Stray Voltage Detection

A SELF-HELP GUIDE FROM...

Table of Contents

Introduction

This publication is intended to give you a basic understanding of stray voltage, some of its common sources, how to determine if it exists on your farm at levels that may be harmful, and when to call for assistance to help reduce stray voltage levels. This document is not intended to make you a stray voltage expert, but should provide you with the information necessary to safely determine if a problematic level of stray voltage is present on your farm at locations that are accessible to your livestock.

This booklet is specifically oriented toward the dairy farmer; however, most of the information provided is applicable to all livestock operations. The *Farm Wiring Checklist,* located on page 9, is included to assist you in visually inspecting your farm's electrical system and noting potential stray voltage sources. A *Data Collection Form* is included on page 10 to help you record milkhouse and livestock area voltage measurements. In addition, this publication will suggest methods for monitoring stray voltage levels on your farm—a practice that is strongly recommended for all livestock operations.

What is Stray Voltage?

WHAT IS STRAY VOLTAGE?

Low levels of AC (Alternating Current) voltage between grounded conductors and conductive surfaces of a livestock confinement facility are a normal and unavoidable consequence of delivering and using electricity. These voltages are termed "stray voltage" when they can be measured between two objects that may be simultaneously contacted by animals. Occasionally, stray voltage levels are significant enough to be felt by you as a "tingling" sensation. This publication concentrates exclusively on measuring and minimizing AC voltages. Small levels of DC (Direct Current) voltage from naturally occurring sources (galvanic action of metals in contact with the soil) is also present on farms, but these small DC voltages pose no risk to farm animals.

REPORTED SYMPTOMS

A wide variety of symptoms have been attributed to stray voltage, although relatively few of these have been confirmed in controlled studies. The effects of excessive stray voltage exposure on farm animals are all "behaviorally mediated." In other words, animals show avoidance behaviors in areas where contact with excessive voltage is perceived as annoying or painful. This may appear as reluctance to cross building thresholds where a significant 'step' potential (voltage between front to rear hooves of a cow) may be present; or reluctance to drink at watering devices at which a significant 'touch' potential (voltage between the watering device and the floor) may be present between the watering device and the adjacent floor. It is important to note, however, that these same symptoms, as well as a number of other behaviors and health concerns can be the result of numerous other non-electrical farm factors.

As a farm manager, you should investigate all possibilities, including stray voltage, when attempting to resolve a behavioral, production, or health problem.

TYPES OF SOURCES

It is important to make a distinction between low-level stray voltage which is a normal and unavoidable consequence of using electricity, and the more hazardous voltages related to electrical faults.

Personal Shock

If you experience a painful shock when you touch a metal object in the barn, it is likely that there is a severe fault in your electrical system. Your animals may also be exposed to excessive voltage levels, depending on the location of the fault. These conditions are hazardous and could result in serious personal injury or start a fire. Call an electrician or your electric service provider if you receive an electrical shock on your farm.

Tingle Sensation

If you feel low-voltage "tingling" when you touch equipment in the barn, it is possible that your livestock may be experiencing a similar sensation. Tingle from metal objects frequently can be eliminated through better bonding (electrically interconnecting metal objects) and grounding. It is recommended that you identify the source of the voltage and continue to take voltage measurements after improving bonding and grounding. Continuing measurements will confirm that the changes made have successfully reduced the voltage that animals may experience to an acceptable level, and will also help to ensure continuing farm electrical safety.

Symptoms present, but no tingle sensation is felt

Livestock may feel voltages not sensed by humans because an animal's exposure conditions are different than that of a human. Animal contact voltage measurements should be taken if livestock exhibit avoidance behaviors. This publication will help you make your own voltage measurements to determine the level of stray voltage on your farm, and whether corrective action might be required. If you are unsure how to take these measurements, you can ask for assistance from your electric service supplier.

CAUSES OF STRAY VOLTAGE

Some level of stray voltage will always be present, even on a properly wired farm. Voltage is developed on the grounded neutral system as the result of load current flowing through the resistance of the grounded-neutral network. This voltage is typically made up of several voltage sources acting simultaneously. Both on-farm and off-farm sources may contribute to the level of stray voltage present.

Stray Voltage Detection

A common on-farm source of stray voltage is the inappropriate interconnection of equipment grounding conductors with the neutral conductors of the farm wiring system. The grounding conductor is intended to ground metal equipment and should never be one of the conductors used to supply power. The neutral, or other conductors supplying power, should never be connected to the metal case of equipment or be interconnected with the grounding conductor at any point other than the main electric service panel for the building.

Other on-farm contributors to stray voltage levels include:

- Unbalanced 120-volt loads (including loads in the house and other buildings) that increase current on neutral conductors
- Corroded or loose electrical connections anywhere on the neutral conductor
- Missing or inadequate grounding systems
- The normal operation of large electrical equipment (such as welders, motors, pumps and conveyors) in remote areas of the barn or other buildings

The degree to which these sources contribute to stray voltage levels depends upon many factors including the layout of the farm wiring system and relative strength of the source. A visual inspection checklist of potential on-farm problems (Stray Voltage Checklist, page 9) is included at the end of this publication. Correction of on-farm deficiencies will normally require the services of a qualified electrician.

Off-farm voltage sources may also be present on your farm. If requested, your electric service provider will conduct an investigation (usually at no charge) using controlled, standardized test procedures to determine to what extent electrical distribution facilities or other off-farm sources contribute to stray voltage levels. If an abnormal voltage from the distribution system is found, your electric service provider will take action to help reduce the level of stray voltage on your farm.

STRAY VOLTAGE DETECTION

You can detect the presence of stray voltage on your farm safely and easily by using a voltmeter to measure the voltage between two points that may be simultaneously contacted by livestock.

CAUTION: For your own safety, do not attempt to make electrical measurements on electrical wiring or within electrical boxes or cabinets unless qualified to do so.

SUITABLE VOLTMETER

Many of the voltmeters in use today can give you misleading readings because of the manner in which they are constructed and the voltage levels they are intended to measure. A suitable voltmeter must not be affected by DC voltage when operating on the AC scale. The meter should also "screen out" low level voltage sources

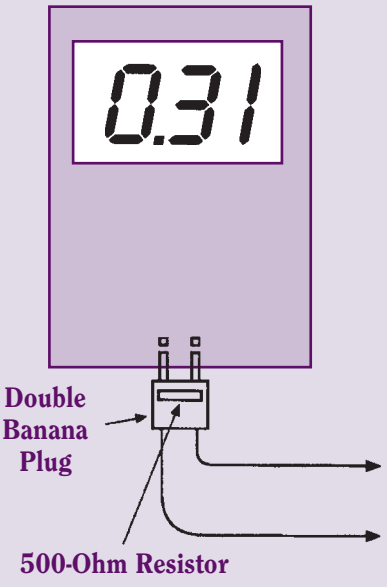


FIGURE 1:
Digital Voltmeter with 500-ohm, two-watt, Flameproof Resistor

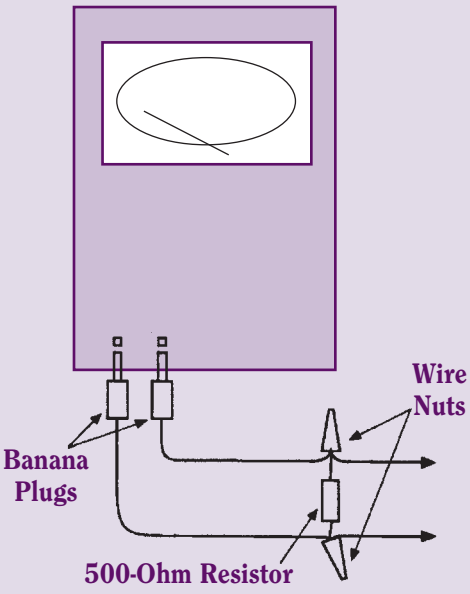


FIGURE 2:
Analog Voltmeter with 500-ohm, two-watt, Flameproof Resistor

NOTE: the shunt resistor should be removed from the meter before making any measurements other than stray voltage (cow-contact measurements).

CAUTION: The shunt resistor is designed for use with very small voltages and MUST be removed from the meter before using the meter to measure the much larger voltages on energized conductors.

Making Electrical Measurements

which are incapable of affecting your livestock. A shunt resistor is used for this purpose.

To accurately measure the stray voltage that livestock may feel, a shunt resistor that approximates the resistance of a cow and its contact to the surfaces it is touching should be connected across the voltmeter leads. (Refer to Figures 1 and 2) A two-watt, flameproof resistor of approximately 500-ohms is recommended. This type of resistor is available at most electronic parts stores. You may use either a digital voltmeter or an analog (needle-type) voltmeter to measure stray voltage. However, you must understand the limitations of each in order to ensure accurate and meaningful measurements.

Digital voltmeter

The digital voltmeter has a digital display and is the preferred method of monitoring stray voltage. A digital voltmeter with a 500-ohm shunt resistor is easy to read and accurate when measuring small voltages. A digital voltmeter without a shunt resistor, however, has an extremely high input resistance (several million ohms). This high input resistance makes it very sensitive to extremely weak voltage sources. Low-level voltage sources do not have the ability to affect your animals. In order to accurately measure the voltage your livestock may feel, you must use a shunt resistor to make your digital voltmeter "look" like a cow in the electrical circuit being measured (See Figure 1).

Analog Voltmeter

If you use an analog voltmeter (one with a moving needle), it must have a voltage scale sensitive enough to accurately display voltages less than 1.0 Volt. A meter with a full-scale reading of 2.5 Volts AC is ideal. A full-scale reading of 5.0 Volts AC is normally acceptable. Any full-scale reading greater than 5.0 Volts AC is generally not sensitive enough for stray voltage measurements.

Your analog voltmeter must also be capable of measuring only AC voltage. Some analog voltmeters do not discriminate between DC and AC voltage and may provide you with misleading information. An analog voltmeter can be tested by setting the meter on the AC scale and touching the leads to the ends of a 1.5 volt battery. The leads should then be reversed and the procedure repeated. If, in one of these two positions, the meter's indicating needle initially "jumps" and then settles to a steady reading of 0.0 volts, the meter is acceptable. An analog voltmeter with a full-scale reading of 5 volts or less and a 500-ohm shunt resistor will give you an accurate measurement of the stray voltage that your livestock may perceive.

MAKING ELECTRICAL MEASUREMENTS

***CAUTION:* For your own safety, do not open or attempt to measure voltage inside electrical devices or equipment or on any other electrical wiring unless qualified to do so.**

There are two basic measurement methods for diagnosing potential stray voltage situations: the animal contact (or point-to-point) method and the point-to-reference ground method.

Animal contact measurement

The animal contact method is a measurement of your animals' voltage exposure. It allows you to determine the levels of voltage that the animals may actually come into contact with. This is the most important measurement and it simply means taking voltage measurements between two points that can simultaneously be touched by livestock.

The animal contact measurement will usually be from metal equipment that animals can access (such as drinking cups or metallic feeders), to the floor. Make sure you have a firm connection to a cleaned surface on metallic contact points.

The meter lead in contact with the floor must be in a wet location with good contact pressure to ensure electrical contact. Attaching the lead to a copper plate placed under pressure on the wet concrete floor is the recommended method. However, other alternatives such as standing on the voltmeter probe or clamp may work satisfactorily for an approximate reading.

The animal contact measurement method, which uses a copper plate on the floor in the rear-hoof area and a 500-ohm shunt resistor across the leads of a digital voltmeter, most accurately represents the actual exposure voltage for dairy cows. Only measurements of the exposure voltage will allow you to determine if the stray voltage present can be harmful to your livestock.

Point-to-reference ground measurement

The point-to-reference ground method of testing is not used to determine exposure voltages. It is used to help the investigator diagnose the sources of stray voltage and involves the use of a remote ground probe as a reference. For reliable accuracy, the remote ground probe should consist of a metal stake or rod driven into moist soil and located at least 30 feet away from any electrical grounds, water pipes or grounded metal equipment. An insulated wire (no. 18 is adequate) should then be used to connect the ground probe to the common terminal of the voltmeter. The other voltmeter probe is used to contact the metal objects within the animal confinement area. The 500-ohm shunt resistor is not used.

This method of measuring usually results in higher voltage readings than the animal contact method, but the voltages measured are not measurements of animal exposure. They are not measurements of exposure because an animal cannot simultaneously contact these two points and, therefore, cannot be harmed by the measured voltage.

Practical suggestions

Most voltmeter leads are too short to make even animal contact voltage measurements. You may want to use a set of light-duty car battery jumper cables or some other type of wire to extend the length of the voltmeter leads when making measurements to the various contact points. Jumper cables may also be used as temporary bonding jumpers to determine the effect of additional bonding.

When you measure voltages on outside equipment, such as feeders or stock waterers, you may use a metal rod driven 12 to 18 inches into the ground approximately six feet from the equipment being measured. This is an adequate method of determining if an unacceptable voltage is present on the device being checked. A more thorough investigation may be required to accurately measure animal-contact (exposure) voltage levels.

RECORDING VOLTAGE DATA

Normally, stray voltage should be measured during milking, when the highest electrical loads are present and the highest stray voltage levels will occur. It is recommended that you take voltage measurements at several animal contact locations to determine where the voltage is greatest. Use the data sheet at the end of this publication for recording voltage measurements. The date and time that measurements were taken should also be included. This information may serve as a future reference to detect any significant changes in farm electrical system sources.

***NOTE:* Your electric service supplier may use specialized equipment and test procedures that allow them to analyze the worst case loading condition at any time during the day so that they may not need to be present during milking.**

INTERPRETING VOLTAGE DATA

Research regarding the levels of stray voltage that should cause concern has taken place at several US universities and in at least five (5) other countries over the last 40 years. This extensive body of research has shown that animal contact voltage levels below 2.0 Volts AC are not harmful to dairy cows. Many electric utilities have taken a conservative approach and recommend a thorough stray voltage investigation whenever voltages of 1.0 Volt AC or greater are measured across cow-contact points using the animal contact measurement method described. Sheep and pigs have levels of sensitivity similar to dairy cows while poultry are much less sensitive to voltage exposure.

TAKING ACTION

If animal contact voltage measurements, taken during milking or at any other time of day, do not exceed 1.0 Volt AC, research indicates that the voltage is too small to affect your livestock. An ample margin of safety is built into this number. Under these circumstances, it is recommended that you use a voltmeter in your barn to regularly monitor the level of stray voltage present. If animal contact voltage levels are later found to exceed 1.0 Volt AC, you may want to contact your electric service supplier for a more thorough stray voltage investigation as a preventive measure.

Monitoring Stray Voltage

If animal contact voltages exceed 2.0 volts AC you should take immediate action to determine the source(s) of the contact voltage, and the safest and most economical way to reduce them.

Call your electric service supplier to request a stray voltage investigation. It will help the investigators if you provide the voltage measurements recorded on the data collection form at the end of this publication.

Finding the sources of stray voltage can be difficult and time consuming. It requires knowing where and what to measure, knowing what type of sources to look for, being familiar with the nature of electricity, and having the ability to perform controlled tests using suitable measuring instruments.

Stray voltage sources may originate from the electrical distribution system. If a higher than expected contribution from off-farm sources is found, your electric service provider will take action to reduce stray voltage from these sources. Your electric service supplier may also identify on-farm sources of stray voltage for you. A qualified electrician may be required to perform work necessary to reduce stray voltage contributions from these on-farm sources.

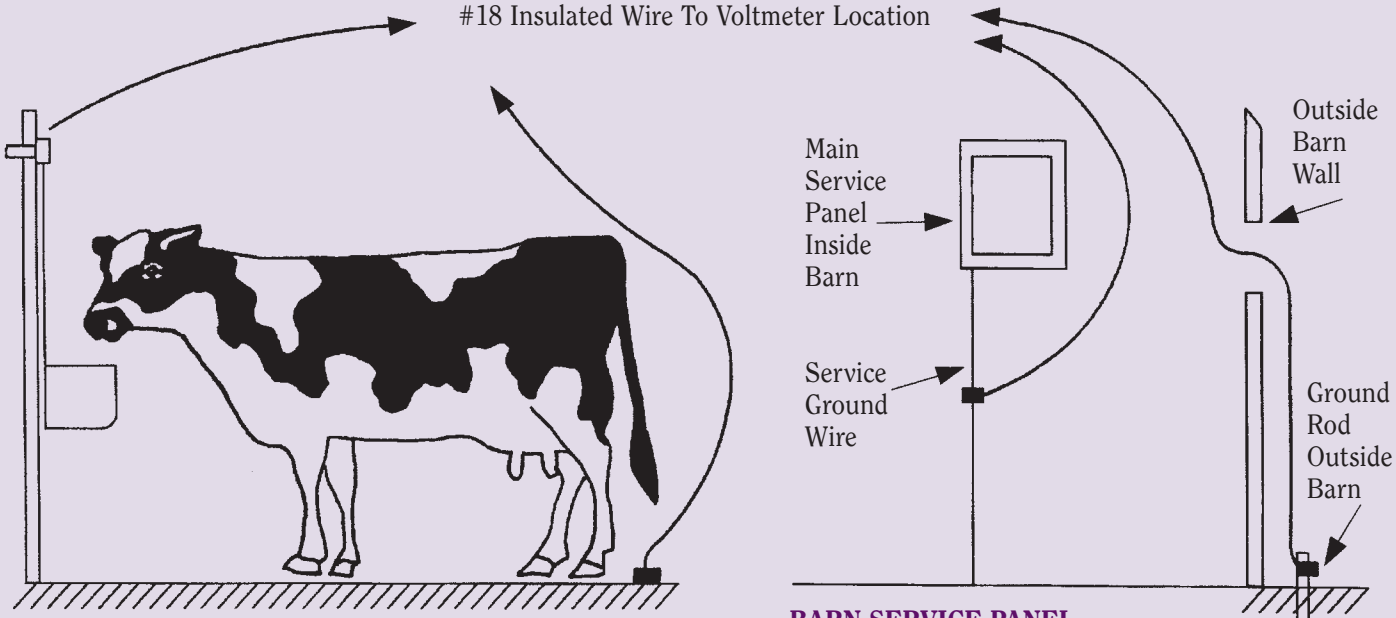
MONITORING STRAY VOLTAGE

A permanently installed voltmeter in your barn is a good way to regularly monitor the level of stray voltage present. Through regular observation, you can quickly become aware of any voltage increase, possibly due to equipment or wiring shorts, which otherwise may go unnoticed. Figure 3, below, indicates typical voltmeter connections. The voltmeter should be installed in a dry location where it can be conveniently read during milking time. Not all voltmeters are suitable for constant exposure to the damp environment found in many locations in a barn. Carefully choose the right meter and the proper installation location.

FOR MORE INFORMATION

Additional publications related to stray voltage are listed at the end of this document. Improperly installed electric fencers and cow trainers are another common cause of unwanted electrical exposure and more information on these is provided in the MREC publication in this list. For more information about stray voltage or its detection, call your electric service supplier for assistance. Your electric service provider can assist you in determining if stray voltage is present, and more importantly, how excessive levels of stray voltage can be minimized.

FIGURE 3: Typical Voltmeter Connections



MILKING PARLOR OR STANCHION
Point-to-Point Stray Voltage Measurement

BARN SERVICE PANEL
Point-to-Reference Ground
(For diagnostic purposes only.)

Farm Wiring Checklist

This checklist will assist farmers in visually inspecting their electrical systems and noting potential stray voltage sources. A check mark placed in the "yes" column indicates a potential problem. In most instances, a qualified electrician should be contacted if any electrical equipment or wiring needs to be repaired or replaced.

	Yes	No
MAIN FARM SERVICE		
Connection to the ground rod - loose, corroded	___	___
Ground rod(s) missing at the service entrance	___	___
BARN SERVICE ENTRANCE		
Ground rod(s) missing at the service entrance	___	___
Connection to ground rod(s) - loose, corroded	___	___
Large accumulation of feed dust or other debris in or on service box	___	___
Corroded or loose neutral connection	___	___
Panel cover missing or removed	___	___
MILKHOUSE		
Wires sitting in water	___	___
Electric portable heaters on bulk tank	___	___
Broken or missing bonding strap for milkline	___	___
Damaged or missing seals on electrical fixtures, switches, outlets, lights, etc.	___	___
Corrosion of electrical fixtures	___	___
IN THE PARLOR OR AROUND THE BARN		
Pulsator wiring		
–Pinched wires	___	___
–Loose, hanging wires, stripped screws	___	___
–Scrapes, breaks or cracks in insulation exposing the conductors	___	___
–Broken stall cocks	___	___
Wires lying in damp or wet areas	___	___
Loose, hanging wires	___	___
Broken or bent conduit		
Energized open wires taped or untaped and extending from ceiling or wall, not in a junction box	___	___
120-volt non-polarized or non-grounded appliances used in barn (clocks, heaters, radios, stereos, etc.)	___	___
Cow trainer insulators *broken, missing, dirty* or covered with whitewash	___	___
OTHER OBSERVATIONS		
Lights alternately brightening or dimming when motors start	___	___
Lights seem too bright	___	___
Electrical shocks from any equipment	___	___
Wires, electrical boxes or motors in wet or damp areas	___	___
Frequent fuse blowing	___	___
Electric fence or cow trainer ground connected to farm electric system ground	___	___
Electric fence or cow trainer ground connected to water or milk lines or stanchions	___	___
Bent or broken conduit	___	___
Damaged wire insulation exposing conductors	___	___
Insulated wires wrapped around metal pipes	___	___
Damaged or frayed extension cords	___	___
Motors, operating irregularly under load, sparking, etc.	___	___
Electrical outlets not properly grounded to accept a three-prong plug	___	___

Data Collection Form

This sheet should be used to record milkhouse and barn area voltage measurements. *If any of the animal contact measurements in Section B made WITH a 500 Ohm resistor are greater than 1.0 Volts AC, you may want to call your electric service provider and request assistance in conducting a more thorough stray voltage investigation.*

NAME: _____

ADDRESS: _____

PHONE: _____

VOLTAGE MEASUREMENTS DATE _____ _____
TIME _____ _____

A. Diagnostic Measurements (taken without 500-ohm resistor)

CONTACT POINTS		VOLTS (AC)	VOLTS (AC)
FROM	**TO**		
Bulk Tank	Milkhouse Floor Drain		
Milk Pipeline	Milkhouse Floor Drain		
Water Pipe	Milkhouse Floor Drain		
Barn Entrance Panel	Remote Reference Ground		
Water Bowl	Remote Reference Ground		
Stanchion	Remote Reference Ground		

B. Stray Voltage Measurements (all measurements should be taken with and without 500-ohm resistor to make sure your electrical connections are good)

Record voltages at several locations in barn while milking equipment is running. Note which equipment is running during measurements.

COW CONTACT POINTS		1ST MEASUREMENT		2ND MEASUREMENT	
		VOLTS (AC)	VOLTS (AC)	VOLTS (AC)	VOLTS (AC)
FROM	**TO**	(with 500-ohm resistor)	(without resistor)	(with 500-ohm resistor)	(without resistor)
Drinking Cup	Floor				
Stanchion	Floor				
Waterer	Floor				
Drinking Cup	Floor				
Stanchion	Floor				
Waterer	Floor				
Drinking Cup	Floor				
Stanchion	Floor				
Waterer	Floor				

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The mission of the MREC is to support outreach, education and research on rural energy issues for the benefit of:

- *Farms and other rural energy consumers*
- *Rural energy suppliers*
- *Farm organizations and agricultural trade associations*
- *Electrical equipment and allied industries*
- *Government regulatory agencies*

Related Publications from the Midwest Rural Energy Council

- *Farming Safely and Efficiently with Electricity*
- *Equipotential Planes for Stray Voltage Reduction: Installation Guidelines*
- *Planning Electrical Systems For Dairy Expansions*
- *Wiring Handbook for Rural Facilities*
- *Power Quality and Computers on the Farm*
- *Installation and Operation of Fencers, Cow Trainers and Crowd Gates*

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