



## What Do We Know About Stray Voltage?

Terms, Sources, Animal Research, Transients, High Frequency, Field Studies, Earth Currents, EMF,

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## Animal Response to Stray Voltage

- 🐄 Avoidance behavior
- 🐄 Milk production
- 🐄 Somatic cells
- 🐄 Reproduction
- 🐄 Milkout problems
- 🐄 Well documented
- 🐄 Documented only for extreme exposure
- 🐄 Not documented
- 🐄 Not documented
- 🐄 Not documented



## Reasonable Level

- 🐄 Zero tolerance is
  - 🐄 Impossible
  - 🐄 Expensive
  - 🐄 May be Dangerous
  - 🐄 Not warranted base on research results
- 🐄 Sensitivity to 50/60 Hz
- 🐄 Sensitivity to High Frequencies



## Types of Voltage/Current

- 🐄 60 Hz voltage
  - 🐄 Steady
  - 🐄 Motor Starts
- 🐄 High Frequency Transients
  - 🐄 Fencers, Trainers, Crowd Gates
  - 🐄 Equipment Switching



## Conclusions From USDA, 1992 for 60 Hz Voltage.

- 🐄 Perception begins 1 to 2 mA (0.5-2 V).
- 🐄 Cows become conditioned.
  - 🐄 Behavioral problems may persist after stimulus is removed.
- 🐄 Keep Cow Contact Voltage < 2- 4 V.
  - 🐄 Consider cost of reducing voltage.
  - 🐄 Economic/Non-Economic Effect.
- 🐄 Milking machine an unlikely pathway.

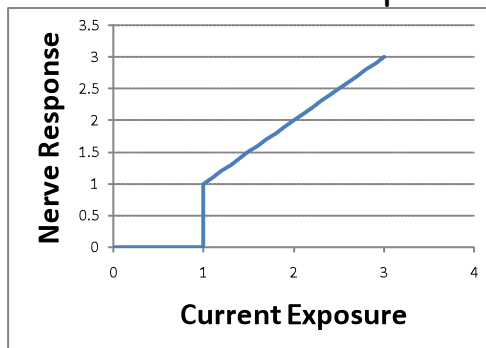


## Wisconsin Rules and Regulations

- 🐄 PSCW stray voltage order.
- 🐄 The "level of concern" for livestock is more than 2 milli-amps of steady state, 60 Hz AC, RMS current in animal contact locations, measured between two points that livestock may contact simultaneously.
- 🐄  $1 \text{ V} = 2 \text{ mA} \times 500 \text{ Ohms}$ .



## 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



## 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



## 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.



## USDA 1991 Summary

- ☛ Consensus opinion of 15 credible researchers
- ☛ *distressed that our research results were being misinterpreted*
- ☛ *Recommend action levels 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*



## USDA 1991 Summary

- To relate voltage measurements to current, the worst case (500 Ohms) and more realistic (1000 Ohms) Resistances 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.

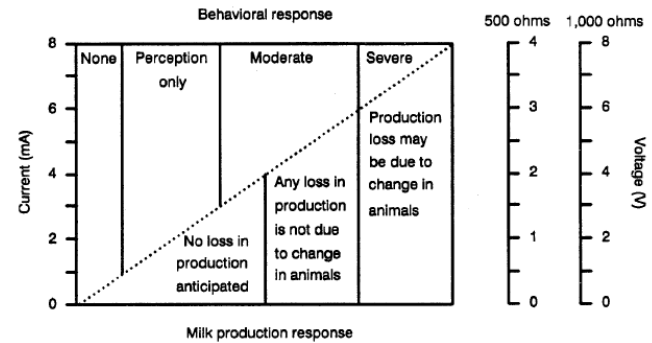


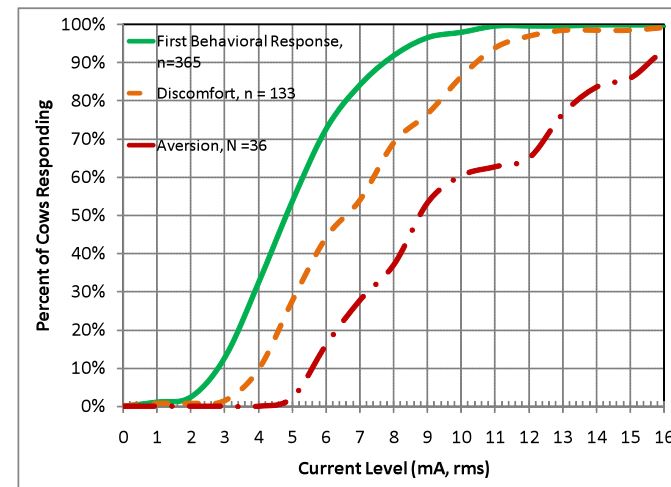
Figure 7-2. Behavioral and milk production responses to increasing current levels. Voltages, on the right, were estimated using a worst case circuit impedance and a more realistic impedance.

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).



## Synthesis of OEB Review 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



## Over 450 cows 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



## Over 300 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



## ☛ Over 300 cows with constant voltage exposure

- ☛ Most responses 2 to 8 Volts

## ☛ Over 450 cows with constant current exposure

- ☛ Most responses 2 to 8 Milliamps

## ☛ Over 750 Cows Tested

- ☛ 1000 Ohms reasonable estimate of cow + contact resistance in real-world situations
- ☛ May be some unusual cases as low as 500 Ohms



## AgroParisTech Rousset (2007)

- ☛ avoidance test threshold level
- ☛ steps of 0.3 Volts up to 5 Volts applied to feeding cup
- ☛  $\geq 2.3V$ , % 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



## 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 likely undetectable on most farms



## 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





## 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



## 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



## 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



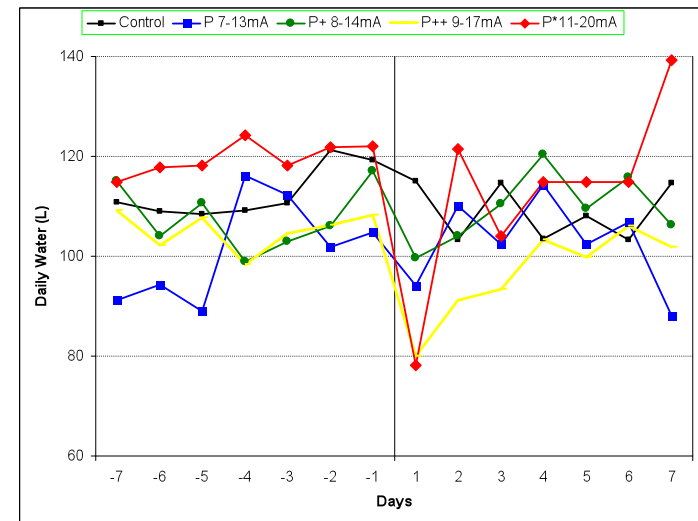
## Exposure at watering devices

- ☛ 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



## 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
- 🐄 Severe aversion > 4 Volts / 8 mA



## 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






## Learned Behavior - Avoid Contact






## 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 and other Farm Locations

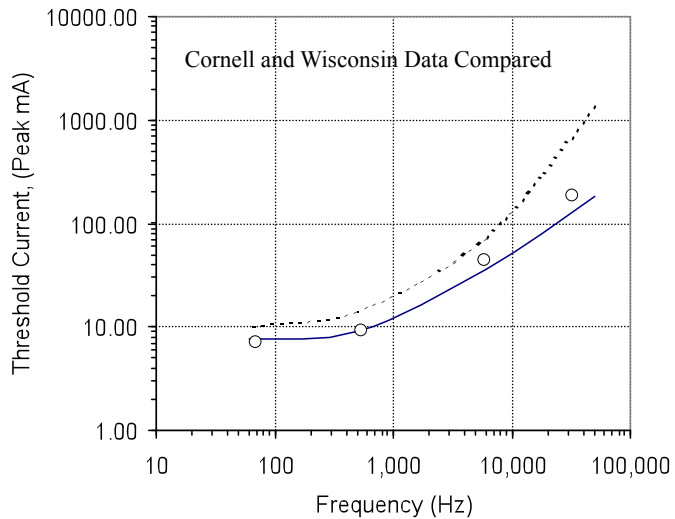
-  Highly unlikely location for problems
-  High resistance contacts Dry bedding to hide / hooves
-  step potentials very low compared to contact with electrical devices
-  Metal in floors acts as equipotential



## 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.





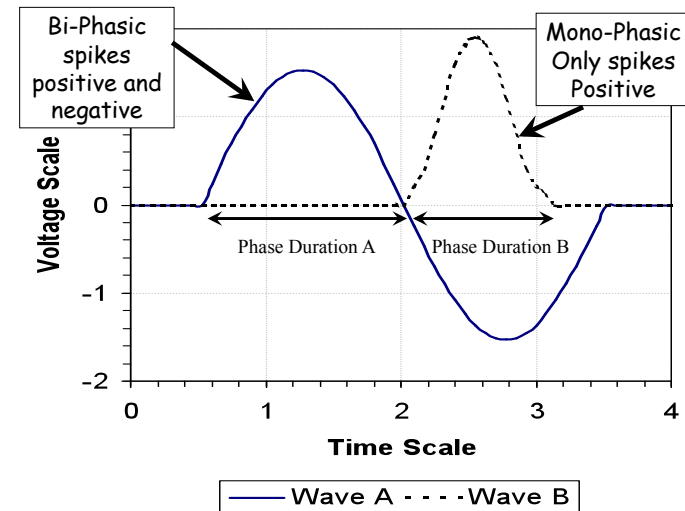
## Cornell VII

- 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

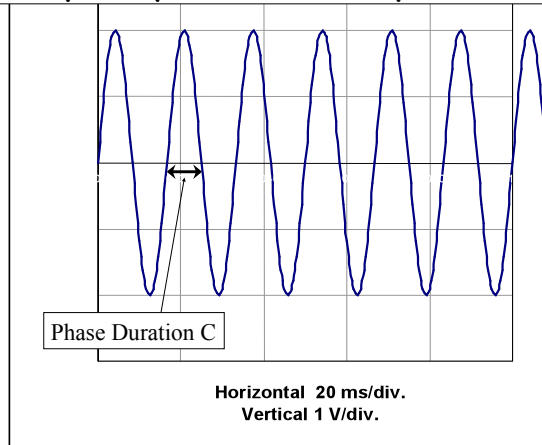


## Effects of Voltage/Current exposure on Mastitis

- 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



## Multiple Cycle = "Steady State"



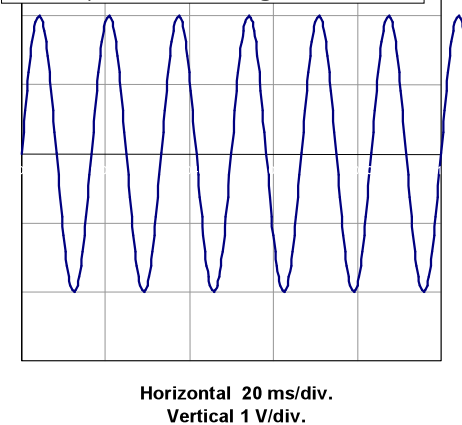
## Timescale

	Second (s)	millisecond (ms)	microsecond ( $\mu$ s)	nanosecond (ns)
Second (s)	1	1,000	1,000,000	1,000,000,000
millisecond (ms)	0.001	1	1,000	1,000,000
microsecond ( $\mu$ s)	0.000,001	0.001	1	1,000
nanosecond (ns)	0.000,000,001	0.000,001	0.001	1

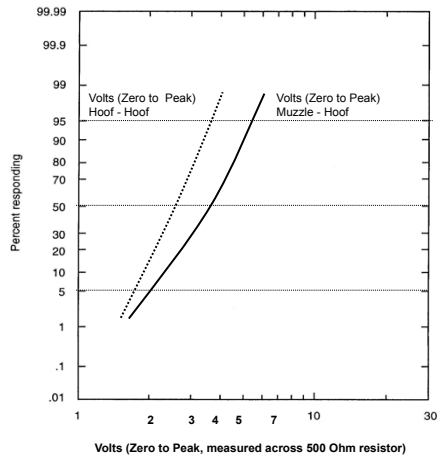
## Conversion from phase duration to frequency

Phase Duration	Frequency
0.0083 s	60 Hz
8.3 ms	60 Hz
8333 $\mu$ s	0.5 Hz
1 s	500 Hz
1 ms	500,000 Hz = 500 kHz
1 $\mu$ s	500,000 kHz = 500 MHz
1 ns	10 Hz
0.05 s = 50 ms	1,000 Hz = 1 kHz
0.5 ms = 500 $\mu$ s	1,000,000 Hz = 1000 kHz
0.5 $\mu$ s = 500 ns	= 1 MHz

## Dairy Cow Response to Steady 60 Hz Voltage/Current



Approximate 60 Hz Steady State Behavioral Response Distribution



Behavioral response for 5% most sensitive cows, sine waves muzzle to hooves exposure

