

A Veterinarian's Perspective of Stray Voltage



John Roberts
REPS-DATCP/PSC

BASIC STRAY VOLTAGE

- OHMS LAW
- CURRENT = VOLTAGE / RESISTANCE
- 1 MILLIAMP = 1/1000 AMPS(0.001 AMPS)
- 1 MILLIAMP = 0.5 VOLTS / 500 OHMS (THE COW = 500 OHMS?)

BASIC STRAY VOLTAGE

ELECTRICAL CONTACT RESISTANCE

(Ohms Law: $\text{Current} = \text{Voltage} / \text{Resistance}$,)

-500 Ohms is worst case

- dry contacts or bedding will increase contact resistance to 1000 Ohms or more
- Cow comfort(4” of bedding) has many benefits
- Milking unit(30-50,000 Ohms) are not a contact pathway
- Human: dry hand = 20,000 Ohms, wet = 2,000 (feeling a tingle is not appropriate!!!)

BASIC STRAY VOLTAGE

- **ELECTRICITY WILL GET BACK TO WHERE IT COMES FROM, AND ONCE IT GETS BACK, IT IS NEUTRALIZED, AND DISAPPEARS**
- **JUST TWO SOURCES**

BASIC STRAY VOLTAGE

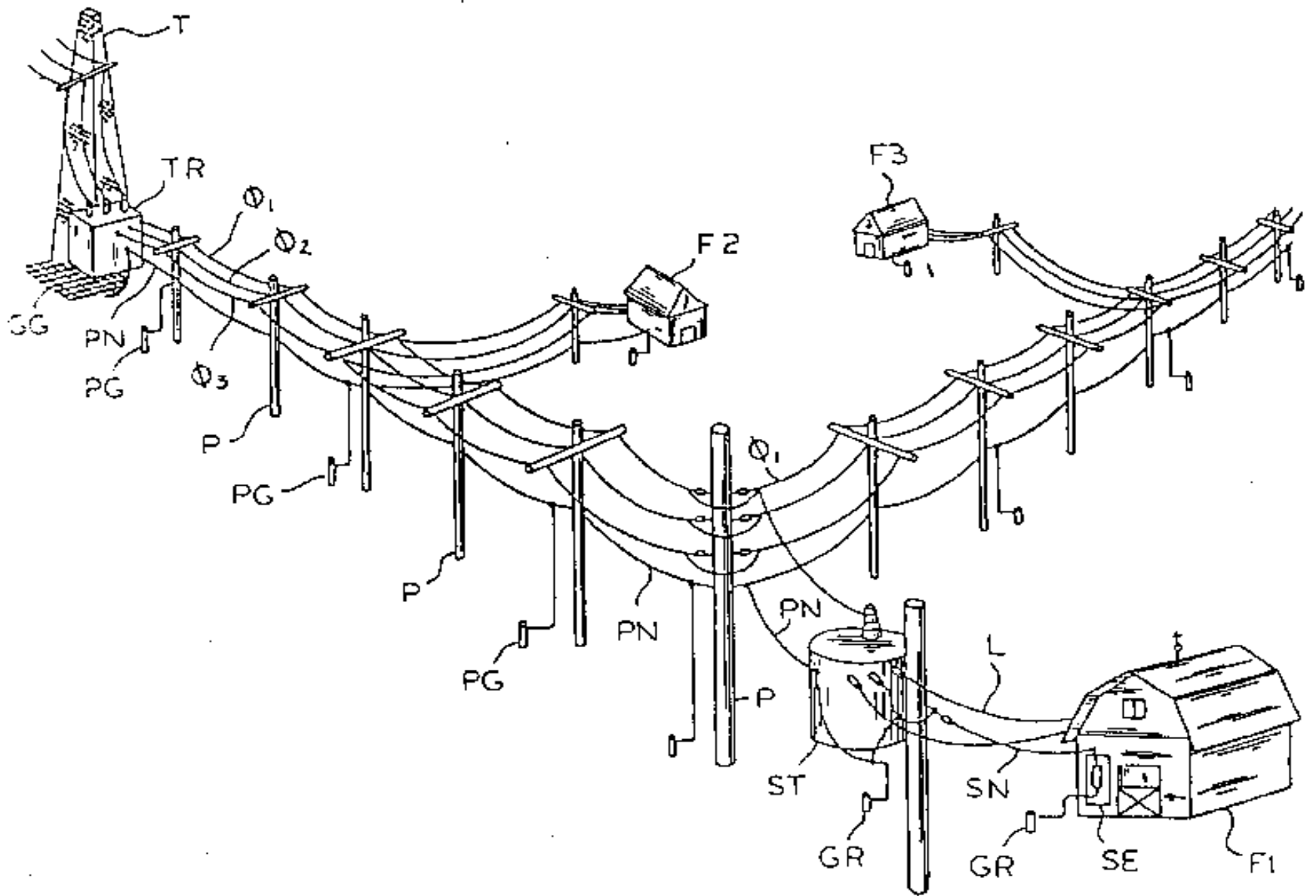
- **ELECTRICITY DOES NOT ONLY TAKE THE RETURN PATH OF LEAST RESISTANCE. TO A VARYING DEGREE, IT TAKES ALL AVAILABLE PATHS TO RETURN**

BASIC STRAY VOLTAGE

- **ELECTRICAL RESISTANCE:**
 - **LONG WIRES**
 - **SMALL WIRES**
 - **TOO MANY SPLICES**
 - **POOR CONNECTIONS**
(Split Bolts, Dissimilar Metals)

BASIC STRAY VOLTAGE

- **THE EARTH IS A VERY BIG LOW RESISTANCE WIRE**
- **CURRENT FOLLOWS THE DISTRIBUTION SYSTEM BACK**
- **CURRENT IS NEUTRALIZED AT ALL POTENTIAL POINTS**



SECONDARY NEUTRAL RESISTANCE

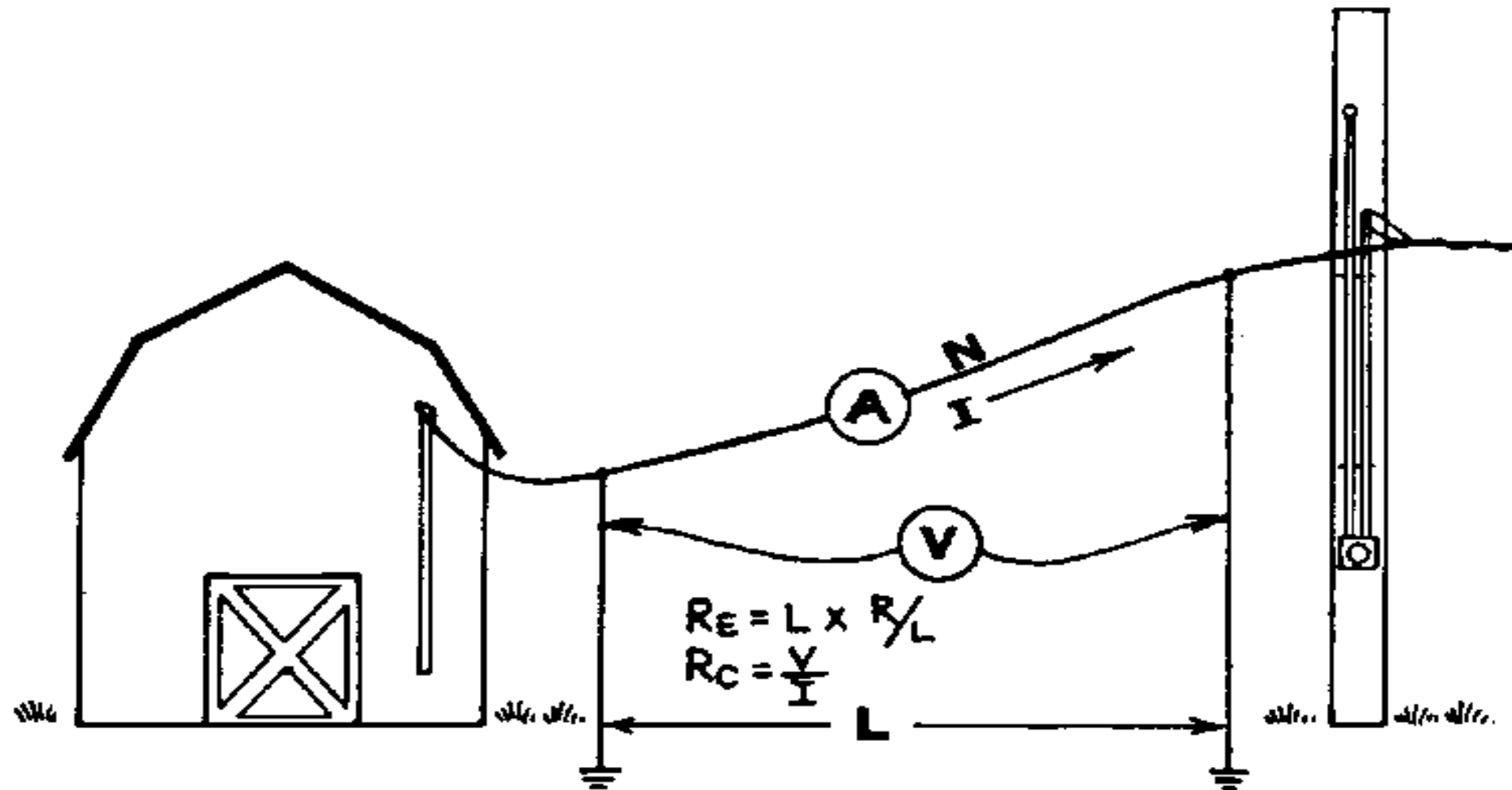
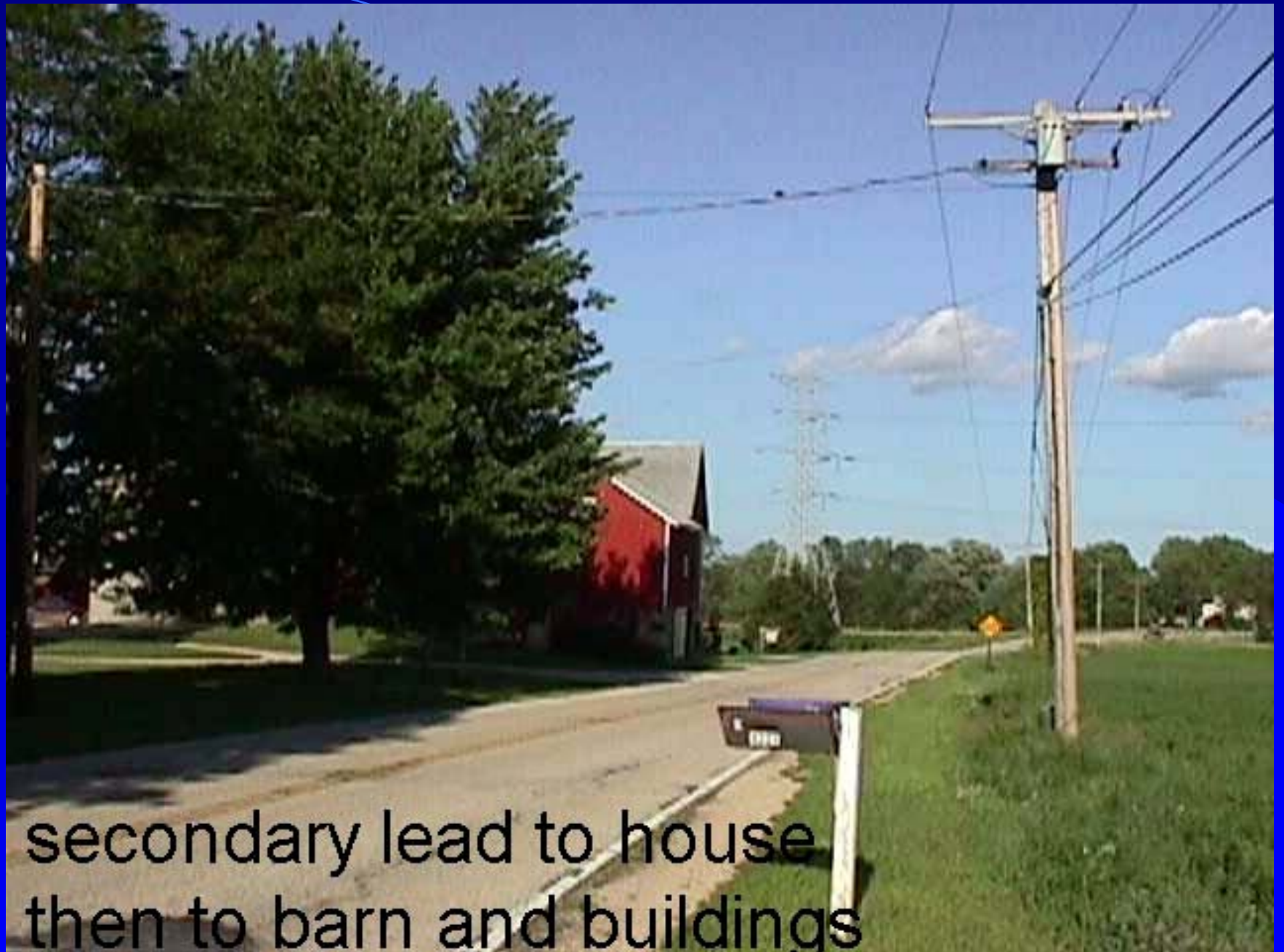


Fig. 2. Resistance in secondary neutral conductor and connections.

R_E = calculated resistance. R_C = corrected resistance.



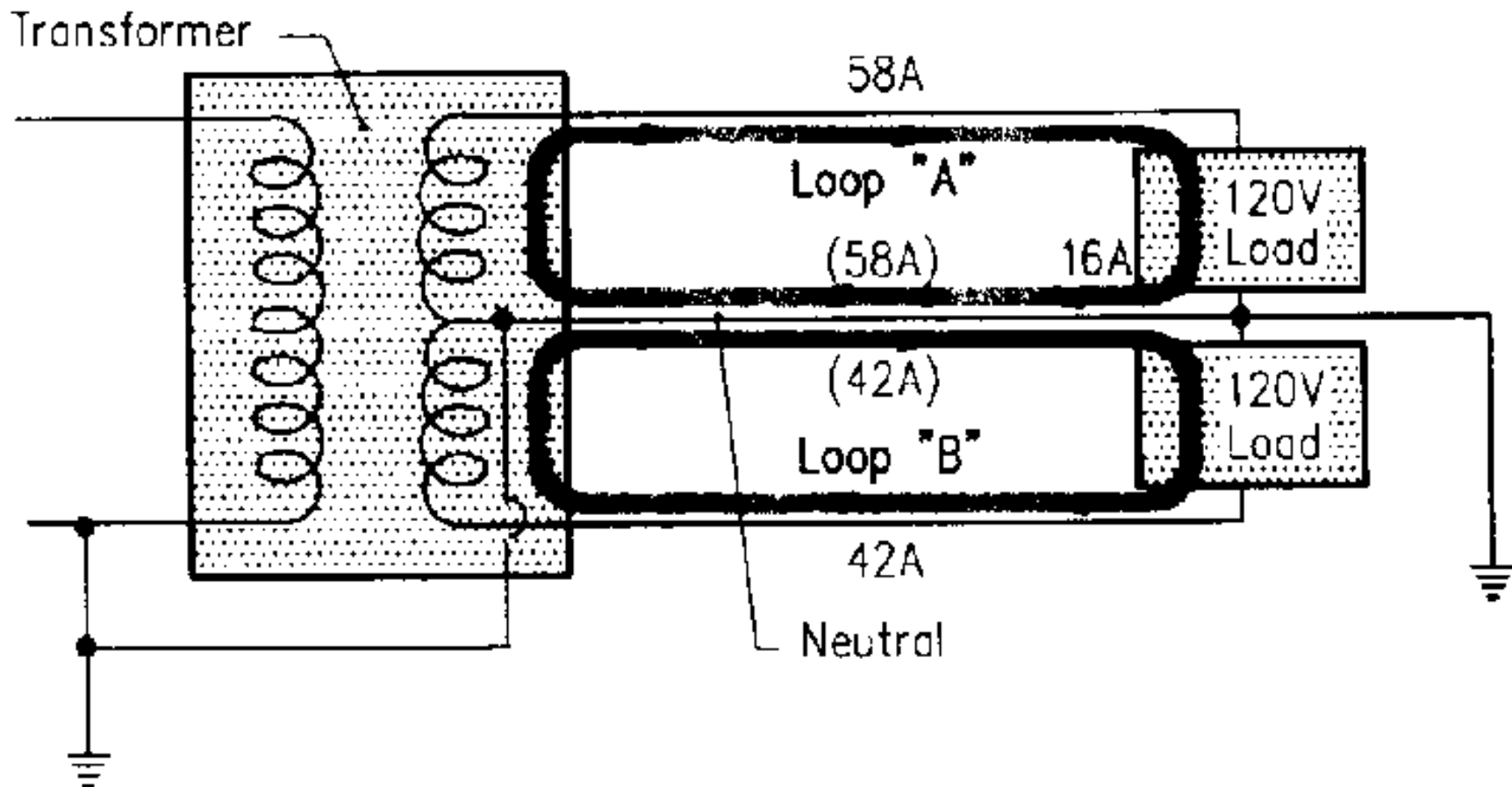
secondary lead to house
then to barn and buildings



EXT CORD
FROM THIS
BLDG

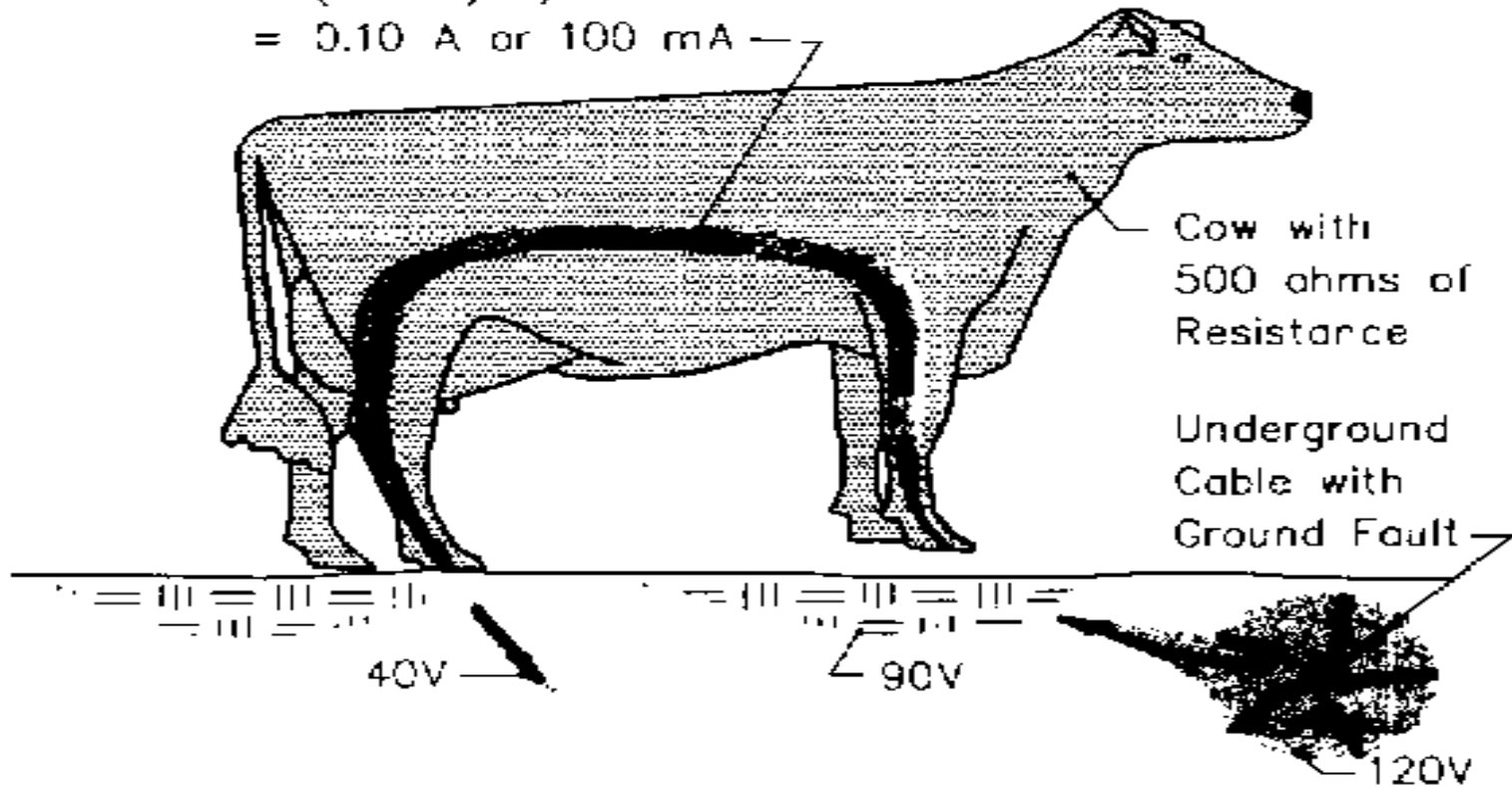
MACHINE SHED

UNBALANCE 120 V LOADS



UNDERGROUND GROUND-FAULT

$$\begin{aligned}\text{Amperage} &= \text{Voltage/Resistance} \\ &= (90-40) \text{ V}/500 \text{ ohms} \\ &= 0.10 \text{ A or } 100 \text{ mA}\end{aligned}$$



FACTS OF UNIVERSAL LAW

→ All currents return to their source.

→ All paths have resistance.

→ Therefore, some primary and secondary Neutral-to-Earth, as well as cow-contact voltage, will exist.

→ These voltages can be reduced, but...

- By how much?
- Cost vs. Benefit?

What's is Stray Voltage?

- The correct definition of what stray voltage is: "Stray" voltage is a special case of voltage in which the neutral-to-earth voltage is present across points (generally grounded metal objects) in which a current flow is produced when an animal comes into contact with them. ...these contact points can include any two conductive points, which the animal may simultaneously contact to complete a circuit, which allows current to flow. Stray voltages are low-level voltages and should be distinguished from painful shocks felt by humans

Other important issues.....

- The “stray” voltage is measured as AC rms, 60 Hz, steady state.
- In the Commission docket 05-EI-115 order, the value for ‘level of concern’ was increased from 1 milliamperes to 2 milliamperes AC RMS 60 Hz, steady state. This is a very conservative, preventive level, below the point where moderate avoidance behavior is likely to occur and well below where a cow's behavior or milk production would be harmed.

You should know that.....

- You should know that investigators can expect to find 2 mA or less on 88% of all farms investigated... About 2% of the investigations will yield values higher than 6 mA.

Perception of Stray Voltage?



Understanding Stray Voltage

- **Read the Press?**
- **Private Consultants?**
- **Ask Farmers?**
- **Watch the Cow?**
- **Government Agencies?**
- **Electrical Industry?**
- **Laboratory testing?**
- **Field studies?**

Read the Press?

- **The Victim Syndrome?**
- **Factionalizing for Effect?**
- **Controversy for Effect?**

- **Beware of statements claiming:**
 - **Nothing is being done?**
 - **We've tried everything and nothing works**

Private Consultants?

- **Inclusive or Exclusive?**
- **Industry Standard Testing?**
- **Provides Report & details of charges**

Ask the Farmer?

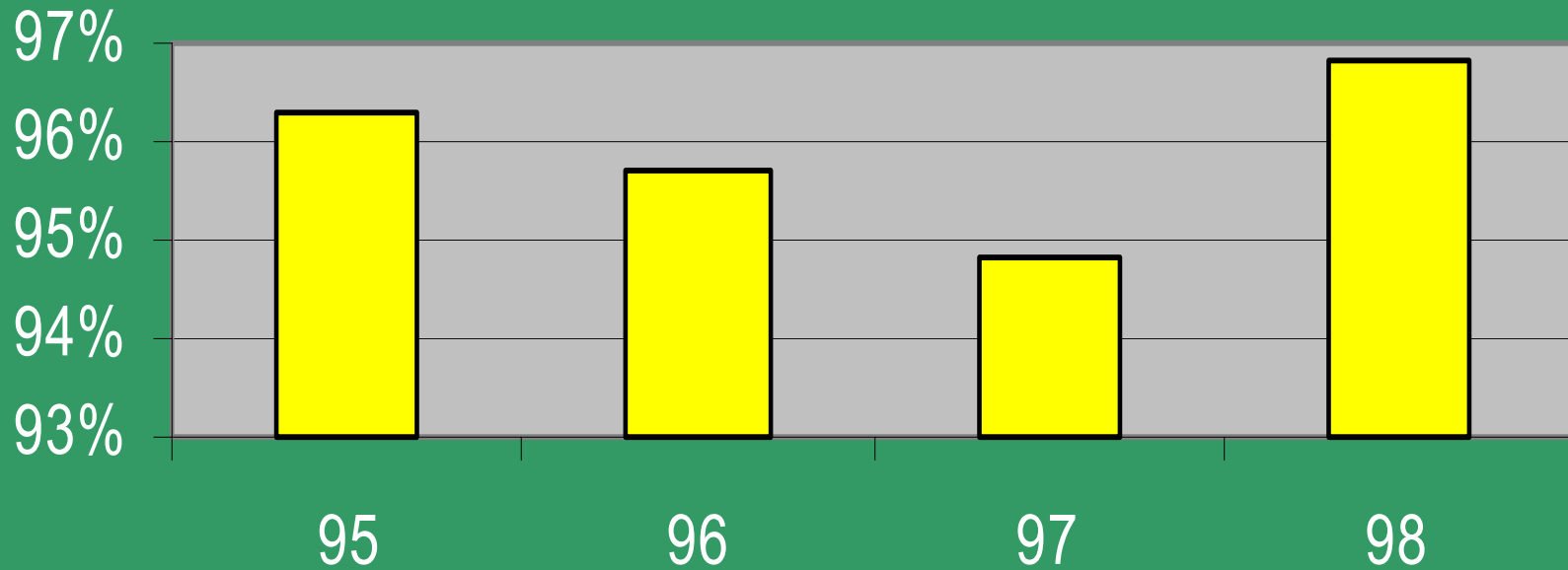
- **Individual**
- **Farm survey(2500 dairy farmers in WI and MN)**
- **Response to Service(95-98)**

Ask the Farmer?

- **60% have been tested**
- **30% have had SV**
- **85% were satisfied**
- **10% presently with a SV concern**

Ask the Farmer?

% Satisfaction with 723 SV investigations (Alliant Energy)



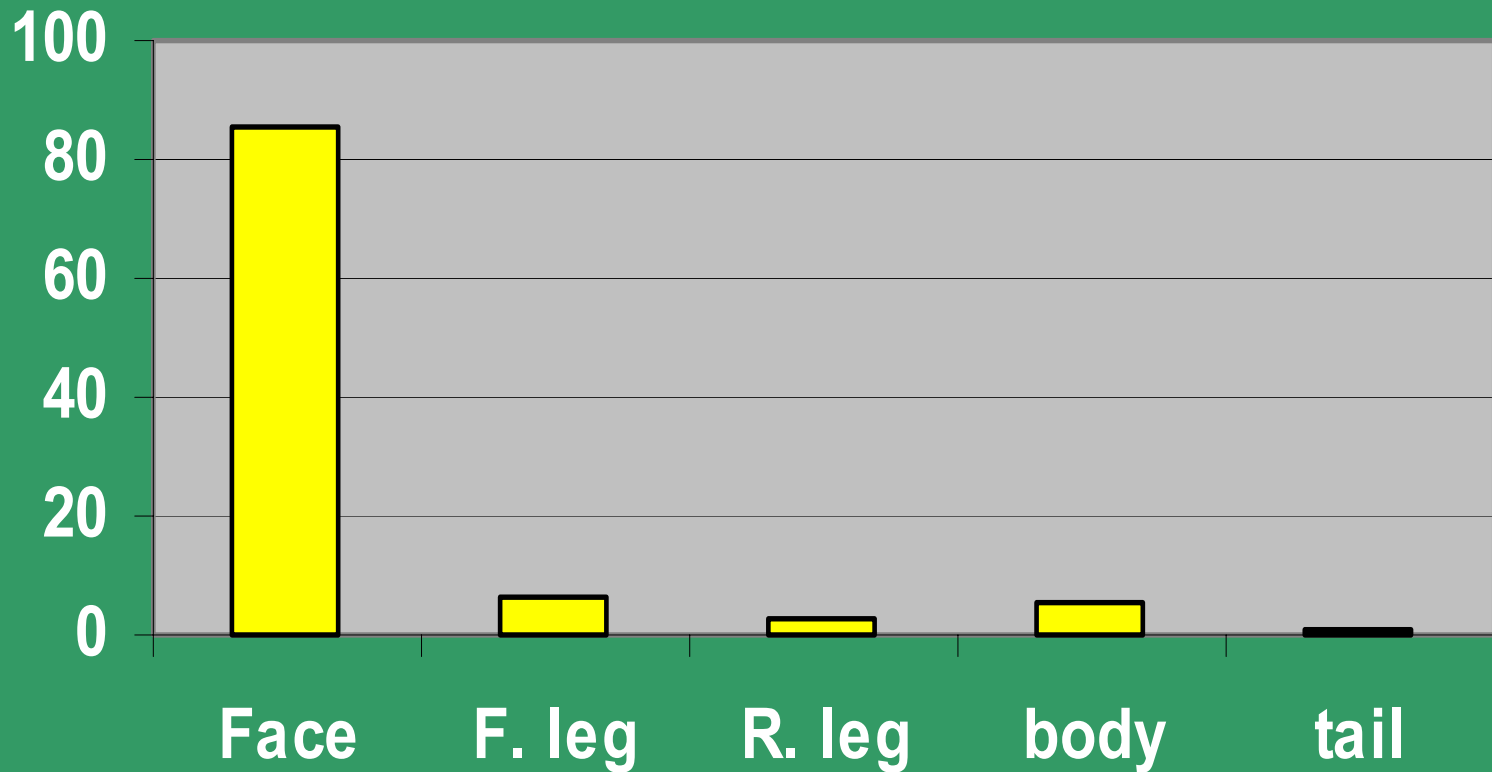
Watch the Cows?

- Tail Switching?
- Lapping of Water?
- Nose Pressing?
- High SCC?
- Self Destructive Syndrome?
- Immune Failure?
- Water Consumption?
- Reluctance to Enter?

**Is Tail Switching an indication
of Stray Voltage?**

What does the Cow Tells Us?

Relationship of Behavioral Responses to Voltage



Case Studies: Tail Switching

- **Origins**
- **Vocal Recordings**
- **Switch Cows**

WHAT IS THE MESSAGE : TAIL SWITCHING

BELLOWING OF YOUNG STOCK
NEXT TO MILKING BARN
STIMULATED ACTIVE
TAIL SWITCHING
IN COWS



FEED NEEDS TO BE PROVIDED
DURING MILKING

WHAT IS THE MESSAGE : REPETITIVE LAPPING



WHAT IS THE MESSAGE : NOSE PRESSING



Flinch, Step, Kick(FSK)

- Agitated display behavior just before, during, or just after milking.
- Expectations are that the source is something during milking
- The actual origin may not be associated with milking
- Milking may just be the trigger event for things that accumulate during the day.

WILL THE COWS TELL YOU THE ENTIRE STORY ABOUT HIGH SOMATIC CELL COUNTS?

- BULK TANK CULTURES????
- STREP. AG.????
- NMC TESTING????
- PIPELINE SLOPE????
- TESTING DURING MILKING????

WILL THE COWS TELL YOU THE ENTIRE STORY ABOUT HIGH COW LOSSES?

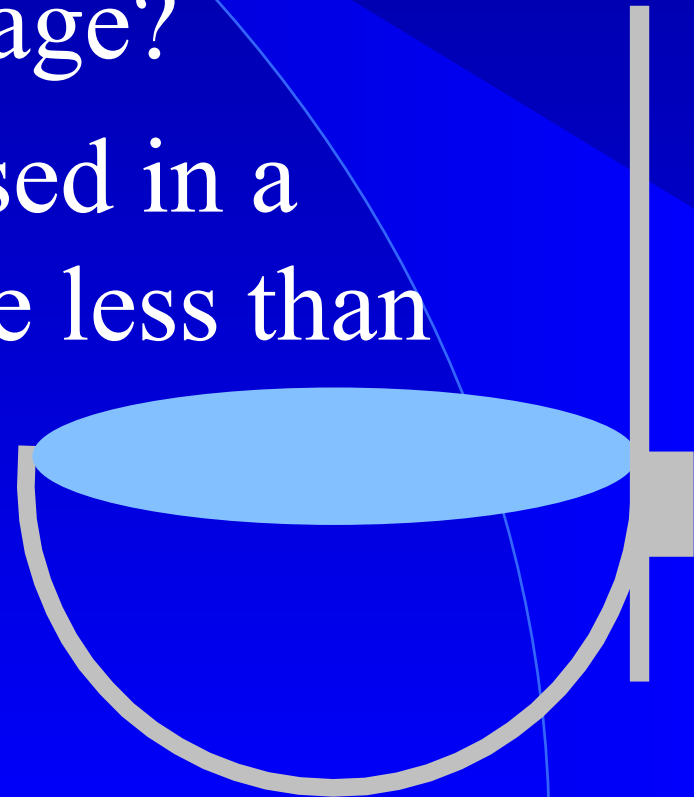
- POST MORTEM????
- ACIDOSIS TESTING????
- NEFA TESTING???
- COW COMFORT ISSUES????

Immune Failure?

- **Easy to blame**
- **Hard to prove**
- **Look closely at chronic risks:
Acidosis, Cow
comfort(standing time on
concrete)**

TRUE or FALSE?

- If water intake is depressed it could be a sign of Stray Voltage?
- Water intake is depressed in a dairy herd if intakes are less than 30 gallons/cow/day?
- 20gallons/cow/day???

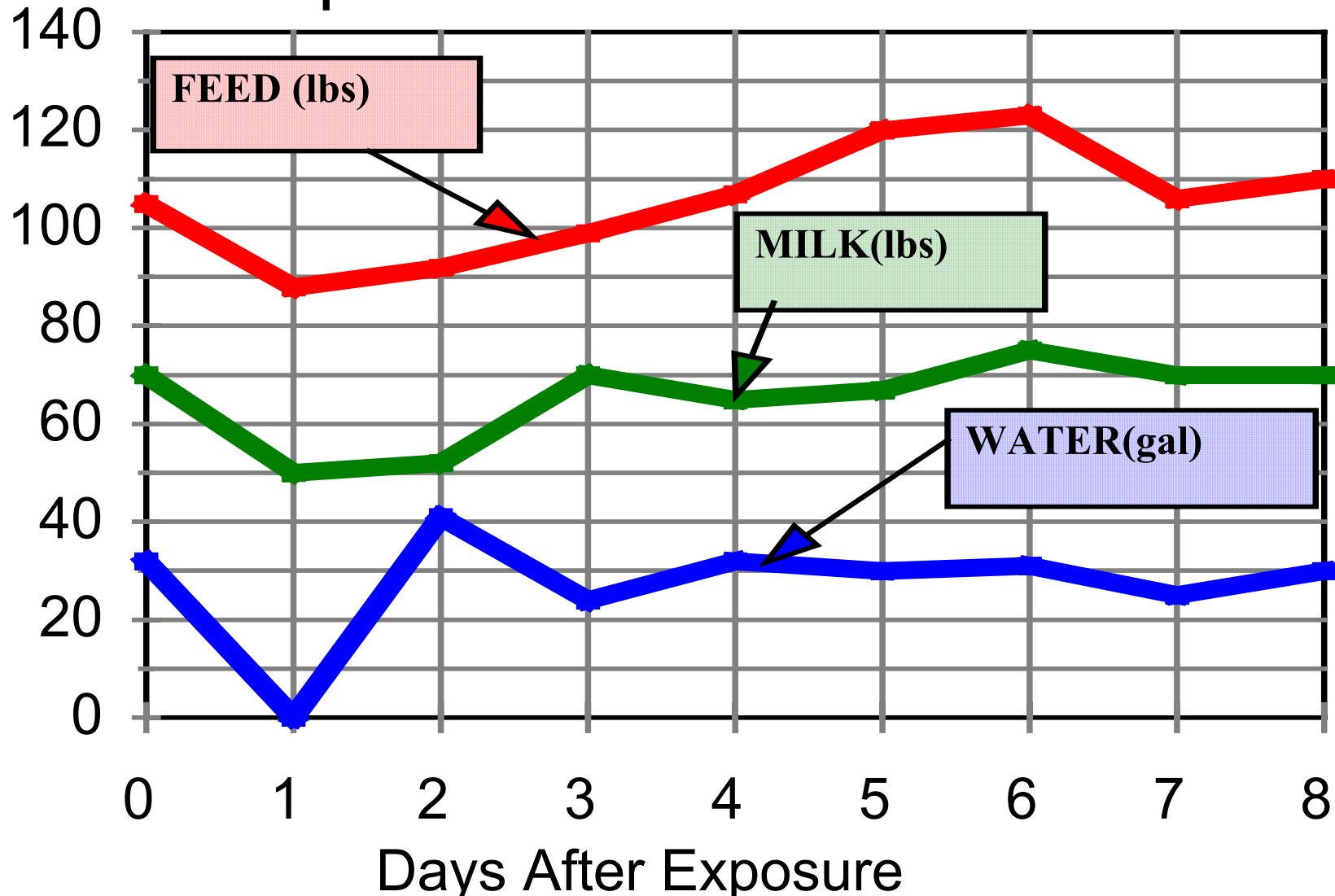


FIELD DATA ON WATER INTAKE 26 HERDS

	MILK PROD. (lb/cow/day)	MEASURED INTAKE (gallons)	CALCULATED INTAKE (gallons)	DIFF- ERENCE
ABOVE 0.5V	54	19.9	20.4	0.5
BELOW 0.5V	52	20.1	20.4	0.3
DIFFERENCE		0.2	0	

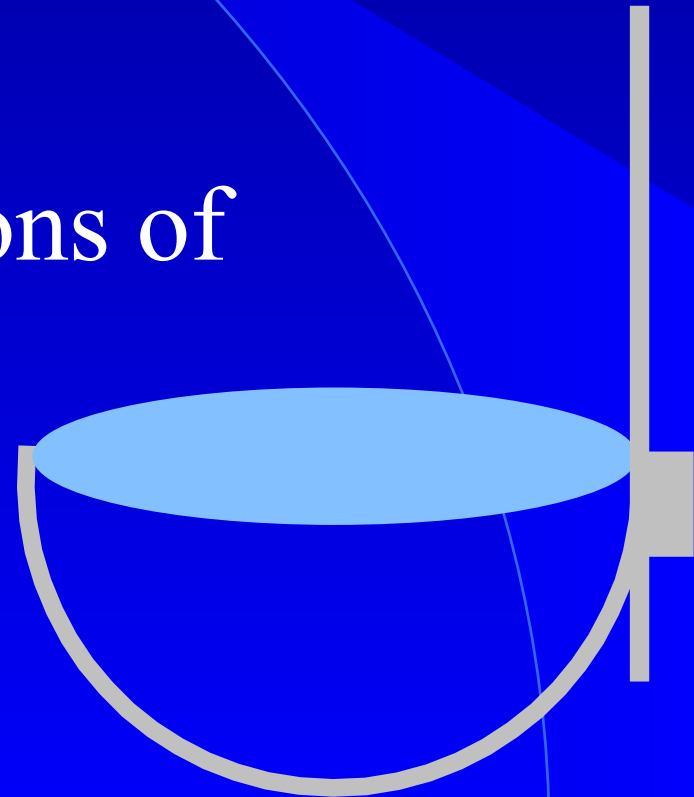
Intakes with SV

adapted from Reinemann



WATER CONSUMPTION?

- Abnormal Behavior does not usually mean decreased consumption
- -Consider the Implications of Source
- -Thirst is a powerful drive



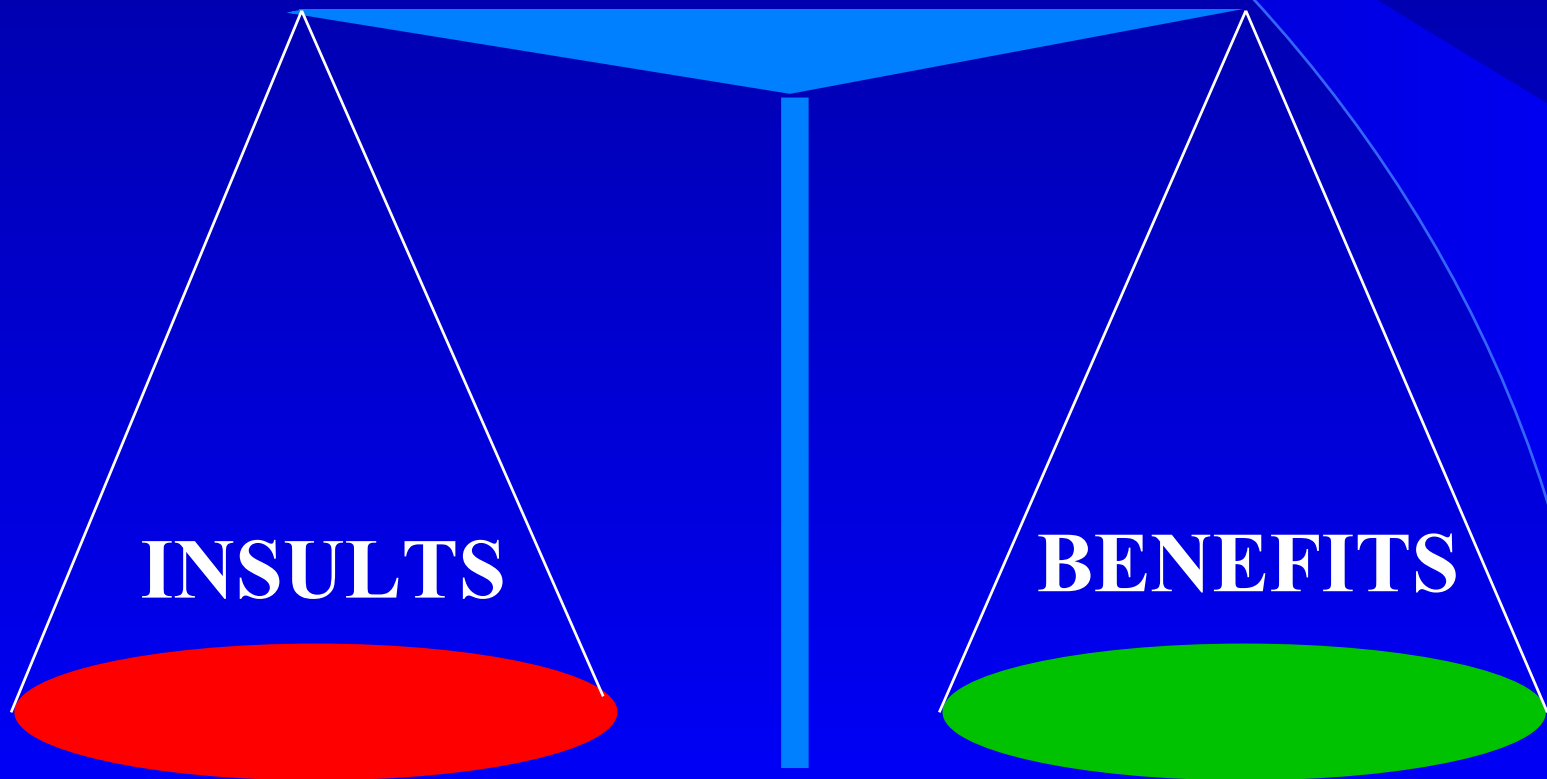
WHAT IS THE MESSAGE : RELUCTANCE TO ENTER



Response of Cows To Different Handling Treatments (Seabrook, 1994).

Action of Cow	Pleasant Handling	Adverse Handling
Parlor Entry Time	9.9 sec	16.1 sec
Flight Distance	0.5 m	2.5 m
Dunging in Parlor	3.0 / hr	18.2 / hr
Approach Humans	10.2 / min.	3 / min.

THE BALANCE BETWEEN HAZARDS AND BENEFICIAL FORCES INFLUENCES SYMPTOMS



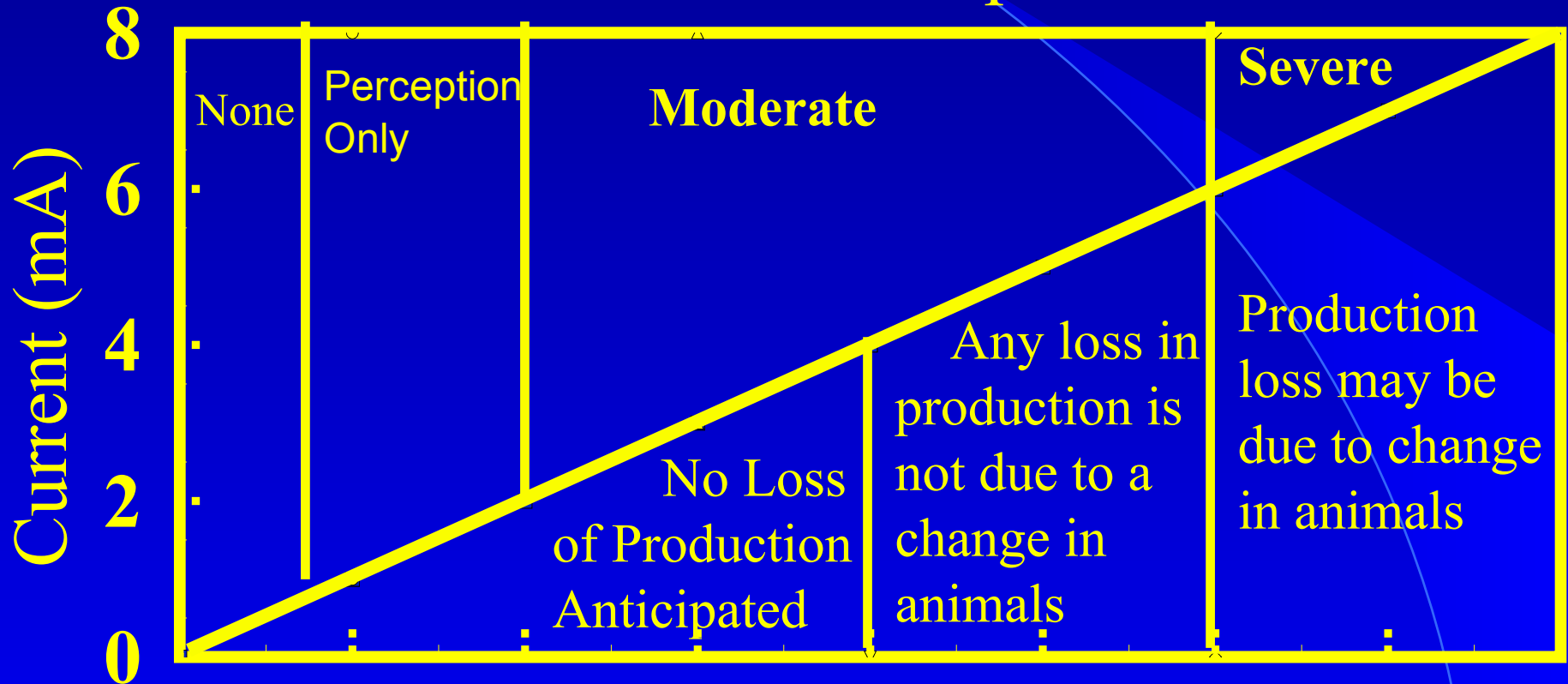
Frustration
is created and increases
when farmers are trying to
understand things and
make decisions without
adequate information

Will You Really Get Enough
Information From Watching The
Cow?

**What Do We Know
About the Relationship
Between Cows and the
Electricity They May Be
Exposed To ?**

USDA Cow Response Summary (60 Hz Steady State AC)

Behavioral Response



Milk Production Response

PSC in Definition

- Between two points a cow can contact
- 2 milliamp steady state, AC current through a 500 ohm resistor = 1.0 volt
- Over 1 ma(0.5volts)from utility requires action
- 6 ma may be more appropriate
- Isolation on request
- Test upon Request at no charge
- Standard test and report(farmer and PSC)

THE LEVEL OF CONCERN

- **LEVEL OF PERCEPTION IN A SMALL PERCENTAGE OF COWS, AND NOT A LEVEL OF ECONOMIC OR HERD HEALTH LOSS**

STRAY VOLTAGE IS NOT.....

▶ ELECTROCUTION
IS NOT STRAY
VOLTAGE

▶ LIGHTENING IS
NOT STRAY
VOLTAGE

▶ Stray Voltage Does Not
Cause:

▶ Burn marks

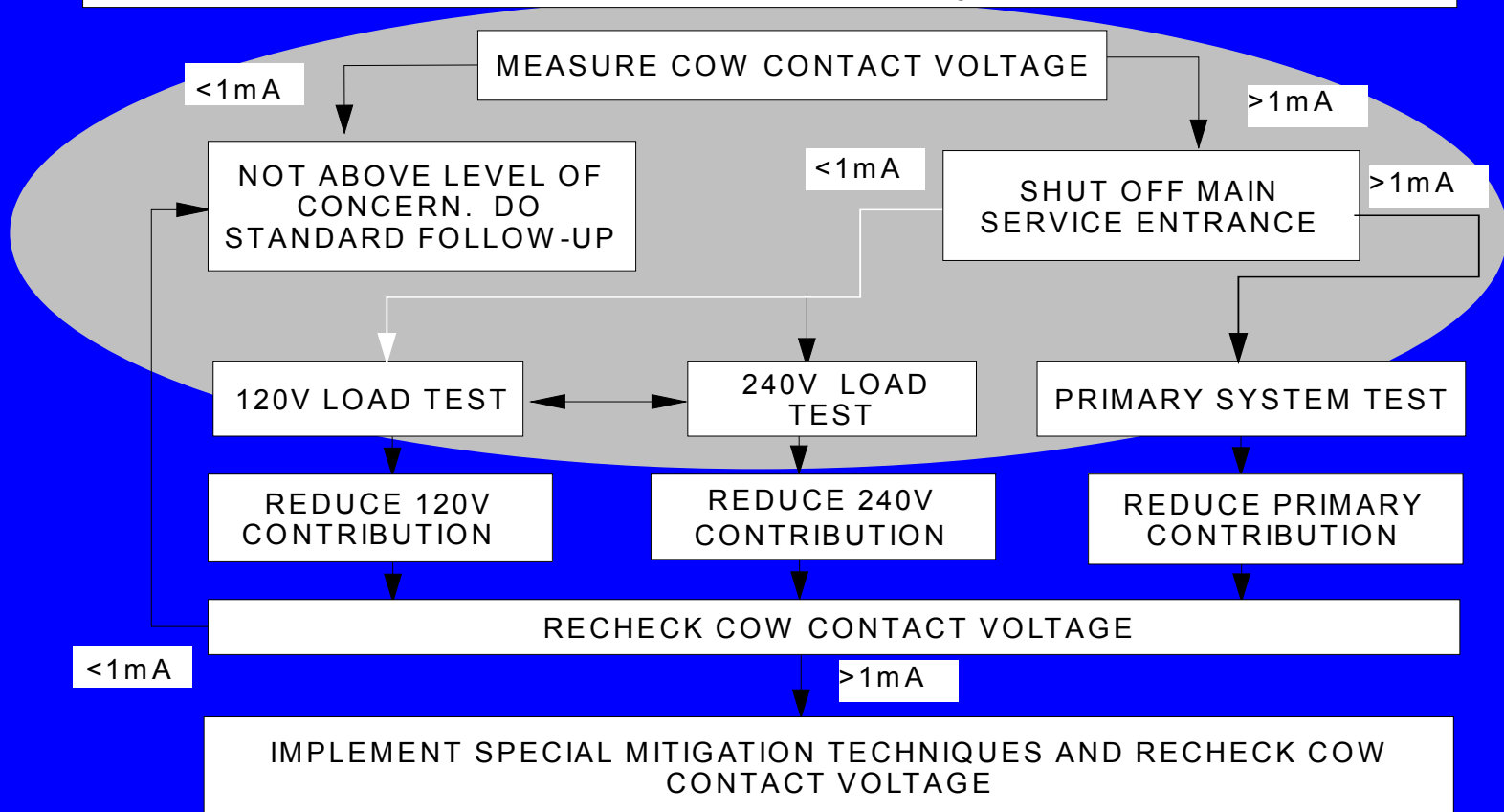
▶ Sores on hooves where
current leaves

▶ Abscesses and muscle
damage from current
passing through
tissue

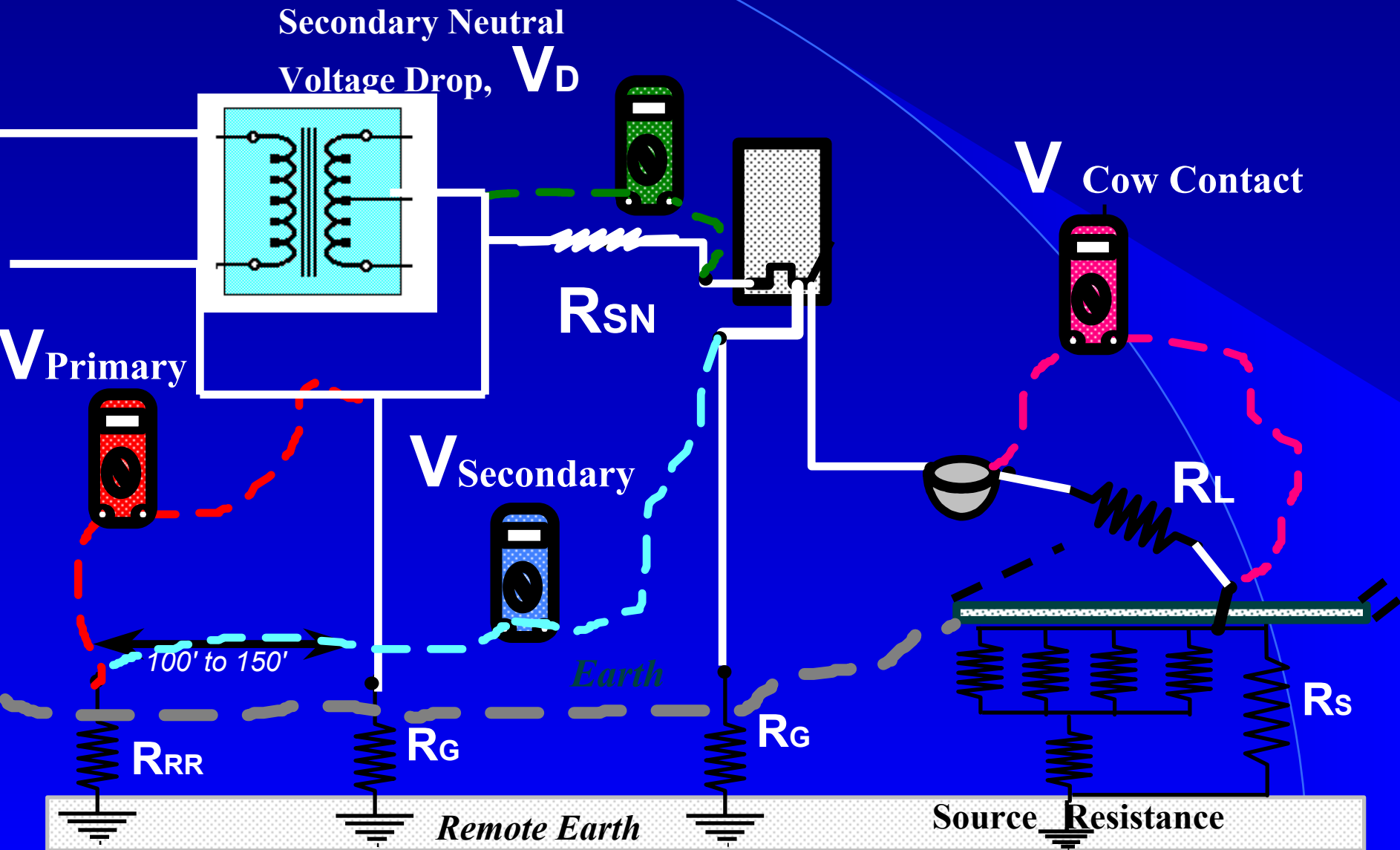
STRAY VOLTAGE IS IDENTIFIED BY ELECTRICAL TESTING

A STRAY VOLTAGE DIAGNOSTIC PROCEDURE

NOTE: PSCW LEVEL OF CONCERN: 1mA through 500 ohm resistor = 0.5V



COW CONTACT VOLTAGE MEASUREMENTS:



Example Case #1:

M = Measured Demand

E = Estimated Demand

X	
E	a.m.
kW : 16	5.55 p.m.

	<u>Location of Readings in Building of Concern:</u>	V_{WO}	V_{Rsh}	mA
Animal Contacts	Waterline to Rear Hoof Area	1.08	0.26	
	Pipeline to Rear Hoof Area	0.88	0.09	
	Stanchion to Rear Hoof Area	0.92	0.21	
Bonding Tests	Service Entrance Ground to Waterline	0.02	0.02	****
	Service Entrance Ground to Pipeline	0.09	0.08	****
	Service Entrance Ground to Stanchion	0.10	0.06	****
	Service Entrance Ground to Rear Hoof Area	1.09	0.29	****
	Service Entrance Ground to Remote Ground Rod	2.06	1.77	****
	Transformer Ground to Remote Ground Rod	2.11	1.79	****
	Transformer Ground to Service Entrance Ground	0.05	0.05	****

Determining the Quality of Measurement Contacts

- **IF VOLTAGE WITH RESISTOR DROPS MORE THAN HALF OF VOLTAGE WITHOUT RESISTOR THE CONTACT IS NO GOOD, AND MEASUREMENTS MAY NOT ACCURATELY DETECT A PROBLEM**

Example Case #2:

M = Measured Demand

E = Estimated Demand

X	
E	x a.m.
kW : 12	10.45 p.m.

	<u>Location of Readings in Building of Concern:</u>	V_{WO}	V_{Rsh}	mA
Animal Contacts	Waterline to Rear Hoof Area	0.76	0.51	0.001
	Pipeline to Rear Hoof Area	0.76	0.39	
	Stanchion to Rear Hoof Area	0.76	0.44	
Bonding Tests	Service Entrance Ground to Waterline	0.01	0.01	****
	Service Entrance Ground to Pipeline	0.03	0.03	****
	Service Entrance Ground to Stanchion	0.09	0.09	****
	Service Entrance Ground to Rear Hoof Area	0.76	0.47	****
	Service Entrance Ground to Remote Ground Rod	0.72	0.50	****
	Transformer Ground to Remote Ground Rod	1.54	1.30	****
	Transformer Ground to Service Entrance Ground	0.82	0.82	****

Example Case #3:

M = Measured Demand

E = Estimated Demand

X	
E	a.m.
kW : 12	5:45 p.m.

	<u>Location of Readings in Building of Concern:</u>	V_{WO}	V_{Rsh}	mA
Animal Contacts	Waterline to Rear Hoof Area	0.75	0.53	0.001
	Pipeline to Rear Hoof Area	0.63	0.21	
	Stanchion to Rear Hoof Area	0.66	0.39	
Bonding Tests	Service Entrance Ground to Waterline	0.08	0.08	****
	Service Entrance Ground to Pipeline	0.42	0.06	****
	Service Entrance Ground to Stanchion	0.10	0.08	****
	Service Entrance Ground to Rear Hoof Area	0.74	0.52	****
	Service Entrance Ground to Remote Ground Rod	1.62	1.38	****
	Transformer Ground to Remote Ground Rod	1.40	1.21	****
	Transformer Ground to Service Entrance Ground	0.22	0.22	****

NERVES ARE STIMULATED BY ELECTRICAL CURRENT

(Natural or External)

BEYOND A THRESHOLD,
THE EFFECT VARIES WITH THE DOSE

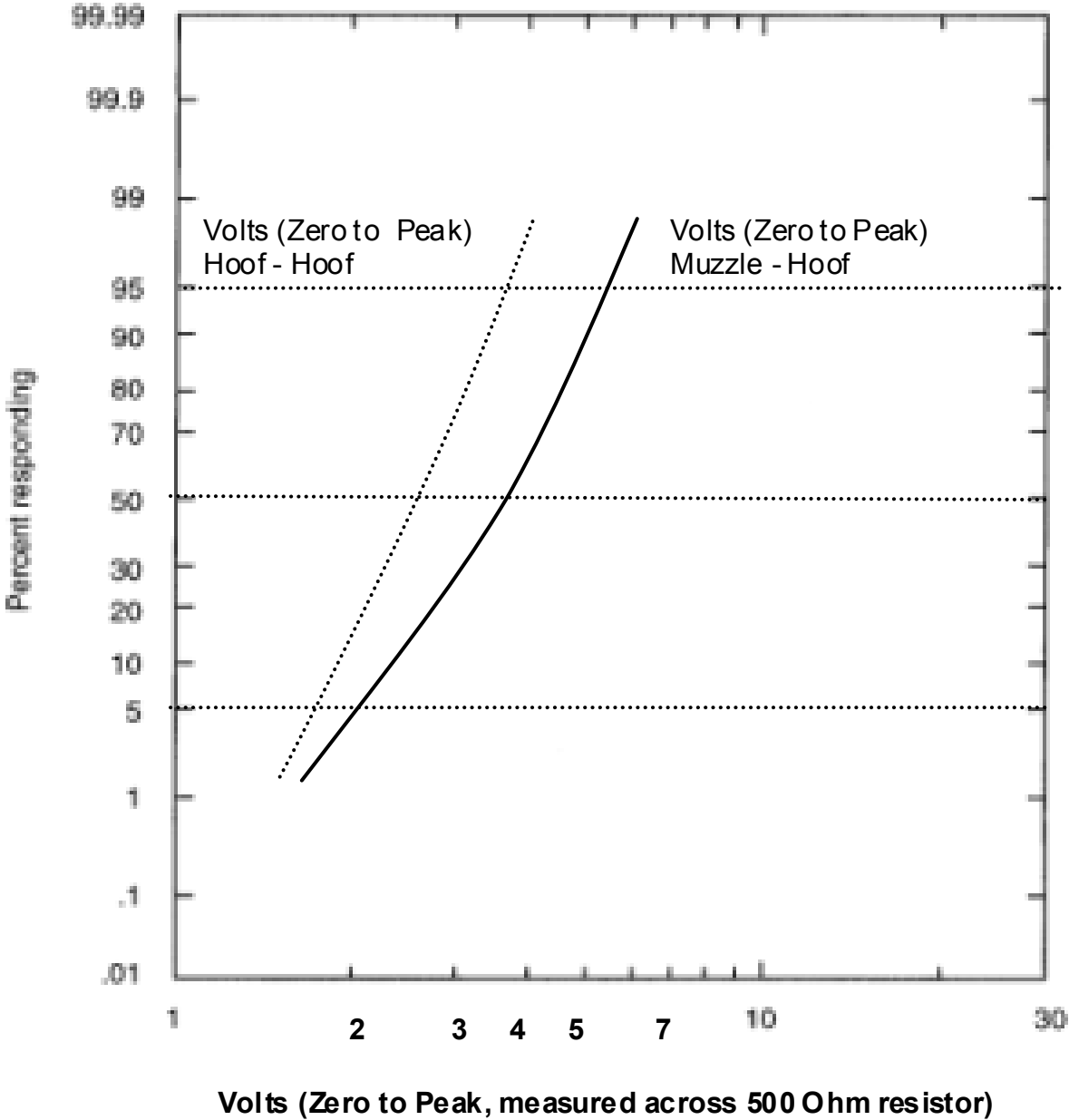
The higher the dose the more the
potential for effect

Factors Influencing the Effect of Dose

CURRENT DENSITY is influenced by the electrical pathway, the size of the animal, and the type of tissue

- Cow/Human
- Cow/Calf
- Male/Female
- Hoof /Hoof
- Muzzle/Hoof

Approximate 60 Hz Steady State Behavioral Response Distribution



Factors Influencing the Effect of Dose

CONTACT RESISTANCE

(Ohms Law: $\text{Current} = \text{Voltage}/\text{Resistance}$,)

500 Ohms is worst case

- dry contacts or bedding will increase contact resistance to 1000 Ohms or more
- Cow comfort(4” of bedding) has many benefits
- Milking unit(30-50,000 Ohms) are not a contact pathway
- Human: dry hand = 20,000 Ohms, wet = 2,000

Cows are less sensitive to current and more sensitive to Voltage

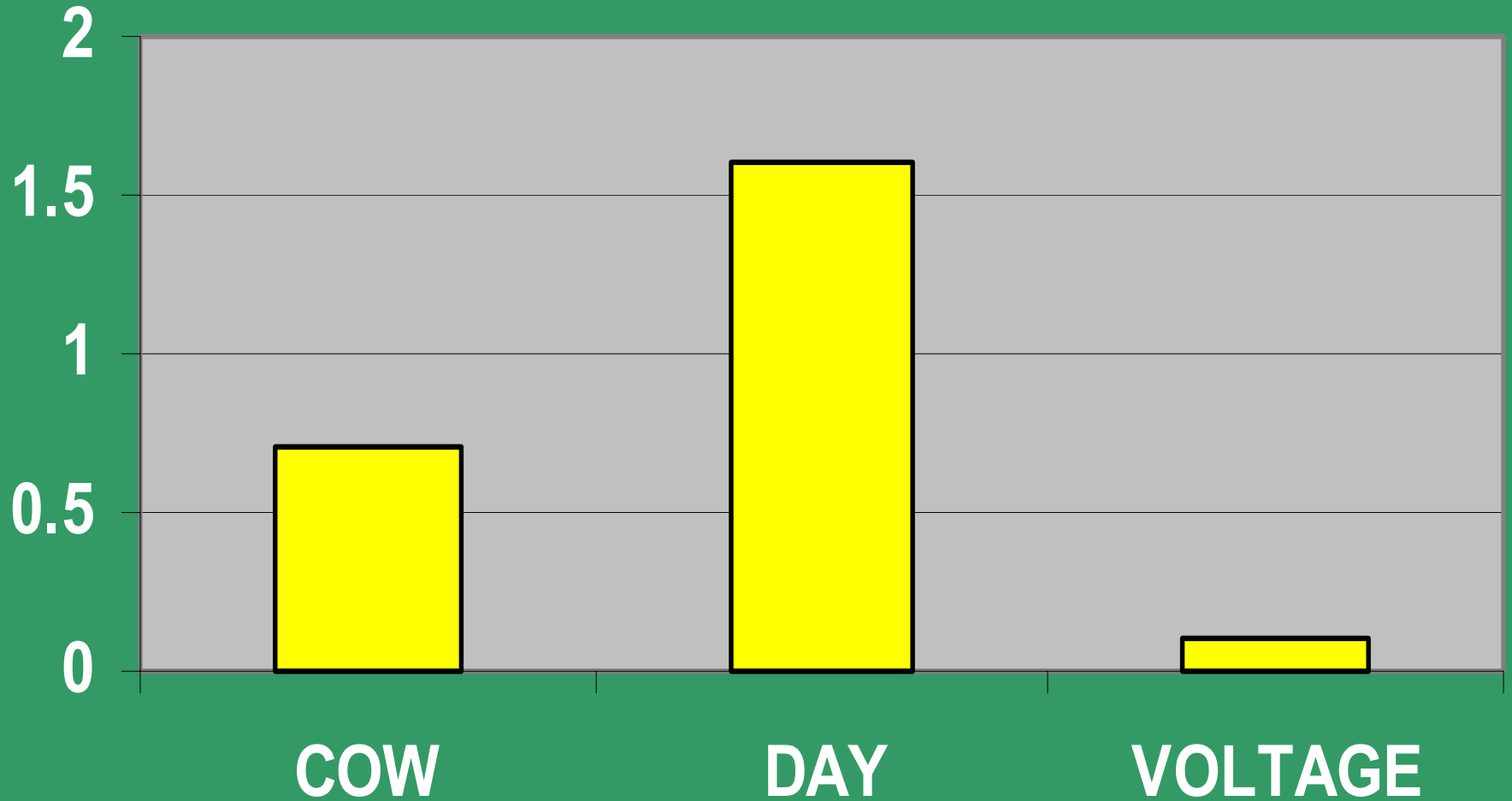
	Cows	People
60 Hz response threshold current	3.7 mA (rms)	0.45 mA (rms)
60 Hz response voltage	1.9 V (rms)	0.9–9 V (rms)

Factors Influencing the Effect of Dose

INDIVIDUAL SENSITIVITY

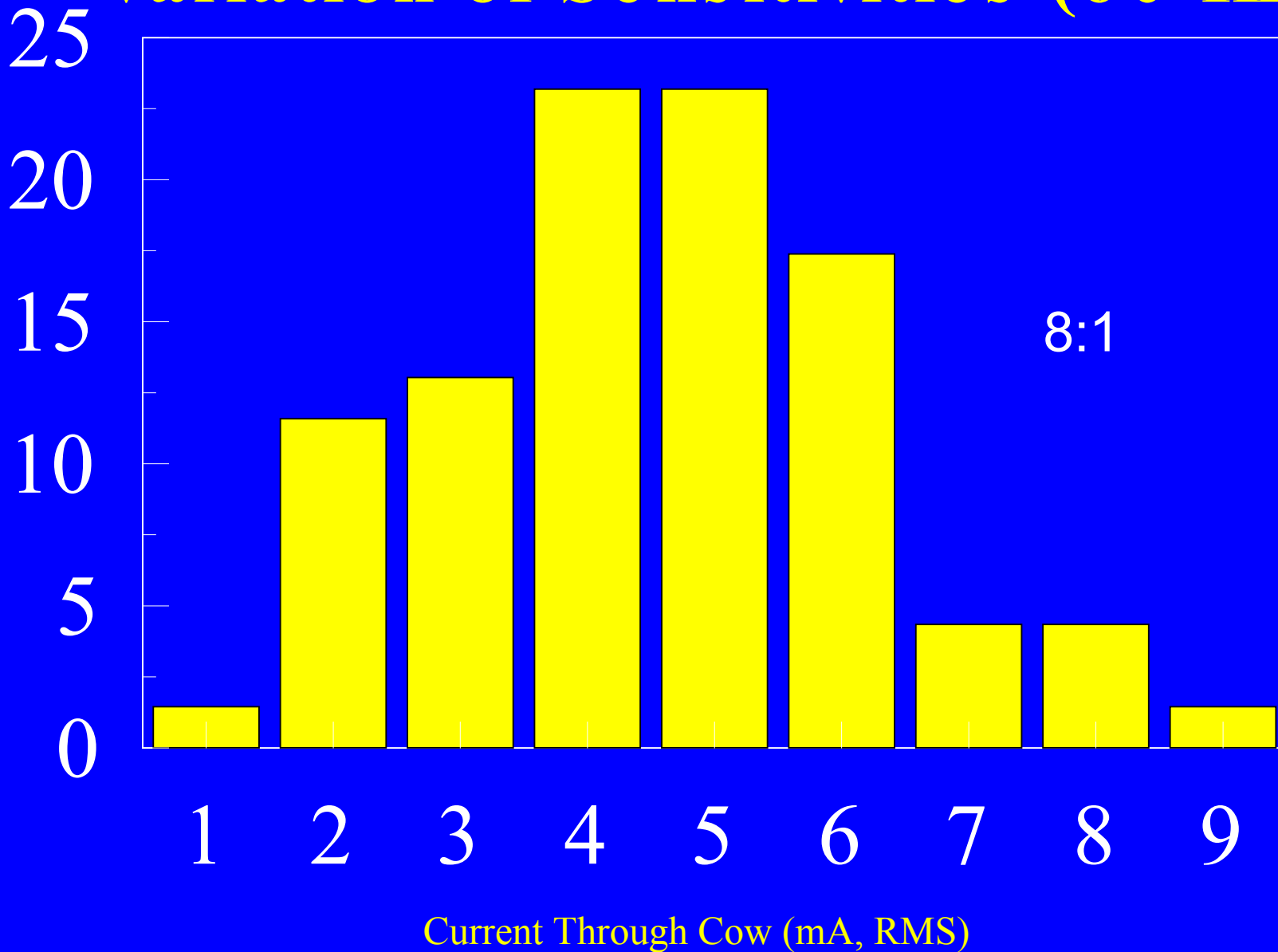
- Personality**
- Stage of Lactation**
- Age**
- Human - Animal Relationship**
- Issues of the Day**

Relative Effects on Response



% of Responses

Variation of Sensitivities (60 Hz)



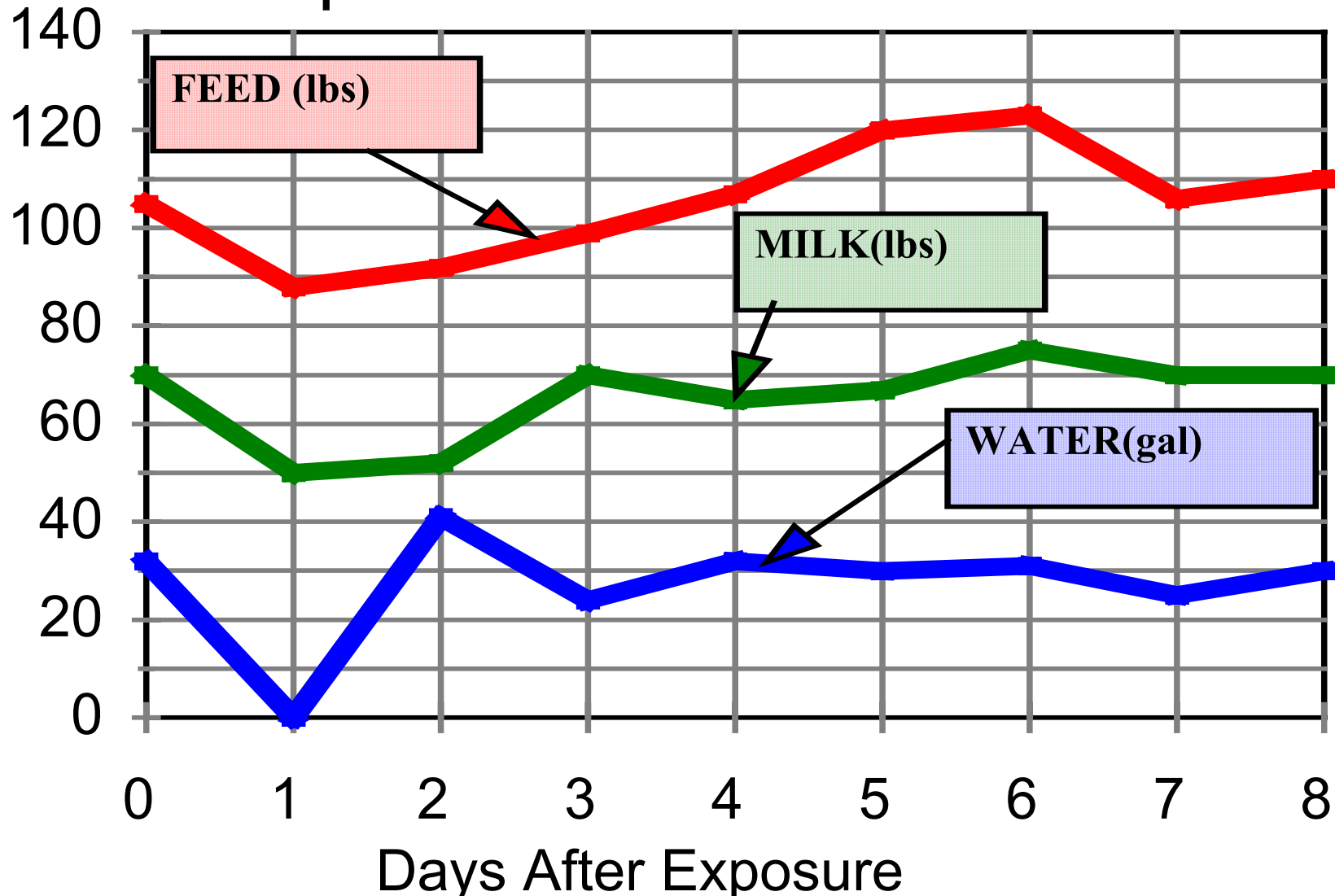
Factors Influencing the Effect of Dose

CONDITIONS OF EXPOSURE

- Adaptation occurs (predictable)**
- Avoidable sources have little effect**

Intakes with SV

adapted from Reinemann



Factors Influencing the Effect of Dose

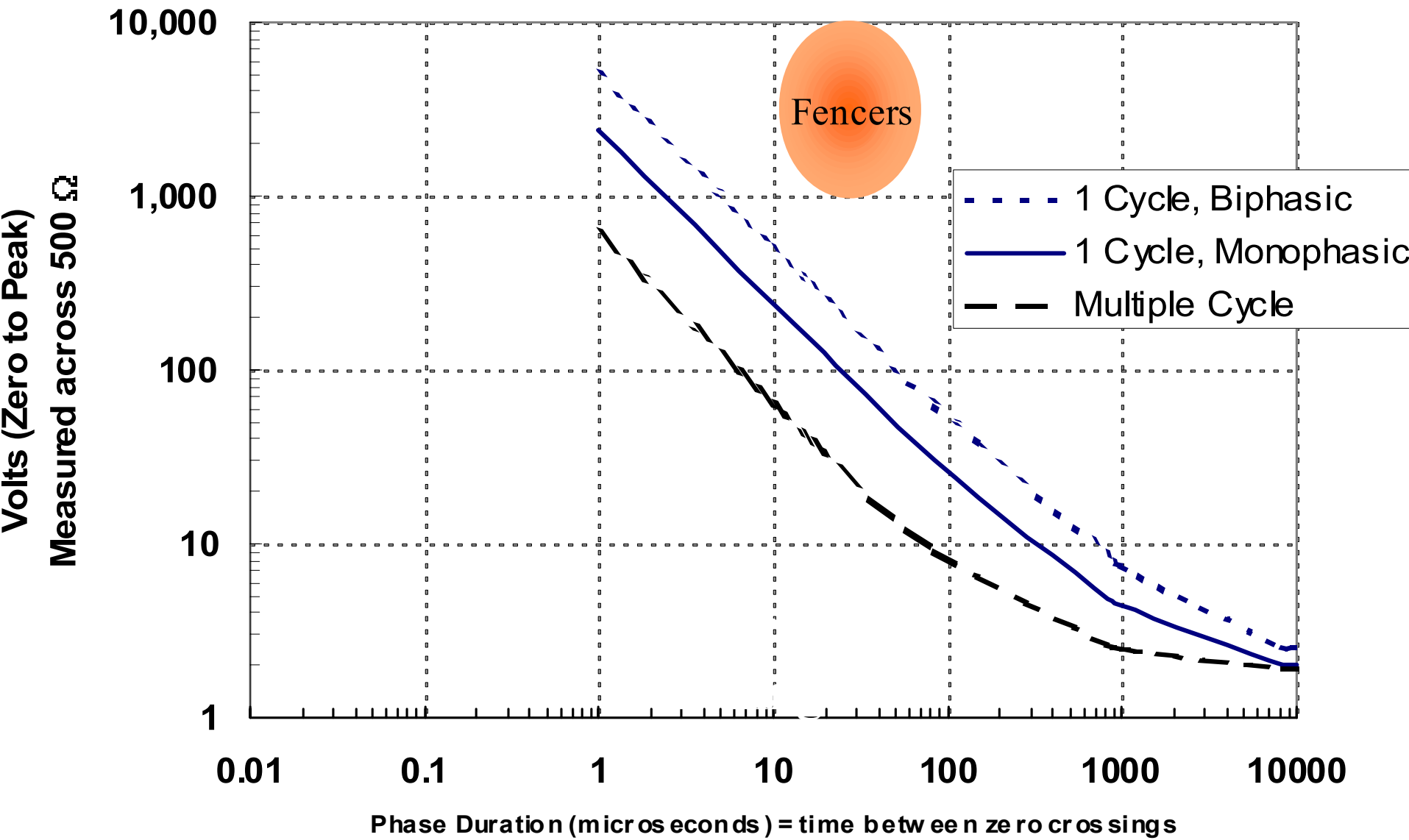
● TIME FACTORS

- Frequency: The higher the electrical frequency the more voltage or current required to have an effect**
- Single exposures are not significant or less significant than continuous exposure**

Frequency (Phase Duration)

- **Motor Starting Transient**
(8400 microseconds = 60 Hz)
- **Electric Fencer Impulse**
(20 microseconds)
- **Switching Transients**
(0.02 microseconds)

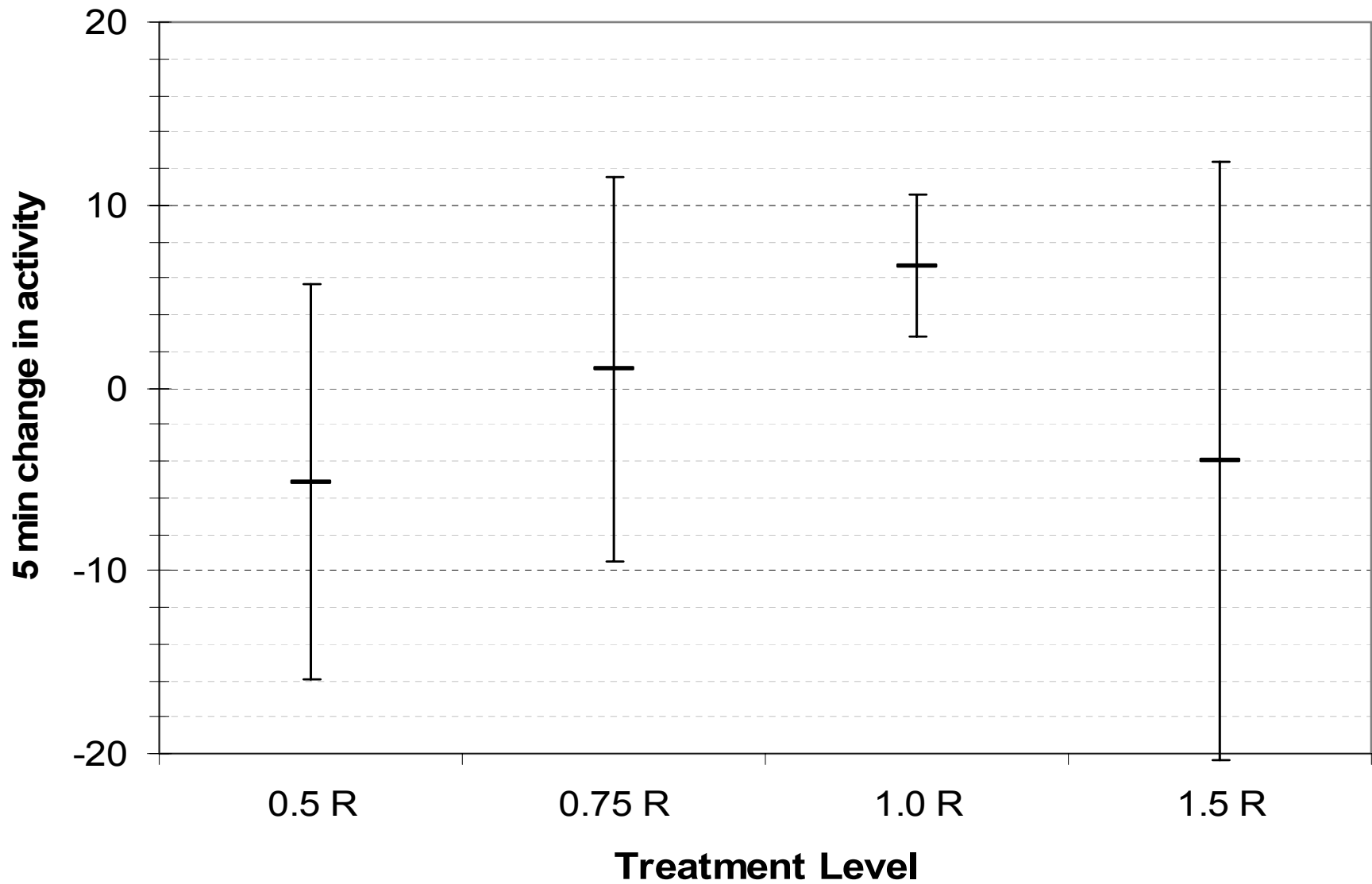
Behavioral response for 5% most sensitive cows, sine waves muzzle to hooves exposure



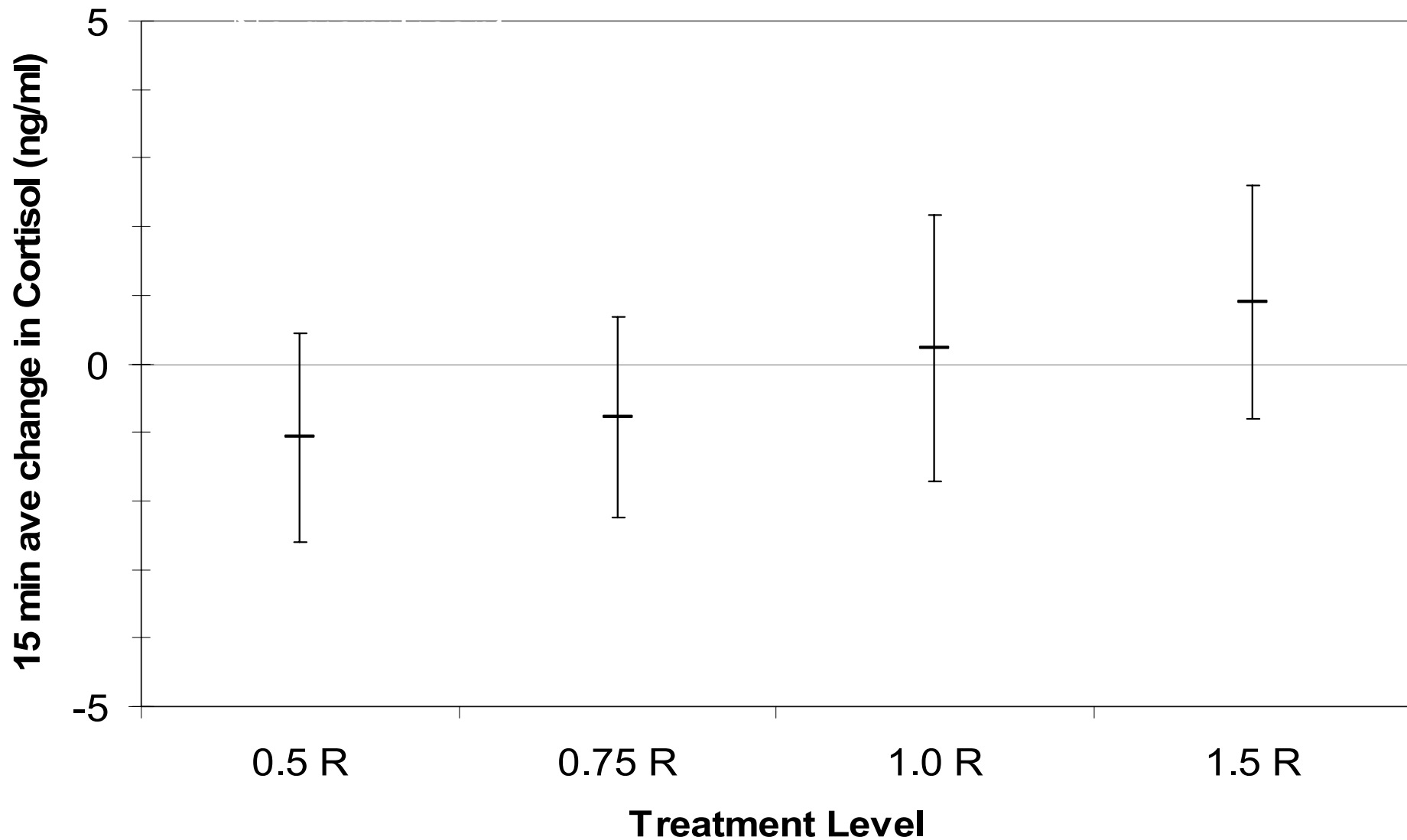
Continuous vs. Intermittent Exposure

Hrs Delay to Drink	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

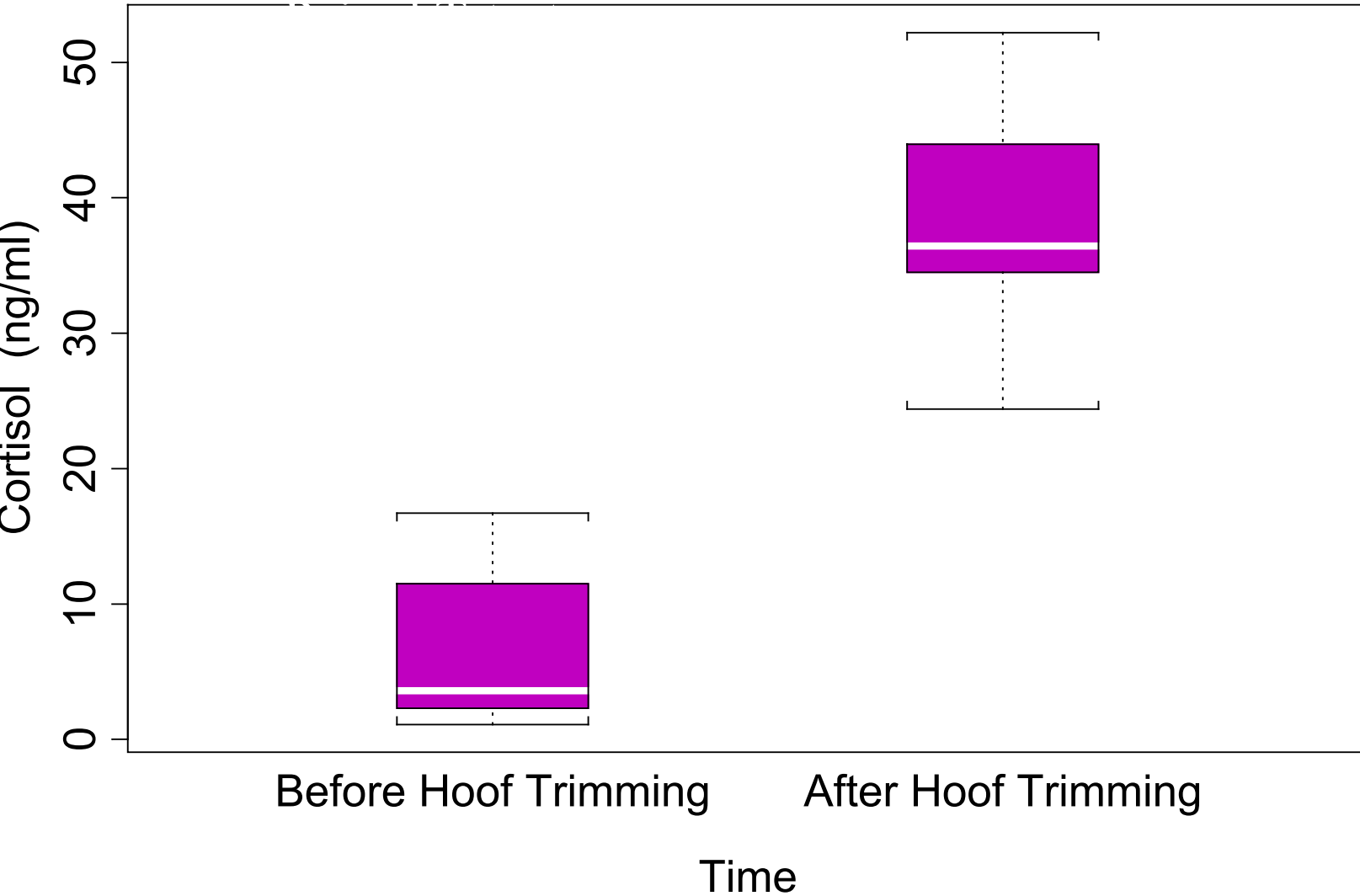
Change in cow activity in response to current exposure



Change in Cortisol concentration in response to current exposure



Hoof Trimming Cortisol Data



Immune Tests

- lymphocyte blastogenesis
- Dose responses to standard mitogens,
 - S. aureus, Phytohemagglutinin, Pokeweed Mitogen and Concanavalin A
- Chemiluminescence measure of Oxidative burst
- Interluken I
- Cortisol
- No Significant Response to tests

The Probability of Response

- **Adverse effect requires BOTH annoying current AND forced exposure**
- **Exposures below perception (1 ma) had no measured impact**
- **1.5 times level of perception is a level that aversion may occur**
- **Behavior (flinch) is primary indicator of exposure**

Field Studies on Potential for Other Effects

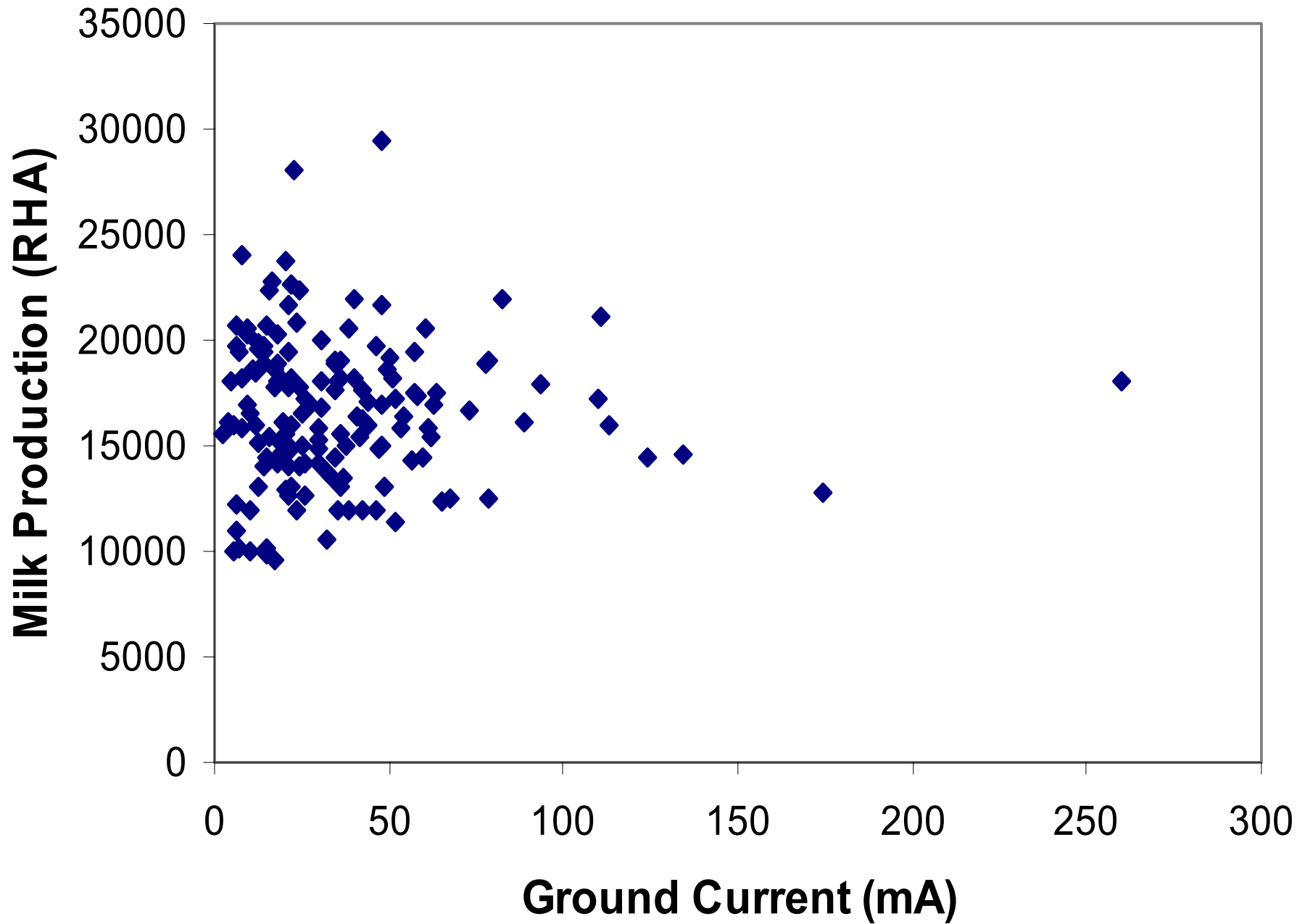
- “Electric and magnetic fields produced by currents flowing on the neutral or grounding system are not perceptible to animals or humans and are much lower than normal household exposure”
- “We have not found credible scientific evidence to verify the specific claim that currents in the earth or associated electrical parameters such as voltages, magnetic fields and electric fields, are causes of poor health and milk production in dairy herds.”

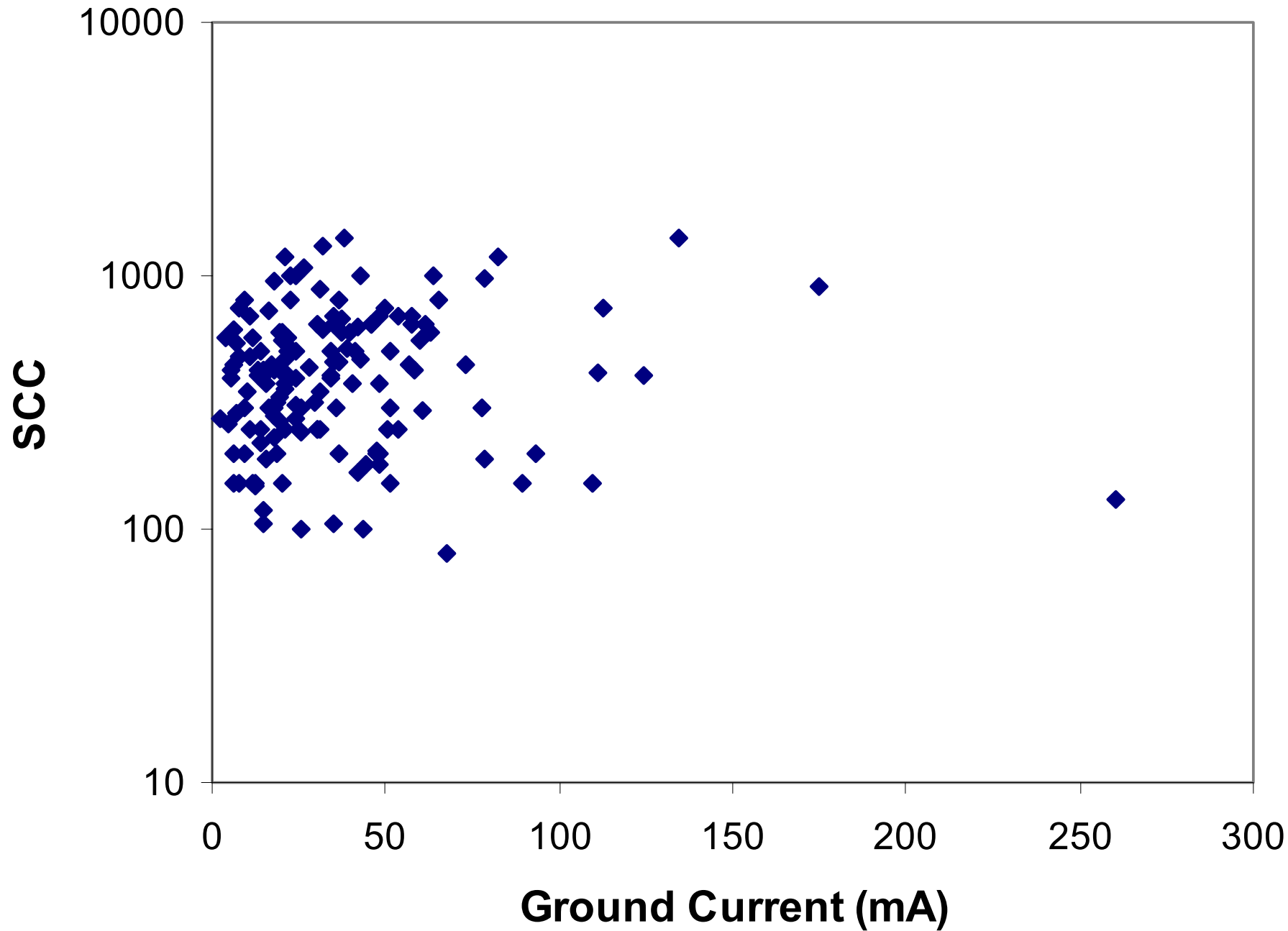
PSCW DATABASE

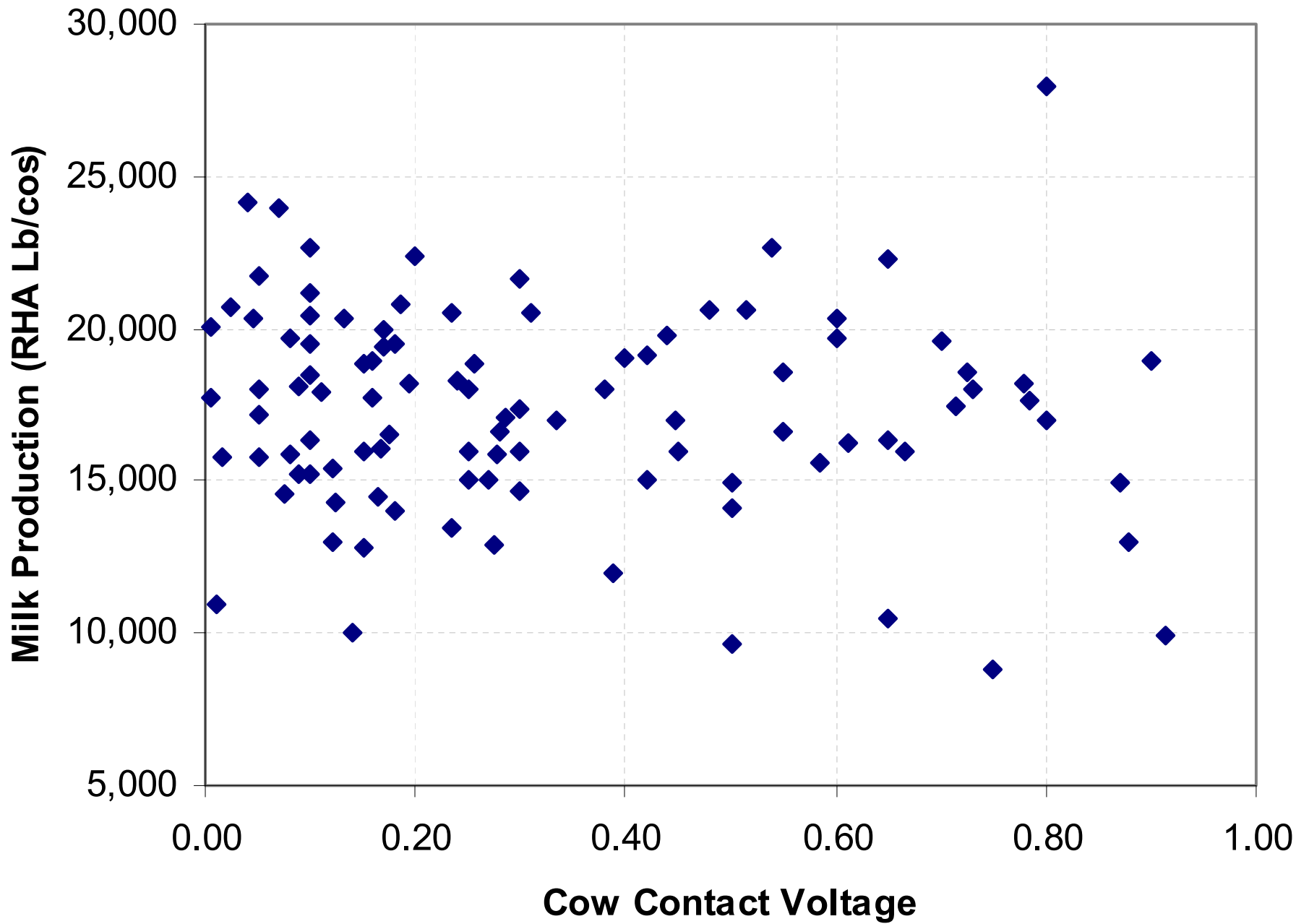
From 4321 entries
of 5 investor-owned utilities in
Wisconsin

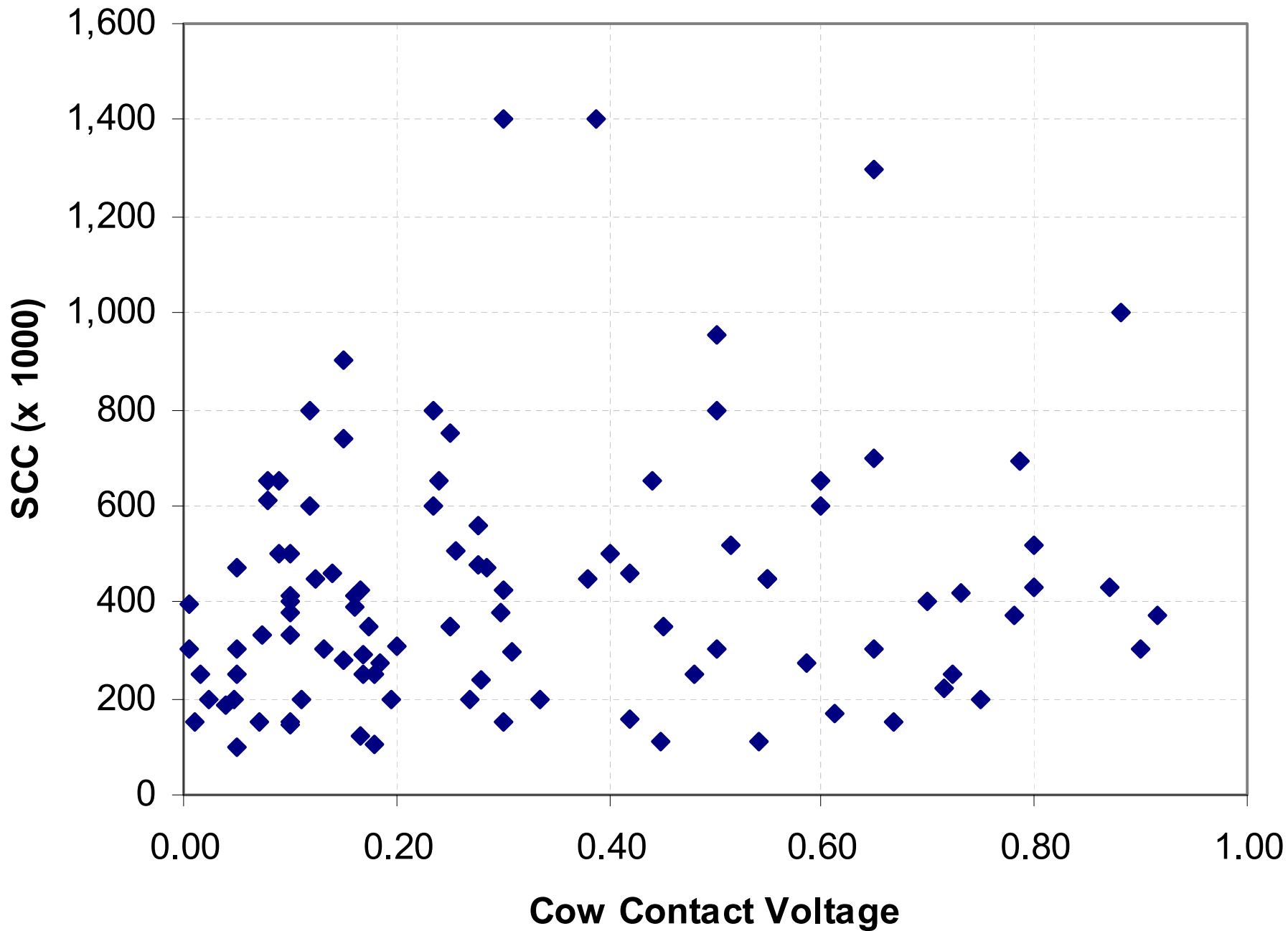
FARM PRODUCTION

- **HERD SIZE AVERAGE = 65 COWS**
(2996 FARMS)
- **PRODUCTION AVERAGE = 18126 lbs**
(2290 FARMS)
- **SCC (x1000) AVERAGE = 376**
(2739 FARMS)



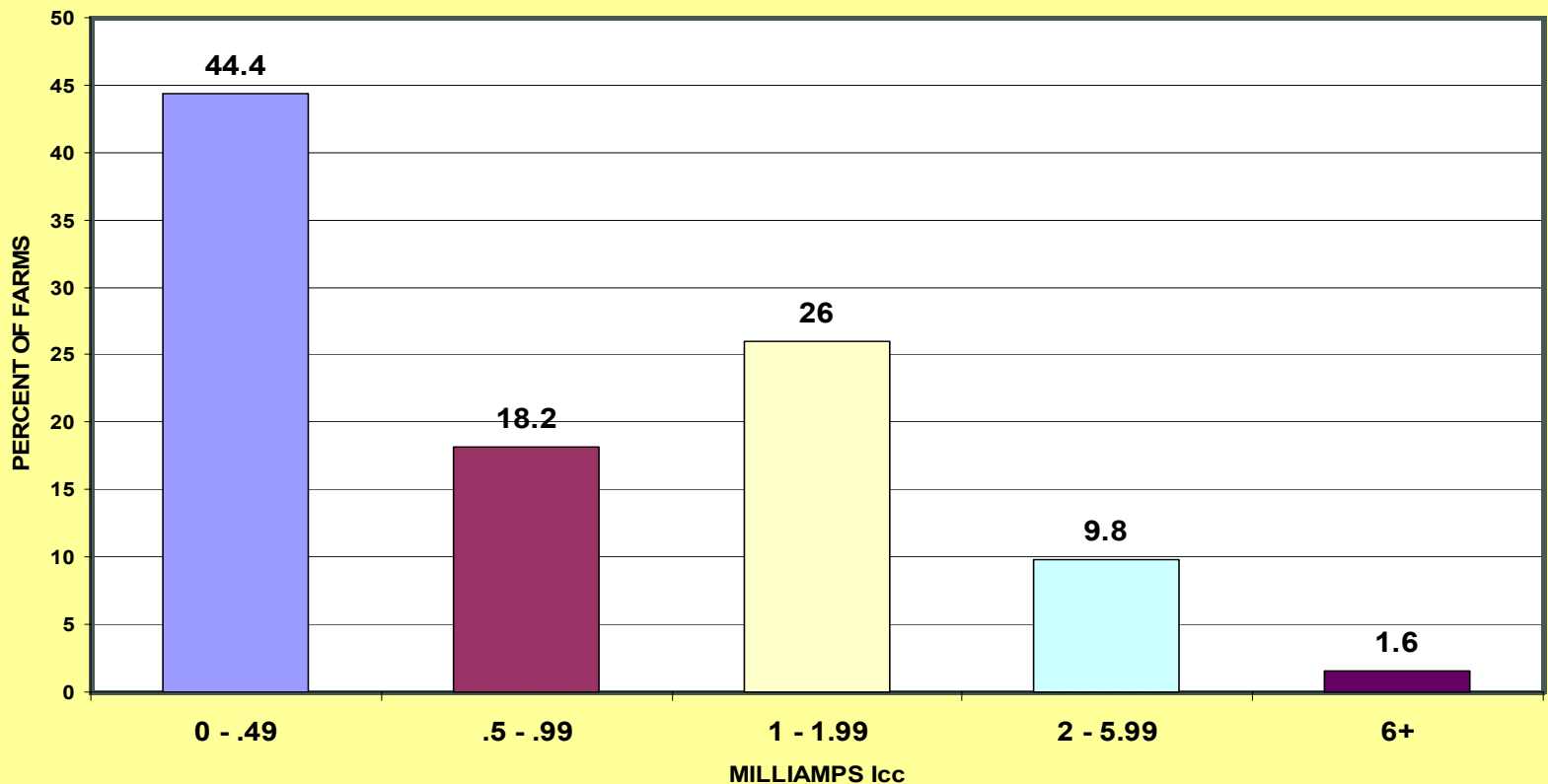






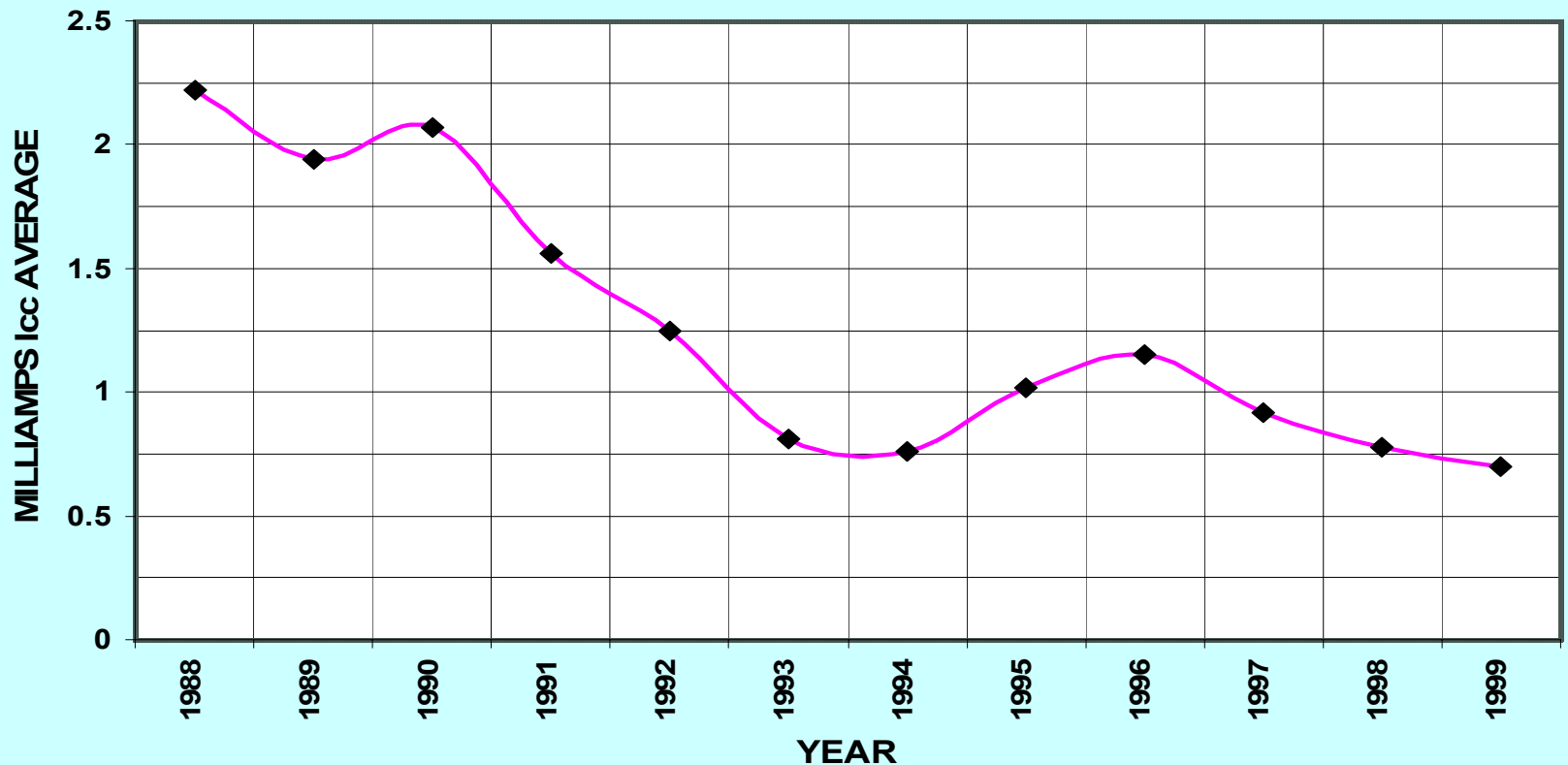
Distribution of Cow Contact Current

DISTRIBUTION OF COW CONTACT CURRENT

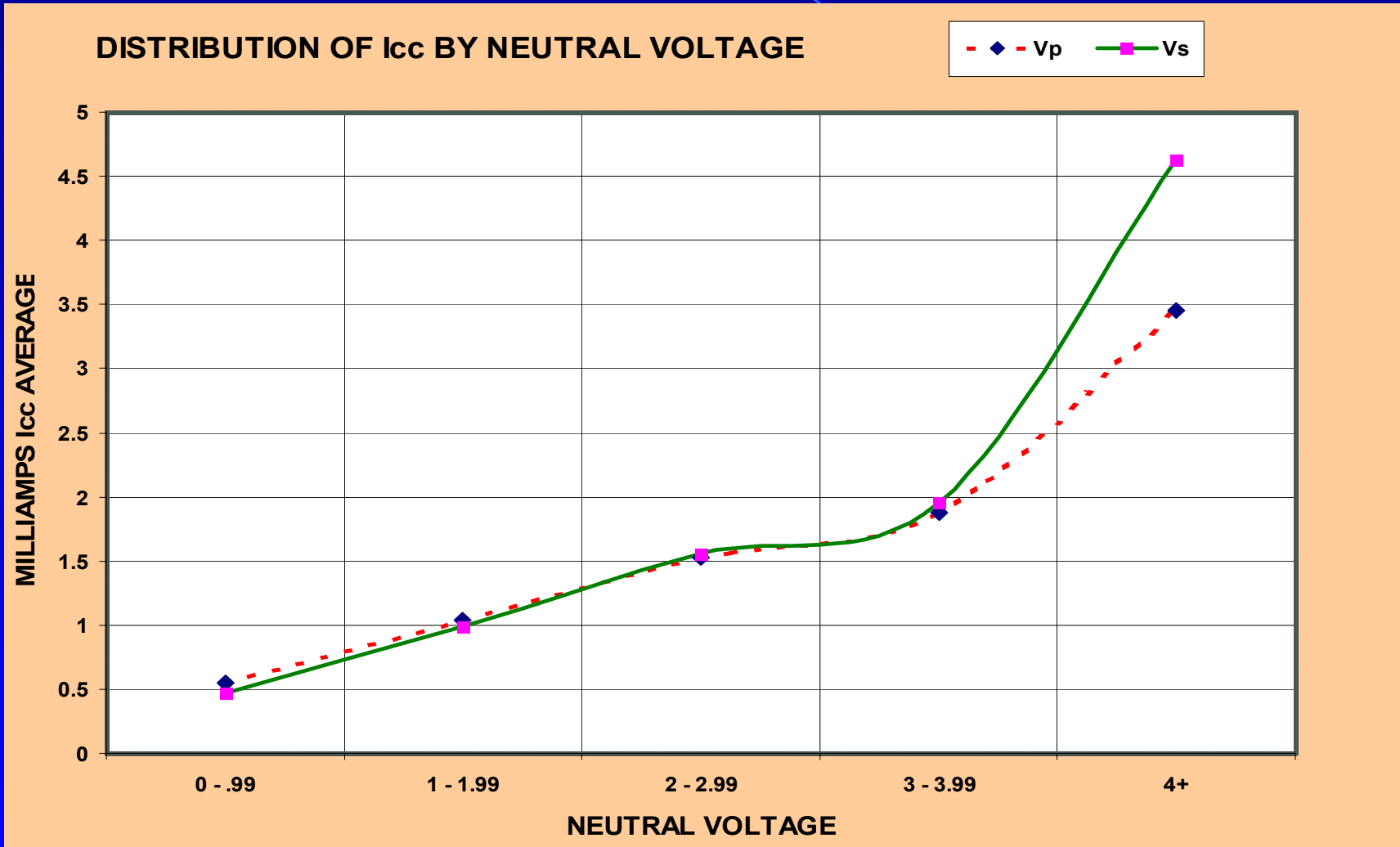


Cow contact current history

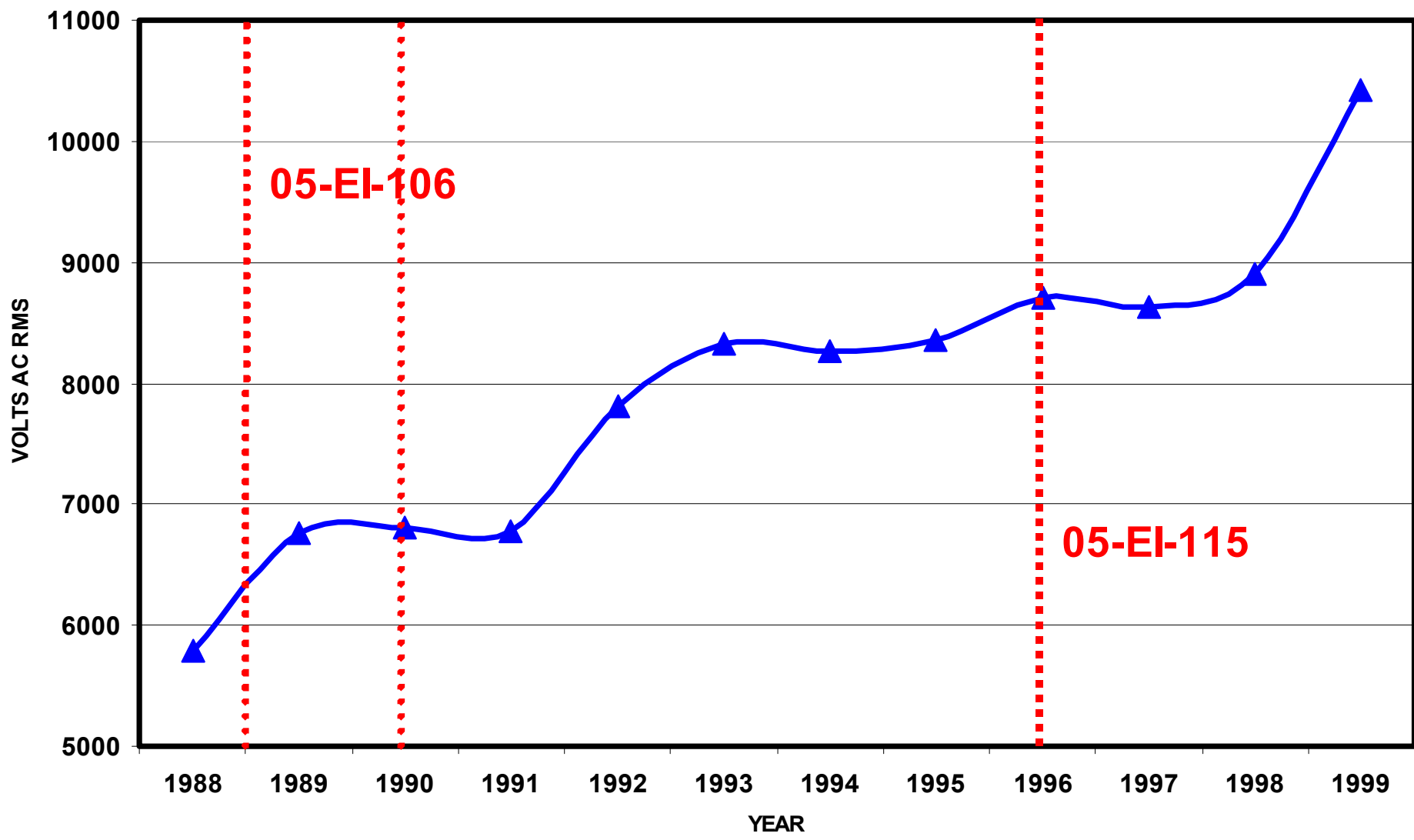
COW CONTACT CURRENT TREND



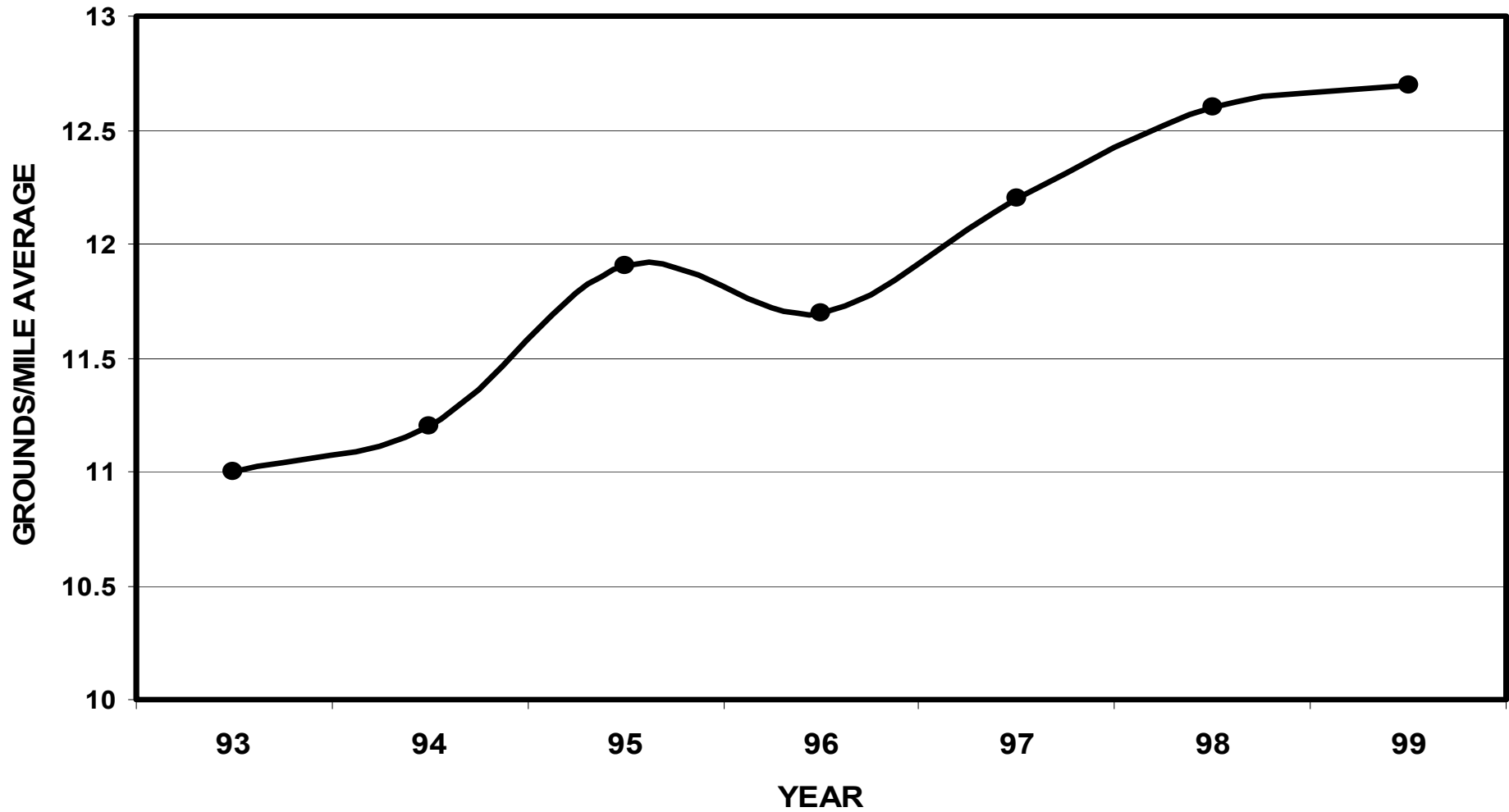
Neutral to reference Icc distribution



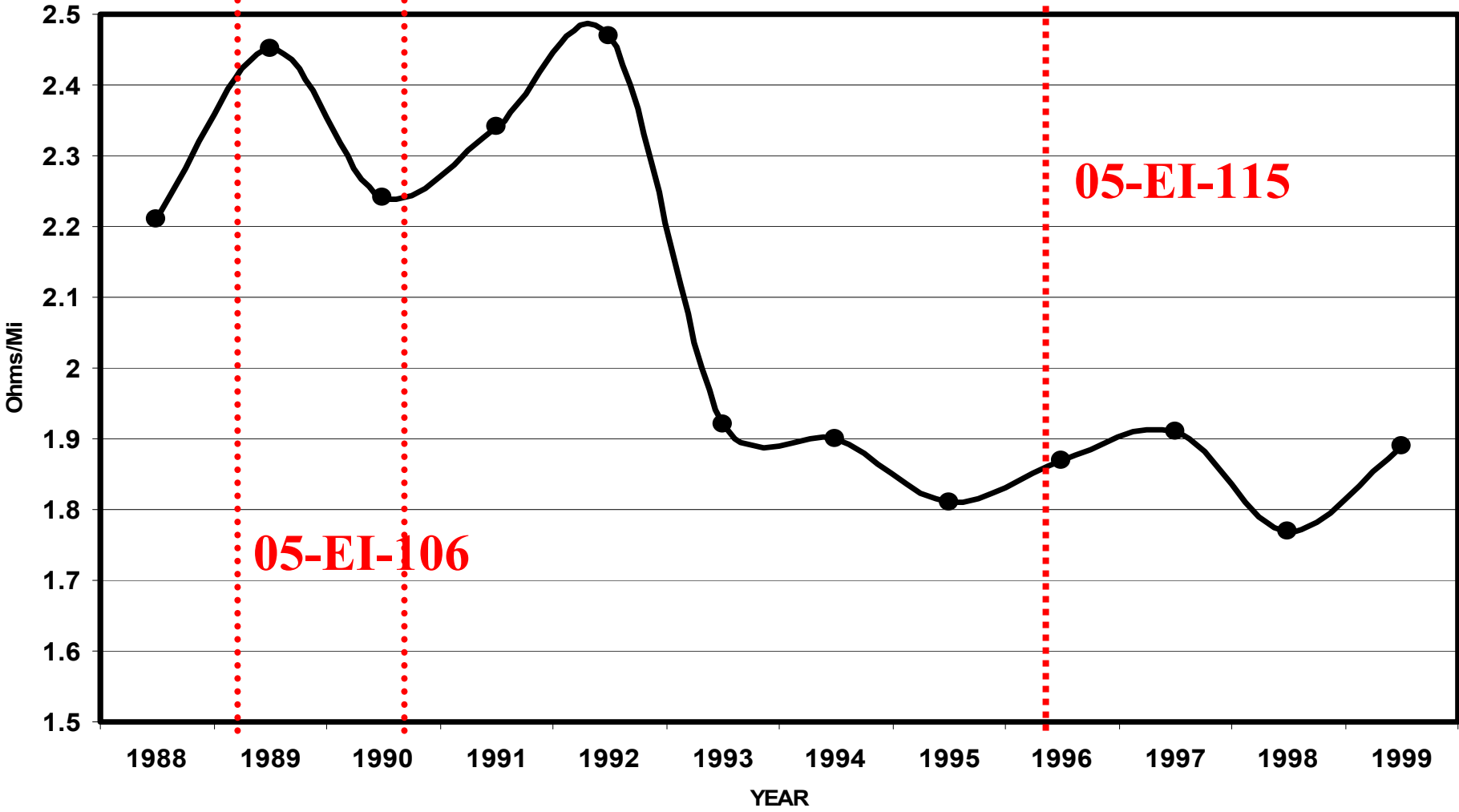
TREND IN PRIMARY VOLTAGE SERVING FARM



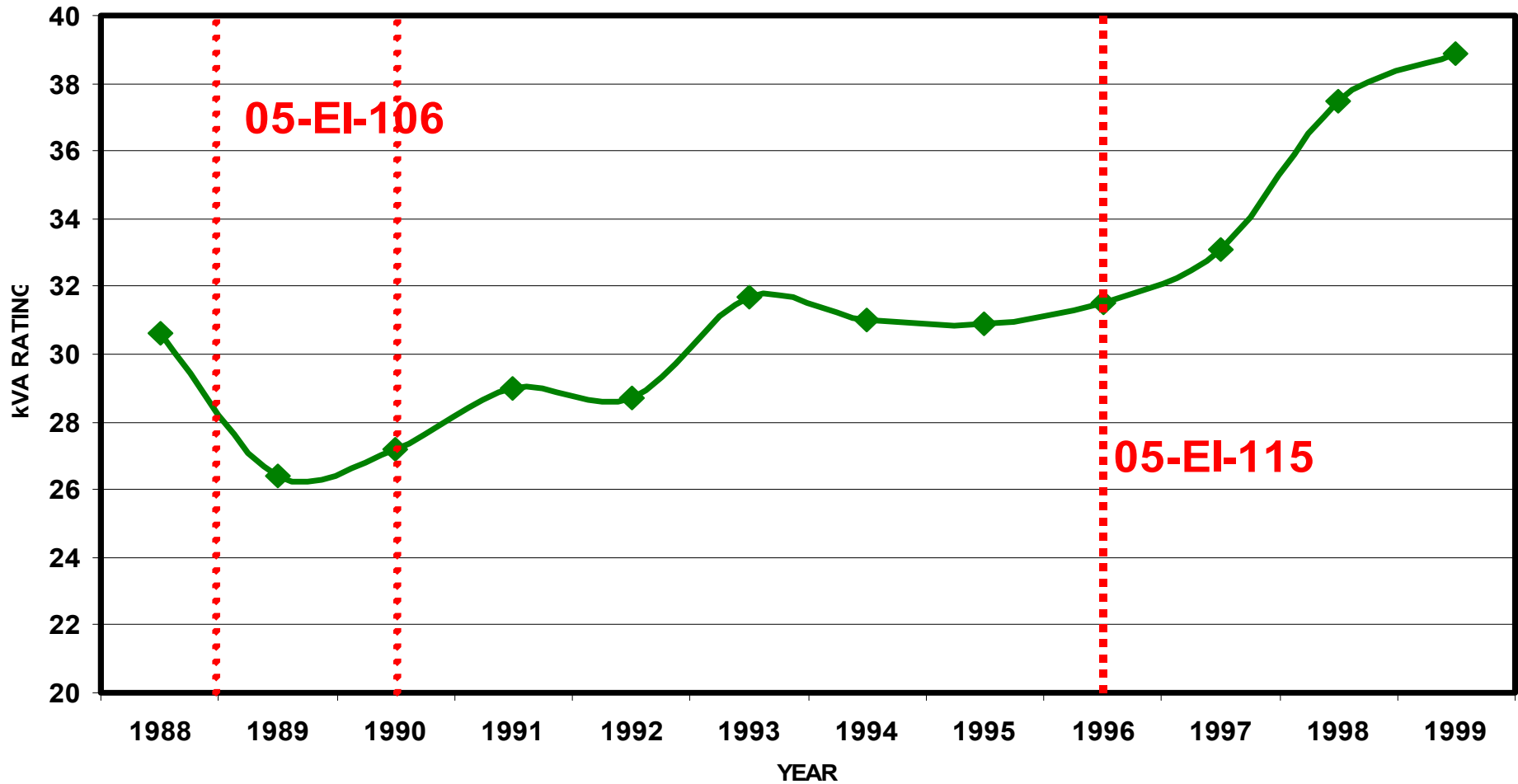
TREND IN GROUNDS/MILE



TREND - Neutral Conductor Resistance

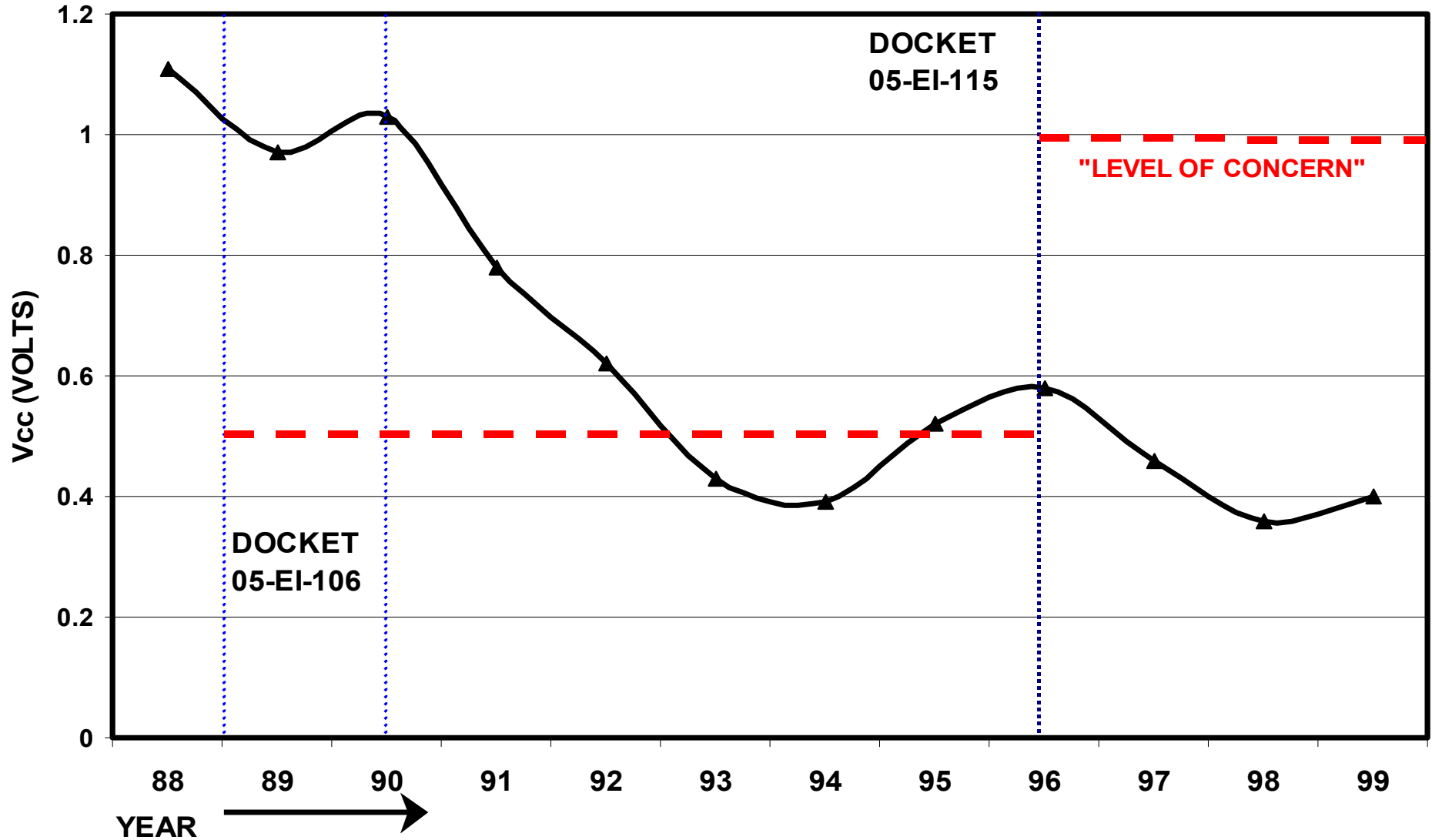


TREND OF AVERAGE TRANSFORMER SIZE FOUND ON FARM



AVG Vcc HISTORIC TREND

4,539 FIRST TIME INVESTIGATIONS



A recent press release:

- The Public Service Commission (PSC) of Wisconsin wants to remind dairy farmers that they may elect to isolate their farm from the utility's power system at any time if they meet certain conditions. This is a result of the PSC's docket 05-EI-115 of 1996 which allows an isolation device to be installed by the utility on request. The isolation device separates the utility's neutral line from the farm's neutral line. For safety reasons, it will automatically connect the two together again if a dangerous high voltage condition exists on either neutral. The only provisions required of the farmer are to have his or her wiring inspected by a state-certified master electrician to assure it meets a certain level of safety and to pay for both the installation and a monthly maintenance fee. Farmer's are urged to call their local utility farm representative to learn more details about this service.

Speaking of safety.....

- REPS would like to remind utilities subject to Public Service Commission (PSC) administrative rules that § PSC 113.1322(4) Wis. Admin. Code states: “A public utility may disconnect commercial or farm utility service, without notice, where a dangerous condition exists for as long as the condition exists.”
- Remind the customer that the National Electric Code (NEC) is a **minimum** safety standard for the wiring and operation of secondary electrical systems. All *certified* electricians are trained in the safety aspect provisions of the NEC. The REPS must emphasize that the provisions of the NEC and all accepted stray voltage mitigative methods are not mutually exclusive. A farm can be wired so that stray voltage is held to minimum acceptable values and still be wired safely to the specifications of the NEC.

Stray Voltage in Context

- **Direct Effect: reluctance, avoidance**
- **Adaptation: predictable, avoidable**
- **Stray Voltage is a cow comfort issue**
- **SV is not a separate issue. It can be a significant issue if annoying and unavoidable, but in reality it is just one of the many everyday cow comfort issues on dairy farms.**

CAN YOU GET INVOLVED AND HELP WITHOUT GETTING IN OVER YOUR HEAD?

- You do not need to be the expert to be valuable



PAY ATTENTION TO FENCERS AND TRAINERS!!!

- **The most common electrical hazard to cows!!!**
- **Visual detection as useful as electrical testing.**
- **Hot wire should have insulation rated to contain 10,000 volts (spark plug wire)**
- **Grounds should be two or more and 35 feet away from any other potential conductor**
- **Units need to be modern and working well**

PAY ATTENTION TO FENCERS AND TRAINERS!!!



HOT WIRE LAYS
ON OTHER WIRES

PAY ATTENTION TO FENCERS AND TRAINERS!!!



wire buried under
drive to new shed

fencer ground

PAY ATTENTION TO FENCERS AND TRAINERS!!!



trainer with steady output
hot wire lays on conduit

PAY ATTENTION TO FENCERS AND TRAINERS!!!



old mercury trainer
with 2-prong plug

PAY ATTENTION TO FENCERS AND TRAINERS!!!



Outside Fencer

STRAY VOLTAGE METERS



ASK QUESTIONS ABOUT SUSPICIOUS WIRING



ASK QUESTIONS ABOUT SUSPICIOUS WIRING



ASK QUESTIONS ABOUT SUSPICIOUS WIRING



overhead lead to out bldgs.
unprotected outside plug to frig

ASK QUESTIONS ABOUT SUSPICIOUS WIRING



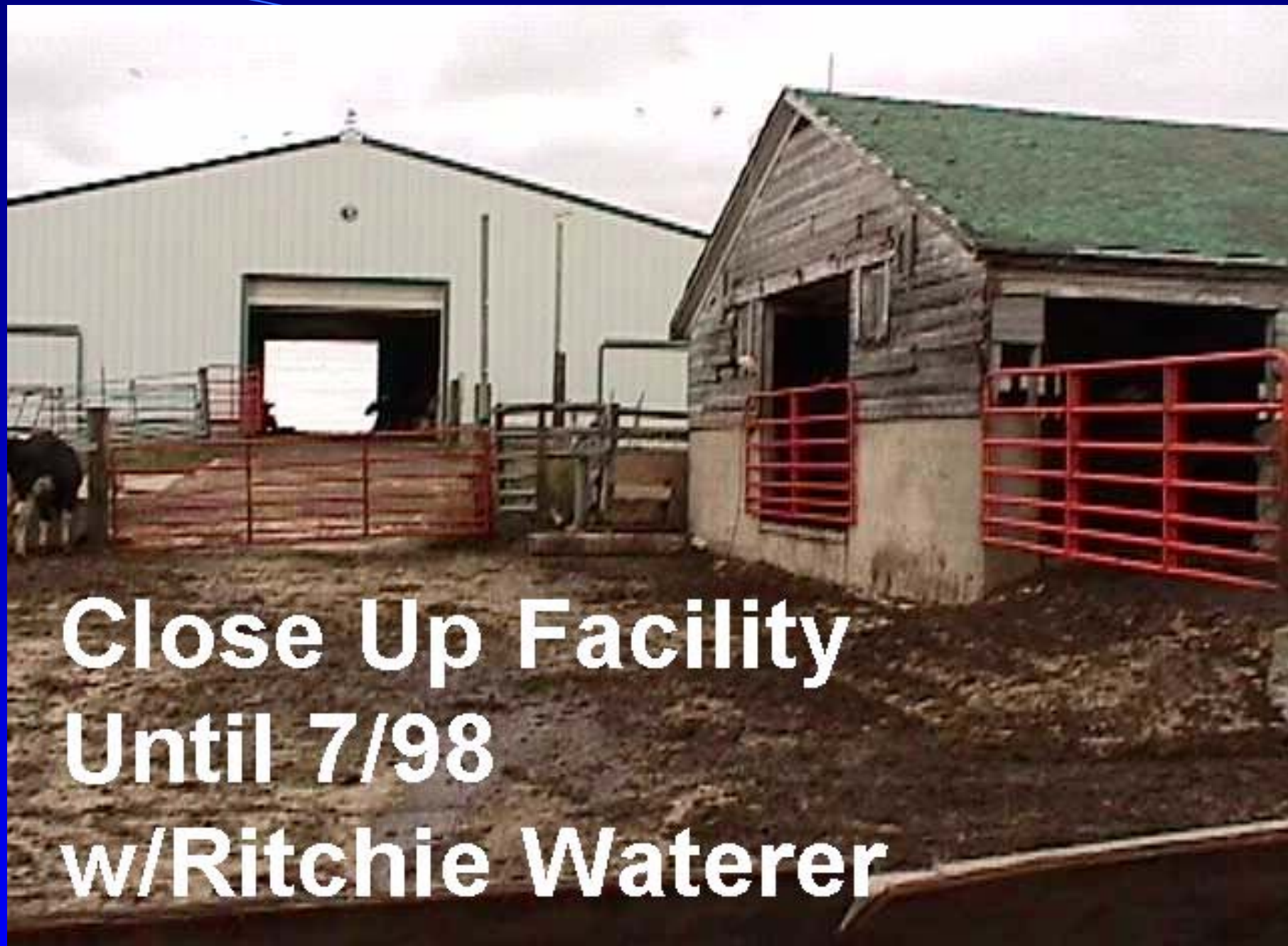
ASK QUESTIONS ABOUT SUSPICIOUS WIRING



ASK QUESTIONS ABOUT SUSPICIOUS WIRING



switch to fluorescents
hanging by clothespin



**Close Up Facility
Until 7/98
w/Ritchie Waterer**

HELPING WITHOUT GETTING IN OVER YOUR HEAD?

- **Look at SV only to your level of comfort otherwise seek help**
- **Advise farmers to check for SV annually**
- **Always check fencers and trainers**
- **Suggest SV meter be installed**
- **Ask questions when wiring looks obviously suspicious**
- **Don't make the mistake of thinking you can detect SV by looking at cows**
- **Stick to what you know and avoid being pressured into taking uncomfortable stands.**