Literature Review and Synthesis of Research Findings on the Impact of Stray Voltage on Farm Operations

Douglas J. Reinemann, Ph.d.
Professor of Biological Systems Engineering
University of Wisconsin-Madison

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1. Scope of this Report

- Literature review
- Pathways whereby stray voltage can affect animals
- Symptoms indicative of stray voltage
- Minimum voltage (or current) level at which impacts can be expected.
- Measures for mitigating stray voltage
- Review of regulatory measures

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Ways That Stray, or Tingle, Voltage Can Impact Farm Operations

- Direct effects
  - Mild behavioral reactions = sensation
  - Involuntary muscle contraction = twitching
  - Intense behavioral responses = pain
- Severity depends on
  - amount of electrical current (milliAmps) flowing through the animal's body
  - Body pathway
  - Individual animal Sensitivity

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Indirect effects

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

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2. Overview of Electrical Exposure and the Physiology of Animal Contact Voltage and Current

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Basic concepts of voltage, current, and resistance

- Ohm's law = relationship between Voltage, Current and Resistance
  - If voltage (across animal contact points) is increased, the current flowing through the animal will increase
  - If resistance (of contact points) is increased, the current flowing through the animal will decrease
    - 1 milliAmp = 1/1000th of an amp

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

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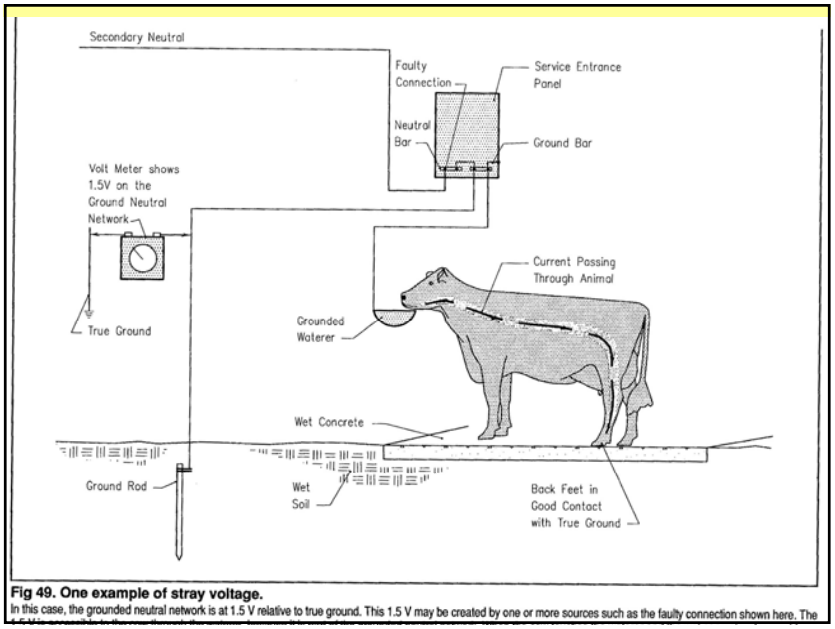
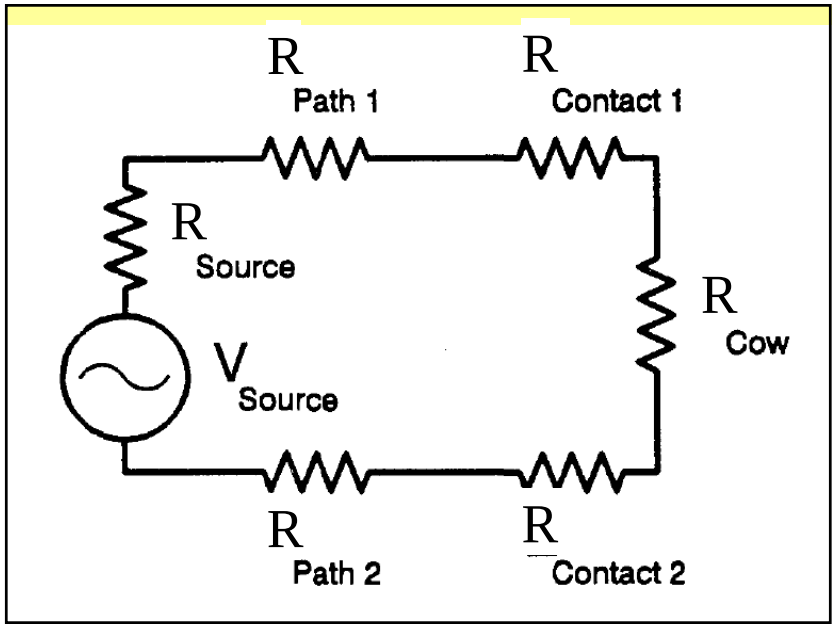
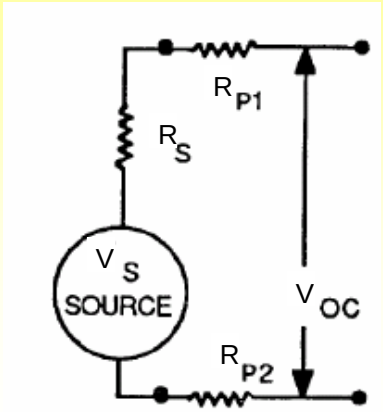


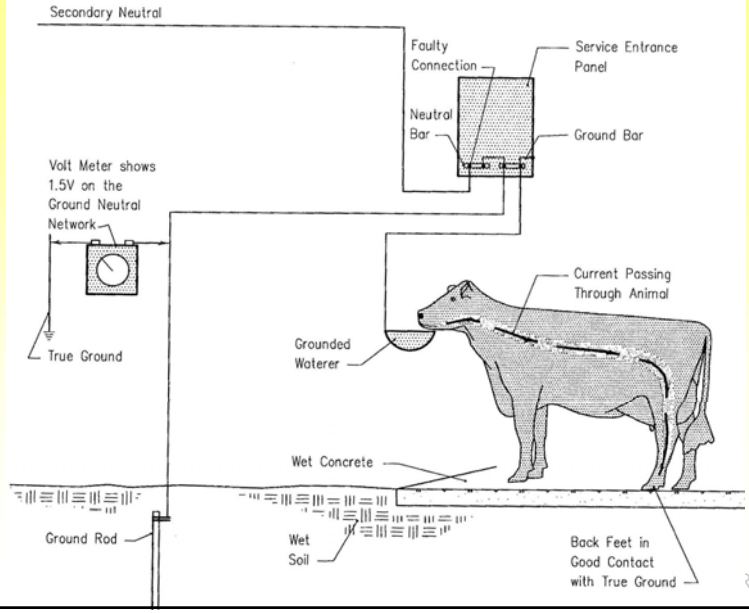
Fig 49. One example of stray voltage.
In this case, the grounded neutral network is at 1.5 V relative to true ground. This 1.5 V may be created by one or more sources such as the faulty connection shown here. The



Elements of the Source Circuit

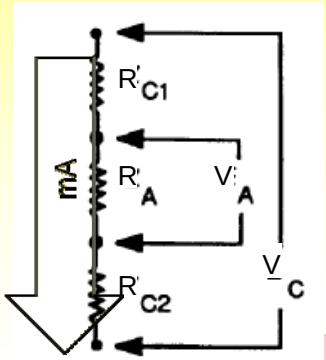
- Vs = Voltage Source (I*R on neutral wire)
- Rs = Source Resistance
- Rp1 = Path Resistance 1
- Rp2 = Path Resistance 2
- Voc = Open Circuit or Source Voltage





Elements of the Animal Circuit

- mA = current through animal
- Rc1 = contact Resistance (Muzzle or front hooves)
- Ra = body Resistance
- Rc2 = contact resistance (all hooves or rear hooves)



Importance of Proper Circuit Identification

V(source)	R(Source)	R(animal + contact)	Animal Contact voltage	Animal contact current
1 volt	100 Ohms	500 Ohms	0.8 Volts	1.7 milliAmps
1 volt	100 Ohms	1000 Ohms	0.9 Volts	0.9 milliamps
1 volt	1000 Ohms	1000 Ohms	0.5 Volts	0.5 milliamps

The Problem of Contact Resistance

- The most variable part of the electrical circuit
- Contact resistances will increase with:
  - smaller contact surface area
  - reduced contact surface pressure
  - drier contact surfaces
  - the amount of debris on contact point
  - resistance value of the debris at the contact margin
- The accepted practice by researchers and regulators has been to assume worst-case (lowest practical values) for contact resistances.

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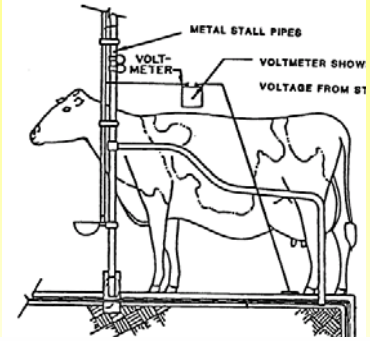

contact. For evaluation purposes, it is often sufficient to consider the worst case resistance, i.e., the lowest resistance likely to be encountered. We consider 500 Ω for the sum of contact and body resistances to be a very conservative estimate of the worst case, or minimum, resistance that is likely to be encountered.

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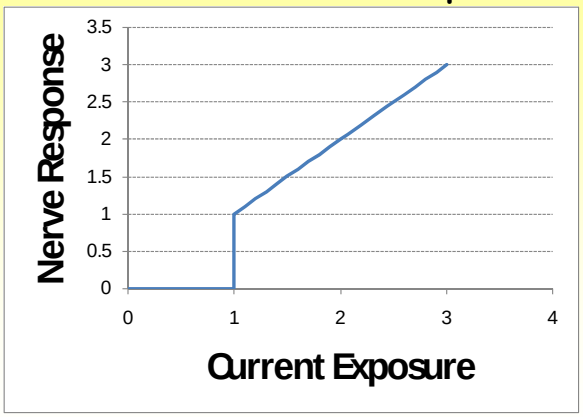
Sensory and Motor Nerve Stimulation and Response



Threshold of Response
(so that they do not fire all the time)

The Bio-mechanics of Nerve Stimulation

- As current levels increase
  - No response below threshold
  - Sensory responses just above threshold
    - Tingling, warmth, startle
  - Motor response
    - Involuntary muscle contraction, twitch
  - Pain

Behavioral Responses

- Each animal will have a behavioral response threshold to current exposure for a particular contact pathway
- Studies have used a variety of behavioral response thresholds
- most sensitive behavioral indicators of perception
  - high variability, rapid acclimation to unfamiliar
- annoyance and/or aversion
  - Change eating / drinking behaviors
- Current applied in a periodic manner
  - repeated series of 'startle' behaviors
- Involuntary muscle contraction
  - Most repeatable, Higher current threshold than sensation

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Literature Review 1962-2008

- 61 Studies of voltage/current application to cows
- 26 Studies of voltage/current application to other farm species
- 8 Studies of Cow Trainers and Fencers
- Studies Reviewed for
  - Data Collection
  - Data analysis
  - Repeatability

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Research Groups Farm Animals and Electrical Exposures

US
U Minnesota - Gustafson/ Cloud/ Brennan/ Appleman/Henke-Drenkard
Cornell - Aneshansley/Gorewit/Price/Wilson/ Ludington/Southwick
Michigan - Surbrook/Kirk/Althouse/Fick
U Missouri - Currence/ Winter/ Stevens/ Dick
Johns Hopkins - Reilly
Purdue - Albright
UWEX – Hendrickson / Kammel
USDA Beltsville - Lefcourt
Washington - Lee et al.
USDA ARS – Stetson
U of Wisconsin - Reinemann/ Scheffield/ Wiltbank/ LeMire/ Armentano/ McGuirk/ Laughlin/
PSCW - Dasho/ Cook/ Reines
DATCP - Kasper/ Roberts/Hansen/Ryder
Minnesota PUC - Hendrickson/ Patoch
Quigley
Halvorson
Godcharles

Canada
Ontario- Rushen
Alberta - Thorne
McGill – Burchard/ Rodriquez/
New Liskeard - Gumprich
Australia
Damask
New Zealand
Phillips, Whittlestone, Woolford, Salisbury
Germany
Bergsten
Oswald
Sweden
Algers
Hultgren
Pehrson
France
AroParisTech - Roussel, Ragalma

29 groups more than 70 people

New Zealand: Phillips,1962

- First published Cow study
- Voltages on milking plants in New Zealand 0 to 20 V - most between 3 and 10 V.
- Sources of voltage: unbalanced loads and High resistance neutrals
- Voltage applied teat-to-rear hooves
- After these experiments **3 volts** was chosen as a likely minimum level for response.

New Zealand: Woolford, 1972

- Use Current Exposure in an attempt to reduce variability of responses
  - front to rear hooves
  - wetted flank to 4-hooves
- changes in cow behavioral when currents reached 3 to 8 milliAmpere
- judged to be uncomfortable for currents of 4.5 to 12 milliAmpere

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New Zealand: Whttlestone, 1975

- Operant conditioning system as a more objective method of measuring behavioral responses
  - cows turned on an electric current by pressing a second manipulanda in order to receive crushed barley
- behaviors changed with currents of
  - 6 mA for the udder, 7 mA for one teat
  - 6 mA for rump, 4 mA chest area.

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Early North American Studies

- Craine, 1975
- Groups of 70 and 30 cows exposed to voltages on a waterer ranging from 0 (control treatment) to 8 volts.
  - Mild aversion noted at 3 volts
  - Suppression of water above 4 volts
  - 8-volt treatment discontinued after 1 day because many cows refused to drink

United States Department of Agriculture Research

- Lefcourt (1982a) EKG patches shaved areas on the front and rear legs
  - Reduce the problem of contact resistance
  - Four cows mild response at about 3 mA
  - One cow mild responded to 0.7 mA (cut in skin?)
- Lefcourt (1982b) 6 cows to subjected to 5 mA before and during milking
  - Milk yield and milking time decreased for intermittent current
  - Continuous treatment had a variable effect on milk yield, milking time and hormonal responses
  - some cows seemed to adapt and enjoy stimulation.

USDA: Lefcourt (1985)

- 7 cows at 3.6 mA and 6 cows to 6.0 mA at a.m. and p.m. milkings for 7 days, subdermal probe
  - One cow removed from the 6.0 mA group because of severe behavioral responses
- Milk yield, milking time, and Wisconsin Mastitis Test scores were not affected
- Peak milk flow rate increased slightly
- Behavioral events increased
- Short Term Heart rate elevation
- Time to peak oxytocin response was delayed in the 3.6 mA group, and peak prolactin and area under prolactin response curves increased

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USDA: Lefcourt (1986)

- Seven lactating cows exposed to 60 Hz currents of 0, 2.5, 5.0, 7.5, 10, then 12.5 mA, biweekly.
- As mA increased, cows became more agitated and
- two cows not shocked at 12.5 mA due to severe behavioral responses
- Short term Heart rate increased at 10 mA and 12.5 mA
- Prolactin, norepinephrine and glucocorticoids were unaffected
- Epinephrine doubled in two exceptional cows at 10 mA
- Dramatic behavioral responses not correlated with significant or prolonged physiological responses
- Electrical exposure not considered a reliable way to induce 'stress' in cows.

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The University of Minnesota

- Electrical resistance of milking machine components
  - milk hose 30,000 Ohms to 80,000 Ohms
  - minimum resistance from the claw through the cow to the floor was 3,000 Ohms.
- 8 pathways through dairy cows
  - mean path 359 ohms for a mouth-all hooves pathway to 738 ohms for a front-rear hooves pathway

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U Minn. suppression of a learned response to obtain food

- 6.0 mA front-rear hooves shock
- Muzzle-all-hooves shock as low as 1.0 mA suppressed plate pressing behavior
- learned escape response to a front-rear hooves shock above a normal activity level occurred between 2.0 and 3.0 mA.
- exposure conditions were not typical of farm exposures.

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Appleman and Gustafson 1985 review

- <10% of cows thought to perceive < 0.35 V (60 Hz rms)
- behavioral modification may occur > 0.7 V (60 Hz rms)
- endocrine response > 3 V or 8 mA (60 Hz rms)
- Resistance 350 to 1700 ohms for different pathways

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Updated review 1987

- Revised based on additional research
- milking machine not likely pathway, high resistance
- no direct and causal relationship between voltage exposures and milking performance and animal health
- Problems may occur
  - mouth-all hooves > 1.0 volt.
  - step potential > 2.0-volt

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Thresholds to DC current (Gustafson 1988)

- behavioral response to DC pulse widths ranging from 0.1 to 300 milliseconds
  - Body resistance decreased
  - more current required to elicit behavioral responses
- with narrower pulse widths.

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Research at Cornell I

- 0, 0.5, 1, 2 and 4 V applied to water bowls for 21 days
- Two cows out of 6 did not drink for 36 hours at 4V
- All 28 others drank normal amounts of water within 2 days.
- Higher voltage = more delay to drink the first gallon of water.

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Cornell II

- 3, 4, 5 and 6 V to water bowls for 48 hours
  - 84 cows ½ Heifers
- 2 heifers at V and 2 heifers at 6 V did not drink for 36 hours.
- Within 2 days those that drank were drinking amounts that were not significantly different from the time before voltage was placed on the water bowl.
- Higher voltage = more delay to drink the first gallon of water.

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Cornell III

- Discontinuous voltages 5 V and 8V applied water bowls to rear hooves.
- Five temporal patterns were used to apply voltage of 50% of the time
- Drinking patterns not consistent but no significant change in amount of water consumed.

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Cornell IV

- 0, 1, 2 or 4V applied from waterer to a metal grid (front hooves) over a full lactation (305 days).
- 4 groups of 10 cows each
- Milk weights, SCC, milk fat, protein, feed consumption and water intake showed not significant differences between groups.
- Voltages did not significantly influence cow health or reproductive performance.

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Cornell V

- Current applied to teats during milking.
- Heifers kicked at milking machines when current exceeded 5 to 12 mA.
- Older cows kicked at milking machines at 8 to 18 mA.

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New Liskeard College of Agricultural Technology

- Groups of 30 cows with 112 day exposrues
- continuous low-level voltage w/ 2 periods of higher levels:
  - 0.30 V and 1.0 V
  - 0.75 V and 2.5 V
  - 0.75 V and 5.0 V
- level (1) higher milk fat percentage
- Milking time longer for level (2)
- residual effect on milk production 2 periods after the treatment at level (3)
- Concluded that up to 5.0 V in well managed tie-stall dairy operations unlikely to cause observable changes in cow milk production or behaviour.

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USDA 1991 Summary

- Consensus opinion of 15 credible researchers
- *distressed that our research results were being misinterpreted*
- *Recommend action levels from <u>2 to 4 Volts</u>*
  - *As conservative as possible to account for indirect losses due to problems resulting from inappropriate response of farmers to changes in animal behavior*

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USDA 1992 Summary

- *To relate voltage measurements to current, the worst case (500 Ohms) and more realistic (1000 Ohms) Resistancs were used.*
- *Attempts to reduce cow contact voltages to below 0.5 to 1.0 V are unwarranted, and totally unnecessary*
- No contradiction to these findings in 2003 NRAES review.

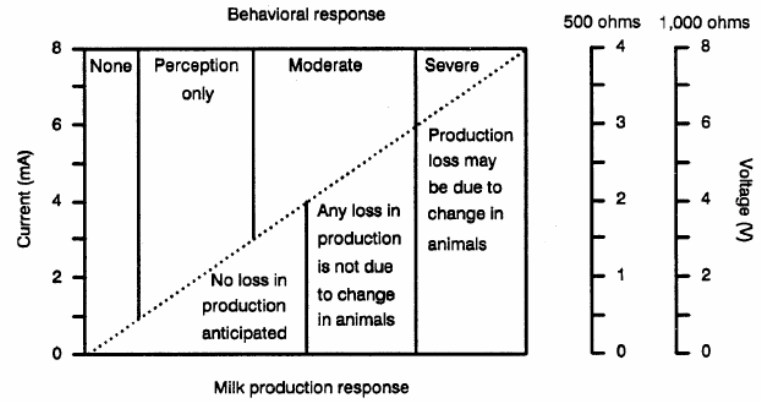

Figure 7-2. Behavioral and milk production responses to increasing current levels. Voltages, on the right, were estimated using a worst case circuit impedance and a more realistic impedance.

Although cows do not respond uniformly to electrical currents, 97 percent of cows tested showed a general uniformity in their behavioral responses to currents of different intensities (fig. 7-2).

Cornell VI

- The average current required to cause cows to stop drinking ranges from 4.9 to 132 mA rms for steady 60 to 30k Hz currents
- 38 to 80 mA peak for DC pulses from 0.4 to 0.1 ms in duration.
- 8.2, 9.3, 9.7 and 10.7 mA rms for steady, 30 cycles, 15 cycles and 6 cycles of 60 Hz
- 180 Hz +60 Hz components peak current explained responses better than rms
- 60 Hz + DC bias of 0.5 to 2 V did not substantially change the response

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Sensitivity to 60 Hz and other waveforms

- ASAE 99-3152 Aneshansley and Gorwit
- Cows less sensitive to high frequency and short duration currents
- No effect of DC bias on sensitivity
- Some differences between RMS sensitivity with VERY LARGE harmonic content.
  - No difference when measured as peak values
  - Explained by other research.

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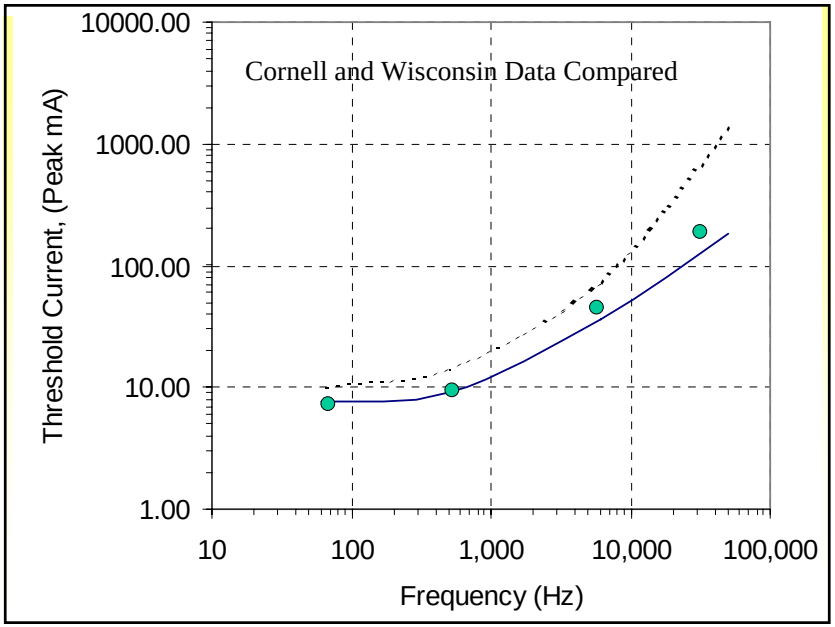

Cornell VII

- 0, 1, 2 and 4 V applied between waterers and rear hooves
- 16 animals with histories of sub-clinical mastitis
- 16 animals challenged with mastitis organism
- No significant change in milk production, feed consumption, milk fat and protein, SCC, blood chemistry, milk microbiology and serum cortisol

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Effects of Voltage/Current exposure on Mastitis

- ASAE 99-3151 Gorewit and Aneshansley
- 0, 1, 2 and 4 V applied to water bowl
- Teats dipped after milking with Strep uberis culture
- Exposure of up to 4 Volts did not promote clinical mastitis

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Dairy Cow Response to Electrical Environment
UW Research Update

Douglas J. Reinemann, Ph.D. Professor of Biological Systems Engineering
University of Wisconsin-Madison
www.uwex.edu/uwmril

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UW Research Initiated and Funded by Wisconsin Dept. Of Agriculture

- Concerns raised by citizens stray voltage advisory board
- Transient voltage
- "Objectionable currents"
- Magnetic fields
- Other phenomena beyond "classical stray voltage"

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UW Research Team

1. D. Reinemann - UW Biological Systems Eng
2. L. Stetson - USDA-ARS
3. Steven D. LeMire, UW Biostatistics
4. N. Laughlin – UW Psychology, Animal Behavior
5. J. P. Reilly - Johns Hopkins APL, Electro-pathology
6. S. McGuirk - UW Vet School, Physiology
7. E. Nordheim - UW Statistics
8. L. Armentano - UW Dairy Science
9. M. Rasmusssen, Danish Inst. Agricultural Science
10. Milo C. Wiltbank, UW-Dairy Science
11. Lewis G. Sheffield, UW-Dairy Science

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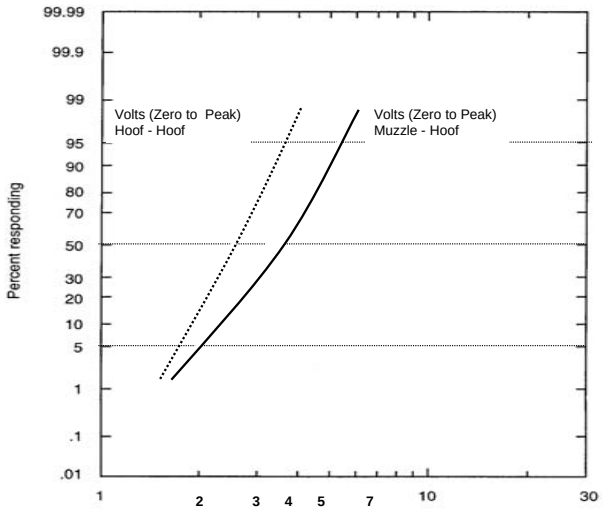
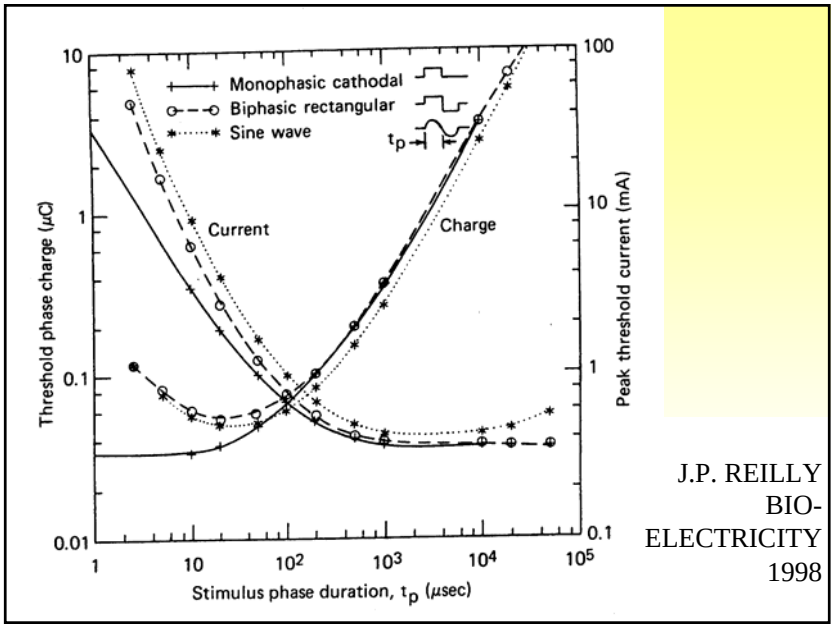
Sensitivity (Behavioral Response) Tests, 500 Cows

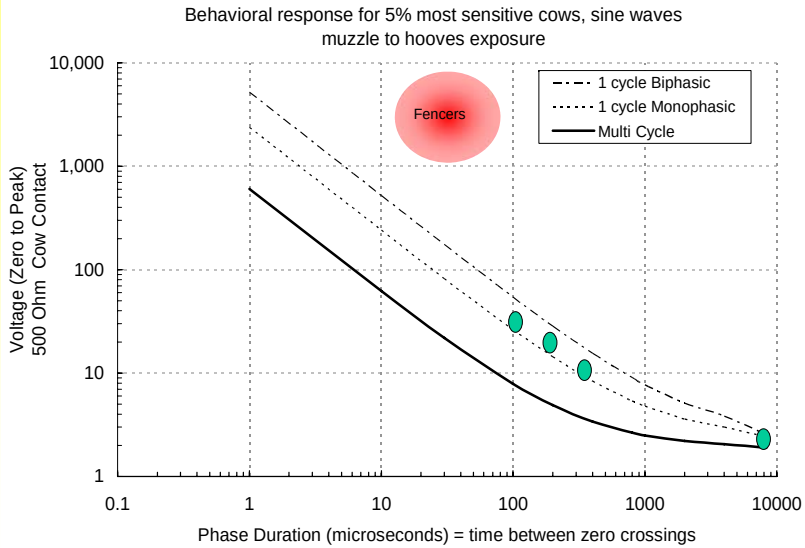
- Muzzle to hooves
  - 60 Hz, 1, 5, 9, 10 cycles
  - 500 Hz, 1 cycle
  - 6000 Hz, 1, 9, 100 cycles
  - 50,000 Hz, 1, 5, 833 cycles, sine, 1/2 sine, square
- Milking machine exposure
- Sensitivity to magnetic fields

Approximate 60 Hz Steady State Behavioral Response Distribution





J.P. REILLY
BIO-
ELECTRICITY
1998



Dairy Cow Response to Multiple Frequency Waveforms

Douglas J. Reinemann, Ph.D.
Paul D. Thompson, PhD
Charles Forster, Mr. Pulsar
University of Wisconsin- Madison

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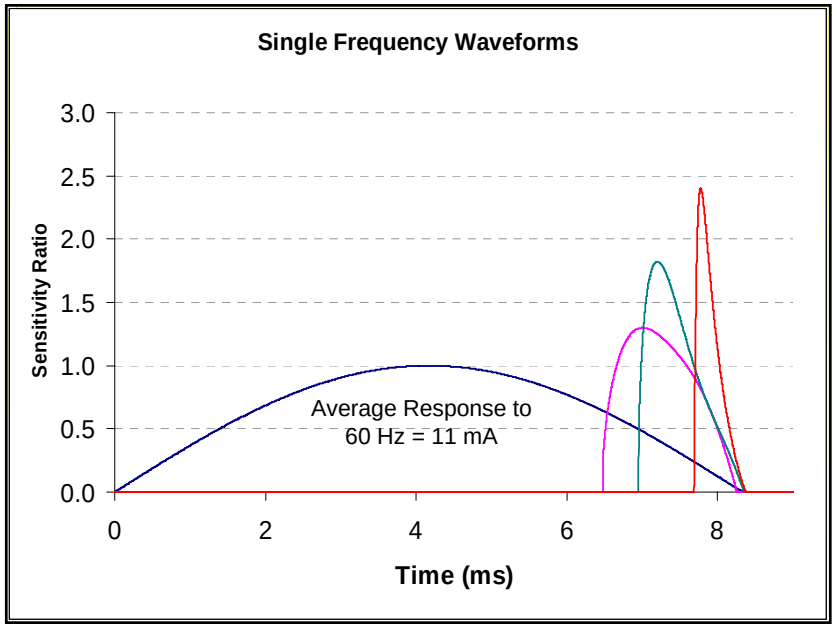
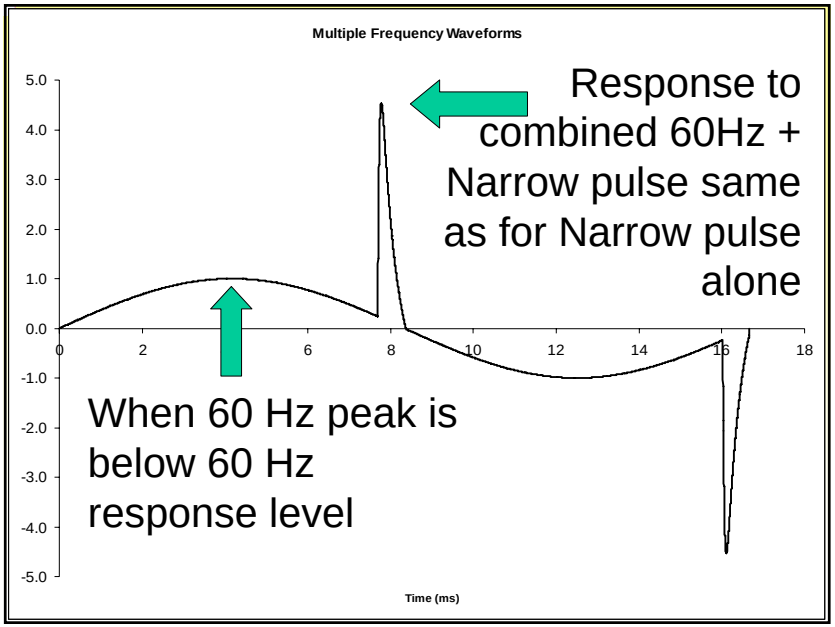
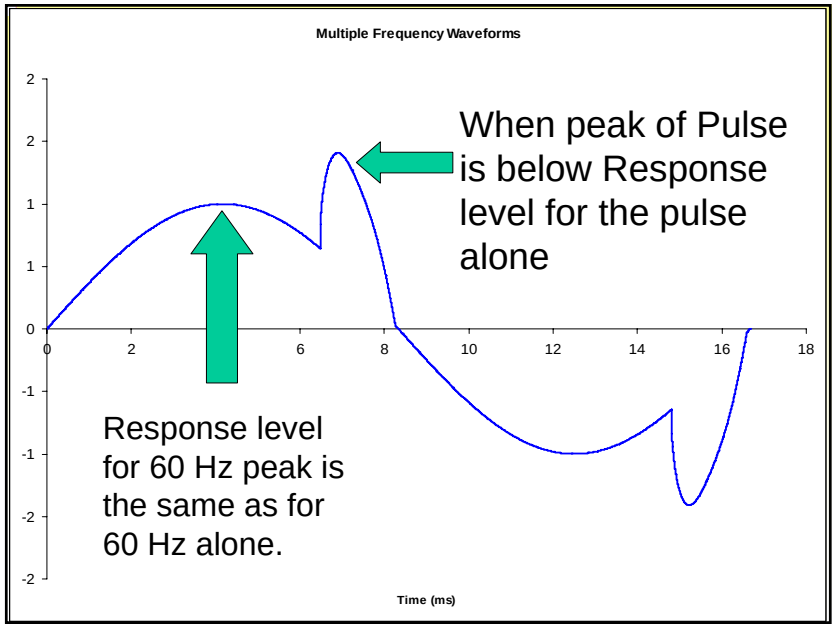
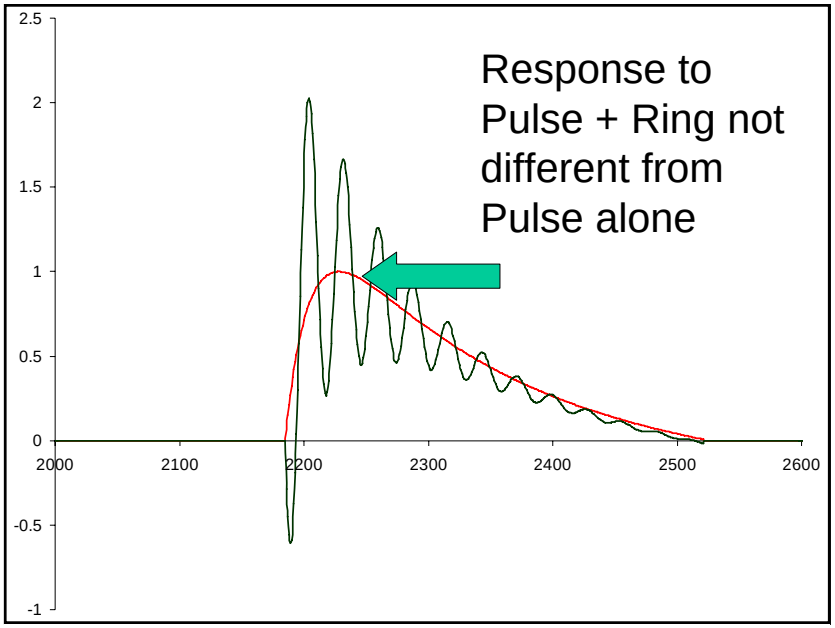



Multiple Frequency Waveforms
Response to combined 60Hz + Narrow pulse same as for Narrow pulse alone
When 60 Hz peak is below 60 Hz response level
Time (ms)


Multiple Frequency Waveforms
When peak of Pulse is below Response level for the pulse alone
Response level for 60 Hz peak is the same as for 60 Hz alone.
Time (ms)



Sensitivity to combined frequency components

- Combining waveforms did not change sensitivity to individual waveforms

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UW Aversion Tests (120 Cows)

- 1 cycle 60 Hz
  - Water bowl to floor
  - 1 per second
  - 3 week exposure
- 1 cycle 6000 Hz
  - Water bowl to floor
  - 1 per second
  - 3 day exposure
- Exposure method
  - Control
  - Reaction level
  - 1.5 time reaction level

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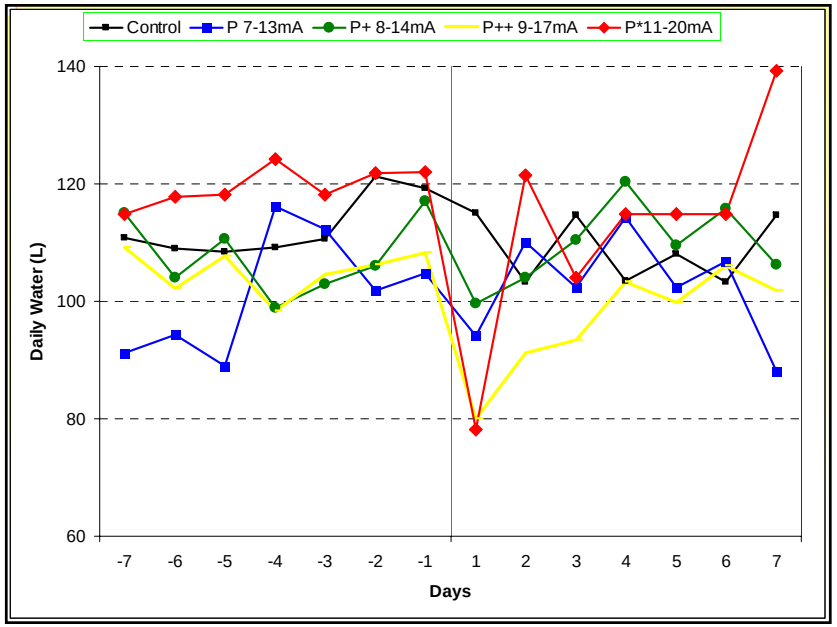
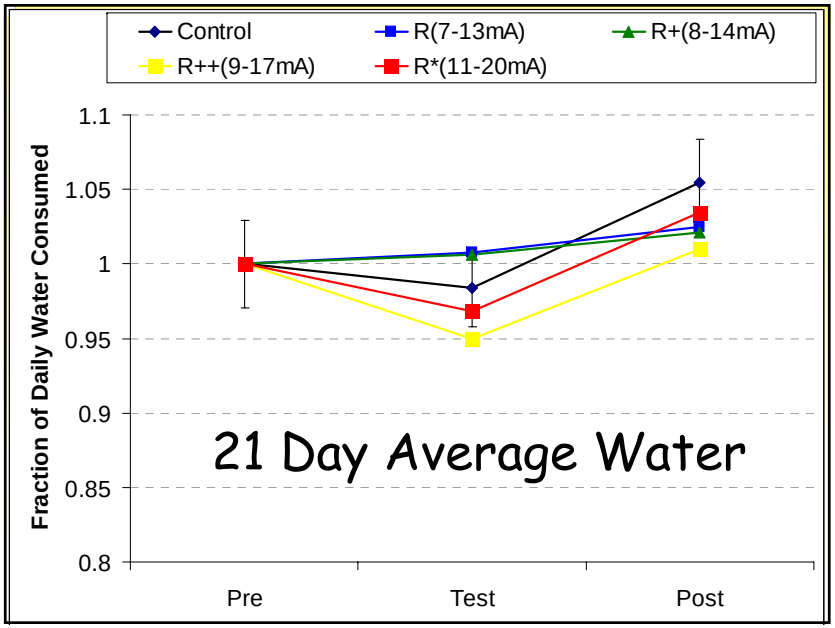
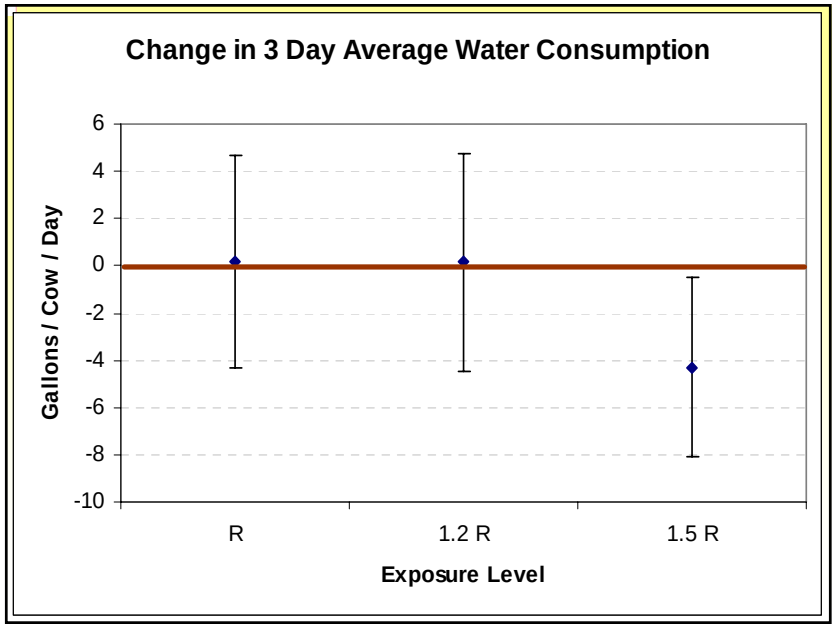
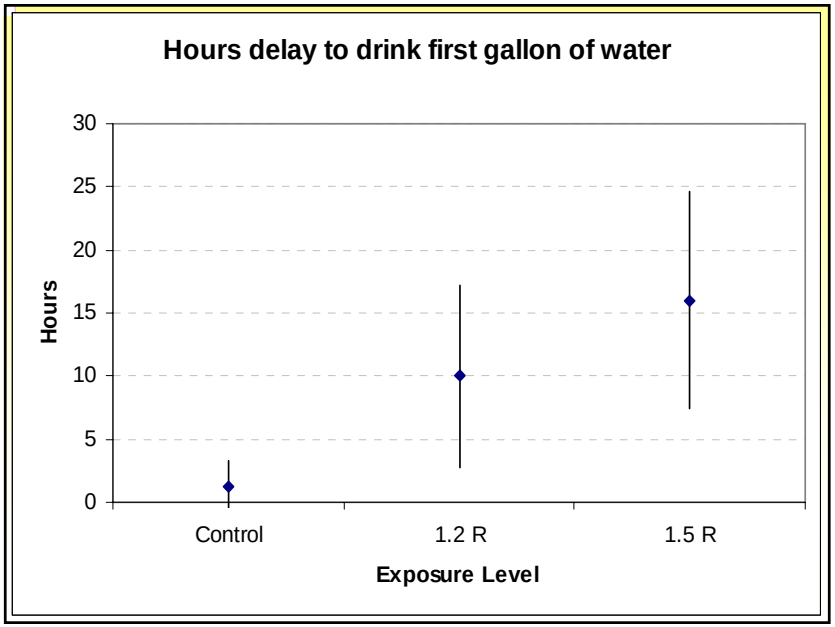



Control
R(7-13mA)
R+(8-14mA)
R++(9-17mA)
R*(11-20mA)
Fraction of Daily Water Consumed
1.1
1.05
1
0.95
0.9
0.85
0.8
21 Day Average Water
Pre
Test
Post


Change in 3 Day Average Water Consumption
Gallons / Cow / Day
6
4
2
0
-2
-4
-6
-8
-10
R
1.2 R
1.5 R
Exposure Level



Continuous Vs. Intermittent Exposure

Hrs Delay	Ave Diff.	P-value	Significant
Control vs. One shock	-0.4	.14	No
Control vs. Intermittent	-0.4	.21	No
Control vs. Continuous	+5.6	<.01	Yes

AgroParisTech Roussel (2007)

- avoidance test threshold level
- steps of 0.3 Volts up to 5 Volts applied to feeding cup
- ≥ 2.3V, % total feed and the time spent eating in the electrified feeder decreased
- > 3 Volts heifers changed more quickly to the non-electrified feeder
- > 2 Volts more muzzle-grooming and head shaking
- 2.3V appeared to be the threshold at which avoidance behaviour starts

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Rigalma (2007) 3-week 3.3 Volt exposure metallic feeders

- continuous (C) or unpredictable (U)
- 20 naïve (NH)and 20 experienced (EH) heifers
- unpredictable exposure
  - more time eating in the electrified feeder
  - more abrupt head movements and more muzzle-grooming behaviors
  - than those in the continuous exposure group
- No behavioral differences between NH and EH
  - NH higher cortisol concentrations on first day
  - NHC ate more and changed feeder quicker than the NHUexposure group
- Unpredictable exposure had more difficulty in adapting and that past-experience seemed to

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Rigalma (2008)

- unpredictable exposure may not offer sufficient time to the heifers to learn how to adapt.

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Study initiated

- Behavioral and endocrine responses for a large sample size of lactating cows (about 100) in a free-stall barn environment.

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Minnesota Science Advisors
Earth Current Study

Endocrine And Immune Function
Response Of Dairy Cows To Electrical
Current Exposure

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Minnesota / Wisconsin Opinion Survey

- Conducted by USDA Agricultural Statistics service
- Random sample of 1300 farms
- Electrical exposures listed in bottom 1/3 of 26 animal health and production concerns
- <2% of farms had unresolved health issued believed to be due to electrical exposures

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Minnesota Field Study

- 60 Hz voltage below perception on all farms
- Motor starts below perception
- High frequency events below perception
- Magnetic fields below level of concern
- Widespread problems with fencers and trainers

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Minnesota Field Study

- Step Potential (Mainly from local sources)
  - Barnyard 1 - 50 mV
  - Field 0 - 11 mV
  - Stall 1 - 30 mV average (3-150 mV Maximum)
- Further study of earth currents from distant sources cannot be justified
- Physiological effects of small step potentials being investigated

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Magnetic Field Measurements on Wisconsin Dairy Farms

- Dasho ASAE 963071
- Measurements on 106 Farms
- Levels in Barns Lower Than in Residence
- No Relationship with Cow Contact Voltage
- Not a likely source of problems

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Minnesota Science Advisors Ground Current Study: The Hypothesis

- Continuous contact of confined cows to low level (sub perception) voltage/current may produce,
- Electric fields inside the cow at levels high enough to produce Biological effects

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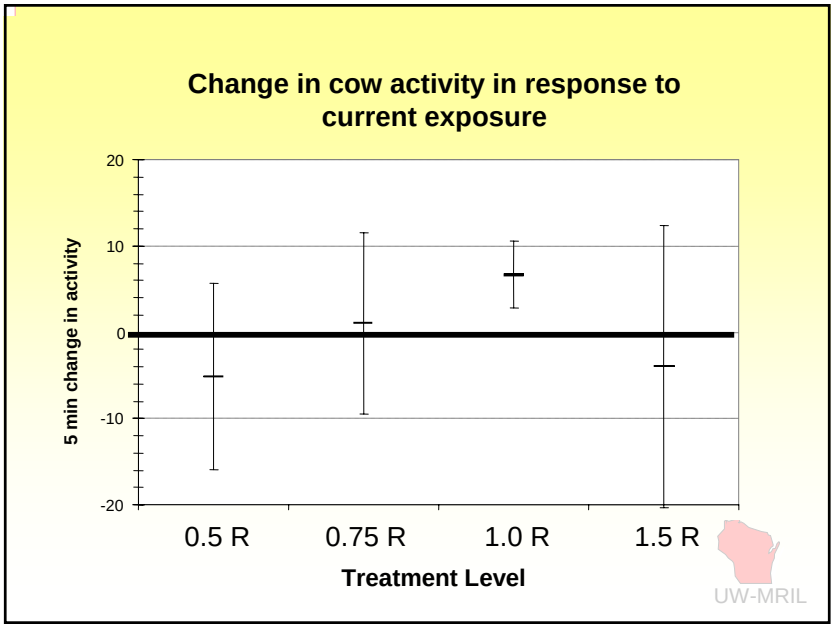
Change in cow activity in response to current exposure
5 min change in activity
20
10
0
-10
-20
0.5 R
0.75 R
1.0 R
1.5 R
Treatment Level
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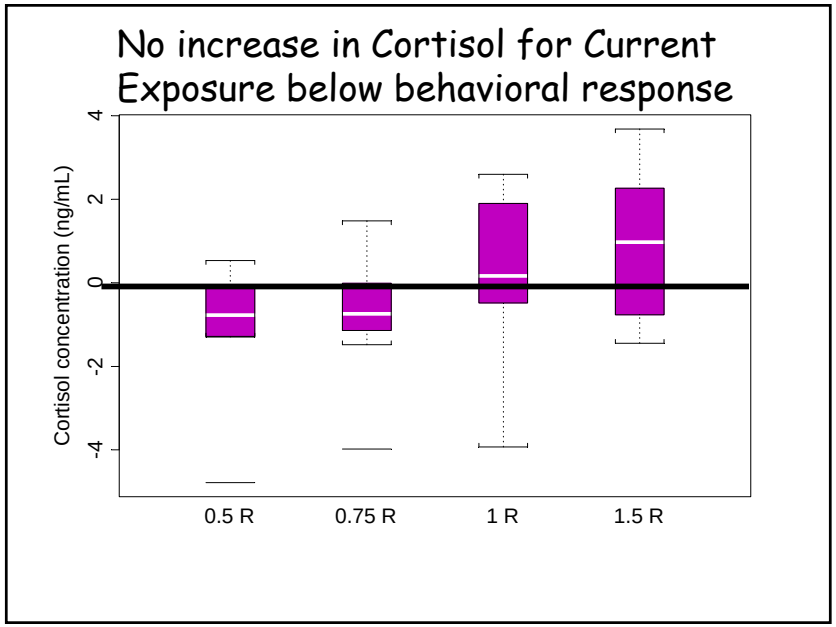
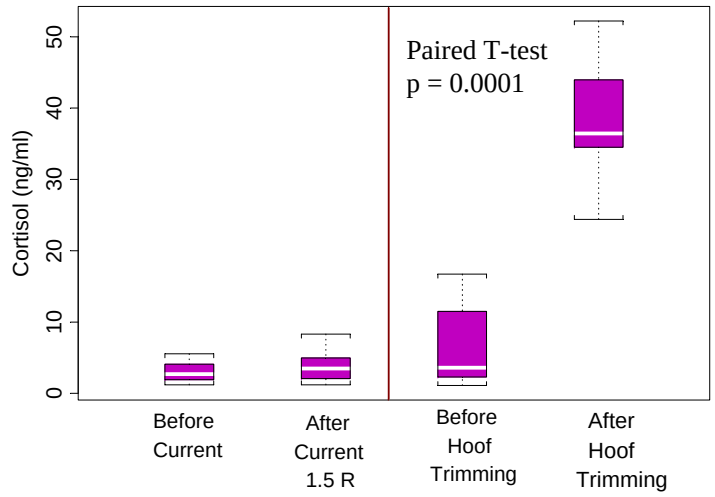

No increase in Cortisol for Current Exposure below behavioral response
Cortisol concentration (ng/mL)
4
2
0
-2
-4
0.5 R
0.75 R
1 R
1.5 R

No Cortisol response for current exposure
Big Cortisol response for hoof trimming



Treatments applied during milking

- Control
- Hoof-hoof voltage exposure below sensitivity threshold
- Milking machine induced stress
- Measures
  - Stepping
  - Average and peak milk flow during milking
  - Pounds of milk yield
  - Milking time

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No response to current Some response for broken milking machine

	Pulsation Failure	1 mA current exposure
Milk Yield (kg)	1.19 +	0.13
Average Flow Rate (kg/min)	0.24 +	0.15
Maximum Flow Rate (kg/min)	0.29 +	0.04
Activity (weight shifts / milking)	-5.84 ***	-1.28
Strip Yield (% of quarters > 10 ml)	-0.10	0.09

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Immune response to continuous low level current exposure

- 1 mA Exposure Front - Rear Hoof,
- 10 Minutes off/on for 2 weeks
- No change in
  - Immune function response
  - Time and pattern of laying
  - Time to re-enter stall after milking

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Immune Tests

- Blood samples twice weekly
- lymphocyte blastogenesis
- Dose responses to standard mitogens,
  - S. aureus, Phytohemagglutinin, Pokeweed Mitogen and Concanavalin A
- Chemiluminescence measure of Oxidative burst
- Interluken I
- Cortisol

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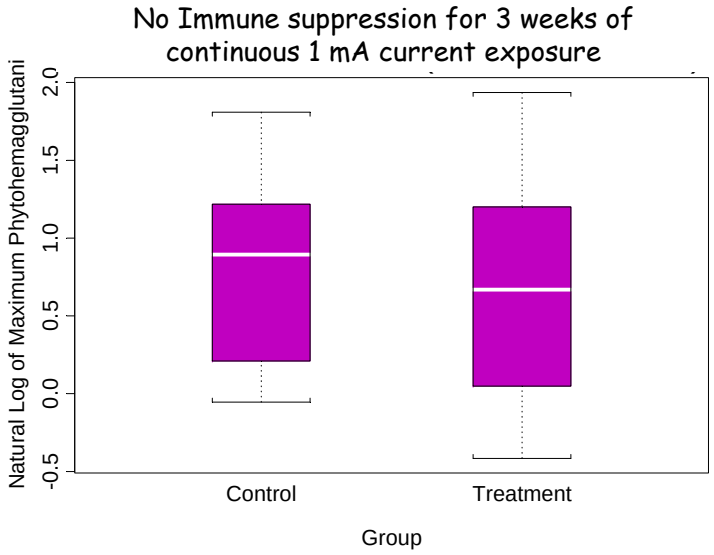

Conclusions

- No difference between control and treatment cows for any of the 3 main response variables
- Statistically significant difference for 1 of 10 of the secondary response variables
  - But did not appear to be consistent with other observations
- Collectively, these results suggest that exposure to 1 ma of current for two weeks had no significant effect on the immune function of dairy cattle.

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Results

Most measures were not affected

A small subset of immune system regulators showed possible changes:

Could be Type I errors, due to the large number of hypotheses tested.

The magnitude of effect was relatively small, compared to that often observed in the literature in response to major immune system challenges

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Immune function conclusions

- Small subset of immune system regulators showed possible changes
  - most disease processes affect a wider spectrum of regulators
  - Type I errors, large number tested (?)
- Any possible impacts of electrical exposure on immune function health and disease are of relatively small and difficult to detect
- Collectively, these results suggest that exposure to 1 ma of current for two weeks had no significant effect on the immune function of dairy cattle

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Findings of the Minnesota Science Advisors

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

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Wisconsin Field Study

- Stray Voltage Analysis Team (SVAT)
  - Public Service Commission of Wisconsin (PSCW)
  - Wisconsin Department of Agriculture Trade and Consumer Protection (WDATCP)
  - > 360 Investigations 88-98
- Electric Utilities
  - 8000 First-Time Farm Investigations 93-2007

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PSCW Field Study
8000+ Farms
No Correlation Between

- Milk production or Somatic Cell Count and
  - Primary NEV
  - Secondary NEV
  - Cow Contact Voltage
  - Ground Rod Current

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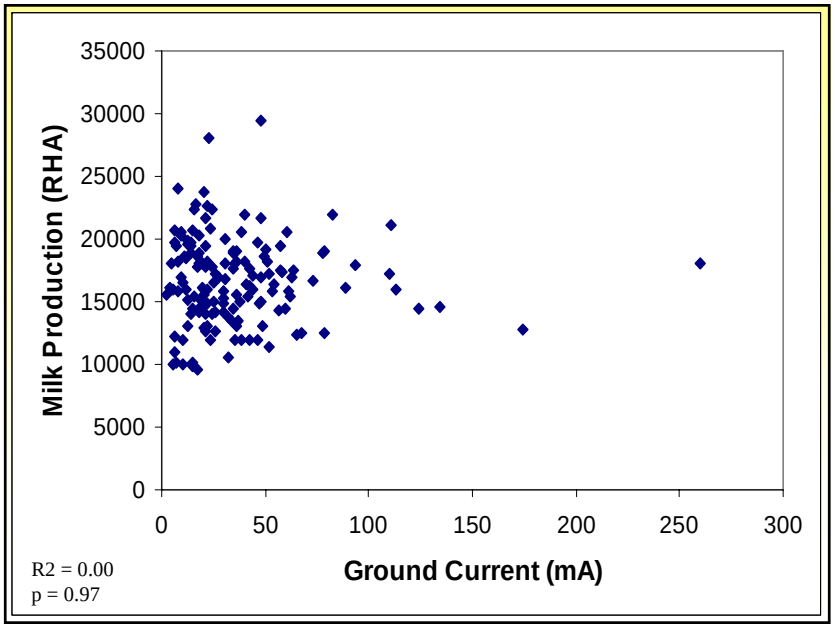
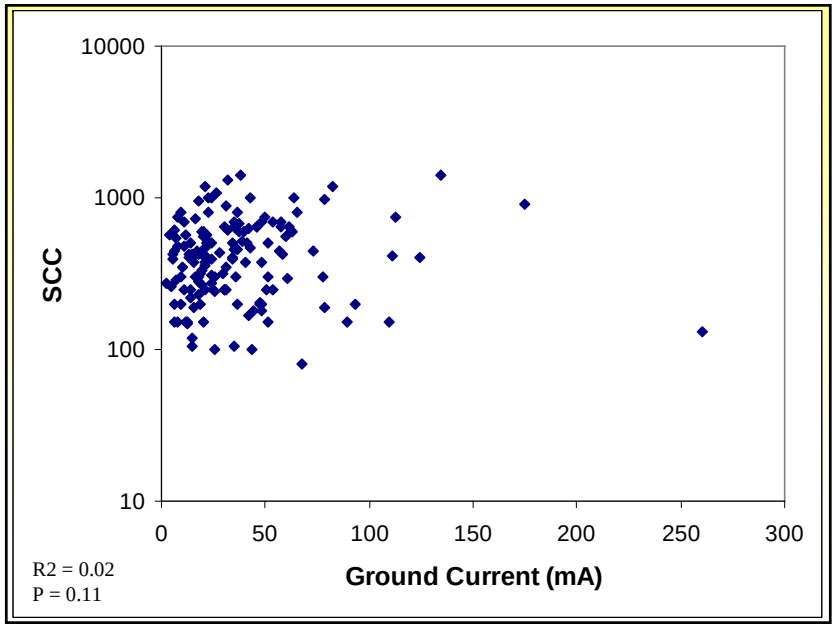
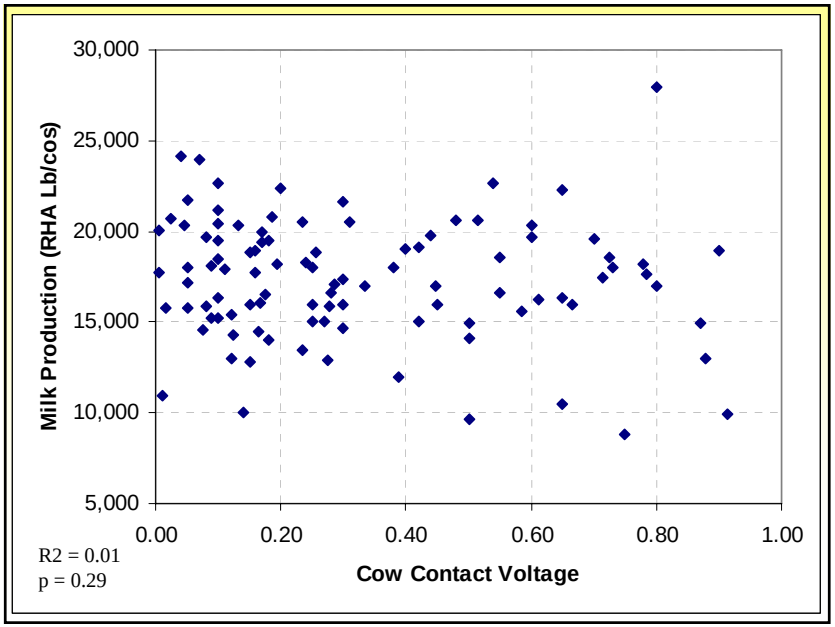
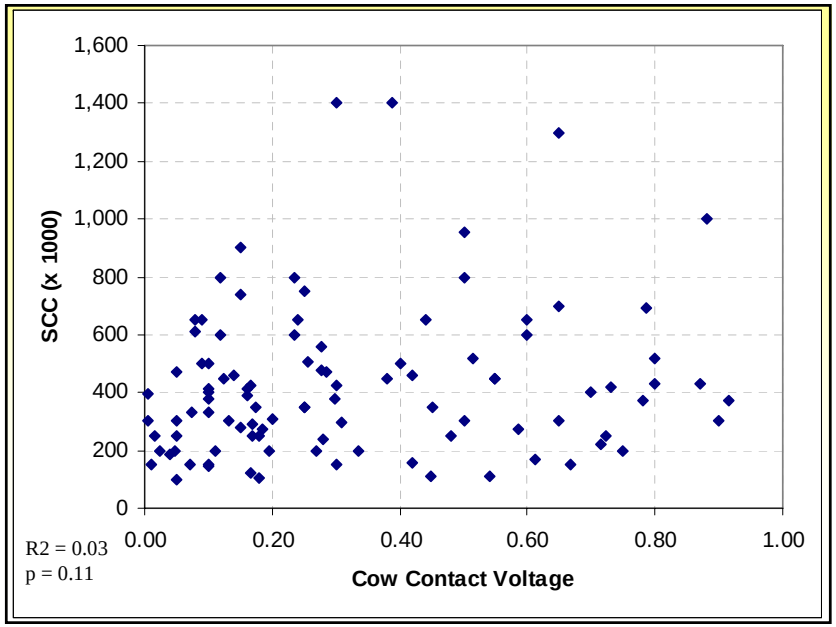
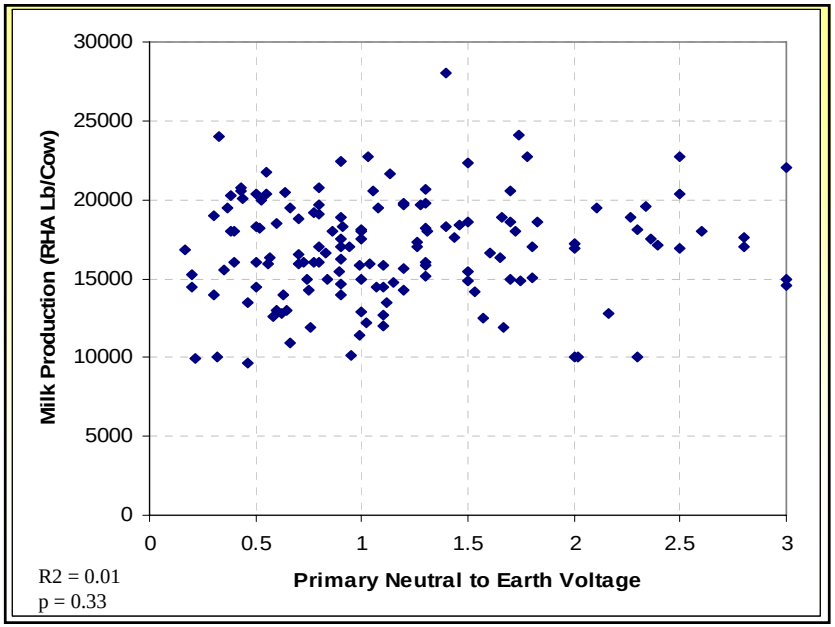
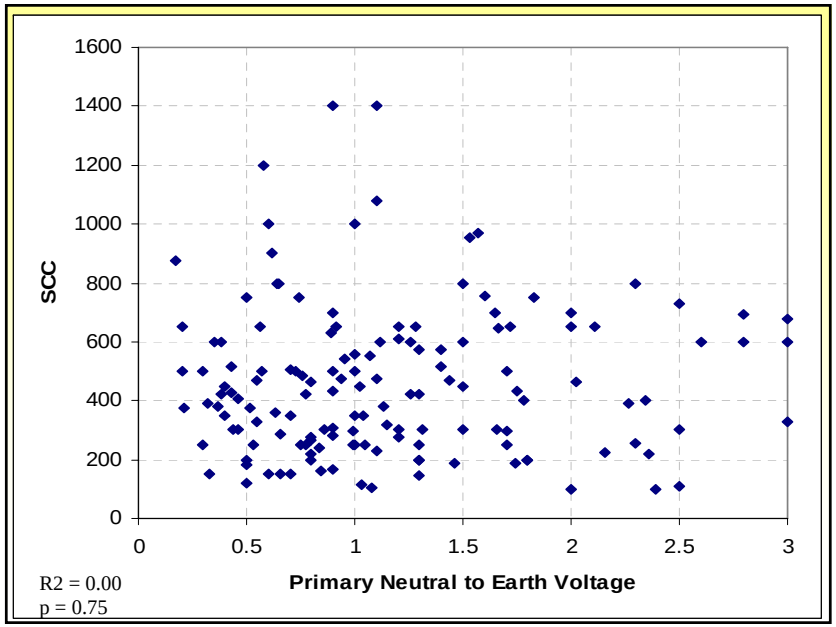

35000
30000
25000
20000
15000
10000
5000
0
Milk Production (RHA)
0
50
100
150
200
250
300
Ground Current (mA)
R2 = 0.00
p = 0.97

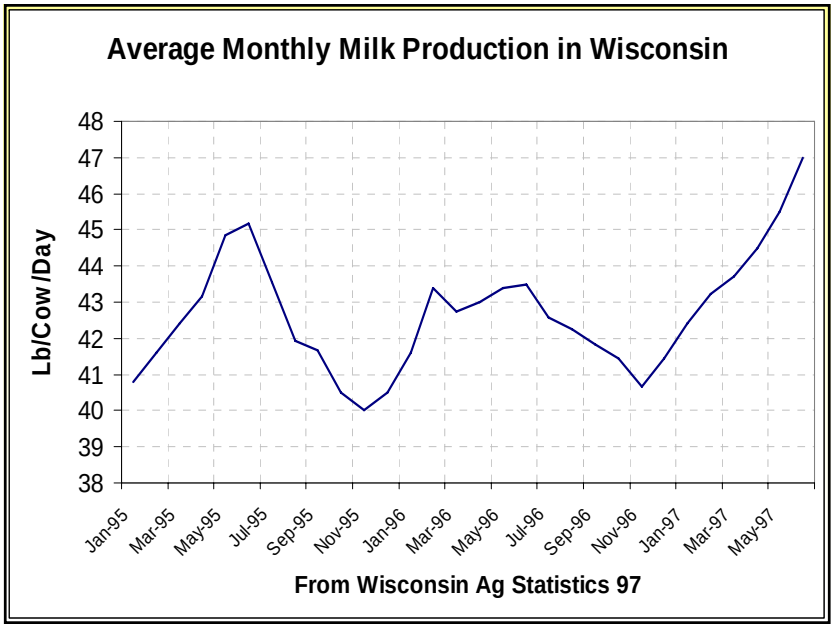

10000
1000
100
10
SCC
0
50
100
150
200
250
300
Ground Current (mA)
R2 = 0.02
P = 0.11

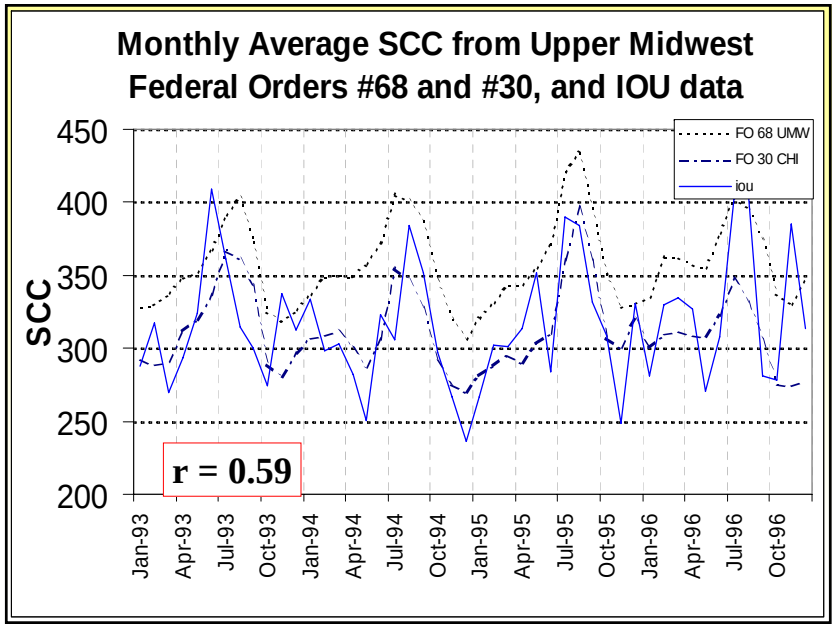

30,000
25,000
20,000
15,000
10,000
5,000
Milk Production (RHA Lb/cos)
0.00
0.20
0.40
0.60
0.80
1.00
Cow Contact Voltage
R2 = 0.01
p = 0.29


1,600
1,400
1,200
1,000
800
600
400
200
0
SCC (x 1000)
0.00
0.20
0.40
0.60
0.80
1.00
Cow Contact Voltage
R2 = 0.03
p = 0.11


30000
25000
20000
15000
10000
5000
0
Milk Production (RHA Lb/Cow)
0
0.5
1
1.5
2
2.5
3
Primary Neutral to Earth Voltage
R2 = 0.01
p = 0.33


1600
1400
1200
1000
800
600
400
200
0
SCC
0
0.5
1
1.5
2
2.5
3
Primary Neutral to Earth Voltage
R2 = 0.00
p = 0.75


Average Monthly Milk Production in Wisconsin
Lb/Cow/Day
48
47
46
45
44
43
42
41
40
39
38
Jan-95
Mar-95
May-95
Jul-95
Sep-95
Nov-95
Jan-96
Mar-96
May-96
Jul-96
Sep-96
Nov-96
Jan-97
Mar-97
May-97
From Wisconsin Ag Statistics 97


Monthly Average SCC from Upper Midwest
Federal Orders #68 and #30, and IOU data
SCC
450
400
350
300
250
200
FO 68 UMW
FO 30 CHI
iou
r = 0.59
Jan-93
Apr-93
Jul-93
Oct-93
Jan-94
Apr-94
Jul-94
Oct-94
Jan-95
Apr-95
Jul-95
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96

Review of Sensitivities of Other Species

- Swine
  - greater than 3.0 mA was needed to affect drinking time and 4.0 mA to affect consumption.
  - feed intake, daily gain were lower in the 5 V group than 2V and control
  - up to 8 V does not impair the welfare, reproductive performance, or health of sows and suckling pigs
  - Up to 8 V no significant effects on feeding, drinking, sitting or lying activities. slight increase in rooting bouts 5-8V head butting 2-5V

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Review of Sensitivities of Other Species

- Sheep
- Above 5.5 V ewes tended to spend more time eating and to eat more from the non-electrified feeder
- At 5V and upwards, lambs spent less time eating in the electrified feeder

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Review of Sensitivities of Other Species

- Poultry
  - 0 to 9 volts did not impair egg production
  - electrical resistance of hens much higher than cattle and pigs
  - as high as 18 V had no effect on hens' production and behavior (2)
  - stray voltage present in many breeder houses may contribute to floor eggs
  - factors other than up to 9 V may have been causing a floor egg problem.

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5. Synthesis of Research Findings

- Compilation of all known experiments in which responses to voltage or current exposure were documented
- Spanning 1962 to 2007 (45 Years)
- From Research Groups Around the World
- Over 100 Scientists Represented

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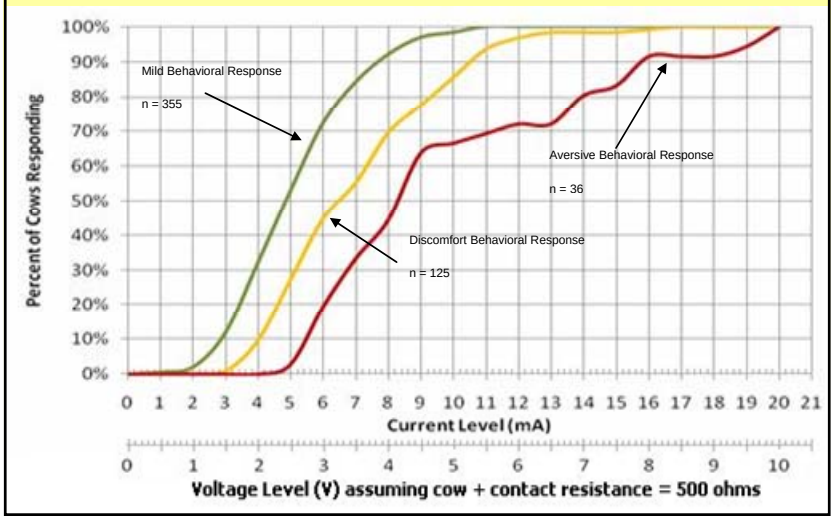
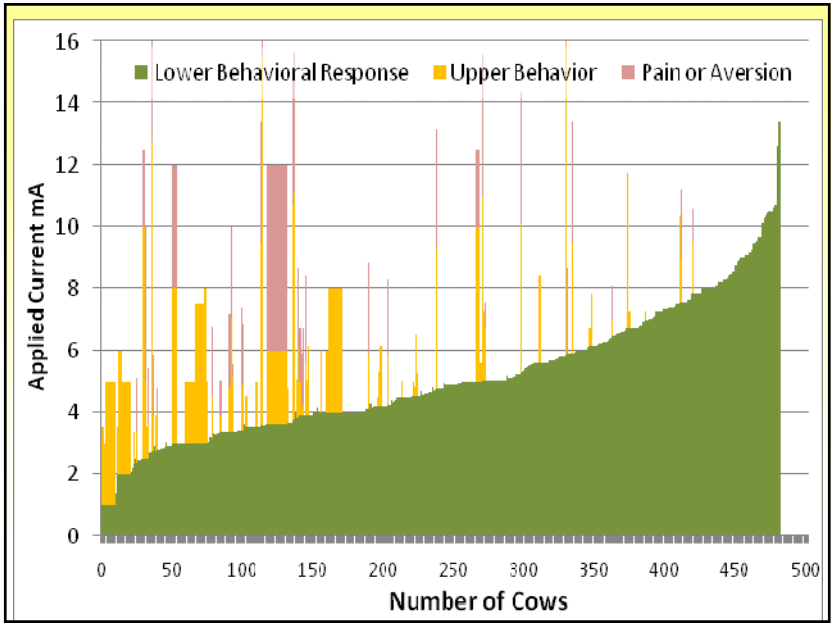
Behavioral Response thresholds for constant current exposures for 539 cow tests





260 cow tests in which groups of cows were exposed to constant current

mA	Author	Year	# Cows	Exposure Pathway	Responses
1.0	Gustafson	1985	6	FH-RH on wet expanded metal plates	NC in hoof lifting (31% compared to 27% for control)
1.0	Gustafson	1985	6	Metallic mouth bit – AH on wet metal plates	NC in mouth Opening (7% compared to 8% for control)
1.0	Norell	1983	7	FH-RH on metal plates in water filled containers	NC in Hoof lifting (23% compared to 18% for control)
1.0	Norell	1983	7	Metallic mouth bit – AH on wet metal plates	Increased mouth opening (14% compared to 0% for control)
1.5	Gustafson	1985	6	Body (metal plate with gel) to AH on wet expanded metal plates	NC in behaviors (30% compared to 26% for control)
2.0	Gustafson	1985	6	FH-RH on wet expanded metal plates	NC in hoof lifting (24% compared to 27% for control)
2.0	Gustafson	1985	6	Metallic bit in mouth to AH on wet expanded metal plates	NC in mouth opening (18% compared to 8% for control)
2.0	Norell	1983	7	FH-RH on metal plates in water filled containers	NC in hoof lifting (25% compared to 18% for control)
2.0	Norell	1983	7	Metallic mouth bit – AH on wet metal plates	Increased mouth opening (30% compared to 0% for control)
2.5	Lefcourt	1986	7	Hock - Hock EKG patches	Mild Behaviors 2 of 7 cows, NC in heart rate, prolactin, glucocorticoids, epinephrine
3.0	Gustafson	1985	6	FH-RH on wet expanded metal plates	Increased hoof lifting (62% compared to 27% for control)
3.0	Gustafson	1985	6	Body (metal plate with gel) – AH on wet expanded metal plates	NC Behaviors (43% compared to 26% for control)
3.0	Gustafson	1985	6	Metallic mouth bit-AH on wet metal plates	Mouth Opening increased (42% compared to 8% for control)
3.0	Norell	1983	7	FH-RH on metal plates in water filled containers	Increased Hoof lifting (43% , compared to 18% for control)
3.0	Norell	1983	7	Metallic mouth bit – AH on wet metal plates	Increased mouth opening (69% compared to 0% for control)
3.6	Lefcourt	1985	7	Hock-Hock EKG Patch, 5s on 25 s off during milking, 7 days	Some behavior change; NC in MY, milking time, or WMT; Oxytocin and Prolactin release delayed in some cows
4.0	Gorewit	1984	6	Udder-AH, during milking for 7 days	Some Behavior change; NC in MY or composition, peak milk flow, milking time, residual milk or SCC

Over 750 cows tests with constant CURRENT exposure

- Many studies report on single animal responses
- Behavior response thresholds vary
  - Moderate: Blink of an eye, nose twitch
  - Pronounced: Involuntary muscle contraction
  - Aversive: Stop Drinking
- Most behavioral response thresholds between from 2 and 8 milliAmps (60 Hz rms)
  - One study reported moderate responses at 1 mA with a nose press to metal plate (current concentration)
- Aversion occurs at higher levels than behavioral response

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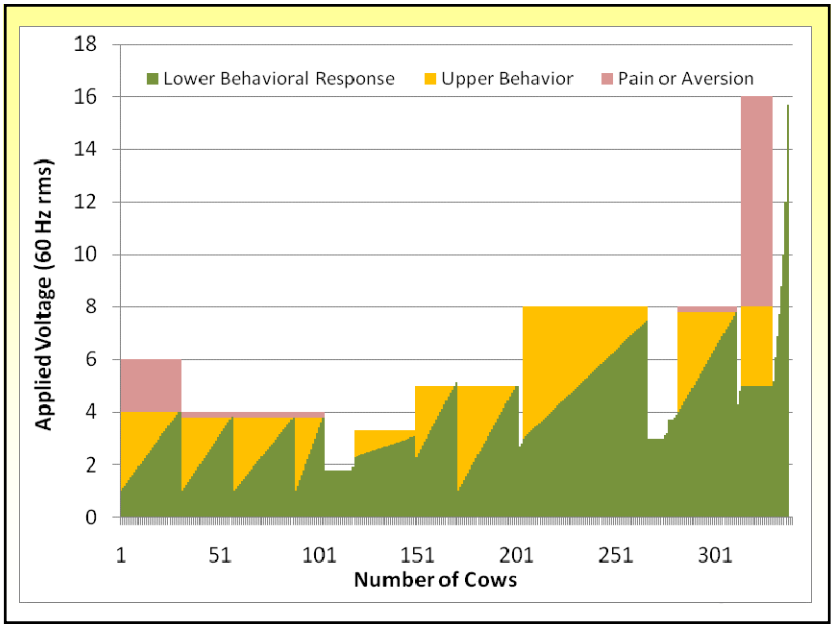

Over 800 Cow tests in which groups of cows were exposed to constant voltage when attempting to eat or drink, or during milking.

V	Author	Year	# Cows	Exposure Pathway and Duration	Responses
0.5	Gorewit	1989	6	Metallic Water Bowl to metal floor plate, 21 Days (0.6 to 1.3 mA)	No delay to drink, NC in daily water Intake, milk production or composition
1.0	Gorewit	1989	6	Metallic Water Bowl to metal floor plate, 21 Days (1.2 mA to 4.0 mA)	Delay to drink in some cows (average about 2 hrs), NC in daily water Intake, milk production or composition
1.0	Gorewit	1992	10	Metallic Water Bowl to FH on metal grid, full lactation	Delay to drink in some cows, NC in feed or water intake, SCC, MY or composition, health or reproductive performance
1.0	Gorewit	1997	4	Metallic Water Bow to FH on metal floor mats, 7 days	Unspecified delay to drink; NC in water or feed, MY or composition, SCC or *staph. aureus* infected quarters, blood chemistry, milk microbiology or cortisol;
1.0	Gorewit	1999	4	Metallic Water Bow to FH on metal floor mats, 7 days with *strep. uberis* mastitis challenge	NC in milk production, feed or water intake, SCC, milk fat or protein
1.0	Gumprich	1992	30	1 V morning and evening for 3 hrs each, 0.3 V other times of day from water bowl and stalls to metal grid at rear of stall, for 2 periods of one week each over 16 weeks	NC in behavior, daily milk production, milking time, water consumption, feed consumption, breeding; Increased milk fat
1.8	Southwick	1992	120	Switchback Farm Study , Maximum cow contact voltage measured waterline - floor	NC in water (although higher during exposure), milk production, SCC (although lower during exposure)
1.85	Craine	1975	30	Ascending 1.85 to 8 V water bowl – AH, 5 days (2-day recovery)	NC in water intake
2.0	Aneshansley	1992	7	Copper Electrodes in teatcups to RH on metal plate, During milking (L1)	NC in behavior, MY or composition, SCC or milking duration
2.0	Gorewit	1989	6	Metallic Water Bowl to metal floor plate, 21 Days (4.7 to 7.9 mA)	Delay to drink (average 3 hrs), NC in daily water Intake, MY or composition
2.0	Gorewit	1992	10	Metallic Water Bowl to FH on metal grid, full lactation	Delay to drink in some cows, NC in feed or water intake, SCC, MY or composition, health or reproductive performance
2.0	Gorewit	1997	4	Metallic Water Bow to FH on metal floor mats, 7 days	Unspecified delay to drink; NC in water or feed intake, MY or composition, SCC or *staph. aureus* infected quarters, blood chemistry, milk microbiology or cortisol;
2.0	Gorewit	1999	4	Metallic Water Bow to FH hooves on metal floor mats, 7 days with *strep. uberis* mastitis challenge	NC in milk production, feed or water intake, SCC, milk fat or protein

Over 800 cows with constant VOLTAGE exposure

- Most studies report on group average rather than single animal responses
- Many studies report moderate behavioral between the range from 2 and 8 volts (60 hz rms)
  - Studies using metallic waterer - metallic floor plate found some delays to drink at 1 Volt
  - Studies using concrete floor did not report behavioral changes at 1 Volts
- Some studies report severe aversion of a few animals between 4 and 8 volts
  - Refusal to drink for up to 36 hours
  - Kicking at milking unit

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- Over 750 cows tests with constant current exposure
  - Most responses 2 to 8 Milliamps
- Over 800 cow tests with constant voltage exposure
  - Most responses 2 to 8 Volts
- Over 1500 Cows Tests
  - 1000 Ohms reasonable estimate of cow + contact resistance in real-world situations
  - May be some unusual cases as low as 500 Ohms

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Animal Response to Stray Voltage

Avoidance behavior	Well documented
Milk production	Documented only for extreme exposure
Somatic cells	Not documented
Reproduction	Not documented
Milkout problems	Only at very high levels
Stress Hormones	Only at very high levels

Exposure Conditions Required to Produce an Effect

- Adverse effect requires BOTH annoying current AND forced exposure
- Contact resistance
  - 500 ohms is worst case
  - 1000 Ohms is typical
  - Dry contacts or bedding will increase contact resistance
- Location
  - Areas vital to normal daily activities
- Times / day
  - Annoying stimulus must occur frequently

Levels That Affect Farm performance

- Current exposure < 3 mA may produce mild behavioral changes in a small percentage of cows
  - Corresponding to < 2 to 3 Volts
  - Aversive behaviors likely short-lived
  - No physiological changes
  - Changes likley undetectable on most farms

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Levels That Affect Farm performance

- Current exposure from 3 to 6 mA may produce observable behavioral changes in some cows
  - Corresponding to 3 to 6 Volts
  - May produce short term changes in eating/drinking for some cows depending on location and time of exposure
    - Likely difficult to detect
  - Aversive behaviors likely short-lived
  - May produce mild increase in 'stress' hormones in some cows

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Levels That Affect Farm performance

- Current exposure above 6 mA likely to produce some behavioral changes in most cows and pronounced behaviors in some cows
  - Corresponding to > 6 Volts
  - Likely to produce changes in eating / drinking for some cows depending on location and time of exposure
    - May be detectable on some farms
  - May produce increase in 'stress' hormones in some cows

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Diagnosis

- Animal behavior or other symptoms CANNOT be used to diagnose stray voltage problems
  - All known responses to stray voltage exposure can be produced by other causes
- The ONLY WAY to determine if stray voltage is a potential cause is to perform electrical testing

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Voltage/Current Sensitivity by Contact Location and Animal Type

- Exposure at watering devices
- Exposure at feeding devices
- Exposure during milking
- Exposure at building transitions
- Exposure in resting areas, pastures and other Farm Locations

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Exposure at watering devices

- Likely location for voltage exposure
  - Metallic water systems connected to grounding system
  - Area necessary for animals
- Worst case (lowest) contact resistances on clean, wet floors
  - Metallic / heated watering devices highest risk
- Severe aversion > 4 Volts / 8 mA

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Exposure at watering devices

- Alternate watering locations w/ lower voltage reduce or eliminate effects
- Non Metallic watering devices much lower risk – high contact resistance
- Equipotential Planes required around watering devices

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Exposure at feeding locations

- Floor feeding unlikely location for problems
  - High resistance of feed
  - Low level 'step' potentials if metal in floor
- Metallic, electrical feeding devices possible location for aversion
  - Resistance values at muzzle and floor higher than for metallic watering devices

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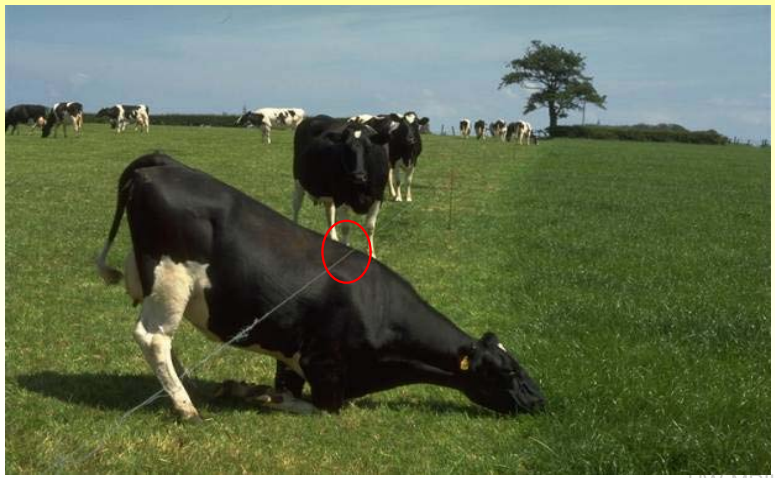
Learned Behavior – Avoid Contact



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Exposure during milking

- Highly unlikely location for problems
  - Milk hose has very high resistance
  - Milking parlors usually well bonded (equipotential)
  - Body resistances high for hide/stall contact

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Exposure at building transitions

- Severe wiring problems may produce aversive step potentials if equipotential plane not installed
- Contact resistances likely > 1000 Ohms
- May make animal handling more difficult but unlikely to affect feeding / drinking behaviors

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Exposure in resting areas, pastures and other Farm Locations

- Highly unlikely location for problems
- High resistance contacts Dry bedding to hide / hooves
- step potentials very low compared to contact with electrical devices
- Metal in floors acts as equipotential

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On-Farm Mitigation Measures

- Farm Wiring
- Equipotential Planes
- Voltage Suppression and Filters
- On farm isolation

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Utility Mitigation Measures

- Distribution Wiring
- Neutral Isolation
- Mitigating Other Sources

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7. Regulatory Approaches and Guidelines to Reducing the Impact of Stray Voltage on Farm Operations

- Wisconsin
- Michigan
- Vermont
- Idaho
- Minnesota
- New York
- Pennsylvania

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Wisconsin, 1987
Docket 05-EI-106

- Stray voltage is from both on and off farm sources.
- Stray voltage can be detected and mitigated.
- Mitigative action should be taken when levels of stray voltage (animal contact voltage) exceed 0.5 volts (1 mA)

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Wisconsin, 1987
Docket 05-EI-106

- Repair and maintenance of the utility and farm wiring systems is a more effective solution to stray voltage than utility isolation.
- The equipotential plane is an effective mitigation strategy.
- Open delta services may increase primary neutral current.

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Wisconsin 1987
Docket 05-EI-106

- Discontinue the use of isolators (Temporary Use Only).
- Improve rural load balance.
- Increase system grounding where appropriate.
- Locate customer yard poles to minimize neutral voltage drop.

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Wisconsin Docket 05-EI-106

- Discontinue use of split bolt connectors.
- Create a statewide uniform stray voltage tariff.
- Ensure that test protocol is consistent with PSCW guidelines.
- Continue to provide educational opportunities.
- Implement farm wiring financial assistance programs.

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Wisconsin 1996 Docket 115

- A scientific consensus exists
- 1987 "Level of Concern" 0.5 volt is extremely conservative.
  - 1.0 volt is below a level where behavior or production would be harmed.
  - 500 ohm resistor used in measurement circuit is part of a conservative measurement process

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Wisconsin 1996 Docket 115

- Concept of equal responsibility "LOC" raised to 1.0 v.
  - Mitigative action is required utility contribution exceeds 0.5 v.
  - Primary NEV standard is not necessary.
  - Transient "LOC" is not necessary.
- Stray voltage not directly cause health problems.

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Wisconsin 1996 Docket 115

- Neutral isolation can hide on farm sources.
  - Utilities may isolate on demand, and the customer pays

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WI 2003 Legislative Action - Assembly Bill 529

- Hearings held by the Assembly Committee on Energy and Utilities.
- This bill prohibits electric utilities and cooperatives from causing objectionable flows of current on the property of others.

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WI 2003 Legislative Action - Assembly Bill 529

- "Objectionable flow of current" is defined as a steady state of load electrical current for five seconds or more on a grounding conductor or any other conductor that normally does not carry electric current.

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WI 2003 Legislative Action - Assembly Bill 529

- The bill provides that an objectionable flow of current that an electric utility or provider causes on the property of another person is a trespass on that property.
- The proposed bill did not make it out of committee.

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Minnesota Public Utilities Commission (MPUC)

- May 1994 - The Minnesota Legislature authorized the MPUC to establish a committee of science advisors in response to claims by some dairy farmers that electric currents in the earth from electric utility distribution systems are somehow responsible for problems with animal behavior, health and production problems of dairy cows.

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July 1998 – The Science Advisors Submit Their Final Report

Stray Voltage is the difference in voltage measured between two surfaces that may be contacted simultaneously by a person or animal (typically less than 10 volts). Sources of stray voltage are neutral to earth voltages resulting from normal current flow on a resistive neutral system. ……. Stray voltage on a farm can exist between two metal objects, between a metal object and the ground, or between two points on the ground. When an animal contacts these two points, it provides a conducting path for current to flow.

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July 1998 – Final Report of the Science Advisors

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.

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Connecticut: Department of Public Utility Control (DPUC)

- May 1994 – DPUC receives stray voltage complaint from a Connecticut dairy farmer.
- August 1994 – DPUC conducts an investigation of the complainant's dairy farm.
- October 1994 to March 1995 – A series of hearings are held.
- June 1995 – DPUC Order

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Connecticut: Department of Public Utility Control (DPUC)

Stray Voltage is used to describe the voltage between two animal contact surfaces, where an animal can come into simultaneous contact with both conductive points, thus completing the circuit. These surfaces include metal parts of the milking parlor or freestall area, feeders, waterers, and concrete floors.

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Connecticut: Department of Public Utility Control (DPUC) 1995

- Findings of Fact:
- Currents from stray voltages can cause:
  - physiological and behavioral changes in livestock
  - production losses
  - physical and manageability problems
  - financial loss and psychological stress for the farmer

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Connecticut: Department of Public Utility Control (DPUC) 1995

- Mitigative action should be taken when there is 0.5 volts / 1.0 milliampere in the cow contact areas and voltages in excess of 1.0 volts between primary neutral and earth (at the farm under investigation).

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Vermont Legislature

- 1994 – Dairy farmer concerns result in legislative hearings concerning stray voltage.

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Statement from the Vermont Public Service Board

- In response to proposed legislation in 1994, the Department of Agriculture, Food and Markets, the Department of Public Service, and electric utilities cooperated to write a proposal describing stray voltage problems on farms, and identifying the steps necessary to mitigate those problems.

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Vermont

- Adhere to the terms of A Voluntary Program for the Control of Stray Voltage on Farms, and adopt a proactive program that ……tests for stray voltage at all …… dairy farm customers and installs, at utility expense, a neutral isolation device if neutral-to-earth voltages in excess of 0.5 Volts are encountered. Statement slightly modified for clarity.

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Vermont

- Majority of dairy farms now isolated.
- Different types of isolation devices used.
- Utilities check isolation effectiveness once a year.

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Michigan Public Service Commission (MPSC)

- April 1997 – Michigan Utilities asks the MPSC to promulgate stray voltage rules (U-11368).
- October 1997 – Hearings are held and testimony is provided.

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Michigan Attorney General

- April 1998 –files a complaint against Consumers Energy (U-11684) alleging:
  - Consumers grounded system is creating harmful earth current
  - Failure to stop the flow of earth current is agricultural discrimination
  - Stray voltage litigation expenses should not be recovered in rates
  - The MPSC lacks authority to allow any stray voltage

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Michigan Public Service Commission (MPSC)

- March 2000 – Previous Docket (U-11368) intended to promulgate stray voltage rules is closed pending outcome of (U-11684).
- November 2003 – The Attorney General's complaint (U-11684) is dismissed.

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Michigan Public Service Commission (MPSC)

- November 2003 – A new docket again intended to promulgate stray voltage rules is opened (U-13934), and the MPSC submits a proposed protocol for comments.
- Michigan utilities and farm organizations submit stray voltage protocol. MPSC rule approved in 2006

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Michigan Public Service Commission (MPSC)

- *Stray voltage means the measured difference in an AC electrical potential when measured with a shunt resistor between 2 points that an animal can simultaneously contact in locations normally accessible by the animal through step or touch both inside and outside of farm buildings.*
- 2 MA / 1 Volt Utility source action level

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Idaho

- February 2004 – An Idaho jury awards a dairy farmer $17,500,000
- March 2005 – Idaho Legislature passes the "Stray Current and Voltage Remediation Act" requiring the Idaho Public Utilities Commission to promulgate stray voltage rules.

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Idaho

- April 2005 - Idaho Public Utilities Commission (IPUC) provides notice that it intends to promulgate rules and to initiate informal rule making procedures.
- July 2005 – IPUC issues its decision on Temporary and Proposed Stray Voltage Rules.

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Idaho

- Four Major Sections of "The Stray Voltage Rules'
  - 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

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Idaho

- Stray Current or Voltage is:
  - a). *Any steady state, sixty (60) hertz (Hz) (including harmonics thereof) root mean square (rms) alternating current (AC) less than twenty (20) milliAmperes (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*

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Idaho

- Stray Current or Voltage is:
  - b). *Any steady state, sixty (60) Hz (including harmonics thereof), rms AC voltage of less than ten (10) volts, 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.*

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Idaho

- Stray Current or Voltage is:
  - 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.

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Idaho

- Stray Current or Voltage is:
  - d). Unless the context otherwise requires, the term "stray voltage" shall mean stray current or stray voltage.

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New York Public Service Commission (NYPSC)

- January 2004 – Jodie Lane Incident
- February 2004 – Order commencing proceeding specific to Consolidated Edison. Directed to test all manholes, vaults, service boxes, and street lights, to report its findings, and submit necessary revisions to its maintenance plan.

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New York Public Service Commission (NYPSC)

- July 2004 – Order Soliciting Comments from all regulated utilities regarding stray voltage rule proposal.

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New York Public Service Commission (NYPSC)

- *Stray Voltage –The term "stray voltage" means voltage conditions on electric facilities that should not ordinarily exist. These conditions may be due to one or more factors, including, but not limited to, damaged cables, deteriorated, frayed or missing insulation, improper maintenance, or improper installation.*

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January 2005 – NYPSC Order all regulated utilities

- Directed utilities to submit within 45 days:
  - the details of their voltage testing programs
  - the details of their inspection programs
  - the safety criteria to be applied
  - an inspection schedule with a five year cycle
  - the details of their quality assurance programs
  - training plans (employee and contractor)
  - a description of planned stray voltage research

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January 2005 – NYPSC Order all regulated utilities

- Specified 8 – 600 volt detection device
- Adopted the NESC in New York
- Denied rate recovery
- Created rate based fines for failure to implement

- June 2005 – Order requiring phone companies to comply with the NESC and perform stray voltage inspections.

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New Jersey Board of Public Utilities (NJBPU)

July 2002 – Twelve customers of Jersey Central Power & Light (JCP&L) residing in Brick and Dover Townships complain to the NJBPU about experiencing tingling sensations in their pools, hot tubs, outdoor showers and other conductive objects.

September 2002 – The NJBPU asks the National Regulatory Research Institute (NRRI) for assistance. The NRRI hires VitaTech Engineering to investigate and provide recommendations.

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New Jersey Board of Public Utilities (NJBPU)

Stray voltage is the non-technical term for a phenomenon known as "neutral-to-earth voltage", which is an extraneous voltage that appears on grounded surfaces (such as wires, pipes and soil) in buildings and other structures. In addition, the normal load current flowing in a distribution system's neutral and ground wires creates stray voltage.

In most instances, stray voltage is not a problem because the levels are generally below the perception level of humans and usually there is no sensitive electronic equipment that can be affected by it.

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New Jersey Board of Public Utilities (NJBPU)

December 2002 – NJBPU accepts the report of its consultant, VitaTech, and directs JCP&L to implement the report's recommendations.

- Increase primary neutral size to match phase conductors on 4 circuits
- Balance loads (4 circuits) to within 10% during (avg), 15% (peak)
- Expand the Substation ground area

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New Jersey Board of Public Utilities (NJBPU)

July 2003 – Following continuing customer complaints, NJBPU asks VitaTech to re-visit the site and submit a second report.

November 2003 – The NJBPU orders JCP& L to implement the eight (8) recommendations contained in VitaTech's second report, and suggests that a Neutral-to-Earth voltage standard may be necessary.

2004 – EPRI Involvement

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Massachusetts

Department of Telecommunications & Energy (DTE)

Stray voltage has caused injuries to pets and the death of at least three dogs in Massachusetts. Other states, notably New York, have encountered similar stray voltage events, including the death of a woman in downtown Manhattan (Jodie Lane) in January 2004. (Navigant Report)

Beginning in June 2004, a number of manhole covers were dislodged on the underground electric distribution systems of electric companies regulated by the Massachusetts Department of Telecommunications & Energy (DTE). Several of these manhole

Massachusetts: Department of Telecommunications & Energy (DTE)

August 2004 – DTE requests information regarding "Maintenance and Inspection Practices of Underground Facilities"

Late 2004 - DTE hires two independent consultants to provide recommendations on Stray Voltage and Manhole Safety

- Navigant Consulting - Independent Assessment of Stray Voltage in Underground Distribution Systems of Massachusetts Electric Companies (Stray Voltage Safety)
- Siemens Power - Independent Assessment of Dislodged Manhole Covers (Manhole Safety)

Massachusetts

Navigant Consulting was asked to determine:

- Adequacy of testing methods to detect stray voltage
- Causes and remedies for stray voltage
- Communications with municipalities regarding facility abandonment
- Procedures for de-energizing facilities that have been abandoned
- Adequacy of remediation plans and implementation
- Adequacy of record keeping procedures
- Assessment of whether hazardous events have been increasing
- If stray voltage hazards are due to geographic or climatic conditions
- If state and municipal de-icing practices lead to equipment deterioration
- Further action to be taken to ensure public safety from stray volt age

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Massachusetts

December 2005 – DTE directs each utility to submit its plans for implementation of the recommendations contained in the final reports of Navigant and Siemens.

With respect to stray voltage these recommendations include:

- Stray voltage plans must achieve a 20 volt detection level with an expectation the detection level will be lowered over time to 8 volts
- Perform stray voltage measurements at least every five (5) years on:
  - Metallic risers, sweeps and conduits
  - Manhole and handhole covers
  - Secondary pedestals
  - Padmount transformers and transclosures
  - Padmount switchgear, termination cabinets and jct boxes
  - Control cabinets such as pole mounted capacitor controls

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Massachusetts

With respect to stray voltage these recommendations include (continued):

- Immediately repair, replace or disconnect equipment with stray voltage greater than 20 volts
- Repair within 24 hours all equipment with stray voltage between 8 volts and 20 volts
- Utility discretion to be used when stray voltage is below 8 volts
- Document all stray voltage events, and submit to DTE
- Promote stray voltage safety awareness

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