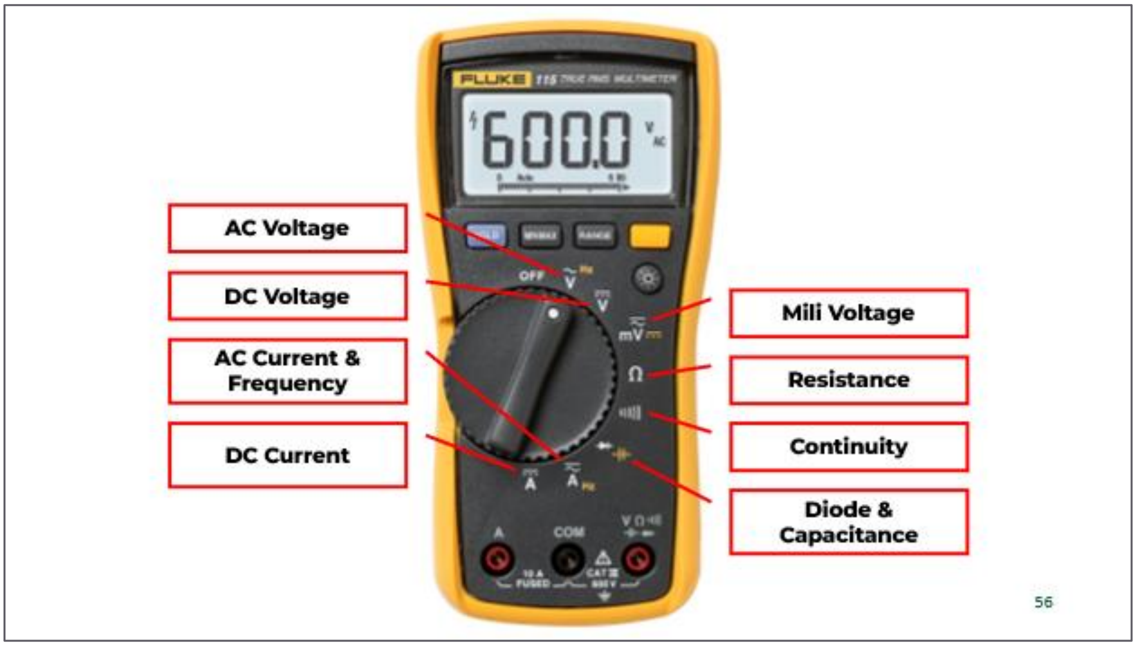

Notes:

- The multimeter takes the most basic measurements:
    - a) Measure AC voltage
    - b) DC voltage
    - c) Resistance
    - d) Check continuity
    - e) Check diodes
    - f) Milliamps and amps
    - g) AC and DC.
- The Fluke® multimeter shown is a popular type of VOM used in many rail maintenance shops.
- There are several switch positions each measuring or testing a number of functions.

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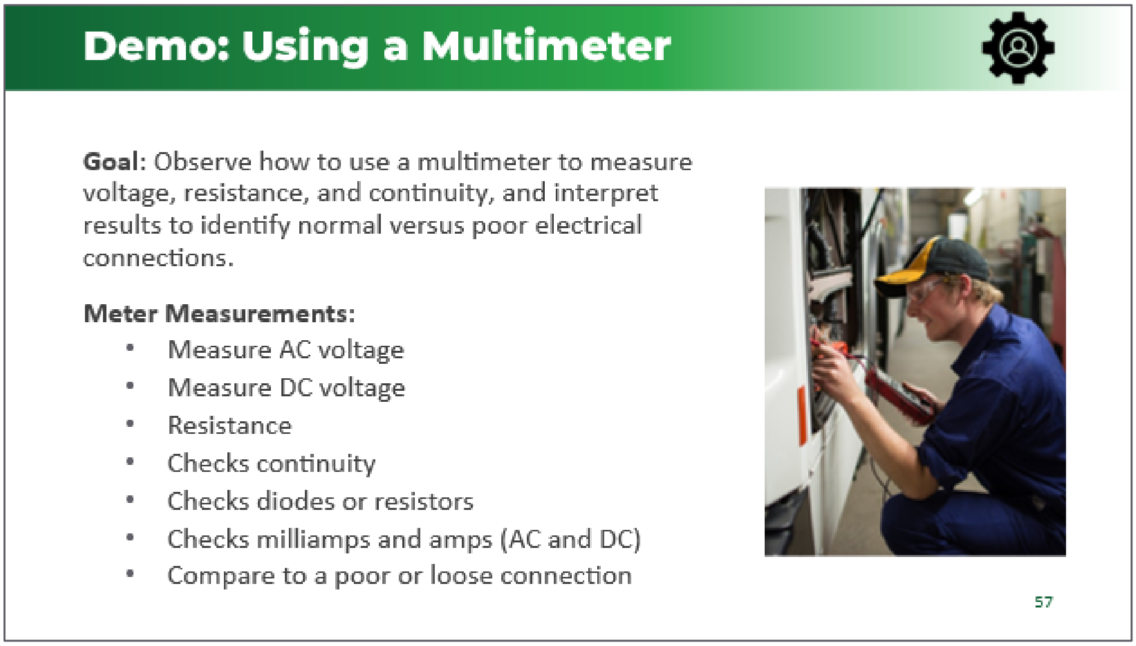
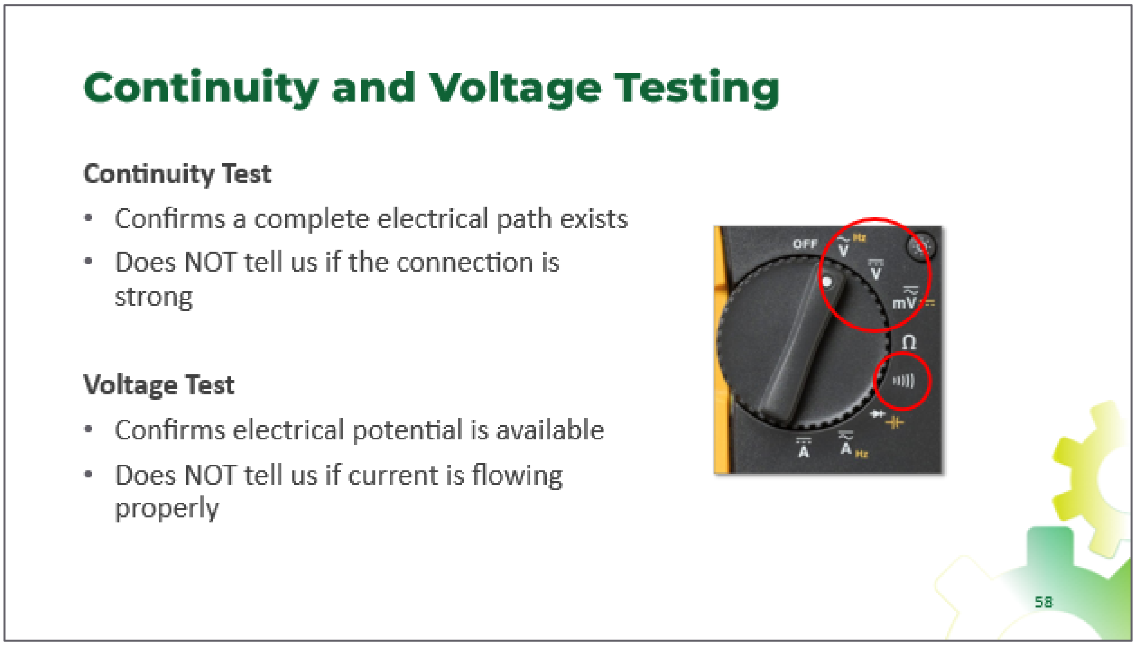
AC Voltage
DC Voltage
AC Current & Frequency
DC Current
Mili Voltage
Resistance
Continuity
Diode & Capacitance
FLUKE
115 TRUE RMS MULTIMETER
600.0 V AC
MINMAX
RANGE
OFF
Hz
mV
A
COM
10 A FUSED
CAT III 600 V



Notes:

- Compare the results measured between:
  a) A properly secured connection
  b) A loose or poor connection

- Reminder: **Meters confirm condition** — <u>they don't fix problems</u>.



Notes:

- Two tests frequently done with multimeters are continuity and voltage tests.
- A **continuity test** confirms that a complete electrical path exists. In simple terms, it tells us electricity *can* travel from one point to another.
    - But the limitation — continuity does not tell us if the connection is strong. A loose or partially damaged connection can still show continuity. It only confirms the path exists, not the quality of that path.
- A **voltage test** confirms that electrical potential (voltage) is available at a given point. In other words, power is present.
    - But voltage alone does not tell us whether current is flowing properly. A system can show voltage and still fail under load if there's high resistance or a weak connection.
- **Key takeaways:**
    - Continuity confirms a path.
    - Voltage confirms power is available.
    - Neither one alone confirms a healthy, reliable connection. That's why we interpret meter readings in context — not in isolation.

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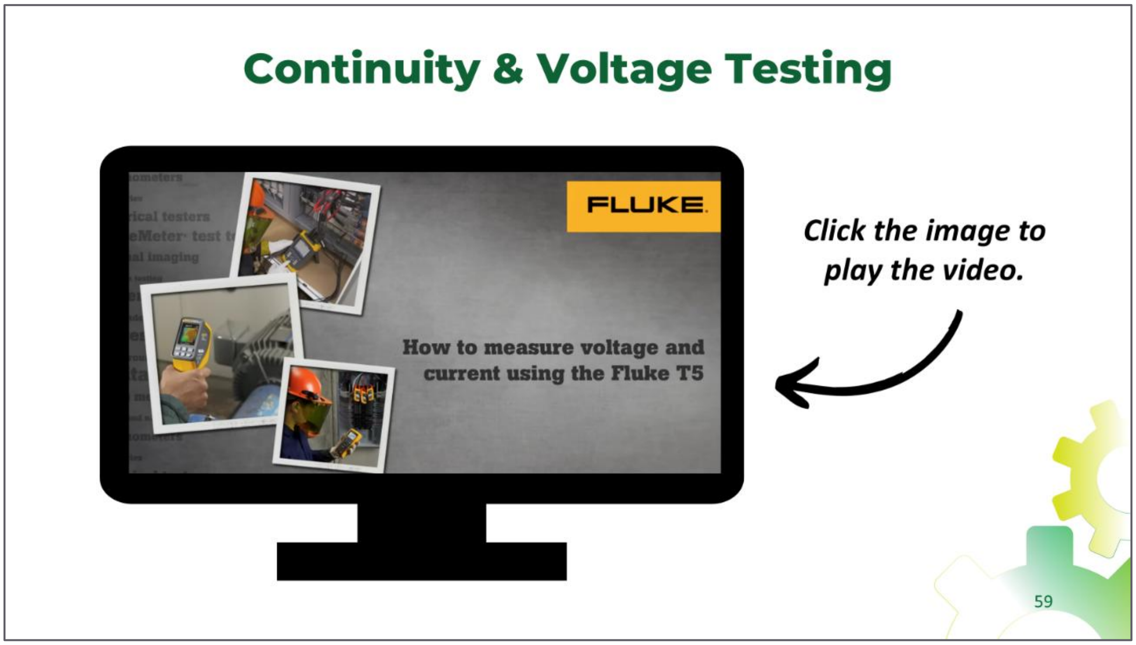
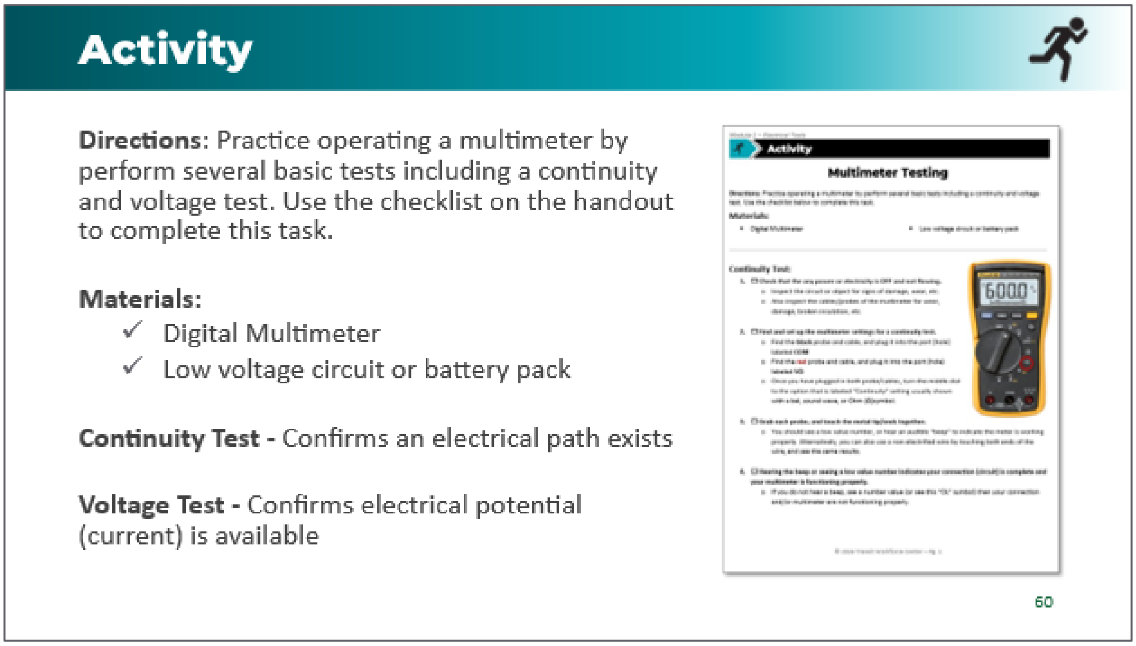


Notes:

- Video Link: https://www.youtube.com/watch?v=_uiY8rI4cbM

Important Safety Information:

- Always connect your clip lead to the ground or neutral first before testing the hot wire.
- Use one hand whenever possible when testing a live circuit. This helps reduce the chance of current traveling across your chest if a fault occurs.
- Avoid using both hands to test a live circuit. A two-handed method can create a path for electricity to travel through vital organs.
- After securing the ground or neutral lead, carefully place the second lead on the hot conductor to take the measurement.
- Safe meter testing habits help reduce the risk of electrical shock and injury.


Activity
Directions: Practice operating a multimeter by perform several basic tests including a continuity and voltage test. Use the checklist on the handout to complete this task.
Materials:
✓ Digital Multimeter
✓ Low voltage circuit or battery pack
Continuity Test - Confirms an electrical path exists
Voltage Test - Confirms electrical potential (current) is available
Activity
Multimeter Testing
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Activity

Multimeter Testing

Directions: Practice operating a multimeter by perform several basic tests including a continuity and voltage test. Use the checklist below to complete this task.

Materials:

- Digital Multimeter
- Low voltage circuit or battery pack

Continuity Test:

1. ☐ **Check that the any power or electricity is OFF and not flowing.**
   - Inspect the circuit or object for signs of damage, wear, etc.
   - Also inspect the cables/probes of the mutlimeter for wear, damage, broken insulation, etc.

2. ☐ **Find and set up the multimeter settings for a continuity test.**
   - Find the **black** probe and cable, and plug it into the port (hole) labeled **COM**
   - Find the **red** probe and cable, and plug it into the port (hole) labeled **VΩ**
   - Once you have plugged in both probe/cables, turn the middle dial to the option that is labeled "Continuity" setting usually shown with a bel, sound wave, or Ohm (**Ω**)symbol.

3. ☐ **Grab each probe, and touch the metal tip/ends together.**
   - You should see a low value number, or hear an audible "beep" to indicate the meter is working properly. Alternatively, you can also use a non-electrified wire by touching both ends of the wire, and see the same results.

4. ☐ **Hearing the beep or seeing a low value number indicates your connection (circuit) is complete and your multimeter is functioning properly.**
   - If you do not hear a beep, see a number value (or see this "OL" symbol) then your connection and/or multimeter are not functioning properly.

DC Voltage Test:

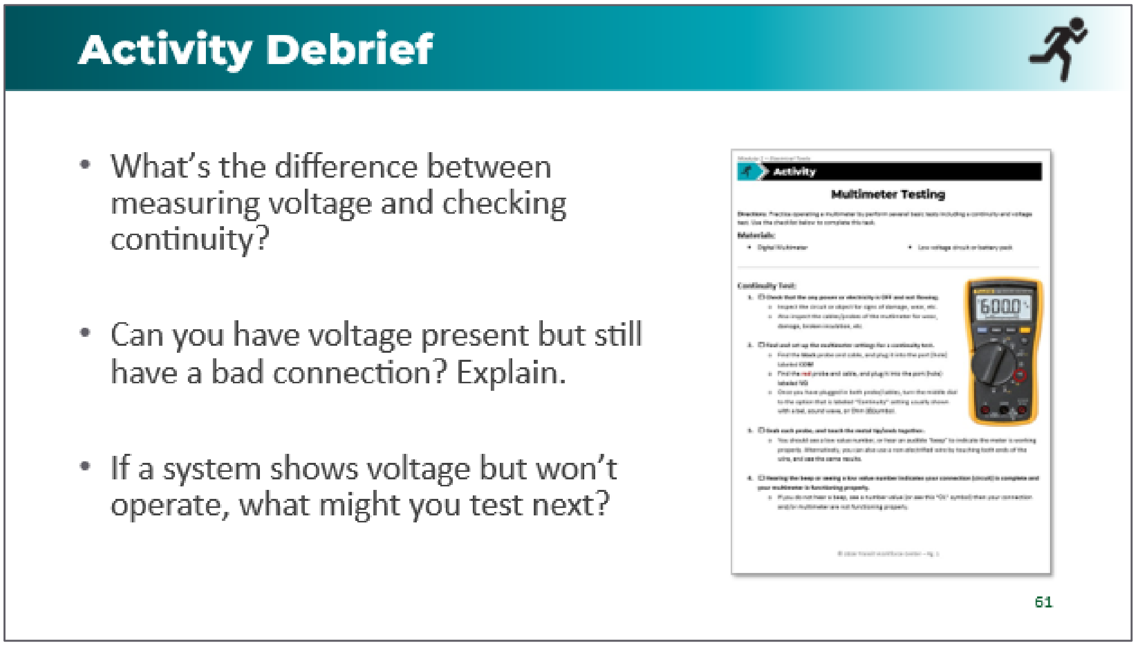
1. ☐ **Turn the dial to the "DC Voltage" setting.**
   - This is often labeled as either $\overline{\overline{V}}$ or VDC.
   - Once again, inspect the circuit or object and probes for signs of damage, wear, broken insulation, etc.

2. ☐ **Identify the positive (+) and negative (-) terminals of the wire, object, battery, etc.**
   - Make sure your fingers are only touching the plastic part of the probe to stay safe from any potential voltage.
   - Take the **black** probe and connect it with the negative (-) end.
   - Take the **red** probe and connect it with the positive (+) end.

3. ☐ **Wait with the probes touching the positive (+) and negative (-) terminals until a number is visible on the multimeter screen.**
   - If everything has been adjusted and tested properly, the value you see is the DC voltage of the object, wire, battery, etc.
   - A positive number tells you the number is connected properly.
   - A negative number tell you the connect is reversed (but still safe so you can switch the probes).

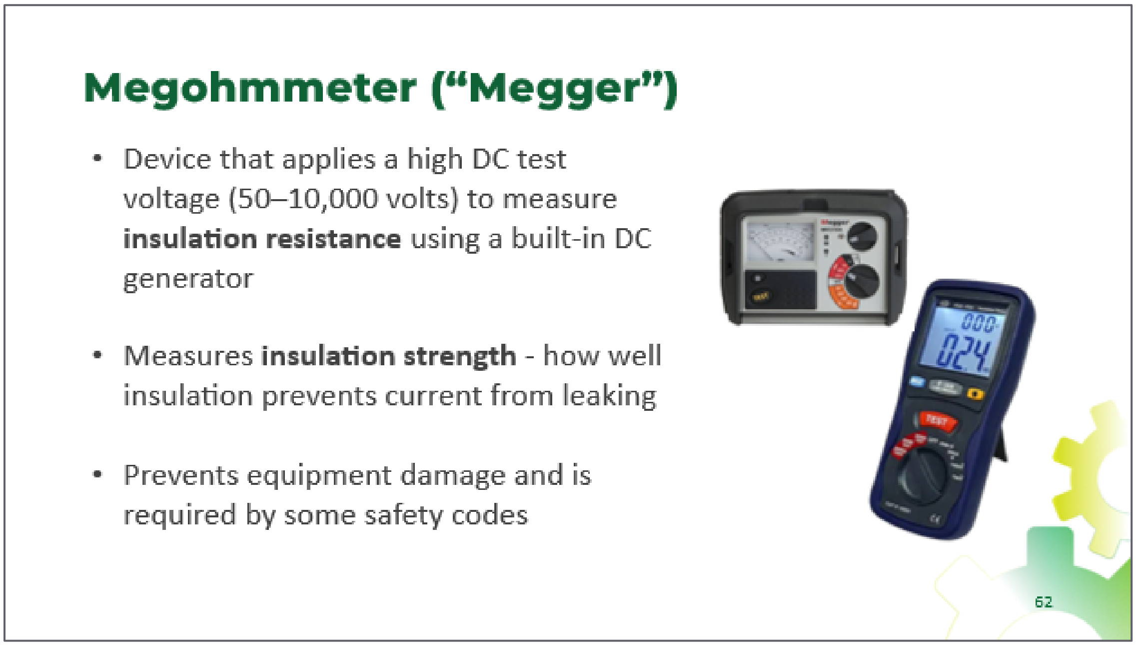
4. ☐ **Remove the probes from the terminals and turn off the multimeter.**

5. ☐ **Record the DC voltage value: _________.**



Notes:

- The following questions to debrief from the activity:
  1. What's the difference between measuring voltage and checking continuity?
  2. Can you have voltage present but still have a bad connection? Explain.
  3. If a system shows voltage but won't operate, what might you test next?



Notes:

- A **megohmmeter**, often called a "Megger", is a portable device used to test **insulation resistance**. The name comes from the original manufacturer, but commonly used to describe this type of tester.
- A megohmmeter applies a high DC test voltage, typically anywhere from 50 volts up to 10,000 volts. It has a built-in DC generator and reads resistance directly in ohms, independent of the applied voltage.
- It measures **insulation strength** — in other words, how well insulation prevents current from leaking.
    - Over time, dirt, moisture, vibration, and aging can weaken insulation. When insulation weakens, current doesn't stay confined to the intended conductor.
    - Instead of flowing through the motor or cable as designed, some of it leaks toward ground.
- This is especially important in motors. If insulation breaks down, not all power flows through the windings, some escapes. That leads to heat, inefficiency, and eventually failure.
- Megohmmeters are commonly used to test cables and motor coils because detecting insulation breakdown early helps prevent equipment damage and safety hazards. In many cases, insulation testing is required to meet safety standards.
- Because this tool generates high voltage, it must be handled carefully.
    - Improper use can create shock hazards. That's why we are not conducting a hands-on activity with this tool in this course — it requires proper PPE and specific procedures.
- **The key takeaway**: The megohmmeter verifies insulation health. Strong insulation keeps current where it belongs. Weak insulation allows leakage — and that's where serious problems begin.

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Notes:

- **Video Link (19 min.) -** https://www.youtube.com/watch?v=VVbQBitWp7E
- **Optional Shorter Video (3 min.)** - https://www.youtube.com/watch?v=3GuSKwlxbVU

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Demo: Using a Megohmmeter

Goal: Checks insulation resistance to detect hidden leakage paths

Steps:

1. Safety check – De-energize, put on PPE when applicable
2. Connect one lead to conductor, one to ground
3. Select appropriate DC test voltage
4. Press test button and allow reading to stabilize
5. Interpret results
    - High resistance = good insulation
    - Low resistance = damage or moisture
6. Discharge circuit by releasing the test button (allow time for discharge)

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Notes:

- Before the demo, first you need to know safety. This tool injects high DC voltage into the circuit.
- Never use it on energized equipment. The circuit must be de-energized and verified before testing. Because it generates high voltage, PPE and proper procedures are required.
- The purpose of this test is to check insulation resistance and detect hidden leakage paths.
- Think of insulation like the rubber coating on a wire. You may not see cracks or breakdown on the outside. This test helps find insulation damage we can't see.
- Megohmmeters are commonly used on motors, cables, traction power components, and before energizing new or repaired equipment.

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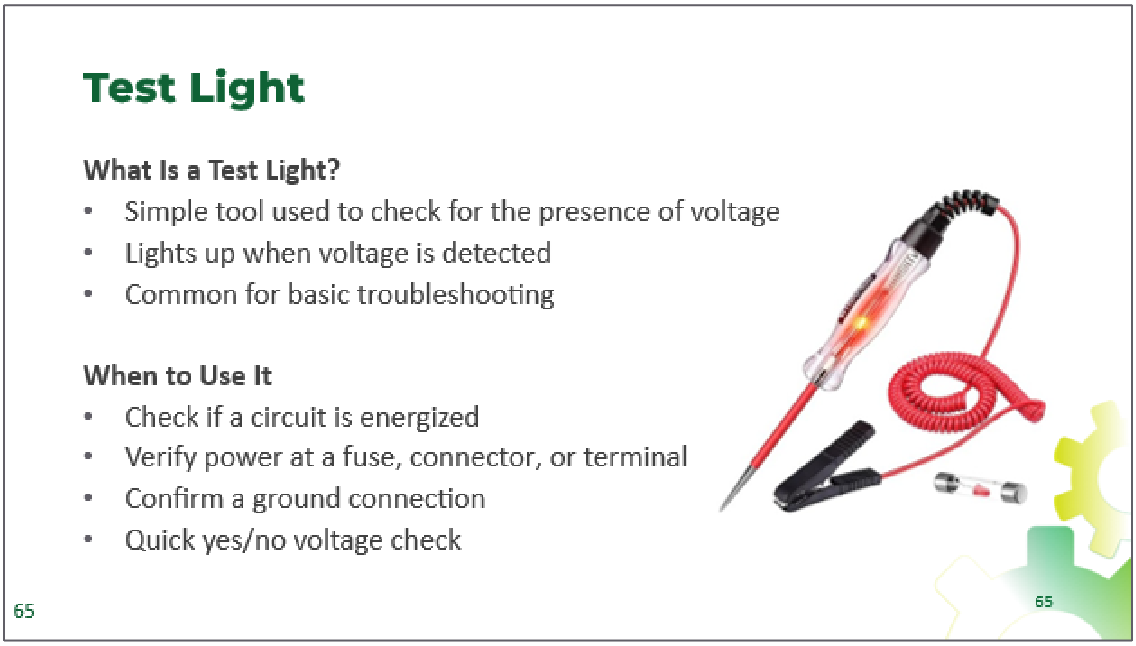
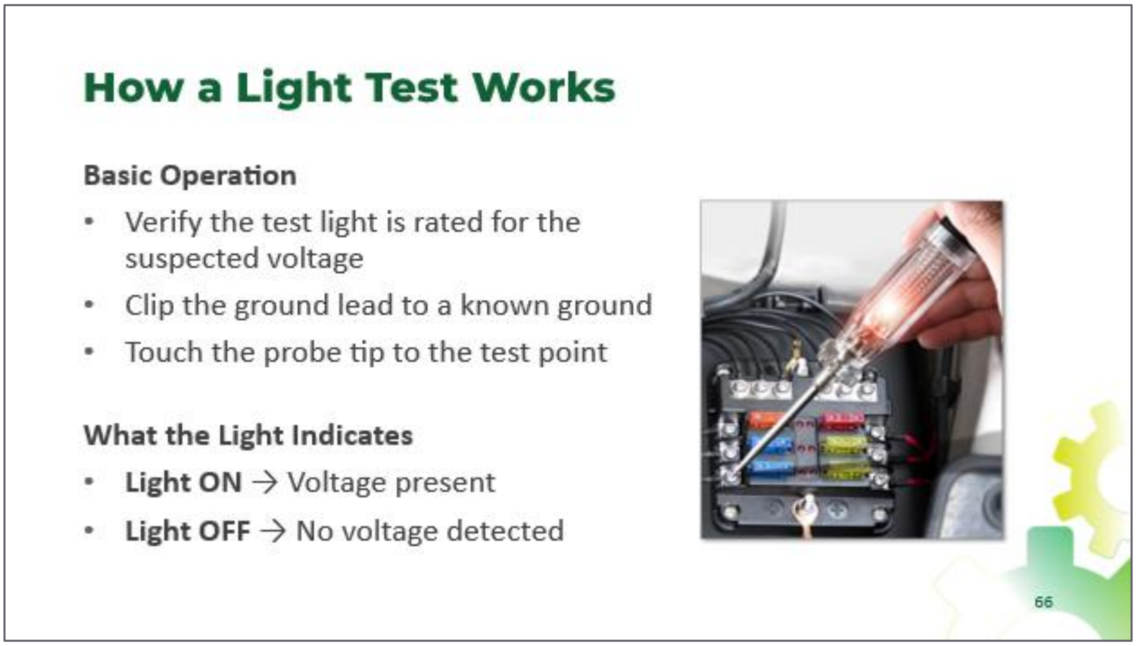


Notes:

- A test light is one of the simplest electrical verification tools. It checks for the presence of voltage. **If voltage is detected, the light turns on.**
- Because it's quick and easy to use, it's commonly used for basic troubleshooting.
- You might use a test light to check whether a circuit is energized, verify power at a fuse or connector, or confirm a ground connection. It's especially useful for a fast yes-or-no voltage check.
- But the key limitation: Just because the test light turns on does not mean the circuit can actually perform work.
- Voltage may be present, but the connection could still be weak, high resistance, or unable to carry current under load.
- So, think of a test light as a quick screening tool — not a full diagnostic tool.



Notes:

- First, verify the test light is rated for the suspected voltage
- Next, clip the ground lead to a known good ground point.
- Then, touch the probe tip to the test point you want to check.
  - If the light turns on, voltage is present at that point.
  - If the light stays off, no voltage is detected.
- It's important to remember — this tool *does not measure voltage level*. It only tells you whether voltage is present or not.
- So, it's a quick yes-or-no tool, not a precision measurement device. That's why it's used for basic checks — not detailed diagnostics.

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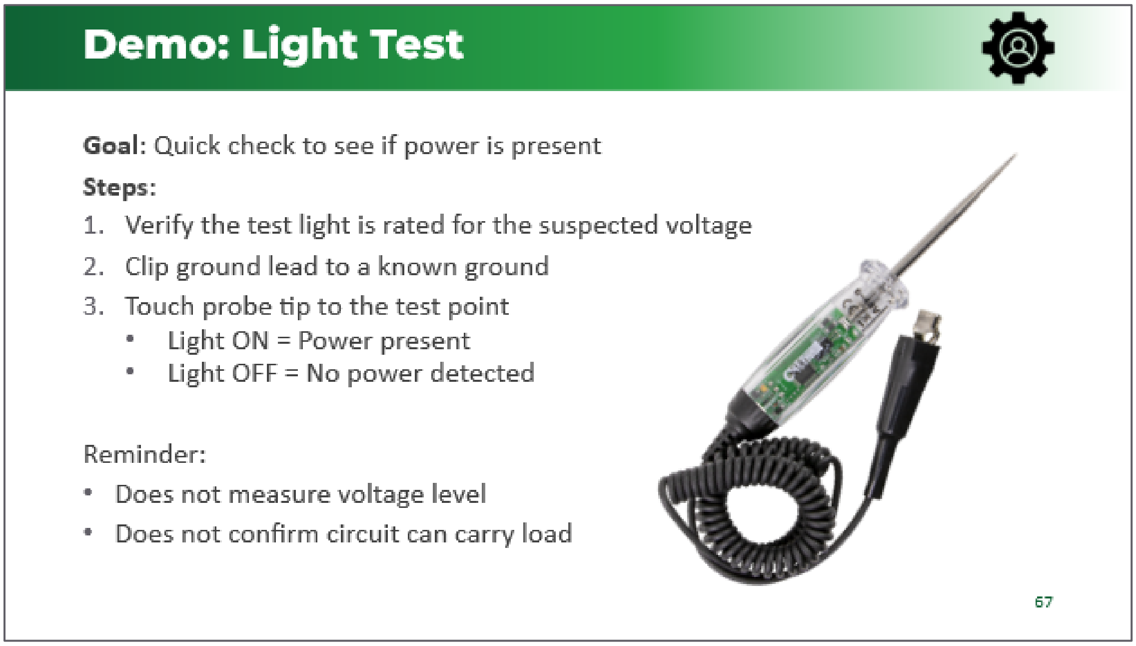

Notes:

- Reminder:
    - A test light *does not* measure voltage level.
    - If voltage is present, it does not guarantee the circuit can carry load.
    - A test light is a quick screening tool — not a full diagnostic tool.

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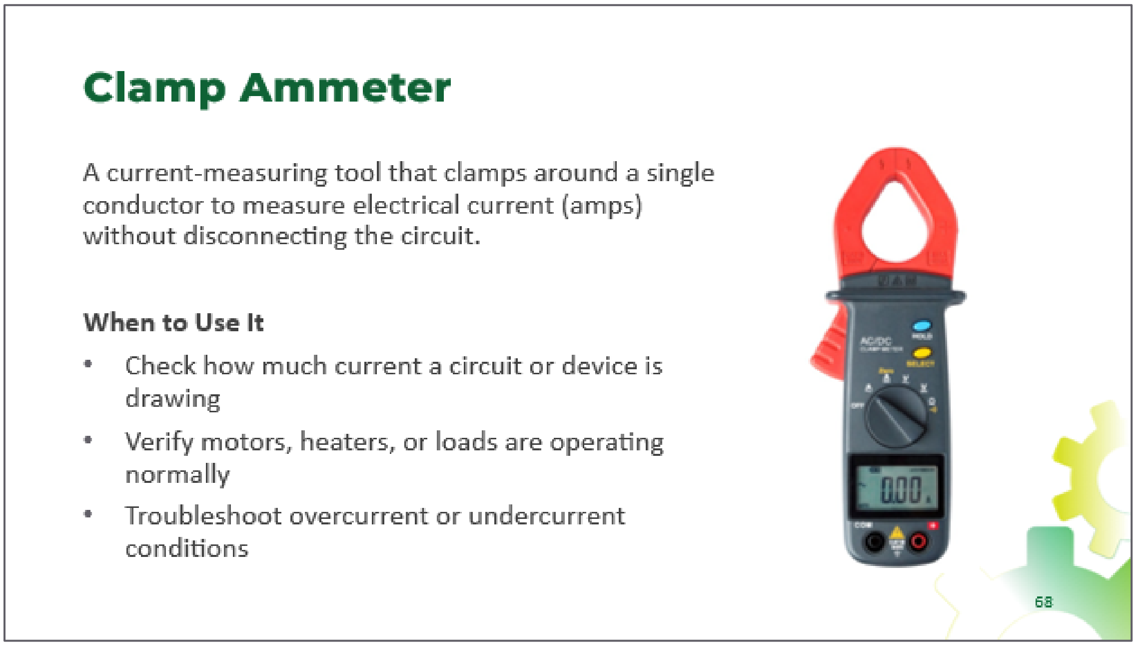

Notes:

- A **clamp ammeter** is a current-measuring tool that allows for measuring amps without disconnecting the circuit.
- Instead of placing test leads in series, simply clamp the meter around a single conductor. This makes it a quick and safer way to measure current.
- You would use a clamp ammeter when you need to know how much current a device or circuit is drawing — especially for motors, heaters, or other loads.
    - It's useful for verifying normal operation or diagnosing overcurrent and undercurrent conditions.
- A few important **limitations**:
    - This tool does not measure voltage or resistance — it only measures current.
    - It also will not work if you clamp around multiple conductors at once. The magnetic fields cancel each other out, and you'll get an incorrect reading.
    - Finally, always make sure the clamp meter is properly rated for the voltage and current class of the circuit.
- To keep the tools straight: Each tool answers a different electrical question.
    a) A **test light** checks for the presence of **voltage**.
    b) A **multimeter** measures **voltage, resistance,** and **continuity**.
    c) A **clamp ammeter** measures **current**.

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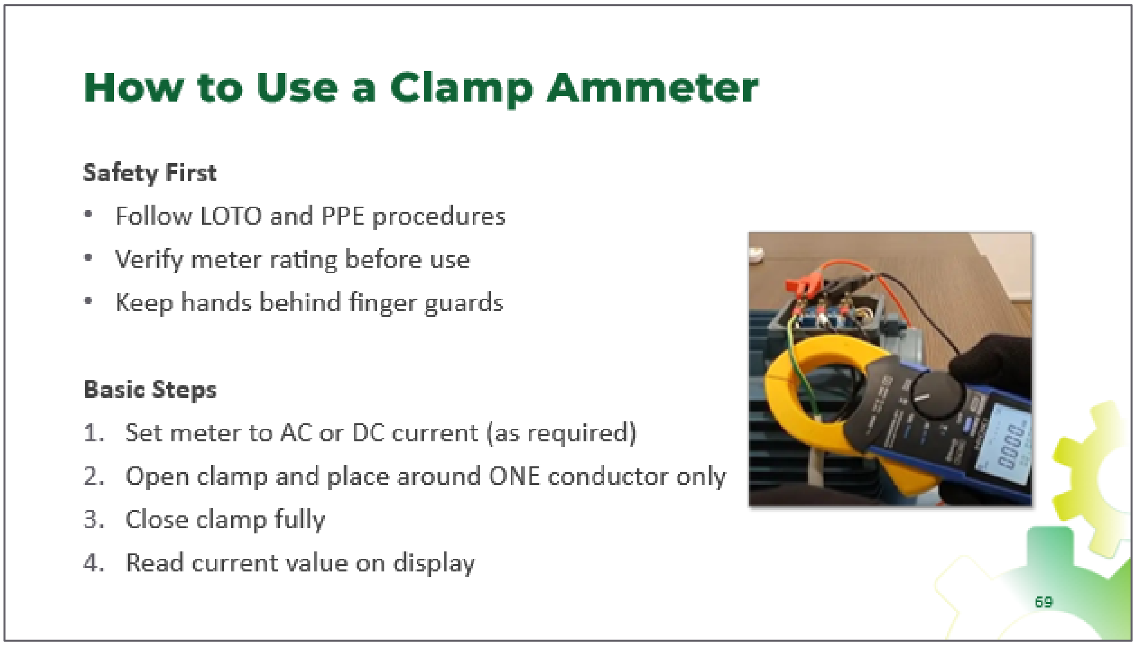

Notes:

- Before using a clamp ammeter, safety comes first.
    a) Always follow lockout/tagout procedures and wear appropriate PPE.
    b) Verify the meter is properly rated for the voltage and current of the circuit you're testing.
    c) And keep your hands behind the finger guards while measuring.
- Here are the basic steps:
    - Set the meter to the correct current setting — AC or DC, depending on the circuit.
    - Open the clamp and place it around **one conductor only**. This is critical.
    - Close the clamp fully to ensure an accurate reading.
    - Then read the current value on the display.
- An important concept: If you clamp around both conductors — for example, the hot and neutral together — their magnetic fields cancel each other out. The meter will show a false zero reading.
- Also remember: A clamp ammeter does not measure voltage or resistance. And it must always be properly rated for the circuit you're working on.
- This tool answers one question: How much current is flowing right now?

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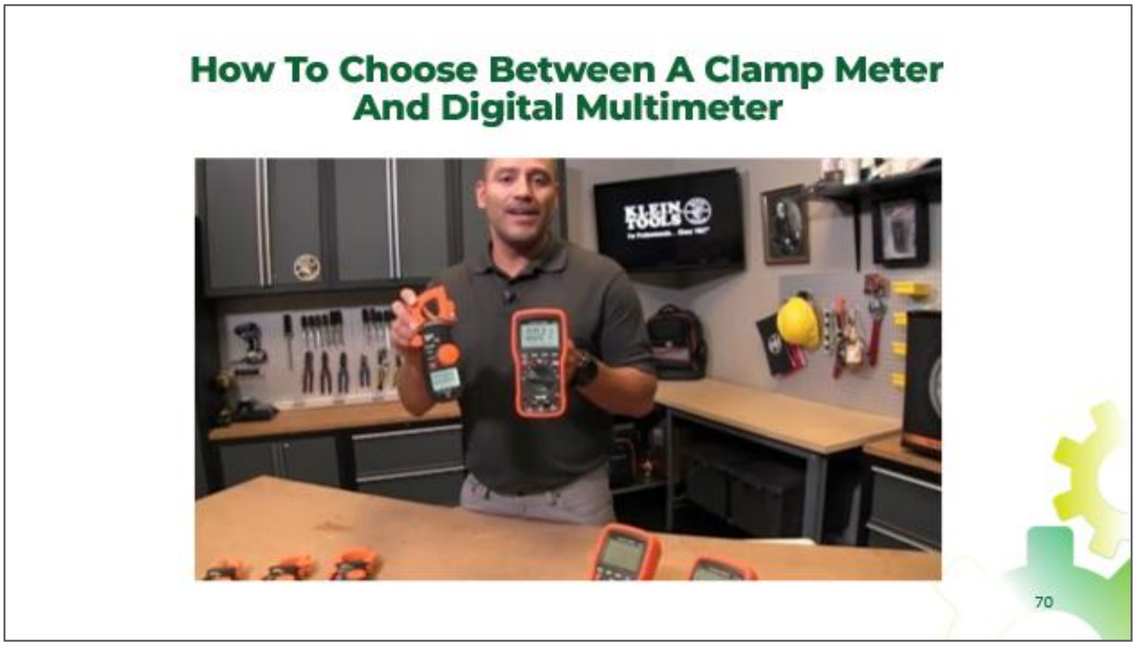
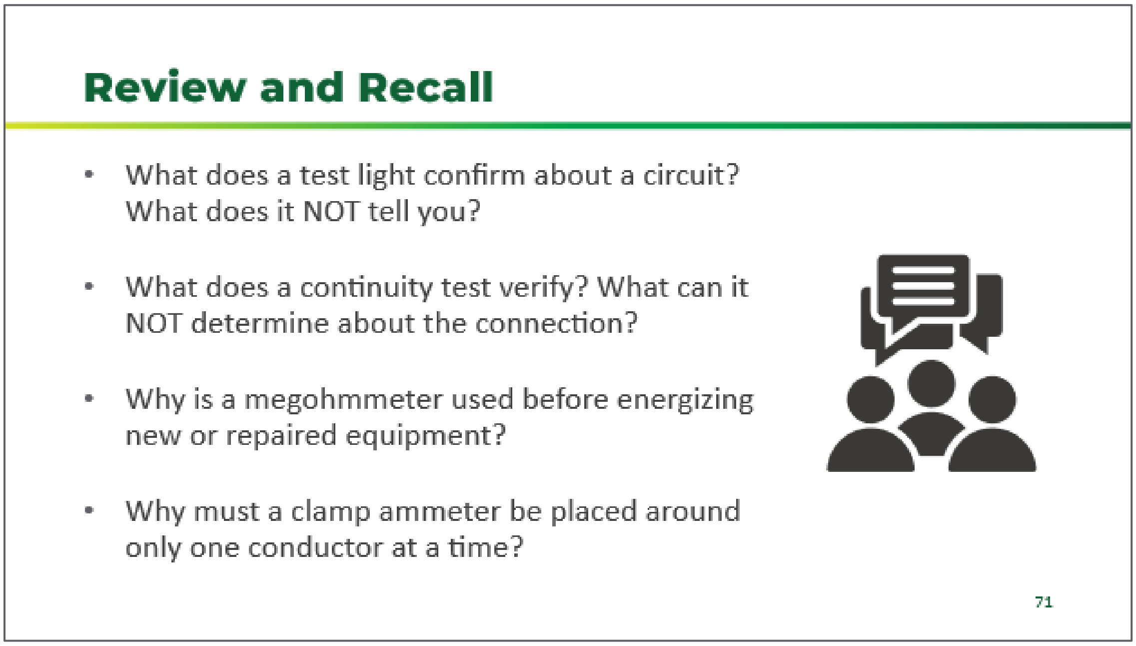


Notes:

- **Video Link (2:35 min.) -** https://www.youtube.com/watch?v=E76bEdlUN1I


Review and Recall
What does a test light confirm about a circuit? What does it NOT tell you?
What does a continuity test verify? What can it NOT determine about the connection?
Why is a megohmmeter used before energizing new or repaired equipment?
Why must a clamp ammeter be placed around only one conductor at a time?
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Knowledge Check
Choose one of the tools below and explain its purpose.
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Knowledge Check

You need to quickly check whether power is present at a connector before starting work. Which tool is the best choice?

Which tool is the best choice?

A. Clamp ammeter
B. Megohmmeter
C. Test light
D. Wire stripper

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Knowledge Check

Which measurement can a multimeter perform?

A. Insulation resistance at a high voltage
B. Current without opening the circuit
C. Shrinking insulation tubing
D. Voltage, continuity, and resistance

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Knowledge Check

A motor cable shows normal voltage during testing but later fails because of insulation breakdown. Which tool would have been most useful to test the insulation before energizing the system?

A. Test light

B. Megohmmeter

C. Multimeter

D. Clamp ammeter

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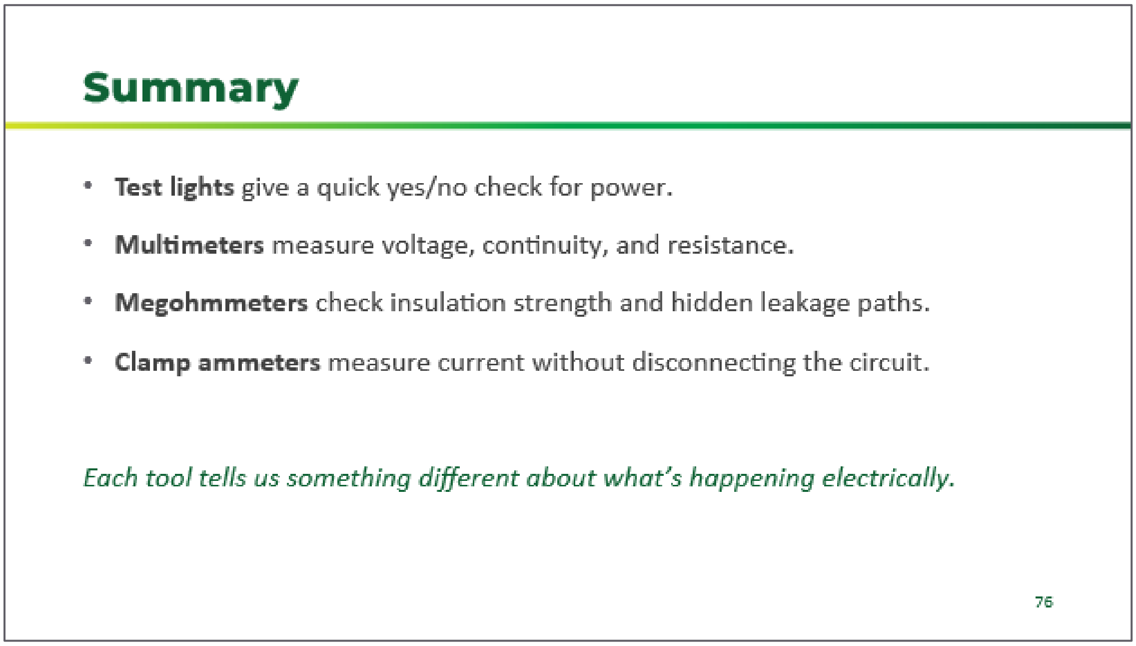
Summary
• Test lights give a quick yes/no check for power.
• Multimeters measure voltage, continuity, and resistance.
• Megohmmeters check insulation strength and hidden leakage paths.
• Clamp ammeters measure current without disconnecting the circuit.
Each tool tells us something different about what's happening electrically.
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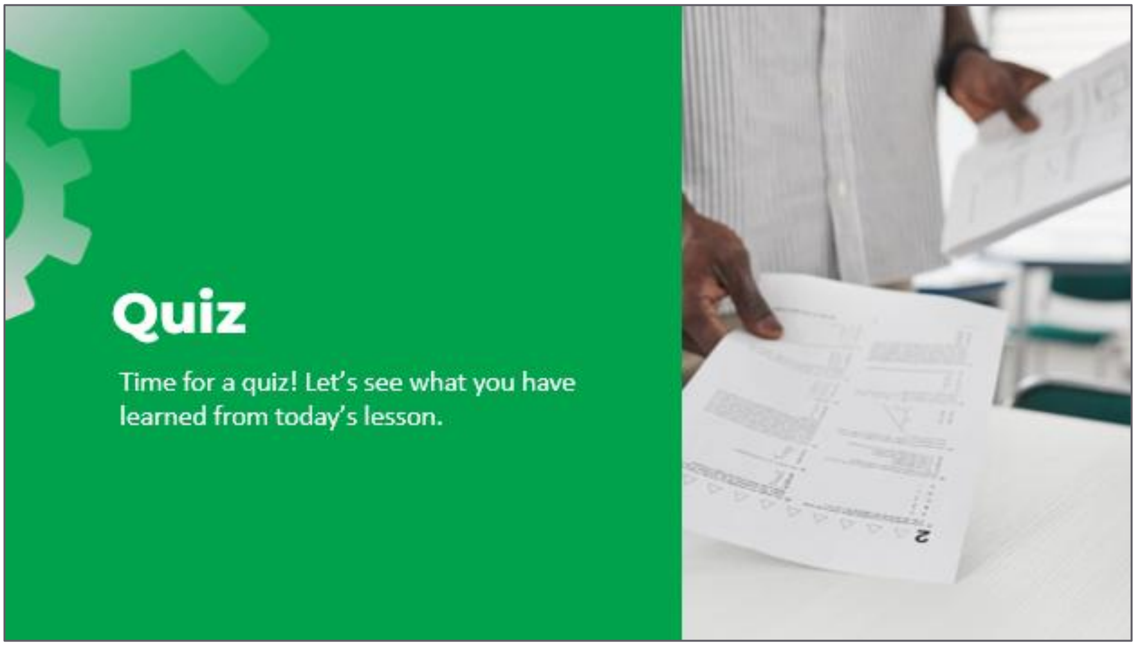

Notes:

- Time for a quiz! Let's see what you have retained from today's lesson.

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Objectives

- Identify common electrical and testing tools.
- Describe the purpose and limitations of common electrical testing tools.
- Make a proper wire connection using the correct tools.
- Inspect wire connections to ensure they are safe.
- Select the right tool to test an electrical circuit.
- Perform basic electrical tests safely.

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Notes:

- If you were explaining today's objectives to someone else, how would you summarize what they mean and why they matter?
- Which of today's objectives do you feel most confident about? Which were most challenging? Explain your reasoning.
- Can you give an example of how you could apply one of today's objectives in a real-world situation?