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October 28, 2013

TO: **Temporary Co-Chairpersons Senator Thomas Courtney and Representative Peter Cownie and Members of the Stray Electric Current and Agriculture Study Committee**

FROM: **Richard Nelson, Senior Legal Counsel, Legal Services Division, Legislative Services Agency**

RE: **Background Information**

The purpose of this memorandum is to provide background information to the members of the Stray Electric Current and Agriculture Study Committee.

The committee was established by the Legislative Council by motion on July 18, 2013. The impetus for the committee's formation stems from contrasting viewpoints regarding the extent to which stray voltage exists in the state of Iowa, the number of cases which have been documented to impact dairy cow milk production, the most effective and appropriate method for stray voltage detection, whether or not standards regarding acceptable and unacceptable threshold levels of stray voltage should be determined, and if so by which entity and to what extent.

In anticipation of the committee's meeting on October 28, 2013, the following documents are attached:

- Committee charge
- Committee member contact information
- Tentative meeting agenda
- Proposed committee rules
- Summary of SF 270/HSB 178. Senate File 270 was recommended by the Senate Committee on Commerce but not considered by the full Senate. House Study Bill 178 was assigned to a subcommittee of the House Committee on Commerce
- Senate File 270 — Stray voltage bill introduced during the 2013 Legislative Session (identical to HSB 178)
- General information articles about stray voltage

Additional information received and distributed in connection with this committee will be posted on the committee's website at:

https://www.legis.iowa.gov/Schedules/committee.aspx?GA=85&CID=930

3954IC

Stray Electric Current and Agriculture Study Committee

CHARGE: Study the issues associated with claims that stray electric current or voltage is affecting dairy cattle milk production. Work with stakeholders in considering options to address the issues and make recommendations to resolve the issues.

MEETING DAYS: 1

MEMBERS: 5 Senate / 5 House

Members

Stray Electric Current and Agriculture Study Committee

Senator Thomas G. Courtney
Temporary Co-chair
2609 Clearview
Burlington, IA 52601

Senator Bill Anderson
1138 Mason Ave
Pierson, IA 51048
H: 712-898-2505

Senator Wally E. Horn
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Cedar Rapids, IA 52404
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Senator Charles Schneider
7887 Cody Dr
West Des Moines, IA 50266

Senator Rich Taylor
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Mt Pleasant, IA 52641

Representative Peter M. Cownie
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P O Box 110
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Representative Nancy Dunkel
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Representative Steven N. Olson
2731 221st Street
DeWitt, IA 52742
H: 563-659-9096 O: 515-231-6463

STRAY ELECTRIC CURRENT AND AGRICULTURE STUDY COMMITTEE

LEGISLATIVE MEMBERS

Senator Thomas G. Courtney, Co-chairperson	Representative Peter Cownie, Co-chairperson
Senator Bill Anderson	Representative Nancy Dunkel
Senator Wally E. Horn	Representative Pat Grassley
Senator Charles Schneider	Representative Bob M. Kressig
Senator Rich Taylor	Representative Steven N. Olson

Tentative Agenda

Monday, October 28, 2013

Room 103, Supreme Court Chamber

State Capitol

10:00 a.m. - 10:15 a.m.	Call To Order Procedural Business Opening Remarks
10:15 a.m. - 11:00 a.m.	Stray Voltage Overview Professor Douglas Reinemann Professor and Chair Biological Systems Engineering University of Wisconsin -- Madison (via telephone)
11:00 a.m. - 11:45 a.m.	Stray Voltage -- Iowa Perspective Patrick Gorden, DVM Director, Food Supply Veterinary Medicine Veterinary Diagnostic and Production Animal Medicine Iowa State University Professor Leo Timms Extension Dairy Specialist and Associate Professor of Animal Sciences, Iowa State University
11:45 a.m. - 12:00 noon	Iowa Utilities Board Libby Jacobs, Board Chair
12:00 noon - 12:30 p.m.	Lunch

12:30 p.m. - 1:00 p.m.	Iowa Farm Bureau Federation Marty Schwager State Policy Advisor Matt Steinfeldt State Policy Advisor
1:00 p.m. - 1:15 p.m.	Iowa State Dairy Association Jessica Bloomberg Industry Relations Manager
1:15 p.m. - 1:30 p.m.	Iowa Association For Justice (Presenter to be announced)
1:30 p.m. - 1:40 p.m.	Stray Voltage Standards Stuart Mondschein Wheeler, Van Sickle, and Anderson, S.C. Madison, Wisconsin
1:40 p.m. - 1:50 p.m.	Economic Development Impact (Presenter to be announced)
1:50 p.m. - 2:00 p.m.	Stray Voltage Litigation -- Costs and Implications Bob Swindell General Manager and Chief Executive Officer Access Energy Cooperative Mt. Pleasant, Iowa
2:00 p.m. - 2:10 p.m.	Stray Voltage Testing and Detection Tony Harvey Senior Agriculture Representative Alliant Energy
2:10 p.m. - 2:20 p.m.	Dairy Farmer Perspective Paul Wells Bloomfield, Iowa
2:20 p.m. - 2:30 p.m.	Stray Voltage Research and Legislative Parameters Dennis Puckett Sullivan and Ward, P.C. Des Moines, Iowa
2:30 p.m.	Committee Discussion/Recommendations Adjournment

PROPOSED RULES

STRAY ELECTRIC CURRENT AND AGRICULTURE STUDY COMMITTEE

1. Six of the voting members shall constitute a quorum, but a lesser number of members may adjourn or recess the committee in the absence of a quorum.
2. A majority vote of those voting members present is necessary to carry any action; however, no recommendations to the Legislative Council or General Assembly may be adopted without the affirmative votes of at least three members of each house.
3. Whenever Mason's Manual of Legislative Procedure does not conflict with the rules specifically adopted by the committee, Mason's Manual of Legislative Procedure shall govern the deliberations of the committee.
4. Meetings shall be set by motion before adjournment, or by call of the co-chairpersons of the committee if meetings are necessary before the date set in the motion.
5. Rules shall be adopted by the affirmative votes of at least three members of each house and may only be changed or suspended by a similar vote of the committee.

Proposed:

_____

October 28, 2013

SENATE FILE 270/HOUSE STUDY BILL 178
OVERVIEW

The bills specify procedures applicable to claims by dairy producers asserting stray current or voltage affecting their dairy cows.

The bills provide that a dairy producer who claims that its cows are being affected by stray current or voltage shall provide written notice to the utility providing electric service explaining why the dairy producer claims its cows are being affected by electricity attributable to the utility.

The utility has fourteen business days after receiving the notice to either take measurements to identify the existence and magnitude of stray current or voltage, or arrange for the taking of those measurements.

Certain procedures apply to taking the measurements -- such as gaining access at a mutually agreed upon time and performing no other service or inspection on the dairy farm. The utility can advise the dairy producer as to recommended remedial action, and perform that action with the dairy producer's permission. Also, the utility is required to abide by the dairy farm's biosecurity protocols or established industry standards for biosecurity protocols.

Either the dairy producer or the utility can also request the Iowa Utilities Board to take separate and independent measurements of stray current or voltage either directly or through a third-party expert. The same basic provisions apply to measurements taken by the board regarding access to the property, performing no other service, and abiding by biosecurity protocols.

If the board takes measurements, the board will subsequently prepare a determination of source document which shall be made available to both the dairy producer and the utility.

The last section of the bills concerns rules. The board must establish procedures and protocols to be used for the measurement of stray current or voltage, which will be reviewed periodically to make sure they are scientifically and technologically accurate and reliable.

Senate File 270 - Introduced

SENATE FILE 270
BY COMMITTEE ON COMMERCE

(SUCCESSOR TO SF 22)

A BILL FOR

An Act specifying procedures applicable to claims asserting stray electric current or voltage.

BE IT ENACTED BY THE GENERAL ASSEMBLY OF THE STATE OF IOWA:

TLSB 1732SV (1) 85
rn/nh

S.F. 270

Section 1. NEW SECTION. **476D.1 Definitions.**

As used in this chapter, unless the context otherwise requires:

1. *"Board"* means the utilities board within the utilities division of the department of commerce.

2. *"Dairy producer"* means any person or entity that owns or operates a dairy farm or that owns cows that do or are intended to produce milk.

3. *"Utility"* means a public utility as defined in section 476.1 or, for purposes of this chapter, any other person owning or operating more than one thousand five hundred miles of transmission lines and associated facilities in this state.

Sec. 2. NEW SECTION. **476D.2 Utility inspections — stray current or voltage.**

1. A dairy producer in this state that claims that its dairy cows are being affected by stray current or voltage shall provide written notice to a utility providing electric service to the dairy producer and may provide written notice to the board. The notice shall include a nonbinding statement as to why the dairy producer claims its dairy cows are being affected by electrical energy attributable to the utility.

2. *a.* Within fourteen business days after receipt of a notice alleging stray current or voltage by a utility pursuant to subsection 1, the utility shall take or arrange for the taking of measurements to identify the existence and magnitude of the stray current or voltage, if any. A dairy producer providing notice of the claim shall permit entry onto the dairy farm at dates and times mutually agreed upon by the dairy producer and the utility. The utility shall perform no other service or inspection on the dairy farm beyond taking measurements of stray current or voltage, except the utility may advise the dairy producer as to recommended on-farm remedial action and may perform such on-farm remedial action with the permission of the dairy producer. The utility or its representative shall abide by the dairy farm's biosecurity

protocols or, if none, generally accepted biosecurity protocols in the industry, prior to entry onto the dairy farm. The utility shall be provided advance notice of any biosecurity protocols adopted by the dairy producer.

b. A dairy producer may include with the notice provided pursuant to subsection 1, or in a subsequent notice, a written request for the board to take or arrange for the taking of separate and independent measurements to identify the existence and magnitude of stray current or voltage, if any. Such a request may also be made by the utility. Measurements by the board shall be taken by a representative of the board directly, or by a neutral third-party expert selected by the board for such purposes. A dairy producer providing notice of the claim shall permit entry onto the dairy farm at dates and times mutually agreed upon by the dairy producer and the board, a representative of the board directly, or by a neutral third-party expert selected by the board for such purposes. The board or a selected third-party expert shall perform no other service or inspection on the dairy farm beyond taking measurements of stray current or voltage, except the board or third-party expert may advise the dairy producer as to recommended on-farm remedial action. The board or the third-party expert shall abide by the dairy farm's biosecurity protocols or, if none, by generally accepted biosecurity protocols in the industry, prior to entry onto the dairy farm. The board shall be provided advance notice of any biosecurity protocols adopted by the dairy producer. The board shall subsequently prepare or cause to be prepared a determination of source document which shall be made available to both the dairy producer and the utility.

Sec. 3. NEW SECTION. **476D.3 Rules.**

The board shall by rule establish procedures and protocols to be used for the measurement of stray current or voltage. The board shall review the rules from time to time, or upon petition to the board, to ensure that the procedures and

S.F. 270

protocols continue to be scientifically and technologically accurate and a reliable means of detecting stray current or voltage.

EXPLANATION

This bill specifies procedures which apply to claims asserting stray electric current or voltage affecting dairy cows.

The bill provides that a dairy producer in Iowa claiming that its dairy cows are being affected by stray current or voltage shall provide written notice to a utility providing electric service to the dairy producer and may provide written notice to the utilities board of the utilities division of the department of commerce. The notice shall include a nonbinding statement as to why the dairy producer claims its dairy cows are being affected by electrical energy attributable to the utility. The bill states that within 14 business days after receipt of the notice, the utility shall take or arrange for the taking of measurements to identify the existence and magnitude of the stray current or voltage, if any. The bill provides that the dairy producer shall permit entry onto the dairy farm at dates and times mutually agreed upon by the dairy producer and the utility. The utility is required to perform no other service or inspection on the dairy farm beyond taking measurements of stray current or voltage, except the utility may advise the dairy producer as to recommended on-farm remedial action and may perform such on-farm remedial action with the permission of the dairy producer. The bill provides that the utility or its representative shall abide by the dairy farm's biosecurity protocols or, if none, generally accepted biosecurity protocols in the industry, prior to entry onto the dairy farm, and that the utility shall be provided advance notice of any biosecurity protocols adopted by the dairy producer.

The bill further provides that the dairy producer may include either as part of the notice or in a separate notification a written request for the board to take or arrange

for the taking of separate and independent measurements to identify the existence and magnitude of stray current or voltage, if any, and that such a request may also be made by the utility. Measurements by the board shall be taken by a representative of the board directly, or by a neutral third-party expert selected by the board for such purposes. The bill specifies that a dairy producer shall permit entry onto the dairy farm at dates and times mutually agreed upon by the dairy producer and the board, a representative of the board directly, or by a neutral third-party expert selected by the board for such purposes. The same restrictions shall apply to measurements taken by the board or a third-party expert with regard to performing no other service or inspection beyond taking measurements of stray current or voltage except providing advice as to recommended on-farm remedial action, and biosecurity protocols. The bill directs the board to subsequently prepare or cause to be prepared a determination of source document which shall be made available to both the dairy producer and the utility.

The bill provides that the board shall by rule establish procedures and protocols to be used for the measurement of stray current or voltage, which the board shall periodically review, either of its own accord or upon petition to the board, to ensure that the procedures and protocols continue to be scientifically and technologically accurate and a reliable means of detecting stray current or voltage.

Publication #AE55

Topics: Agricultural and Biological Engineering | Dairy Management | Bray, David R | Bucklin, Ray A | Talbot, Michael T | Becker, William J

Stray Voltages In Dairies [1]

R.A. Bucklin, M.T. Talbot, W.J. Becker and D.R. Bray[2]

A stray electrical current passing through a cow's body may cause reduced milk production and health problems. The electrical current can be caused by poor or faulty wiring, faulty equipment, improper grounding, or originate off the farm and be introduced through the grounded neutral wiring network. Stray voltages are usually low alternating current voltages on the grounded neutral wires of the farm wiring system. Power suppliers may use the terms neutral-to ground voltage and neutral-to earth voltage to refer to the problem. Lost milk production and the costs for treatment of the cow's health problems can lead to substantial losses for dairymen.

Symptoms

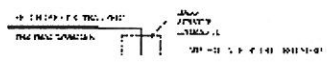
The reaction of animals to stray voltages varies with the amount of the voltage. Cows are more sensitive to small voltages than people, and will react to voltages that humans cannot feel. One or more of the following symptoms may indicate that stray voltages exist in a dairy, but similar symptoms can be produced by other problems such as animal mistreatment, milking machine problems, disease, poor sanitation, or nutritional disorders. Common symptoms of stray voltage are:

1. Cows often hesitate to enter the parlor. They may stampede or rush out of the parlor when released.
2. Cows often dance or step around constantly while in the milking parlor. Nervousness can also be caused by other sources such as malfunctioning milking equipment or rough handling.
3. Normal milk letdown is interrupted, thus requiring more time for milking and machine stripping. This adds more time and money into the production process.
4. Udder irritation can be caused by incomplete milkout, which increases the incidence of mastitis.
5. If cows are exposed to stray voltages while eating, they will be reluctant to eat and feed intake will be reduced.
6. Stray voltages may enter the parlor through the water supply or metal drinking cups. Animals will hesitate to drink and may lap the water. Each of these symptoms is associated with stress, reduced nutrient intake or disease. All of these will cause a drop in milk production.

Causes of Stray Voltage

Electrical power is supplied to dairies over a complex electrical distribution network. This network interconnects with an electrical system that includes grounded primary and secondary neutral wires. The grounded neutral system is connected to earth by ground rods driven into the soil at various locations along the neutral wire. Any stray voltage between neutral and earth should be monitored. An alternating current (AC) with a stray voltage of 0.5 volts or more between the neutral and earth voltage should be cause for concern. Stray voltages less than 0.5 volts are considered normal. Stray voltages vary, depending upon the circuits being used and the amount of moisture in the soil around the grounding rod.

An example of how stray voltage can cause current to flow through the cow's body is shown by Figure 1. The animal's feet provide a connection to the ground through wet concrete and the underlying soil. Other parts of the cow's body may be in contact with the grounded neutral system through the drinking cup, stanchion, milking machine, or feeder. The animal is subjected to the neutral-to-earth voltage, as shown by the voltmeter.



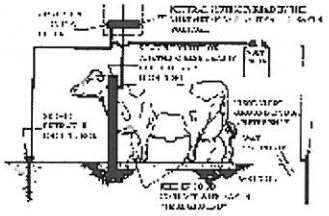


Figure 1.

Measuring Stray Voltage

The voltmeter used to check for stray voltage should have a 0 to 5 AC volt scale graduated in 0.1 volt increments. It should also have relatively high input impedance of 5,000 to 10,000 ohms, and be battery operated to be independent of an AC power supply. The meter should not read direct current voltage on the AC scale. Test the voltmeter by checking the voltage of a DC battery on the AC scale. If a DC voltage reading is obtained, check the voltmeter instructions.

Reducing the Effects of Stray Voltage

Voltages between the isolated ground and the system neutral greater than 0.5 AC volts should be reduced. A voltage of 0.5 AC volts or less is within the electrical system's normal operating tolerances. Contact your local power supplier if you suspect a stray voltage problem on your farm. All metal structures or equipment that a cow can touch should be electrically bonded together so that no potential difference can exist. A voltage can still exist between the concrete floor and the exposed metal. If this is caused by secondary currents in the farm wiring system, the first step is to reduce the secondary neutral resistance. By improving the neutral wire connection or providing a larger neutral, you will provide a better path for the 115 volt neutral currents.

Another method is to reduce the ground rod resistance at the service entrance to the milking parlor. Voltages between the barn floor and all metallic structures can be eliminated by one of several methods. The concrete floor can be made conductive during construction of the milking parlor by embedding a wire mesh in the floor and bonding all metal structures to the wire mesh.

One effective means to reduce stray voltage is to add 2 x 2 inch square wire mesh made of 10 gauge galvanized welded wire embedded about 2 inches below the floor surface. The mesh should cover both the stall floors and the milking pit area to minimize the chance of a potential difference. Tapering the mesh depth may be necessary to provide gradual transitions between the parlor floor and entrance areas. Welded connections to all reinforcing bars in the floor can also be used, but may be less effective.

Laying a ground wire in a trench around the milking parlor floor area is another method. Number 4 copper wire should be bonded to all metal structures. In existing floors, slots can be cut and No. 10 gauge copper wire can be added in the floor and grouted over. The grounding conductors should be attached to the common bond between all metal structures in the parlor. The bond between the grounded conductor at the service entrance can be removed, and a separate insulated grounding conductor can be established at the distribution transformer.

Equipment such as isolating transformers and saturating reactors reduce stray voltage problems in some cases. Tests indicate that these electrical devices eliminate stray voltage problems caused primarily by neutral voltages. Not all distribution systems can utilize this method because of system constraints such as poor primary grounding, dependence on service grounds, or primary or neutral inadequacies. However, these devices may offer many users experiencing stray voltage problems an inexpensive, code-recognized, reliable device for solving this problem.

Experience has shown that cows remember unpleasant experiences such as shocks for an extended period. It also appears that being subjected to shocks may produce an increased sensitivity to shock for some animals. Correction of stray voltage problems may not produce immediate improvements in the reaction or production of the herd.Applying these procedures usually reduces stray voltages to acceptable levels. Continuous monitoring of voltages during milking may be necessary to determine the source of the stray voltage problem for difficult cases. Sources of stray voltage can often be identified by noticing stray voltage increases when an electrical appliance is turned on. If this phenomenon is observed, then the appliance must be checked for proper wiring and grounding.

Conclusion

Reduction of stray voltages in dairy parlors can be accomplished if careful analysis of the problem is made and corrective measures are taken to eliminate the problem. Proper measurement techniques, identification of the stray voltage source and application of recommended techniques in construction and bonding provide the most satisfactory approach to eliminating stray voltage problems.

References

North Central Regional Extension Publication 125, Stray VoltageProblems with Dairy Cows, by Cloud, Appleman and Gustafson.University of Georgia Cooperative Extension Leaflet L-256, StrayVoltages in Dairies, by Hammond, Winsett and Guthrie.

Footnotes

1. This document is AE55, one of a series of the Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date 1986. Revised 1992. Reviewed June 2003, April 2010, and January 2013. Visit the EDIS website at http://edis.ifas.ufl.edu.

2. R. A. Bucklin, associate professor; M. T. Talbot, associate professor; W.J. Becker, associate professor; and D. R. Bray, professor, Agricultural Engineering Department; and Extension Dairyman, Dairy Science Department; Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

What do we know about Stray Voltage?

Douglas J. Reinemann, Ph.D.
Professor of Biological Systems Engineering
University of Wisconsin - Madison
April 2009

Introduction

The term stray voltage describes a special case of voltage developed on the grounded neutral system of a farm. If this voltage reaches sufficient levels, animals coming into contact with grounded devices may receive a mild electric shock that can cause a behavioral response. The term stray voltage is often applied incorrectly to other electrical phenomena such as electric fields, magnetic fields, and electric current flowing in the earth or on grounding systems.

A great deal of research on the effects of stray voltage on dairy cows has been conducted over the past 40 years. A comprehensive review of this research is presented in a report to the Ontario Energy Board cited in the reference section. The review of literature in this report used published studies that included data from controlled experiments and field studies and summarizes the conclusions of hundreds of researchers to provide the basis for a consensus view of the scientific community. A brief summary of this review is presented here.

Sources

The source of stray voltage is a voltage that is developed on the grounded neutral wiring network of a farm and/or the electric power delivery system. The magnitude of the voltage source is a product of the current flowing on the neutral system and the resistance of that neutral system. Grounding is provided to keep the voltage potential between the neutral system and the ground below levels that could be harmful to people or animals. Neutral-to-earth, or stray voltage can be reduced in three fundamental ways:

- Reduce the current flow on the neutral system,
- Reduce the resistance of the neutral system, or
- Improve the grounding of the neutral system

The first step in a competent stray voltage investigation is to determine the major sources of neutral-earth voltage. Any major faults or code violations in the wiring system that could pose an electrocution hazard or are a major source of neutral to earth voltage should be corrected immediately. If the wiring systems (farm and utility) are operating correctly then the above three actions can be assessed to determine which is most practical, safe and efficient way to reduce neutral-earth voltage. Equipotential planes are effective in eliminating contact potentials even if substantial levels of neutral-to-earth voltage are present.

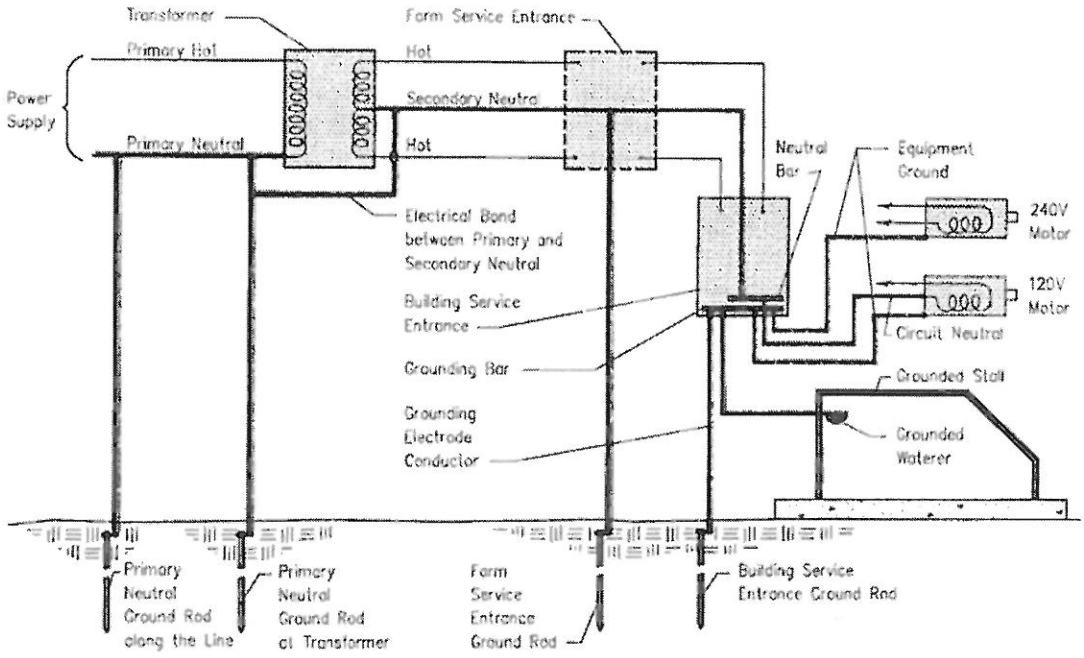


Figure 1. Illustration of Primary and Secondary Grounded Neutral Systems.

Nerve Stimulation and Animal Responses

The widely accepted understanding of the way that stray voltage affects animals is through nerve stimulation. The bio-mechanics of nerve stimulation with electrical exposure has been widely studied and is well understood. The 1998 Reilly text cited in the references is a definitive reference on the biomechanics of nerve stimulation and resulting pathologies. Both sensation and muscle reactions can be elicited with electric currents conducted through the skin. These effects occur when nerves (or neurons) are excited – sensory neurons in the case of sensation, or motor neurons in the case of muscle reactions. Sensory effects are usually elicited with lower stimuli than are motor effects.

Nerve stimulation is characterized by a current threshold (current exposure "2" on the graph). Current applied below the threshold will not produce nerve excitation, and hence no sensation, motor response or behavioral response can occur. At the current level just above the threshold of nerve excitation sensation will result (Nerve response "1" on the graph), which may be perceived but is not painful. As the current level is increased above the threshold involuntary muscle contraction begins to occur. This lower margin of muscle contraction is not painful. Pain can be experienced as current exposures are increased further due to both increased sensory stimulation and more intense muscle contraction.

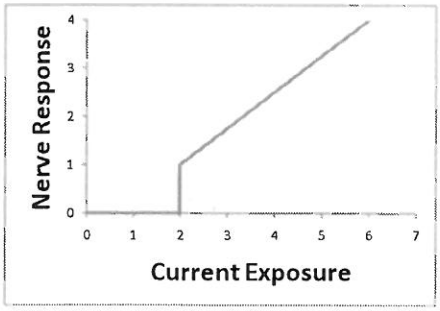


Figure 2. Conceptual Illustration of threshold response.

Studies have shown that each animals exhibit behavioral responses at animal specific threshold current exposures for a particular contact pathway. Levels of current exposure just above the threshold will result in mild behavioral reactions, such as the blink of an eye, which tend to become less pronounced over time as animals become accustomed to the sensation. As current exposure is increased above this threshold, behavioral responses become more pronounced and more persistent, indicative of annoyance, pain or involuntary muscle contraction (twitches).

Basic concepts of Voltage, current, and Resistance

Ohms Law describes the relationship between voltage exposure and current conducted through the animal. A common form of Ohm's Law is:

$$Current\ (Amps) = \frac{Voltage\ (Volts)}{Resistance\ (Ohms)}$$

Ohms law indicates that if the Voltage (across animal contact points) is increased, the current flowing through the animal will increase. Likewise, if the resistance (of contact points) is increased, the current flowing through the animal will decrease. The current measure used in many stray Voltage studies is milliamps or 1/1000th of an amp. The measurement circuit used for field investigations uses a 500 Ohm Resistor to simulate the combined resistance of a cow's body + conservative estimates of the resistance of the two contact points. Using these values a cow contact current of 2 milliAmps would result from a cow contact Voltage of 1 V and a cow+ contact resistance of 500 Ohms.

$$Current\left(\frac{1}{500}\ Amps = \frac{2}{1000} Amps = 2\ Milliamps\right) = \frac{1\ Volt}{500\ Ohms}$$

This simple relationship has been a source of much confusion and resulting controversy in the stray Voltage debate. One way to think about electricity is that Voltage is the driving force and current is the resulting movement of electrons through the resistance of the wire (or animal). It is possible to have a Voltage source with no resulting current flow if the resistance value is infinite (as is the case when a switch is turned off, or a valve is shut). It is not possible to produce current flow in the absence of Voltage, however, regardless of the resistance of the circuit.

It is critically important to use a realistic value of animal resistance (or impedance) to relate Voltage exposures to the level of current conducted through an animal and the resulting effects on nerve stimulation, sensation and behavioral reaction.

The body resistance of cows has been measured in several studies. Measures of an animal's body resistance depends on the pathway between the 2 contact points (e.g. muzzle-hoof or hoof-hoof) and the way in which the contact is made including factors such as the area over which the contact is made, pressure applied to the contact, and use of conductive liquids or gels on the measurement connection.

Some studies have tried to isolate the body resistance of animals using contact conditions not encountered in normal farm operations. Contact resistances are the most difficult value to

predict in real-world farm situations. Fewer studies have been done to characterize real-world contact resistances. It is clear, however from these studies as well as physical principles, that real-world contact resistances have enormous variability. The lowest contact resistances would be expected if a clean, wet body part (such as a cow's muzzle) comes into contact with a clean, wet, metallic object with a substantial mutual contact area and substantial contact pressure. Contact resistances will increase with:

- Smaller contact surface area (e.g. a point contact the size of a pencil eraser compared to a metal plate applied over a surface the size of your hand)
- Reduced contact surface pressure (e.g. a light touch versus a contact applied with the weight of an animal)
- Drier contact surfaces
- Amount of debris on either the animal contact point (e.g. bedding/manure impacted in hooves or feed at the muzzle)
- Resistance value of the debris at the contact margin (e.g. dry straw compared with wet manure)

The accepted practice by researchers and regulators has been to assume worst-case (lowest practical values) for contact resistances. Studies done to measure more typical body + contact resistances that would occur on farms have shown that 500 Ohms is a reasonable value to use in a measurement circuit to estimate the current that would flow through a cow's body. Although the resistance of the cows body is typically less than 500 Ohms for the muzzle to hoof pathway (other pathways have a higher resistance), it has been shown to be a 'worst case' or minimum resistance value for the combination of a dairy cows body + real-world contact resistance in the farm environment.

Effects of Voltage/Current Exposure

The direct effect of animal contact with electrical voltage can range from:

- Mild behavioral reactions indicative of sensation at exposure levels that are just perceptible to the animal. Behaviors indicative of perception (eg, flinches) may result with little change in normal routines.
- Involuntary muscle contraction – or twitching, that occurs at exposure levels somewhat above the exposure threshold for perception.
- Intense behavioral responses indicative of pain at levels considerably above the exposure threshold for perception.

The indirect effects of these behaviors can vary considerably depending on the specifics of the contact location, level of current flow, body pathway, frequency of occurrence, and many other factors related to the daily activities of animals. There are several common situations of concern in animal environments:

- Animals avoiding certain exposure locations which may result in,
    - Reduced water intake that may result if painful exposure is required for animals to access watering devices,
    - Reduced feed intake that may result if painful exposure is required for animals to accesses feeding devices or locations,
- Difficulty of moving or handling animals in areas of annoying voltage/current exposure,
- The release of stress hormones produced by contact with painful stimuli.

The majority of stray voltage research has been done on dairy cows. The accepted practice by researchers and regulators has been to assume worst-case (lowest practical values) for cow contact resistances. Studies done to measure typical body + contact resistances that would occur on farms have shown that 500 Ohms to 1000 Ohms is a reasonable range to use in a measurement circuit to estimate the current that would flow through a cow's body.

The most sensitive dairy cows (<1%) begin to experience mild behavioral modifications at current exposures exceeding 2 milli-Amps (60 Hz AC rms) corresponding to 1 Volt to 2 Volts (60 Hz, AC rms) of cow contact exposure in farm exposure situations. As the voltage and current increase, a larger percentage of cows react with behavioral responses that become more pronounced. Aversion has been documented to require substantially higher voltage and current exposures than the levels that produce behavioral modification. Numerous studies have documented avoidance behaviors at levels above the first reaction threshold. The median avoidance threshold for 60 Hz current flowing through a cow is about 8 milliamps (or 4 to 8 Vrms). This response assumes that the cow comes into contact with objects that have different voltages and that this voltage causes sufficient current to flow through the cow. Even when the threshold is exceeded, not all the animals respond behaviorally all the time, nor do they exhibit the same signs; however, as the voltage increases, signs in the herd become more widespread and uniform. Cows have been shown to resume normal behaviors within 1 day of removal of adverse voltage and current levels.

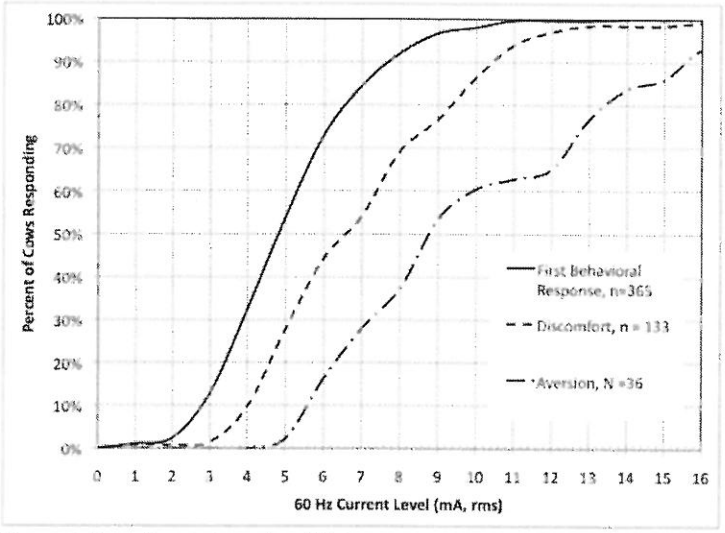


Figure 3. Experimental results of dairy cow responses to 60 Hz current exposure.

It has also been shown that the equivalent to 2 milli-Amps of 60 Hz AC current (2 Volts of 60 Hz AC rms voltage) is about 2.8 mA of DC current (2.8 Volts DC). In addition dairy cows are much less sensitive to high frequency or short duration electrical exposures than for 60 Hz rms AC current (A much higher current is required to elicit the same response). Numerous studies have documented that cows rapidly acclimate very quickly to even very high levels of voltage/current exposure and behavioral modifications become less pronounced in a matter of several days.

A number of studies have been done to investigate direct physiological effects that may be produced at levels above those that produce behavioral changes, as well as potential detrimental physiological responses that may result from animals' exposure to voltage/current below levels which may produce sensation and behavioral response. These studies have shown that increased concentrations of the stress hormones do not occur at levels below behavioral response levels and only become apparent in some, but not all cows, at substantially higher

voltage/current exposures than the threshold required for behavioral modification, and typically at levels that produce severe behavioral changes and probably at current levels that produce discomfort and/or pain. Furthermore, the failure of several experimental and field studies to demonstrate detrimental effects of current exposure on the incidence of mastitis and immune function response indicate that the levels of voltage/current exposure that elicit behavioral changes do not compromise the immune function of dairy cows.

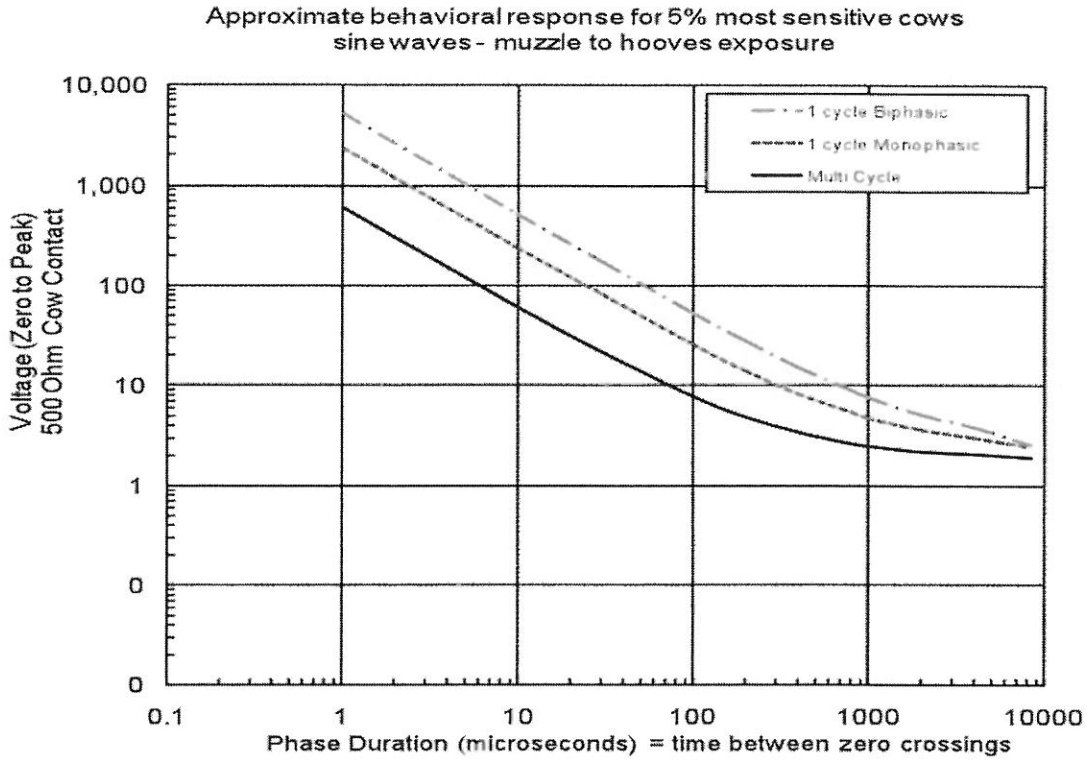


Figure 4. Relative response thresholds for long phase duration (low frequency) voltage and short phase duration (high frequency) voltage exposure with different waveforms. Note: 60 Hz voltage appears on the far right of this graph.

Exposure at watering devices

Farm animals' Contact with watering devices has been the most widely studied area of stray Voltage exposure. Water intake is essential for animal productivity and health. Metallic water pipes are required by electrical codes to be bonded, or electrically connected, to the grounded neutral system of a farm. This connection to the grounded neutral system provides a path for fault current in the event that an energized or 'live' wire comes into contact with metal pipes. This fault path allows the circuit breakers to activate and de-energize the faulted wire to prevent the risk of electrocution. This connection also provides a conduit for neutral Voltage to access watering devices. Watering devices are therefore one of the more likely points of contact between farm animals and neutral to earth Voltage.

The watering device provides one contact point to the animals' mouth or muzzle. The resistance of this contact point is quite variable depending on the specific type or watering device. For example, in a large concrete tank from which cows can drink without making physical contact with the concrete, the contact resistance is quite high, as water is a relatively poor conductor of electricity. When drinking from a metallic water bowl, typical of a tie-stall or stanchion barn application, a large area of a cow's muzzle must make firm contact with a large metallic paddle in order to start the flow of water into the bowl. The contact resistance in this scenario is quite low. There are other types of watering devices that have intermediate muzzle contact resistance such as heated waterers that may use a float to control water levels. Some watering devices are made of plastic, which is a relative poor conductor of electric current.

The second contact point at watering locations is usually the floor surrounding the watering device. The contact resistance of this surface will be influenced by the type of flooring (usually concrete), the amount and type of debris that may be present of the floor and the wetness of the floor. The experiments that have been done using used flooring conditions designed to minimize this contact resistance (a clean, wet metal plate with some contouring to clean hooves and provide points of high pressure to facilitate a low resistance electrical connection) that it has not been possible to maintain this low resistance continuously and during the course of a day this contact resistance ranged from a few Ohms up to several hundred Ohms. Experiments that have been done using a more normal concrete floor have indicated that this contact resistance typically ranges between several hundred and several thousand Ohms depending mainly on the amount of water and/or urine standing on the floor surface.

The 'worst case' or lowest resistance value for the contact resistance recommended by the authors of USDA handbook 696 is about 150 Ohms. This combined with that average cow body resistance from muzzle to 4 hooves provides a cow + contact resistance of 500 Ohms. This value is supported well by experimental evidence and is a reasonable value to use for cow + contact resistance at watering devices. Exposure risks can be reduced by:

- Using watering devices that do not required firm contact with grounded metallic components, or using non metallic watering devices
- Avoid the use of electric heating elements in watering devices if possible.
- Provide an equipotential plane around watering devices containing electrified and/or electrically conductive materials, as required by electric codes.
- Providing good drainage around watering devices to avoid standing water and urine on floor surfaces
- Provide several watering locations that are easily accessible to animals in the event that Voltage exposures are excessive at one of the watering locations.

The primary symptoms of stray Voltages at watering are changes in drinking behaviors. Mild changes in drinking behaviors, such as reduced number of drinks per day and longer interval between drinks have been documented in several studies. These changes in behavior may not be sufficient to affect total daily water intake. More severe aversions have also been observed at extreme levels of Voltage/current exposure resulting in depressed daily total water intake and in some cases refusal to drink for an entire day.

Experiments have shown that when given free choice, cows show a preference to warmed water over cold water (ground water temperature) that may be perceived as an avoidance of the cold-water locations. There are a number of other sensory differences that may incline cows to show a preference to one watering location rather than another, which may be perceived as avoidance of that alternate source. Avoidance of watering locations could also be due to unpleasant tastes or smells, however, the powerful drive to drink will normally overcome all but the most foul of tastes.

Lapping or playing at a watering device has been attributed to stray Voltage exposure, but no controlled study has ever confirmed this behavior in the presence of Voltage/current exposure. Cows may demonstrate avoidance or modified drinking behaviors in response to group dominance challenges. Cows have been shown to develop what may appear to be unusual behaviors as a way to cope with stressors such as confinement and for many other unknown reasons.

There are well developed experimental techniques to establish cause and affect relationships between a specific stimulus and a specific behavior or avoidance. It is very difficult to establish these relationships on an operating farm unless careful measurement of behaviors is done and sources variability and confounding effects are controlled for.

Mild behavioral modification would be expected at current levels of 2 mA for the most sensitive dairy cows, 5 mA for 50% of cows, and about 8 mA for the least sensitive cows. Using a worst case cow+contact resistance of 500 Ohms at poorly drained, wet locations surrounding watering devices, this corresponds to Voltage exposure levels from 1 V for the most sensitive, 2.5 V for 50% of cows and 4 V for the least sensitive cows. While these levels have been well documented for dairy cows, it is expected that they would also apply to beef cattle. In well designed, constructed and managed facilities in which higher contact resistances are more typical this would correspond to Voltage exposure levels of 2 V for the most sensitive cows, 6 V for 50% of cows and 8 V for the least sensitive cows.

Short-term avoidance behaviors, which may result in short term depression of milk production, would be expected at about 3 mA for the most sensitive cattle (1.5 to 3 V), 7.5 mA (3.8 to 7.5 V) for 50% of cattle and 12 mA (6 to 12 V) for the least sensitive cattle. Reduction in water intake and resulting decreases in milk production would only be expected if there were no other source of water than that which applied this level of current during drinking and if the current dose were consentient enough during the course of a day so that cows could not fulfill their water needs during periods of low exposure.

Exposure at feeding devices

There have been relatively few studies that have specifically examined animal responses to Voltage exposure at feeding devices. Notable in the literature are the recent studies performed in France in which Holsteins showed preference for non-electrified feed bowls when exposures exceeded 2.3 V, and behavioral modification (but not feed reduction) was noted at exposure levels of 3.3 V. These studies indicate that dairy cows have similar sensitivity to feeding exposures as to drinking exposures; however, the feed bowls used in these studies were not

typical of those used in farm practice as they were specifically chosen to be small enough and deep enough so that cows would make contact with the electrified surface when eating.

While there are many ways in which feed is delivered to animals, it is relatively uncommon to have feeding devices that require animals to come into direct contact with metallic or conductive elements in order to obtain feed. Feeding locations also pose less of a risk because both mouth and floor contact resistances are typically higher than for watering locations because both are dryer and covered with a high resistance, dry feed or feed debris. Situations in which feed is placed on a concrete floor (feed manger) are unlikely location for problems because, even if an equipotential plane has not been purposefully installed, conductive elements are almost always present in concrete creating at least a partial equipotential plane in some areas of the barn.

The primary symptoms associated with Voltage exposures at feeding locations would be the same sorts of avoidance behaviors produced by excessive Voltage present at watering locations. These behaviors may be very difficult to observe in situations in which animals have free choice of several feeding locations and/or large feed mangers. The behaviors would be more apparent for situations in which animals had only one feeding location, as may occur for swine.

Exposure during milking

Several studies have been done on behavioral responses to Voltage/current exposure during milking. Voltage exposures are less likely to occur for dairy cows in milking parlors than at drinking locations because the metallic components of milking parlor stalls are more likely to be bonded to conductive elements in concrete floors and the floors are more likely to contain a substantial number of conductive elements. This will act to reduce both touch and step potentials.

The milking machine has been shown to be a very unlikely pathway for problematic current flow because of the very large resistance values of the milk hose and milking machine components. Milking machine components, including the long and short milk tubes, long and short pulse tubes and milking liners are good electrical insulators. The mixture of milk and air in milk tubes also has relative high resistance resistances making milk hose resistance in the range of 30,000 Ohms to 80,000 Ohms depending on the milk flow rate. Several studies have documented these resistance values and the unlikely path of Voltage/current exposure through the milking machine unless source Voltages are well in excess of those commonly considered stray Voltage, up to hundreds of V for 60 Hz and thousands of V for high frequency sensing pulses.

Cows are not required to make muzzle contact with any metallic components during milking, except in the uncommon situations in which feed might be provided during milking. The contact resistance through a pathway that includes dairy cow's coat is much higher than for muzzle contact resistance because it is drier and hair covered, thus making stall to floor potentials of less concern that water bowl potentials.

Current sensitivity levels are similar for udder-hooves pathways as for muzzle-hooves pathways but cow+contact resistance values are typically higher. A cow + contact resistance value of 1000 Ohms or more is appropriate for milking machine exposure estimation. There are numerous behavioral symptoms associated with cow's unease during milking due to fear of operators, unfamiliar surroundings or aggressive or faulty milking machine settings. Very careful measurement technique and comparison with a negative control condition would be required to differentiate electrical exposures from the many other causes of behavioral modification during milking in a field situation.

Exposure at building transitions

Step potentials may occur at building transitions where animals are walking onto concrete floors or walking from one section of floor to another which are not electrically bonded by an equipotential plane. Cows are somewhat more sensitive to single hoof-single hoof exposures than to muzzle-to-all-hooves exposures

The contact points for this exposure is from front to rear hooves. The same considerations for hoof contact resistance as was discussed in the feeding exposure section apply here. If floors are well drained and contain organic debris, the hoof contact resistance can be considerable. Cows have been shown to be slightly more sensitive to currents applied from one front to one rear hoof than for muzzle-all-hooves pathway because of the concentration of current in one hoof.

The symptoms of step potential exposure would likely be cows' hesitation to cross building entrances, exits, or transitions. The discomfort associated with step potentials less than 10 V would not cause most cows to completely avoid the transition but could cause balking at the transition and/or rapid passing through the transition. The author had a report of a milking parlor that had in excess of 50 V at the entrance to the milking parlor. The reported behavioral modification was cows hesitating at the entrance and then 'jumping' into and out of the parlor. There were no apparent effects on milk yield or milking performance, likely because cows had developed adaptive behaviors to avoid undue stress from Voltage/current exposure and once the cows were inside the relatively well-bonded milking parlor the step potential was eliminated.

There are also a number of other reasons that animals might hesitate to enter or leave a building or move from one part of a building to another including; changes in light levels, shadows on the floor that may appear as obstacles, exploration of a new environment, identification of dominant herd mates and changes in temperature or ventilation levels.

The consequences of a step potential at a building transition are not likely as problematic for animal performance as similarly annoying exposures at watering devices. This exposure pathway is much less of a concern with beef cattle, swine, sheep and poultry that typically stay in the same housing area during the day, than for dairy cows that are moved 2 or 3 times per day to a different building location for milking. Beef cattle are less likely to be housed in buildings that have a concentration of electrical equipment.

Ground Currents, Electric and Magnetic Fields:

The electric and magnetic fields caused by current flowing on the farm grounding system has been raised as a possible concern. Problems with utility and farm wiring can increase both the voltage on the neutral wire as well as the current flowing on the grounding system. The electric and magnetic fields produced by these currents are not perceptible to animals or humans and are much lower than normal household exposure. Electric and magnetic fields act on animals in a different way than the mild shock associated with stray voltage.

A team of experts was assembled by the State of Minnesota to review the evidence on the possible effects of currents flowing in the earth on the health and productivity of dairy cows. A survey of dairy producers conducted as part of the Science Advisors study revealed that the vast majority of diary producers do not consider stray voltage or other forms of electrical exposure a problem on their farms. Several field studies have shown that the electric and magnetic field levels of found on dairy farms are well below those shown to produce biological effects. Although the science advisors found no evidence to suggest that earth currents or the EMF produced by them were harmful, one mechanism was postulated that could produce a biological effect; current flowing through a cow producing a small internal electric fields. Research conducted to examine this possibility showed no ill effect on cows exposed to these low level currents.

The Science Advisors gave three main findings in their report:

- *"We have not found credible scientific evidence to verify the specific claim that currents in the earth or associated electrical parameters such as voltages, magnetic fields and electric fields, are causes of poor health and milk production in dairy herds."*
- *"At the present time, there is no basis for altering the PUC-approved standards by which electric utilities distribute power onto or in the vicinity of individual dairy farms."*
- *"There are many well-documented non-electrical factors that are known and accepted by the scientific community, and by most farmers as well, to cause dairy cow health and production problems. Among the most noteworthy factors are poor nutrition, poor cow comfort and hygiene, and low or no use of vaccinations and related preventive veterinary practices. These factors should always be addressed by those who want to improve performance of dairy herds."*

Other Species

Research suggests swine respond to voltage/current exposure in a similar way to. Behavioral modification has been observed at about 5 Volts with avoidance behaviors at exposures of 8 V. The body + contact resistance for swine appears to be somewhat higher than for cows and 1000 Ohms appears to be a conservative value for measurement purposes.

Neuro- electric principles suggest that the current sensitivity of sheep is lower than for cows, but that their body resistance is higher than cows. Ewes have been shown to avoid electrified feed bowls when exposure levels exceed 5.5 V while Lambs showed this same preferential behavior when exposure levels exceeded 5 V.

Exposures to voltages as high as 18 V had no effect on the hens' production and behavior. This is likely due to the very high electrical resistance of poultry that has been documented to be between 350,000 and 544,000 Ohms.

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6. Regulatory Approaches and Guidelines to Reducing the Impact of Stray voltage on Farm Operations

Several states have conducted scientific and technical reviews and held public hearings to address concerns and inform public policy on stray voltage issues. Some States have adopted regulations dealing with stray voltage while others have developed multi-agency and stakeholder groups to develop guidelines and standard practices. Following is a brief summary of the regulatory approaches and/or guidelines adopted by several states in the USA.

6.1. Wisconsin

The State of Wisconsin has a well established inter-agency cooperative program headed by the Rural Electric Power Services Program (formerly Stray voltage Program) jointly administered by the Public Service Commission of Wisconsin and the Wisconsin Department of Agriculture, Trade and Consumer Protection with research and educational support provided by the faculty from the University of Wisconsin-Madison and the University of Wisconsin Cooperative Extension service. These activities have resulted in the development of standardized measurement protocols and a long series of educational programs and publications. Public Service Commission of Wisconsin (PSCW) has also conducted several public hearings and investigations that have resulted in orders that define and regulate stray voltage.

Docket 05-EI-106 defines stray voltage is a special case of voltage in which the neutral to earth voltage is present across points (generally grounded metal objects) in which a current flow is produced when an animal comes into contact with them. These contact points can include any two conductive points which the animal may simultaneously contact to complete a circuit which allows current to flow. PSCW also adopted standardized tests and measurements to screen for the presence of stray voltage and to diagnose the source. The PSCW ordered the utilities to use these specific, standard tests and no others. The PSCW concluded that a specific testing protocol was necessary in order to:

1. provide a consistent systematic analysis which can readily be documented and duplicated,
2. avoid needless controversy over whether an adequate analysis was performed or whether the nature of the tests were valid, and
3. To best recognize the various interests of [all] parties working on a stray voltage analysis.

The standardized tests and measurements are set forth in the 106 Order. In the 106 Order, the PSCW established a level of concern for stray voltage in Wisconsin. The level of concern is the point at which the average cow's behavior may be adversely affected. The level of concern is expressed in mA (mA), the unit of measurement for current. As previously noted, stray voltage is the voltage difference between points. However, it is actually the current flowing through the animal that affects it and, therefore, the Commission finds that the level of concern should be stated in mA measurement unit of current flow.

In Docket 05-EI-115 the PSCW updated its earlier decisions about stray voltage and its effects on cows. In the 115 Order, the PSCW modified the level of concern in Wisconsin to take into account a customer's contribution of stray voltage. The level of concern in Wisconsin for stray voltage is 2 mA of current flowing through a cow. This level of concern is a conservative, preventative level and is well below

where a cow's behavior or milk production would be harmed. In its Ultimate Findings of Fact in the 115 Order, the PSCW found that the level of concern for stray voltage that the Commission established in docket 106 is extremely conservative, because only one percent of cows perceive the presence of 1.0 mA of electrical current.

Reasonable regulation for Wisconsin, a dairy state, is to set a stray voltage level of concern at a conservative, preventative level that is below the point where moderate avoidance behavior is likely to occur. A conservative, preventative level of concern in Wisconsin is 2.0 mA of AC RMS 60 Hz current, steady state. This level of concern is well below where a cow's behavior or milk production would be harmed.

Stray voltage can occur from both on-farm and off-farm sources, so it is reasonable to apply the 2.0 mA level of concern as an overall standard that includes both sources. It is also reasonable to split this 2.0 mA overall level of concern equally between the utility and the farmer. The utility's level of concern is therefore 1.0 mA, for stray voltage from off-farm sources, and the farmer's level of concern is 1.0 mA, for stray voltage from on-farm sources. If the utility's contribution of stray voltage exceeds 1.0 mA, the utility must reduce its contribution to 1.0 mA or below. If the stray voltage from on-farm sources exceeds 1.0 mA, the Commission recommends that the farmer improve the farm wiring, grounding or equipment or take other measures to reduce the level from these sources below 1.0 mA.

In the 115 Order, the PSCW determined that stray voltage measurements should be made using a 500 ohm resistor to approximate a cow's actual resistance. Using a 500 ohm resistor in the testing protocol is conservative, because it calculates stray voltage levels that equal or exceed the actual amount of current a cow in the barn would experience.

The PSCW relied on, and found persuasive, the United States Department of Agriculture's Effects of Electrical voltage/Current on Farm Animals, Agricultural Handbook No. 696: December 1991. In the 115 Order, the PSCW issued these Ultimate Findings of Fact concerning the Handbook:

- A scientific consensus exists about the effects of stray voltage.
- The major work published on this subject is the USDA Handbook.
- The conclusions in the USDA Handbook are still shared today by all of the authors.
- Figure 4 (in this document) from USDA Handbook 696 shows research results about the effect of steady state, 60 Hz current passing through a cow. This Figure indicates that 1 mA is the lowest threshold at which the most sensitive cows perceive the presence of electricity. Stray voltage at this level has no effect on milk production.
- Currents up to 4.0 mA do not appear to inhibit the milk ejection reflex, depress milk production significantly, or increase the incidence of mastitis or other diseases of the cow.
- Above 6.0 mA, a cow's behavioral response can become severe and the loss in milk production may be due to changes in the animal, such as increased stressed hormone levels.

Long-term and on-farm experiments conducted after the publication of the USDA Handbook confirm the Handbook's conclusions. The USDA Handbook's conclusions are reasonable and remain valuable today.

The level of concern set forth in the 115 Order applies to earth currents and ground currents. For a cow to be affected by electricity, current has to flow through the cow. The level of concern of 2.0 mA of current flowing through a cow applies regardless of the source of the current.

In Docket 05-EI-108 the PSCW investigated the effects of electromagnetic fields, direct currents, and ground currents on dairy cows. Earth currents are an inherent, inevitable, and unavoidable result of a multi-grounded neutral distribution system. On normally operated grounded wye distribution systems, both ground current and earth current will flow as a result of voltages on the grounding system. The Minnesota PUC had already established a scientific advisory panel and the PSCW worked with the PUC on that study and concurred with their conclusions (see below).

The PSCW also maintains an extensive database of on-farm stray voltage investigations that dates from 1989. Data from over 8000 first time on-farm investigations from investor owned utilities and electric cooperatives. These data were collected using a standardized measurement protocol developed by the PSCW which quantifies the highest level of animal-contact current on the farm, the contribution from on-farm and off-farm sources as well as many other electrical and herd production data.

6.1. Michigan

The State of Michigan's Public Service Commission defines a preventative action level as a steady state animal contact current that meets or exceeds 2 mA RMS using a nominal 500 ohms resistor at 60 Hz from all sources, including off-premises and on-premises sources.

Measurement Methods: The level of animal contact current shall be determined from measurements of animal contact voltage using Ohm's Law. The voltage measurement shall be made between 2 points, which an animal can simultaneously contact and under which animal contact voltage is most likely to occur. When measuring from the floor or earth, a single metallic plate with an area of 12 to 16 square inches shall be used to simulate the foot of the animal. One lead of the measuring instrument shall be connected to the plate, which shall be placed on the floor or earth where an animal may stand. The other lead of the measuring instrument shall be connected to a conductive object that an animal could reasonably contact while 1 of its feet is at the location of the plate. For all measurements of animal contact voltage a shunt resistor shall be used to simulate the resistance of the animal. A suitable material, such as a medical grade electrode contact gel, shall be used to simulate real conditions and maintain conductivity to the floor or earth for the duration of the testing period.

Action required to mitigate animal contact current: If the steady state animal contact current from all sources as measured by the utility in accordance with this rule meets or exceeds the preventive action level, and if the utility contribution exceeds 1 mA RMS, then the utility shall commence action within two business days, or at a mutually agreed upon time frame between the complainant and the utility, to reduce the utility contribution to 1 mA or less.

Further sections detail procedures for: Request for an investigation, Appointment of Experts, Request for a contested case hearing, Protocol to evaluate utility contribution.

6.3. Vermont

Scruton (2003) reported that in 1994 the legislature held hearings and a program was initiated with the Public Service Board, Public Service Department, Vermont Department of Agriculture, Food and Markets, The University of Vermont and Vermont Utilities. Utilities agreed to test all farms for stray voltage. Neutral isolation devices are installed, at the unities' expense when neutral to earth voltage in excess of 0.5 V are encountered. If less than 0.5 V are found, the utility may install an isolator; or voltages will be monitored for a sufficient period to ensure that voltage does not exceed the 0.5 V threshold.

6.4. Idaho

In March 2005 the Idaho Legislature passed the Stray Current and voltage Remediation Act requiring the Idaho Public Utilities Commission to promulgate stray voltage rules. The Idaho Public Utilities Commission (IPUC) has developed Stray voltage Rules composed of four Major Sections:

- Qualifications of persons analyzing stray voltage data
- Calibration and standards of recording equipment
- Six stray voltage tests and data collection forms
- Analyzing data and conducting remediation actions, if required

The IPUC has accepted the following definitions of Stray Current and voltage as:

a) Any steady state, sixty (60) hertz (Hz) (including harmonics thereof) root mean square (rms) alternating current (AC) less than twenty (20) mA through a five hundred (500) ohm resistor (i.e. shunt resistor) connected between cow contact points, as measured by a true rms meter; or

b) Any steady state, sixty (60) Hz (including harmonics thereof), rms AC voltage of less than ten (10) V, across (in parallel with) a five hundred (500) ohm resistor (i.e. shunt resistor) connected between cow contact points, as measured by a true rms meter.

c) Stray current and voltage is a normal, inherent and unavoidable result of electricity traveling through grounded electrical systems, including a dairy producer's on-farm system and a utility's distribution system. These systems are required by the National Electrical Code (NEC) and the National Electrical Safety Code (NESC) to be grounded to the earth to ensure safety and reliability.

d) Unless the context otherwise requires, the term stray voltage shall mean stray current or stray voltage.

6.5. Minnesota

The Minnesota PUC assembled a team of Science Advisors study farmers' claims that electric currents in the earth from electric distribution systems caused behavior, health, and production problems in cows

in Minnesota. The Science Advisors were a multidisciplinary group with expertise in the fields of agricultural engineering, animal physiology, biochemistry, electrical engineering, electrochemistry, epidemiology, physics, soil science and veterinary science. The Science Advisors to the Minnesota PUC issued its Final Report to the Minnesota PUC in July 1998. In its Final Report, the Science Advisors to the Minnesota PUC reached three conclusions:

1. We have not found credible scientific evidence to verify the specific claim that currents in the earth or associated electrical parameters such as voltages, magnetic fields and electric currents, are causes of poor health and milk production in dairy herds.
2. At the present time there is no basis for altering the PUC approved standards by which electric utilities distribute power onto or in the vicinity of individual dairy farms.
3. There are many well-documented non-electrical factors that are known and accepted by the scientific community, and by most farmers as well, to cause dairy cow health and production problems. Among the most noteworthy stressors are poor nutrition, poor cow comfort and hygiene, and low or no use of vaccinations and related preventive veterinary practices. Those who want to improve performance of dairy herds should always address these factors.

6.6. New York

The New York State Stray voltage Committee was formed in the early 1980's as a forum for utility risk management personnel to share information about existing or potential litigation on 'stray voltage' (28). New York investor owned utilities shared experiences, solutions and research funded by the Stray voltage Research Council. In 1993 efforts were directed to neutral isolation devices for cable television and underground telephone services due to the expansion of cable television into traditionally agricultural areas and electric utilities found itself at odds with cable and telephone policies on bonding and grounding. The expertise of Cornell University was requested to develop a standardized test procedure and to outline required tests and test methods and allow the utilities to formalize the procedures based on their internal work rules. At this time the Empire State Electric Energy Research Council also funded additional research on 'the effects of transients and multiple stresses on dairy cows'. The New York State Stray voltage Committee continues to disseminate information and work with Cornell University, local, state, and federal agencies on stray voltage issues so that problems can be avoided rather than perpetuated.

6.7. Pennsylvania

The Pennsylvania State University began a research project for the Pennsylvania Department of Agriculture (PDA) in February 2001 to examine stray voltage issues on PA dairy farms (161). Based on the initial project findings a second project proposal was funded in 2002 to develop an interdisciplinary approach to respond to farmers' stray voltage concerns. This study found that less than 10% of investigations found stray voltage levels high enough to affect cow behavior. The author notes that while the instances that stray voltage directly affects animal performance is infrequent, the resources that farmer and utilities spend chasing stray voltage are significant, and that misinformation and

misdiagnoses of stray voltage and its symptoms are expensive to both farmers and utilities. The following steps were recommended:

1. Establish a statewide stray voltage task for with representatives from utilities, state government, extension, farm organizations, veterinarians, equipment suppliers, nutritionists and other service providers.
2. Establish a standard protocol for stray voltage investigation.
3. Establish a minimum threshold for mitigation.
4. Public and private collaboration on a multidisciplinary response to stray voltage complaints.
5. Education.

The final conclusions of the stray voltage committee were that it is in the best interest of utilities and farmers to accurately diagnose and identify problems that can be associated with stray voltage. For utilities, repeat service calls, customer dissatisfaction and litigation can all be the result of an unhappy farmer. For farmers, believing that stray voltage is the issue when it is not is costly because it delays solving the real problem.