EFFECTS OF SOURCE RESISTANCE ON COW CONTACT VOLTAGE MEASUREMENTS.

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Summary:
It is essential to determine the resistance of the source circuit, and understand its effect on the current likely to flow through an animal in order to correctly assess stray voltage in animal confinement facilities.   This paper presents a results of source resistance measurements made on 43 farms. The relationship between source resistance measurements made with a single contact pint and with four contact points was determined.

Keywords: Stray Voltage, Measurements, Source Resistance , Animal Currents

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INTRODUCTION

When dealing with stray voltage problems, it is important to know the amount of electrical current likely to flow through an animal (dairy cow, hog or other animals in confinement facilities). It has been demonstrated in many studies that current flow through the body is the critical factor affecting animal response. Although current flow through the animal is know to be the parameter influencing response this measurement is impractical in field applications. Field measurements are commonly made with a resistor of know value in place of the animal in the measurement circuit.

The resistance value assumed for body resistance of the animal will influence the current flow in such a test circuit. Another factor affecting expected current flow through an animal in contact with "stray voltage" is the internal resistance of the voltage source, or source resistance. It is, therefore, important to use correct means to determine the amount of current that can access the animals by proper measurements of voltage available and the shock strength of the voltage source or stated another way the internal source resistance of the voltage source. This internal electrical resistance of the source voltage includes the contact resistance between the hooves and floor and the path from floor through the earth and/or embedded metal objects to the grounding buss of the service entrance and then back to the second point of cow contact.

Animal contact measurements are commonly measured using a single contact point at the floor. an animal, however, normally contacts the floor with four hooves. concern has been expressed over the proper method of converting measurements of source resistance made with a single point measurement into a realistic value for an animal in contact with the floor at 4 points.

OBJECTIVE

The objective of this paper is to determine the relationship between source resistance measurement made with a single point and that measured with four contact points.

MEASURING SOURCE RESISTANCE
(put all the measurement stuff from the appendix and in here)

To predict the current in the cow it is necessary to establish an equivalent circuit Fig. 1 which requires the following three parameters:

> **The magnitude of the source voltage, Vs:** The source voltage commonly called "Stray Voltage" to which the cow may be exposed is determined by the currents and other parameters in the grounding network of the electrical system.

> **The internal electrical resistance of the voltage source, Rs:** Source resistance includes the contact resistance from hooves to floor, the resistance of the concrete, resistance of the soil, resistance of the electrical system path from the voltage source including both the on and off farmstead electrical systems, the resistance of the connection from the electrical system to the water system or other applicable metallic structures and the resistance of the water system to the cow's environment. The measurement of the four hooves source resistance is considerably more difficult and time consuming than the measurement of the single hoof resistance. This paper gives data to convert the normally obtained single hoof resistance to the four hooves resistance value that can be used to evaluate the cow currents.

> **The electrical resistance of the path through the cow, Rc:** The electrical resistance of the current path through a cow has been well documented in the literature (Appleman and Gustafson, 1985 and USDA, 1991).

Internal Source Resistances (Rs1) and source voltage (Es)
The determination of the source resistance requires two voltage measurements using a measuring instrument with a high input impedance (1 megohm minimum).

1) Voltage (Vwor) across the contact points with no shunt load resistor.
2) Voltage (Vwr) across the contact points with a shunt load resistor (RL) of known
value (e.g. 500 ohms).

By using these two measured voltages (taken in rapid sequence to preclude a change in the source voltage) both the correct source voltage (Es) and internal source resistance (Rs1) can be determined. Refer to Figure A1:
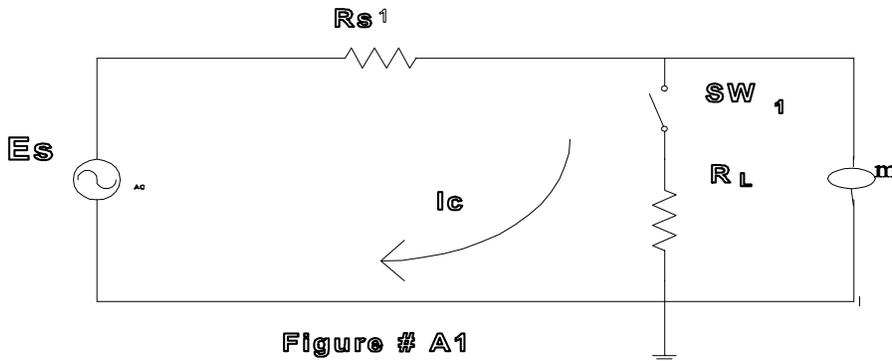

Figure # A1

Es = Voltage with Switch (SW1) Open (No Shunt Load Resistor) (Vwor)
Vwr = Voltage with

Switch (SW1) Closed (With Shunt load Resistor RL)
$Rs1 = RL (Vwor - Vwr)/Vwr$ Equation A1
$Es = Vwr (1 + Rs1/RL)$ Equation A2

In order to measure the strength of the voltage source when taking animal contact voltage readings, a shunt with known resistance (RL) (usually about 100 to 500 ohms) is used to simulate the body resistance of a cow.

To determine Rs1, measure animal contact voltages both with (Vwr) and without (Vwor) the shunt resistor. Use a high impedance voltmeter (1 megohm minimum). The measurement without the shunt resistor (Vwor) is the open circuit voltage Es. These two readings should be taken with minimum time delay between the readings. If the difference between the animal contact voltage with and without the shunt resistor is large, then the value Rs1 will be large. A source resistance greater than 500 ohms may indicate poor connections to the measurement points or may be an accurate reflection of high source resistance (e.g. inadequate water system/electrical system bonding, or a capacitively coupled voltage source). If this procedure for setting up the cow contact measurement is followed and Rs1 is still above 500 ohms, recheck all connections. If Rs1 is high because of high contact resistance, the animal current will be underestimated. If Rs1 is above 500 ohms and connections are good, it may be an indication that the voltage source is weak.

Poorly made meter connections will result in incorrect voltage measurements and the animal currents calculated from these measurements. Ensuring good (low resistance) animal contact and meter connections in determining the source resistance will help to produce consistent repeatable animal contact voltage measurements and an accurate diagnosis of "stray voltage" problems.

In the barn environment there are many factors that will affect source resistance. It is not uncommon for the "stray voltage" investigator to find loose or corroded connections in the barn metal work, poor bonding between the electrical and water systems, corroded stanchion pipes, rubber animal comfort mats, and straw or other bedding materials in stalls. These factors and conditions such as soil moisture and soil temperature may change with time resulting in changing source resistance (and a change in resulting current flow through the animal). The investigator should attempt to make "stray voltage" measurements under both "as found" and "worst case" conditions. The investigator should first determine existing animal contact

voltages and source resistances prior to making any modifications in the electrical system. A worst case scenario can then be created by modifying the electrical system to obtain the lowest possible source resistance. Calculations made with the lowest possible source resistance will produce the highest possible animal current.

Good bonding between water cups or stanchion and the secondary neutral of the farm electrical system will usually reduce Rs1 and produce higher animal current. Bonding can be done quite easily on a temporary basis by running a jumper from metal in the proximity of the animal contact location back to the secondary neutral or to a location where the secondary neutral is well bonded to barn metalwork. Making this modification will ensure that you have the required electrical system bonding and are making worst case animal contact measurements. It must be remembered that modifications to the voltage source pathway (e.g. additional bonding for safety reasons) may lower source resistance and increase animal current.

Good contact to the floor is essential in determining the true source resistance. A 4-inch square stiff copper plate with pressure applied by a jack post or dead weight is required to produce a reliable and repeatable contact point on a concrete floor. A paper towel wetted with salt water should be placed underneath the copper plate. The concrete should be clean and free of debris. It is recommended that the copper plate be placed at least 18 inches from stanchions, metal barn posts or other metal objects embedded in the floor. The integrity of this contact to the floor should be checked before extensive measurements are made with a resistor shunt on the meter. If recording devices are employed for long periods of time (over several hours), periodic checks of the integrity of the contact to the floor should be made. This can be done by temporarily removing the resistor and noting the increase in recorded voltage. The ratio of voltage without the resistor and with the resistor should remain essentially constant unless the floor contact looses its integrity. As a minimum this type of check test should be done at the beginning and at the end of the recording time. The floor plate should be kept moist at all times.
The other contact point for "stray voltage" measurement should be the water cup, stanchion, water line or other cow contact point. The surface chosen should be scraped free of dirt and corrosion and the meter lead should be solidly connected with a clamping device.

Cow Contact Circuit:

$Ic=Es/(Rc+Rs4)$
Equation 1.

Or

$Ic= Vwr(1+Rs1/RL)/(Rc+Rs4)$
Equation 2.

Figure # 1
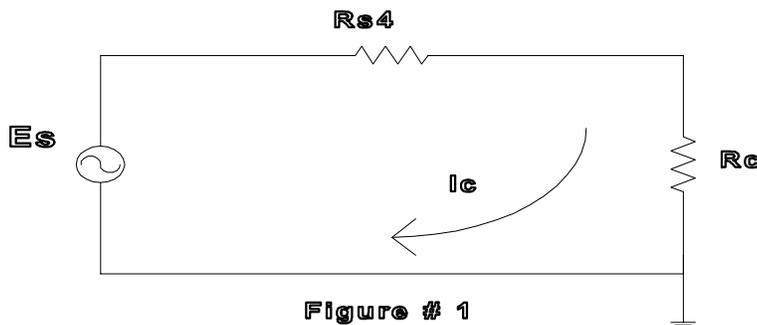
Where:

Ic = Current through a cow whose resistance is Rc (amperes).

Vwr = Voltage measured with a shunt resistor RL (volts).

Vwor= Voltage measured without a shunt resistor (volts).
Es =Open circuit voltage without shunt load resistors (volts).

Rs1 = Source resistance for single hoof contact to floor (ohms).

Rs4 = Source resistance for four hooves contact to floor (ohms).

RL= Shunt load resistor connected across metering system (ohms).

Rc = Cow resistance (ohms).

Determination of Rs4:

The relationship between Rs1 (single hoof source resistance) and Rs4 (four hooves source resistance) was determined from analysis of the field data. In order to measure the strength of the voltage source when taking animal contact voltage readings, a shunt with known resistance (RL) (usually about 100 to 500 ohms) is used to simulate the body resistance of a cow.

To determine Rs1, measure animal contact voltages both with (Vwr) and without (Vwor) the shunt resistor. Use a high impedance voltmeter (1 megohm minimum). The measurement without the shunt resistor (Vwor) is the open circuit voltage Es. These two readings should be taken with minimum time delay between the readings. If the difference between the animal contact voltage with and without the shunt resistor is large, then the value Rs1 will be large. A source resistance greater than 500 ohms may indicate poor connections to the measurement points or may be an accurate reflection of high source resistance (e.g. inadequate water system/electrical system bonding, or a capacitively coupled voltage source). If this procedure for setting up the cow contact measurement is followed and Rs1 is still above 500 ohms, recheck all connections. If Rs1 is high because of high contact resistance, the animal current will be underestimated. If Rs1 is above 500 ohms and connections are good, it may be an indication that the voltage source is weak.. One hundred and one (101) different stalls on forty-three (43) farms were tested and with over 2800 readings begin taken and recorded.

$$Fa = Rs1/Rs4 \qquad \text{Equation 3}$$

MATERIALS AND METHODS

Voltages normally developed on the farm were used to determine source resistance values and were measured by placing four copper plates each four inches (4") square in the stall to represent each of the cows hooves. Plate locations were scraped to bare concrete and covered with a wet paper towel soaked in salt solution. The plates were then secured to the floor with pressure from a jack post.

The measurements were taken in an orderly sequence as rapidly as possible to limit the likelihood of the source voltage changing. This was done using a set of single-pole, double-throw, center-off switches. The connections of the plates, voltmeters, reference rods, switches and shunt resistor are shown in Figure 2.
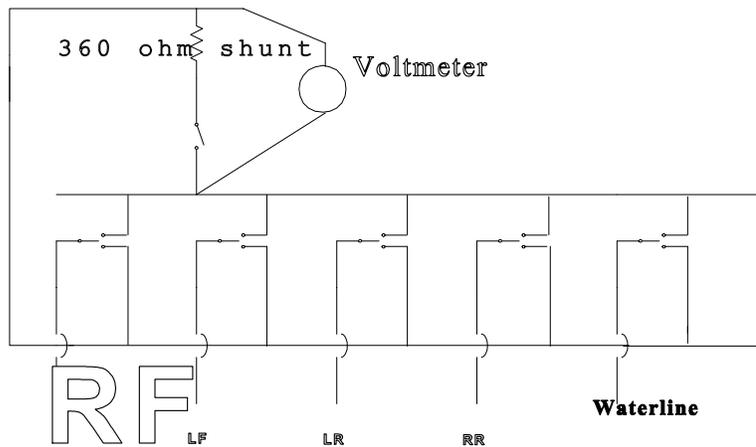
Figure 2.

The center position was connected to each point to be measured and either side of the voltmeter could then be connected to these points with a throw of a switch. A switchable shunt resistor (360 ohms in these tests) was placed across the voltmeter, and the open-circuit voltages were recorded for each plate or combination of plates to water line.

Voltages were measured from each plate or combination of plates to waterline with and without a shunt resistor of 360 ohms. During each measurement the voltage from waterline to a remote reference rod was checked to confirm that the source voltage remained constant during each set of measurements. If the source voltage changed the measurement of each plate was retaken.

It was noted that the voltages measured without a shunt resistor from the water cups to the floor was essentially the same regardless of which hoof position was being evaluated.

RESULTS AND DISCUSSION

The resistance data is presented in Table l. and Figures 1 to 4. These graphs show the range of source resistance for the four hooves (on the Y axis) to be between 36 and 480 ohms and the range of source resistances of a single hoof (on the x axis) to be between 56 and 1125 ohms.

The slope, S, of the straight lines (Y=SX) determined by regression analysis is used to obtain the conversion factor Fa which translates single hoof measurements (Rs1) to four hooves equivalents (Rs4) by

$$Rs4 = Rs1/Fa \qquad Equation\ 4$$

<u>Sample Calculation of Current:</u>

The minimum current that a given portion of dairy cows will experience can be determined by dividing the open circuit contact voltage (Es) by the sum of the appropriate cow resistance (Rc) and the four hooves source resistance (Rs4) as shown in equation 1.

For example, the general case may be calculated using Es=1 volt (RMS) Rs4 = 115 ohms (the median value) and the mouth-to-all hooves pathway resistances published in the literature (Appleman and Gustafson, 1985). The minimum calculated currents are as follows:

Percent of cows	Cow Resistance (ohms)	Minimum Current(Milliamps/volt)
90	525	1.56
50	361	2.10
10	244	2.78

SUMMARY AND CONCLUSIONS

1. The source resistance of all four hooves-to-waterline (Rs4) are was less than the resistance of any single hoof to waterline (Rs1).

2. The all four hooves resistance (Rs4) may be used as the source resistance to predict cow current.

3. The all four hooves resistance (Rs4) may be determined by dividing the appropriate single hoof resistance (Rs1) by the factor shown in Table 1 namely Rs4 = Rs1/Fa   Equation 5

4. A median resistance of 115 ohms can be used for four hooves source resistance if single hoof resistance has not been determined.

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