Review of Research on Animal Exposure Risk from Stray Voltage

Also: Assessing Animal Exposure Risk from SV Test Results

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Presentation given at the Midwest Rural Energy Council's 54th Annual Rural Energy Conference and Workshop, March 2-4, 2016, La Crosse, Wisconsin

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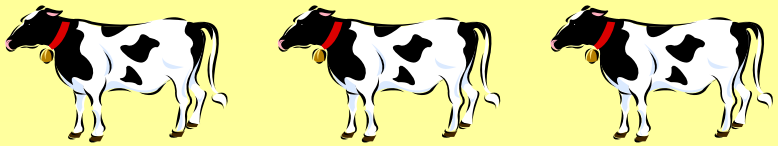

Will the real body resistance please stand up

Douglas J. Reinemann

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Department of Biological Systems Engineering

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USDA 1991 Summary

- Consensus opinion of 15 credible researchers
- *distressed that our research results were being misinterpreted*
- *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.

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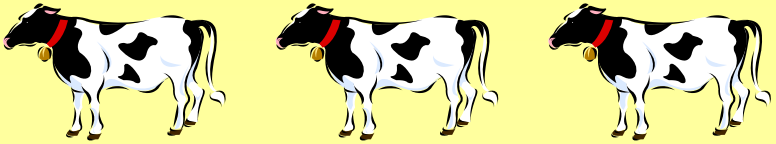


USDA 1991 Summary

- Recommend action levels 4 mA or from 2 to 4 Volts
  - As conservative as possible to account for indirect losses due to problems resulting from inappropriate response of farmers to changes in animal behavior
- To relate voltage measurements to current, the worst case (500 Ohms) and more realistic (1000 Ohms) Resistances were used.

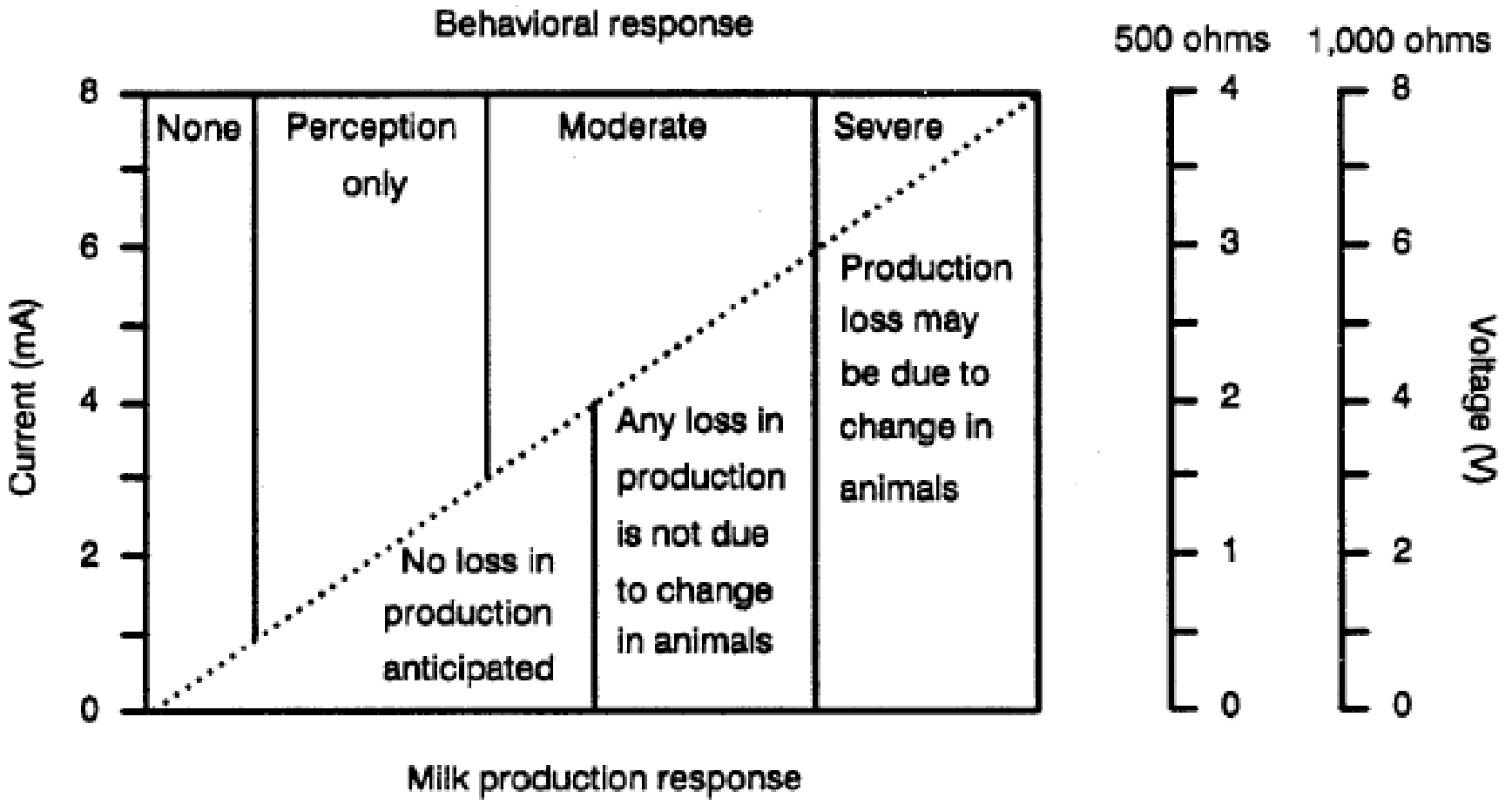
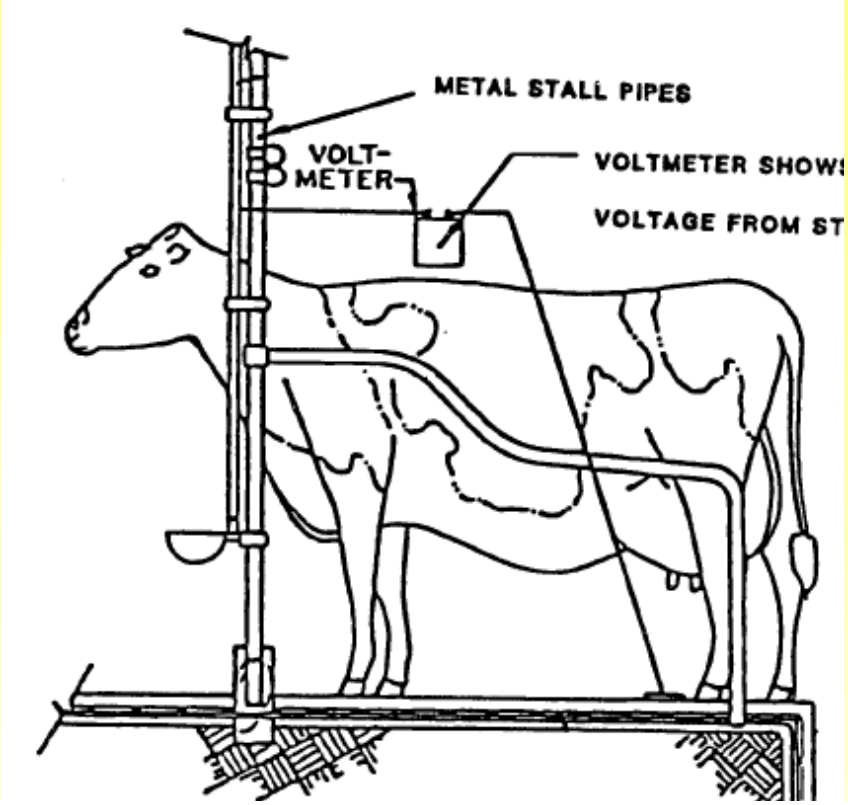


Figure 7-2. Behavioral and milk production responses to increasing current levels. Voltages, on the right, were estimated using a worst case circuit impedance and a more realistic impedance.

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).



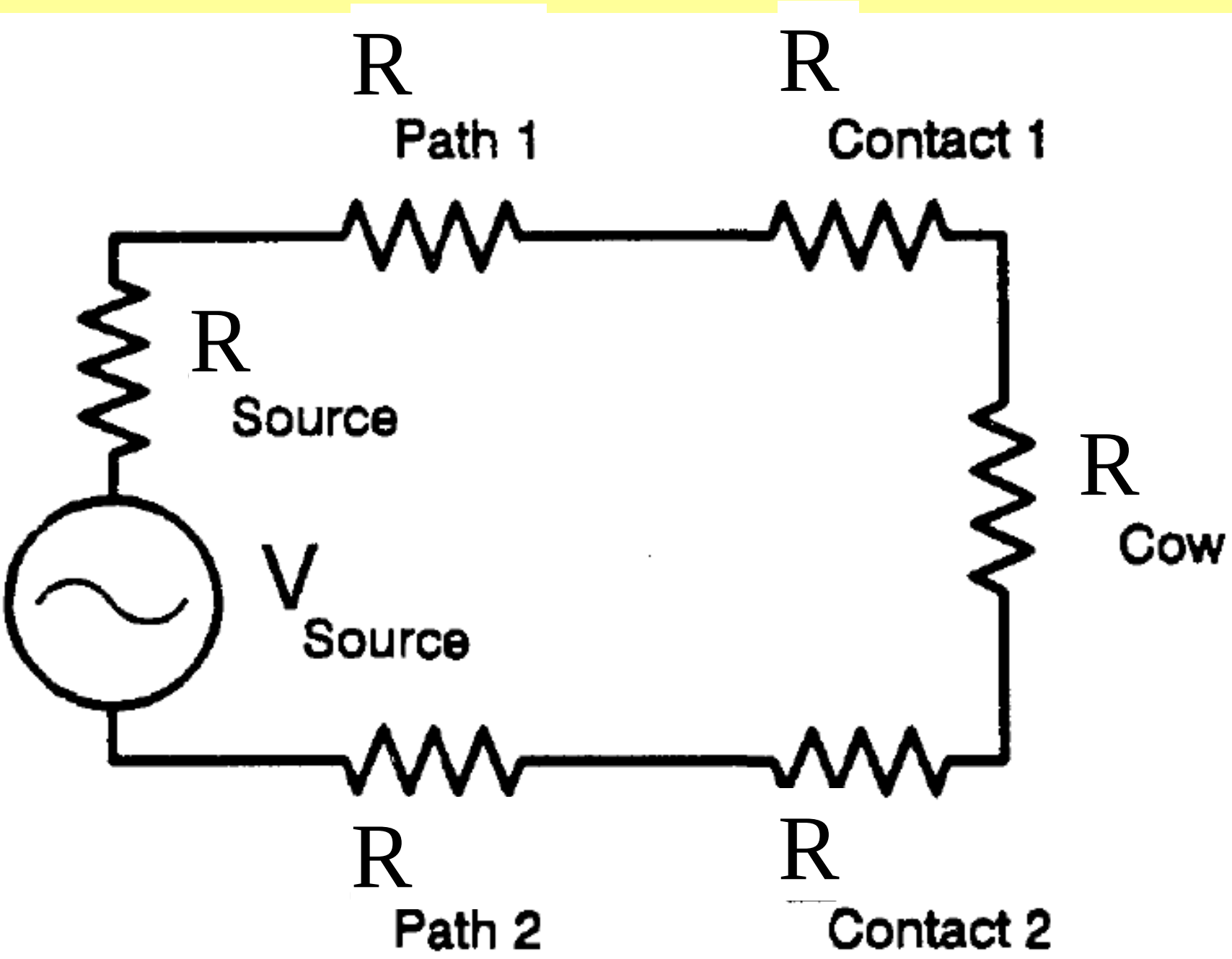
contact. For evaluation purposes, it is often sufficient to consider the worst case resistance, i.e., the lowest resistance likely to be encountered. We consider 500 Ω for the sum of contact and body resistances to be a very conservative estimate of the worst case, or minimum, resistance that is likely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

USDA 696

- Chapter 3, Verse 1.2
  - it is the total series impedance that limits the current cows receive and not just body impedance.
  - The total series impedance is the sum of source, path, contact, and body impedances.

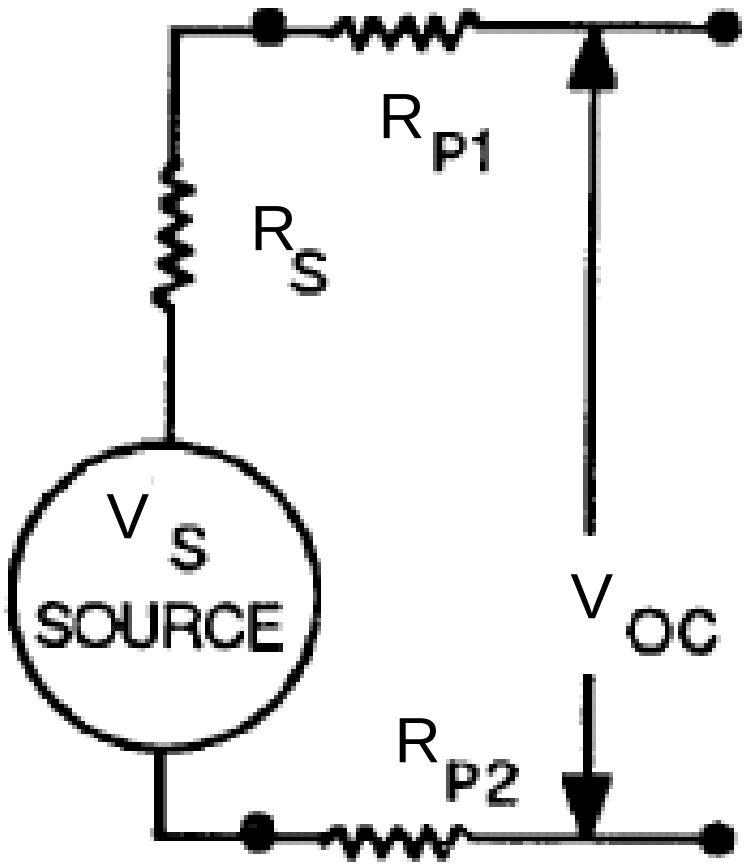
USDA 696

- Chapter 3, Verse 1.5
  - The voltages needed to deliver these currents depend on
  - body impedance of the cow,
  - contact impedances between the cow and the conductive structures,
  - impedance of the conductive structures, and
  - impedance of the voltage source.


R
Path 1
R
Contact 1
R
Source
R
Cow
V
Source
R
Path 2
R
Contact 2

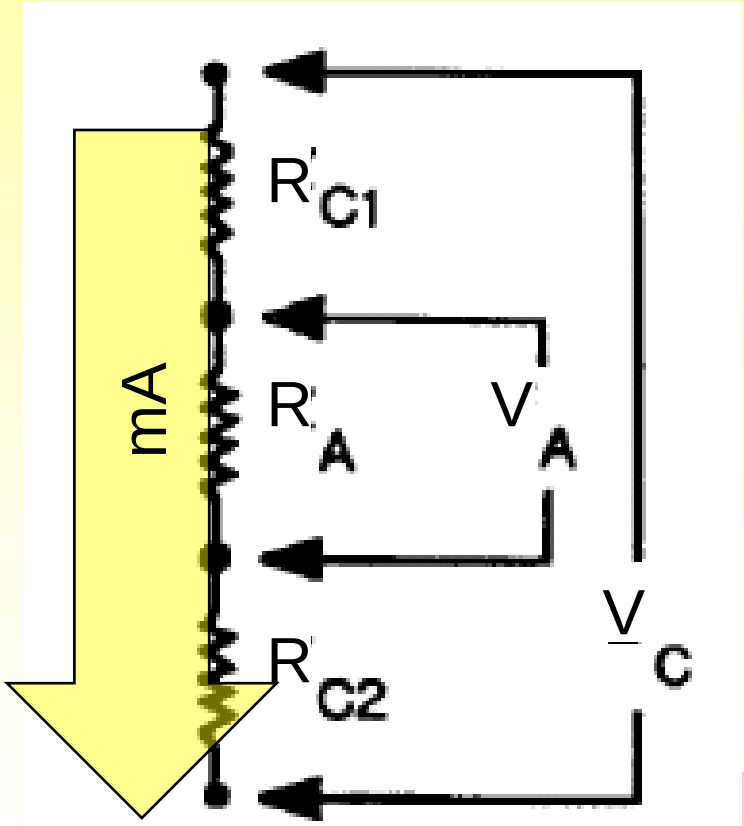
Elements of the Source Circuit

- 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

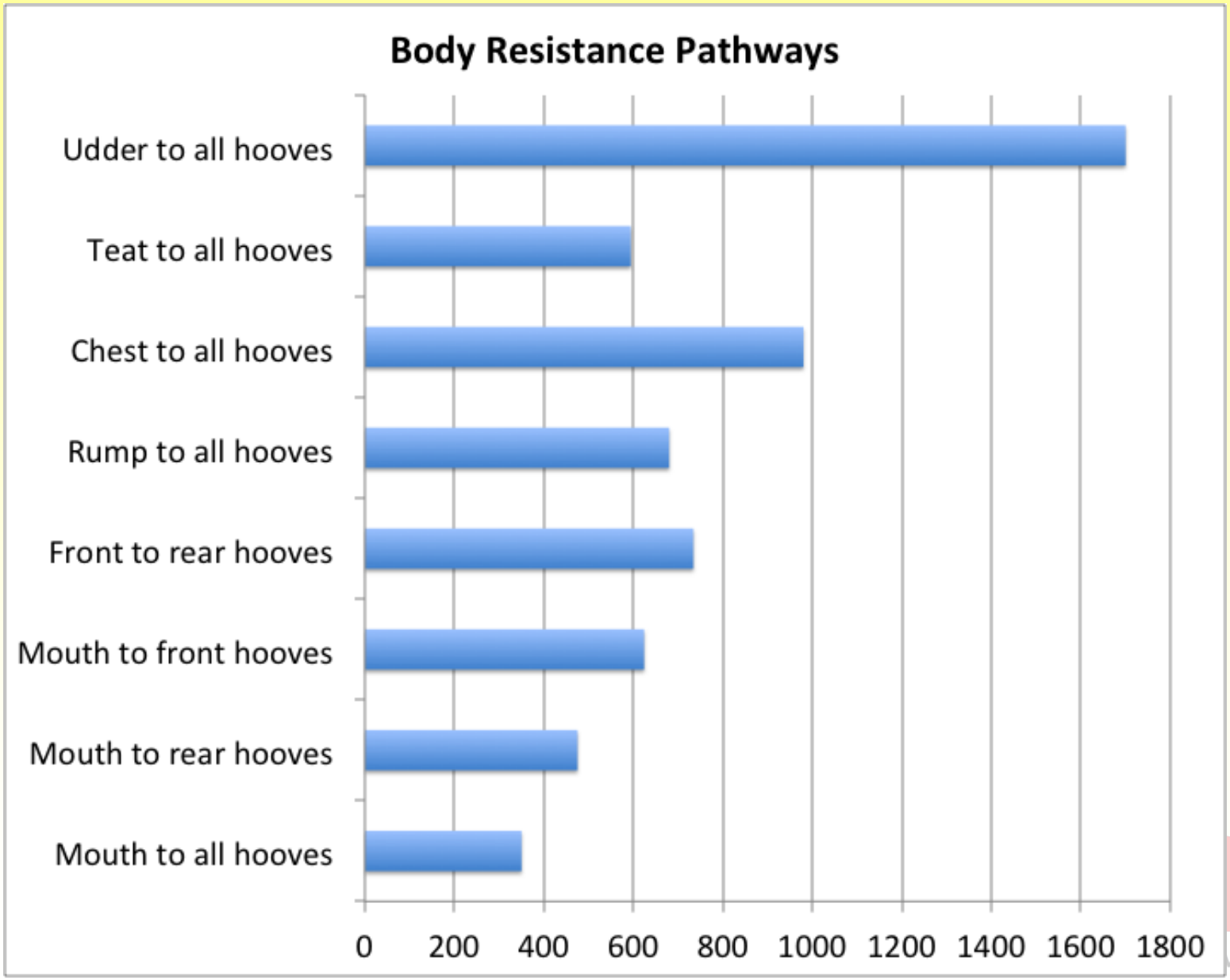


Elements of the Animal Circuit

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



USDA 696 Values



Effect of measurement method on muzzle-hoof 'body' resistance values

- Jagged metal plate versus concrete -100 ohms hoof contact resistance
- Nose clip versus waterer – 50 ohms muzzle contact resistance
  - Broken skin – ??? ohms

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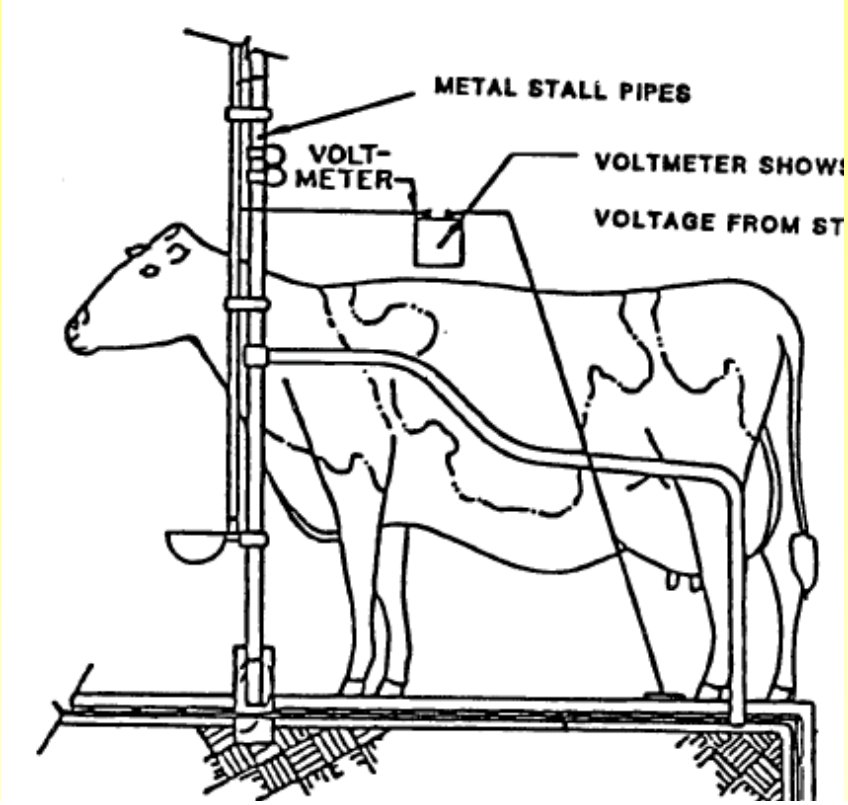
The Problem of Contact Resistance

- 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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Proper Cow Contact Test method

- Eliminate contact resistance
- 500 Ohm Shunt resistor represents cow+contact resistance.
- To make the test repeatable
  - Because
  - Contact resistance is highly variable

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RTE

The effects of stray voltage in ruminants reared under farm conditions

Karim Rigalma, Christine Duvaux-Ponter, François Gallouin, François Deschamps and Sabine Roussel

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Behavioral Reaction threshold, delay to eat or drink

Feeder:
Metallic Bowl to Metal Plate
2.3 V 2.5 mA

Metallic Water bowl – metal plate
1.8 V 3.6 mA

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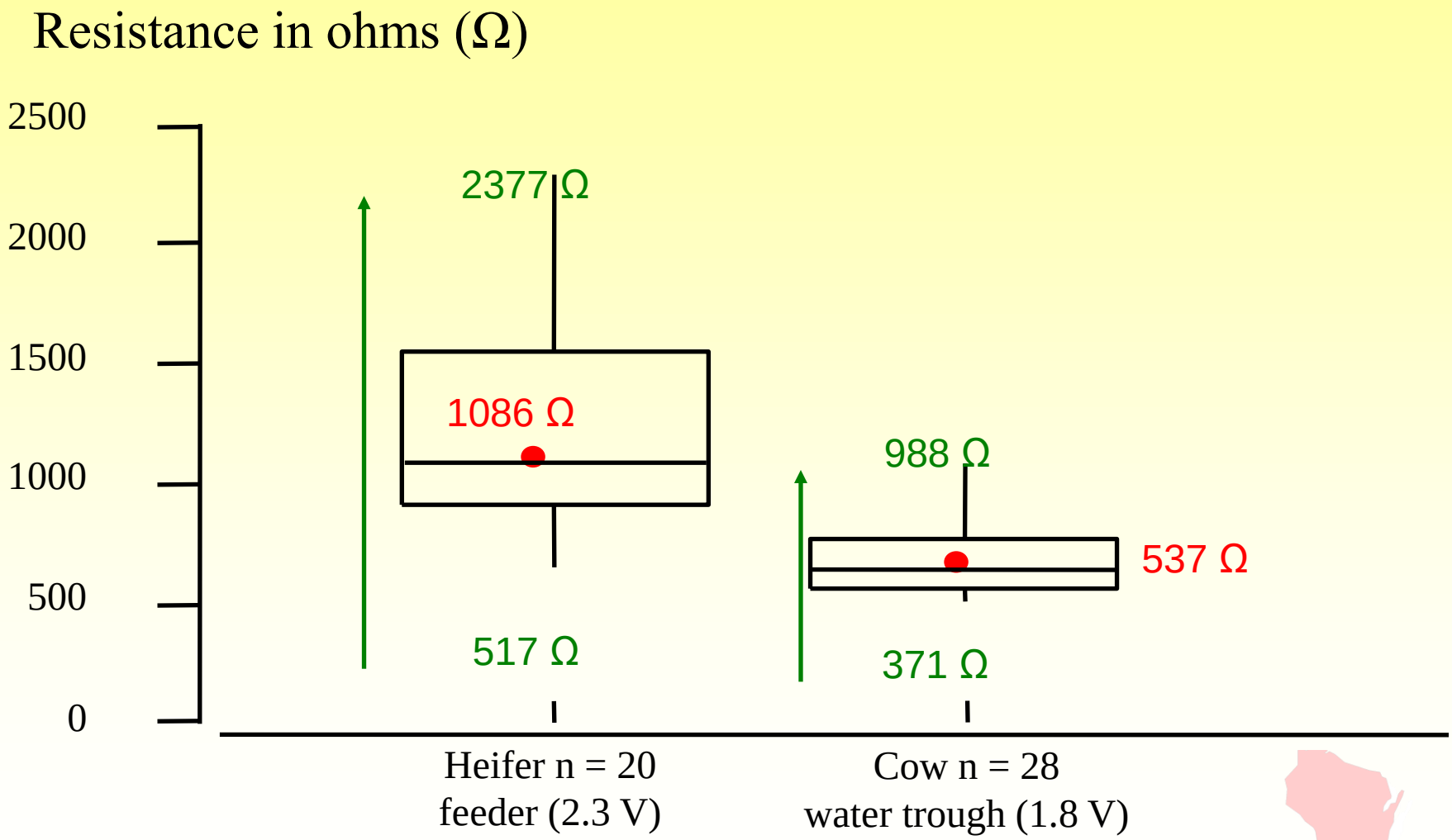
Individual variability in electric resistance



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What do the resistance numbers say?
Voltage or current? Level of Concern?

V Open Circuit	R source	R Cow + Contact	Cow Current	V Cow Contact
1 volt	200 Ohms	200 Ohms	2.5 mA	0.5 Volts
1 volt	200 Ohms	500 Ohms	1.4 mA	0.7 Volts
1 volt	200 Ohms	1000 Ohms	0.8 mA	0.8 Volts

What do the resistance numbers say?
Voltage or current? Level of Concern?

V Open Circuit	R source	R Cow + Contact	Cow Current	V Cow Contact
1 volt	400 Ohms	200 Ohms	1.7 mA	0.3 Volts
1 volt	400 Ohms	500 Ohms	1.1 mA	0.6 Volts
1 volt	400 Ohms	1000 Ohms	0.7 mA	0.7 Volts

What do the resistance numbers say?
Voltage or current? Level of Concern?

V Open Circuit	R source	R Cow + Contact	Cow Current	V Cow Contact
1 volt	0 Ohms	200 Ohms	5.0 mA	1 Volt
1 volt	0 Ohms	500 Ohms	2.0 mA	1 Volt
1 volt	0 Ohms	1000 Ohms	1.0 mA	1 Volt

What do the resistance numbers say?
Voltage or current? Level of Concern?

V Open Circuit	R source	R Cow + Contact	Cow Current	V Cow Contact
1 volt	200 Ohms	1000 Ohms	0.8 mA	0.8 Volts
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1 volt	200 Ohms	200 Ohms	2.5 mA	0.5 Volts
1 volt	400 Ohms	200 Ohms	1.7 mA	0.3 Volts
1 volt	0 Ohms	200 Ohms	5.0 mA	1 Volt

Goal of a stray voltage investigation

- Farm survey of cow contact locations
- 24 hour or more recording at cow-contact location(s)
- Bottom line report results
  - Highest cow contact voltage
    - Worst-case location
    - Highest voltage over entire recording period
  - One number

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Assessing exposure risk

- Where is it?
  - Resting
  - Eating
  - Standing /Moving
  - Drinking
  - Milking

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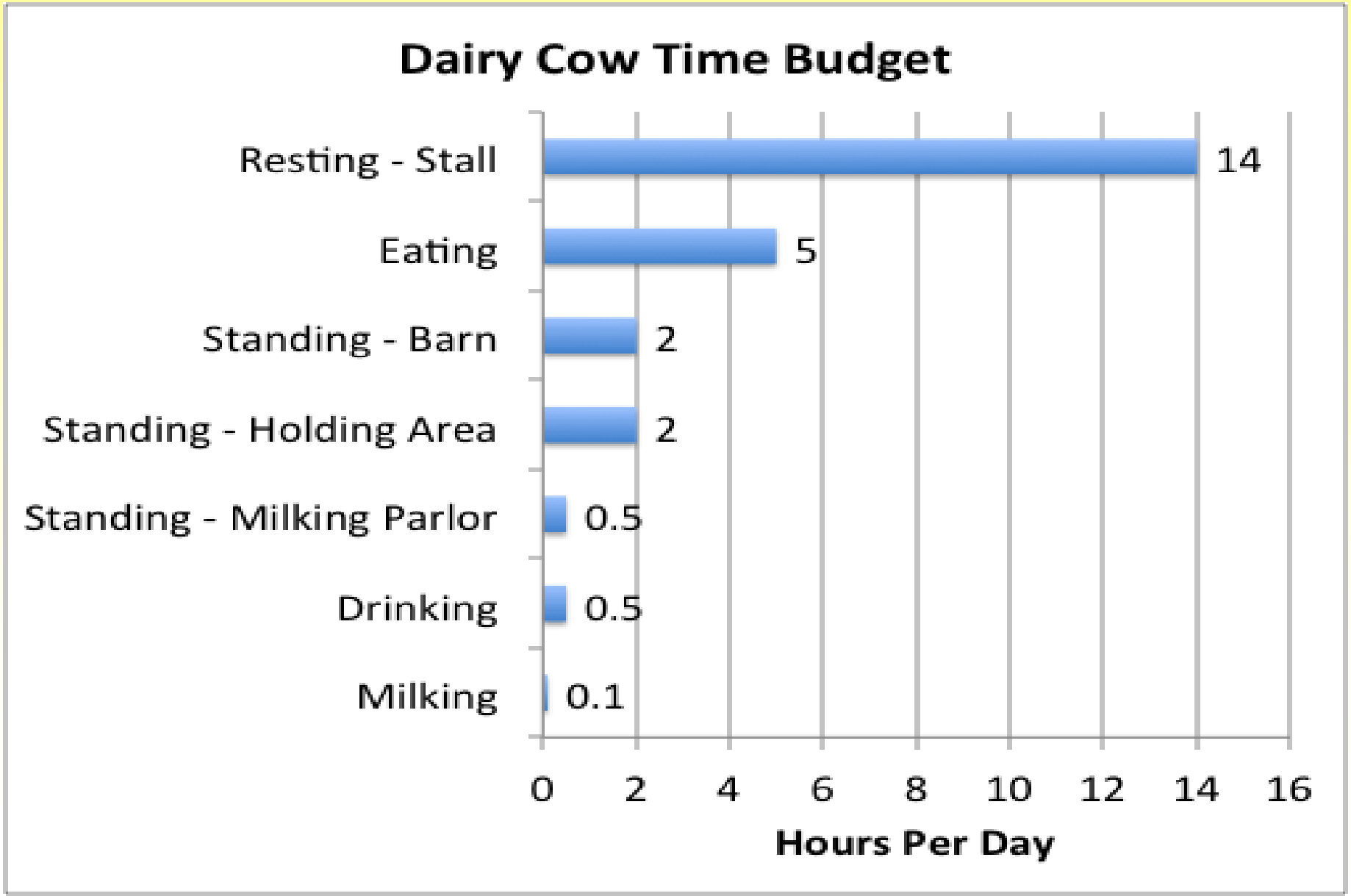
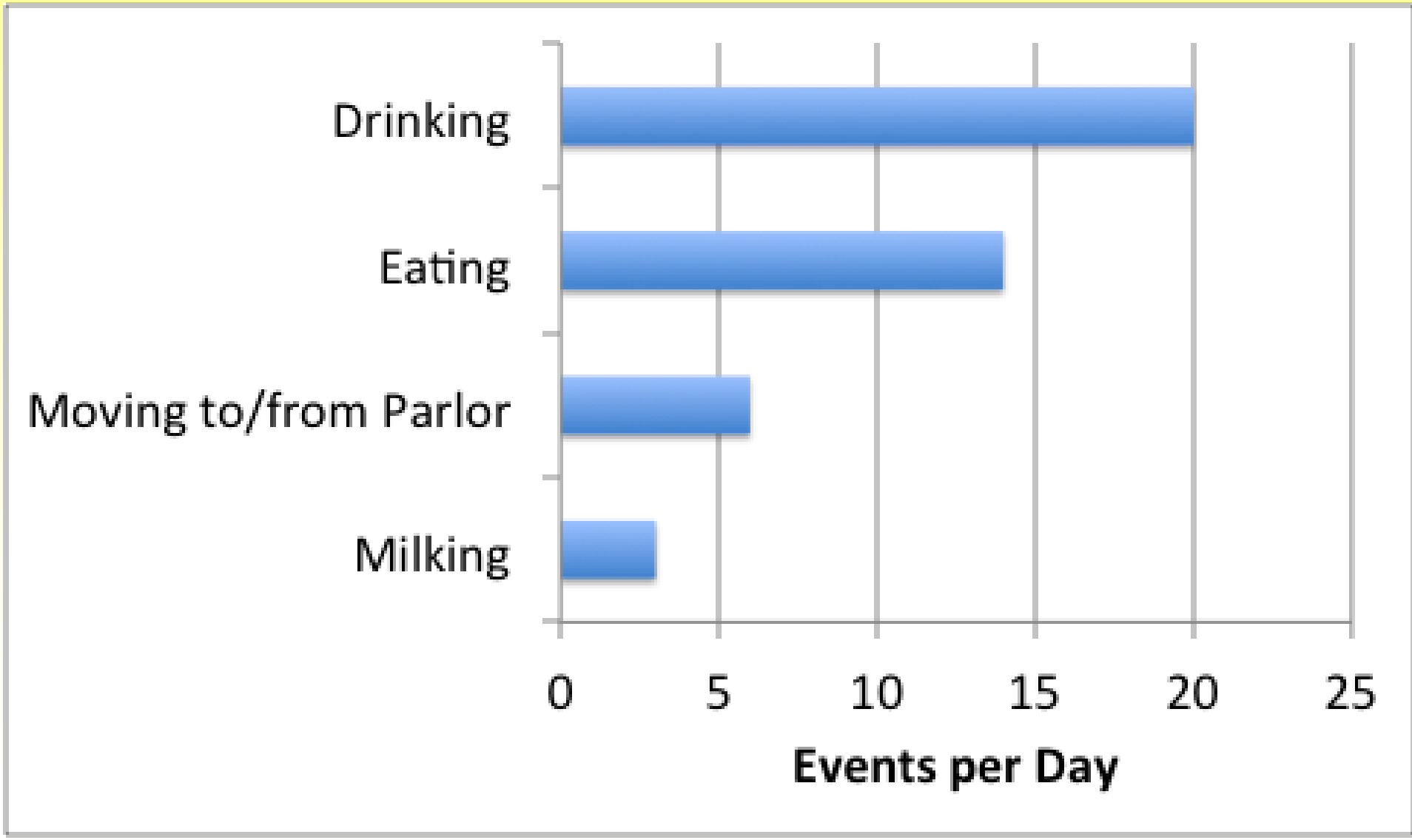
Assessing exposure risk



Assessing exposure risk
Cow Behavior



Are there ways to avoid contact?

- Multiple waterers
- Alternate Traffic lanes
- If cows can avoid it – they will

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Exposure Conditions Required to Produce an Effect

- Adverse effect requires BOTH annoying current AND forced exposure
- Location
  - Areas vital to normal daily activities
- Times / day
  - Annoying stimulus must occur frequently
- Are there ways to avoid contact?
  - Multiple waterers
  - Alternate Traffic lanes
  - If cows can avoid it – they will

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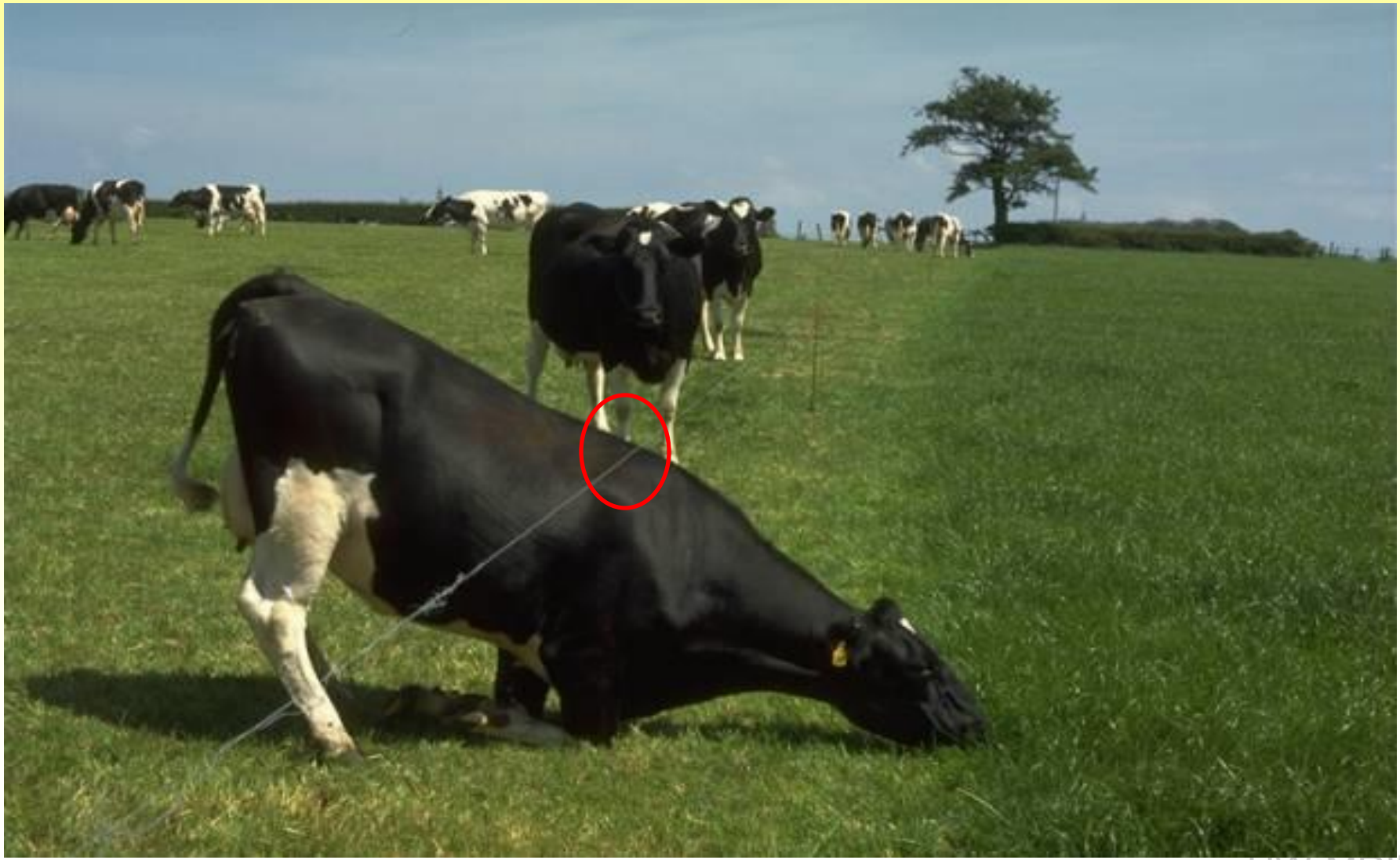
Learned Behavior – Avoid Contact



Probability of Exposure - Transients

- Number of electrical events per day

+

- Number of cow contacts per day

=

- Probability that a cow will be in contact when the electrical event occurs – number of true contacts

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Animal Response to Stray Voltage

Behaviors	Documented > 2- 4V
Milk production	Some effect >8V for extreme exposure
Somatic cells	No effect up to 8V
Reproduction	No effect up to 8 V
Milkout problems	Some effects >12 V
Stress Hormones	Some effects >16V

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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

Reducing Risk at watering devices

- Provide multiple watering locations
- Non Metallic watering devices much lower risk – high source resistance
- Equipotential Planes required around watering devices
- Aversion > 4 Volts / 8 mA

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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

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

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

Exposure in resting areas, pastures & other 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

Stray Voltage and Milk Quality: A Review

The results of several studies showed that somatic cell counts and the incidence of mastitis were not increased at exposure levels sufficient to produce aversive behavior in dairy cows.

Stray Voltage and Milk Quality: A Review

There have been no studies in the large body of research that support the hypothesis that stray voltage exposure of up to 8 V will result in increased somatic cell count or incidence of mastitis.

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Case Study: Free choice Experiment

- 70 cows had free choice of 0, 3, and 6 volts Cow contact at waterers
- Results:
  - waterer nearest the cows had highest water intake, regardless of the voltage
  - 20% water reduction at 3V waterer
  - 66% water reduction at 6V waterer

Case Study: Probability of contact

- Exposure level = 4 to 15 mA
  - Cow specific aversion levels
- # events change in 8 hr water

Steady State	Yes
1 per second	Yes
Every 10 minutes	No
1 per day	No

Case Study: The jumping cows

- Open on-farm neutral for about 1 month
- Equipotential Plane (mostly)
- Worst case Cow-contact voltage
  - 56 volts step potential entering holding area and exiting parlor
- Other cow contact locations minimal contact voltage

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Case Study: The jumping cows

- Results:
  - No loss in production
  - No change in Somatic Cell Count
  - Cows initially reluctant to enter/leave parlor
  - Cows learned to jump in and jump out or parlor - over step potential.

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Steady Stream Of Unorthodox Approaches

- Not based on sound scientific principles
- Produced a great deal of mistrust in the agricultural community
- Have not stood the test of time as effective means to address stray voltage concerns.

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Does it work?

The soundness and repeatability of scientific research and the success of its practical application has been validated over the past 25 years on over 9000 stray voltage investigations on farms in Wisconsin.

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