The Effects of Ground Currents on Dairy Cows: A Case Study

Daniel Hartsell, *DVM* **Duane Dahlberg**, *PhD*,
David Lusty, and **Robert Scott**, *DVM*
Alexandria, MN

Introduction

Before the advent of air monitoring systems, coal miners would take canaries into the mines to warn the miners of impending danger from low oxygen or the presence of gasses which might be toxic to the miners themselves. When the canaries stopped singing the miners knew that the air was unsafe. Today dairy cows may be inadvertently serving a similar role. On dairy farms throughout the country, electricity is adversely affecting the health and life of cows, especially while they are in the barn (Bodman, *et al* 1981; Dahlberg 1986; Fairbank 1977; Rodenburg 1984). Not only the cows but the people who work in the dairy barns are also experiencing adverse health effects (Dahlberg and Falk 1993). One can only wonder how many other buildings and locations may be similar to those in the dairy barn.

An overwhelming body of evidence has been generated over a period of at least one hundred years that links various forms of electromagnetic (EM) energies to biological changes and health effects in living organisms (Barnothy 1969; Presman 1970). Since the publication of the results of the New York State Power Line Project, (Ankloom, *et al* 1987) and increasing quantity of information has been presented in various journals, magazines and books relating health effects to EM energies (Brodeur 1990; McAauliffe 1985; Edwards 1987). Specific cause and effects links, however, have been difficult to establish. The complexity of EM energies to which living organisms are exposed and the rapid increase in electrical use in all areas of society have complicated the determination of cause. In addition there is a large number of health effects that could be caused by the various electromagnetic fields (EMF) and currents, and the mechanisms may be very similar.

On dairy farms and in other livestock confinement operations there is a problem called "stray voltage". This problem is considered by professionals in livestock operations to be serious and associates electrical conditions with behavioral, health and production effects in animals and health effects in humans. Some temporary corrective procedures have been attempted, but the problem continues to drive farmers out of the business and no effective solution has been suggested nor successfully implemented. In the dairy industry there has been a general belief that if cows receive shocks (perceived responses) from electric current through the body, behavioral, health and production problems can result. Traditionally, the assumption has been that if electricity is causing effects in a dairy herd only shock currents can produce the effects (Phillips 1962). Consequently, only alternating current (AC) potentials between a reference rod and the neutral ground point, and contact potentials have been measured. Although shock currents are inflicting a certain level of misery for the dairy cow, the cow may choose whether or not to make contact with conducting parts of the barn which might be grounded. In some barns where the AC potential on the conducting parts of the barn are especially high one notes that the cows do stay away from all conducting parts. In most stray voltage barns, however, cows will tend to press their bodies including mouths and noses tightly against conducting parts in the barn. Such action should imply that it is not the shock that the cow wishes to escape. Even so, the model of the shock current as the only possible cause of electrical effects has so shaped opinions about stray voltage problems that it is difficult to deal with the fact that reducing the shock currents below perceivable levels does not necessarily eliminate the stray voltage effects.

Many mitigation concepts have been introduced and implemented. From studying the mitigation methodologies on a few hundred farms, The Electromagnetics Research Foundation, Inc. (TERF) has concluded that none of the present mitigation methods resolves the stray voltage problem as measured by the behavior, health and production of the dairy herd. Measurements reveal, however, that the remedial methods of isolation and the equipotential plane can reduce the shock current below the point of producing any perceived response. Also each of the mitigation methods, in general, can be correlated with changes in the behavior, health and production of the cows and the health of the operators. On approximately 30% of the farms, the change has been beneficial and continues to be beneficial. For the other approximately 70%, the changes have been beneficial for a short time, have had no real beneficial impact or have caused more serious problems for the cows and operators. The equipotential plane has

rarely improved conditions and often appeared to be associated with an increase in the adverse effects. Isolation has been the most beneficial of all suggested mitigation procedures. All of these are primarily focused on the reduction in the AC that can intermittently shock the cow when it drinks water or touches conducting parts in the barn with its head, mouth or other part of the body. Isolating devices can only be temporary since they redirect the current that enters and is in the earth (Aneshansley, Gorewit 1992; Appleman 1987).

Over the past ten years the perceived associations between electromagnetic (EM) energies and the health of animals and humans in field settings have been investigated. Attempts have been made to quantify the total EM environment of the subjects. An important discovery was the presence of significant EM energies moving through and emanating from the earth. Investigations have revealed that in the existing national electric transmission/distribution system, a large fraction of the current on the neutral side of the system has inadvertently ended up in the earth rather than in the neutral conductor. Therefore about 65% of the current on the neutral side of the transmission/distribution system flows in the earth (Gonen 1986; Morrison 1963). No one has assessed the total impact of this amount of current continually flowing in the earth. In addition it is well known in the dairy industry that dairy cows experience a set of behavioral, health and production effects when an electrical ground fault occurs in the region of the dairy farm in which electricity is short circuited into the earth. Consequently, dairy farmers' attention has been directed toward the electricity that reaches humans and animals through the earth and its effects. Dairy farmers have, in fact, discovered an association between the effects in dairy herds and the grounding of the electric utility neutral on or near the farms. Although the discovery was serendipitous, many measurements have been made of the alternating and direct currents which are entering and leaving the earth by means of the primary and secondary grounding systems. These measurements show, in most cases, a significantly smaller resistance for the electrical grounding on the farm than on the primary neutral. The implication is that under nonisolation conditions, considerably more of the primary neutral current will reach the earth on the farm grounding system than on the electric utility grounding system. With isolation more current will enter the earth on the primary neutral because the farm grounds can no longer be used. The loss of the lower resistance grounding system causes an increase in the primary neutral voltage.

Study Case

In recent years professionals have associated a significant number of health effects in dairy animals with electrical conditions on the dairy farm. Noted especially is the appearance of effects from a continuous exposure which can impact the animal chronically. The general well being of the animals degrades in direct relationship to time spent in the barn. One of the authors of this paper has discovered specific cases in which the blood chemistry of the cow changes with exposure. Subtle responses are also documented, such as the cows' inability to drink from the water cups. The obvious consequence is dehydration. In order to detect the effect in the dairy herd, farmers have begun installing water meters to record water intake of the animals.

Over a period of time dairy farmers have observed that changes in the grounding of the secondary and primary neutral lines affect the behavior, health and production of the dairy cows. One of the changes is the installation of an isolation device which prevents the current on the primary neutral from going directly onto the farm neutral grounding system. Often the use of the isolator is ineffective, however, and additional changes have been examined. Empirical evidence has convinced many dairy farmers that disconnecting the primary grounding at the transformer pole and at adjacent electric utility poles affects the well being of the dairy cows. They report water consumption increases, cows relax and milk out better and appear less agitated, as evidenced by a marked reduction in tail switching and repeated moving about in the stall. The real tragedy is that when the ground wires are reconnected to comply with national electric codes, the cows' condition degenerates again.

On a dairy farm owned and operated by David and SuAnn Lusty, Miltona, MN stray voltage has been a problem for years. They have a modern operation, milking about 30 Holstein and Ayrshire dairy cows.

Dave has trained himself in basic electricity and has become an expert in the "stray voltage" problem, assisiting other farmers throughout the region. He has tried every solution suggested by the university specialists and has done all he could to change everything on his farm to prevent the cows from being shocked. Since the isolation device was ineffective on his farm, he finally resorted to disconnecting the primary grounding wires. The results of this final action were especially beneficial for his dairy cows. The longer the grounding wires were disconnected the greater the improvement in the herd.

The electric utility company serving the farm, however, informed the Lustys by letter that sometime during the week of April 10, 1992 they were going to reconnect the ground wires and that service would be discontinued if the wires were disconnected again. This impending connection by the power company provided a perfect opportunity to see how the simple act of connecting the

grounding wires might affect the health and production of his herd.

Methodology

The purpose of this research project was to test the hypothesis that the grounding of the electrical utility neutral on the Lusty farm is affecting the behavior, health and production of the dairy cows owned and managed by the Lustys on their farm. This farm offered an especially valuable opportunity to test the hypothesis because Lusty had a record of being in the upper 20% in milk quality in the milk processors first district and known to be excellent dairy operators.

For a number of years previous to the beginning of this test, the wires connecting the utility meutral to ground rods were disconnected. The methodology consisted of three tests involving a body scoring procedure and a blood analysis. One test was conducted on April 2, 1992 while the ground wire was still disconnected. On April 14, 1992, the utility company returned to the farm. The ground wires were reconnected and the system was grounded according to the power company specification. One week later, on April 22, 1992 only the body scoring procedure was done on the herd. The body scoring and the blood analysis were done again on May 1, 1992, 17 days after the ground wire on the transformer was connected to ground by the power company. The body scoring was done on the entire herd on all three test days, and blood analyses were done for the same ten cows on the first and third test days, separated by almost one month. During the entire test period the Lustys maintained the same management practices. The cows received the same rations, the milking routine was kept the same, and the farm was held to the same daily schedule. The only known change on the farm was the connecting of the electric utility ground wires. Of significance is that the Lustys have an isolator at the transformer which disconnects the utility neutral from the farm neutral. The only path available for the electric current on the utility neutral to reach the farm grounding system and/or the barn, therefore, is through the earth. On April 2, 1992, Dave installed a water meter in his barn in order to determine the water intake of the dairy herd. During the month of April the Lustys maintained their own cattle records and asked the creamery and milk processor to measure the SCC for each milk pickup.

Dr. Daniel Hartsell, one of the authors of this paper, carried out the body scoring procedures. This procedure is done by veterinary clinicians and nutritionists as a service for clients as a way to evaluate the flesh and condition of their animals. In the test the entire herd was body scored. In addition some comments were recorded for some individual cows.

Dr. Hartsell also drew the blood samples. These blood samples were taken from 10 cows which were selected at random to assure a truly representative sample. In this case 1/3 of the herd is more than an adequate statistical sample. These blood samples were then subjected to 17 different types of tests. The tests are devised by scientists and medical persons to measure the liver and kidney function and to evaluate the numbers, percentages and kinds of blood cells in the sample. Some of the tests were done by the Alexandria Veterinary Clinic, and some were performed by the Douglas County Hospital. The Douglas County Hospital is a full service human hospital. The tests which were run on the cows' blood are also tests which are used to measure human blood cells and are an accepted procedure recognized by both human and veterinary doctors.

To assist the lay reader, a short description of the blood tests is offered to aid in interpreting the results of the tests. The description is in many cases short but inclusive and may be enlarged upon by the skilled medical reader.

Test — *Normal Cow Value*

TP Total Protein — **6.7 - 7.5**
Protein content in the blood.

TP Heat Heated Total Protein
The difference between the TP and TP heated leaves fibrinogen which is an indicator of animal health.

FIB Fibrinogen (expressed in g/dl) — **0.3 - 0.70**
Fibrinogen is a soluble protein in the blood plasma. When elevated, it can be a sensitive indicator of an inflammatory process.

BUN Blood Urea Nitrogen — **20 - 26.3**
Measures kidney and liver function.

CREA Creatinine — **.28 - 1.24**
Measures kidney function.

WBC White Blood Cell (Counted in thousands/cubic mm) — **9**
The first line of defense against insults or invaders. WBC's are the "policemen" of the blood.

RBC Red Blood Cell (Counted in thousands/cubic mm) — **7**
Red blood cells are the oxygen carrying vehicles in the blood containing an iron compound called hemoglobin.

HgB Hemoglobin (grams/deciliter) — **12**
The iron bearing chemical in the red blood cell. HgB carries oxygen.

HCT Hematocrit (%) **30 - 40**

Packed Cell Volume. This test gives an indicator of how many cells are present in any given time. Variations from normal are a signal to look for insults to the individual. Very valuable test for quick comparisons.

MCV Mean Corpuscular Volume (picogram) **40 - 60**

The average volume of RBC. The number gets bigger if the animal is anemic. Decrease with iron and copper deficiency.

MCH Mean Corpuscular Hemoglobin (picogram) **no standard**

Amount of hemoglobin by weight.

MCHC Mean Corpuscular Hemoglobin concentration (expressed in grams/deciliter) **26 - 34**

Ratio of weight to volume or concentration of HgB in the average RBC. This number can never increase but decreases when copper or iron are deficient.

SEG Segmented or Immature Neutrophils (%) **30**

The neutrophil is a white blood cell. The larger number in this test means more segmented cells are being manufactured. More segs are evidence that the number of these cells is being increased. This test measures stress or infection.

Lymph Lymphocytes (%) **60**

A white blood immune cell which will decrease because of systemic stress. Lower than normal numbers here mean stress.

Mono Monocytes (%) Scavengers for Bacteria **5**

These cells literally pick up bacteria and remove them from circulation. An increase in Mono cells is evidence of infection.

EOS Eosinophils (%) Deactivate Histamine **5**

Eosinophils increase when allergies or parasites are present. Decrease is evidence of stress.

BASO Basophils (%)

Basophils carry enxymes to initiate inflammatory response and cellular immune reactions. They are literally messenger cells and an increase indicates an attempt on the part of the body to mobilize the defense system.

All of these blood parameter numbers will increase with dehydration. Therefore, if cows cannot drink water, the numbers are expected to be higher. The TP, TP Heat, FIB, BUN, CREAT, tests were done at the Alexandria Vet Clinic with a"Vet Test" 8008 Analyzer machine which is a standard in the industry. The WBC, RBC, HgB, HCT, MCV, MCHC, SEG, LYMPH, MONO, EOS, BASO tests were done by the Douglas County Hospital lab in Alexandria, MN.

Body scoring was based on condition and "fleshiness" of cows using a scale of 0 - 4. The 0 cow is an extremely thin cow with no external fat or flesh over the ribs and pelvic bones. The 4 cow is the other extreme with a roll of flesh almost completely covering and concealing the ribs and pelvic bones.

Results

In this study both qualitative and quantitative results are presented and considered valuable. The blood tests and body scoring results are reported in two tables with the identifiers as follows:

Blood Tests

A blood drawn 5/1/92
B blood drawn 4/2/92

Body Score and Comments

A taken on 4/2/92
B taken on 4/22/92
C taken on 5/1/9

Of the ten cows for which blood work was done, two, #36 and #31, could not be used because insufficient data were available. Either the data were lost or the blood samples were not of sufficient quality for running a worthwhile test. The information on the other eight cows revealed that for 5 of the cows the FIB dropped with two dropping significantly when the grounds were connected; for three there was an increase in FIB with two being significant; for five cows there was a decrease in WBC with three being significant; and for three of the cows the WBC increased with none being significant. In addition seven cows had a decrease in segmented neutrophils and for six the decrease in segmented neutrophils and for six the decrease was significant; all eight cows had an increase in lymphocyte count with six being significant; and six of the cows had a significant decrease in monocyte counts while one had a significant increase.

In Dr. Hartsell's body scoring analysis, he observed that the cows became more restless and were having more difficulty getting up and lying comfortably after the grounds were connected on April 14. The results of the body scoring showed that even a week after the grounds were connected, cows were beginning to have some rubbed and hairless spots on their hocks and carpal joints. Seventeen days later more than one-third of

the cows had either swollen or scraped hocks or carpal joints. This condition should cause an increase in fibirinogen and an increase in monocyte counts. In the blood tests, however, the opposite occurred. There was a greater tendency for a decrease in fibirinogen and a significant decrease in nonocytes for six of the eight cows tested. Additional investigations will be required in order to understand this **reversed** condition.

From the milk processor's records, the SCC went from 141,000 for the first one half of April to 758,000 for the milk picked up on April 20. By the end of April the SCC had dropped to 355,000. While the grounds were disconnected, the SCC count was significantly lower than after they were connected. Milk production was difficult to monitor during this period because of the number of fresh cows. The Lustys, therefore, were unable to provide any clear data on how much milk production decreased after the neutral wires were connected. Water consumption, however, could be carefully monitored revealing a drop in water consumption from 16.3 gallons per cow for the period of April 8-14 to 13.1 gallons per cow for the period of April 15-21. This reduced water consumption is significant because 16.3 gallons is already low. After the neutrals were connected the cows also ate 25% less hay. The behavior of the cows changed abruptly after the neutrals were connected becoming very difficult to manage. Most of cows showed signs of stiffness and developed sore and swollen legs within a few days after the reconnection. In addition a significant increase in electric spikes from the turning on and off of 240 VAC motors in the barn were measured after the reconnection of the neutral. Of general interest also is the observation that during the year following the reconnection, production has decreased, herd health problems have increased and Dave and Sue Lusty are experiencing more health problems associated with the time spent in the barn. Also of interest is the fact that when the cows can spend the majority of time, night and day, away from the barn, they are healthier and produce more.

All voltages measured in the Lusty's barn, over many years of testing, have revealed that, except for transients, the cows cannot receive a shock voltage of over 0.25 VAC, much less than the shock voltages used in university research. At the same time electricity from the utility system is reaching Lusty's barn, probably directly through the earth. On the Lusty farm many measurements have been made of current reaching the barn as a result of electricity traveling directly through the earth and emanating from the primary neutral and other more distant sources. As an example, Dave made some measurements of currents in the grounding system during a power outage on June 22, 1993 beginning at 11:35 AM and lasting about 30 minutes. The entire three phase line feeding the area around the Lusty farm was out. While the power was off, there was from 110 to 120 mAAC in the primary neutral ground wire and from 100 to 110 mA after the power came back on. On the secondary side the current in the ground wire at the transformer pole was between 18 and 20 mA when the power was off and 16-18 after coming back on. All wires connected to ground rods had currents both when the power was off and when it was on. Therefore, even when the entire three phase line was not energized, there was AC in the barn. Obviously, the currents measured when the power was off had to come from sources not only other than the farm but beyond the region served by this three phase line. The fact that the current decreased when the power was on again related to the phase relationships of the various sources. Measurements made in the barn also show increases in voltages and currents when 240 VAC loads are turned on. Again because the 240 VAC loads do not add to the current on the secondary neutral system, the only source for this increase is from the primary neutral system.

Discussion

It is evident that these behavioral, health and production effects are being caused by electrical exposures which go beyond the traditional shock voltages characterized by neutral to earth voltage measurements. The only change made in this test was the connection of two ground wires to the ground rods on the electric utility system. Nevertheless these cows showed very definite negative responses after the connections were made, which was also reflected in the significant changes in some of the blood parameters.

Since more current was entering the earth on the farm after April 14 when the grounds were connected to the neutral, one might postulate that the cows were being exposed to more electricity and consequently, placed under greater stress. Acute stress or infection are, however, expected to cause significant increases in segmented neutrophils and decreases in lymphocytes which is totally opposite of the results of these tests. The fact that the blood samples were taken 17 days after the connection of the ground wire and the beginning of greater exposure of ground currents suggests that by then the blood should not show a picture of **acute** stress. The fact that the blood tests revealed significant increases in lymphocytes and a significant decrease in segmented neutrophils at the time of the second blood test, would, most likely, indicate that electricity can also produce other effects on the cows. These changes in blood parameters could be pointing to the beginning of a total immune system breakdown and/or indicative of a dangerous precancerous condition. This possibility is significant because, as veterinarians have worked with the stray voltage problem, they are more often express-

ing their concern that electricity appears to be breaking down the immune system of cows.

An experienced clinician recognizes that the values of the blood parameters fluctuate in all living animals. On any specific day the values of the parameters will depend of the response of the animal to insults experienced. Since, in this case, the insults were from EM energies, it is realized, after the fact, that additional measurements were necessary. A single blood test, as was performed in this study, represents only one point in the dynamics of the body of the animals. This particular test could be analogous to the "lag" phase following a vaccination. The immune system is showing a change and from a clinical point of view, the change means a worsening condition for the animal.

This study was developed to determine if connecting two wires from the primary neutral to ground rods could effect the health and production of dairy cows. No other changes was made during the entire test period except connecting the neutral to ground rods (one on the farm and one a short distance from the farm).

Summary

These results are especially important since the majority of studies on stray voltage have concluded that there is no noticeable effects on cows' production, health, blood chemistry, SCC or water consumption when the cows are exposed to shock currents as they touch the metal parts of the stall or waterer (Southwick et. al. 1992). In the work discussed in this paper the only change on the farm was the connecting of the electric utility grounds to their neutral. This was an electrical change that increased the electric current going into the ground on the farm by means of the primary neutral. The results included both observed and measured changes in health, blood chemistry, SCC and water consumption.

New models are needed which can better match the behavior, health and production of the dairy cows to their electrical exposure. Simply an analysis of the information already generated would greatly assist in this process. It is hoped that this study will trigger new research and additional debate in connection with stray voltage and the effects of EM energy with a special consideration to the effects of the electricity that gets into the earth from the multitude of sources. The results of such research and debate could reveal significant effects for all living organisms that go far beyond what is known about the effects of electrical shock. An understanding of the effects discovered in this test could be the key to dealing with the many dairies in the country that are experiencing the erosion of their profits and health. If we ignore the canaries that stop singing, we can only blame ourselves for the inevitable results.

Acknowledgement

We acknowledge the Alexandria Veterinary Clinic P.A. for their valuable assistance in this project.

References

Ahkbom, A., E. Albert, A. Fraser-Smith, A Grodzinsky, M. Marron, A. Martin, M. Persinger, M. Shelanski, & E. Wolpow 1987. Biological Effects of Power Line Fields. New York State Powerlines Project. Scientific Advisory Panel. Aneshansley, D.J. and Gorewit, editors. 3. Physiological and Behavioral Effects. Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems US GPO 1992. 617. 013/46592. Appleman, R.D., editor 1992. Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems. US GPO 1992. 617. 013/46592. Appleman, Robert O. 1987. Production Record Analysis of Dairy Herd Response to Neutral Isolation. American Society of Agricultural Extension Service. Univ. of Minn., St. Paul, MN. Appleman, R.D., R.J. Gustafson, and T.M. Brennan. Production Record Analysis of Dairy Herd Response to Neutral Isolation. 1987 Summer Meeting for the American Society of Agriculture Engineers. St. Joseph, MI 49085-9659. Barnothy, M.F., editor, 1969. Biological Effects of Magnetic Fields. Plenum Press, New York. Becker, R.O. and H.A. Marino, Electromagnetism and Life, State University of New York Press, Albany, NY. 1982. Bodman, G.R., L.E. Stetson, and H. Shull. 1981. Investigation of Extraneous Voltage in Nebraska Dairies. American Society of Agricultural Engineers. Paper No. 81-3510. Brodeur, Paul, Currents of Death: Power Lines, Computer Terminals, and the Attempt to Cover Up Their Threat to Your Health, Simon and Schaster, 1989. Burk, Lawrence D. Jr., M.D. The Basics of Bioelectromagnetism. The AAMA Review, 1990, vol 2, No. 1. P. 13) 15. Chang, Walter H. 1984. A Study on the Improvement of Callaus Formation of Fracture by a Specific Change in Electomagnetic Field. pp. 261-269 in D.J. Bem, W. Moron and R.G. Struzak (eds.) 1984 Electromagnetic Compatibility Seventh International Wroclaw Symposium, Technical Univ. of Wroclaw (Part 1). Committee on Interior and Insular Affairs House of Representatives, Health Effects of Transmission Lines, Serial No. 100-22 October 6, 1987. Crain, L.B. 1975. Effects on Mammals of Grounded Neutral Voltages from Distribution Power Lines. Institute of Electrical Engineers. 75-303-3-IA. Crain, L.B. 1980. Nationwide Occurrences of Electrical Neutral-to-Earth Voltages on Dairy Farms. Paper No. 82-3510, ASAE, St. Joseph, MI 49085. Dahlberg, Duane A. 1985. A Study of Electro-magnetic Effects on the Health and Production of Dairy Cows. Minnesota Department of Agriculture. Paper. Dahlberg, Duane A. 1991. Electromagnetic Fields and Currents: An Emerging Environmental Issue. Concordia College, Moorhead MN. Research Paper. Dahlberg, Duane A. 1986. Electromagnetic Synergistics: A Depressing Problem in the Dairy Industry. Concordia College Moorhead MN. Research Paper. Dahlberg, Duane and Laurance Falk. An Exploration of the Relation of Self-Reported Health Characteristics to Electro-Magnetic Fields in an Urban Setting. Fargo ND: Paper presented at the Joint Meeting of the Great Plains Sociological Association and Sociologists of MN, October 5, 1990. Dahlberg, Duane and Laurance L. Falk. 1991 Human Response to Electromagnetic Fields. Concordia College, Moorhead MN. Research paper. Dow Associates, Inc. Biological Effects and Physical Characteristics of Fields, Irons and Shock, MEQB, August 28, 1980. Edwards, Diane D., ELF the Current Controversy, Science News, 131, 107, Feb. 14, 1987. Fairbank, W. C. 1977. Stray Electrical Currents Can Cut Production. *Hoard's Dairyman* 122:1093. Gonen, Turan, 1986. Electric Power Distribution System Engineering. McGraw Hill. p 322. Gustafson, Robert J., Harold A. Cloud, and Robert D. Appleman. Understanding and Dealing with Stray Voltage Problems. *The Bovine Practitioner*, No. 17. Nov. 1982. Jones, Charles. 1989. Cause and Cures for Ground Currents. Stray Voltage Beyond the Shock, Conference, April 15, U of Wisc., River Falls, Wisc. Larkin, R.P. and

P.J. Sutherland. 1977. Migrating Birds Respond to Project Seafarer's Electromagnetic Field. *Science* 195: 777-779. LeBars H. and G. Andre. 1976. Biological Effects of an Electric Field on Rats and Rabbits. *RGE-FRA*, Special Issue, ISSN 0035-3116: 91-97. Lefcourt, A.M. 1985. Physiological Stress Response to Electrical Shock. National Stray Voltage Symposium, Oct. 10-12, 1984, Syracuse, NY. ASAE Pub. 3-85, ASAE, St. Joseph, MI 49085. Lefcourt, A.M. 1991. Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems. *U.S. Department of Agriculture, Agriculture Handbook* No. 696. Marino, Andrew A. Assessments and Viewpoints on the Biological and Human Health Effects of Extremely Low Frequency Electromagnetic Field (a compilation of commissioned papers for ELF literature review project), 1985. McAuliffe, Kathlene, The Mind Fields, *Omni*, February, 2985. Morrison, C. 1963. A Linear Approach to the Problem of Panning New Feed Through Points Into a Distribution System. AIEE Trans. III. (PAS) Dec. 1963 p 819-832. Nair, I., *et al* 1989. Biological Effects of Power Frequency Electric and Magnetic Fields, Office of Technology Assessment, Congress of the United States. Noland, David, Power Play, Discover, December, 1989. Nordenstorm, Dr. Bjorn. 1983. Biological Closed Electric Circuits: Clinical, Experimental, and Theoretical Evidence for an Additional Circulatory System. Stockholm: Nordenstrom. Paul, Bill. 1988. Concerns About Low Energy Radiation Leads to New Rules, Research and Suits. *Wall Street Journal* (October 11): B6 Phillips, D.S.M., 1962. Production of Cows May Be Affected by Small Electrical Shocks from Milking Plants. New Zealand Journal of Agriculture 105:221. Presman, A.S. 1970. Electromagnetics and Life. Plenum Press. New York. Rodenburg, J. 1984. Tingle Voltage, The Result of a Recent Study of 140 Ontario Dairy Farms. *Ontario Milk Producer* (July 16): 10-11. Scarborough, L.P. Electrical Safety Standards With Regard to Stray Voltages. The Potomac Edison Company, Mar. 12, 1981. Smith, Lawrence B. 1984. Electric Field Therapy for Equine Stereotypical Behaviors. *Journal of Biological Physics* 12:33. Southwick, Lee H., David J. Wilson and Philip M. Sears. 1992. Milk Production, Water Consumption and Somatic Cell Count Responses of Cows Subject to One to Two Volts of Alternating Current. *JAVMA*. 201:441. Stray Voltage: Proceedings of the National Stray Voltage Symposium, 1985 October 10-12, ASAE Publication. Stray Voltage Study: Results Surprise Researchers. *Rural Minnesota News*. Oct. 1988. p 4. Surbrook, T.C. and N.D. Reese. 1981. Stray Voltage on Farms. *American Journal of Agricultural Engineers Papers* No. PNR-84-309. Wertheimer, Nancy and Ed Leeper, 1982. Adult Cancer Related to Electrical Wires Near the Home. *International Journal Epidemiology* 11:345-355. Wertheimer, Nancy and Ed Leeper, 1979. Electrical Wire Configuration and Childhood Cancer. *American Journal of Epidemiology* 109: 273-284. Whittlestone, W.G., M.M. Mullord, R. Filggour, and L.R. Cate. 1975. Electric Shocks During Milking. *New Zealand Veterinary Journal* 23: 105. Williams, G.F. 1981. Stray Electric Currents: Economic Losses, Symptoms, and How it Affects the Cows. Proc. 20th Ann. NMC Mtg. Nat Mastitis Council, Arlington, VA. Wright, R.E., C.W. Ackerman, and R.A. Spray. 1986. Stray Electricity Reduces Swine Unit Productivity. *Nordon News* (Summer): 12-14.

Blood Test Results

TEST	21		26		8		29		36	
	B	A	B	A	B	A	B	A	B	A
TP	7.8	8.5	7.2	8.0	7.0	7.5	8.0	8.0	7.5	8.2
TP	7.2	8.0	6.5	7.8	7.5	7.2	8.4	7.5	8.5	8.0
FIB	.6	.5	.7	.2	.5	.3	.4	.5	1.0	.2
BUN	18.6	18.5	16.9	15.6	14.1	13.1	18.9	15.6	12.0	12.6
CREA	.7	.72	.62	.71	.59	.73	.55	.65	.58	.56
WBC	9.0	8.4	9.3	5.0	11.0	11.4	10.0	12.0	14.6	NA
RBC	5.31	4.82	4.52	4.85	5.28	4.76	4.48	4.41	4.91	NA
HgB	10.5	9.7	9.0	9.5	10.3	9.4	9.4	9.2	9.7	NA
HCT	27.0	24.3	23.4	24.5	28.9	24.9	22.2	21.7	26.1	NA
MCV	51.0	50.4	52.2	50.6	54.8	52.3	49.4	49.3	53.1	NA
MCH	20.0	20.3	20	19.7	19.5	19.8	20.9	20.9	19.8	NA
MCHC	39.3	40.2	38.3	38.9	35.5	37.8	42.3	42.4	37.4	NA
SEG	45	15	58	15	57	45	36	23	45	NA
Lymph	31	78	20	70	35	42	55	68	42	NA
Mono	9	3	6	0	2	1	2	1	2	NA
Eos	15	4	16	15	6	12	7	8	11	NA
BASO	-	-	-	-	-	-	-	-	-	NA

TEST	19		10		24		22		31	
	B	A	B	A	B	A	B	A	B	A
TP	8.2	8.8	7.1	7.5	8.0	9.8	7.4	9.5	7.2	NA
TP	9.0	8.2	8.0	7.5	7.5	8.6	7.0	7.5	7.0	NA
FIB	.8	.6	.95	.5	.5	1.2	.4	2.0	.2	NA
BUN	14.4	10.6	17.7	13.2	21.7	15.2	19.9	15.6	10.6	NA
CREA	.64	.95	.51	.71	.59	.68	.63	.87	.58	NA
WBC	10.0	9.2	14.0	10.4	7.8	5.8	12.7	13.7	11.1	NA
RBC	5.72	5.86	5.36	4.95	4.92	5.36	5.68	5.57	5.5	NA
HgB	11.4	11.5	10.8	9.8	10.2	10.9	11.5	11.0	11.1	NA
HCT	31.8	31.9	26.3	24.2	25.0	27.0	32.3	30.7	27.0	NA
MCV	55.6	54.4	49.2	48.9	50.9	50.4	56.8	55.2	49.1	NA
MCH	19.9	19.5	20.2	19.9	20.8	20.5	20.2	19.8	21.1	NA
MCHC	35.8	35.9	41	40.7	40.9	40.6	35.6	36.0	42.9	NA
SEG	40	38	54	22	39	33	13	15	NA	NA
Lymph	50	51	35	71	58	59	79	81	NA	NA
Mono	3	1	2	2	1	8	4	1	NA	NA
Eos	6	10	8	5	2	0	3	3	NA	NA
BASO	1	-	1	-	-	-	1	-	NA	NA

Body Scores And Comments

#	A	B	C	A	B	C
10	2	2+	2	thin bone	none	thin, both hocks slightly swollen
9	3+	N/A	N/A	fleshy	left barn	N/A
8	2	2	2+	thin	sore rt hock (hairless)	rt hock slight swelling
7	2+	N/A	N/A	average	not in barn	not in barn
6	2+	2+	2	average	good	rt hock swollen
5	2+	2+	2+	due to calve wks	fresh new good flesh	good
4	2+	2+	2+	dry-average	fresh 1 wk, bloody milk, good	good
29	2	2	2	thin	sore hairless left stifle, thin	thin
2	2+	2+	2+	average	hairless left stifle, good	good
1	2+	2+	2+	average	good	good
20	2+	2+	2+	average	good	swollen rt hock, left hock scraped
19A	2+	2	2+	average	good	scraped both hocks
18	N/A	2+	2+	not in barn	good	both hocks scraped and hairless
17	2+	2+	2+	thin	good	good
35	2+	2+	2+	thin bone	rubbed rt hock, good	good, scraped rt hock
33	3	2+	2+	fleshy	both hocks a little swollen	both hocks scraped
14	2+	2+	2+	average	good	bruised left achilles
36	2+	2+	2+	average	good	very good
32	2+	N/A	N/A	average	left barn	left barn
34	2+	2	2+	average	sore rt front carpus (knob)	good
31	2	N/A	N/A	thin	left barn	left barn
27	2+	N/A	N/A	average	sold	sold
26	2+	2+	2+	tall and big	good	good
25	2+	2+	2+	average	rubbed left hock, good	good
24	2+	2+	2+	good flesh	hairless sore on rt hock lateral and medial	both hocks swollen bad swelling on rt carpus down to hoof
23	2	2+	2+	thin	good	good
22	2	2+	2+	thin	good	left hock swollen
21	2+	2+	2+	average	good	good
9	N/A	1+	1+	not in barn	fresh hfr sore left hock gant tucked in	left hock draining, thin, front legs swollen
32	N/A	2	2+	not in barn	fresh 2 wks left hock rubbed gant	left hock draining and swollen tender on front feet
11	N/A	2+	N/A	not in barn	good	sold
28	N/A	2	2	not in barn	swollen left hock just fresh gant	swollen left hock
27	N/A	2	2	not in barn	thin, not fresh yet found red on all 4 feet shakes, still	swollen left hock
7	N/A	N/A	2+	not in barn	not in barn	left hock swollen and calloused