

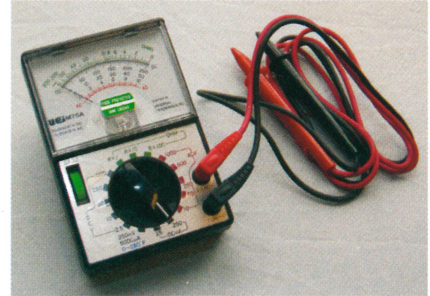
SELECTING AND USING TEST INSTRUMENTS

Single Instrument

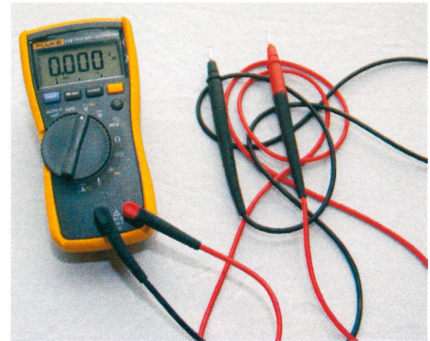
A multimeter combines the voltmeter, ohmmeter, and milliammeter into a single instrument. In the field, this one instrument can be used to measure (alternating current) ac and (direct current) dc voltages, ac and dc current flow, and electrical resistance.

Although analog multimeters have long been available, most multimeters used today are digital multimeters (DMMs).

Analog:



Digital:



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Instrument Safety Categories

Overvoltage Categories for Test Instruments

Overvoltage Category	In Brief	Examples
CAT IV	Three-phase at utility connection, any outdoor conductors	<ul style="list-style-type: none">• Refers to the “origin of installation”: i.e., where low-voltage connection is made to utility power• Electricity meters, primary overcurrent protection equipment• Outside and service entrance, service drop from pole to building, run between meter and panel• Overhead line to detached building, underground line to well pump
CAT III	Three-phase distribution, including single-phase commercial lighting	<ul style="list-style-type: none">• Equipment in fixed installation, such as switchgear and polyphase motor• Bus and feeder in industrial plants• Feeders and short branch circuits, distribution panel devices• Lighting system in larger buildings• Appliance outlets with short connection to service entrance

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Overvoltage Category	In Brief	Examples
CAT II	Single-phase receptacle connected loads	<ul style="list-style-type: none">• Appliance, portable tool, and other household and similar loads• Outlet and long branch circuits• Outlets at more than 10 meters (30 ft) from CAT III source• Outlets at more than 20 meters (60 ft) from CAT IV source
CAT I	Electronic	<ul style="list-style-type: none">• Protected electronic equipment• Equipment connected to (Source) circuits in which measures are taken to limit transient overvoltages to an appropriately low level• Any high-voltage, low-energy source derived from a highwinding resistance transformer, such as the high-voltage section of a copier



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Selecting an Appropriate Multimeter

- Choose a meter that is properly rated for the circuit or component to be tested.
- Ensure that both the meter and the leads have the correct category rating for each task.
- Check that the ratings of the leads or accessories meet or exceed the rating of the multimeter.
- Ensure that the meter case is not wet, oily, or cracked; that the input jacks are not broken; and that there are no other obvious signs of damage.
- Check the test leads carefully. Ensure that the insulation is not cut, cracked, or melted and that the tips are not loose.

Testing a Multimeter

To measure continuity:

- Set the multimeter to the lowest setting for resistance.
- Touch the tips of the two probes together.
- The display should show 0 ohms (Ω). A DMM will typically display OL (overload or out of limits) when a circuit is open (lacks continuity).
- If OL is displayed during this test, either the meter is defective or the test leads are defective.

To check a meter's ability to measure resistance:

- Use a resistor with a known value.
- Set the multimeter to measure resistance.
- Place one probe at each end of the resistor.

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- The value in the display should be very close to the known value of the resistor being used for the test.
- If the multimeter does not measure the resistance correctly, double-check it by repeating the test with a different resistor of a known value.

To check the dc voltage function:

- Use a new battery.
- Set the multimeter to measure dc voltage.
- Place the red probe on the positive terminal of the battery and the black probe on the negative terminal.
- The multimeter should display a reading of, or close to, the battery's labeled voltage.
- Reversing the leads on a digital meter will display a negative (–) reading.

To check the ac-voltage function:

- Use a 120 volts ac receptacle known to be energized.
- Plug in and turn on a lamp or another simple device to ensure that the receptacle is energized. Set the multimeter to measure ac voltage.
- Place the red probe into the energized side—the smaller slot of the receptacle—and the black probe into the other side (neutral).
- The multimeter should display a reading of, or close to, 120 volts ac.

If the multimeter fails any one of these tests, it is best to return it to the manufacturer for service. Technicians should never attempt to open and repair the meter's electronics or movement. If the multimeter will not perform any functions or provide a display when tested, the problem may be weak or dead batteries. DMMs have a battery indicator that will display when the battery is weak but still functional. Always replace

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the battery as soon as the indication is displayed to ensure continued reliable operation.

If the batteries are not the problem, determine if there is an accessible fuse inside the battery compartment. If there is, check to see whether it is open; another meter may be needed to check the continuity of the fuse if its condition cannot be determined visually. Replace an open fuse with one of the proper current and voltage rating. Using the wrong fuse, especially one that has a higher current rating than it should, can result in the meter being damaged beyond repair.

Return a multimeter to the manufacturer for an annual calibration to ensure its accuracy.

Common Testing Errors

Try to avoid the following common errors when using a multimeter to measure voltage:

- Measuring voltage while the red test lead is in the wrong jack. The test-lead jack for the red lead is usually marked with the V symbol and is often marked with the Ω symbol. Applying voltage to the meter while the red lead is plugged into the wrong jack may damage the meter.
- Measuring ac voltage on a dc setting. The dial symbol usually associated with measuring ac voltage is a V with a wavy line above it, or an mV with the same wavy line above. The latter is for measuring in the millivolt range.
- Keeping the test probe in contact with an energized surface longer than necessary. The longer it is in contact, the more time there is for an accident to occur.
- Using the meter above its rated voltage. Technicians should have a general idea of the expected voltage or current to be measured and ensure that the meter is capable of safely making such readings.



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Using a Multimeter to Measure Voltage

Take all available and necessary precautions to avoid contact with energized surfaces, and ensure that the probe of the test lead does not accidentally bridge two points with different electrical potentials. Use test leads with finger guards, and always keep fingers behind them.

- Select an appropriate multimeter for the job.
- Visually inspect it and the test leads for any signs of damage. Before using the multimeter on the job, always test it on a known voltage source to verify that it is functioning properly.
- Insert the black test lead into the common input jack (COM) and the red test lead into the input jack for ac volts (V or V Ω). Take care to insert the test leads into the correct jacks.
- Select ac as the type of voltage to be measured. If the meter has no auto-ranging feature, select the voltage range.
- Place the red probe onto the energized side of the circuit.
- Place the black probe onto the neutral side of the circuit or to ground.
- Read the voltage displayed on the meter while both probes make good electrical contact with their individual targets.

Using a Multimeter to Measure Resistance

- The ohmmeter function can be used to determine whether a circuit has continuity or to determine a specific resistance value.
- Select an appropriate multimeter for the job. Visually inspect it and the test leads for any signs of damage.
- Test the multimeter to verify that it is functioning properly and can measure continuity and resistance. A small resistor of a known value can be used to verify meter operation.

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- Insert the black test lead into the common input jack (COM) and the red test lead into the input jack for $V\Omega$ or Ω . If the meter has no auto-ranging feature, select the voltage range, starting with the highest.
- Set the meter to measure resistance (Ω).
- Ensure the circuit is deenergized.
- Touch the test leads to the two points in the circuit across the resistance.
- Read and record the resistance value displayed on the meter.

Using a Multimeter to Measure Current

A technician will frequently use a meter to measure ac. In some cases, ac values that are in the milliamp, or even the microamp (μA), range may need to be measured.

Most multimeters can measure these small current values by placing the meter in series with the circuit and then energizing the circuit to read the current flow.

Multimeters typically have a maximum current limit of 10 A when using this method of measurement. Do not exceed the maximum current limit of the meter.

Remember that exceeding the current limit with the meter in series with the load can result in significant damage to the meter.

To measure current values that exceed the meter's limit, use either a clamp-on ammeter or a clamp-on ammeter accessory designed for the multimeter in use.

Selecting a Clamp-On Ammeter

Many clamp-on ammeters are designed to provide most or all the functions of a DMM, with the added convenience of a built-in ammeter that can measure a significant amount of current. Therefore, they may



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be used to measure voltage, resistance, and current like any DMM. A major distinguishing feature of a clamp-on ammeter is that it has a current transformer built into the jaws that can be opened and closed around a conductor. Closing the jaws around a conductor enables the current flow to be measured without having to handle the conductor or disrupt the operation of the component or system being tested. Through induction, a small current is induced in the jaws by the current in the conductor.

Typical clamp-on ammeter features and functions include, but are not limited to, the following:

- A selector switch for selecting the desired test function (voltage, current, or resistance)
- An auto-ranging feature to automatically select the proper measurement range
- A HOLD function to freeze the reading shown on the display
- A minimum/maximum memory function to determine the highest and lowest reading over the course of a test. (The maximum function is valuable for measuring the inrush current when a motor starts.)
- A capacitor-testing feature that measures capacitance and checks for shorts and opens
- A continuity beeper that is activated when continuity through a circuit is detected. (The beeper is an advantage for troubleshooting, particularly in tight spaces, because attention can remain focused on the meter leads—listening for the beeper instead of diverting attention from the leads to check the readings.)
- Overload protection to prevent damage to the meter and to protect the user

Always read and follow the manufacturer's instructions for the meter to make the best use of its features.

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Carefully review an ammeter's specifications, features, and functions. Be sure that it has overload protection to protect the meter and the user. Choose an ammeter that can provide the degree of accuracy required. Ensure the ammeter is properly rated for the expected current. Inductive loads, such as electric motors, experience a significant inrush of current when they start. This surge occurs when a motor is first energized and must be brought up to speed from a complete stop. Although the surge may last less than one second, the current can be many times higher than the current shown on the motor data plate, especially if the motor has mechanical or electrical defects. Remember to consider the possible inrush current when selecting an ammeter and the range. The range can be changed, if needed, to a more appropriate level while the ammeter is actively measuring current. Meters with an auto-ranging feature eliminate this concern. Ensure that the ammeter has the correct category rating for each task. Also, be sure that the ratings of the leads or other accessories meet or exceed the rating of the ammeter. When making a current measurement, ensure that the clamp is firmly and completely closed to get an accurate reading.



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Testing a Clamp-On Ammeter

- Verify that the clamp-on ammeter is working properly before using it. The procedures for testing a clamp-on ammeter are the same as those used to test the functions of a multimeter.
- Always inspect a clamp-on ammeter before using it. Ensure that the case is not cracked or greasy and that there are no obvious signs of damage. Be sure that the jaw tips are not dirty and that they meet and interlock properly. Proper jaw alignment at the tips is essential for an accurate measurement. If the jaws are dirty or misaligned, the meter will not read correctly.
- Test a clamp-on ammeter to verify that it can measure continuity/resistance and voltage. Do not use the meter if it fails any one of the tests. If the ammeter is not performing any functions at all when it is tested, check for a blown fuse and/or replace the battery.

Using a Clamp-On Ammeter to Measure Current

Most digital clamp-on ammeters have an auto-ranging feature. If, however, the range needs to be set manually, always start at the highest range and adjust the range as needed to obtain an accurate reading.

Place the jaws of the ammeter around only one conductor at a time. Placing the jaws around two conductors at the same time will produce an inaccurate reading.

- While the system is deenergized, select the location for the current measurement and separate the target conductor from others so that the jaws can safely and easily be snapped closed around the conductor when the power is on.
- Make any preparations for measurement that can be made while the power is off to significantly reduce exposure to serious injury.
- Note that wire insulation is not a factor; there is no need to place the jaws around bare conductors. In fact, doing so can be dangerous.

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- If the current reading is expected to be at the low end of the lowest ammeter range, a more accurate reading can be obtained by wrapping the single conductor wire multiple times around one jaw of the ammeter.
- It is not often necessary for digital meters, but it is a significant help to read low current values on an analog model. Each time the wire passes through the jaws, the current it carries is sensed by the meter.
- If the same conductor passes through the jaws five times, the current measured will be five times the actual current flow. Be sure, however, to divide the reading by the number of times the wire passes through the jaws.
- While wrapping the conductor, do not allow the wraps to cross over each other. This can affect the accuracy.
- Note that this works equally well with a clamp-on ammeter accessory used with multimeters.

Non-Contact Voltage Tester





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Although a non-contact voltage tester is not suitable for work that requires any level of accuracy, it is useful for quickly verifying that a circuit is energized or deenergized. It is important to note that it should not replace voltmeter testing to prove that a circuit is deenergized for safety reasons. Electrical safety demands that a more dependable test device be used. The test instrument must be able to test each phase conductor or circuit part both phase-to-phase and phase-to-ground.

Non-contact voltage testers are relatively small, compact, battery-powered instruments that fit in a shirt pocket. They typically have the following features:

- An On/Off power button
- A flashlight or indicator light that shows the tester is operational and the flashlight may help illuminate the workplace (in some models, the flashlight can be operated independently of the voltage tester)
- A high-intensity LED light and/or a warning tone to notify when voltage is detected
- An automatic shutoff to conserve power and extend battery life
- A low-battery indicator
- A built-in self-test feature

Non-contact voltage testers are available in several voltage ranges. A standard model may be sensitive only to voltages above a range of 90–100 volts ac.

Dual-voltage models can register and differentiate between standard voltages and lower voltages. This feature makes these models more suitable for testing low-voltage ac circuits for the presence of power.

Note that these tools are not designed to sense the presence of dc voltage, since they rely on the presence of a magnetic field generated by ac. They may occasionally respond to the presence of dc voltage, but not reliably.

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Selecting a Non-Contact Voltage Tester

- When selecting a non-contact voltage tester, choose one with a range suitable for the expected voltage.
- Be sure the instrument is sensitive enough in terms of the minimum voltage that it can detect. Inspect the tester for any obvious signs of damage. Ensure the batteries for the tester are working.
- Many testers offer a battery test button to ensure the device is working properly.

Testing a Non-Contact Voltage Tester

Check the tester on a known, energized voltage source prior to using the instrument in the field. Use the built-in self-test feature, if the tester is so equipped. Otherwise, a simple way to test it is to place the tip of the tester near the line-voltage side (smaller slot) of an electrical outlet known to be energized. If the tester is working properly, the tester should give a clear audible and/or visual indication that voltage is present.

Using a Non-Contact Voltage Tester

Although non-contact voltage testers may detect voltages up to 1000 volts ac or more, working near voltages this high can be extremely hazardous. They are best used to detect voltages well below that value.

When safety is at stake and the intention is to make contact with conductors and/or electrical parts, use a multimeter to conduct the test to ensure that the circuit has been deenergized.

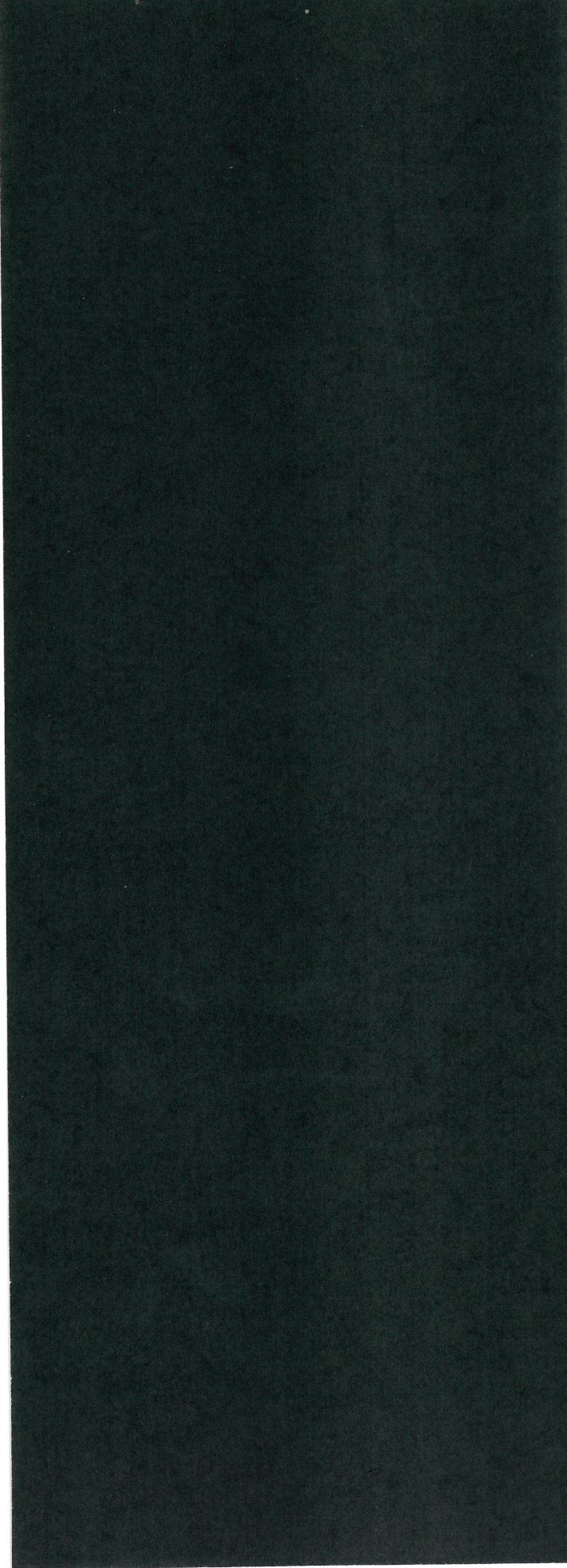
- Select an appropriate non-contact voltage tester for the job.
- Inspect it for any obvious damage.
- Ensure the batteries are working. If the instrument is equipped with a self-test feature, use it to ensure the instrument is functioning properly.



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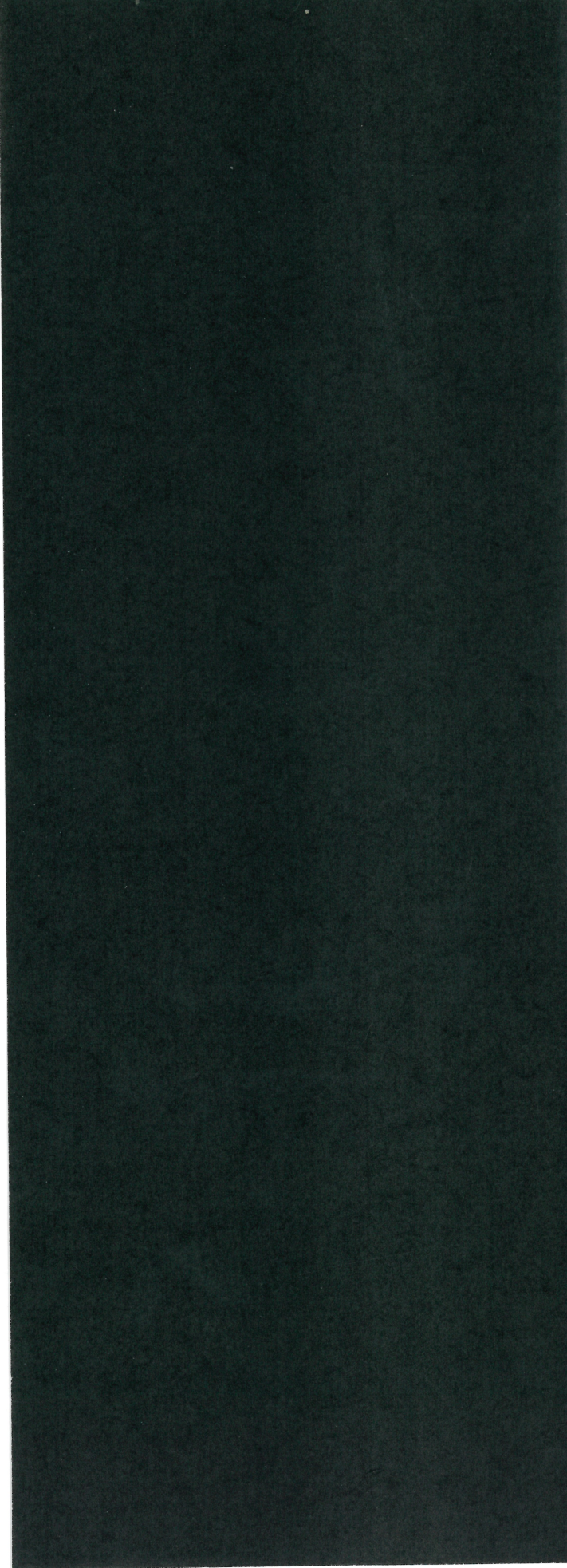
- Before using the voltage tester on the job, always test it to verify that it is functioning properly.
- Gradually move the tester as close as possible to the wire you wish to test.
- If voltage is present, the tester will react with both an audio and visual signal.
- If the circuit is off, there should be no voltage present and no response from the tester.
- If the circuit is live, the tester should provide a visual, and possibly an audible, indication that voltage is present.
- Move the tester from one power wire to the other to be sure.
- Cycle the power off and watch for the indication that voltage is no longer present.

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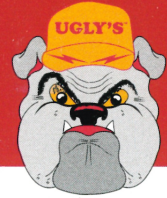
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