Understanding Non Contact Voltage Testers

“Who does that kid think he is?” Handyman Joe said to himself. “I’ve been wiring houses before he was an itch in his Daddy’s pants.” “I don’t need no safety equipment. Only sissy’s use volt sticks, they don’t work anyway.” “That kid should keep his mouth shut or go back to electrical school.” “Now he’s gone and got me all upset. I need another blood pressure pill. How many is that today already? Never mind; now what did that little Lady say? Something about getting a shock when she touched the shower valve. I need a little water to wash down that stupid pill. I’ll just get me a little drink out this here hose bib. Ahh, that’s good-Zaapppp!

“Uncle Joe, Uncle Joe. Wake up! I told you to be careful. You really scared us. Thought we lost you there for a minute.” “How many times now have you been zapped out so far? You need to be more careful. Next time use the tester!”

**Non Contact Voltage Testers** are an important personal safety device. These devices offer significant protection for any person who may come in contact with energized electrical components. I was surprised to discover there is not any comprehensive information regarding these devices. I have tried to gather what information I could find into one place in order to provide a starting place for better understanding of these important safety devices.

This article is intended help educate homeowners, home inspectors, and environmental investigators to the benefits and the shortcomings of these devices. The following discussion is limited primarily to single phase, residential type wiring and does not necessarily address three phase or direct current.

**Amprobe TIC 300**

“Voltage Proximity Testers are a relatively simple testing instrument that enables electricians and other uses to locate, trace and identify common electrical problems. These testers can locate wires behind walls, underground, and inside junction boxes. Others are designed to find blown fuses or test light fixtures. Some testers can even locate neutrals, ground faults, and high voltage lines without interrupting power. Most products are capable of continuity checks and audible continuity measurements. Continuity checks test a circuit for completeness, while audible continuity measurements beep when probes touch each other.”

http://www.texsoinstruments.com/tic-300-pro
**MIS-INFORMATION:** There is considerable confusion regarding the use of non-contact voltage detectors. While they are generally regarded as an important safety device, there are a number of prominent electricians who are hesitant to recommend their use. There is a general misunderstanding of the proper use of these devices. One use is for safety and the other is for diagnostics. From what I can determine, they are superior for safety but not so good for diagnostics. In addition, electricians tend to use these devices in the context of a repair, where an inspector is likely to use them in a context of safety. An electrician is going to use their tools to check wires and breakers for performance where an inspector is going to check any suspect metal components for safety. Metal ducts, pipes, and vents are all possible electrical safety hazards, especially in confined spaces. **Accordingly, electricians must be clear on the intended use of the device before making any recommendations regarding the use of these devices.**

**RISK MANAGEMENT:** Risk management is the primary focus of any successful business. Men and women who are active in a business that come in close proximity with energized electrical components must be aware of the dangers associated with electricity. These people must understand that electricity is lethal. The first and foremost safety standard is education. No amount of safety equipment will protect a person from disaster if they do not understand electricity. Accordingly, each person who presumes to work in close proximity with electrical components must assume the associated risks.

**EVERY TOOL HAS LIMITATIONS:** The razor knife for example, is an indispensable tool for almost every trade yet it is responsible for a large number of job site injuries. Many years ago, I inadvertently stabbed

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**Tic Tracer 300HV**

This "Proximity" (Various Ranges) allows you to detect electricity without breaking into power lines. The Proximity tester has a Beep effect, the closer it comes to live electrical lines, the louder the signal of the beeper becomes. You don't have to assume the unnecessary risk of touching live electrical wires when using this Tic Tracer. The Proximity Voltage detector is adaptable to Hot Sticks. The Proximity Detector comes standard with two different Ranges: High Voltage Range: 1500 - 122,000 Volts and Low Voltage Range: 30 - 1500 Volts. Use the Proximity Detector to safely check on power tools. Check if power tools are properly grounded. Also test whether AC power is connected to outlets, lamps, switches. Check fuse panels. Find breaks in insulated wire. Identify which conductor is power or ground. Sense the presence of AC voltage, from 30 to 122,000 VAC

http://www.texsoinstruments.com/tic-tracer-300hv
myself in the wrist with a razor knife by doing something stupid. I plunged the knife in up to the hilt and caused a wound that would not stop bleeding. It could have been serious if medical care was not available. Looking back, I wonder if gloves would have prevented the accident. Maybe a long sleeved shirt, or a heavy coat. Now I know that at that age I could have worn body armor and still found a way to hurt myself. Each layer of protection will lower the probability of an accident. Multiple layers will improve safety until 100% safety is approached, but 100% can never be achieved due to the uncertainty of the human condition. Education, experience and the proper use of tools will combine to provide protection that approach safe levels. A person who uses single levels of protection, that is to say, relies on only one tool for safety in a hazardous environment may well be putting his life at risk. I have learned to use all the tools in my belt to discern the potential dangers before beginning work. The non-contact voltage tester is usually used first, but it should be backed up with voltage testers and other tools as conditions require. No matter what, education is far more important than any tool. If you understand the systems and their associated hazards then you will probably be safe, until something goes wrong…

**DIAGNOSTICS:** Entry-level units are not particularly suited for diagnostics. Some of the upper priced units have varying degrees of increased diagnostic capabilities. This discussion is primarily devoted to the entry level, low cost testers commonly used by homeowners, technicians, home inspectors, and some electricians. Their diagnostic capabilities are directly proportional to the capability of the user.

**The AC HotStick** consists of a high sensitivity AC amplifier for the frequency range below 100 Hz. The special logarithmic amplifier is capable of receiving AC signals over a very wide amplitude range. Such signals, emanating from an unshielded, voltage-carrying surface, can be made audible and visible as a signal. The warning signal (beeps and LED flashes) become more rapid as the AC HotStick approaches the source, making source location quick. In the presence of high-tension wires the sensitivity can be reduced by selecting the **Low sensitivity** or the **Front focused** mode. The sensitive section of the AC HotStick is located in the red striped area. When used in the **High** or the **Low sensitivity mode** the unit will respond to signals from all sides (Omni-directional sensitivity). When the **Front Focused mode** is selected the unit responds only to signals received from the front of the AC HotStick. This reduces the sensitivity and concentrates detection into a small frontal area, permitting pinpointing of the source and distinguishing between adjacent wires.”

http://www.hotstickusa.com/
WHERE ARE YOU FROM? Many years ago, I had a college professor who stressed the importance of localities and how different tools, methods or designs could be called by different names in different areas, or more importantly, in different countries. This lecture was for a construction management class but it easily applies to hand tools. Tradesmen will have many different names for tools and these names will change from region to region and country to country. Regardless of the name of the tool, it is the function that is important, not the name. It is important to confirm that we are talking about apples and apples, not apples and oranges. Non-contact voltage testers are known by many different names which can lead to confusion.

WRONG NAME: Non-contact voltage detectors are known by many different names. Forty years ago, my father called them “Voltage Sniffers”, or just “Sniffer.” Other names are “Volt Stick,” “Tic-Tracer,” “Tick-Tracer,” “Ticker,” “Pocket Tester,” “Beeper Tester,” “Pen Tester,” “Proximity Tester,” “Voltage Proximity Tester,” “Glow Meter,” “Mag-Probe,” “AC Sensor,” “Capacitive Voltage Sensors,” “Stray Voltage Detector,” and finally, “Inductive Voltage Probe.” These names describe a device that really should be called an “Electromagnetic Field Detector.” I suspect the marketing divisions for the various manufacturers decided that it would be more profitable to associate these devices with voltage rather than magnetism in order to increase sales. By mis-characterizing the true function of these devices, the sales departments may have contributed to their poor reputation.

YOUR BODY IS A CONDUCTOR: The human body is a pretty good conductor. Under certain conditions
electricity can flow through your body. The current can range from a barely noticeable tingle starting from about 1 milliamp, ranging up to about 40 milliamps which can cause ventricular fibrillation, and a relative quick death.

**Release Threshold:** The muscles in the body are activated by tiny electrical currents. These tiny nerve related currents can be overwhelmed by an errant electricity resulting contraction of the muscles. Generally, the muscles that tighten are larger then the muscles that loosen. The hands for example will contact, or automatically grasp a live wire. If the current exceeds the grasp threshold of 17 to 25 milliamps then you will not be able to open your hand until the power is turned off.

If the circuit is limited to your hand then you may be no worse for wear with no permanent damage. If the current finds a path through the heart then it could well be a life-ending event. 7 milliamps applied directly to one’s heart can cause death. **That's equivalent to a 9 volt radio battery!** Due to the location of the heart and the body’s natural resistance, the minimum lethal amperage is about 40 to 100 milliamps for an adult. Keep in mind that children are far more susceptible to electrocution. **Due to their smaller size, these currents must be lowered by about 50%. It doesn’t take much to kill a small child!**

When current passes through the heart, it disrupts the natural rhythm of the heart and causes it to go into fibrillation, the uncoordinated contraction of the heart muscles. The heart effectively quits pumping blood and death occurs in 4 to 6 minutes. The heart must be stopped and restarted, rebooted if you will, to restore coordinated contractions and restore blood flow. Accordingly, it seems to me that every electrician and any other trade who encounter electricity should know CPR. 4 to 6 minutes is not very much time to save an electrocuted person. CPR could provide enough time for emergency personnel to arrive and save a life. CPR stands for **Cardio** (heart) **Pulmonary** (lung) **Resuscitation** (revive, revitalize)

See the Red Cross web site for more information.

http://www.redcross.org/portal/site/en/menuitem.86f46a12f382290517a8f210b80f78a0/?vgnextoid=aea70c45f663b110VgnVCM10000089f0870aRCRD

**X Marks the Spot!** It is important to be aware of the different paths through which current can flow. Your heart is centrally located in the chest with your arms and legs extending generally away from the heart. **Electrocution occurs when current passes through the heart,** or through the head. Consider the different paths that current can take to pass through the heart. Right hand to left hand and current goes through the chest/heart. Right hand to left foot or left hand to right foot and current again passes through the chest/heart. Right hand to right foot or left hand to left foot and current passes through the sides of the chest and maybe misses the heart. Foot to foot may not kill you but it may well be an experience never to be forgotten! The point is to be cognizant of your geometry and do not put yourself in a position to allow current to pass through your chest. Be aware of the potential current pathways through your body so you can minimize a shock to a relatively inconsequential area and keep the vital areas safe. Do not put yourself in a position to be shocked, and if must do so; manage the risk by positioning yourself to protect the vital areas of the body.

Lastly, there does not appear to be set standards for these amperages and voltages. The numbers change from author to author. These numbers can only be approximations and will change with local conditions.
and from person to person. Just keep in mind that under the proper conditions voltages down to 30 volts and tiny currents can kill.

You must read this Darwin Awards Article that discusses 9-volt batteries and electrocution. Can this be true?


See this web site for an in depth discussion on electrocution.

http://bme.ccny.cuny.edu/faculty/mbikson/BiksonMSafeVoltageReview.pdf

INSTINCTIVE WITHDRAWAL: Another consideration is the natural reaction to a shock. There is a natural tendency to suddenly withdraw from a shock. The quick withdrawal of a hand can cause you to impale yourself on nearby metal edges, or if you are on a ladder, then the momentum could cause you to pull the ladder over the center of balance and fall. Sometimes the shock is minimal but it can cause significant secondary injuries. You always must be cognizant of your surroundings and the potential repercussions of a shock. Was it the shock or the fall that killed him?

LAST CHANCE BEFORE GRASPING ANYTHING METAL: My father taught me to touch any suspect area with the back of the index finger on the right hand before beginning any work. If there is any current, it will automatically cause the finger to contract and automatically pull away from the power with little consequence. He explained the right hand was farther from your heart then your left hand and therefore safer than the left hand. There is no excuse for an intentional shock but I still do this instinctively as a last resort after having used my best judgment and the tools at hand before grasping anything that could be energized. Ultimately, I trust my finger above any man made contrivance.
**Two Types of Testers?**

**Magnetic Induction Tester:** The original type of detector is a magnetic induction air-core transformer. Magnetic fields induce a secondary current in the tester thus indicating a voltage. They will not detect a live wire that is not grounded. A wire may be energized but not connected to a circuit thus showing a false negative. If the wire does not create a magnetic field, the tester will not register.

**Capacitive Coupling Tester:** This is a newer type of non-contact voltage detector that uses capacitive coupling to detect an electric field. These upgrade detectors can detect an energized wire that is not conducting current. They detect electrostatic fields associated with live wires that are not necessarily part of a close circuit.

An electric field is associated with a stationary charged particle. An electric field will exist even when there is no current flowing. When the charged particle moves through a conductor, it creates an electromagnetic wave. Electric fields are part in parcel with magnetic fields and are associated with voltage. When electrons move through a wire, an electromagnetic field is induced around the conductor. These electromagnetic waves can induce a current on the secondary wiring inside the tester. Whether is be from induction or from capacitive coupling there must be electric field present to activate the tester.

**Faraday’s Law of Induction**

\[
\text{The induced electromotive force in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit}
\]

**It Does Not Measure Voltage:** We now understand that non-contact voltage testers do not actually measure voltage. It measures the movement of electrons through the conductor. Whether it is an electric field or electromagnetic radiation, the voltage is reported as a secondary reading based on the incredibly complicated movement of electrons and their associated wave functions. (It was so much easier when my father explained electricity. He used water tanks and water pipes as metaphors for voltage and wires.) However, for ours purposes here voltage is the measurement between the hot (Black Wire) and the neutral (White Wire) or the grounding wire (Bare Wire) or Earth. The whole point of this discussion is to prevent a person from somehow holding the hot wire in one hand and the neutral or bare wire in the other. Being cognizant of the conditions of the wiring system and the history of the electrical system is a good first step. The first layer of protection is to ask the occupant what he knows about the wiring! A second layer of protection is wearing insulating gloves, eye protection and rubber soled shoes. A non-contact voltage tester is the third layer of protection. The fourth layer would be a good physical tester that can measure Here is my “Wiggy.” A Gardner Bender Voltage Tester #GET-3100. This very simple neon light indicator can show a voltage between a hot and ground. This one ranges from 80 volts to 250 volts. Simple little tools like this can save your life.
voltage between two metal components. Another layer would be increasingly sophisticated testers. Remember, the best layer is of protection is education.

**DIRECT CURRENT DOESN'T WORK:** The reason these testers do not work on direct current is that current is induced in the secondary circuit during the build up and collapse of the magnetic field associated with alternating current. On direct current, the magnetic field is built up and maintained in one direction during current flow; but the magnetic field must collapse to induce a voltage in a secondary circuit. There is no magnetic flux on direct currents i.e. Steady State. I suppose if you turned on a DC circuit on and off 60 times a second it would activate the tester. Hall Effect sensors are capable detecting steady state magnetic fields on DC circuits. Direct current is a very dangerous and specialized subject that is well beyond the experience of this author.

**THREE PHASE:** Three-phase power is primarily associated with commercial and industrial applications. There are very few homes that utilize three phase power. Three-phase power requires a step up in education and experience to handle safely. It is possible for the magnetic fields to be cancelled out in these systems that would cause a false negative reading on the tester. This could be a very dangerous situation. Non-contact testers are not suited for layman’s use on three phase systems. The bottom line is to stay with what you know. If you don’t know three phase power or direct current then stay away and stay alive!

**IT’S NOT THE INVERSE SQUARE LAW:** The inverse square law is only for spherical source radiation and does not apply to wires.

\[
\text{Force} = \frac{1}{\text{Distance} \times \text{Distance}}
\]

**FOR STRAIGHT WIRES:** Magnetic fields are created as electrons move through the wire. On a straight wire, the magnitude of the magnetic field is inversely proportional to the distance from the wire. Electric fields are also proportional to the distance to the wire but the mathematics is well beyond the scope of this discussion.

\[
B_{\text{perpendicular}} = \frac{\mu_0 I}{(2\pi r)}
\]

\[
B, \text{ magnetic field strength, measured in Tesla}
\]

\[
\mu_0, \text{ permeability of free space} = 4\pi \times 10^{-7} \text{Tm/A}
\]

\[
I, \text{ current flowing through the wire, measured in amps}
\]

\[
r, \text{ distance from the wire, measured in meters}
\]

What this means is that the magnetic force is proportional to the current and that the force drops off very quickly as you move away from the wire. It also assumes the wire is round. When you are dealing with
enclosures that are square or other unusually shaped objects the force field will change shapes accordingly. So in order to use the tester correctly you must place the tester as close as possible to the suspect area and move the tester across the surface from corner to corner searching out the magnetic waves.

See these web sites for a complete discussion of magnetism in current carrying wires.


http://hyperphysics.phy-astr.gsu.edu/Hbase/magnetic/forwir2.html


http://www.associatedcontent.com/article/215036/understanding_electric_fields_and_coulombs.html

http://electricitymagnetism.suite101.com/article.cfm/understanding_gausss_law

**DIRTY ELECTRICITY:** While we are on the subject of electromagnetism we should all be familiar with the possible ill effects that electromagnetic radiation has on biological organisms. There are alarming increases in childhood asthma, leukemia, and autism that match the increase in the intensity of electrical devices that surround us in our homes. There is an increasing amount of antitodal evidence that electromagnetic radiation could be linked to these illnesses. Intuition tells us that living inside a microwave oven is bad; perhaps living in close proximity to lower doses of radiation over a long period of time is not so good. Sweden has already set standards in this regard. It will be interesting to watch how this subject plays out.

**THE CANADIAN INITIATIVE TO STOP WIRELESS, ELECTRIC, AND ELECTROMAGNETIC POLLUTION**

http://www.weepinitiative.org/index.html

**FALSE POSITIVES:** Non-contact testers are subject to several different types of false positive readings. Every tester has different settings based on the manufacturer and the intended use. Some are very sensitive and can even be set off from nearby high voltage lines. Others are designed to detect up to 500,000 volts. Of course, the very sensitive units are for very specialized uses and the high voltage units are clearly for highly trained personnel. The run of the mill units seem to start at about 90 volts and go up to 300 volts or so. Be sure to pick out the right tester for the right job. It is interesting to note that 90 volts is well above the minimum lethal voltage of 30 volts. Perhaps it would be wise to use a tester that starts at 30 volts. I may have to buy a new tester…

**Ghost Voltages** can be high enough to set off the tester but have virtually no current. Look out for disconnected wiring that is running parallel to energized wiring. Capacitive coupling from the energized wiring can cause a voltage in loose wiring. This is common on wiring that is inside a conduit. It can also show up on water piping that is not properly bonded. Remember, magnetic waves can induce a current on any metal components within its field and that secondary current can set off the tester.
**Static Voltage:** Many times a tester will not show any voltage while *held still* but as soon as you move the tester across the surface of the suspect component, you will get a positive reading. This is some kind of residual voltage in the system and is a clue that the bonding/grounding system may not be proper.

**Feed Back:** When there is an open neutral on the utility and the system is not bonded. Voltage can show up in the home even when the main breakers are off.

**Stray Voltage** is primarily associated with dairies but it can show up in residential neighborhoods. I read one article where children were being shocked when using a hose bib in the back yard. It is usually associated with improper neutral connections in the utility supply lines.

Just because you get a response on the tester, it does not necessarily indicate a dangerous voltage. It could indicate many conditions. The tester has done its job and alerted the user to a possible hazardous condition. **It is then up to the user to review the conditions and make an informed decision on how to proceed.**

**FALSE NEGATIVES:** The real danger with this type of tester, or any tester for that matter is when the device fails to indicate a hazardous condition. In these cases, the user is unaware of hazardous condition and could unknowingly get into trouble. Non-contact voltage testers are subject to some false negative conditions. It is important that the user be aware how these may manifest themselves. From what I can determine, the only way these testers can be fooled is by somehow having two out of phase magnetic fields that cancel each other out. This may be found in a common neutral in a single-phase panel. This is an important safety consideration. If **any reader has more information on how a non-contact voltage tester can fail to indicate a voltage** then please let me know so it can be included in this article.

**Common Neutral?** I was told that a neutral that is being used as a common in a balanced service can be energized but show no voltage. The alternating currents exactly cancel out the magnetic fields. There must still be a voltage between the hot and the neutral but the magnetic waves may be cancelled out?

**SHIELDING:** Now that we understand that we are not really measuring voltage, but waves, we must be aware that waves can be shielded much the same way wiring can be insulated. Electromagnetic waves emanating from wiring inside of a conduit, or armored cable will be stopped by the metal housing. **I do not consider this a false negative in that the user is not subject to an electric shock.** The energized
wiring is contained inside the conduit; the conduit is not energized, therefore the conduit is not a threat. If the conduit was energized then it would show up on the tester and alter the user to the possible danger.

Similarly, wiring that is inside a panelboard, or a disconnect box will effectively be shielded by the metal enclosure and not show up on the tester. Once the lid is opened then the magnetic fields will reach the tester.

I am sure there are cases where there could be one side of the wiring that is shielded and the other side is energized much the same as one end of a conduit could be safe and the other end missing. The user must be cognizant of the surroundings and the limitations of the device.

**Water** can also shield magnetic fields. Wet insulation will shield magnetic fields much the same way as a conduit. This is an important condition; first, there could be an unknown energized wire nearby but more importantly, if the wire is wet then the entire area may be wet subjecting the person to a heightened probability of electrocution. Do not touch electrical components if they are wet; turn the power off and dry the area before accessing the area.

**How To Use A Non-Contact Voltage Tester:**

1. First, pick out a tester that fits the parameters of the work. Be sure the unit is not too sensitive or not sensitive enough. Some higher cost units have variable ranges, blinking lights and buzzers. Choose the one that best fits your needs.

2. Check the batteries.

3. Always check the tester on a known voltage source prior to using it on the suspect areas. There is some uncertainty here because the typical residential wiring is either 110 volt or 220 volts but we know that voltages down to 30 volts can be lethal. Therefore, to really confirm the function of the equipment we need to test the lower detection limit and the upper detection limit of the unit. In the real world, this may be impossible and we will have to accept the risk of testing the unit on a known 110-volt circuit prior to use. Some of the literature says to test the device after use, but this seems to be a little late to me.

4. Be sure to wear protective clothing appropriate to the task. Insulating gloves, rubber shoes, eye protection, good tools, no drugs, and a good night’s sleep can help protect you from the “dirt nap.”

5. Always start at the main service disconnect. Check to see if the outer cover is energized then remove the outer cover. Look at the dead front cover for scorching or rust. Next, remove the dead front cover. Be especially careful to keep from causing a dead short at the upper edge. Some of the older panels have exposed lugs at the top that can come in contact with the dead front cover when it is levered out. If the cover touches the lug, it will explode and spray you with molten metal. 40 years ago, I ruined a brand new set of eyeglasses removing a panel on a remodel for my father. I should have listened to the “ole man”, now I can’t forget his advice and exercise caution whenever removing covers.
6. Once the dead front cover is removed check to see if the system is grounded and bonded correctly. Look for overheating and corrosion issues. More importantly, check to see if the system has been professionally installed or if a homeowner/handyman has somehow changed the system. Homeowners/handyman installed changes are inherently hazardous. Has there been any a remodel or additions? This will give you a “heads up” on what to expect on other areas of the system. Ask the occupant for the history of the electrical system.

7. Look to see if the area is wet or dry. Water increases the risk of electrocution exponentially. Water can shield magnetic fields and it greatly increases the conductivity of your body. Don’t work in wet areas!

8. When checking a suspect component stand clear of any projecting parts that may be energized. Slowly scan the area with a side-to-side motion ever getting closer and closer to the component. If the component is an odd shape then be sure to scan the entire area. Remember the magnetic field will change shape according to the shape of the component. If the component is energized, the intensity of the voltage can sometimes be estimated by the intensity of the flashing light or sound of the buzzer. Some electricians have reported being able to estimate voltages based on how the tester responds to the voltage.

9. Look to see if the component is somehow shielded. Conduits, panel covers and wet insulation will dampen magnetic fields and mask a voltage.

10. Watch for “ghost voltage” that may be caused by induction or capacitance coupling. Loose wires that show a voltage should be removed, and energized metal pipes may be an indication of improper bonding or worse.

11. Be aware that it is possible for a component to be energized without showing any voltage. While this is a low probability, it does happen. Look at what you are doing. Do you understand what is happening? If you don’t then don’t do it. Now is the time to pull out the wiggy (voltage meter) and check for voltage.

12. Lastly, before committing to touching the component touch the system with the back of the index finger on your right hand just to be sure it is not energized.

13. There is now an acceptable probability that the component should now be safe to touch. We have managed the risk.

Non-contact voltage testers are an important safety device but they must be understood in order to be used properly. I hope the foregoing discussion has provided useful information. Any comments are welcome.

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