

A Farmer's Guide to Stray Electricity Measurements

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Chapter A



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A1 - Introduction

This guide is for farmers and electricians that are new to stray voltage.

Ever since 1981 I have been tracking down stray voltage, working to train others to do the same and staying busy in the pursuit of solutions. A lot of my time is spent trying to prevent people from taking off on tangents with the latest new “solution” for stray voltage when they should be checking the basics first.

You may have heard the debate over current or voltage measurements. I will discuss that later, but for now I may interchange the terms “stray voltage”, “stray current” or “stray electricity”.

There are many people providing the farmer with totally different theories on stray electricity. If you listen to all the conflicting information, you will be confused. I will go back to the basics using the facts and methods that have been used successfully for many years. The original methods have not changed because they are based upon good scientific techniques.

I will try not to give you my opinions but help you develop your own. I will show you how to understand what is happening on your farm and help you make decisions on what to do next.

To understand what is happening on your farm (electrically) you have to make some measurements. If you follow stray voltage discussions you will hear people telling you to measure steady state, RMS, peak, peak to peak, impulses, transients, magnetic fields, measure only voltages, measure only currents and on and on and on.

Well all of these items are important but first let’s get back to basics. Stray voltage implies that you have a concern for electricity on the farm in places that we do not want excess electricity to be. If you have a perfect power supply system and a perfectly wired farm, you still will detect some electricity in every part of your farm. The trick is to keep the level of electricity low enough not to be a real concern where the cows are.

Stray electricity will come from off-farm sources such as utility neutral conductors, telephone shield wires, rural water systems, CATV systems, neighboring homes and farms. It will also come from on-farm sources such as your electrical devices and/or wiring in and around the farm and home. It may come from fencers, cow trainers, cow identification systems and variable speed motor drives.

My approach will be to see what electricity is getting to the animal. If you determine that the level of electricity at the animal is too high for your personal level of concern, we can discuss what is required to reduce the levels later.

A2 - Spot measurements at “Cow Contact” points:

In order to determine what level of stray electricity is getting to the animals, you have to make measurements where the animals are located. These are called “Cow Contact” (CC) points. There are quite a few CC points on the average farm, but there are not so many they cannot all be measured. In this chapter I will show you one method to measure these multiple CC points.

At each CC point we will measure the voltage across the CC point. **Yes, I said voltage not current.** Your animals respond to current passing through their bodies. If you put current sensors on each leg of a cow you could measure the current flowing through the cow. It’s nearly impossible to measure in this manner so we measure the voltage impressed across the cow from mouth to hoof or hoof-to-hoof. From these voltage measurements we can accurately determine the current that flows through the cow.

It’s hard to get a cow to stand still and allow us to hook wires to it. We know that the average body resistance of a cow varies from about 250 to 1100 ohms plus any resistance in the animal’s contact with surrounding objects. Most people assume an average body resistance of 500 ohms for a cow, which assumes a good connection to the floor and/or water cup. If you accept 500 ohms as a reasonable resistance for the cow in its environment, we can place a 500 ohm resistor across a CC point, measure the voltage across the resistor and then calculate the current flowing through the resistor. This value of current would be a reasonable approximation of the current would flowing through the body of a cow standing in that location.

Ohm’s law tells us if we use a 500 ohm cow resistor the following relationship exists between current through the resistor (our cow) and voltage measured across the resistor.

Voltage measured (In volts)	Current Flowing (In amperes)	Current Flowing (In milliamperes)
0.0 volts	0.0 amperes	0.0 milliamperes
0.1 volts	0.0002 amperes	0.2 milliamperes
0.2 volts	0.0004 amperes	0.4 milliamperes
0.3 volts	0.0006 amperes	0.6 milliamperes
0.4 volts	0.0008 amperes	0.8 milliamperes
0.5 volts	0.001 amperes	1.0 milliamperes
1.0 volts	0.002 amperes	2.0 milliamperes
2.0 volts	0.004 amperes	4.0 milliamperes

The above conversion holds true for steady state, momentary swells, impulse, transient and all other forms of electricity.

I am making a simplification. As the duration of an impulse (the time between zero crossing on a scope) gets less and less, the frequency gets higher. At higher frequencies the resistance of a cow decreases to about 100 ohms. For practical purposes I will assume a constant 500 ohm resistive cow. This makes any error in calculations benefit the cow. There are other items such as capacitive impedance and total impedance that could be discussed on a very technical level, but let's just stick with a 500 ohms resistor.

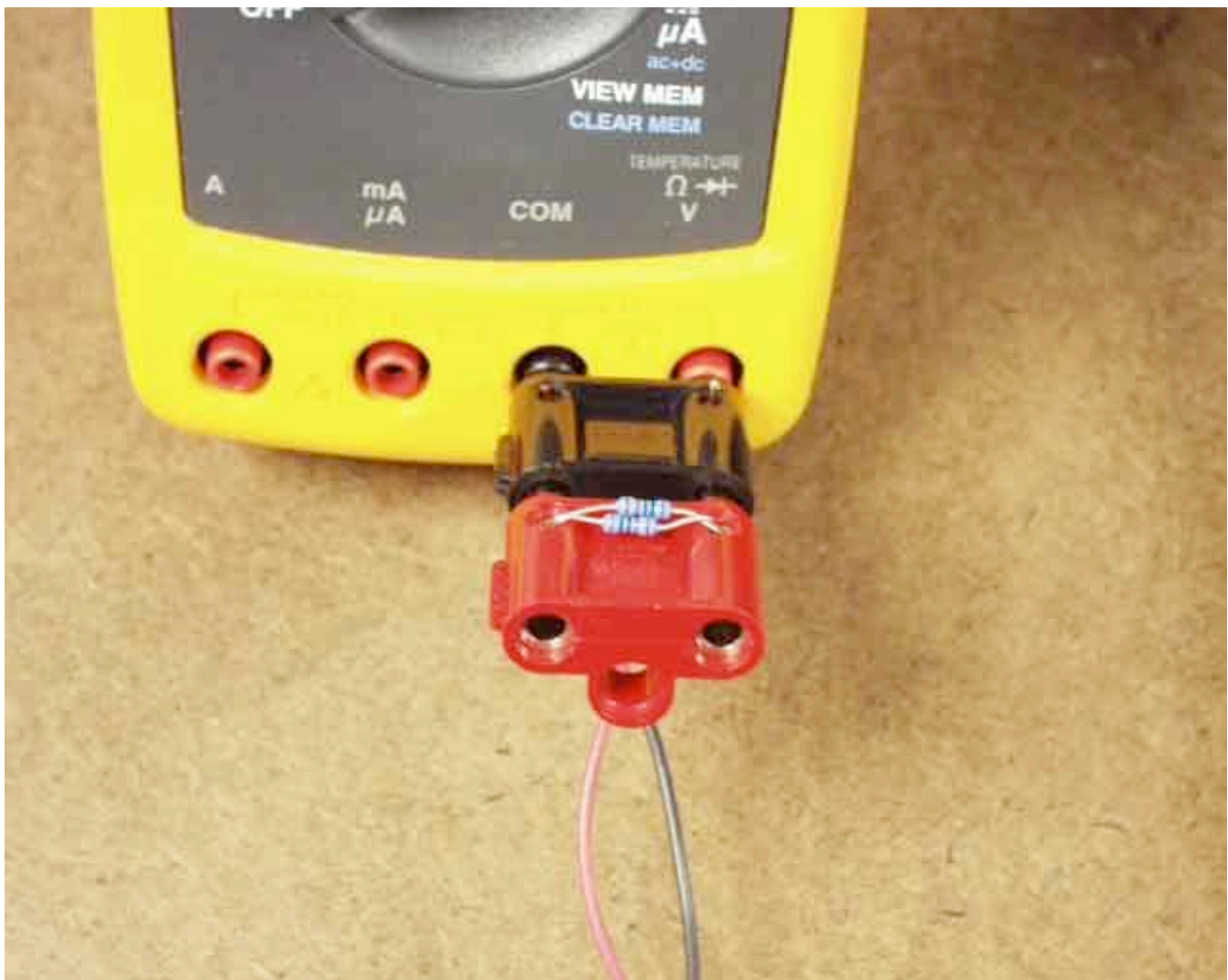
A3 – Getting your meter ready:

Bring the wires from each of the two cow contact points to the meter and connect to a “banana plug”, then to the meter as shown below. The banana plug can be purchased at Radio Shack. With this connection you will be reading the CC voltage **without** the cow resistor.



Next take a second banana plug and put a 500 ohm resistor between the terminals. Use two 1,000 ohm resistors in parallel as shown below. Resistors are available from Radio Shack. Use 1/2 watt or 1 watt types. This will be your 500 ohm “Cow Resistor”.

Insert the cow resistor into the banana plug, tighten the screws on the banana and plug the assembly into the voltmeter input. If you set the meter to AC volts, the reading will be the CC voltage **with** a cow resistor. The voltage value **with** the resistor is normally lower than the voltage **without** the resistor. The voltage **without** the resistor shows what level of voltage is available to that CC point. The voltage **with** the resistor shows what voltage would be across a 500 ohm-cow that contacted the same two (2) cow contact points.



As long as you have your meter handy, plug ONLY the 500 ohm resistor into the meter, put the meter on the ohms (Ω) scale and measure to make sure your resistor is between 475 and 525 ohms.



A4 – A “Many Point Tester”:

When you do your spot cow contact measurements you should perform the cow contact test at **ANY** point on the farm that a dairy animal might frequent.



The above unit is a suggestion for a tool you can construct that will make this task much easier. The unit is made up using 1.5-inch pvc pipe. The handle on top is a tee fitting. The shaft is approximately 3 feet of 1.5-inch pipe, cut to a length to suit your use. The lower fitting is a 1.5 inch pvc to 1.5 inch threaded pipe adaptor. The metal plate is a 1.5-inch metal pipe floor fitting.



The #12 stranded copper wire, stripped from a three conductor portable cable, makes the connection from the bottom plate to the tee fitting.

I found a 1/4-20 brass screw and brass locknut at my local hardware store along with a 1/4-20 tap and tap drill. The cast metal base can be tapped with the 1/4-20 tap in a variable speed drill and a drop of oil for tapping.

Make sure you grind the excess material off the brass bolt so the bolt does not stick out preventing you from getting the metal floor plate to lay flat on the floor during measurement. A little anti-ox electrical joint compound in the tapped hole helps to preserve a good electrical connection.

OK, that's one end of the unit. Next you need something to make a connection to the waterline, water cup or metal portion of a watering unit.

If you make two floor contact testers as shown above you can do step potentials on barn floors, the earth or ramps to equipotential planes.

A metal file is used to make the connection to the metallic portion of the cow contact point. To make the connection to the metal file, I grind the surface of the connection point as shown below:



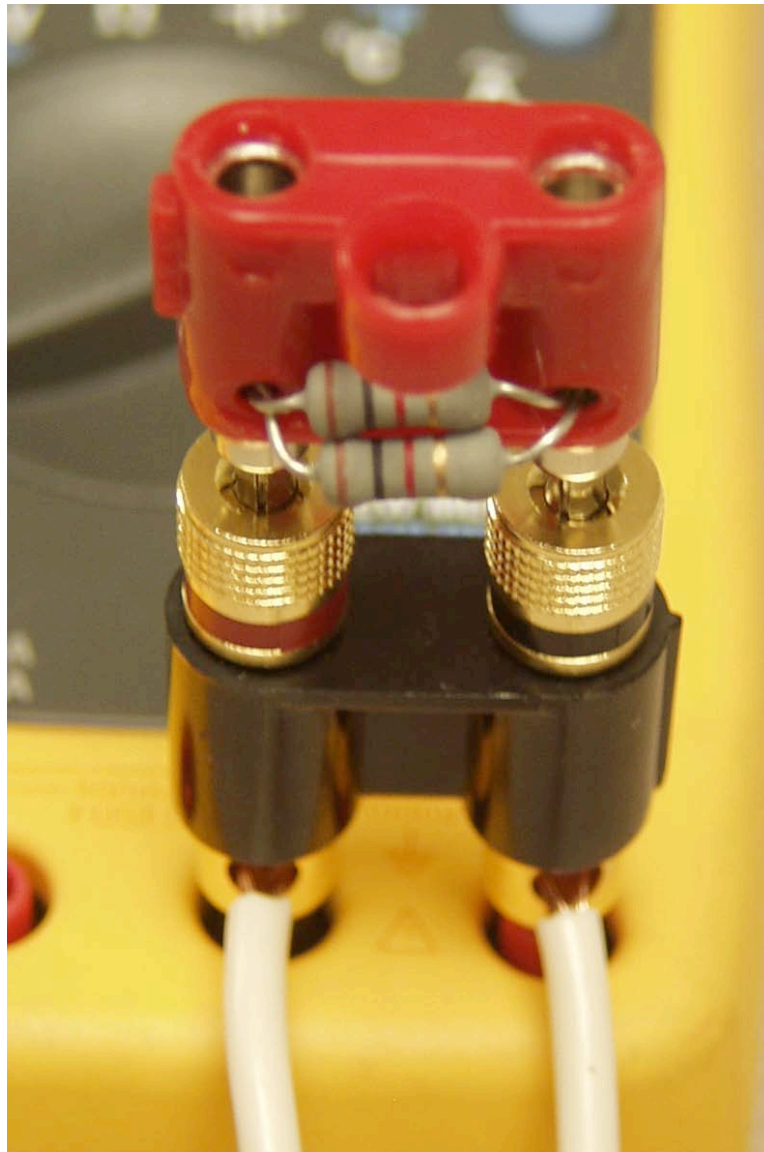
Next I use a brass welding unit or just a MAPP torch and flux coated brass rod to add a layer of brass to the steel of the file. With brass metal base makes it easy to solder a copper wire to the file.



The completed "handle" is covered with heat shrink tubing or tape. The covering makes holding the file more comfortable and insulates you from affecting the electrical circuit you are measuring.



The last thing to do is to make a connection to your meter. On a trip to Radio Shack I found a high power audio system connector that allows you to connect two large copper wires to a banana jack. This banana jack makes a nice connection to your voltmeter. In addition another regular dual banana jack allows you to insert a 500 ohm resistor across the circuit when needed as shown below.



Using the Many Point Tester is best with at least two people. With three people the third person can record the measurements.



A5 – Keeping track of your spot measurements:

One way is to make a sketch of the area being checked and note the millivolts recorded at the location it was measured. Later as you review your work it will become clear what area of the farm has the highest levels of stray electricity. The points of highest voltage determine where you may want to record voltages for a day or so.

I call this a “cow contact profile”. The procedure is to use a voltmeter or oscilloscope, set for AC millivolt measurements, with or without a resistor, and then determine the spot on the farm that has the highest cow contact voltage at the time of the test. The actual cow contact voltage measured is not the issue. I am looking for the cow contact point with the highest voltage.

It does not matter what time of day the tests are made, as long as you locate the point with the highest voltage at that time. I use a 500 ohm resistor from time to time to determine the strength of the cow contact voltage.

40/5	7/3
13/10	7/2
12/8	4/2
13/7	4/1
13/5	4/3
15/10	20/19

Note the conditions under which the above measurements were made. Was the farm isolated, what time of day, were any special or large loads running at the time? **If you do**

not plan to make long term recordings at the highest cow contact points, you may want to have the farm electrical loads at maximum levels for the final spot checks. Make a note if your voltages are AC or DC with AC preferred. I suggest you measure in AC millivolts because I hope that you will find low-level voltages where the cows are located.

In the example above when you see " xxx / xxx " – the first number is CC in millivolts rms without the cow resistor, the second value is CC in millivolts rms with a 500 ohm cow resistor.

When you see only " xxx " – the number is CC in millivolts rms without a cow resistor.

As a reminder:

0.001 volts = 1 millivolts

0.01 volts = 10 millivolts

0.100 volts = 100 millivolts

1.0 volts = 1000 millivolts

mv = millivolts

In the above example on the upper left corner of the room I measured 40/5 mv. In the lower right I measured 20/19 mv. What is the greatest area of concern?

The 40/5 reading indicates a higher possible source voltage, but when the cow resistor is placed in the circuit it is clear the voltage to the cow drops considerably. This is what people mean when they say the stray voltage source has a high source resistance. The 5 mv reading is the important measurement.

Many times fluorescent lights, variable speed drives and other electrical equipment may couple into your test leads creating large voltages when measuring without a cow resistor. The 500 ohm resistor will reduce the voltage to the correct value.

The 20/19 reading indicates a lower source voltage, but the source resistance is low. When the 500 ohm cow is placed in the circuit, the voltage does not drop. I would place more attention on the 20/19 spot reading.

There is another item to consider. When you make the spot reading without a resistor, the voltage shown is the maximum possible at that point. The spot reading without a resistor is a good overall survey measurement, but it is important to remember that the cow will not see a voltage this high.

When you put the 500 ohm cow resistor in the circuit, the voltage that a 500 ohm cow would experience is measured. Be careful with the measurement with a 500 ohm resistor, a poor connection either cow contact point could result in a deceptively low reading.

If the value measured without a 500 ohm cow resistor is below your level of concern, there is no real need to make the measurement with the resistor, other than making a more complete investigation.

Performing initial tests on the cow contact point:

With the meter connected to the cow contact points and no 500 ohm resistor installed, switch the meter to the AC **volt** scale and record the **volts AC** = _____(Vacw/o). (Remember 1 volt = 1,000 millivolts)

Plug in the 500 ohm resistor and record the volts AC = _____(Vacw).

Switch the meter to the DC scale and record the volts DC = _____(Vdcw).

Remove the 500 ohm resistor and record the volts DC = _____(Vdcw/o).

If the voltage values are below 0.2 volts you may want to switch to the millivolt (mv) range. Just be sure to record if you measured in volts or millivolts.

The Fluke 189 meter reads AC voltage when the round selector switch is in the position V_{\sim} or $V_{\sim} \text{mv}$. The meter reads DC voltage when the round selector switch is in the position $V_{\text{---}}$ or $V_{\text{---}} \text{mv}$.

Hopefully the voltage without a resistor (Vacw/o) is higher than voltage with a resistor (Vacw). Voltage (Vdcw/o) should be higher than voltage (Vdcw). Voltages Vacw/o and Vacw have no relationship to Vdcw/o and Vdcw.

The fact that the voltage with the 500 ohm resistor is lower than without the resistor is due to an calculated resistance we call “source resistance”. In other words there may be 1.0 volts without a resistor indicating that a voltage source of 1.0 volts is present, but the measurement drops to 0.3 volts when the resistor is applied. The cow will only see 0.3 volts. If this seems a little confusing, don’t worry about it now.

You could calculate the AC source resistance of the cow contact measuring point. This is a check to make sure that the test wires are making contact with the remote rods, plates and connections.

If the calculated cow contact source resistance is above 500 ohms, check that the floor plate is making as good a connection to the floor or cow contact point as possible. If the calculated cow contact source resistance is below 50, ohms check to make sure the floor plate is not coupling directly to some metallic object above or below the floor.

This example assumes the cow resistor was 500 ohms, the $V_{acw/o}$ measured 0.8 volts and the V_{acw} measured 0.2 volts. The source resistance is calculated as follows:

Subtract V_{acw} from $V_{acw/o}$ or $0.8 - 0.2 = 0.6$

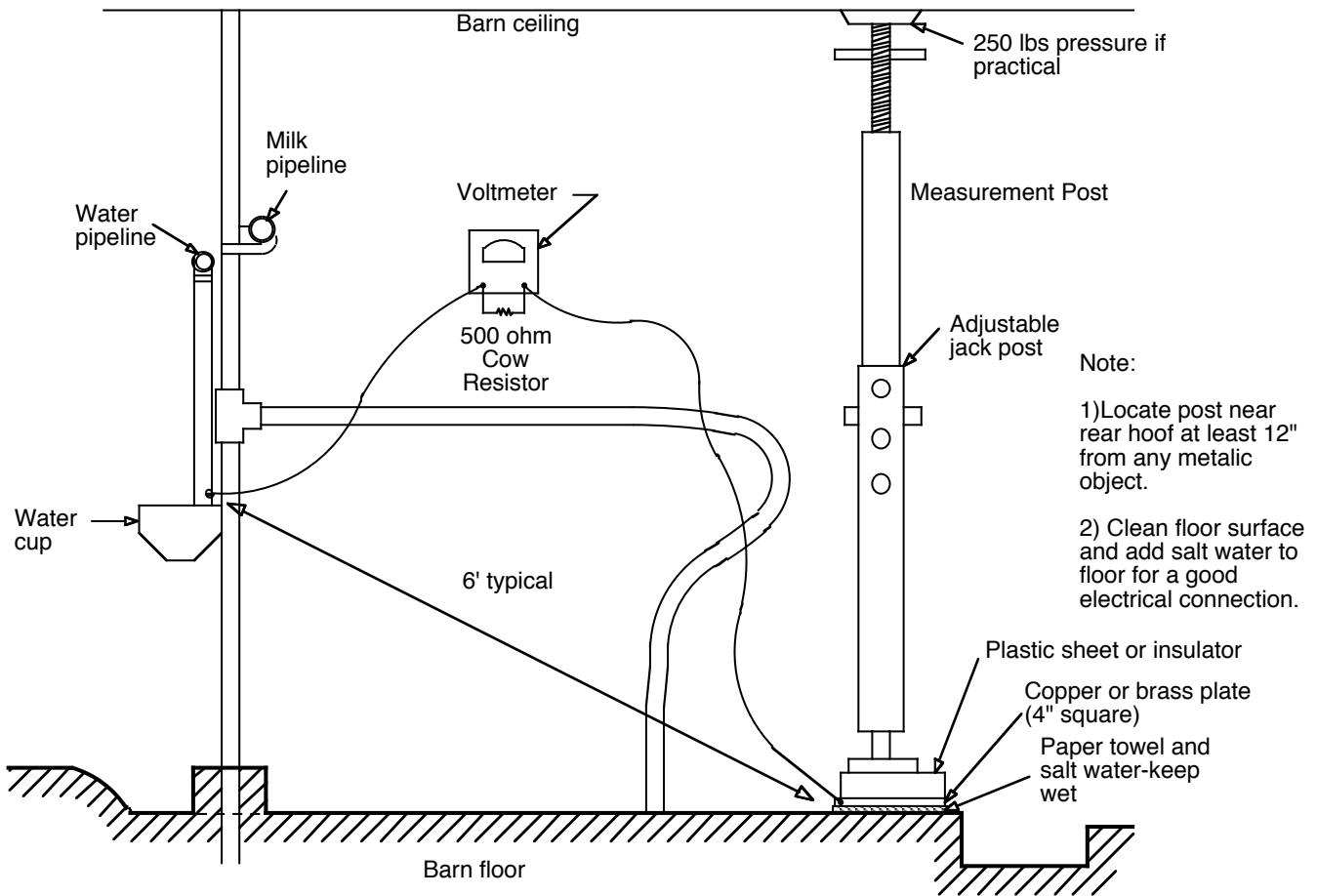
Divide the above answer by V_{acw} or $0.6 / 0.2 = 3.0$

Multiply the cow resistor value by the above answer or $3.0 * 500 = 1,500$

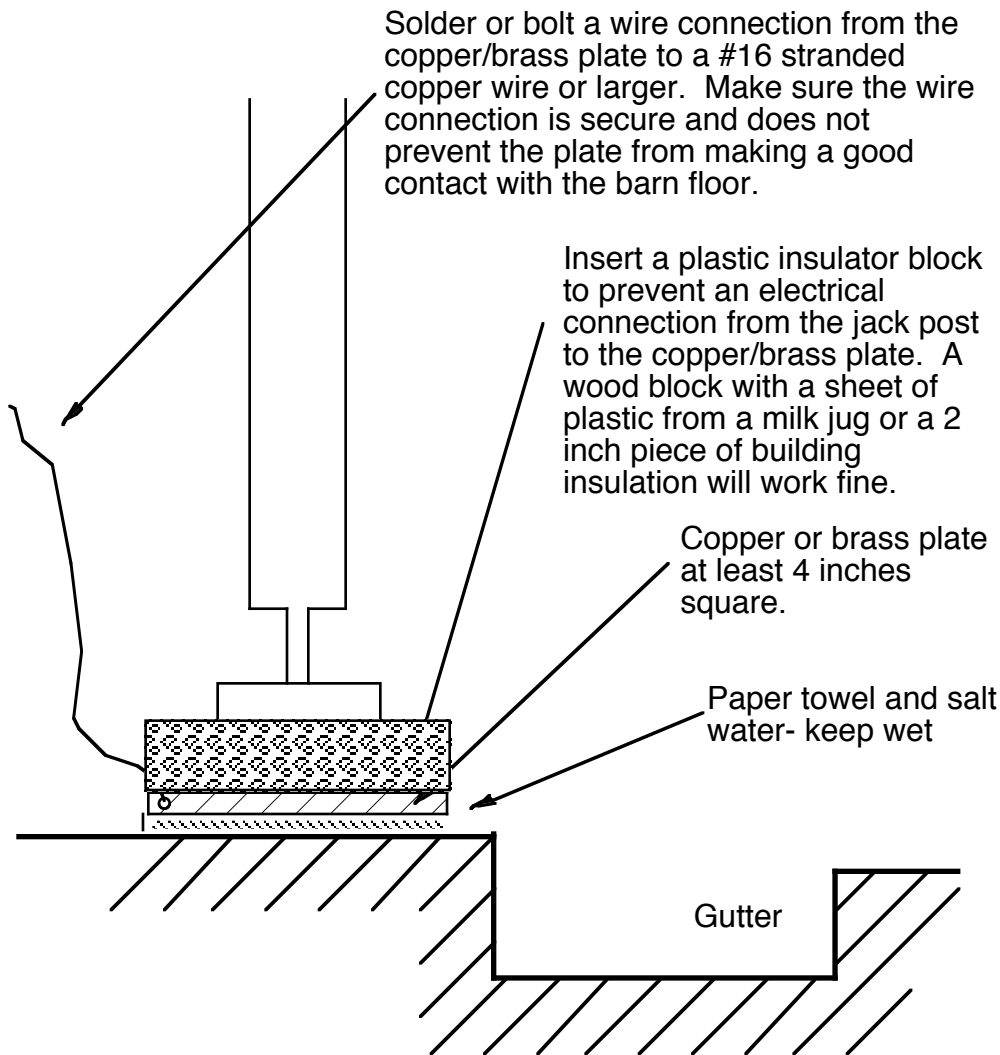
The source resistance is calculated at 1,500 ohms which looks high.

A6 - Long term measurements at “Cow Contact” points:

You will need a voltmeter, a 500 ohm resistor, a “banana plug”, a brass or copper floor plate, some plastic from a milk jug, a piece of 2” building foam or wood, a jack post, some hose clamps and wire. It will all be connected as shown below. The figure below is for a typical stanchion CC point. A CC point can be any point at which a cow may be located. The drinking water tanks to earth are other areas of concern.



COW CONTACT AREA MEASUREMENT MOUTH TO REAR HOOVES



JACK POST CONTACT PLATE

Filing or sanding the corrosion from the metallic pipe will improve the connection to the stanchion or waterline. Fasten a copper wire to the pipe using a stainless steel radiator hose clamp. A pipe clamp from the local hardware store made for grounding electrical services will also work fine. Just make sure you have a good electrical connection to the steel pipe. A clean looking pipe may have an oxidation layer that prevents a good electrical connection, so be sure to sand or file the pipe surface before making your wire connection.

When connecting to a metallic milkline, use a stainless steel hose clamp and attach your wire to the hose clamp. Some people are concerned if the copper wire makes direct

contact with the stainless steel pipeline for an extended period of time. A form of corrosion can occur between the copper and stainless steel.

If you would like to locate the meter at a point remote from the CC point, make the connection using a twisted pair shielded cable such as Belden type 1032A cable. This is a two conductor, twisted pair #18 copper wire cable with a foil shield. If you like, ground the foil shield wire at only one end.

If this type of cable is not available, use two of the three wires in an extension cord. I suggest cutting the plug and receptacle off the cord before you use the wire so someone does not plug one end into the outlet while the meter or a CC point is at the other end of the cable.



The type of meter you select to use is not critical at this point, but a recording voltmeter is suggested.

Below I am showing a Fluke Model 189 digital multi-meter. The meter is in the AC voltage measuring position. If you have a fixed range meter, I suggest a full scale of 2 volts AC. The Fluke 189 meter records true RMS values in the AC position. The true RMS value will consider all harmonics and frequencies up to 100,000 Hertz that are present and give you a reading that is consistent with other true RMS meters. This meter has the advantage of being able to log readings to a computer.

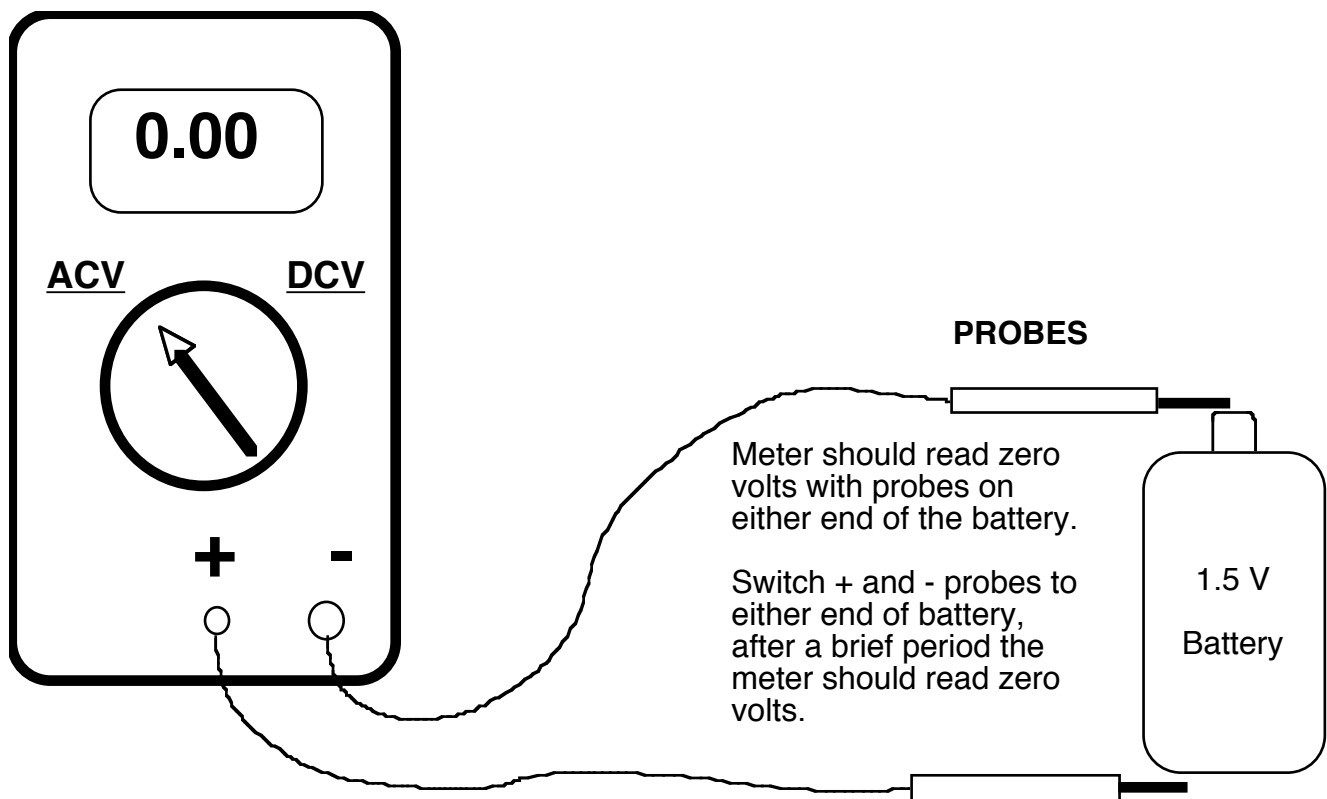


A7 – Measurement hints:

Hint #1 - You can use any meter in place of the Fluke 189 digital multimeter. An oscilloscope, commercial stray voltage monitor or any similar device will work with the method described above.

Hint #2 - Each measurement instrument has limitations. It is important to know your equipment limitations to avoid confusing and erroneous readings.

Hint #3 - Don't forget to test your meter to make sure when it is in the AC voltage setting it only reads AC volts and not DC volts. You do have on-farm sources of DC voltage up to 0.6-0.7 volts even when all the power is shut off. We are looking for on and off farm sources of AC voltage. Some meters mix the AC and DC voltages and report them as only AC, this is not correct and is also very confusing when making measurements.



**TESTING YOUR METER FOR DC
BLOCKING WHEN SET TO AC RANGE**

Hint #4 - Bio-security is important! While at a farm wear disposable plastic boots or rubber footwear. Before and after leaving a farm wear wash your foot ware with an agricultural disinfectant.



Plain English disclaimer because of some attorneys:

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If you have any questions or find that you are not clear on an item discussed, please send me an email with your questions. I ask that you do not telephone me with questions on these handouts unless you are one of my regular clients.

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Chuck Forster, P.E.
cforster@phasorlabs.com