College of Agricultural & Life Sciences
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Energy Efficiency for Dairy Farms

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FARM ENERGY

Five ways to save energy and $$$ in crop production:

- Limiting tillage operations
- Plant shorter season hybrids (corn for drying)
- Type / Management of grain dryers
- Ballasting tractors for energy efficiency
- Nitrogen fertilization in corn production
- Tractor maintenance

FARM ENERGY

Energy to Produce Corn Crop:

- Field Production – 4.6 – 7.5 gal* / acre
- Fertilizer (N) – 13 to 19 gal eq / acre
- Drying Grain – 7 to 11 gal eq / acre

- Grain - Total 24 to 36 gallons diesel eq / acre
- Silage – 17 to 25 gallons diesel eq / acre

*Diesel Fuel or equivalent

FARM ENERGY

Field Operations – conventional - Grain

Moldboard plow	1.70 gal/acre*
Field cultivate / Disk	.65
Plant	.40
Spray (2x)	.20
Combine	+ 1.45
Hauling	0.20
Total	**4.60 gal/acre**

2.25 gal/acre

Typ. Range 4-6 gal/acre

* Diesel Fuel

FARM ENERGY

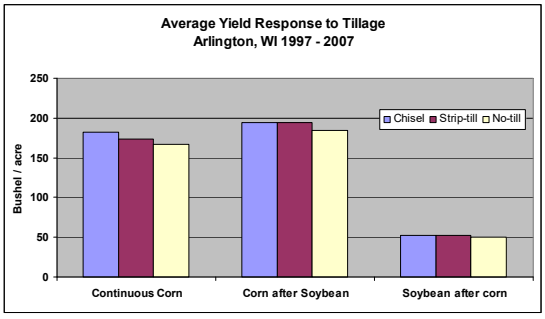
Field Operations – conventional - Silage

Moldboard plow	1.70 gal/acre*
Field cultivate / Disk	.65
Plant	.40
Spray (2x)	.20
Chopping	3.25
Hauling	+ 1.25
Total	**7.45 gal/acre**

5.1 gal/acre

* Diesel Fuel

FARM ENERGY



Source: Wolkowski,, Cox, Leverich, Strip-tillage: A conservation option for Wisconsin Farmers – 2009, A3883

FARM ENERGY

Comparison of 2007 Cost of Production (COP)

Arlington, WI - Yield Average 1997-2007

Crop/System	1997-2007 Ave Yield (Bu)	2007 COP / acre ($/acre)	2007 COP/bushel ($/Bushel)
Continuous Corn			
Chisel Plow (CH)	182	-	-
Strip-Tillage (ST)	174	-$23.20	-$0.02
No-Till (NT)	167	-$25.90	$0.08
Corn after Soybeans			
CH	194	-	-
ST	194	-$23.20	-$0.12
NT	185	-$25.90	-$0.03
Soybeans after Corn			
CH	52	-	-
ST	52	-$11.20	-$0.18
NT	50	-$25.90	-$0.26

Source: Wolkowski., Cox, Leverich, Strip-tillage: A conservation option for Wisconsin Farmers – 2009, A3883

FARM ENERGY

Advantages of reduced tillage

- Reduced moisture loss
  - ~ ½" H_2O loss per tillage operation
- Reduced CO_2 emissions from soil
- More residue cover – Less Soil Erosion
- Reduced energy, labor & equipment cost
- Yield equal or only slightly lower
- Cost reduction per bushel

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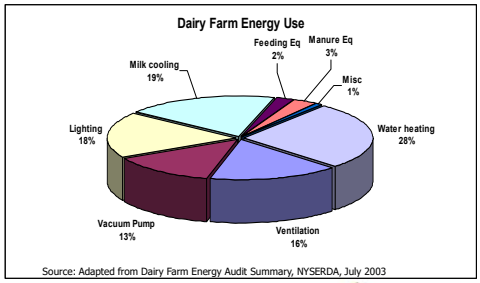
FARM ENERGY

Nitrogen Efficiency

- Incorporation of Manure
  - Solid - 25% loss
  - Liquid – 20% loss
  - Incorporate within 72 hours
    - Reduced Odor & runoff potential
- Crop Rotation
  - Corn after Alfalfa
    - 120 – 190 lb/ac - 1st year – no nitrogen needed
    - 50 lb/ac – 2nd year – ~ 1/3 savings

Source: L.G. Bundy, Corn Fertilization, A3340, University of Wisconsin Extension, 1998)

NYS Dairy Farm Survey
Electric & Water heating



Source: Adapted from Dairy Farm Energy Audit Summary, NYSERDA, July 2003

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Energy Efficiency Dairy Benchmark

- Total electrical usage – 750 kWh/cow-yr
- Vacuum pump – 50 kWh/cow-milking-yr
- Milk Cooling – 0.7 kWh/cwt
- Ref: Dairy Farm Energy Audit Summary Report, New York State Energy Research and Development Authority, 2003

Refrigeration System

- Scroll Compressor
  - 15-20% more efficient than reciprocating type
    - Less moving parts – high reliability
  - Standard with most new systems (check if not specified)
  - Planned Replacement
  - <u>Can directly replace reciprocating compressors if:</u>
    - Condenser unit is in well maintained condition
    - Capacity of new compressor is within 5% of existing compressor
    - Requires new mounting holes & rewiring of controls
    - Incremental cost - $300-$500

Refrigeration System – Condenser Unit

- Location of condenser unit
  - Location with access for cleaning
  - Inside provides space heating
    - Avoids need for space heater
    - Need to accommodate outside air for summer cooling
  - Outside

    Adv: Reduced energy cost – lower rejection temperatures

    Disadv: Maybe increased maintenance because of leaves, dust, debris

    ** Don't install on or at ground level **

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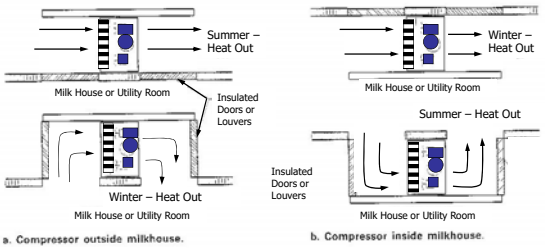
Compressor Location



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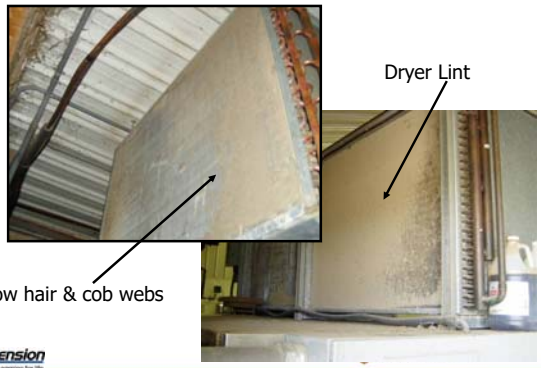
Condenser Unit Maintenance



Refrigeration System Maintenance

- Maintenance of condenser unit
  - Clean condensing unit – 2X/yearly min.
    - DISCONNECT POWER BEFORE CLEANING!!!!
    - Electrical Savings - **3 to 5% from cleaning alone**
    - Use Condenser coil cleaner only
    - High pressure power sprayers not recommended
    - Protect / Remove open enclosure fan motors
  - Keep brushes, vines, trees trimmed
  - Open winter covers when weather warms
  - Lubricate louvers and check proper operation of power opening louvers and exhaust fans
  - Service - Check Refrigerant level and pressures yearly

Well Water Precoolers

- Reduce refrig cooling up to 60%
  - Up to 40ºF temp reduction
  - Within 3-4ºF of well water temp
- Cooling Amount
  - Water:Milk Flow Ratio, Residence Time, Surface Area
- Water supply critical for savings potential
  - 1:1 water / milk ratio or greater
  - Most require 2 or 3 : 1 ratio
  - Typical milk pump – 25 - 35 gpm
  - Need 1"+ piping
- Herd size > 100 to 150 cows

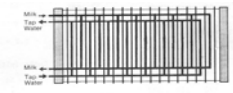


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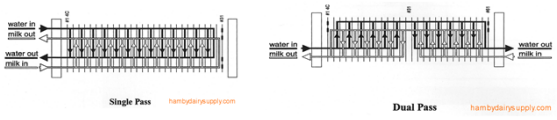
Plate coolers

- Temperature Lowering Ranges*
  - Single-pass 25° F
  - Dual/Multi-pass 35° F
  - Dual Coolant 45° F+



*Use manufacturer's specifications to determine potential cooling

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Plate Cooler Water Reuse

- Typical Water Reuse System
  - Water storage
  - Pump
  - Distribution Piping
- Water uses
  - Livestock water
  - Cleaning parlor
  - Flushing
- Potable versus Non-potable
  - Usually Non-potable
  - Use for livestock water

Variable Speed Milk Pump

- An accessory for a precooler
- Ramps milk pump speed up/down to maintain milk level in receiver jar
- Slows milk flow which increases water:milk ratio
  - which results in more cooling of the milk in the precooler
  - which reducing compressor run times = less electricity used.
- Typical Energy Savings
  - Increase in milk cooling 15-20ºF
- Increased cooling = more water use w/VS milk pump

Water Heating

- Average gas/oil water heater
  - 80% Thermal Efficiency
  - 2.5%/hour Standby heat loss (60% per day)
  - Overall efficiency ~ 50 to 55%
- Purchase well insulated water heaters!!
  - Efficiency information
  - Air-Conditioning, Heating and Refrigeration Institute
  - Directory of Certified Products Performance
  - www.ahridirectory.org/ahriDirectory/pages/home.aspx
- Using lots of water?? - High Efficiency water heaters
  - Condensing types – 90%+ efficient
  - Low standby losses – 1% per hour (24%/day)
- Electric water heaters
  - ~99% Thermal Efficiency – 0.5 to 1% Standby losses
  - 79 to 88% overall efficiency

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Instantaneous Water Heater

- No Standby losses
- Electric, Natural gas, Propane
- Efficiency – Std – 85%; HE – 95-97%
- Water flow rate needs to match application – 0.5 to 9.0 gal/min
- Dedicate Inst. Water heater
  - Milking system / Bulk tank separate
- Some have small tanks
  - No delay in getting hot water
- Longer life / take less space

Water Heaters

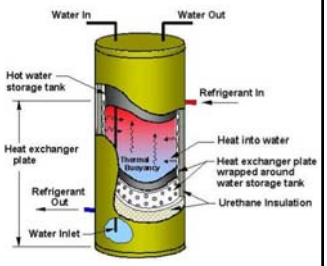
- Insulation
  - Add insulation jacket to water heater tank
  - Only if dry location – free of rodents
- Insulate pipes
  - Reduce heat loss from pipes
- Turn-down Water Temperature
  - May depend on time of year – Heat loss in pipeline
- Tune milk pipeline Washing System (use less water)
- Use water directly from Refrigeration Heat Recovery
  - Non-critical uses – clean up, manual washing

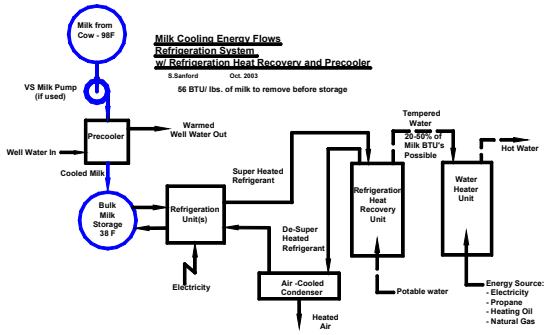
Refrigeration Heat Recovery Unit

- Transfers heat from hot refrigerant to water
- Pre-heats water before entering water heater
- Captures 20-50% of heat in milk
- Typically replace ½ of hot water needs
- Increases refrigeration system Efficiency

Refrigeration Heat Recovery Unit

- Water temperatures – 100F to 120F++
- Can accommodate 1 or 2 compressors
- Oversized RHR tank will decrease savings
- Match size to water use
- Maintenance Important
  - Flushing tank required for long life





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Precooler – Heat Recovery Interaction

- Water Heating
  - Increase water temp - 110° F
  - Water heater energy efficiency = 50%
  - 2 Unit In = 1 Unit usable
- Milk Cooling
  - Decrease milk temp - 60° F
  - Compressor efficiency = 200%
  - 1 unit In = 2 units removed
- Refrigeration Heat Recovery
  - ¼ to ½ unit of energy recovered
  - Milk cooling energy efficiency = 225 to 250%

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Equipment Interactions

- Precooler energy savings = 1unit
- Refrigeration Heat Recovery =1 unit
- Precooler + RHR ≠ 2 units
- Dairies with < 100 cows
  - Generally only use either / or not both
  - Cover water heating needs first
- Dairies with > 150 cows
  - Usually both precooler and Refrigeration Heat Recovery

Variable Speed Vacuum Pump

- Typically reduces VP electrical usage by 60%.
  - Ranges from 30 to 80%.
- Oversize pump heads reduce potential savings.
  - Air volume per revolution
- Pays when milking
  - > 6-8 hours per day
  - 3 times per day milking
- Reduces Demand Load
- Don't create Stray Voltage!!

Variable Speed Vacuum Pump

- Components
  - Variable Frequency Controller (Drive)
  - Lobe/blower type vacuum pump*
  - Pressure Transducer (sensor)
    - Mounted in vacuum line near receiver jar
  - 3 phase motor
  - Single or 3 phase electrical input

*Replace Rotary vane with Lobe pump if VP replacement required

Air Compressor

- Compressing air – 12-14% efficient
- Electric cost will account for **70%** of the cost of ownership over 10 years
- Scroll compressors highest efficiency
- Set to lowest possible pressure setting
- Air leaks!!!
- Zero-loss drain valve instead of timer
- Controller – on/off versus unloading valve
- Needs totally enclosed motor for Ag Application

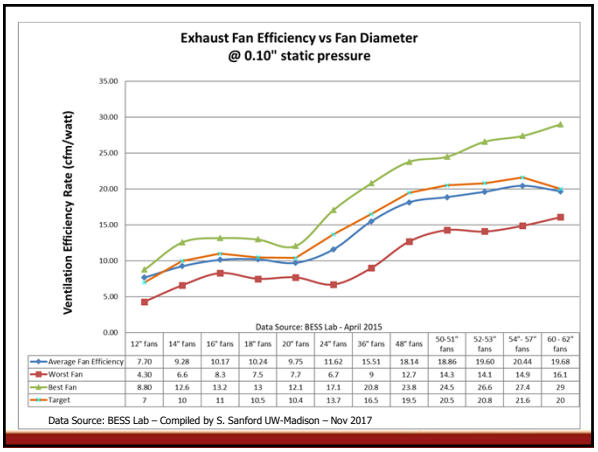
Reference: http://www.compressedairchallenge.org/library/

Got Fans!!

- Does the design make sense?

Ventilation - Exhaust Fans

- All fans are not created equal
  - 2:1 difference in energy consumption for same size fan
  - Larger Diameter fans → efficiency increases
  - Diffuser cones save 12-23% in energy cost
  - HE fans ~ 20% higher energy efficiency
  - Efficient Replacement Motors!!!
- Performance Data
  - BESS Lab (U of IL) - www.bess.uiuc.edu
  - Efficiency test data
    - XX CFM/watt @0.05" SP



	12" fans	14" fans	16" fans	18" fans	20" fans	24" fans	36" fans	48" fans	50-51" fans	52-53" fans	54"- 57" fans	60 - 62" fans
Average Fan Efficiency	7.70	9.28	10.17	10.24	9.75	11.62	15.51	18.14	18.86	19.60	20.44	19.68
Worst Fan	4.30	6.6	8.3	7.5	7.7	6.7	9	12.7	14.3	14.1	14.9	16.1
Best Fan	8.80	12.6	13.2	13	12.1	17.1	20.8	23.8	24.5	26.6	27.4	29
Target	7	10	11	10.5	10.4	13.7	16.5	19.5	20.5	20.8	21.6	20

Data Source: BESS Lab – Compiled by S. Sanford UW-Madison – Nov 2017

Ventilation System Maintenance

- Dirty louvers can decrease fan efficiency by 40%
  - Clean and lubricate louvers (use graphite not grease)
  - Clean guards and fan blades
- Belt slippage - decreased airflow rates up to 30%
  - Check and tighten belts every 3 months
  - Retrofit existing fans with self tightening devices for belts.
- Always use Totally Enclosed motors
  - Required by electrical codes for farm use.
- Clean dirt off Thermostats
- Clean dirt off motor – for motor cooling
- Clean air inlets
- Clear brush, limbs, weeds away from fan openings

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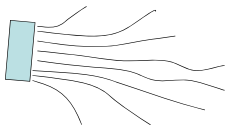
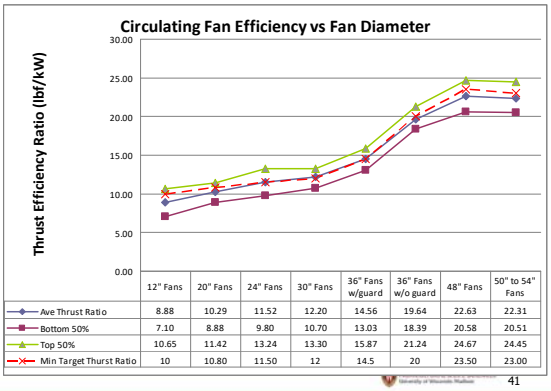
Stirring Fans

Circulation Fan Ratings

- BESS Lab testing (http://bess.illinois.edu/)
  - Thrust efficiency ratio – lbf / kW
  - Centerline velocity @ 5D
  - Thrust is proportional to air flow





	12" Fans	20" Fans	24" Fans	30" Fans	36" Fans w/guard	36" Fans w/o guard	48" Fans	50" to 54" Fans
Ave Thrust Ratio	8.88	10.29	11.52	12.20	14.56	19.64	22.63	22.31
Bottom 50%	7.10	8.88	9.80	10.70	13.03	18.39	20.58	20.51
Top 50%	10.65	11.42	13.24	13.30	15.87	21.24	24.67	24.45
Min Target Thurst Ratio	10	10.80	11.50	12	14.5	20	23.50	23.00

Data Source: BESS Lab – Compiled by S. Sanford UW-Madison – Oct 2011

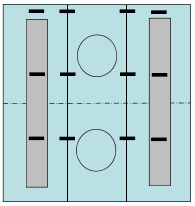
HVLS Fans in Freestall barn

High Volume Low Speed Fans

- 24 foot HVLS fans moves ~ 300,000+ cfm
- Uses 2 HP per HVLS fan
- Typical Dairy barn installation
  - Hang in center of barn @ 60 foot spacing
- Observations:
  - Dryer floors
  - Reduced bird traffic
  - Less flies
- Lower air velocities at cow level
  - Hanging fans over cow beds – much better

HVLS versus High Speed fans

- Assume 4 or 6 row barn
- 48” fans spaced at 40 foot
  - 10 ft per foot of fan diameter
  - 2 rows per pen
  - 1 HP per fan
- 1 HVLS fan covers 60 feet
  - 2 HP per Fan
- Comparison
  - In same space = 1.5 fans per row x 4 rows
  - Six 48” fans in same space as 1 HVLS fan
  - 5.8 kW compared to 1.8 KW for HVLS
  - Savings = 4.0 kW per hour of operation



Frost-Free Livestock Water Fountains

- Save $60 to $100/yr Plus
  - Poorly maintained waterer can use $200+ in electricity/yr
- May not be suitable for low numbers of animals
  - Check manufacturers recommendations
  - May require a low wattage heater
    - With Thermostat

- Requires daily maintenance during sub-zero temperatures
  - Check that covers / balls are not frozen open or closed
- Research studies in Manitoba and North Dakota found they performed acceptably without heaters

Resources

- Hanna, M.2001. Fuel Required for Field Operations, Iowa State Extension publication PM 709. Available at:
  - *http://www.extension.iastate.edu/Publications/PM709.pdf*
- Wolkowski, R., T. Cox, J. Leverich, "Strip-tillage: A conservation option for Wisconsin farmers", Bulletin No. A3883, University of Wisconsin Extension, 2009. Available at:
  - *http://learningstore.uwex.edu/Assets/pdfs/A3883.pdf*
- On-Farm Energy Conservation & Efficiency curriculum, Bioenergy Training Center
  - http://fyi.uwex.edu/biotrainingcenter/online-modules/
- Lighting Technology: LED lamps for Home, Farm and Small Business, Scott Sanford, University of Wisconsin Extension, To Be Published Spring 2014.

Energy Conservation in Agriculture Publications

- A3784-1 – Energy Efficient Dairy Farms
- A3784-2 – Heating Water on Dairy Farms
- A3784-3 – Well Water Precoolers
- A3784-4 – Refrigeration Systems
- A3784-5 – Variable Speed Vacuum Pumps
- A3784-6 – Ventilation and Cooling EC
- A3784-7 – Variable Speed Milk Pumps
- A3784-14 – Energy Efficient Lighting

Available from UW Extension Publications
http://learningstore.uwex.edu/Energy-C29.aspx

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Questions??

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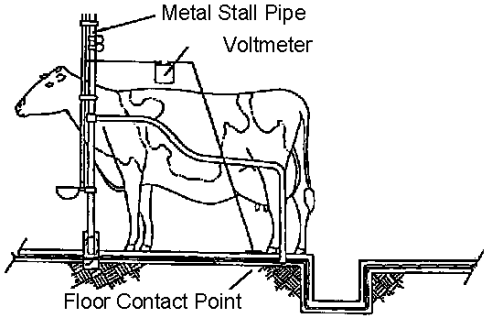
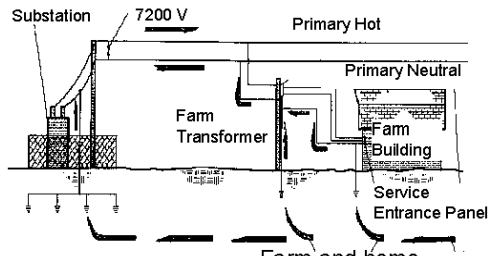
What Is Stray Voltage?

- A difference in voltage measured between two surfaces that may be contacted simultaneously by an animal (USDA, 1992).
- It IS a Mild Shock
  - caused by a contact voltage
- It is NOT Electric/Magnetic Fields
  - (EMF)
- It is NOT "Ground Currents"
  - Unless they produce contact voltage

Cow Contact Voltage Measurement



Where does Stray Voltage come from?



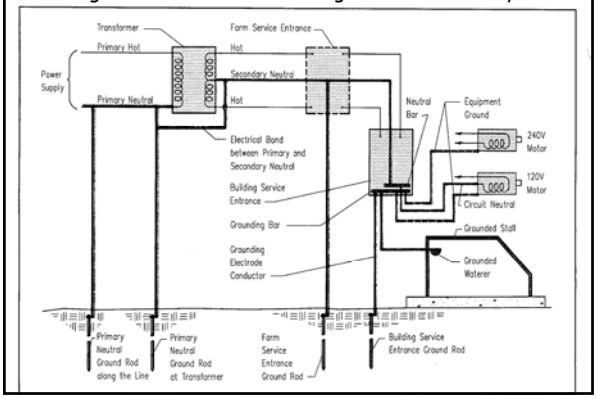
Utility Distribution - Primary Neutral to Earth Voltage

Farm and home Secondary Neutral to Earth Voltage

How Can Neutral Voltage Be Reduced?

- Reduce Resistance
  - Size of Conductor
  - Quality of jumpers and connections
  - Number and quality of grounds
- Reduce Current
  - Balance loads
  - Fix faults

The source of Stray Voltage is voltage developed by current flowing on the resistance of the grounded neutral system



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	• 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.