Stray Voltage — Is It Really a Problem?

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Can stray voltage be a problem on dairy farms? Yes

Is stray voltage as big a problem as the popular press would have you to believe? No.

In order for any discussion on stray voltage to be meaningful we first have to define what is meant by stray voltage. For the purposes of this paper I will use the definition found in the USDA Handbook 696, "EFFECTS OF ELECTRICAL VOLTAGE / CURRENT ON FARM ANIMALS -- How To Detect and Remedy Problems."[1] That definition reads as follows: "Stray voltage is a small voltage (less than 10V) that can be measured between two possible contact points. If these two points are contacted by an animal or person, a current will flow. The amount of current depends on the voltage and the circuit impedance, which includes the source, contact and body impedances. Animals or persons respond to the resulting current flow and not the applied voltage." From this definition there are two things I want you to notice:

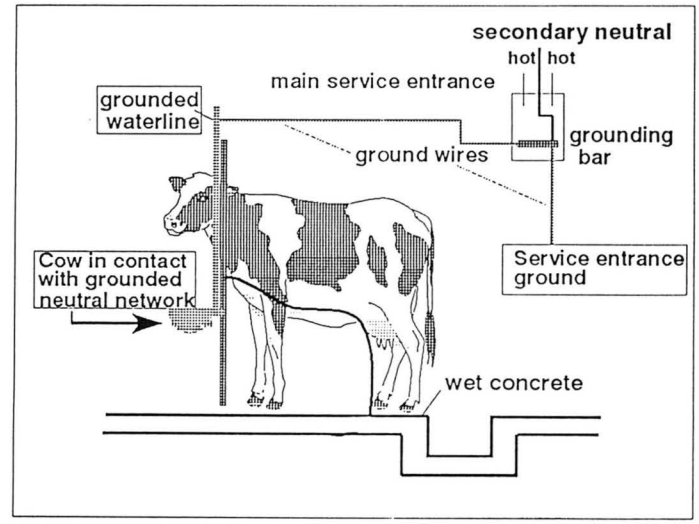
First, stray voltage is found at cow contact points. It is not voltage found between a reference ground rod and the service entrance neutral wire (neutral to earth voltage [nev]) or the water bowl or any other contact point in the barn. Voltage between those points may indicate possible stray voltage but they are not stray voltage in themselves.[1]

Second, it is not the voltage, but the current, which the animal reacts to so any stray voltage investigation should determine current as well as voltage. We will discuss these points in more detail later.

Where does stray voltage come from?

Most dairy farms are served by a single phase electrical system. In a single phase system, the farm service entrance has three wires coming in from the power supplier. Two the wires are "hot" (240 volts between them) and a third wire is called the neutral wire (it is grounded and is therefore neutral in relation to earth) and the voltage between the neutral wire and either of the "hot" wires is 120 volts. The neutral wire is also attached to the neutral/grounding bar in the entrance panel. Since all electrical equipment is grounded and all metal in the barn is (by code) also bonded to the grounding bar, the neutral wire is in effect attached to all of them and a portion of the voltage on the neutral wire could also show up on any metal parts in the barn. Two (2) volts on the neutral may show up as 1 volt between a water bowl and the floor (cow contact voltage).

Figure 1.

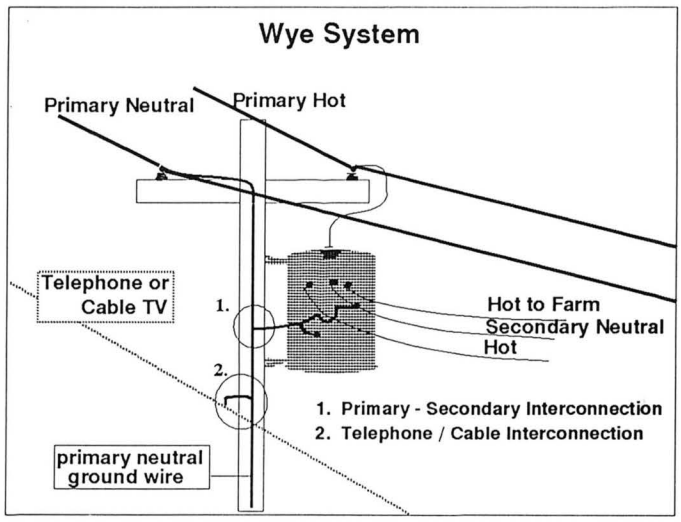


Stray voltage can come from off-farm as well as on-farm sources.

Off-farm sources come mainly from the interconnection of neutral wires and/or other connections to wires from off the farm. Some electrical distribution systems are multi-grounded. In a multi-grounded system, the power supplier's neutral wire (primary neutral wire) is connected with the customer's neutral wire (secondary neutral wire) and all customers share a common neutral wire. Any voltage on the primary neutral wire could, through the interconnection, show up on the secondary neutral at the service entrance and possibly in the barn as stray voltage. Note: Telephone grounds, and more recently cable TV carriers, have been shown to provide the same type of interconnection. If voltage from the power supplier's neutral has been a problem and the

primary and secondary neutrals have been separated, be sure that the telephone and/or cable TV is not bypassing the separation.

Figure 2.



On-farm sources of stray voltage can include:

Unbalanced electrical loads -- Since 120 volt loads use the neutral wire as a current carrying conductor, the ideal is to keep the 120 volt loads balanced between the two "hot" conductors as much as possible. This will, in turn, keep the current flow on the neutral low. Large loads on one of the "hot" conductors as compared to the other "hot" conductor will cause substantial current flow on the secondary neutral which is a possible source of stray voltage. Equipment such as 120 volt fans, agitator motors, feeders etc., sometimes have a high current draw when starting. This may cause a voltage/current spike on the neutral when the motor starts as well as an imbalance when it is running. **Note** - If large 240 volt loads cause a voltage to appear on the secondary neutral (which should not happen) it is possible that the primary side of the system has become unbalanced (due to the large load) causing voltage on the primary neutral which in turn shows up on the secondary neutral and perhaps at cow contact points.

Poor/improper wiring -- It is important that farm wiring be "up to code." Sub-panels that are not four wired, undersized wire and poor grounds can all cause increased current flow on the secondary neutral wire. Improper grounding or location of electric fencers/ cow trainers and other remote electrical equipment can also have an impact on the secondary neutral wire. The electrical system not only needs to meet code, it also needs to be maintained. Loose connections, corroded wires, open panel boxes etc., can cause a high current flow on the secondary neutral wire resulting in possible stray voltage.

Faults -- Current from a short or ground fault in electrical equipment must somehow return to the electrical system. The proper way would be through the grounding conductor (equipment ground wire). However, depending on conditions such as loose connections, undersized wire, remote or no ground, etc., it could also go back through the neutral wire, the earth or metal parts in the barn. All of these conditions could cause stray voltage. Water heaters, underground wires and submersible pumps are all installed under unfavorable electrical conditions and are more apt to have electrical faults.

How do cows respond to stray voltage?

Many lists of stray voltage symptoms have been compiled. These symptoms include: high somatic cell count, increased mastitis, poor milk let-down, lower milk production, increased urination and defecation, reluctance to enter or exit, kicking, reproduction problems, etc. We can only assume that cows feel current the same way humans do. That sensation, tingle, burning, pain, will, if strong enough, cause them to try to avoid or escape the situation which causes the sensation. The main symptom of a stray voltage problem is a change in the cow's behavior. Depending on the severity of the change and/or farmer's reaction to it, all or some of the other symptoms listed above may be observed. When looking at behavior of cows and changes which may occur we need to remember how a "normal" cow acts. Cows are a herd animal and tend to do what everybody else is doing. They are normally curious and their reaction to stimulus is sometimes exaggerated. They get bored, lap water, and lick and sniff everything in sight. They swish their tails, kick, urinate 9-10 times a day and defecate 12-18 times a day.[2] Therefore, it is important to look closely at and document the "abnormal" behavior that is being attributed to stray voltage.

What questions should you ask when stray voltage testing is being or has been done?

1. What type of voltmeter was used? A digital autoranging voltmeter with a high internal impedance would be the best. Be sure it does not read DC voltage on the AC scale.
2. Was a resister used and if so what was the resistance? A 500 ohm resister in parallel will give you a fair indication of the current the cow may be exposed to. Without a resister you are measuring open-circuit voltage. A digital voltmeter with a high internal impedance may measure a high open-circuit voltage with little or no current flow. The resister loads the circuit and allows you to determine approximate current flow (what the cow may be reacting to).
3. How was contact made with the concrete floor? When testing on concrete, a 4 inch x 4 inch square steel or copper plate should be placed on the floor and the lead from the meter attached to it. If the

concrete floor is dry, place a paper towel soaked in a salt solution under the plate first.

4. Where were the measurements taken? Testing can be done between any two cow contact points, such as water bowl to floor, rump shield to floor, etc. This method is known as point to point measurement (figure 3) and any two places the cow may come in contact with, that may have an electrical difference, is a good place to test. Testing between a reference rod outside the barn and different points inside the barn, also known as point to reference ground measurement (figure 4), is useful for identifying sources of stray voltage. However, voltages are usually higher than actual cow contact voltages. When taking point to reference measurements, a resister should not be used.

Figure 3.

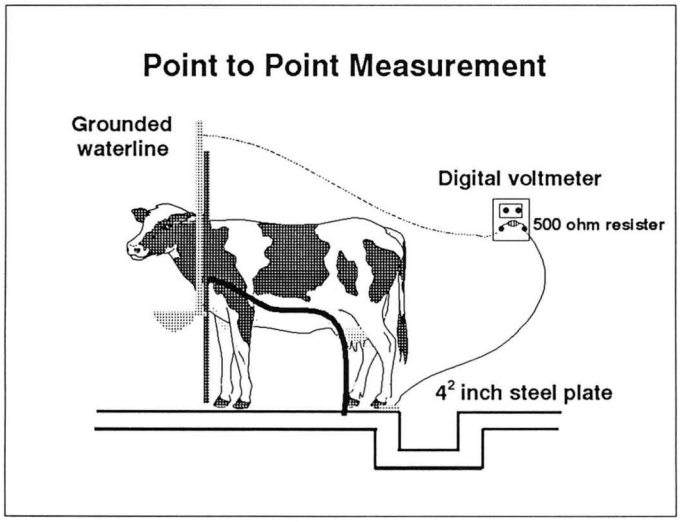
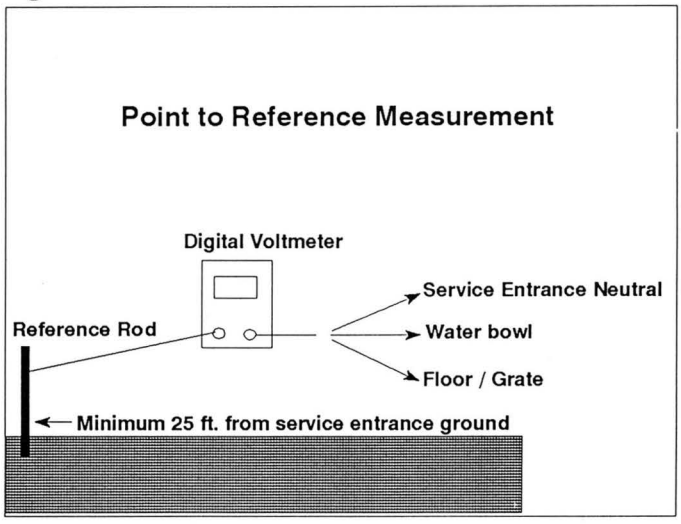


Figure 4.



5. Were voltages recorded over a period of time? Since electrical loads vary from day to day and even from minute to minute, any stray test should include long term (four to seven days) recording of voltages at cow contact areas as well as secondary neutral to a reference rod if possible. It is important to test at cow contact areas. Also, places the cows may seem to avoid and areas in the barn where they are nervous are all good areas to test.

At what point (voltage / current level) does stray voltage become a problem?

As with all living things, the reaction to voltage/current flow varies from cow to cow. We do know, however, that some cows will respond to .002 amperes (2.0 milliamps [mA]) and most cows will respond to 4.0 to 5.0 mA.[3,4,5] How much voltage is required to produce 4.0 to 5.0 mA? To answer that question we need to review the familiar Ohm's law. Ohm's law states E = I x R where E is electrical potential in **volts**, I is the current flow in **amperes** and R is the resistance in ohms (**the cow**). If we know the resistance of the cow (R) and the voltage (E) at cow contact, we can find the current by dividing E by R. For example, a cow with a resistance of 1000 ohms is exposed to 2 volts between the water bowl and the floor. 2.00 volts divided by 1000 ohms = .002 amperes. This amount of current (2.0 mA) is the point at which some cows may respond. However, if the same cow, in the same situation had her hooves trimmed and her resistance went to 500 ohms she would then be exposed to 2.00 volts divided by 500 ohms which equals 4.0 mA (.004) amperes) the amount of current at which most cows would respond. Analyzing any given situation to try and determine if a stray voltage problem exists and the severity of it is not simple.

To help in trying to determine the amount of current cows may be exposed to at various voltage levels, research has been conducted on the various electrical pathways through cows and the resistance of those pathways. The following is a table (from USDA 696)[1] of cow's resistances. Keep in mind that these resistances are with good floor contact. Cows on good clean bedding, rubber mats or even dry concrete will have higher contact resistances, thereby increasing the overall circuit resistance and lowering the current flow.

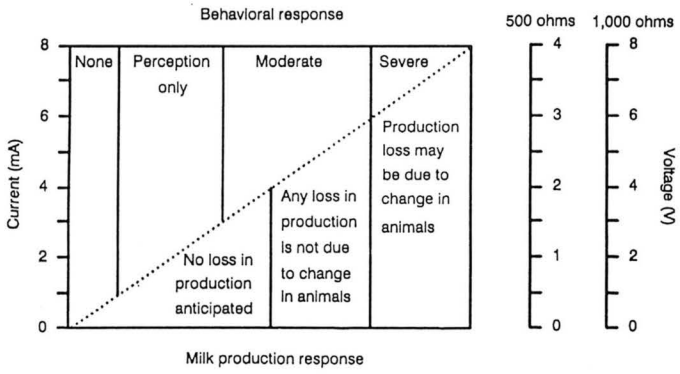
The following figure "Behavioral and Milk Production Responses to Increasing Current Levels" (also from USDA 696)[1] puts all of this information in perspective. On the left of the chart is current measured in mA; on the right is voltage at two levels of resistance (remember resistance determines current flow). The top of the chart shows the estimated behavioral response and the bottom shows that anticipated milk production response. For example, 4 mA (left side) is produced by 2 volts at 500 ohms or 4 volts at 1000 ohms (on the right side the chart). In either case, there should be little or no loss of production and moderate behavioral changes

Table 3-1. Resistances of various electrical pathways through the cow.[1]

Pathway	n[2]	Resistance Mean (ohms)	Resistance Range (ohms)	Current Frequency (Hz)	References
Mouth to all hooves	70	350	324-393	60	Craine et al. 1970
	28	361	244-525[3]	60	Norell et al. 1983
Mouth to rear hooves	28	475	345-776[3]	60	Norell et al. 1983
Mouth to front hooves	28	624	420-851	60	Norell et al. 1983
Front leg to rear leg	5	300	250-405	60	Lefcourt, 1982
	13	362	302-412	60	Lefcourt et al. 1985
Front to rear hooves	28	734	496-1152[3]	60	Norell et al. 1983
Rump to all hooves	7	680	420-1220	50	Whittlestone et al. 1975
Chest to all hooves	5	980	700-1230	50	Whittlestone et al. 1975
	?	1000	?	50	Woolford, 1972
Teat to mouth	28	433	294-713[3]	60	Norell et al. 1983
Teat to all hooves	28	594	402-953	60	Norell et al. 1983
	4	880	640-1150	50	Whittlestone et al. 1975
Teat to rear hooves	28	594	402-953[3]	60	Norell et al. 1983
Teat to front hooves	28	874	593-1508	60	Norell et al. 1983
All teats to all hooves[4]	6	1320	860-1960	50	Whittestone et al. 1975
	?	1000	?	50	Phillips et al. 1963
Udder to all hooves	12	1700	650-3000	60	Henke Drenkard et al. 1985

[1] Adapted from Appleman and Gustafson (1985b).
[2] Number of animals
[3] Ranges given are for 10-90% percentile, or percent of cows with measured resistance between the reported limit.
[4] Measured during milk flow.

Figure 3-4. Behavioral and milk production responses to increasing current levels. Voltages (right vertical axis) were estimated using a worst-case circuit impedance (500 ohms) and a more realistic impedance (1,000 ohms).



in the animals. However, 6 mA can be produced by 3 to 6 volts and may cause severe behavioral and production changes in the cows.

What do we know about the long term effects of stray voltage on cattle?

A lot of the research done in the past was criticized because of the short duration and small number of cows studied. In the last few years long term studies (full lactation) have been completed and published. The results tend to verify previous findings. In a 5 year study,[6] Canadian researchers exposed 30 cows in a tie stall barn to as much as 5 volts. Their conclusions are: ". . findings indicate that production, reproduction and animal health are not significantly affected at voltages up to 5.0 volts (this experiment) under commercial conditions." They do state however, "It seems therefore that the 5.0 volt level, in a tie stall barn, with high level management, may be the threshold level." At Cornell University, forty cows in groups of ten were exposed to 0, 1, 2, or 4 volts for a full lactation.[7] The voltage was applied to the water bowls and cows were housed in a free stall and milked in a parlor. Their conclusions: ". . . milk weights for 305 d showed no significant differences between groups exposed or not exposed to voltage . . . . Somatic cell counts, milk fat, and protein showed no significant difference between groups exposed or unexposed to voltage. Feed and water intakes were not affected by voltage." In a parallel study[8] they also found: "Voltages did not significantly influence cow health or reproductive performance." Research has also recently all but eliminated the milking machine as a possible cow contact point for stray voltage. When voltage was applied to electrodes placed at the top of the short milk tube, 8.0 volts were required to cause heifers to kick the unit off and 16.0 volts for older cows to kick the units off.[9] Because of the high resistance of the liners and milk hose, over 100 volts would be required on the milk-line to cause 16 volts at the claw.

Recent research indicates that the level of concern for stray voltage begins somewhere between 2.0[1] to 5.0[5] volts. Remember, however, that it is current, not voltage, that the cow responds to and there may be situations (step potentials, computer feeders, etc.) where contact resistance is low enough that 1.0 volt may cause enough current to be a problem with some animals. The percentage of farms with a stray voltage problem remains a mystery. Stray voltage, as defined in the beginning of this paper, can be present on a farm with no effect on the cattle or production.[10] Stray voltage can also create many problems on a dairy farm. What must be remembered, however, is that on any given farm the percentage will either be 0% (there will be no stray voltage problem) or 100% (there will be a stray voltage problem on the farm). Therefore any stray voltage investigation should be as thorough as possible. When conducting a stray voltage investigation all aspects of the dairy operation that relate to the perceived problem need to be examined. Although the percentage of farms with stray voltage may be low, the effects of stray voltage on any given farm can be devastating.

References

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